Chapter 27. Central and South America

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Changes in climate variability and in extreme events have been severely affecting Central America (CA) and South America (SA) during the last 60 years. Increases in observed warm days and decreases in cold days and nights have been identified in CA, Northern SA, Northeast Brazil (NEB), Southeastern South America (SESA) and the West Coast of SA (medium-lower confidence). More frequent and intense rainfall extremes in SESA have favored an increase in the occurrence of landslides and flash floods (low confidence). On seasonal scales, it is likely that changes in hydrometeorological extremes in regions such as Amazonia, La Plata basin and Northern South America observed during the last 10 years have been related to changes in natural climate variability, determining changes in extreme streamflow variability in the La Plata and Amazon Rivers (27.1.2.2, 27.2.1.1).

The projected mean warming for CA by the end of the century, according to different global and regional climate models from the CMIP3 and CMIP5 ranges from 1.5°C to 4.0 °C, while rainfall tends to decrease between 5 and 10% by 2100. SA shows a warming between 1.0°C to 5.0 °C, with rainfall reduction up to 10% in tropical SA and an increase of about 10-15% in SESA. Projections for the 21st century from CMIP3 global models suggest a weakening of the North American Monsoon System NAMS and precipitation reduction in June-July, accompanied by projected warming in most of CA (medium confidence). Analyses from global and regional models in SA show common patterns of projected climate in some sectors of the continent, with a very likely increase of precipitation in SESA, Northwest of Peru and Ecuador and western Amazonia, while decreases are projected for northern SA,
Eastern Amazonia, central eastern Brazil, NEB, the Altiplano and southern Chile. With lower-medium confidence, heavy precipitation is likely projected to increase in SESA, while dry spells would increase in northeastern South America. Increases in warm days and nights are very likely to occur in most of SA (27.2.1.2).

In CA and SA there is evidence of changing conditions in terms of geophysical variables (cryosphere and runoff) that affect streamflow and finally water availability (high confidence). Since AR4, there is growing evidence that glaciers (both tropical and extratropical) are retreating and the cryosphere in the Andes is changing according to the warming trends. These changes affect streamflow availability in different seasons of the year. Robust trends are apparent associated with changes in precipitation such as increasing runoff in the SESA region (La Plata basin), and reducing runoff in the Central Andes (Chile, Argentina) and Central America. In contrast to these findings, no robust trend in streamflow in the Amazon Basin has been detected (27.3.1.1).

Land cover change is a key driver of environmental change with significant impacts that may increase the potential negative impacts from climate change. Deforestation and land degradation are mainly attributed to increased extensive and intensive agriculture, both from traditional export activities such as beef and soy production, but more recently from biomass for biofuel production. The agricultural expansion has affected fragile ecosystems such as the edges of the Amazon forest and the tropical Andes increasing the vulnerability of communities to extreme climate events, particularly floods, landslides and droughts. Even though deforestation rates in the Amazon have decreased substantially in the last eight years to a current value of 0.29%, the lowest for all forest biomes in Brazil, other regions like the Cerrado and the Chaco forests still present high levels of deforestation with rates as high as 1.33% (27.2.2.1).

Socioeconomic development shows a high level of structural heterogeneity and a very unequal income distribution resulting in high vulnerability of the region to climate change. There is still a high and persistent level of poverty in most countries of the region (45% for CA and 30% for SA for year 2010) in spite of the sustained economic growth observed in the last decade. In terms of human development, the performance of different countries varied greatly from Chile and Argentina at the high end of human development, and Guatemala and Nicaragua with the lowest indices. The economic inequality translates into inequality in access to water, sanitation and adequate housing, particularly for the most vulnerable groups: indigenous peoples, Afro-descendants and women living in poverty which translates into low adaptive capacities to climate change for these groups (27.2.2.2).

Coastal and marine ecosystems have been undergoing significant transformations that pose threats to fish stocks, corals, mangroves, places for recreation and tourism, and controls of pests and pathogens. Frequent coral bleaching events have been recently reported for the Mesoamerican Coral Reef. In CA and SA, some of the main drivers of mangrove loss are deforestation and land conversion, agriculture and shrimp ponds to an extent that the mangroves of the Atlantic and Pacific coasts of CA are some of the most endangered in the planet. Changes over 2 mm/yr of sea-level rise (SLR) have been found in CA and SA, which is reason for concern since 3/4 of the population of the region live within the range of 200 km of the coast (27.3.3.1). In Brazil, fisheries’ co-management - a participatory process involving local fishermen communities, government, academia and NGOs - favors a balance between conservation of marine fisheries, coral reefs and mangroves, and the improvement of livelihoods, as well as the cultural survival of traditional populations (27.3.3.2).

Conversion of natural ecosystems is the main proximate cause of biodiversity and ecosystem loss in the region, and in parallel is a driver of anthropogenic climate change. Plant species are rapidly declining in CA and SA; the highest percentage of rapidly declining amphibian species occurs also in CA and SA; with Brazil being among the countries with most threatened bird, mammal species and freshwater fish. However, the region has still large extensions of natural vegetation cover for which the Amazon is the main example. Ecosystem-based Adaptation practices, such as conservation agreements and community management of natural areas, begin to multiply across the region (27.3.2.2).

Although there is high uncertainty in terms of climate change projections for regions with high vulnerability in terms of current water availability, this vulnerability is expected to increase in the future due to climate change impacts (high confidence). Already vulnerable regions in terms of water supply, like the semi-arid zones in Chile-Argentina, North Eastern Brazil and Central America and the tropical Andes, are expected to increase even further their
vulnerability due to climate change. Glacier retreat is expected to continue, and a reduction in water availability due
to expected precipitation reduction and increase evapotranspiration demands is expected in the semi-arid regions of
CA and SA. These scenarios would affect water supply for large cities, small communities, hydropower generation
and the agriculture sector (27.3.1.1, 27.3.1.2, 27.6.1). Current practices to reduce the mismatch between water
supply and demand could be used to reduce future vulnerability. Constitutional and legal reforms towards more
efficient and effective water resources management and coordination among relevant actors in many countries in the
region (e.g. Honduras, Nicaragua, Ecuador, Peru, Uruguay, Bolivia and Mexico) also represent an adaptation
strategy to climate variability and change (27.3.1.2).

Changes in agricultural productivity attributed to climate change are expected to have a great spatial variability. In
SESA, where projections indicate more rainfall, average productivity could be sustained or increased until the mid-
century (SRES: A2, B2) (medium confidence). In CA, northeast of Brazil and parts of the Andean region increases
in temperature and decreases in rainfall could decrease the productivity in the short-term (before 2025), threatening
the food security of the poorest population (medium confidence). The great challenge for CA and SA will be to
increase the food and bioenergy production and at the same time to sustain the environmental quality in a scenario of
climate change (27.3.4.1).

Renewable energy (RE) has a potential impact on land use change and deforestation, but at the same time will be an
important means of adaptation, with the region, mainly SESA being key in this process. Hydropower is currently the
main source of RE in CA and SA, followed by biofuels, notably bioethanol from sugarcane and biodiesel from soy.
SESA is one of the main sources of production of the feedstocks for biofuels’ production. Sugarcane and soy are
likely to respond to the elevation of CO₂ and temperature with an increase in growth, which might lead to an
increase in productivity and production. However, the drought effects expected for some regions in CA and SA will
be critical and scientific knowledge has to advance in this area. Advances in second generation bioethanol from
sugarcane and other feedstocks will be important as a measure of adaptation, as they have the potential to increase
biofuels productivity in the region. In spite of the large amount of arable land available in the region, the expansion
of sugarcane and soy, related to biofuels production, might have some indirect land use change effects, producing
teleconnections that could lead to deforestation in the Amazon and loss of employment in some countries. This is
epecially derived from the expansion of soy, which is used for biodiesel production inclusively (27.3.6.).

Climate variability and climate change are negatively affecting human health in CA and SA, either by increasing
morbidity, mortality, and disabilities (very high confidence), and through the emergence of diseases in regions
previously non-endemic, or the re-emergence of diseases in areas where they have previously been eradicated or
controlled (high confidence). Climate-related drivers have been recognized for respiratory and cardiovascular
diseases, vector- and water-borne diseases (malaria, dengue, yellow fever, leishmaniasis, cholera, and other diarrheal
diseases), Hantaviruses and Rotaviruses, pregnancy-related outcomes, diabetes, chronic kidney diseases, and
psychological trauma (27.3.7.1). Vulnerabilities vary with geography, age, gender, race, ethnicity, and socio-
economic status, and are rising in large cities (27.3.7.2). It is very likely that Climate change and variability may
exacerbate current and future risks to health, given the region’s vulnerabilities in existing health, water, sanitation
and waste collection systems, nutrition, and pollution.

The best way to be prepared to adapt to future climate change is by assisting people to cope with current climate
variability. Long-term planning and the related human and financial resource needs may be seen as conflicting with
present social deficit in the welfare of the CA and SA population. Such conditions weaken the importance of
adaptation planning to climate change on the political agenda. Various examples demonstrate possible synergies
between development, adaptation and mitigation planning, which can help local communities and governments to
allocate efficiently available resources in the design of strategies to reduce vulnerability (27.3.4, 27.4.1, 27.4.2,
27.4.3, 27.4.4, 27.5).
27.1. Introduction

27.1.1. The Central and South America Region

The CA and SA region harbours unique ecosystems and maximum biodiversity, has a variety of eco-climatic gradients, and it is rapidly developing. Agricultural and beef production is quickly increasing mostly by expanding agricultural frontiers; accelerated urbanization and demographic changes are remarkable; poverty and inequality are decreasing continuously, but at a low pace; while adaptive capacity is improving related to poverty alleviation. The region has multiple stressors being climate variability/climate change and land cover change two of the most remarkable drivers of changes. Climate variability at various time scales has been affecting social and natural systems, and extremes in particular have affected large regions. During 2000-2010, almost 630 weather and climate extreme events occurred in CA and SA, leaving near to 16,000 fatalities and 46.6 million people affected; and generating economical losses amounting to US$ 208 million (CRED, 2011). Land is facing increasing pressure from competing uses like cattle ranching, food production and bioenergy.

CA and SA are thought to have some key roles in the future because some countries, especially in SA, are rapidly developing and becoming economically important in the world scenario. The region is bound to be exposed to the pressure related to increasing land use and industrialization. Therefore, it is likely to have to deal with increasing emission potentials. Therefore, science-based decision-making is thought to be an important tool to control innovation and development of the countries in the region.

Two other important contrasting features characterize the region: having the biggest tropical forest of the planet on the one side, and possessing the largest potential for agricultural development during the next decades on the other. This is the case because the large countries of SA, especially, would have a major role in food and bioenergy production in the future, as long as policies towards adaptation to global climate change (GCC) will be strategically designed. The region is already one of the top producers and user of bioenergy and this experience will serve as an example to other developing regions as well as developed regions.

27.1.2. Summary of the AR4 and SREX Findings

27.1.2.1. AR4 Findings

During the last decades of the 20th century, unusual extreme weather events have been severely affecting the LA region contributing greatly to the strengthening of the vulnerability of human systems to natural disasters. In addition, increases in precipitation were observed in SESA, northwest Peru and Ecuador; while decreases were registered in southern Chile, southwest Argentina, southern Peru and western CA since 1960. Mean warming was near to 0.1ºC/decade. The rate of SLR has accelerated over the last 20 years reaching 2-3mm/year. The glacier-revetreat trend has intensified, reaching critical conditions in the Andean countries. Rates of deforestation have been continuously increasing mainly due to agricultural expansion, and land degradation has been intensified for the entire region.

Mean warming for LA at the end of 21st century could reach 1ºC to 4ºC (SRES B2) or 2ºC to 6ºC (SRES A2). Rainfall anomalies (positive or negative) will be larger for the tropical part of LA. The frequency and intensity of weather and climate extremes is likely to increase.

Future impacts include: “Significant species extinctions, mainly in tropical LA” (high confidence). “Replacement of tropical forest by savannas, and semi-arid vegetation by arid vegetation” (medium confidence). “Increases in the number of people experiencing water stress” (medium confidence). “Probable reductions in rice yields and possible increases of soy yield in SESA; and increases in crop pests and diseases” (medium confidence). “Some coastal areas affected by sea level rise, weather and climatic variability and extremes” (high confidence).
Some countries have made efforts to adapt to climate change and variability, for example through the conservation
of key ecosystems, the use of early warning systems and climate forecast, and the implementation of disease
surveillance systems. However, several constraints like the lack of basic information, observation and monitoring
systems; the lack of capacity-building and appropriate political, institutional and technological frameworks; low
income; and settlements in vulnerable areas, outweigh the effectiveness of these efforts.

27.1.2.2. SREX Findings

As reported by the IPCC SREX (IPCC, 2012), a changing climate leads to changes in the frequency, intensity,
spatial extent or duration of weather and climate extremes, and can result in unprecedented extremes. Levels of
confidence in historical changes depend on the availability of high quality and homogeneous data, and relevant
model projections. This has been a major problem in CA and SA, where a lack of long-term homogeneous and
continuous climate and hydrological records, and of complete studies on trends have not allowed for an
identification of trends in extremes, particularly in CA. Recent studies and projections from global and regional
models suggest changes in extremes. With medium confidence, increases in warm days and decreases in cold days,
as well as increases on warm nights and decreases in cold nights have been identified in CA, Northern SA, NEB,
SESA and west coast of SA. In CA, there is low confidence that any observed long-term increase in tropical cyclone
activity is robust, after accounting for past changes in observing capabilities. In other regions, such as the Amazon
region, insufficient evidence, inconsistencies among studies and detected trends result in low confidence of observed
rainfall trends. While it is likely that there has been an anthropogenic influence on extreme temperature in the
region, there is low confidence in attribution of changes in tropical cyclone activity to anthropogenic influences.

Projections for the end of the 21st century for differing emissions scenarios (SRES A2 and A1B) show that for all
CA and SA, models project substantial warming in temperature extremes. It is likely that increases in the frequency
and magnitude of warm daily temperature extremes and decreases in cold extremes will occur in the 21st century on
the global scale. With medium-high confidence, it is very likely that the length, frequency and/or intensity of heat
waves will experience a large increase over most of SA, with weaker tendency towards increasing in SESA. With
low to medium confidence, the models also project an increase of the proportion of total rainfall from heavy falls for
SESA and the West coast of SA; while for Amazonia and the rest of SA and CA there are not consistent signals of
change. In some regions, there is low confidence in projections of changes in fluvial floods. Confidence is low due
to limited evidence and because the causes of regional changes are complex. There is medium confidence that
droughts will intensify along the 21st century in some seasons and areas due to reduced precipitation and/or
increased evapotranspiration in Amazonia and NEB.

The character and severity of the impacts from climate extremes depend not only on the extremes themselves but
also on exposure and vulnerability. These are influenced by a wide range of factors, including anthropogenic climate
change, natural climate variability, and socioeconomic development. Disaster risk management and adaptation to
climate change focuses on reducing exposure and vulnerability and increasing resilience to the potential adverse
impacts of climate extremes, even though risks cannot be fully eliminated.

27.2. Major Recent Changes and Projections in the Region

27.2.1. Climatic Stressors

27.2.1.1. Climate Trends, Long-term Variability, and Extremes

In CA and SA, decadal variability and changes in extremes have been affecting large sectors of the population,
especially those more vulnerable and exposed to climate hazards. Observed changes in some regions have been
attributed to natural climate variability while human influences (changes in extremes due to urbanization, for
instance) have been attributed to land use change. Table 27-1 summarizes observed trends in the region’s climate.
Table 27-1: Regional observed changes in temperature, precipitation and climate extremes in various sectors of CA and SA. Additional information on changes in observed extremes can be found in the IPCC SREX Chapter 3 (IPCC, 2012) and in WGI AR5 [2.4, 2.5, 2.6].

Many areas in the Intra American Seas region that includes tropical and subtropical western North Atlantic Ocean encompassing the Gulf of Mexico, the Caribbean Sea, the Bahamas and Florida, the northeast coast of SA, and the juxtaposed coastal regions, including the Antillean Islands, show severe anomalies in rainfall. In CA and the North American Monsoon System (NAMS), rainfall has been starting increasingly later and has become more irregular in space and time, while the intensity of rainfall has been increasing during the onset season (see references in Table 27-1) since around 1950. Arias et al. (2012) found decadal rainfall variations in NAMS.

In SA, the West coast has shown a prominent but localized coastal cooling during the past 30-50 years extending from central Peru down to central Chile. Presumably, this occurs in connection with an increased upwelling of coastal waters favored by the trade winds (Narayan et al., 2010), that are associated with a negative trend in the sea surface temperature (SST) over a large oceanic region off the coast of northern Chile during the same period (Schulz et al., 2011). In the extremely arid northern coast of Chile, rainfall, temperature and cloudiness show strong interannual and decadal variability, and since the mid-70s, the minimum daily temperature, cloudiness and precipitation have decreased. In central Chile, a negative trend in precipitation was observed over the period 1935-1976, and an increase after 1976, while further south, the negative trend in rainfall that prevailed since the 1950s has intensified by the end of the 20th century (Quintana and Aceituno, 2012).

Towards the east of the Andes, NEB exhibits large interannual rainfall variability and a slight decrease since the 1970s. Although droughts in this region (e.g. 1983, 1987, 1998) have been associated with El Niño, the recent extremely intense drought in 2012-2013 occurred during La Niña (Marengo et al., 2013). In the La Plata Basin, various studies have documented interannual and decadal scale circulation changes that have led to decreases in the frequency of cold nights in austral summer, as well as to increases in warm nights and minimum temperatures during the last 40 years (see references in Table 27-1). Simultaneously, a reduction in the number of dry months in the warm season is found since the mid-1970s (see references in Table 27-1). Heavy rain frequency is increasing in SESA (references in Table 27-1).

In the central Andes, in the Mantaro Valley (Peru), precipitation shows a strong negative trend, while warming is also detected (SENAMHI, 2007). In the southern Andes of Peru, minimum air temperatures have increased during 1964-2006, while the number of frost days during September-April has also increased, but no clear signal on precipitation changes has been detected (Marengo et al., 2009a). In the northern Andes (Colombia, Ecuador), changes in temperature and rainfall in 1961-90 have been identified by Villacís (2008). In the Patagonia region, Masiokas et al. (2008) have identified an increase of temperature together with precipitation reductions during 1950-90.

For the Amazon basin, Marengo (2004), Marengo et al. (2009a; 2010), Satyamurty et al. (2010), and Buarque et al. (2010) concluded that no systematic unidirectional long-term trends towards drier or wetter conditions in both the northern and southern Amazon have been identified since the 1920s. Rainfall fluctuations are more characterized by inter-annual scales linked to ENSO or decadal variability. Analyzing a narrower time period, Espinoza et al. (2009a; 2009b) found that mean rainfall in the Amazon basin for 1964–2003 has decreased, with stronger amplitude after 1982, especially in the Peruvian western Amazonia (Lavado et al., 2012), consistent with reductions in convection and cloudiness in the same region (Arias et al., 2011). Recent studies by Donat et al. (2013) suggest that heavy rains are increasing in frequency in Amazonia. Regarding seasonal extremes in the Amazon region, two major droughts and three floods have affected the region from 2005 to 2012, although these events have been related to natural climate variability rather than to deforestation (Marengo et al., 2008; Espinoza et al., 2011; Lewis et al., 2011; Espinoza et al., 2012; Marengo et al., 2012a). On the impacts of land use changes on changes in the climate and hydrology of Amazonia, Zhang et al. (2009) suggest that biomass-burning aerosols can work against the seasonal monsoon circulation transition, thus re-inforce the dry season rainfall pattern for Southern Amazonia, while Wang et al. (2011) suggests the importance of deforestation and vegetation dynamics on decadal variability of
rainfall in the region. Costa and Pires (2010) have suggested a possible decrease in precipitation due to soybean expansion in Amazonia, mainly as a consequence of its very high albedo.

In the SAMS region in the last 50 or 60 years, positive trends in rainfall extremes have been identified (see Table 27-1). These studies suggest a pattern of increasing frequency and intensity of heavy rainfall events, with a tendency for early onsets and late demise of the rainy season.

Collini et al. (2008) and Saulo et al. (2010) find the SESA precipitation to be more responsive to changes in soil moisture, and although feedback mechanisms are present at all scales, the atmosphere influence is more significant at large scales. Moreover, land use change studies in the Brazilian southern Amazonia for the last decades showed that the impact on the hydrological response is time lagged at larger scales (Rodriguez et al., 2010)

27.2.1.2. Climate Projections

Since the AR4, substantial additional regional analysis has been carried out using the CMIP3 model ensemble. In addition, projections from CMIP5 models, and new experiences using regional models (downscaling) have allowed for a better description of future changes in climate and extremes in CA and SA. Using CMIP3 and CMIP5 models, Giorgi (2006), Diffenbaugh et al. (2008), Xu et al. (2009) and Diffenbaugh and Giorgi (2012) have identified areas of CA/western North America and the Amazon as persistent regional climate change hotspots throughout the 21st century of the RCP8.5 and RCP4.5. Table 27-2 summarizes projected climatic changes derived from global and regional models for the region, indicating the projected change, models, emission scenarios, time spans and references.

[INSERT TABLE 27-2 HERE]

Table 27-2: Regional projected changes in temperature, precipitation, and climate extremes in different sectors of CA and SA. Various studies used A2 and B2 scenarios from CMIP3 and various RCPs scenarios for CMIP5, and different time slices from 2010 to 2100. In order to make results comparable, the CMIP3 and CMIP5 at the time slice ending in 2100 are included. Additional information on changes in projected extremes can be found in the IPCC SREX (see IPCC, 2012), and WG1 AR5 Chapter 9 and 14 [9.5, 9.6 and 14.2, 14.7]]

In CA and Northern Venezuela, projections from CMIP3 models and from downscaling experiments suggest precipitation reductions and warming together with an increase in evaporation, and reductions in soil moisture for most of the land during all seasons by the end of the 21st century (see references in Table 27-2). However, the spread of projections is high for future precipitation.

Analyses from global and regional models in tropical and subtropical SA show common patterns of projected climate in some sectors of the continent. Projections from CMIP3 regional and high resolution global models show by the end of the 21st century for a high emission scenario A2, a consistent pattern of increase of precipitation in SESA, Northwest of Peru and Ecuador and western Amazonia, while decreases are projected for northern SA, Eastern Amazonia, central eastern Brazil, NEB, the Altiplano and southern Chile (see references in Table 27-2). For some regions, projections show mixed results in rainfall projections, for the Amazonia and the SA monsoon region (see references in Table 27-2).

As for extremes, CMIP3 models and downscaling experiments show increases in dry spells are projected for Eastern Amazonia and NEB, while rainfall extremes are projected to increase in SESA, in western Amazonia, Northwest Peru and Ecuador, while over southern Amazonia, northeastern Brazil and eastern Amazonia, the maximum number of consecutive dry days tends to augment, suggesting a longer dry season. Increases in warm nights throughout SA are also projected by the end of the 21st century (see references in Table 27-2). Shiogama et al. (2011) suggest that although the CMIP3 ensemble mean assessment suggested wetting across most of SA, the observational constraints indicate a higher probability of drying in the eastern Amazon basin.

The CMIP5 models project an even larger expansion of the monsoon regions in NAMS and SAMS in the future scenarios (Kitoh et al., 2012; Jones and Carvalho, 2013). A comparison from eight models from CMIP3 and CMIP5
identifies some improvements in the new generation models. For example, CMIP5 inter-model variability of
temperature in summer was lower over northeastern Argentina, Paraguay and northern Brazil, in the last decades of
the 21st century, as compared to CMIP3. Although no major differences were observed in both precipitation datasets,
CMIP5 inter-model variability was lower over northern and eastern Brazil in summer by 2100 (Blázquez and Nuñez,
2012).

The projections from the CMIP5 models at regional level for CA and SA (using the same regions from the IPCC
SREX) are shown in Figure 27-1, and update some of these previous projections based on SRES A2 and B2
emission scenarios from CMIP3. Figure 27-1 shows that in relation to the baseline period 1986-2005, for CA and
northern South America-Amazonia, temperatures are projected to increase approximately by 1.8 °C and 3 °C for the
RCP4.5 scenario, and by 4 °C and 5 °C for the RCP8.5 scenario. For the rest of South America, increases by about
1.8 to 2 °C are projected for the RCP4.5 and by about 4 °C to 5 °C for the RCP8.5 scenario. The observed records
show increases of temperature from 1900 to 1986 by about 1 °C. For precipitation, while for CA and northern South
America-Amazonia precipitation is projected to decrease by about 10% (with large spread among models). For
Northeast Brazil, there is a spread among models between +20 to -20% making hard to identify any projected
change. This spread is much lower in the western coast of South America and SESA, where the spread is between
+10 and -10%, and in SESA, the tendency is for an increase of precipitation that may reach 30%.

[INSERT FIGURE 27-1 HERE]

Figure 27-1: Observed and simulated variations in past and projected future annual average temperature over land
areas of the Central and South American "SREX regions". Black lines show several estimates from observational
measurements. Shading denotes the 5-95 percentile range of climate model simulations driven with "historical"
changes in anthropogenic and natural drivers (68 simulations), historical changes in "natural" drivers only (30), the
"RCP4.5" emissions scenario (68), and the "RCP8.5" (68). Data are anomalies from the 1986-2006 average of the
individual observational data (for the observational time series) or of the corresponding historical all-forcing
simulations. Further details are given in Box 21-3.]

27.2.2. Non-Climatic Stressors

27.2.2.1. Trends and Projections in Land Use and Land Use Change

Land use and land cover change are key drivers of environmental change for the region with significant impacts that
may increase the potential negative impacts from climate change (Sampaio et al., 2007; Lopez-Rodriguez and
Blanco-Libreros, 2008). The high levels of deforestation observed in most of the countries have been widely
discussed in the literature as a deliberate development strategy based on the expansion of agriculture to satisfy the
growing world demand for food, energy and minerals (Benhin, 2006; Grau and Aide, 2008; Mueller et al., 2008).

Land is facing increasing pressure from competing uses, among them cattle ranching, food and bioenergy
production. The enhanced competition for land increases the risk of land use changes, which may lead to negative
environmental and socio-economic impacts. Agricultural expansion has relied in many cases on government
subsidies, which have often resulted in lower land productivity and more land speculation (Bulte et al., 2007;
Roebeling and Hendrix, 2010). Some of the most affected areas due to the expansion of the agricultural frontier are
fragile ecosystems such as the edges of the Amazon forest in Brazil, Colombia, Ecuador and Peru, and the tropical
Andes, where activities such as deforestation, agriculture, cattle ranching and gold mining are causing severe
environmental degradation (ECLAC, 2010d), and the reduction of environmental services provided by these
ecosystems.

Deforestation rates for the region remain high in spite of a reducing trend in the last decade (Ramankutty et al.,
2007; Fearnside, 2008). Brazil is by far the country with the highest area of forest loss in the world according to the
latest FAO statistics (2010): 21,940 km² per year -39% of world deforestation for the period 2005-2010. Bolivia,
Venezuela and Argentina follow in deforested area (Figure 27-2) with all four countries accounting for 54% of the
forest loss in the world for the same period. The countries of CA and SA lost a total of 38,300 km² of forest per year
in that period (69% of the total world deforestation) (FAO, 2010). These numbers are limited by the fact that many
countries do not have comparable information through time, particularly for recent years.
Deforestation in the Amazon forest has received much international attention in the last decades, both because of its high rates, and its rich biodiversity. Brazilian Legal Amazon is now one of the best-monitored ecosystems in terms of deforestation since 1988 (INPE, 2011; see Figure 27-3). Deforestation rates for this region peaked in 2004 and have steadily declined since then currently exhibiting the lowest rates during the entire record. Such reduction results from a series of integrated policies to control illegal deforestation particularly enforcing protected areas, which now shelter 54% of the remaining forests of the Brazilian Amazon (Soares-Filho et al., 2010). Deforestation in Brazilian Amazon for the period 2005-2010 accounted for 41% of the total deforestation for that country and showed the lowest rate for all forest biomes in Brazil (0.29%), with the Cerrado forest (drier ecosystem south of Amazon) presenting the forest biome with the highest deforestation rates (1.33%), accounting for 37% of Brazil’s total deforestation (FAO, 2009).

The amount of forest loss in CA is considerably less than in SA, owing to smaller country sizes. When deforestation rates are considered, Honduras and Nicaragua show the highest values for the area (Carr et al., 2009). At the same time, CA includes three countries where forest cover shows a recovery trend in the last years: Costa Rica, El Salvador and Panama. This forest transition is the result of: (1) economies less dependent on agriculture, and more on industry and services (Wright and Samaniego, 2008); (2) processes of international migration with the associated remittances (Hecht and Saatchi, 2007), and (3) a stronger emphasis on the recognition of environmental services of forest ecosystems (Kaimowitz, 2008). The same positive trend is observed in some SA countries (Figure 27-2).

However, a substantial amount of forest is gained through (single-crop) plantations, most noticeably in Chile (Aguayo et al., 2009), which has a much lower ecological value than natural forests (Izquierdo et al., 2008).

Land degradation, is also an important process compromising extensive areas of CA and SA very rapidly. According to data from the Global Land Degradation Assessment and Improvement (GLADA) project of the Global Environmental Facility (GEF), additional degraded areas reached 16.4% of the entire territory of Paraguay, 15.3% of Peru and 14.2% of Ecuador for the period 1982-2002. In CA, Guatemala shows the highest proportion of degraded land, currently at 58.9% of the country’s territory, followed by Honduras (38.4%) and Costa Rica (29.5%); only El Salvador shows a reversal of the land degradation process, probably due to eased land exploitation following intensive migratory processes (ECLAC, 2010d).

Deforestation and land degradation are mainly attributed to increased extensive and intensive agriculture. Two activities have traditionally dominated the agricultural expansion: soy production (only in SA) and beef; but more recently, biomass for biofuel production has become as important (Nepstad and Stickler, 2008) with some regions also affected by oil and mining extractions. Deforestation by small farmers, mainly coming from families who migrate in search for land and using shifting agriculture techniques is relatively low. In this line, Oliveira et al. (2007) found that only 9% of the deforestation in the Peruvian Amazon between 1999 and 2005 happened in indigenous territories. Pasture for livestock production is the predominant land use in deforested areas of tropical and subtropical Latin America (Wassenaar et al., 2007). More than 2/3 of the total deforested areas in Colombia (Etter et al., 2006) and in the Brazilian Amazon (Nepstad et al., 2006) are converted to cattle ranching. Forest conversion to pasture for livestock is also the major land use change driver in eastern Bolivia (Killeen et al., 2008).

In recent years, soybean croplands have expanded continuously in SA, becoming increasingly more important in the agricultural production of the region. Soybean-planted area in Amazonian states (mainly Mato Grosso) in Brazil expanded 12.1% per year during the 1990s, and 16.8% per year from 2000 to 2005 (Costa et al., 2007). This landscape-scale conversion from forest to soy and other large-scale agriculture can alter substantially the water...
balance for large areas of the region resulting in important feedbacks to the local climate (Hayhoe et al., 2011; Loarie et al., 2011) (see section 27.3.4.1).

Soybean and beef production have also impacted other ecosystems next to the Amazon, such as the Cerrado (Brazil) and the Chaco dry forests (Bolivia, Paraguay, Argentina and Brazil). Gasparri et al. (2008) estimated carbon emissions from deforestation in Northern Argentina and concluded that deforestation in the Chaco forest has accelerated in the past decade from agricultural expansion and is now the most important source of carbon emission for that region. In northwest Argentina (Tucumán and Salta provinces) 1.4 Mha of dry forest were cleared from 1972 to 2007 as a result of technological improvements and increasing rainfall (Gasparri and Grau, 2009).

Deforestation continued during the 1980s and 1990s resulting in cropland area covering up to 63% of the region by 2005 (Viglizzo et al., 2011). In central Argentina (northern Córdoba province), cultivated lands have increased from 3% to 30% (between 1969 and 1999); and the forest cover has decreased from 52.5% to 8.2%. This change has also been attributed to the synergistic effect of climatic, socioeconomic, and technological factors (Zak et al., 2008).

Losses in the Atlantic forest are estimated in 29% of the original area in 1960, and in 28% of the Yunga forest area, mainly due to cattle ranching migration from the Pampas and Espinal (Vigliizzo et al., 2011).

Oil palm is a significant biofuel crop also linked to recent deforestation in tropical CA and SA. Its magnitude is still small compared with deforestation related to soybean and cattle ranching, but it is considerable for specific countries and expected to increase due to increasing demands for biofuels (Fitzherbert et al., 2008). The main forest regions where oil palm has recently expanded are the Chocó region in Colombia and the Sucumbios region of Ecuador. Oil palm production is also important in Brazil (with 75% of the area planted in the state of Bahia) and emerging in the Amazonian region of Peru, where 72% of new plantations have expanded into forested areas (Gutiérrez-Vélez et al., 2011).

However, forests are not the only important ecosystems threatened in the region. An assessment of threatened ecosystems in SA by Jarvis et al. (2010) concluded that grasslands, savannas and shrublands are more threatened than forests, mainly from fires and grazing pressure. An estimation of burned land in Latin America by Chuvieco et al. (2008) also concluded that, proportionally, the most affected ecosystems were the savannas of Colombia and Venezuela. In the Río de la Plata region (Central-East Argentina, southern Brazil, and Uruguay), grasslands decreased from 67.4% to 61.4% between 1985 and 2004. This reduction was associated with an increase in annual crops, mainly soybean, sunflower, wheat, and maize (Baldi and Paruelo, 2008).

Even with technological changes that might result in agricultural intensification, the expansion of pastures and croplands is expected to continue in the coming years (Wassenaar et al., 2007; Kaimowitz and Angelsen, 2008), particularly from an increasing global demand for food and biofuels (Gregg and Smith, 2010) with the consequent increase in commodity prices. This agricultural expansion will be mainly in Latin America and Sub-Saharan Africa as these regions hold two-thirds of the global land with potential to expand cultivation (Nepstad and Stickler, 2008). It is important to consider enforceable policy and legal reforms to keep this process of large-scale change under control as much as possible; these reforms should aim to reduce the impact on poor households who depend directly on the natural resources being depleted (Takasaki, 2007). Indigenous groups require particular attention in this respect; there is a growing acknowledgment that recognizing the land ownership and authority of indigenous groups can help central governments to better manage many of the natural areas remaining in the region (Oltremari and Jackson, 2006; Larson, 2010). Many indigenous groups are important drivers of land use change in the region and their well-being should be considered when designing responses to pressures on the land by a globalized economy (Gray et al., 2008; Killeen et al., 2008).

27.2.2.2. Trends and Projections in Socioeconomic Conditions

Development in the region has traditionally displayed four characteristics: low growth rates, high volatility, structural heterogeneity and a very unequal income distribution (ECLAC, 2008; Bárcena, 2010). This combination of factors has generated high and persistent poverty levels (45% in CA and 30% for SA in year 2010), with the rate of poverty being generally higher in rural than urban areas (ECLAC, 2009c). SA has based its economic growth in natural resource exploitation (mining, energy, agricultural), which involves direct and intensive use of land and
water, and in energy-intensive and, in many cases, highly polluting natural-resource-based manufactures. In turn, CA has exploited its proximity to the North American market and its relatively low labor costs (ECLAC, 2010e).

The region shows a marked structural heterogeneity, where modern production structures coexist with large segments of the population with low productivity and income levels (ECLAC, 2010g). The GDP per capita in SA is twice that of CA; in addition, in the latter poverty is 50% higher (see Figure 27-4).

[INSERT FIGURE 27-4 HERE]

Figure 27-4: Evolution of GDP per capita and poverty (income below US$ 2 per day) from 1990-2011: CA and SA (US-Dollars per inhabitant at 2005 prices and percentages) (ECLAC on the basis of CEPALSTAT (2012)and ECLAC (2011c)).

The 2008 financial crisis reached CA and SA through exports and credits, remittances and worsening expectations by consumers and producers (Bárcena, 2010; Kacef and López-Monti, 2010). This resulted in the sudden stop of six consecutive years of robust growth and improving social indicators, which contributed to higher poverty in 2009 after six years where poverty had declined by 11%. Poverty rates fell from 44% to 33% of the total population, leaving 150 million people in this situation while extreme poverty diminished from 19.4% to 12.9% (which represents slightly more than 70 million people) (ECLAC, 2010e).

In the second half of 2009 industrial production and exports began to recover and yielded a stronger economic performance (GDP growth of 6.4% in SA and 3.9% in CA in 2010) (ECLAC, 2012). SA benefited the most because of the larger size of their domestic markets and the greater diversification of export markets. Conversely, slower growth was observed in CA with more open economies and a less diversified portfolio of trading partners and a greater emphasis on manufacturing trade (ECLAC, 2010g).

The region is expected to continue to grow in the short term, albeit at a pace that is closer to potential GDP growth, helped by internal demand as the middle class becomes stronger and as credit becomes more available. In SA, this could be boosted by external demand from the Asian economies as they continue to grow at a rapid pace. The macroeconomic challenge is to act counter cyclically creating conditions for productive development that is not based solely on commodity exports (ECLAC, 2010f).

In spite of its economic growth, the region still displays high and persistent inequality: most countries have Gini coefficients between 0.5 and 0.6, whereas the equivalent figures in a group of 24 developed countries vary between under 0.25 and around 0.40. The average per capita income of richest 10% of households is approximately 17 times that of the poorest 40% of households. Nevertheless, during the first decade of the century, prior to the financial crisis, the region has shown a slight but clear trend towards a more equitable distribution of income and a stronger middle class population resulting in a higher demand for goods (ECLAC, 2010g; UN, 2010; ECLAC, 2011b). Latin American countries also reported gains in terms of human development, although these gains have slowed down slightly over recent years. In comparative terms, the performance of countries as measured by the Human Development Index (HDI) varied greatly (from Chile with 0.878 and Argentina with 0.866 to Guatemala-0.704- and Nicaragua -0.699-) although those with lower levels of HDI showed notably higher improvements than countries with the highest HDI (UNDP, 2010).

Associated with inequality are disparities in access to water, sanitation and adequate housing for the most vulnerable groups - for example indigenous peoples, Afro-descendants, children and women living in poverty- and in their exposure to the effects of climate change. The strong heterogeneity of subnational territorial entities in the region takes the form of high spatial concentration and persistent disparities in the territorial distribution of wealth (ECLAC, 2010g; UN, 2010; ECLAC, 2011b).

The region faces significant challenges in terms of environmental sustainability and adaptability to a changing climate (UN, 2010), reflecting the specific characteristics of its population and economy already discussed and added to a significant deficit in infrastructure development. The stakeholders - the State, private sector and civil society- have made progress in incorporating environmental protection into decision-making processes, and particularly in terms of environmental institutions and legislation. Difficulties, however, remain in effectively mainstreaming the environment into public policies (UN, 2010). While the global economic and financial crises
together with climate change impose new challenges, they also provide an opportunity to shift development and growth patterns towards a more environmentally friendly economy.

27.3. Impacts, Vulnerabilities, and Adaptation Practices

27.3.1. Freshwater Resources

CA and SA are regions with a high average but unevenly distributed water resources availability (Magrin et al., 2007a). The main user of water is agriculture, accounting for 70% of all withdrawals used to feed more than 20 Mha of irrigated land (14% of the world’s total cultivated area) (ECLAC et al., 2010). The second use is composed by the region’s 580 million inhabitants (including the Caribbean), of which 86% had access to water supply by 2006 (ECLAC, 2010b), although in rural areas only 51% of the population have access to those services. In terms of non-consumptive water uses, according to the International Energy Agency (IEA), the region meets 60% of its electricity demand through hydropower generation, which contrast with the 20% average contribution of other regions (see case study 27.6.1).

27.3.1.1. Observed and Projected Impacts

In CA and SA there are many evidences of changing conditions in terms of hydro-geophysical variables (cryosphere and runoff) that affect streamflow and finally water availability.

The most robust trend for major rivers is found in the sub-basins of the La Plata River basin (high agreement, robust evidence). This basin, second only to the Amazon in size, and third in streamflow (21,500 m²/s) (Pasquini and Depetris, 2007), shows a positive trend in streamflow in the second half of the 20th century at different sites (Pasquini and Depetris, 2007; Krepper et al., 2008; Saurral et al., 2008; Amsler and Drago, 2009; Conway and Mahé, 2009; Dai et al., 2009; Krepper and Zucarelli, 2010a; Dai, 2011; Doyle and Barros, 2011). An increase in precipitation and a reduction in evapotranspiration from land use changes have been associated with the trend in streamflows (Saurral et al., 2008; Doyle and Barros, 2011), with the former being more important in the southern sub-basins and the latter in the northern ones (Doyle and Barros, 2011) (see section 27.2.1). Increasing trends in streamflows have also been found in the Laguna Mar Chiquita (a closed lake), and in the Santa Fe Province, both in Argentina, with ecological and erosive consequences (Pasquini et al., 2006; Rodrigues Capítulo et al., 2010; Troin et al., 2010; Venencio and García, 2011; Bucher and Curto, 2012). The effect of reservoirs on changing hydrologic conditions has been reported for the San Francisco River basin in Northeast Brazil (Andrade e Santos et al., 2012; Genz and Luz, 2012).

There is no clear long-term trend for the Amazon River, owing to its strong interannual and decadal variability. Extremely low levels were experienced during the droughts of 2005 and 2010, while record high levels for the same rivers were detected during the 2009 and 2012 floods (see section 27.2.1). Espinoza et al. (2009a; 2011) showed that the 1974-2004 apparent stability in mean discharge at the main stem of the Amazon in Obidos is explained by opposing regional features of Andean rivers (e.g. increasing trends in the Peruvian Amazons, Lavado et al., 2012) (see section 27.2.1). Major Colombian rivers draining to the Caribbean Sea (Magdalena and Cauca) exhibit decreasing trends along their main channels (Carmona and Poveda, 2011), while significant trends are absent for all other major large rivers in the Brazilian North East, and northern SA (Dai et al., 2009). The only study done for rivers in CA is that of Dai (2011) who showed a drying trend in this region.

Water resources are threatened by the rapid retreat and melting of the Andean cryosphere, which has been further reported following the IPCC AR4, through diverse techniques such as aerial photography, satellite imagery, ice coring, and lichens in the tropical glaciers of Venezuela, Colombia, Ecuador, Peru and Bolivia (see reviews in Vuille et al., 2008a; Jomelli et al., 2009; Bradley et al., 2009; Poveda and Pineda, 2009; Rabatel et al., 2012) and specific papers in Table 27-3a). A synthesis of the studies recognizes with high confidence (based on high agreement, and robust evidence) that tropical glaciers’ retreat has accelerated since the middle of the 20th century (Table 27-3a). In early stages of glacier retreat runoff tends to increase due to an acceleration of glacier melt, but after a peak in
discharge as the glacierized water reservoir gradually empties, runoff tends to decrease, as evidenced in the Cordillera Blanca of Peru (Chevallier et al., 2011; Baraer et al., 2012), where seven out nine river basins have probably crossed a critical threshold, exhibiting a decreasing dry-season discharge (Baraer et al., 2012). In general, runoff tends to decrease during the period in the year when precipitation is at its lowest level. Likewise, glaciers and icefields in the extra tropical Andes located in Central-South Chile and Argentina face significant reductions (see Table 27-3b), with their effect being compounded by changes in snowpack extent, thus magnifying changes in hydrograph seasonality by reducing flows in dry seasons and increasing them in wet seasons.

[INSERT TABLE 27-3 HERE]

Table 27-3: Observed trends related to Andean cryosphere.

a) Andean tropical glacier trends since the Little Ice Age (LIA) maximum and, particularly, during the last decades
b) Extra tropical Andean cryosphere (glaciers, snowpack, runoff effects) trends]

Some regions in Central-South Chile and Argentina also face significant reductions in precipitation (section 27.2.1), which has contributed to runoff reductions in the last decades of the 20th century (Seoane and López, 2007; Rubio-Álvarez and McPhee, 2010; Urrutia et al., 2011), contrasted with long-term trends found through dendrochronology (Lara et al., 2007; Urrutia et al., 2011). Trends in precipitation and runoff are less evident in the Central-North region in Chile (Fiebig-Wittmaack et al., 2012; Souvignet et al., 2012).

Assessment on future impacts (see Table 27-4) show a large range of uncertainty across the spectrum of climate models. It is hard to make conclusive statements in terms of trends on some particular regions/rivers. Nohara et al. (2006) studied climate change impacts on 24 of the main rivers in the world (considering an uncertainty analysis driven by use of 19 GCMs), and found no robust change for the Paraná (La Plata Basin) and Amazon Rivers. Nevertheless, in both cases the average change showed a positive value consistent at least with observations for the La Plata Basin. On top of such climatic uncertainty, future streamflows and water availability projections are confounded by the potential effects of deforestation (Moore et al., 2007; Coe et al., 2009).

[INSERT TABLE 27-4 HERE]

Table 27-4: Synthesis of projected climate change impacts on hydrologic variables in large South American basins and major glaciers.

Since the AR4 several studies have been developed to associate future climate scenarios with the evolution of glaciers, especially in the tropical Andes. Juen et al. (2007) and Chevallier et al. (2011) developed “regression” type of analysis relating glacier evolution (manifested as downstream streamflow) to changes in temperature. Similarly, Poveda and Pineda (2009) performed linear extrapolations on historic glacier retreat rates to estimate the fate of the six remaining glaciers in Colombia. In general, these studies indicate that glaciers may continue their retreat (Vuille et al., 2008a) as glacier Equilibrium Line Altitudes rises, with larger hydrological effects during the dry season (Kaser et al., 2010; Gascoin et al., 2011). This is expected to happen during the next 20-50 years (Juen et al., 2007; Chevallier et al., 2011) (see Table 27-4). After that period water availability during the dry months is expected to diminish. A forecast, for instance, by Baraer et al. (2012) for the Santa River in the Peruvian Andes finds that once the glaciers are completely melt, annual discharge would decrease by 2%–30%, depending on the watershed.

Significant effects are foreseen in the energy balances of the Andes, through changes in temperature and albedo, thus influencing hydrologic regimes. In Central Chile, Vicuña et al. (2011) project changes in the seasonality of streamflows of the upper snowmelt-driven watersheds of the Limari River, associated with temperature increases and reductions in water availability owing to a reduction (increase) in precipitation (evapotranspiration) (see Table 27-4). Similar conclusions are derived across the Andes on the Limay River in Argentina by Seoane and López.
Projected changes in the cryosphere conditions of the Andes could affect the occurrence of extreme events, such as the Glacial-lake outburst floods occurring in the icefields of Patagonia (Dussaillant et al., 2010), volcanic collapse and debris flow associated with accelerated glacial melting in the tropical Andes (Carey, 2005; Carey et al., 2012b; Fraser, 2012), and with volcanoes in southern Chile and Argentina (Tormey, 2010), as well as scenarios of water quality pollution by exposure to contaminants owing to glaciers retreat (Fortner et al., 2011).

27.3.1.2. Vulnerability and Adaptation Practices

Vulnerability for the region considers both ‘future/outcome vulnerability’ (related to impacts associated with climate change) and ‘actual/contextual vulnerability’ (depending on social, political, economic, cultural, and institutional factors) (O’Brien et al., 2007). Current highly vulnerable regions include the semi-arid regions in Chile-Argentina and North East Brazil, certain regions in CA, and communities along the tropical Andes.

Semi-arid regions are characterized by pronounced climatic variability and often by water scarcity and related social stress (Krol and Bronstert, 2007; Scott et al., 2012). The semi-arid regions of Central Chile-Argentina are expected to face streamflow reductions and changes in seasonality, with potentially significant effects on already vulnerable and highly populated regions (e.g. Santiago, Chile) and extensive agriculture irrigation demands (ECLAC, 2009a; Souvignet et al., 2010; Fiebig-Wittmaack et al., 2012). The need to develop special adaptation tools to face the threats of climate change is particularly special for the most vulnerable communities in this region (Young et al., 2010), such as those located in the transition between the semi-arid and arid climates (Debels et al., 2009) (see Table 27-4).

Another semi-arid region that has been studied thoroughly is the Northeast Brazilian ( Hastenrath, 2012). De Mello et al. (2008), Gondim et al. (2008), Souza et al. (2010) and Montenegro and Ragab (2010) have shown that future climate change scenarios would decrease water availability for agriculture irrigation owing to reductions in precipitation and increases in evapotranspiration. Krol and Bronstert (2007) and Krol et al. (2006) presented an integrated modeling study that linked projected impacts on water availability for agriculture with economic impacts that could potentially drive full-scale migrations in the Brazilian northeast region.

In CA, Benegas et al. (2009), Manuel-Navarrete et al. (2007) and Aguilar et al. (2009) provide different frameworks to understand vulnerability and adaptation strategies to climate change and variability in urban and rural contexts, although no specific adaptation strategies are suggested.

The retreat of Andean glaciers can exacerbate water resources vulnerability (Bradley et al., 2006; Casassa et al., 2007; Vuille et al., 2008b; Mulligan et al., 2010). Glacier retreat diminishes the mountains’ water regulation capacity, making it more expensive and less reliable the supply of water for diverse purposes, as well as for ecosystems integrity (Buytaert et al., 2011). Impacts on economic activities associated with conceptual scenarios of glacier melt reduction have been monetized (Vergara et al., 2007), representing about US$100 million in the case of water supply for Quito, and between US$212 million to US$1.5 billion in the case of the Peruvian electricity sector due to losses of hydropower generation (see case study 27.6.1). Andean communities face an important increase in their vulnerability, as documented by Mark et al. (2010), Pérez et al. (2010) and Buytaert and De Bièvre (2012). Different issues have been addressed in the assessment of adaptation strategies for these communities such as the role of governance and institutions (Young and Lipton, 2006; Lynch, 2012), technology (Carey et al., 2012a), and the dynamics of multiple stressors (McDowell and Hess, 2012).

A series of policies have been developed to reduced vulnerability to climate variability as faced today in different regions and settings of CA and SA. In 1997, Brazil instituted the National Water Resources Policy and created the National Water Resources Management System under the shared responsibility between the States and the Federal government. Key to this new regulation has been the promotion of decentralization and social participation through the creation of National Council of Water Resources and their counterparts in the states, the States Water Resources Councils. The challenges and opportunities dealing with water resources management in Brazil in the face of climate variability and climate change have been well studied (Abers, 2007; Kumler and Lemos, 2008; Medema et al., 2008; Engle et al., 2011; Lorz et al., 2012). Other countries in the region are following similar approaches. In the last five
years, there have been constitutional and legal reforms towards more efficient and effective water resources
management and coordination among relevant actors in Honduras, Nicaragua, Ecuador, Peru, Uruguay, Bolivia and
Mexico; although in many cases, these innovations have not been completely implemented (Hantke –Domas, 2011).

Institutional and governance improvements are required to assure an effective implementation of these adaptation
measures (e.g. Halsnæs and Verhagen, 2007; Engle and Lemos, 2010; Lemos et al., 2010; Zagonari, 2010; and
Pittock, 2011).

The particular experience in Northeast Brazil provides other examples of adaptation strategies. Broad et al. (2007)
and Sankarasubramanian et al. (2009) studied the potential benefits of streamflow forecast in this region as a way to
reduce the impacts of climate change and climate variability on water distribution under stress conditions. An
historical review and analysis of drought management in this region are provided by Campos and Carvalho (2008).
Souza Filho and Brown (2009) studied different water distribution policy scenarios finding that the best option
depended on the degree of water scarcity. The study by Nelson and Finan (2009) provides a critical perspective of
drought-related policies, arguing that they constitute an example of maladaptation as they do not try to solve the
causes of vulnerability and instead undermine resilience. Tompkins et al. (2008) are also critical of risk reduction
practices in this region because they have fallen short of addressing the fundamental causes of vulnerability needed
for efficient longer-term drought management.

Other types of adaptation options that stem from studies on arid and semi-arid regions are related to: a) increase in
water supply from groundwater pumping (Döll, 2009; Kundzewicz and Döll, 2009; Zagonari, 2010; Burte et al.,
2011); fog interception practices (Holder, 2006; Klemm et al., 2012), and reservoirs and irrigation infrastructure
(Fry et al., 2010; Vicuña et al., 2010; 2012); b) improvements in water demand management associated with
increased irrigation efficiency and practices (Geerts et al., 2010; Montenegro and Ragab, 2010; Van Oel et al., 2010;
Bell et al., 2011; Jara-Rojas et al., 2012), and changes towards less water intensive crops (Montenegro and Ragab,
2010).

Flood management practices also provide a suite of options to deal with actual and future vulnerabilities related to
hydrologic extremes, such as the management of ENSO-related events in Peru via participatory (Warner and Oré,
2006) or risk reduction approaches (Khalil et al., 2007), the role of land use management (Bathurst et al., 2010;
2011; Coe et al., 2011), and flood hazard assessment (Mosquera-Machado and Ahmad, 2006).

27.3.2. Terrestrial and Inland Water Systems

27.3.2.1. Observed and Projected Impacts and Vulnerabilities

CA and SA house the largest biological diversity and several of the world’s megadiverse countries (Mittermeier et
al., 1997; Guevara and Laborde, 2008). However, land use change has led to the existence of six biodiversity
hotspots, i.e. places with a great species diversity that show high habitat loss and also high levels of species
endemism: Mesoamerica, Chocó-Darien-Western Ecuador, Tropical Andes, Central Chile, Brazilian Atlantic forest,
and Brazilian Cerrado (Mittermeier et al., 2005). Thus, conversion of natural ecosystems is the main proximate
cause of biodiversity and ecosystem loss in the region (Ayoo, 2008). Tropical deforestation is the second largest
driver of anthropogenic climate change on the planet, adding up to 17%–20% of total greenhouse gas emissions
during the 1990s (Gullison et al., 2007; Strassburg et al., 2010). In parallel, the region has still large extensions of
wilderness areas for which the Amazon is the most outstanding example. Nevertheless, some of these areas are
precisely the new frontier of economic expansion. For instance, between 1996 and 2005 Brazil deforested about
19,500 km² per year, which represented 2% to 5% of global annual CO₂ emissions (Nepstad et al., 2009). Between
2005 and 2009, deforestation in the Brazilian Amazon dropped by 36%, which is partly related to the network of
protected areas that now covers around 45.6% of the biome in Brazil (Soares-Filho et al., 2010). Using LandSHIFT
modeling framework for land use change and the IMPACT projections of crop/livestock production, Lapola et al.
(2011) projected that zero deforestation in the Brazilian Amazon forest by 2020 (and of the Cerrado by 2025) would
require either a reduction of 26%–40% in livestock production until 2050 or a doubling of average livestock density
from 0.74 to 1.46 head per hectare. Thus, climate change may imply reduction of yields and entail further
deforestation.
Local deforestation rates or rising greenhouse gases globally drive changes in the regional SA that during this century might lead the Amazon rainforest into crossing a critical threshold at which a relatively small perturbation can qualitatively alter the state or development of a system (Cox et al., 2000; Salazar et al., 2007; Sampaio et al., 2007; Lenton et al., 2008; Nobre and Borma, 2009). Various models are projecting a risk of reduced rainfall and higher temperatures and water stress, that may lead to an abrupt and irreversible replacement of Amazon forests by savanna-like vegetation, under a high emission scenario (A2), from 2050-2060 to 2100 (Betts et al., 2004; Cox et al., 2004; Salazar et al., 2007; Sampaio et al., 2007; 2008; Malhi et al., 2008; Sitch et al., 2008; Malhi et al., 2009; Nobre and Borma, 2009; Marengo et al., 2011c). The possible ‘savannization’ or ‘die-back’ of the Amazon region would potentially have large-scale impacts on climate, biodiversity and people in the region. The possibility of this die-back scenario occurring, however, is still an open issue and the uncertainties are still very high (Rammig et al., 2010; Shiogama et al., 2011).

Plant species are rapidly declining in CA, SA, Central and West Africa, and Southeast Asia (Bradshaw et al., 2009). Risk estimates of plant species extinction in the Amazon, which do not take into account possible climate change impacts, range from 5%-9% by 2050 with a habitat reduction of 12%-24% (Feeley and Silman, 2009) to 33% by 2030 (Hubbell et al., 2008). The highest percentage of rapidly declining amphibian species occurs in CA and SA. Brazil is among the countries with most threatened bird and mammal species (Bradshaw et al., 2009).

A similar scenario is found in inland water systems. Among the components of aquatic biodiversity, fish are the best-known organisms (Abell et al., 2008) with Brazil accounting for the richest ichthyofauna of the planet (Nogueira et al., 2010). For instance, the 540 Brazilian small microbasins host 819 fish species with restriction distribution. However, 29% of these microbasins have historically lost more than 70% of their natural vegetation cover and only 26% show a significant overlap with protected areas or indigenous reserves. Moreover, 40% of the microbasins overlap with hydrodams (see 27.6.1 and Chapter 3) or have few protected areas and high rates of habitat loss (Nogueira et al., 2010).

The faster and more severe the rate of climate change, the more severe the biological consequences such as species decline (Brook et al., 2008). Vertebrate fauna in North and South America is projected to suffer species losses until 2100 of at least 10%, as forecasted in over 80% of the climate projections based on low emissions scenario (Lawler et al., 2009). Vertebrate species turnover until 2100 will be as high as 90% in specific areas of CA and the Andes. For instance, 540 Brazilian small microbasins host 819 fish species with restriction distribution.

In addition to climate change impacts at individual species level, biotic interactions will be affected. Modifications in phenology, structure of ecological networks, predator-prey interactions and non-trophic interactions among organisms have been forecasted (Brooker et al., 2008; Walther, 2010). The outcome of non-trophic interactions among plants is expected to shift along with variation in climatic parameters, with more facilitative interactions in more stressful environments, and more competitive interactions in more benign environments (Brooker et al., 2008; Anthelme et al., 2012). These effects are expected to have a strong influence of community and ecosystem (re-)organization given the key engineering role played by plants on the functioning of ecosystems (Callaway, 2007). High Andean ecosystems, especially those within the tropics, are expected to face exceptionally strong warming effects during the 21st century because of their uncommonly high altitude (Bradley et al., 2006). At the same time they provide a series of crucial ecosystem services for millions people (Buytaert et al., 2011). For these reasons shifts in biotic interactions are expected to have negative consequences on biodiversity and ecosystem services in this region.
Although in the region biodiversity conservation is largely confined to protected areas, with the magnitude of climatic changes projected for the century, it is expected that many species and vegetational types will lose representativeness inside such protected areas (Heller and Zavaleta, 2009).

27.3.2.2. Adaptation Practices

The sub-set of practices that are multi-sectoral, multi-scale, and based on the premise that ecosystem services reduce the vulnerability of society to climate change are known as Ecosystem-based Adaptation (EbA) (Vignola et al., 2009; see also Glossary). Schemes such as the payment for environmental services (PES) and community management fit the concept of EbA that begins to spread in CA and SA (Vignola et al., 2009). The principle behind these schemes is the valuation of ecosystem services that should reflect both the economic and cultural benefits derived from the human-ecosystem interaction and the capacity of ecosystems to secure the flow of these benefits in the future (Abson and Termansen, 2011).

Since PES schemes have developed more commonly in CA and SA than in other parts of the world (Balvanera et al., 2012), this topic will be covered as a case study (see 27.6.2 in this Chapter).

Ecological restoration can be an important tool for adaptation. A meta-analysis of 89 studies by Benayas et al. (2009) (with timescale of restoration varying from <5 to 300 years), including many in SA, showed that ecological restoration enhances the provision of biodiversity and environmental services by 44% and 25%, respectively, as compared to degraded systems (Benayas et al., 2009). Moreover, ecological restoration increases the potential for carbon sequestration and promotes community organization, economic activities and livelihoods in rural areas (Chazdon, 2008), as seen in examples of the Brazilian Atlantic Forest (Calmon et al., 2011; Rodrigues et al., 2011). Chazdon et al. (2009) also highlight the potential of restoration efforts to build ecological corridors (see Harvey et al., 2008, for example in Central America).

Community management of natural areas is another efficient tool to adapt to climate change and to reconcile biodiversity conservation with socio-economic development. Porter-Bolland et al. (2012) compared protected areas with areas under community management in different parts of the tropical world, including CA and SA, and found that protected areas have higher deforestation rates than areas with community management. Similarly, Nelson and Chomitz (2011) found for the region that (i) protected areas of restricted use reduced fire substantially, but multi-use protected areas are even more effective; and that (ii) in indigenous reserves the incidence of forest fire was reduced by 16% as compared to non-protected areas. This somehow contrasts with the findings of Miteva et al. (2012) that found protected areas more efficient in constraining deforestation than other schemes. Other good examples of adaptive community management in the continent include community forest concessions (e.g., Guatemala; Radachowsky et al., 2012), multiple-use management of forests (Guariguata et al., 2012; see also examples in Brazil – Klimas et al., 2012, Soriano et al., 2012, and Bolívia – Cronkleton et al., 2012); and local communities where research and monitoring protocols are in place to pay the communities for collecting primary scientific data (Lazar et al., 2011).

27.3.3. Coastal Systems and Low-Lying Areas

27.3.3.1. Observed and Projected Impacts and Vulnerabilities

Climate change is altering coastal and marine ecosystems (Hoegh-Guldberg and Bruno, 2010). Coral reefs, seagrass beds, mangroves, rocky reefs and shelves, and seamounts have few to no areas left in the world that remain unaffected by human influence (Halpern et al., 2008). Anthropogenic drivers associated with climate change decreased ocean productivity, altered food web dynamics, reduced abundance of habitat-forming species, shifting species distributions, and greater incidence of disease (Hoegh-Guldberg and Bruno, 2010). Coastal and marine impacts and vulnerability are often associated with collateral effects of climate change such as sea-level rise, ocean warming and ocean acidification. Overfishing, habitat pollution and destruction, and the invasion of species also negatively impact biodiversity and the delivery of ecosystem services (Guarderas et al., 2008; Halpern et al., 2008).
Such negative impacts lead to losses that pose significant challenges and costs for societies, particularly in developing countries (Hoegh-Guldberg and Bruno, 2010). For instance, the Ocean Health Index (Halpern et al., 2012) that measures how healthy the coupling of the human-ocean system is for every coastal country (including parameters related to climate change), indicates that CA countries rank amongst the lowest values. For SA, Suriname stands out with one of the highest scores.

Since the coastal states of Latin America and the Caribbean have a human population of more than 610 million, 3/4 of whom live within 200 km of the coast, marine ecosystems have been undergoing significant transformations (Guarderas et al., 2008). Fish stocks, places for recreation and tourism, and controls of pests and pathogens are all under threat (Guarderas et al., 2008; Mora, 2008). Moreover, changes over 2 mm yr\(^{-1}\) of sea-level rise have been found in CA and SA. The Western equatorial border, influenced by the ENSO phenomenon, shows a lower variation (of about 1 mm yr\(^{-1}\)) and a range of variation under El Niño events of the same order of magnitude that the sustained past changes. The distribution of population is a crucial factor for inundation impact, with coastal areas being non-homogeneously impacted. A scenario of 1m SLR would affect some coastal populations in Brazil and the Caribbean islands (see Figure 27-5). (ECLAC, 2011a)

The greatest flooding levels (hurricanes not considered) in the region are found in Rio de La Plata area, which combine a 5 mm yr\(^{-1}\) change in storm surge with SLR changes in extreme flooding levels (ECLAC, 2011a). Extreme flooding events may become more frequent since return periods are decreasing, and urban coastal areas in the eastern coast will be particularly affected, while at the same time beach erosion is expected to increase in southern Brazil and in scattered areas at the Pacific coast. (ECLAC, 2011a)

The majority of literature concerning climate change impacts for coastal and marine ecosystems considers coral reefs, mangroves and fisheries. Coral reefs are particularly sensitive to climate-induced changes in the physical environment (Baker et al., 2008) to an extent that 1/3 of the more than 700 species of reef-building corals worldwide are already threatened with extinction (Carpenter et al., 2008). Coral bleaching and mortality are often associated with ocean warming and acidification (Baker et al., 2008). If extreme sea surface temperatures are to continue, the projections of scenario SRES A1F indicate that it is possible that the Mesoamerican coral reef will collapse by mid-century, causing major economic losses (Vergara et al., 2009). Extreme high sea surface temperatures have been increasingly documented in the western Caribbean near the coast of CA and have resulted in frequent bleaching events (1993, 1998, 2005, and again in 2010) of the Mesoamerican coral reef, located along the coasts of Belize, Honduras and Guatemala (Eakin et al., 2010). Reef but also mangrove ecosystems are estimated to contribute greatly to goods and services in economic terms. In Belize, for example, this amount is approximately US$395-8559 million annually, primarily through marine-based tourism, fisheries and coastal protection (Cooper et al., 2008). In the Eastern Tropical Pacific, seascape trace abundance of cement and elevated nutrients in upwelled waters are factors that help explain high bioerosion rates of local coral reefs (Manzello et al., 2008). In the southwestern Atlantic coast, eastern Brazilian reefs might suffer a massive coral cover decline in the next 50 years. Francini-Filho et al. (2008) pointed out that coral diseases intensified between 2005 and 2007 based on qualitative observations since the 1980s and regular monitoring since 2001. They have also predicted that Mussismilia braziliensis- a major reef-building coral species that is endemic in Brazil- will be nearly extinct in less than a century if the current rate of mortality due to disease is not reversed (Francini-Filho et al., 2008).

Mangroves are largely affected by anthropogenic activities whether or not they are climate driven. All mangrove forests, along with important ecosystem goods and services, could be lost in the next 100 years if the present rate of loss continues (1-2% a year) (Duke et al., 2007). Moreover, estimates are that climate change may lead to a maximum global loss of 10-15% of mangrove forest by 2100 (Alongi, 2008). In CA and SA, some of the main drivers of loss are deforestation and land conversion, agriculture and shrimp ponds (Polidoro et al., 2010). The Atlantic and Pacific coasts of CA are some of the most endangered in the planet with regards to mangroves, since approximately 40% of the present mangroves’ species are threatened with extinction (Polidoro et al., 2010).

Approximately 75% of the mangrove extension of the planet is concentrated in 15 countries, among which Brazil is
included (Giri et al., 2011). The rate of survival of original mangroves lies between 12.8% and 47.6% in the Tumaco Bay (Colombia), resulting in ecosystem collapse, fisheries reduction and impacts on livelihoods (Lampis, 2010). Gratiot et al. (2008) project for the current decade an increase of mean high water levels of 6 cm followed by 90m shoreline retreat implying flooding of thousands of hectares of mangrove forest along the coast of French Guiana. Peru and Colombia are two of the eight most vulnerable countries to climate change impacts on fisheries, due to the combined effect of observed and projected warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities (Allison et al., 2009). Fisheries production systems are already pressured by overfishing, habitat loss, pollution, invasive species, water abstraction and damming (Allison et al., 2009). In Brazil, a decadal rate of 0.16 trophic level decline has been detected through most of the northeastern coast, between 1978 and 2000, which is one of the highest rates documented in the world (Freire and Pauly, 2010).

Despite the focus in the literature on corals, mangroves and fisheries, there is evidence that other benthic marine invertebrates that provide key services to reef systems, such as nutrient cycling, water quality regulation, and herbivory, are also threatened by climate change (Przeslawski et al., 2008). The same applies for seagrasses for which a worldwide decline has accelerated from a median of 0.9% yr\(^{-1}\) before 1940 to 7% yr\(^{-1}\) since 1990, which is comparable to rates reported for mangroves, coral reefs, tropical rainforests and place seagrass meadows among the most threatened ecosystems on earth (Waycott et al., 2009).

A major challenge of particular relevance at local and global scales will be to understand how these physical changes will impact the biological environment of the ocean (e.g., Gutiérrez et al., 2011b), as the Humboldt Current system - flowing along the west coast of SA - is the most productive upwelling system of the world in terms of fish productivity.

27.3.3.2. Adaptation Practices

Designing marine protected areas (MPAs) that are resilient to climate change is a key adaptation strategy in coastal and marine environments (McLeod et al., 2009). By 2007, Latin America and the Caribbean (which includes CA and SA countries) had over 700 MPAs established covering around 1.5% of the coastal and shelf waters, most of which allow varying levels of extractive activities (Guarderas et al., 2008). This protected area cover, however, is insufficient to preserve important habitats or connectivity among populations at large biogeographic scales (Guarderas et al., 2008).

In Brazil, a protected area type known as “Marine Extractive Reserves” currently benefits 60,000 small-scale fishermen along the coast (Moura et al., 2009). Examples of fisheries’ co-management, a form of a participatory process involving local fishermen communities, government, academia and NGOs, are reported to favor a balance between conservation of marine fisheries, coral reefs and mangroves on the one hand (Francini-Filho and Moura, 2008), and the improvement of livelihoods, as well as the cultural survival of traditional populations on the other (Moura et al., 2009; Hastings, 2011).

In addition to marine protected areas that include mangroves and functionally linked ecosystems, Gilman et al. (2008) list a number of other relevant adaptation practices: coastal planning to facilitate mangrove migration with sea-level rise, management of activities within the catchment that affect long-term trends in the mangrove sediment elevation, better management of non-climate stressors, and the rehabilitation of degraded areas.

Significant financial and human resources are expended annually in the marine reserves to support reef management efforts. These actions, including the creation of marine reserves to protect from overfishing, improvement of watershed management, and protection or replanting of coastal mangroves, are proven tools to improve ecosystem functioning. However, they may also actually increase the thermal tolerance of corals to bleaching stress and thus the associated likelihood of surviving future warming (Carilli et al., 2009).
Adaptations to sea level rise involve redirecting new settlements to better-protected locations and to promote investments in appropriate infrastructure. This shall be required in the low elevation coastal zones (LECZ) of the region, particularly in lower income countries with limited resources, which are especially vulnerable. The same applies to countries with high shares of land (e.g., Brazil ranking 7th worldwide of the total land area in the LECZ) and/or population (e.g., Guyana and Suriname rank 2nd and 5th by the share of population in the LECZ, having respectively 76% and 55% of their populations in such areas (McGranahan et al., 2007). Adaptation will demand effective and enforceable regulations and economic incentives, all of which require political will as well as financial and human capital (McGranahan et al., 2007).

27.3.4. Food Production Systems and Food Security

27.3.4.1. Observed and Projected Impacts and Vulnerabilities

Increases in the global demand for food, forage, fiber and biofuels promoted a sharp increase in agricultural production in SA and CA mainly associated with the expansion of planted areas (see Chapter 7). This trend is predicted to continue since SA accounts for 40% of the global potential arable land (Nellemann et al., 2009). Agro-ecosystems are being and will be affected in isolation and synergistically by climate variability/change and land use changes, which are comparable drivers of environmental change. According to projections based on 30 GCMs (under SRES A1B and B1) by the end of 21st century (2070-2099), SA could lose between 1% and 21% of its arable land due to climate change and population growth (Zhang and Cai, 2011).

In the future, SA will face both the great challenge of fulfilling the growing food and biofuels demand and the impact of climate change, trying to preserve natural resources. Although optimal land management could combine efficient agricultural and biofuels production with ecosystem preservation under climate change conditions, current practices are far from optimal, leading to a deterioration of ecosystems throughout the continent (see section 27.3.2).

Examples for this are, e.g., in southern Brazilian Amazonia water yields were near four times higher in soy than forested watersheds, and showed greater seasonal variability (Hayhoe et al., 2011). In the Argentinias Pampas current land use changes disrupt water and biogeochemical cycles and may result in soil salinization, altered C and N storage, surface runoff and stream acidification (Nosetto et al., 2008; Berthrong et al., 2009; Farley et al., 2009). In central Argentina flood extension was associated with the dynamics of groundwater level that, in turn, has been influenced by precipitation and land use change (Vigliizzo et al., 2009).

Observed impacts: The SESA region has shown significant increases in precipitation and wetter soil conditions during the 20th century (Giorgi, 2002) (see Table 27-1). Rainfall increases benefited summer crops and pastures productivity, and contributed to a significant expansion of agricultural areas, mainly in climatically marginal regions of Argentina (Barros, 2010; Hoyos et al., 2012). Comparing the periods 1930-60 and 1970-2000, maize and soybean yields increased between 9% and 58% in Argentina, Uruguay and South Brazil (Magrin et al., 2007b) mainly due to precipitation increases. However, current agricultural production systems, which evolved partially in response to wetter conditions, could be threatened if climate reverts to a drier situation, putting at risk the viability of continuous agriculture in marginal regions of the Argentina’s Pampas (Podestá et al., 2009). During the 1930s-1940s, dry and windy conditions together with deforestation, overgrazing, overcropping and non-suitable tillage technology produced devastating results including severe dust storms, cattle mortality, crop failure, farmer bankruptcy and rural migration (Vigliizzo and Frank, 2006).

At the global scale, warming since 1981 has reduced wheat, maize and barley productivity, although the impacts were small compared with the technological yield gains over the same period (Lobell and Field, 2007). In central Argentina, simulated potential wheat yield has been decreasing at increasing rates since 1930 (1930-2000: -28 kg/ha/year; 1970-2000: -53 kg/ha/year) in response to increases in minimum temperature during October-November (1930-2000: +0.4°C/decade; 1970-2000: +0.6°C/decade) (Magrin et al., 2009). Lobell et al. (2011) showed that the observed changes in the growing season temperature and precipitation between 1980 and 2008 have slowed the positive yield trends due to improved genetics in Brazilian wheat, maize and soy, as well as Paraguayan soy. In contrast, rice in Brazil and soybeans in Argentina have benefited from precipitation and temperature trends. In
Projected impacts: In SESA climate change could benefit some crops until mid-21st-century if CO₂ effects are considered (see Table 27-5), although interannual and decadal climate variability could provoke important damages. In Uruguay, productivity could increase steadily until the 2030s-2050s depending on the SRES scenario (ECLAC, 2010c). In Argentina, average yields of soy, maize, and wheat could increase or remain almost stable. Increases in temperature and precipitation may benefit crops towards the southern and western zone of the Pampas (Magrin et al., 2007c; ECLAC, 2010c). In South Brazil, irrigated rice yield (Walter et al., 2010) and bean productivity (Costa et al., 2009) is expected to increase. If technological improvement is considered, the productivity of common bean and maize could increase between 40% and 90% (Costa et al., 2009). Sugarcane production could benefit as warming could allow the expansion of planted areas towards the south, where low temperatures are a limiting factor (Pinto et al., 2008). Increases in crop productivity could reach 6% in São Paulo state towards 2040 (Marin et al., 2009). In Paraguay, the yields of soybean and wheat could remain almost stable or increase slightly until 2030 (ECLAC, 2010a).

In Chile and western Argentina, yields could be reduced by water limitation. In central Chile (30°S to 42°S) temperature increases, reduction in chilling hours and water shortages may reduce productivity of winter crops, fruits, vines and radiata pine. Conversely, rising temperatures, more moderate frosts and more abundant water will very likely benefit all species towards the South (Meza and Silva, 2009; ECLAC, 2010a). In northern Patagonia (Argentina) fruit and vegetable growing could be negatively affected because of a reduction in rainfall and in average flows in the Neuquén River basin. At the same time in the region, in specific in the north of the Mendoza basin, increases in water demand, because of population growth, may compromise the availability of subtropical water for irrigation, pushing up irrigation costs and forcing many producers out of farming towards 2030. Also, water quality could be reduced by the worsening of existing salinization processes (ECLAC, 2010a).

In CA, northeastern Brazil and parts of the Andean region (Table 27-5) climate change could affect crop yields, local economies and food security. Results from 23 GCMs suggest a high probability (>90%) that growing season temperatures in parts of tropical SA, east of the Andes and CA will exceed the extreme seasonal temperatures documented from 1900 to 2006 at the end of this century, affecting regional agricultural productivity and human welfare (Battisti and Naylor, 2009). For NEB, declining crop yields in subsistence crops such as beans, corn and cassava are projected (Lobell et al., 2008; Margulis et al., 2010). In addition, increases in temperature could reduce the areas currently favorable to cowpea bean (Silva et al., 2010). The warming up to 5.8 °C foreseen for 2070 could make the coffee crop unfeasible in Minas Gerais and São Paulo (SE Brazil) if no adaptation action is accomplished. By 2070 the coffee crop may have to be transferred to southern regions where frost risk will be much lower (Camargo, 2010). A Great increases in Arabica coffee production (principally in the Uruguayan border and North of Argentina) are expected in low climatic risks areas with 3°C increases in mean temperature (Zullo et al., 2011). Brazilian potato production could be restricted to a few months in currently warm areas, which today allow potato production all around the year (Lopes et al., 2011). Large losses of suitable environments for the “Pequi” tree (Caryocar brasiliense; an economically important Cerrado fruit tree) are projected by 2050, mainly affecting the poorest communities in Central Brazil (Nabout et al., 2011). Climate change in the Amazon region may also have a critical impact on the yields of commonly cultivated crops. Lapola et al. (2011) showed that by 2050 soybean yields would be reduced by 44% in the worst-case scenario (HadCM3 climate and no CO₂ fertilization).

Teixeira et al. (2011) identified hot spots for heat stress towards 2071-2100 under the A1B scenario and suggest that rice in South East Brazil, maize in CA and SA, and soybean in Central Brazil will be the crops and zones most affected by increases in temperature.

In CA, warming conditions combined with more variable rainfall are expected to reduce maize, bean and rice productivity endangering the food security of many people and increasing poverty (ECLAC, 2010c) (see Table 26-7). According to Lobell et al. (2008), rice and wheat yields could decrease up to 10% by 2030. In Panamá, maize production could modestly increase over the century because of accelerated development helping the grain-filling period to be completed before the worst water stresses occur, although the large interannual climate variations will continue to be the dominant influence on seasonal maize yield into the coming decades (Ruane et al., 2011).
One of the uncertainties associated with the impacts of climatic change is the effect of CO\textsubscript{2} on plant physiology. According to DaMatta \textit{et al.} (2010), many crops (such as soybean, common bean, maize and sugarcane) can probably respond with an increasing productivity as a result of higher growth rates and better water use efficiency. However, food quality could decrease due to higher sugar contents in grain and fruits, and decreases in the protein content in cereals and legumes.

Uncertainties associated with climate and crop models, as well as with the uncertainty in human behavior, potentially lead to large error bars on any long-term prediction of food output. However, the trends presented here represent the current available information (see Table 27-5).

Climate change may also alter the current scenario of plant diseases and their management, having effects on productivity (Ghini \textit{et al.}, 2011). In Argentina, years with severe infection of late cycle diseases in soybean could increase; severe outbreaks of the Mal de Rio Cuarto virus in maize could be more frequent; and wheat head fusariosis will increase slightly in the south of the Pampas region, and decrease in the north by the end of the century (ECLAC, 2010a; Martínez \textit{et al.}, 2011). Potato late blight (\textit{Phytophthora infestans}) severity is expected to increase in Perú (Giraldo \textit{et al.}, 2010). However, there is uncertainty related to how plants will respond to diseases because of a potential increase in plants’ photosynthesis and accelerates in their metabolism under the effect of elevated CO\textsubscript{2} and higher temperature (Sage, 2002), possibly offsetting many of the diseases’ effects in the future.

The impacts of climate change on livestock production would vary by species and climate scenarios. By 2060, under a hot and dry scenario, beef and dairy cattle, pigs and chickens could decrease between 0.9 and 3.2%, while sheep could increase by 7% mainly in the Andean mountain countries. Dairy cattle could increase only in Uruguay and Argentina. Under a milder and wetter scenario, beef cattle choice declines in Colombia, Ecuador, and Venezuela, but increases in Argentina and Chile. Sheep increase in Colombia and Venezuela, but decrease in the high mountains of Chile where chickens are chosen more frequently Seo \textit{et al.} (2010). Future climate could strongly affect milk production and feed intake in dairy cattle in Brazil. Furthermore, substantial modifications in the Brazilian areas at present suitable for livestock, particularly in the main Pernambuco region are expected (Silva \textit{et al.}, 2009).

Climate change impact on regional welfare will depend not only on changes in yield, but also in international trade. By 2030, global cereal price could change between +32% (low-productivity scenario) and -16% (optimistic yield scenario). A rise in prices could benefit net exporting countries like Brazil, where gains from terms of trade shifts could outweigh the losses due to climate change. Despite experiencing significant negative yield shocks, some countries tend to gain from higher commodity prices (Hertel \textit{et al.}, 2010). Increases in prices during 2007-2009 led to rising poverty in Nicaragua, but decreasing poverty in Peru (see chapter 7).

27.3.4.2. Adaptation Practices

Genetic advances and suitable soil and technological management may induce an increase in some crops’ yield despite unfavorable future climate conditions. In Argentina, genetic techniques, specific scientific knowledge and land-use planning are viewed as promising sources of adaptation (Urcola \textit{et al.}, 2010). Adjustments in sowing dates and fertilization rates could reduce negative impacts in maize and wheat crops in Argentina and Chile (Magrin \textit{et al.}, 2009; Meza and Silva, 2009; Travasso \textit{et al.}, 2009b). Furthermore, in central Chile and southern Pampas in Argentina warmer climates could allow performing two crops per season increasing productivity per unit land (Monzon \textit{et al.}, 2007; Meza \textit{et al.}, 2008). In Brazil, adaptation strategies for coffee crops include: planting at high densities, vegetated soil, accurate irrigation and breeding programs, and shading management system (arborization) (Camargo, 2010). Shading is also used in Costa Rica and Colombia. In South Brazil, a good option for irrigated rice could be to plant early cultivars (Walter \textit{et al.}, 2010).
Several adaptation practices have been oriented towards water management (see section 27.3.1), especially in irrigated crops for a needed better preparedness regarding water scarcity. Adaptive strategies might need to look at the harvest, storage, temporal transfer and efficient use of rainfall water (Quiroga and Gaggioli, 2011). Adaptation to water scarcity can be improved by taking into account a well-known set of agronomic practices like: fallowing, crop sequences, groundwater management, no-till operations, cover-crops and fertilization. Deficit irrigation could be an effective measure for water savings in dry areas such as the Bolivian Altiplano (quinoa), central Brazil (tomatoes) and northern Argentina (cotton) (Geerts and Raes, 2009).

The best way to be prepared to adapt to future climate change is by assisting people to cope with current climate variability (Baethgen, 2010), for which the use of climatic forecasts in agricultural planning presents a measure. Increased access to scientific forecasts, and increased availability of improved forecast information would greatly enhance the ability of the farmers in the Brazilian Amazon to cope with El Niño events (Moran et al., 2006). Other climatic indices such as the SOI (Southern Oscillation Index) for maize and the SSTSA (Sea Surface Temperature South Atlantic) for soybean and sunflower were the best indicators of annual crop yield variability in Argentina (Travasso et al., 2009a). Another possibility to cope with extreme events, consists in transferring weather-related risks by using different types of rural insurance (Baethgen, 2010). Index insurance is one mechanism that has been recently introduced to overcome obstacles to traditional agricultural and disaster insurance markets (see chapter 15). For the support of such a parametric agricultural insurance, a Central American climate data base was recently established (CRRH-SICA, 2010).

Local and indigenous knowledge have the potential to bring solutions even in the face of rapidly changing climatic conditions (Folke et al., 2002; Alteri and Koohafkan, 2008). Crop diversification is used in the Peruvian Andes to suppress pest outbreaks and dampen pathogen transmission (Lin, 2011). In Honduras, Nicaragua and Guatemala traditional practices such as soil and water conservation, cover cropping, organic fertilizer and integrated pest management have proven more resilient to erosion and runoff and have helped retain more topsoil and moisture during periods of droughts (Holt-Gimenez, 2002). A case study with indigenous farmers in highland Bolivia indicates that constraints on access to key resources must be addressed for reducing vulnerability over time (McDowell and Hess, 2012). Otherwise, adaptation measures may include an orientation towards non-farming activities as was the case for NEB. In that case, vulnerability has been increasing since the late 1990s due mainly to the overuse of natural resources to which smallholders responded with off-farm activities to sustain their livelihoods (Sietz, 2011). In El Salvador, if local sustainability efforts continue the future climate vulnerability index could only slightly increase by 2015 (Aguilar et al., 2009).

Shifting in agricultural zoning has been an autonomous adaptation observed in SA. In Argentina e.g., increases in precipitation promoted the expansion of the agricultural frontier to the West and North of the traditional agricultural area, resulting in environmental damage that could be aggravated in the future (Barros, 2007; República Argentina, 2007). Adjustment of production practices, like farmers in the semi-arid zones of mountain regions of Bolivia have begun as they noticed strong changes in the climate since the 1980s, including upward migration of crops, selection of more resistant varieties and water capturing, presents a further adaptation measure (PNCC, 2007).

Organic systems are highly adaptive to climate change due to the application of traditional skills and farmers’ knowledge, soil fertility-building techniques and a high degree of diversity (ITC, 2007). A controversial, but important issue in relation to adaptation is the use of genetically modified plants to produce food, with biotech crops being likely to be key to cope with the needed food productivity increase considering global population trend (see Chapter 7) Brazil and Argentina are the 2nd and 3rd fastest growing biotech crop producers in the world after the US (Marshall, 2012).

Two of the main challenges to maintain food quality and food security in most regions of the world will be 1) the integration of agriculture based in breeding and biotech with organic strategies and 2) the integration between food and bioenergy production. These two issues have to be addressed by increasing the production of scientific knowledge in agriculture, which according to Nivia et al. (2009) in CA and SA is the one that receive the lowest investments when compared to the rest of the world.
27.3.5. Human Settlements, Industry, and Infrastructure

According to the World Bank database (The World Bank, 2012) CA and SA are the geographic regions with the second largest urbanization rate (79%), only behind North America (82%) and clearly above the world average (50%). It is therefore of high relevance the assessment of the literature on climate change impacts and vulnerability of urban human settlements in this region as presented in this section. The information provided should be complemented with other sections of the chapter (see 27.2.2.2; 27.3.1; 27.3.3; and 27.3.7).

27.3.5.1. Observed and Projected Impacts and Vulnerabilities

Urban human settlements suffer from many of the vulnerabilities and impacts already presented in several sections of this chapter. The provision of critical resources and services as already discussed in the chapter – water, health and energy – and of adequate infrastructure and housing remain factors of urban vulnerability likely to be enhanced by climate change (Smolka and Larangeira, 2008; Winchester, 2008; Roberts, 2009; Romero-Lankao, 2012).

Water resource management for example (see section 27.3.1), is a major concern for many cities in view of both controlling flooding while retaining water for other uses (Henríquez Ruiz, 2009). More than 20% of the population in the region tends to be concentrated in the largest city of each country (The World Bank, 2012), and hence water availability for human consumption in the region’s megacities (e.g. São Paulo, Santiago, Lima, Buenos Aires) is of great concern. In this regards, reduction in glacier and snowmelt related runoff in the Andes poses important adaptation challenges for many cities, e.g. the metropolitan areas of Lima, La Paz/El Alto and Santiago de Chile (Bradley et al., 2006; Hegglin and Huggel, 2008; Melo et al., 2010). The excess of water is also a preoccupation in several cities. In São Paulo for example, according to Marengo et al. (2009b; 2012b) the number of days with rainfall above 30 mm were almost absent during the 1950s and now they occur between 2 to 5 times per year (2000-2010). The increase in precipitation is one of the expected vulnerability issues affecting the city of São Paulo as presented in Box 27-1. Increases in flood events during 1980-2000 have been observed also in the Buenos Aires province and Metropolitan Area (Andrade and Scarpati, 2007; Barros et al., 2008; Hegglin and Huggel, 2008; Nabel et al., 2008). There are also the combined effects of climate change impacts, human settlements’ features and other stresses, such as more intense pollution events (Moreno, 2006; Nobre et al., 2011; Nobre, 2011; Romero-Lankao et al., 2013b) and more intense hydrological cycles from urban heat-island effects.

Box 27-1. Vulnerability of South American Megacities to Climate Change: The Case of the Metropolitan Region of São Paulo (MRSP)

Research in the Metropolitan Region of São Paulo (MRSP), between 2009 and 2011, reveals a very comprehensive and interdisciplinary project on the impacts of climate variability and change, and vulnerability of Brazilian megacities. Studies derived from this project (Nobre et al., 2011; Marengo et al., 2012b) identify the impacts of climate extremes on the occurrence of natural disasters and the impacts on human health. These impacts are linked to a projected increase of 38% in the extension of the urban area of the MRSP by 2030, accompanied by a projected increase in rainfall extremes. These may induce an intensification of urban flash floods and land slides, affecting large areas of the population that is already vulnerable to climate extremes and variability. The urbanization process in the MRSP has been affecting the local climate, and the intensification of the heat island effect to a certain degree may be responsible for the 2°C warming detected in the city during the last 50 years (Nobre et al., 2011). This warming has been further accompanied by an increase in heavy precipitation as well as more frequent warm nights (Marengo et al., 2012b; Silva Dias et al., 2012). By 2100, climate projections based on data from 1933-2010 show an expected warming between 2-3°C in the MRSP, together with a possible doubling of the number of days with heavy precipitation in comparison to the present (Marengo et al., 2012b; Silva Dias et al., 2012).

With the projected changes in climate and in the extension of the MRSP (Marengo et al., 2012b) more than 20% of the total area of the city could be potentially affected by natural disasters. Related, more frequent floods may increase the risk of leptospirosis, which together with increasing air pollution and worsening environmental
conditions that trigger the risk of respiratory diseases would leave the population of the MRSP more vulnerable.

Potential adaptation measures include a set of strategies needed to be developed by the MRSP and its institutions to face environmental changes. Among them are a better building control to avoid construction in risk areas, investment in public transportation, protection of the urban basins and the establishment of forest corridors in the collecting basins and slope regions. The lessons learned suggest that the knowledge on the observed and projected environmental changes, as well as on the vulnerability of populations living in risk areas is of great importance on the definition of adaptation policies as a first step towards improving the quality of life and building resilient cities in Brazil.

Changes in prevailing urban climates have led to changing patterns of disease vectors, also water-borne disease issues linked to water availability and subsequent quality (see section 27.3.7). The influence of climate change on particulate matter and other local contaminants is also relevant in this regard (Moreno, 2006). The relationship between the two factors – water and disease – is important to highlight given the on-going problems of water stress, also intense precipitation events. Both give rise to changing disease risks, as well as wider problems of event-related mortalities and morbidity, and infrastructure and property damage. For low-income groups concentrated in settlements with little or no service provision, e.g. waste collection, piped drinking water, sanitation, these risks are compounded (ECLAC, 2008). Existing cases of flooding, air pollution and heat waves reveal that not only low-income groups are at risk, but also that wealthier sectors are not spared. Factors such as high-density settlement (Barros et al., 2008) and the characteristics of some hazards explain this – e.g., poor and wealthy alike are at risk from air pollution and temperature in Santiago de Chile and Bogota (Romero-Lankao et al., 2012; 2013b).

There are also other climate change risks in terms of economic activity location and impacts on urban manufacturing and service workers, e.g. thermal stress (Hsiang, 2010), and the forms of urban expansion or sprawl into areas where ecosystem services may be compromised and risks enhanced, e.g. floodplains. Both processes are also related to rising motorisation rates; the number of light vehicles in Latin America and the Caribbean is expected to double between 2000 and 2030, and be three times the 2000 figure by 2050 (ECLAC, 2009b).

While urban populations face diverse social, political, economic and environmental risks in daily life, climate change adds a new dimension to these risk settings (Pielke Jr et al., 2003; Roberts, 2009; Romero-Lankao and Qin, 2011). Since urban development remains fragile in many cases, with weak planning responses, climate change is likely to compound existing challenges. The probabilities and magnitudes of these events in each urban center will differ significantly according to socioeconomic, institutional and physical context.

27.3.5.2. Adaptation Practices

Given high regional urbanization rates in CA and SA, the direct (e.g. flooding, heat islands) and indirect effects (e.g. food insecurity, watershed management) of climate change present an urban set of challenges and opportunities for mainstreaming flood management, warning systems and other adaptation responses with sustainability goals (Bradley et al., 2006; Hegglin and Huggel, 2008; Hardoy and Pandiella, 2009; Romero-Lankao, 2012; Romero-Lankao et al., 2013a).

Increasingly the links between adaptation and a wide variety of local development issues are being highlighted and brought into urban and regional planning in SA and CA. These issues include connections with natural hazards and risk assessment, disease transmission, resource availability, land use considerations, poverty linked to vulnerability, and with appropriate governance frameworks. (Barton, 2009; Luque et al., 2013)

Population, economic activities and authorities have a long experience of responding to climate related hazards, particularly through disaster risk management (e.g., Tucuman and San Martin, Argentina (Plaza and Pasculi, 2007; Sayago et al., 2010)) and land use and economic develop planning to a limited extent (Barton, 2009). Climate policies can build on these. Several adaptation plans have been generated over the last five years in São Paulo, Buenos Aires, Quito, Esmeraldas, Santiago and other large cities (Romero-Lankao, 2007b; Carmin et al., 2009; 2011).
Romero-Lankao, 2012; Luque et al., 2013; Romero-Lankao et al., 2013a). Local administrations participate in the
ICELI, C40 and other networks demonstrating their engagement towards climate resilient cities. In smaller
settlements, there is lower capacity to respond (e.g., climate change and vulnerability information (Hardoy and
Romero-Lankao, 2011). These policies, plans and programs are required to reduce social vulnerability, and identify
and reduce potential economic effects of climate on the local economy. Rio de Janeiro, for example, with its
coastline property and high dependence on tourists (and their perceptions of risk), cannot ignore these climate
related hazards (Gasper et al., 2011).

Poverty and vulnerability, as interlinked elements of the adaptation challenge in CA and SA, remain pivotal to
understanding urban responses and provoke the need for ‘pro-poor’ responses that engage with broader development
issues and not solely the capacity to respond to climate change (Hardoy and Pandiella, 2009; Winchester and
Szalachman, 2009; Hardoy and Romero-Lankao, 2011). These broader links are part of the complexity of defining
and operationalizing vulnerability concepts, and the need to develop these alongside more dominant infrastructural
responses to adaptation, as with mitigation (Romero-Lankao, 2007a; Romero-Lankao and Qin, 2011). Within these
response options, a focus on social assets has been highlighted by Rubin and Rossing (2012), rather than a, purely,
physical asset focus.

Much urbanisation involves in-migrating or already resident, low-income groups and their location in risk-prone
zones (Costa Fereira et al., 2011). The need to consider land use arrangements, particularly risk-prone zones, as part
of climate change adaptation have highlighted the role of public space in order to increase vegetation, thus mitigate
the heat island effect, also to reduce risks from landslides and flooding (Rodríguez Laredo, 2011).

In the case of governance frameworks, there is clear evidence that incorporation of climate change considerations
into wider city planning is still a challenge, as are more inter-sectoral and participative processes that have been
linked to more effective policies (Barton, 2009; De Oliveira, 2009; Romero-Lankao et al., 2013a). Several
metropolitan adaptation plans have been generated over the last five years, although these have been largely
restricted to the largest conglomerations, and are included as an addition to principally mitigation plans, e.g. São
Paulo and Buenos Aires.

27.3.6. Renewable Energy

27.3.6.1. Observed and Projected Impacts and Vulnerabilities

Table 27-6 shows the relevance of RE in the Latin America energy matrix as compared to the world for 2009
according to the International Energy Agency statistics (IEA, 2012). Hydropower is the most representative source
of RE in the region and therefore analyzed separately from this section and all other RE sources (see case study in
section 27.6.1.). At the same time, geothermal energy will be not discussed as it is assumed that there is no impact of
climate change on the effectiveness of this energy type (Arvizu et al., 2011).

[INSERT TABLE 27-6 HERE]

Table 27-6: Comparison of consumption of different energetics in Latin America and the world (in thousand tonnes
of oil equivalent (ktoe) on a net calorific value basis).

Lucena et al. (2009) demonstrated that hydro and wind energy, as well as biodiesel production might be particularly
sensitive to climate change in Brazil. With the vital role that RE plays in mitigating the effects of GCC, this
sensitivity translates into the importance of accounting with knowledge on the implementation of RE projects as
well as on the crops providing bioenergy, being by far the most important sources of non-hydro RE in SA and CA.

For historical reasons, CA and SA developed sugarcane as bioenergy feedstock, as sugarcane has been considered
advantageous for its high sugar contents. Brazil accounts for the most intensive RE production in the form of
bioethanol, which is used by 90% of the cars in the country (Goldemberg, 2008) whereas biodiesel comprises 5% of
all diesel nationwide. In 2011, countries like Colombia and Chile have started efforts to increase their bioenergy
production from sugarcane and eucalyptus, respectively. With the continent’s long latitudinal length, the expected
impacts of climate changes on plants are very complex due to a wide variety of climate conditions, imposing the problem of using different crops in different regions. For biodiesel, in Brazil 80% is produced from soybeans, but there are promising new sources such as the African palm dendé (Lucena et al., 2009). As mentioned in the section 27.2.2, the development of palm oil as well as soybeans are important factors that induce land use change, with a potential to influence stability of forests in certain key regions in SA, such as the Amazon.

Biofuels are promising sources of RE that can help CA and SA to decrease emissions from energy production and use. At the same time, RE might imply potential problems such as those related to positive net emissions of greenhouse gases, threats to biodiversity, an increase in food prices and competition for water resources (see also 27.2.3), some of which can be reverted or attenuated (Koh and Ghazoul, 2008). For example, the sugarcane agroindustry in Brazil, besides producing bioethanol, combusts the bagasse to produce electricity, in a process called cogeneration, providing power for the bioethanol industry and increasing sustainability. The excess heat energy is then used to generate bioelectricity, thus allowing the biorefinery to be self-sufficient in energy utilization (Amorim et al., 2011; Dias et al., 2012). In 2005/2006 the production of bioelectricity was estimated to be 9.2 kWh per ton of sugarcane (Macedo et al., 2008), approximately 2% of Brazil’s total energy generation production.

Most bioenergy feedstocks at present in production in CA and SA are grasses. In the case of sugarcane, the responses to the elevation of CO₂ concentration up to 720ppmv have been shown to be positive in terms of biomass production and principally regarding water use efficiency (Souza et al., 2008).

The production of energy from renewable sources such as hydro- and wind power are greatly dependent on climatic conditions and therefore may be impacted in the future by GCC. The analysis by Lucena et al. (2010a), related to liquid biofuels and hydropower, suggests an increasing energy vulnerability of the poorest regions of Brazil to GCC together with a possible negative influence on biofuels production and electricity generation, mainly biodiesel and hydropower respectively.

Expansion of biofuel plantations in Brazil might cause both direct and indirect land use changes (e.g., biofuel plantations replacing rangelands, which previously replaced forests) with the direct land use changes, according to simulation performed by Lapola et al. (2010) of the effects for 2020. The same study shows that sugarcane ethanol and biodiesel derived from soybean each contribute with about one half of the indirect deforestation projected for 2020 (121.970 km²) (Lapola et al., 2010). Thus, indirect land use changes, especially those causing the rangeland frontier to move further into the Amazonian forests, might potentially offset carbon savings from biofuels production.

The increase in global ethanol demand, driven by global concern for addressing climate change, is leading to the development of new hydrolytic processes which aim at converting cellulose and hemicelluloses into ethanol (Santos et al., 2011). The expected increase in the hydrolysis technologies is likely to balance the requirement of land for biomass crops. Thus, the development of these technologies has a strong potential to diminish social (e.g. negative health effects due the burning process, poor labor conditions) and environmental impacts (e.g. loss of biodiversity, water and land uses) whereas at the same time it can improve the economic potential of sugarcane. One adaptation measure will be to increase the productivity of bioenergy crops due to planting in high productivity environments with highly developed technologies, in order to use less land. As one of the main centers of biotech agriculture application in the world (Gruskin, 2012), the region accounts with a great potential to achieve this goal.

As the effects previously reported on crops growing in SESA might prevail (see 27.3.4.1), i.e. that an increase in productivity may happen due to increasing precipitation, future uncertainty will have to be dealt with by preparing adapted varieties of soybean in order to maintain food and biodiesel production, mainly in Argentina as it is one of the main producers of biodiesel from soybean in the world (Chum et al., 2011).

Other renewable energy sources—such as wind power generation—may also be vulnerable, raising the need for further research. According to Lucena et al. (2009; 2010b) the projections of changes in wind power in Brazil, may not negatively influence the use of this kind of energy in the future.
Minimization of the impact of sugarcane on biodiversity and the environment is expected to improve its sustainability. As the demand for bioethanol increases, improvement of productivity will result in a greater demand of land for sugarcane production. In this context, an expansion of land under sugarcane production is likely, especially in Brazil’s Central-South region (Lapola et al., 2010). However, this region also includes the cerrado (savannah) biome, which requires protection from expanding agriculture (Sawyer, 2008). It is important to ensure the protection of this unique region of Northern Brazil and Colombia as sugarcane grows into a commodity and policy is formed (Sawyer, 2008).

Initiatives such as the soy moratorium in the Amazon have an inhibitory effect over deforestation rates. Rudorff et al. (2011) showed that from 2008 to 2010 soybean was planted only on 0.25% of deforested land, which represents 0.027% of the total soybean cover in Brazil. Therefore, increased protection of natural areas in species-rich areas is necessary to preserve biodiversity in the face of these pressures (Brooks et al., 2009).

27.3.6.2. Adaptation Practices

RE will, in general, become increasingly more important over time as this is closely related with the emissions of GHG (Fischedick et al., 2011). Thus, RE could have an important role as adaptation means to provide sustainable energy for development in the region. However, it has to be noted that the production of RE requires large available areas for agriculture, which is the case of Argentina, Bolivia, Brazil, Chile, Colombia, Peru and Venezuela, that together represent 90% of the total area of CA and SA. However, for small countries it might not be possible to use bioenergy. Instead, they could benefit in the future from other types of RE, such as geothermal, eolic, photovoltaic etc, depending on policies and investment in different technologies. This is important because economic development is thought to be strongly correlated with an increase in energy use (Smil, 2000), which is itself associated with an increase in emissions (Sathaye et al., 2011).

Latin America is second to Africa in terms of technical potential for bioenergy production from rain-fed lignocellulosic feedstocks on unprotected grassland and woodlands (Chum et al., 2011). Some of the most important adaptation measures regarding RE are: (1) management of land use change (LUC); (2) modeling indirect land use change (ILUC); and (3) development of policies for financing and management of science and technology for all types of RE in the region.

If carefully managed, biofuel crops can be used as a means to regenerate biodiversity as proposed by Buckeridge et al. (2012) who pointed the fact that the technology for tropical forest regeneration has become available to the present, and that forests could share land with biofuel crops (such as sugarcane) taking advantage of forests’ mitigating potential. A possible adaptation measure could be to expand the use of reforestation technology to other countries in CA and SA.

One of the main adaptation issues is the one of food vs. fuel, i.e. the possibility that bioenergy crops would compete for land with food crops (Valentine et al., 2012). This issue is important because an uncontrolled increase in bioenergy feedstocks might threaten primary food production in a scenario expected to feed future populations with an increase of 50% to 70% in production (Gruskin, 2012; Valentine et al., 2012). This issue is particularly important in the region as it has one of the highest percentages of arable land available for food production in the world (Nellemann et al., 2009). As CA and SA develop new strategies to produce more RE in the region, LUC may push ILUC so that the pressure for more acreage to produce bioenergy, for instance, might be put forward on food crops on the one hand and on biodiversity and ecosystem services on the other hand. As climate change will affect bioenergy and food crops at the same time, their effects, as well as the adaptation measures related to agriculture will be similar in both cases. The main risks identified by Arvizu et al. (2011) are: (1) business as usual; (2) un-reconciled growth, and (3) environment and food vs. fuel. Thus, the most important adaptation measures will probably be the ones related to the control of economic growth, environmental management and agriculture production. These three factors will have to be carefully managed so that their sustainability levels should be the highest possible. With this, lower emissions and consequently lower impacts of the GCC will be expected. The choice for lignocellulosic feedstocks (eg. sugarcane second generation technologies) will be quite important because these feedstocks do not compete with food (Arvizu et al., 2011). In the case of sugarcane, for instance, an increase
of ca. 40% in the production of bioethanol is expected as a result of the implantation of second generation technologies coupled with the first generation ones already existent in Brazil (Buckeridge et al., 2012; Dias et al., 2012).

Biodiesel production has the lowest costs in Latin America (Chum et al., 2011), probably due to the high production of soybean in Brazil and Argentina. The use of biodiesel to complement oil-derived diesel is a productive choice for adaptation measures regarding this bioenergy source. Also, the cost of ethanol, mainly derived from sugarcane, is the lowest in CA, SA and Latin America (Chum et al., 2011) and as an adaptation measure, such costs, as well as the one of biodiesel, should be lowered even more by improving technologies related to agricultural and industrial production of both. Indeed, it has been reported that in LA the use of agricultural budgets by governments for investment in public goods induces faster growth, decreasing poverty and environmental degradation (López and Galinato, 2007). One issue that may become important in the future is that the pressure of soy expansion due to biodiesel demand can lead to land use change and consequently to economic teleconnections, as suggested by Nepstad et al. (2006). For example, these teleconnections may link Amazon deforestation derived from soy expansion to the economic growth in China due to changes in the demand of soy. The effects of such teleconnections may possibly mean a decrease in jobs related to small to big farms in agriculture in Argentina (Tomei and Upham, 2009) on the one hand, and deforestation in the Amazon due to the advance of soybean cropping in the region on the other (Nepstad and Stickler, 2008) (see Figure 27-6).

[INSERT FIGURE 27-6 HERE]

Figure 27-6: Soy teleconnections and major effects in SA. Economic growth giant consumers as China pressurize the soy production system in SA, increasing the production of biodiesel, but demanding more energy in general. (partly based on Nepstad and Stickler (2008), and Tomei and Upham (2009).]

27.3.7. Human Health

27.3.7.1. Observed and Projected Impacts and Vulnerability

Climate variability and climate change (CV/CC) are negatively affecting human health in CA and SA, either by increasing morbidity, mortality, and disabilities (very high confidence), and through the emergence of diseases in regions previously non-endemic, or the re-emergence of diseases in areas where they have previously been eradicated or controlled (high confidence) (Winchester and Szalachman, 2009; Rodríguez-Morales, 2011). Heat waves and cold spells are affecting mortality rates in cities (McMichael et al., 2006; Bell et al., 2008; Hardoy and Pandiella, 2009; Muggeo and Hajat, 2009; Hajat et al., 2010). Outbreaks of leptospirosis, dengue fever, and cholera were triggered in CA by hurricane Mitch in 1998 (Costello et al., 2009; Rodríguez-Morales et al., 2010). The 2010-2012 floods in Colombia (Poveda et al., 2011a) caused hundreds of deaths and thousands of displaced people. Dengue fever outbreaks followed floods in Brazil in the last decade (Teixeira et al., 2009).

Indices of malaria have increased in the last five decades, along with air temperatures, in Colombia (Poveda et al., 2011b; Arevalo-Herrera et al., 2012), as well as in urban and rural areas of Amazonia, concomitantly with large environmental changes (Gil et al., 2007; Tada et al., 2007; Cabral et al., 2010; Da Silva-Nunes et al., 2012). Malaria vector densities have increased in northwestern Argentina along with climate variables (Dantur Juri et al., 2010; 2011). Besides, El Niño is a major driver of malaria outbreaks in Colombia (Mantilla et al., 2009; Poveda et al., 2011b), amidst drug resistance of the parasite (Restrepo-Pineda et al., 2008), and human migration (Rodríguez-Morales et al., 2006; Osorio et al., 2007). Linkages between ENSO and malaria have been also reported in Ecuador and Peru (Anyamba et al., 2006; Kelly-Hope and Thomson, 2010), French Guiana (Hanf et al., 2011), Amazonia (Olson et al., 2009), and Venezuela (Moreno et al., 2007), including unheard malaria in the Andes up to 2200 m a.s.l. (Benítez and Rodríguez-Morales, 2004).

Dengue fever (DF) and dengue hemorrhagic fever (DHF) have risen in tropical America in the last 25 years, posing an annual toll of US$ 2.1±[1 to 4] billion (Torres and Castro, 2007; Tapia-Conyer et al., 2009; Shepard et al., 2011). Environmental and climatic variability affect DF and DHF incidence in Honduras and Nicaragua (Rodríguez-Morales et al., 2010), in Costa Rica (Fuller et al., 2009; Mena et al., 2011), in French Guiana being concurrent with
malaria (Carme et al., 2009; Gharbi et al., 2011), in cities of Colombia (Arboleda et al., 2009) and Venezuela. In Caracas, DF increases (decreases) during La Niña (El Niño) (Rodríguez-Morales and Herrera-Martínez, 2009; Herrera-Martínez and Rodríguez-Morales, 2010). Weather and climate variability are also associated with DF in southern SA (Honório et al., 2009; Costa et al., 2010; De Carvalho-Leandro et al., 2010; Degallier et al., 2010; Lowe et al., 2011). A study in Rio de Janeiro found that a 1°C (10-mm) increase in monthly minimum temperature (rainfall) led to a 45% (6%) increase in DF in the following month (Gomes et al., 2012). Despite large vaccination campaigns, the risk of major Yellow Fever (YF) outbreaks has increased in tropical America amidst changes in climate and environmental conditions (Jentes et al., 2011), mainly in densely populated poor urban settings (Gardner and Ryman, 2010).

Schistosomiasis (SCH) is an endemic Neglected Tropical Disease (NTD) in rural areas, including Brazil (Igreja, 2011), Suriname, Venezuela, and the Andean highlands, while uncontrolled peripheral urbanisation and environmental degradation increase its incidence in Brazil (Barbosa et al., 2010; Kelly-Hope and Thomson, 2010). It is possible that the incidence of SCH will increase as a result of increasing temperatures (Mangal et al., 2008; Mascara et al., 2009; Lopes et al., 2010), while vegetation indices (e.g. Normalized Difference Vegetation Index), which are directly related to climate conditions, are associated with human fascioliasis in the Andes (Puentes, 2004).

Hantaviruses (HV) have been reported in Honduras, Panama, Costa Rica, Venezuela, Argentina, Chile, Paraguay, Bolivia, Peru, and Brazil (Jonsson et al., 2010; MacNeil et al., 2011). There is evidence that El Niño and climate change enhance the prevalence of HV (Dearing and Dizney, 2010). In Venezuela, RVs are more frequent, more severe, and more (less) common in cities with minimal (marked) seasonality (Kane et al., 2004). The seasonal peak of RV in Guatemala coincides with the dry season, being responsible for 60% of diarrhoea cases (Cortes et al., 2012).

In spite of its rapid decline, Chagas disease is still a major public health issue, in which climate and environmental changes play an important role (Abad-Franch et al., 2009; Araújo et al., 2009; Moncayo and Silveira, 2009), as in Panama and Argentina (Tourre et al., 2008; Gottdenker et al., 2011). Ciguatera fish poisoning (CFP) is a tropical disease correlated with water temperature, and thus climate change could increase its incidence across the Caribbean (Tester et al., 2010). Climate is an important factor of Paracoccidioidomycosis, Latin America’s most prevalent mycosis (Barrozo et al., 2009), while ENSO is associated with recent outbreaks of bartonellosis in Peru (Payne and Fitchett, 2010).

Cutaneous leishmaniasis (CL) is correlated with climate in LA, with highest incidence in Bolivia, where it increases (decreases) during La Niña (El Niño) (Gomez et al., 2006; García et al., 2009). CL is affected in Costa Rica by temperature, forest cover, and ENSO indices (Chaves and Pascual, 2006; Chaves et al., 2008). Land use, altitude, and diverse climatic variables are associated with increasing trends of CL in Colombia (Valderrama-Ardila et al., 2010), which also increases (decreases) during El Niño (La Niña) (Cárdenas et al., 2006; 2007; 2008). The situation of CL in Colombia is aggravated by the internal conflict (Beyrer et al., 2007). In Venezuela, CL increased (67%) during a weak La Niña (Cabaniel et al., 2005). CL is a seasonal disease in Suriname peaking during the March dry season (35%) (Van der Meide et al., 2008), while in French Guiana it is intensified after the October-December dry season (Rotureau et al., 2007). The incidence rates of visceral leishmaniasis (VL) have been increasing in Brazil (the highest in LA) owing to deforestation (Cascio et al., 2011; Sortino-Rachou et al., 2011), and to the occurrence of El Niño (Ready, 2008), as is also the case in Argentina, Paraguay, and Uruguay (Bern et al., 2008; Dupnik et al., 2011; Salomón et al., 2011; Fernández et al., 2012). VL transmission in western Venezuela is also associated with the bimodal annual rainfall regime (Feliciangeli et al., 2006; Rodríguez-Morales et al., 2007). On the other hand, the incidence of skin cancer in Chile has increased in recent years, which is statistically correlated to climatic and geographic variables (Salinas et al., 2006).

Onchocerciasis (river blindness) is another climate-related disease (Botto et al., 2005), whose vector exhibits clear-cut wet-dry seasonal biting rates (Rodríguez-Pérez et al., 2011). Leptospirosis is particularly prevalent in warm and humid tropical regions of CA (Valverde et al., 2008). Other climate-driven infectious diseases are ascariasis and gram-positive cocci in Venezuela (Benítez et al., 2004; Rodríguez-Morales et al., 2010), and Carrion’s disease in Peru (Huarcaya et al., 2004).
Sea water temperature affects the abundance of the bacteria responsible for cholera (Koelle, 2009; Jutla et al., 2010; Marchegiani et al., 2010; Hofstra, 2011), and thus high correlations exist between El Niño and cholera in Peru, Ecuador, Colombia, Mexico and Venezuela (Cerda Lorca et al., 2008; Martínez-Urtaza et al., 2008; Salazar-Lindo et al., 2008; Holmner et al., 2010; Gavilán and Martínez-Urtaza, 2011; Murugaiah, 2011). Extreme temperatures and changes in rainfall may also increase food safety hazards along the food chain (Sivakumar et al., 2005; Tirado et al., 2010).

Air pollution and higher temperatures exacerbate chronic respiratory and cardiovascular problems. Dehydration from heatwaves increases hospitalizations for chronic kidney diseases (Kjellstrom et al., 2010), mainly affecting construction workers, and CA sugarcane and cotton workers (Crowe et al., 2009; 2010; Kjellstrom and Crowe, 2011; Peraza et al., 2012). In the region, atmospheric pollutants are associated with atherosclerosis, respiratory and cardiovascular diseases, pregnancy-related outcomes, cancer, cognitive deficit, otitis, and diabetes (Olmo et al., 2011). The worsening of air quality in large cities is increasing allergic respiratory diseases, and morbidity from asthma and rhinitis (Grass and Cane, 2008; Martins and Andrade, 2008; Gurjar et al., 2010; Jasinski et al., 2011; Rodriguez et al., 2011).

Extreme weather and climate events affect mental health by exposure to psychological trauma (Higginbotham et al., 2006; Berry et al., 2010). Drought-prone areas in NEB are vulnerable to lower socioeconomic and educational levels, in turn associated with depression, psychological distress, and anxiety (Coelho et al., 2004). Hospital admissions for mania and bipolar disorder are associated with climate seasonality in Brazil. Extreme weather, meager crop yields, and low GDP are also linked with increased violence (McMichael et al., 2006). All these problems may be exacerbated by climate change (Schulte and Chun, 2009).

Many factors increase CA and SA’s vulnerability to climate change: precarious health systems, socio-economic factors, inadequate water and sanitation services, poor waste collection and treatment systems, air, soil and water pollution, lack of social participation, and inadequate governance (Luber and Prudent, 2009; Rodríguez-Morales, 2011; Sverdlik, 2011). Human health vulnerabilities exhibit serious biases with geography, age (Perera, 2008; Martiello and Giacchi, 2010; Graham et al., 2011; Åstrom et al., 2011), gender (Oliveira et al., 2011), race, ethnicity, and socio-economic status (Diez Roux et al., 2007; Martiello and Giacchi, 2010). Malnutrition due to crop failure and drought adds up to vulnerability (Schmidhuber and Tubiello, 2007). NTDs cause 1.5-5.0 million disability-adjusted life years (DALYs- a measure of disease burden, expressed as the number of years lost owing to disability, ill-health or early death) in LA, many of which are climate-sensitive diseases (Hotez et al., 2008; Allotey et al., 2010). Mega-cities’ vulnerability (see 27.3.5) is aggravated by the provision of drinking water and by the rapid spread of diseases. It further is increasing due to migration from rural areas forced by environmental degradation and disasters (Campbell-Lendum and Corvalán, 2007; Borsdorf and Coy, 2009; Hardoy and Pandiella, 2009), and in turn mega-cities are vulnerable to natural disasters (earthquakes, fires, storms etc.) that might change the frequency and intensity in the context of global climate change. The provision of drinking water and the spread of diseases make mega-cities vulnerable to global environmental change (Borsdorf and Coy, 2009). Diverse vulnerability assessments to the impacts of climate change on human health have been developed in Brazil at national, regional and municipal scales. The approach uses composite indicators, which included downscaled climate scenarios, epidemiological variables, economic and demographic projections and the status of natural ecosystems (Confalonieri et al., 2009; 2011; Barbieri and Confalonieri, 2011; FIOCRUZ, 2011). The Andes and CA are among the regions of highest predicted losses [1% to 27%] in labor productivity from future climate scenarios (Kjellstrom et al., 2009). Argentina and Chile (under the sub-Antarctic atmospheric circulation) might suffer serious health effects from impacts to water and food availability, and extreme weather (Team and Manderson, 2011).

27.3.7.2. Adaptation Strategies and Practices

Despite the attempt to implement adaptation strategies in CA and SA ((Blashki et al., 2007; Costello et al., 2011), several factors hamper their effectiveness, such as: a lack of political commitment, gaps in scientific knowledge, and institutional weaknesses of health systems (Keim, 2008; Lesnikowski et al., 2011; Olmo et al., 2011) (see section 27.4.3).
Research priorities and current strategies must be reviewed to achieve better disease control (Halsnæs and Verhagen, 2007; Romero and Boelaert, 2010; Karanja et al., 2011). The low adaptive capacity of rural communities associated with poor health systems and limited resources exacerbate human health stressors from climate change, and thus regional responsive systems must be put in place in key operational areas (Bell, 2011), involving adaptive capacity building, and implementation of adaptation actions (Huang et al., 2011), which in turn require considering the potential magnitude and uncertainty of the hazards, and the effectiveness, costs, and risks of the proposed responses (Campbell-Lendrum and Bertollini, 2010).

Diverse human wellbeing indices must be explicitly stated as climate change policies of adaptation and mitigation in LA, along with the Millennium Development Goals (Franco-Paredes et al., 2007; Halsnæs and Verhagen, 2007; Mitra and Rodriguez-Fernandez, 2010). South-south cooperation and multidisciplinary research is required to study the health impacts of climate change and to identify resilience, adaptation, and mitigation strategies (Tirado et al., 2010; Team and Manderson, 2011). Colombia is starting to develop a pilot human health adaptation program, to cope with climate-driven changes in malaria transmission and exposure (Poveda et al., 2011b). The city of São Paulo has implemented diverse local pollution control measures, with the co-benefit of reducing GHG emissions, such as the 11% reduction of methane by landfills (De Oliveira, 2009; Nath and Behera, 2011).

27.4. Adaptation Opportunities, Constraints, and Limits

27.4.1. Adaptation Needs and Gaps

During the last years, the study of adaptation to climate change has progressively switched from an impact-focused approach (mainly climate-driven) to a vulnerability-focused vision (Boulanger et al., 2011). While different frameworks and definitions of vulnerability exist, a general tendency aims at studying vulnerability to climate change especially in SA and CA using a holistic or systemic approach (Ison, 2010; Carey et al., 2012b), where climate drivers are actually few with respect to all other drivers related to human and environment interactions including physical, economic, political and social context, as well as local characteristics such as occupations, resource uses, accessibility to water, etc. (Manuel-Navarrete et al., 2007; Young et al., 2010).

In developing and emergent countries, there exists a general consensus that the adaptive capacity is low, strengthened by the fact that poverty is a limit to resilience (Pettengell, 2010) leading to a “low human development trap” (UNDP, 2007). Although this is true, Magnan (2009) suggests that this analysis is biased by a “relative immaturity of the science of adaptation to explain what are the processes and the determinants of adaptive capacity”. Increasing research efforts on the study of adaptation is therefore of great importance to improve our understanding of the actual societal, economical, community and individual drivers defining the adaptive capacity. Especially, a major focus on traditions and their transmission (Young and Lipton, 2006) may actually indicate potential adaption potentials in remote and economically poor regions of SA and CA. Such a potential does not dismiss the fact that the nature of future challenges may actually not be compared to past climate variability (e.g. glacier retreat in the Andes).

Coping with new situations may require new approaches such as a multilevel risk governance (Young and Lipton, 2006; Corfee-Morlot et al., 2011) somehow associated with decentralization in decision-taking and responsibility. While the multilevel risk governance and the local participatory approach are interesting frameworks for strengthening adaptation capacity, their major counterpart is that at all levels it requires (from local to national levels) capacity-building and information transmission on future risks, major challenges and possible methodologies to plan adaptation strategies to climate change. At present, despite an important improvement during the last years, there still exists a certain lack of awareness of environmental changes and mainly their implications for livelihoods and businesses (Young et al., 2010). Moreover, considering the limited financial resources of some states in CA and SA, long-term planning and the related human and financial resource needs may be seen as conflicting with present social deficit in the welfare of the population. This situation weakens the importance of adaptation planning to climate change in the political agenda, and requires therefore international involvement as one facilitating factor in natural hazard management and climate change adaptation (Carey et al., 2012b). However, as pointed out by McGray et al. (2007), development, adaptation and mitigation issues are not separate issues. Especially,
development and adaptation strategies should be tackled together in developing countries such as SA and CA, focusing on strategies to reduce vulnerability. The poor level of adaptation of present-day climate in SA and CA countries is characterized by the fact that responses to disasters are mainly reactive rather than preventive. Some early warning systems are being implemented, but the capacity of responding to a warning is often limited, particularly among poor populations. Finally, actions combining public communication (and education), public decision-maker capacity-building and a synergetic development-adaptation funding will be key to sustain the adaptation process that CA and SA require to face future climate change challenges.

27.4.2. Practical Experiences of Adaptation, including Lessons Learned

Adaptation processes have been in many cases initiated a few years ago, and there is still a lack of literature to evaluate their efficiency in reducing vulnerability and building resilience of the society against climate changes. However, some lessons have already been learned on these first experiences (see section 27.3). In CA and SA, many societal issues are strongly connected to development goals and are often considered priority in comparison to adaptation efforts to climate change. However, according to the 135 case studies analyzed by McGray et al. (2007), 21 of which were in CA and SA, the synergy between development and adaptation actions allows to ensuring a sustainable result of the development projects.

Vulnerability and disaster risk reduction may not always lead to long-term adaptive capacity (Tompkins et al., 2008; Nelson and Finan, 2009), except when structural reforms based on good governance (Tompkins et al., 2008) and negotiations (Souza Filho and Brown, 2009) are implemented. While multi-level governance can help to create resilience and reduce vulnerability (Roncoli, 2006; Young and Lipton, 2006; Corfee-Morlot et al., 2011), capacity-building (Eakin and Lemos, 2006), good governance and enforcement (Lemos et al., 2010; Pittock, 2011) are key components.

Local adaptation to climate and non-climate drivers may undermine long-term resilience of social-ecological systems when local, short-term strategies designed to deal with specific threats or challenges do not integrate a more holistic and long-term vision of the system at threat (Adger et al., 2011). Thus, policy should identify the sources of and conditions for local resilience and strengthen their capacities to adapt and learn (Adger et al., 2011; Eakin et al., 2011), as well as to integrate new adapted tools (Oft, 2010). This sets the question of convergence between the local-scale/short-term and broad scale/long-term visions in terms of perceptions of risks, needs to adapt and appropriate policies to be implemented (Eakin and Wehbe, 2009; Salzmann et al., 2009). Even if funding for adaptation is available, the overarching problem is the lack of capacity and/or willingness to address the risks, especially those threatening lower income groups (Satterthwaite, 2011). Adaptation to climate change cannot eliminate the extreme weather risks, and thus efforts should focus on disaster preparedness and post-disaster response (Sverdlik, 2011). Migration is the last resort for rural communities facing water stress problems in CA and SA (Acosta-Michlik et al., 2008).

In natural hazard management contributing to climate change adaptation, specific cases such as the one in Lake 513 in Peru (Carey et al., 2012b) clearly allowed to identify facilitating factors for a successful adaptation process (technical capacity, disaster events with visible hazards, institutional support, committed individuals, and international involvement) as well as impediments divergent risk perceptions, imposed government policies, institutional instability, knowledge disparities, and invisible hazards).

In certain cases, forward-looking learning (anticipatory process), as a contrast to learning by shock (reactive process), has been found as a key element for adaptation and resilience (Tschakert and Dietrich, 2010) and should be promoted as a tool for capacity-building at all levels (stakeholders, local and national governments). Its combination with role-playing game and agent-based models (Rebaudo et al., 2011) can strengthen and accelerate the learning process.
27.4.3. Observed and Expected Barriers to Adaptation

It is usually considered that a major barrier to adaptation is the perception of risks and many studies focused on such an issue (Bonatti et al., 2012). However, new studies (Adger et al., 2009) identified social limits to possible adaptation to climate change in relation with issues of values and ethics, risk, knowledge and culture, even though such limits can evolve in time. Indeed, while being a necessary condition, perception may not be the main driver for initiating an adaptation process. As pointed out by Tucker et al. (2010), exogenous factors (economic, land tenure, cost, etc.) may actually strongly constrain the decision-making process involved in possible adaptation process.

Moreover, it is difficult to describe adaptation without defining at which level it is thought. Indeed, while a lot of efforts are invested in national and regional policy initiatives, most of the final adaptation efforts will be local. National and international (transborder) governance is key to build adaptive capacity (Engle and Lemos, 2010) and therefore to strengthen (or weaken) local adaptation through efficient policies and delivery of resources. At a smaller scale (Agrawal, 2008), local institutions can strongly contribute to vulnerability reduction and adaptation. However, at all levels, the efficiency in national and local adaptation activities strongly depend on the capacity-building and information transmission to decision-makers (Eakin and Lemos, 2006).

27.4.4. Planned and Autonomous Adaptation

Autonomous adaptation strategies are mainly realized at local levels (individual or communitarian), but not always respond to climate forcing. For instance, the agricultural sector adapts rapidly to economic stressors, while, despite a clear perception of climate risks, it may last longer before responding to climate changes (Tucker et al., 2010). In certain regions or communities, such as Anchioreta in Brazil (Bonatti et al., 2012), adaptation is part of a permanent process and is actually tackled through a clear objective of vulnerability reduction, maintaining and diversifying a large set of natural varieties of corn allowing the farmers to diversify their planting. Another kind of autonomous adaptation is the southward displacement of agriculture activities (e.g. wine, coffee) though the purchase of lands, which will become favorable for such agriculture activities in a warmer climate. In Argentina, the increase of precipitacion observed during the last 30 years contributed to a westward displacement of the crop frontier.

Planned adaptation is by definition associated to government policies and planning. During the last years, there has been a growing awareness of CA and SA governments on the need to integrate climate change and future climate risks in their policies. Up to date, in total 18 regional Non-Annex countries, including Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Guyana, Panama, Paraguay, Peru, Suriname, Uruguay and Venezuela, have already responded through their initial and most cases second National Communication to the UNFCCC from 1997 until 2012 (see UNFCCC, 2012) allowing to measure the country’s emissions and to assess its present and future vulnerability. In addition, for instance Argentina, Brazil and Uruguay among others, created specific Secretaries in the government organizations specifically dedicated to climate change in order to coordinate actions between different ministries and secretaries of state. Finally, most of the countries in the region (Keller et al., 2011) are now involved in international networks focused on adaptation to climate change, or in international projects aiming at capacity-building and design of adaptation strategies. As an example, the ‘CentroAmerican Integration System’ (see SICA, 2013 gathers every three months climate experts for regional institutions as well as sectorial experts (agriculture, energy, etc.) in order to discuss climate trends, increase capacity-building and anticipate major climate threats. It is of course too early to evaluate the actual impact of such new initiatives on regional or national adaptation to climate change. However, new tools (Debels et al., 2009) or international platforms for CA and SA may help to prioritize adaptation policies according to their efficiency and the limited financial resources in the future (Kok et al., 2007).

Table 27-7 presents programs, projects and initiatives with focus on current and past practical adaptation measures maintained in the data collection by the UNFCCC under the Nairobi Work Programme (NWP) (distinguishing Private Sector Initiatives (PSI); Local Coping Strategies (LCP) (UNFCCC, 2012b); EbA approaches; and Adaptation Practices (AP); complemented with international projects from the weAdapt database (weAdapt, 2012).
27.5. Interactions between Adaptation and Mitigation

As demonstrated in ‘The SouthSouthNorth Capacity Building Module on Poverty Reduction’ (see SSN, 2006), a synergy between adaptation and mitigation strategies can be reached especially when the community organizes itself in a cooperative. In many examples, mitigation strategies based on a cooperative system, which manages recycling or renewable energy production, actually lead to an increase in energy availability, crucial to increase production capacity and thus to create new financial resources for the community. As also pointed out by (Venema and Cisse, 2004), the growth of renewable energy in CA and SA (see also section 27.3.6) should not be limited to large infrastructure projects, and should also encompass the development of decentralized renewable energy solutions. In spite of their smaller size (individual or communitarian), these solutions offer adaptation and mitigation benefits. On one hand, fossil-based energy consumption is reduced, while energy availability is increased. On the other hand, reduction of energy precariousness is key in any development strategy. Thus, it allows local community and individuals to growing socially and economically; and therefore to reducing its vulnerability avoiding the poverty trap (UNDP, 2007), and to initiating an adaptation process based on non-fossil fuel energy sources. Such initiatives also depend on local and organizational leaderships (UN-Habitat, 2011).

At national and regional scales, CA and SA countries will require the allocation of human and financial resources to adapt to climate change. While resources are limited, too large an economic dependence of these countries to fossil fuels will reduce their adaptive capacity. The reduction in energy consumption and the integration of renewable energies in their energetic matrix is therefore a key issue for all these countries in order to sustain their development and growth and therefore increase their adaptive capacity (see also section 27.3.6).

27.6. Case Studies

27.6.1. Hydropower

Hydropower is the main source of renewable energy in CA and SA (see section 27.3.6). Although there is debate about GHG emissions from hydropower reservoirs (especially in tropical environments, Fearnside and Pueyo, 2012) this form of electricity generation is often seen as a major contributor to mitigating GHG emissions worldwide (see IPCC SRREN [5]; Kumar et al. (2011). On the other hand, hydropower is also a climate-related (water) sector, thus making it prone to serious effects from climate change (see section 27.3.1.1).

The CA and SA region constitute a unique example to study these relations between climate change mitigation and adaptation in relation to hydropower generation. According to the Special Report on Renewable Energy Sources and Climate Change Mitigation (see Table 5.1 SRREN; IPCC, 2011) CA and SA are second to Asia in terms of hydropower energy generation in the world, displaying a 20% share of total annual generation. The quality of water resources availability in CA and SA is the largest in the world with an average regional capacity factor of over 50%. As a result, the region has by far the largest proportion of electricity generated through hydropower facilities (Table 27-6 in section 27.3.6.1). The hydropower proportion of total electricity production is over 40% in the region, and in some cases is near or close to 80%, as in the case of Brazil, Colombia and Costa Rica.

Diverse studies have analyzed the potential impacts of climate change on hydropower generation (see details in Table 27-4 in section 27.3.1.1). Maurer et al. (2009) studied future hydrologic conditions for the Lempa River basin across El Salvador, Honduras and Guatemala, which feeds major hydroelectric facilities. Assessment of projections including uncertainty analysis show a reduction in hydropower capacity of 33% to 53% by 2070-2099. A similar loss is expected for the Sinu-Caribe basin in Colombia were, despite a general projection of increased precipitation, losses due to evaporation enhancement reduces inflows to hydroelectric systems, thus reducing electricity generation up to 35% compared to base conditions (Ospina-Noreña et al., 2009a). Further studies (Ospina-Noreña et al., 2011a;
2011b) have estimated vulnerability indices for the hydropower sector in the same basin, and identified reservoir operation strategies to reduce this vulnerability. Overall reductions in hydropower generation capacity are also expected in Chile for the main hydropower generation river basins: Maule, Laja and Biobío (ECLAC, 2009a; McPhee et al., 2010; Stehr et al., 2010), and also in the Argentinian Limay River basin (Seoane and López, 2007). Ecuador, on the other hand, faces an increase in generation capacity associated with an increment in precipitation on its largest hydroelectric generation Paute River basin (Buytaert et al., 2010). In Brazil, the country with the largest installed hydroelectric capacity in the region, continuous efforts are made to improve the management of the system under variable climatic conditions (Lima and Lall, 2010). There is still unused generation capacity in sub-basins of the Amazon River (Soito and Freitas, 2011), but future climate conditions plus environmental concerns pose an important challenge for the expansion of the system (Freitas and Soito, 2009; Finer and Jenkins, 2012). According to Lucena et al. (2009), hydropower systems in southern Brazil (most significantly the Paraná River system) could face a slight increase in energy production under an A2 scenario. However, the rest of the country’s hydropower system, and especially those located in the North East region, could face a reduction in power generation, thus reducing the reliability of the whole system (Lucena et al., 2009).

An obvious implication of the mentioned impacts is the need to replace the energy lost due to climate change impacts. In this regard, a typical adaptation measure would be to increase alternative energies (see 27.3.6.2). Lower cost of adaptation measures have been studied for Brazil (Lucena et al., 2010a), with results implying an increase in natural gas and sugarcane bagasse electricity generation in the order of 300 TWh, increase in operation costs in the order of 7 billion USD annually and 50 billion USD in terms of investment costs by 2035. In the case of Chile, ECLAC (2009a) assumed that the loss in hydropower generation would be compensated by the least operating cost source available (not used probably at full capacity), which is a coal-fired power plant. In this case, the amount of average electricity that needs to be replaced for the 2011-2040 period is around 18 TWh of electricity, a little over 10% of actual total hydropower generation capacity in the country (ECLAC, 2009a). According to the same study (ECLAC, 2009a), this implies an increase in operating costs of the order of 100 million USD annually and an increase of 2 MTCO₂ (total emissions from the electricity generation subsector in Chile are around 25 MTCO₂ in 2009). Ospina-Noreña (2011a; 2011b) studied some adaptation options, such as changes in water use efficiency or demand growth that could mitigate the expected impacts on hydropower systems in the Colombian Sinú-Caribe River basin.

Some other implications are, for instance, changes in the seasonality of inflows to hydropower generation systems such as those projected for Peru (Juen et al., 2007), Chile (ECLAC, 2009a), and Argentina (Seoane and López, 2007), that could affect the relationship between different water users within a basin. In Chile for example, hydrologic impacts of climate change could affect water supply to agriculture irrigation triggering economic and social conflicts between this and the hydropower sector that share water resources from the same river basin. It is worth noting that those regions which are projected to face an increase in streamflow and associated generation capacity, such as Ecuador or Costa Rica, also share difficulties in managing deforestation, erosion and sedimentation which limits the useful life of reservoirs (see section 27.3.1.1). In these cases it is important to consider these effects in future infrastructure operation (Ferreira and Teegavarapu, 2012) and planning, and also enhance the on-going process of recognizing the value of the relation between ecosystem services and hydropower system operations (Leguía et al., 2008) (see more on PES in section 27.3.2.2).

27.6.2. Payment for Ecosystem Services

Payment for ecosystem services (PES) is commonly described as a set of transparent schemes for securing a well-defined ecosystem service (or a land use capable to secure that service) through conditional payments or compensations to voluntary providers (Engel et al., 2008; Tacconi, 2012). Van Noordwijk et al. (2012) provides a broader definition to PES by arguing that it encompasses three complementary approaches, (i) the one above, i.e., commodification of pre-defined ecosystem services so that prices can be negotiated between buyers and sellers; plus (ii) compensation for opportunities forgone voluntarily or by command and control decisions; and (iii) co-investment in environmental stewardships. Therefore, the terms ‘conservation agreements’, ‘conservation incentives’ and ‘community conservation’ are often used as synonyms or as something different or broader than PES (Milne and
Niessen, 2009; Cranford and Mourato, 2011). For simplicity, we refer to PES in its broadest sense (sensu van
Noordwijk et al., 2012).

Services subjected to such types of agreements often include regulation of freshwater flows, carbon storage,
provision of habitat for biodiversity, and scenic beauty (De Koning et al., 2011; Montagnini and Finney, 2011).
Since the ecosystems that provide the services are mostly privately owned, policies often aim at supporting
landowners to maintain the provision of services over time (Kemkes et al., 2010). Irrespective of the debate of as to
whether payments or compensations should be designed to focus on actions or results (Gibbons et al., 2011),
experiences in Colombia, Costa Rica and Nicaragua show that PES can finance conservation, ecosystem restoration,
and better land use practices (Montagnini and Finney, 2011; see also Table 27.5). However, based on examples
from Ecuador and Guatemala, Southgate et al. (2010) argue that uniformity of payment for beneficiaries can be
inefficient if recipients accept less compensation in return for conservation measures, or if recipients that promote
greater environmental gains receive only the prevailing payment. Other setbacks to PES schemes might include
cases where there is a perception of commoditization of nature and its intangible values (e.g. Bolivia, Cuba, Ecuador
and Venezuela), cases where mechanisms are inefficient to reduce poverty, slowness to build trust between buyers
and sellers, as well as gender and land tenure issues that might arise (Asquith et al., 2008; Peterson et al., 2010;
Balvanera et al., 2012; van Noordwijk et al., 2012).

Table 27-8 lists selected examples of PES schemes in Latin America, but a more complete and detailed list is given
in Balvanera et al. (2012).

[INSERT TABLE 27-8 HERE]

Table 27-8: Cases of government-funded PES schemes in CA and SA.]

The PES concept (or ‘fishing agreements’) also applies to coastal and marine areas, although only a few cases have
been reported. Begossi (2011) argues that this is due to three factors: origin (the mechanism was originally designed
for forests), monitoring (marine resources such as fish are more difficult to monitor than terrestrial resources) and
definition of resource boundaries in offshore water. One example of a compensation mechanism in the region is the
so-called defeso, in Brazil. It consists of a period (reproductive season) when fishing is forbidden by the government
and fishermen receive a financial compensation. It applies to shrimp, lobster and both marine and freshwater
fisheries (Begossi et al., 2011).

27.7. Data and Research Gaps

The lack of high quality and continuous climate, oceanic and hydrological records, together with the very few
complete regional studies, poses challenges for the region to address climate variability and the identification of
trends in climatic extremes, in particular for CA. The non-availability of high resolution climatic and hydrological
data also hampers studies on frequency and variability of extremes. This situation affects the studies of related
impacts and vulnerability analyses in present climates, and the development of vulnerability assessments and
adaptation actions for the future.

Related with observed impacts in most of the sectors, there is a great difference in information availability between
countries, While more studies have been performed for the SESA region, much less are available for CA and for
some regions of tropical SA. The problem is not only the lack of studies of observed impacts, but also the lack or
poor dissemination of results in peer-reviewed publications. There is a need for studies focused on current impacts
and vulnerabilities in all the sectors throughout CA and SA, potentially with a certain emphasis on extremes in order
to improve risk management assessments.

The complex interactions between climate and non-climate drivers can challenge impacts assessment and
projections, as can for instance be the case for water availability and streamflow when looking at current and
potential deforestation; or overfishing and pollution regarding the impacts on fisheries, or impacts on hydroenergy
production. In this sense, the lack of interdisciplinary integrated studies limits the knowledge of such complex
processes that involve not only physical but also socioeconomical factors.
In addition, the accelerated changes in some issues like deforestation and changes in land use, as well as economic conditions, demand continuous and detailed studies to update available information to be made available to the research community.

To address the global challenge of food security and food quality, being important issues in CA and SA, investments in the production of scientific agricultural knowledge will be reinforced in relation to: integration of agriculture with organic production; and the integration of food and bioenergy production. With the important interlinkages of renewable energy, adaptation and mitigation, sufficient knowledge on RE project implementation and on crops is requested.

Also, a better understanding is needed of potential adverse effects of bioenergy production and indirect land use changes. Equally, further research is needed on future projections of renewable energy, e.g. wind power. However, it is indispensable that the competition for food and bioenergy production considers ethical aspects; identifying which activity is most important and whether bioenergy production would affect food security.

Sea level rise and costal erosion are also relevant issues, and the lack of comparable measurements of sea level rise in CA and SA makes integrated assessments on sea level rise and impacts on the region difficult, both for the present and future. Of local and global importance will be an enhancement of the understanding of the physical processes on the ocean, in specific the Humboldt Current system flowing along the West Coast of SA, being the most fish productive system worldwide.

While the majority of the coastal section literature focuses on fisheries, there is a recognized need for research on how corals reefs, mangroves and benthic marine invertebrates, that are key to reef systems as well, could be impacted upon by climate change.

There is still a need for more research and information about the impacts of climate variability and change on human health, mainly in CA. One problem is the difficulty to accessing health data that are not always archived and ready to be used in integrated studies. Another need refers to building the necessary critical mass of transdisciplinary scientists to tackle the climate change-human health problems in the region. The prevailing gaps in scientific knowledge hamper the implementation of adaptation strategies, thus demanding a review of research priorities towards better disease control. With the aim of further studying the health impacts of climate change and identifying resilience, mitigation and adaptation strategies, South-South cooperation and multidisciplinary research are considered to be relevant priorities.

In despite of the uncertainty that stems from global and regional climatic projections, the region needs to act. In this sense it is usful to promote research activities leading to assist people to cope with current climate variability, as for example, risk assessment and risk management. Other important aspect is the improvement of climate modeling that can be done in the region, thus lowering uncertainties. Since the AR4, experiences on model development and the generation of high resolution climate scenarios have allowed for the production of the first integrated regional studies on impacts and vulnerability assessments of climate change, for sectors such as agriculture, energy and human health.

Research on adaptation and the scientific understanding of the various processes and determinants of adaptive capacity is also key to the region, with particular potential in increasing adaptation capacity when focusing on traditions and how they are transmitted. Linking indigenous knowledge with scientific knowledge is also needed. Although adaptation processes have mostly been intiated in the past years, still their efficiency is difficult to determine owing to a lack of literature to evaluate them.

There is a need for change in the research agenda in order to address vulnerability and foster adaptation in the region; encompassing an inclusion of the regions’ researchers and focusing also on governance structures and action-oriented research that also addresses resource distribution inequities.
Regional and international partnerships, networks, research programs have allowed a linkage of those programs with local strategies for adaptation and mitigation, also providing opportunities to address research gaps and exchange among researchers. Examples are the Ibero-American Network of Climate Change Offices- RIOCC; the European Union funded projects CLARIS LPB in SESA and AMAZALERT in Amazonia. Other important initiatives come from the WHO, GEF, IDB, ECLAC (CEPAL), La Red, BirdLife International. The same holds for local international networks such as ICLEI or C40, of which CA and SA cities form part. The weADAPT initiative is a good example on how practitioners, researchers and policy makers for CA and SA can have access to credible, high quality information and to share experiences and lessons learnt in other regions of the world.

27.8. Conclusions

In CA and SA there is ample evidence of increases in extreme climate events and on their impacts on natural and human systems. Changes in climate variability and in extreme events have been severely affecting CA and SA since the second half of the 21st century. Since the AR4, unusual extreme weather and climate events have occurred in most countries: drought/flood episodes in Amazonia in 2010/2009, 2012, the drought in NE Brazil in 2012, cold waves and floods in the Andes from 2010-2012, among others. Temperature increases have been identified in most of CA and SA, with the exception of the southern coast of South America that has experienced cooling during the last decades. Changes in observed warm days and cold nights have been identified in CA, and some sectors of SA, while more frequent and intense rainfall extremes in SESA have favored an increase in the occurrence of landslides and flash floods. Since the AR4, there is growing evidence that glaciers (both tropical and extratropical) are retreating and the cryosphere in the Andes is changing according to the warming trends, affecting the hydrometeorological regimes in SA.

Land cover change is a key driver of environmental change with significant impacts on climate change. Deforestation and land degradation are mainly attributed to increased extensive and intensive agriculture, both from traditional export activities such as beef and soy production, but more recently from biomass for biofuel production. Even though deforestation rates in the Amazon have decreased substantially in the last eight years, other regions like the Cerrado and the Chaco forests still present high levels of deforestation with rates as high as 1.33%. In Argentina, Bolivia, Brazil and Paraguay, agricultural expansion, mainly soybean, has exacerbated deforestation and has intensified the process of land degradation. The agricultural expansion has affected fragile ecosystems such as the edges of the Amazon forest and the Pampas region; or the tropical Andes, increasing the vulnerability of communities to extreme climate events, particularly floods, landslides and droughts.

Socioeconomic development shows a high level of structural heterogeneity and a very unequal income distribution resulting in the high vulnerability of the region to climate variability and change. There is still a high and persistent level of poverty in most countries in spite of the sustained economic growth observed in the last decade. The economic inequality translates into inequality in access to water, sanitation and adequate housing; particularly for the most vulnerable groups living in poverty. However, high vulnerability can be found in regions with high income.

Coastal and marine ecosystems have been undergoing significant transformations that pose threats to marine ecosystems and to the services they offer. Frequent coral bleaching events have been recently reported for the Mesoamerican Coral Reef. In CA and SA, some of the main drivers of mangrove loss are deforestation and land conversion, agriculture and shrimp ponds, to an extent that the mangroves of the Atlantic and Pacific coasts of CA are some of the most endangered in the planet. Changes over 2 mm/yr of sea-level rise have been found in CA and SA, which is reason for concern since 3/4 of the population of the region live within the range of 200 km of the coast.

Conversion of natural ecosystems is the main proximate cause of biodiversity and ecosystem loss in the region, and in parallel is a driver of anthropogenic climate change. Plant species are rapidly declining in CA and SA; the highest percentage of rapidly declining amphibian species occurs also in CA and SA; with Brazil being among the countries with most threatened bird, mammal species and freshwater fish. However, the region has still large extensions of natural vegetation cover for which the Amazon is the main example. Ecosystem-based Adaptation practices, such as
conservation agreements, community management of natural areas, and payment for ecosystem services, begin to appear across the region.

Figure 27-7 presents a summary of some of the main observed trends in global environmental change drivers across different representative regions of CA and SA. The figure presents changes in climate and non-climate drivers and has to be compounded with other socioeconomic related trends, such as the rapid urbanization process experienced the region.

[INSERT FIGURE 27-7 HERE]

Figure 27-7: Summary of observed changes in climate and other environmental factors in representative regions of CA and SA. The boundaries of the regions in the map are conceptual (not precise geographic nor political) and follow those developed in Figure 3-1 of the IPCC SREX (IPCC, 2012). Information and references to changes provided are presented in different sections of the chapter.]

In terms of attribution to climate change, some of the observed impacts on human and natural systems detected and reported in the literature are shown in Figure 27-8. Some of them can be directly or indirectly attributed to human influences, and can be summarized as:

• Reduction in tropical glaciers and icefields in tropical and extra tropical Andes over the second half of the 20th century that can be attributed to an increase in temperature.
• There have changes identified in river flows in SA. Extreme streamflow in the Amazon River have changed during the last two decades, robust positive trends in streamflow in different sites have been detected in sub-basins of the La Plata River basin and increased dryness for most of the river basins in west coast of South America have been detected during the last 50 years.
• Mangrove degradation in the Northern South American coast and reduction in fisheries stock.
• Increase in agricultural yield in SESA, and shifting in agricultural zoning: significant expansion of agricultural areas, mainly in climatically marginal regions.
• Increase in frequency and extension of dengue fever, yellow fever and malaria.

However, the fact that in some impacts the number of studies is still insufficient leads to extreme low levels of confidence for attribution to human influences.

[INSERT FIGURE 27-8 HERE]

Figure 27-8: Observed impacts of climate variations and attribution of causes in CA and SA.]

By the end of the century, the projected mean warming for CA ranges from 1.5°C to 4.0 °C, while rainfall tends to decrease between 5 and 10%. SA shows a warming between 1.0°C to 5.0 °C, with rainfall reduction up to 10% in tropical SA and an increase of about 10-15% in SESA, and in other regions of the continent. Heavy precipitation is projected to increase in SESA, while dry spells would increase in northeastern South America. Increases in warm days and nights are very likely to occur in most of SA. Projections for CA show summertime precipitation reduction, accompanied by projected warming in most of the region. However, there is some degree of uncertainty on climate change projections for regions, particularly for rainfall.

In present climates, there are regions that experience vulnerability in terms of current water availability, and this vulnerability is expected to increase in the future due to climate change impacts. Already vulnerable regions in terms of water supply, like the semi-arid zones in SA and CA and the tropical Andes, are expected to increase even further their vulnerability due to climate change. This would be complicated by the expected glacier retreat, and a reduction in water availability due to expected precipitation reduction and increase evapotranspiration demands as expected in the semi-arid regions of CA and SA. These scenarios would affect water supply for large cities, small communities, hydropower generation and the agriculture sector.

This results in a need for re-assessing current practices to reduce the mismatch between water supply and demand. This could be used to reduce future vulnerability, and to implement constitutional and legal reforms towards more efficient and effective water resources management in the region, as part of adaptation strategies to cope with
climate variability and change. Changes in agricultural productivity as a consequence of climate change are
expected to have a great spatial variability, and while in SESA projections show that average productivity could be
sustained or increased until the mid-century (SRES: A2, B2), in other regions increases in temperature and decreases
in rainfall could decrease the productivity in the short-term (before 2025), threatening the food security of the
poorest population. The great challenge for CA and SA will be to increase the food and bioenergy production and at
the same time sustain the environmental quality in a scenario of climate change.

Renewable energy has a great potential for adaptation and mitigation. Hydropower is currently the main source of
RE in CA and SA, followed by biofuels, notably bioethanol from sugarcane and biodiesel from soy. SESA is one of
the main sources of production of the feedstocks for biofuels’ production, mainly with sugarcane and soybean, and
future climate conditions may lead to an increase in productivity and production. Advances in second generation
bioethanol from sugarcane and other feedstocks will be important as a measure of adaptation, as they have the
potential to increase biofuels productivity in the region. In spite of the large amount of arable land available in the
region, the expansion of sugarcane and soy, related to biofuels production, might have some indirect land use
change effects, producing teleconnections that could lead to deforestation in the Amazon and loss of employment in
some countries. This would also also affect food security.

Climate variability and climate change are negatively affecting human health in CA and SA, either by increasing
morbidity, mortality, and disabilities and through the emergence of diseases in regions previously non-endemic, or
the re-emergence of diseases in areas where they have previously been eradicated or controlled. Climate-related
drivers have been recognized for respiratory and cardiovascular diseases, vector- and water-borne diseases, mainly
malaria, dengue and yellow fever. Vulnerabilities vary with geography, age, gender, race, ethnicity, and socio-
economic status, and climate change and variability may exacerbate current and future risks to health.

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. The best way to be prepared to adapt to future climate
change is by assisting people to cope with current climate variability, particularly to weather and climate extremes.
Long-term planning and the related human and financial resource needs may be seen as conflicting with present
social deficit in the welfare of the CA and SA population. Such conditions weaken the importance of adaptation
planning to climate change on the political agenda. In the present, there are few experiences on synergies between
development, adaptation and mitigation planning, which can help local communities and governments to allocate
available resources in the design of strategies to reduce vulnerability and to develop adaptation measures. 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 sustainable development.

Frequently Asked Questions

FAQ 27.1: What is the impact of receding glaciers on natural and human systems in the tropical Andes?
Andean tropical glaciers retreat, with some fluctuations, started after the Little Ice Age (16th to 19th centuries) but the
rate of retreat has accelerated since the middle of the 20th century. Depending on the size and phase of glacier retreat
there is an expected effect in terms of changes in runoff in basins fed from these glaciers. In an early phase of the
glacier retreat runoff tends to increase due to an acceleration of glacier melt, but after a peak in discharge as the
glacierized water reservoir gradually empties, runoff tends to decrease. This reduction in runoff is more evident
during dry months when glacier melt is the major contribution to runoff. A reduction in runoff could reduce water
related benefits and intensify conflicts among different users of water in high elevation Andean tropical basins
which concentrates highly vulnerable populations. Glacier retreat has also been associated with disasters such as
glacial lake outburst floods (GLOFS) that are a continuous threat in the region. And finally glacier retreat could have
impacts on activities that rely on these high mountainous ecosystems such as alpine tourism, mountaineering and
adventure tourism.

FAQ 27.2: Can PES be used as an effective way for helping local communities to adapt to climate change?
PES can be used as an effective way to help local communities to adapt to climate change. It can simultaneously
help protect natural areas, while improving livelihoods and human well-being. However, during design and
planning, a number of factors at local level need to be taken into consideration in order to avoid potentially negative side effects. Reported setbacks include: poor definition if design should focus on actions or results, perception of commoditization of nature and its intangible values, inefficiency in reducing poverty, difficulties in building trust between parts involved in agreements, and eventual gender or land tenure issues.

**FAQ 27.3: Are there emerging and re emerging human diseases as a consequence of climate variability and change in the region?**

Climate variability and climate change (CC/CV) are negatively affecting human health in CA and SA, either by increasing morbidity, mortality, and disabilities (very high confidence), or by the emergence of diseases in previously non-endemic regions, or the re-emergence of diseases in areas where they have previously been eradicated or controlled (high confidence). Climate-related drivers have been recognized for respiratory and cardiovascular diseases, vector- and water-borne diseases (malaria, dengue, yellow fever, leishmaniasis, cholera, and other diarrheal diseases), Hantaviruses and Rotaviruses, pregnancy-related outcomes, diabetes, chronic kidney diseases, and psychological trauma. It is very likely that CC/CV together augment current and future risks to health, amidst the region’s vulnerabilities in existing health, water, sanitation and waste collection systems, nutrition, and pollution.

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Table 27-1: Regional observed changes in temperature, precipitation, river runoff and climate extremes in various sectors of CA and SA. Additional information on changes in observed extremes can be found in the IPCC SREX (Seneviratne et al., 2012) and Chapter 2 IPCC WGI AR5 [2.4, 2.5, 2.6]

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**Amazon region**

| Decadal variability of rainfall in northern and southern Amazonia | 1920-2008 | -3 STD/30 years in northern Amazonia and +4 STD/30 years in southern Amazonia since the middle 1970’s | Marengo et al. (2009a), Satyamurty et al. (2010) |
| Decrease in rainfall in all the region | 1975-2003 | -0.32 %/28 years | Espinoza et al. (2009a; 2009b) |
| Delay on the onset of the rainy season in southern Amazonia | 1950-2010 | -1 month since 1976 to 2010 | Butt et al. (2011), Marengo et al. (2011b) |
| Increase of precipitation in the SAMS core region | 1979-2008 | +2 mm/day decade⁻¹ | Wang et al. (2012) |
| Onset becomes steadily earlier from 1948 to early 1970s, demise dates have remained later, and SAMS duration was longer after 1972. | 1948-2008 | SAMS from 170 days (1948–1972) to 195 days (1972–1982). | Carvalho et al. (2011) |
| Spatially varying trends of heavy precipitation (R95), increase in many areas and insufficient evidence in others | 1961-1990 | +100 mm/31 years in western and extreme eastern Amazonia, | Marengo et al. (2009a) |
| Spatially varying trends in dry spells in (CDD), increase in many areas and decrease in others | 1961-1990 | +15 mm/31 years in Western Amazonia, -20 mm/ in southern Amazonia | Marengo et al. (2009a; 2010) |
| Negative runoff trends of the Amazon River | 1948-1968 | -1.5 mm/day/50 years | Dai et al. (2009), Dai (2011) |
| Positive runoff trends of the Tocantins River | 1948-1968 | +0.5 mm/day/50 years | Dai et al. (2009), Dai (2011) |
| Positive rainfall trends in most of Amazonia and negative trends in western Amazonia | 1948-2008 | +1 mm/day/50 years, -1.5 mm/day/50 years | Dai et al. (2009), Dai (2011) |
| Increased dryness as estimated by the Palmer Drought Severity Index PDI in southern Amazonia and moister conditions in western Amazonia | 1950-2008 | -2 to -4/50 years, +2 to +4 /50 years | Dai (2011) |
| Decrease of seasonal mean convection and cloudiness | 1984-2007 | +30 W/m²/23 years, -8 %/23 years | Arias et al. (2011) |
| Delayed onset of rainy season in southern Amazonia due to land use change | 1970-2010 | -0.6 days/30 years | Butt et al. (2011) |
Northeast Brazil

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Table 27-2: Regional projected changes in temperature, precipitation, river runoff and climate extremes in different sectors of CA and SA. Various studies used A2 and B2 scenarios from CMIP3 and various RCPs scenarios for CMIP5, and different time slices from 2010 to 2100. In order to make results comparable, the CMIP3 and CMIP5 at the time slice ending in 2100 are included. Additional information on changes in projected extremes can be found in the IPCC SREX (see IPCC, 2012), and Chapters 9 and 14 from IPCC WG1AR5 [9.5, 9.6 and 14.2, 14.7].

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<td>+2.2 C by 2075; +3.3 C by 2100</td>
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<td>20 km MRI JMA model, A1B</td>
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<td>20 km MRI JMA model, A1B</td>
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<td>9 CMIP3 models, A2</td>
<td>Reduction in precipitation between -10% and -30%, an temperature increase of +3 C</td>
<td>Minvielle and Garreaud (2011)</td>
</tr>
<tr>
<td>Amazon region</td>
<td></td>
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<tr>
<td>Rainfall reduction in central and eastern Amazonia, warming in all region by 2100</td>
<td>Eta forced with HadCM3, A1B</td>
<td>Precipitation: -20 top -30%, +20 to +30%; temperature: +5 to +7 C</td>
<td>Marengo et al. (2011a)</td>
</tr>
<tr>
<td>Reduction in the intensity of the South Atlantic Convergence Zone and in rainfall in the South American monsoon region, 2081-2100</td>
<td>10 CMIP3 models, A1B</td>
<td>Precipitation: -100 to -200mm/20 years</td>
<td>Bombardi and Carvalho (2009)</td>
</tr>
<tr>
<td>Small increases of precipitation in western during summer and decreases in winter in Amazonia by 2100</td>
<td>5 CMIP3 models, A2 and ANN</td>
<td>+1.6% in summer and -1.5% in winter</td>
<td>Mendes and Marengo (2010)</td>
</tr>
<tr>
<td>Increase in the number of South American Low Level Jet east of the Andes events (SALLJ), and in the moisture transport from Amazonia to the La Plata basin by 2100</td>
<td>PRECIS forced with HadAM3, A2</td>
<td>+50 events of SALLJ during summer, increase in moisture transport by 50%</td>
<td>Soares and Marengo (2009)</td>
</tr>
<tr>
<td>Increase of precipitation in the South American monsoon during summer and spring, and reduction during fall and winter by 2100</td>
<td>9 CMIP3 models, A2</td>
<td>Increase of +0.15 to +0.4 mm/ reductions of -0.10 to -0.26 mm/day</td>
<td>Seth et al. (2010)</td>
</tr>
<tr>
<td>Topic</td>
<td>Methodology</td>
<td>Results</td>
<td>References</td>
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<td>----------------------------------------------------------------------</td>
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<tr>
<td>Increase in warm nights, increase of consecutive dry days in eastern Amazonia, increase of heavy precipitation in western Amazonia and reduction in eastern Amazonia by 2100</td>
<td>PRECIS forced with hadAM3, A2</td>
<td>Increase of +12 to +15%, by 25-30 days in eastern Amazonia, increase in western Amazonia by 75-105 days and reduction by -15 to 75 days in eastern Amazonia</td>
<td>Marengo et al. (2009a)</td>
</tr>
<tr>
<td>Increase in air temperature, rainfall increase in western Amazonia and decrease in eastern Amazonia by 2100</td>
<td>CMIP3 models, A1B</td>
<td>Increase of +4 to +6 C, increase of +10% and decrease between -10 to -30%</td>
<td>Giorgi and Diffenbaugh (2008)</td>
</tr>
<tr>
<td>Reduction of consecutive dry days and increase in heavy precipitation by 2099</td>
<td>20 km MRI-JAM model, A1B</td>
<td>Reduction of -5 to -10 days, increase by +2 to +8 %</td>
<td>Kamiguchi et al. (2006)</td>
</tr>
<tr>
<td>Early onset and late demise of the rainy season in SAMS by 2040-2050 relative to 1951-80</td>
<td>10 CMIP5 models, RCP8.5 (high emission)</td>
<td>Onset 14 days earlier than present, demise 17 days later than present</td>
<td>Jones and Carvalho (2013)</td>
</tr>
<tr>
<td>Increase precipitation in SAMS during the monsoon wet season in 2071-2100 relative to 1951-80</td>
<td>10 CMIP5 models, RCP8.5 (high emission)</td>
<td>Increase of 300 mm during the wet season</td>
<td>Jones and Carvalho (2013)</td>
</tr>
<tr>
<td>Increase of precipitation in western Amazonia, reduction of heavy precipitation in northern Amazonia and increase in southern Amazonia, reduction of consecutive dry days in western Amazonia and increase in eastern Amazonia by 2099</td>
<td>RCA forced with the ECHAM5 mode, A1B</td>
<td>Increase of +1 to +3 mm/day, reduction of -1 to -3 mm, in increase of +5 to _10 mm, decrease of -5 to -10 days, increase by +20 to +30 days</td>
<td>Sörensson et al. (2010)</td>
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<tr>
<td><strong>Northeast Brazil</strong></td>
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<tr>
<td>Rainfall reduction in the entire region, temperature increases by 2100</td>
<td>Eta forced with HadCM3, A1B</td>
<td>Precipitation: -20 to -20%; temperature: +3 to +4 C</td>
<td>Marengo et al. (2011a)</td>
</tr>
<tr>
<td>Increase of warm nights, of consecutive dry days, and reduction of heavy precipitation by 2100</td>
<td>PRECIS forced with HadAM3, A2</td>
<td>Increase by +18 to +24%, by +25 to +30 days and -15 to -75 days</td>
<td>Marengo et al. (2009a)</td>
</tr>
<tr>
<td>Increase in temperature, reductions in precipitation by 2100</td>
<td>23 CMIP3 models, A1B</td>
<td>Increase of +2 to +4 C, reduction of -10 to -30%</td>
<td>Giorgi and Diffenbaugh (2008)</td>
</tr>
<tr>
<td>Reduction of consecutive dry days and increase in heavy precipitation by 2099</td>
<td>20 km MRI-JMA model, A1B</td>
<td>Reduction of -5 to -10% and increase of +2 to +6 %</td>
<td>Kamiguchi et al. (2006)</td>
</tr>
<tr>
<td>Increase of precipitation, in heavy precipitation and consecutive dry days by 2099</td>
<td>RCA forced with ECHAM5 model, A1B</td>
<td>Increase of +1 to +2 mm/day, increase by +5 to +10 mm, and increase by +10 to +30 days</td>
<td>Sörensson et al. (2010)</td>
</tr>
</tbody>
</table>
Table 27-3: Observed trends related to Andean cryosphere.

<table>
<thead>
<tr>
<th>Country</th>
<th>Documented massifs (latitude)</th>
<th>Significant changes recorded and reference (dates in AD)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Venezuela</td>
<td>Cordillera de Merida (10°N)</td>
<td>Four glacial advances between 1250 and 1810. Glaciers have been rapidly retreating since at least 1870. Equilibrium Line Altitude (ELA) raised up by ~300-500m between LIA maximum and today. Accelerated melting since 1972. Remaining glaciers are at risk of disappearing completely in the next years since ELA lies near to the Pico Bolivar summit (4979m).</td>
<td>Polissar et al. (2006); Morris et al. (2006)</td>
</tr>
<tr>
<td>Colombia</td>
<td>Parque Los Nevados (4°50N) Sierra Nevada del Cocuy (56°30N) Sierra Nevada de Santa Marta (10°40N)</td>
<td>LIA maximum occurred between 1600 and 1850. Loss of 60-84% in glacierized areas during the 1850-2000 period and many small/low elevation glaciers have disappeared. In the past 50yrs, 50% of glacier areas have been lost, and in the past 15yrs 10-50%. Since 2000, glaciers retreated at a rate of 3.0km²/yr. Glacier areas total 45km² in Colombia in 2011.</td>
<td>Ruiz et al. (2008); Ceballos et al. (2006); Poveda and Pineda (2009)</td>
</tr>
<tr>
<td>Ecuador</td>
<td>Antisana (0°28S) Chimborazo and Carihuayrazo (1°S) Ecuadorian volcanoes</td>
<td>LIA maximum occurred in around 1720 and 1830 (Chimborazo). Historical evidences of ELA at 4700±50m in around 1740. ELA raised up 300m between the middle 18th and the last decades of the 20th (~200m during only the 20th century). A slight glacier reduction was reported between 1956 and 1976, but in the 1976-2006 period, glacier areas lost ~45%. Glaciers at low elevation (&lt;5300m) are in process of extinction. Glaciers in Ecuador total less than 50km² in 2011.</td>
<td>Francou (2004); Jordan et al. (2005); Jomelli et al. (2009); Cáceres et al. (2006)</td>
</tr>
<tr>
<td>Peru</td>
<td>Cordillera Blanca (9°S)</td>
<td>LIA maximum occurred in around 1630±27. Loss of 12-17% of glaciers during the 18th century, and 17-20% during the 19th. Rapid retreat in the 1930s-1940s and from 1976-80. ELA increased by ~100m from the LIA maximum to the beginning of the 20th century, and by more than 150m during only the 20th century. The lost of glacial area reported by several teams since the 1960s to the 2000s converge on a range of 20-35%. Physical observations of the Yanamarey glacier show acceleration in frontal retreat at a rate of 8 m decade⁻¹ since 1970, accompanied by total volume loss on the order of 0.022 km³. Increase of 1.6 (± 1.1) percent in the specific discharge of the more glacier-covered catchments (&gt;20 percent glacier area) Seven out of nine watersheds exhibit decreasing dry-season discharge. Median (out of 9 glaciers analyzed) average ice area loss of 0.61% a⁻¹. Glaciers of Coropuna have retreated by 26% between 1962 and 2000.</td>
<td>Kaser and Georges (1997); Georges (2004); Mark and Seltzer (2005); Silverio and Jaquet (2005); Raup et al. (2007); Jomelli et al. (2009); UGHR (2010); Bury et al. (2011); Mark et al. (2010); Baraer et al. (2012)</td>
</tr>
<tr>
<td>Coropuna volcano (15°33S)</td>
<td>Glaciers of Coropuna receded by 26% between 1962 and 2000</td>
<td></td>
<td>Racoviteanu et al. (2007)</td>
</tr>
<tr>
<td>Cordillera Vilcanota (13°55S)</td>
<td>Qori Kalis glacier receded in the 1991-2005 period 10 times faster than during the 1963-2005 period</td>
<td></td>
<td>Thompson et al. (2006; 2011)</td>
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<tr>
<td>Country</td>
<td>Region</td>
<td>Description</td>
<td>References</td>
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<tr>
<td>Bolivia</td>
<td>Cordillera Real and Cordillera Quimza Cruz (16°S)</td>
<td>On the Telata glacier, strong melting after the maximum extent occurred from 10.8±0.9 to 8.5±0.4kyr ago, followed by a slower retreat until the Little Ice Age, about 200 years ago. The LIA maximum is dated between 1657±20 and 1686±20 in the north of Bolivia. Between the LIA maximum and the late 20th century, the ELA increased by 300m (180-200m during the only 20th century). Proxy of vertical englacial temperature in Bolivia (Ilímami, 6340m, 16°S) shows two warming phases from AD 1900 to 1960 (+0.5±0.3 K) starting in 1920-1930 and from 1985 to 1999 (+0.6±0.2K), corresponding to a mean atmospheric temperature rise of 1.1±0.2 K over the 20th century. From 1956 to 1963-1976, glaciers were near the equilibrium, but the recession was very strong after 1976. Small glaciers at low elevation (&lt;5300-5400m) are in process of extinction (Chacaltaya vanished in 2009). Since 1991, Zongo glacier (6000-4900m) has lost a mean of 0.4m we/yr and only 20% of the mass balances measured in the 1991-2011 period have been positive or near the equilibrium. Glaciers of the Cordillera Real have lost 43% of their volume between 1963 and 2006, essentially over the 1976-2006 period, and 48% of their surface area between 1976 and 2006. Studies of sensitivity have shown that during the October-March wet period, crucial for the year mass balance, +1°C temperature increases the ELA by ~200m.</td>
<td>Jomelli et al. (2011); Rabatel et al. (2005); Rabatel et al. (2006; 2008); Gilbert et al. (2010); Soruco et al. (2009); Lejeune (2007)</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Sur Lipez, Caquella, 21°30S</td>
<td>Evidence of recent degradation of Caquella rock glacier</td>
<td>Francou et al. (1999)</td>
</tr>
</tbody>
</table>
b) Extra tropical Andean cryosphere (glaciers, snowpack, runoff effects) trends.

<table>
<thead>
<tr>
<th>Region</th>
<th>Documented massifs/latitude</th>
<th>Significant changes recorded and reference</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andes of Chile, Argentina and Bolivia and Argentinan Patagonia</td>
<td>Snow cover extent</td>
<td>The 1979–2006 period shows a sinusoidal like pattern for both snow cover and snow mass, though neither trend is significant at the 95% level.</td>
<td>Foster et al. (2009)</td>
</tr>
<tr>
<td>Desert Andes (17°S-31°S)</td>
<td>Review on extra tropical glaciers</td>
<td>Most areas in the Andes of extratropical SA have experienced a general pattern of glacier recession and significant ice mass losses</td>
<td>Masiokas et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Huasco basin glaciers (29°S)</td>
<td>Glacier mass loss is evident over the study period, with a mean of −0.84 m w.e. yr⁻¹ for the period 2003/2004–2007/2008</td>
<td>Nicholson et al. (2009); Rabatel et al. (2011); Gascoin et al. (2011)</td>
</tr>
<tr>
<td>Central Andes (31°S-36°S)</td>
<td>Review on extra tropical glaciers</td>
<td>Most areas in the Andes of extratropical SA have experienced a general pattern of glacier recession and significant ice mass losses</td>
<td>Masiokas et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Piloto/Las Cuevas (32°S)</td>
<td>Within the 24-year period, 67% of the years show negative net annual specific balances, with a cumulative mass balance loss of - 10.50 m w.e.</td>
<td>Leiva et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Aconcagua basin glaciers (33°S)</td>
<td>Reduction in glacier area of 20% (0.63 km² a⁻¹) over last 48 years. Glaciar Juncal Norte, exhibits a smaller reduction (14%) between 1955 and 2006.</td>
<td>Nicholson et al. (2009); Bown et al. (2008)</td>
</tr>
<tr>
<td></td>
<td>Central Andes glaciers (33–36 °S)</td>
<td>All studied glaciers exhibited a negative trend during the 20th century with mean frontal retreats between −50 and −9 m y⁻¹, thinning rates between 0.76 and 0.56 m y⁻¹ and a mean ice area reduction of 3% since 1955.</td>
<td>Le Quesne et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>ELA across central Andes</td>
<td>Analysis of radiosonde data of central Chile shows mid-tropospheric warming with an elevation increase of the 0°C isotherm of 122 ± 8 m and 200 ± 6 m in winter and summer, respectively, during the 27-year period between 1975 and 2001.</td>
<td>Carrasco et al. (2005)</td>
</tr>
<tr>
<td>Snowpack (30 °S-37°S)</td>
<td>Snowpack extent</td>
<td>Marked interannual variability, and a positive, though nonsignificant, linear trend for period (1951–2005)</td>
<td>Masiokas et al. (2006)</td>
</tr>
<tr>
<td></td>
<td>Morenas coloradas rock glacier (32 °S-33°S)</td>
<td>A significant change in the active layer and suprapermafrost possibly associated with warming processes.</td>
<td>Trombotto and Borzotta (2009)</td>
</tr>
<tr>
<td></td>
<td>Mendoza river streamflow</td>
<td>Possible link to rising temperatures and snowpack/glacier effects. Not conclusive.</td>
<td>Vich et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Aconcagua basin streamflow</td>
<td>Significant decrease in streamflow that could be explained by a progressive change in glaciers area and volume in the basin.</td>
<td>Pellicciotti et al. (2007)</td>
</tr>
<tr>
<td></td>
<td>Streamflow from basins between 28 °S and 47 °S</td>
<td>Not significant increase in February run-off trends for period 1950–2007 that might suggest an increase of glacier melt in the Andes.</td>
<td>Casassa et al. (2009)</td>
</tr>
<tr>
<td></td>
<td>Streamflow timing between 30 °S and 40 °S</td>
<td>Significant (95% confidence level) negative trend (CT date shifting towards earlier in the year) for 23 out of the 40 analyzed series. More relevant is precipitation rather than temperature.</td>
<td>Cortés et al. (2011)</td>
</tr>
<tr>
<td>Patagonian Andes (36°S-55°S)</td>
<td><strong>Review on extra tropical glaciers</strong></td>
<td>Most areas in the Andes of extratropical SA have experienced a general pattern of glacier recession and significant ice mass losses</td>
<td>Masiokas et al. (2009)</td>
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<tr>
<td>Casa Pange Glacier (41°S)</td>
<td>Between 1961 and 1998, mean thinning rate of $\sim 2.3 \pm 0.6 \text{ m a}^{-1}$. When ice thinning is computed for the period between 1981 and 1998, the resulting rate is 50% higher ($\sim 3.6 \pm 0.6 \text{ m a}^{-1}$).</td>
<td>Bown and Rivera (2007)</td>
<td></td>
</tr>
<tr>
<td>North Patagonian Icefield (NPI)</td>
<td>Glacial lake outburst flood (GLOF) interpreted as a delayed paraglacial response to the retreat of Calafate glacier during the twentieth century.</td>
<td>Harrison et al. (2006)</td>
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</tr>
<tr>
<td>Southern Patagonia Icefield (SPI)</td>
<td>Retreating glaciers with larger rates observed on the west side coinciding with lower elevations of the ELAs (relative to the east side).</td>
<td>Barcasa et al. (2009)</td>
<td></td>
</tr>
<tr>
<td>NPI, SPI and the Cordillera Darwin Icefield (CDI)</td>
<td>The majority of glaciers have retreated between 1945 and 2005 with maximum values of 12.2 km for Marinelli Glacier in the CDI, 11.6 km for O'Higgins Glacier in the SPI and 5.7 km for San Rafael Glacier in the NPI</td>
<td>Lopez et al. (2010)</td>
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</tr>
<tr>
<td>Cordón Martial glaciers (54°S)</td>
<td>Ice loss rate for the period April 2002-December 2006 of $27.9 \pm 11 \text{ km3/year}$, equivalent to an average loss of -1.6 m/year of ice thickness.</td>
<td>Chen et al. (2007)</td>
<td></td>
</tr>
<tr>
<td>Gran Campo Nevado (GCN) (53°S)</td>
<td>Glaciers slowly receding from Late Little Ice Age (LLIA). Acceleration started 60 years ago</td>
<td>Strelin and Iturraspe (2007)</td>
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<tr>
<td>Proglacial lakes located in Andean Patagonia between ~40°S and ~50°S</td>
<td>Summertime negative trend on lakes with a direct influence of glaciers interpreted as an indication that melt water is decreasing because the ice volume reduction.</td>
<td>Pasquini et al. (2008)</td>
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</tr>
<tr>
<td>Northwestern Patagonia between ca. 38° and 45°S.</td>
<td>Recession of 6 glaciers based on areal photograph analysis.</td>
<td>Masiokas et al. (2008)</td>
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</tr>
<tr>
<td>Streamflow from basins between 28°S and 47°S</td>
<td>Not significant increase in February run-off trends for period 1950–2007 that might suggest an increase of glacier melt in the Andes.</td>
<td>Casassa et al. (2009)</td>
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</tbody>
</table>
Table 27-4: Synthesis of projected climate change impacts on hydrologic variables in large South American basins and major glaciers.

<table>
<thead>
<tr>
<th>Region</th>
<th>Basins studied</th>
<th>Hydrologic Variable</th>
<th>Projected Change</th>
<th>Period</th>
<th>GCM</th>
<th>Scenarios</th>
<th>References</th>
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<tbody>
<tr>
<td><strong>La Plata Basin and SESA</strong></td>
<td>Paraná</td>
<td>Runoff</td>
<td>Runoff: + 4.9% (not robust) Runoff: +10 to +20%</td>
<td>2081-2100</td>
<td>CMIP3</td>
<td>A1B and A1B</td>
<td>Nohara et al. (2006)</td>
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<td></td>
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<td>2100</td>
<td>Eta forced with HadCM3</td>
<td></td>
<td>Marengo et al. (2011a)</td>
</tr>
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<td></td>
<td>Carcarañá</td>
<td>ET, Recharge</td>
<td>Increase in ET not compensated with increase in precipitation, slight reduction in recharge.</td>
<td>2010-2030</td>
<td>HadCM3</td>
<td>A2</td>
<td>Venencio and García (2011)</td>
</tr>
<tr>
<td><strong>Grande (Parana)</strong></td>
<td>Runoff</td>
<td></td>
<td>Range from +20 to -20%</td>
<td>Different periods</td>
<td>7 CMIP3 models</td>
<td>Prescribed temperature changes and emission scenarios</td>
<td>Todd et al. (2011) ; Gosling et al. (2011) ; Nóbrega et al. (2011)</td>
</tr>
<tr>
<td><strong>Itaipu (Parana)</strong></td>
<td>Runoff</td>
<td></td>
<td>2010–2040: Left bank: ~5 to ~15%; Right bank: +30% 2070-2100: 0 to ~30%</td>
<td>2010–2040 and 2070-2100</td>
<td>CCCMA-CGCM2</td>
<td>A2</td>
<td>Rivarola et al. (2011)</td>
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<tr>
<td><strong>Amazon Basin</strong></td>
<td>Peruvian Amazon–Andes basin</td>
<td>Runoff</td>
<td>Some basins increased, some reduced</td>
<td>Three time slices</td>
<td>BCM2, CSMK3 and MIHR</td>
<td>A1B, B1</td>
<td>Lavado Casimiro et al. (2011)</td>
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<tr>
<td>Ecuador - Tomebamba/Paute</td>
<td>Runoff</td>
<td></td>
<td>Some scenarios increase and some reduction</td>
<td>2070-2100</td>
<td>CMIP3</td>
<td>A1B</td>
<td>Buytaert et al. (2011)</td>
</tr>
<tr>
<td><strong>Amazon at Obidos</strong></td>
<td>Runoff</td>
<td></td>
<td>Average change + 5.4% (not robust)</td>
<td>2081-2100</td>
<td>CMIP3</td>
<td>A1B</td>
<td>Nohara et al. (2006)</td>
</tr>
<tr>
<td>Amazon -Orinoco</td>
<td>Runoff</td>
<td></td>
<td>+6%</td>
<td>2000-2100</td>
<td>ECBilt-CLIO-VECODE</td>
<td>A2</td>
<td>Aerts et al. (2006)</td>
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<tr>
<td><strong>Tropical Andes</strong></td>
<td>Colombian glaciers</td>
<td>Glacier extent</td>
<td>Glacier disappearance by 2020s</td>
<td>Linear extrapolation</td>
<td></td>
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<td>Poveda and Pineda (2009)</td>
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<tr>
<td>Cordillera Blanca basins</td>
<td>Runoff</td>
<td></td>
<td>Increase for next 20-50 years, reduction afterwards</td>
<td>2005-2020</td>
<td>Temperature output only</td>
<td>B2</td>
<td>Chevallier et al. (2011)</td>
</tr>
<tr>
<td>Glacier extent</td>
<td></td>
<td></td>
<td>2050: area is reduced by 38 to 60%. Increased seasonality 2080: area is reduced by 49 to 75%. Increased seasonality</td>
<td>2050 (climatology)</td>
<td>Not specified</td>
<td>A1, A2, B1, B²</td>
<td>Juen et al. (2007)</td>
</tr>
<tr>
<td><strong>Basins providing water to cities of Bogota, Quito, Lima and La Paz</strong></td>
<td>Water availability</td>
<td></td>
<td>Inner tropics: Only small change because of an offset of an increase in precipitation by an increase in evapotranspiration. Outer tropics: severe reductions due to a decrease in precipitation and increase in evapotranspiration</td>
<td>2010-2039 and 2040-2069</td>
<td>19 CMIP3 models</td>
<td>A1B and A2</td>
<td>Buytaert and De Bièvre (2012)</td>
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<tr>
<td>Region</td>
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<tr>
<td>Central Andes</td>
<td>Maipo</td>
<td>Runoff</td>
<td>Reduction up to 30% Unmet demand up to 50%</td>
<td>Three 30-year periods 2070-2090 HadCM3 A2, B2 Melo et al. (2010); ECLAC (2009a); Meza et al. (2012)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maule, Laja</td>
<td>Runoff</td>
<td>Reduction up to 30%</td>
<td>Three 30-year periods HadCM3 A2, B2 McPhee et al. (2010); ECLAC (2009a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North East Brazil</td>
<td>Limari</td>
<td>Runoff</td>
<td>Reduction range -10 to -20%.</td>
<td>2080s (climatology) HadCM2 Not specified Seoane and López. (2007)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North East Brazil</td>
<td>Paracatu (Sao Francisco)</td>
<td>Runoff</td>
<td>No significant change up to 2025. After 2025: strong reduction with ECHAM4; slight increase with HadCM2.</td>
<td>2000-2100 HadCM2, ECHAM4 Not clear Krol et al. (2006); Krol and Bronstert (2007)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jaguaribe</td>
<td>Demand</td>
<td>Increase in demand: +33 to +44%</td>
<td>2040 HadCM3 A2, B2 Gondim et al. (2008)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paranaiba</td>
<td>Runoff</td>
<td>-80%</td>
<td>2050s HadCM3 A2 Palmer et al. (2008)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mimoso catchment</td>
<td>Runoff</td>
<td>Dry scenario: -25 to -75%; Wet scenario: +40 to +140%; Similar changes in GW recharge</td>
<td>2010–2039, 2040–2069, and 2070–2099 CSMK3 and HadCM3 A2, B1 Montenegro and Ragab (2010)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tapacurá River</td>
<td>Runoff</td>
<td>Low emission: decrease by 4.89%, 14.28% and 20.58%; High emission: increase by 25.25%, 39.48% and 21.95%</td>
<td>Three 30-year periods CSMK3 and MPEH5 A2, B1 Montenegro and Ragab (2012)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bengué catchment</td>
<td>Runoff</td>
<td>-15% reservoir yield</td>
<td>Sensitivity scenario in 2100 selected from TAR and AR4 GCMs with good skill. + 15% PET, -10% Precip Krol et al. (2011)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North SA</td>
<td>Essequibo (Guyana)</td>
<td>Runoff</td>
<td>-50%</td>
<td>2050s HadCM3 A2 Palmer et al. (2008)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sinu (Colombia)</td>
<td>Runoff</td>
<td>-2 to -35%</td>
<td>2010–2039 CCSRNIES, CSIROMK2B, CGCM2, HadCM3 (different runs of these models) A2 Ospina-Noreña et al.(2009a; 2009b)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA</td>
<td>Lempa</td>
<td>Runoff</td>
<td>Statistically significant reduction in the order of 13% (B1) and 24% (A2).</td>
<td>2000-2100 (results presented for 2070-2100) CMIP3 A2, B1 Maurer et al. (2009)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td>Component</td>
<td>Change</td>
<td>Time Period</td>
<td>Model</td>
<td>Scenario</td>
<td>Authors</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
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<td></td>
</tr>
<tr>
<td>Grande de Matagalpa</td>
<td>Runoff</td>
<td>-70%</td>
<td>2050s</td>
<td>HadCM3</td>
<td>A2</td>
<td>Palmer <em>et al.</em> (2008)</td>
<td></td>
</tr>
<tr>
<td>Mesoamerica (6.5-22 N and 76.5-99 W)</td>
<td>Runoff</td>
<td>Decrease across the region (different magnitudes and uncertainty associated) even in areas where precipitation increases</td>
<td>2070-2100</td>
<td>CMIP3</td>
<td>A2, A1b, B1</td>
<td>Imbach <em>et al.</em> (2012)</td>
<td></td>
</tr>
</tbody>
</table>
### Table 27-5: Impacts on agriculture.

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Activity</th>
<th>Time slice</th>
<th>SRES</th>
<th>CO₂</th>
<th>Changes</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uruguay</strong></td>
<td>Annual crops</td>
<td>2030/2050/2070/2100</td>
<td>A2</td>
<td>+185/-194/-284/-508</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(SESA)</td>
<td></td>
<td>2030/2050/2070/2100</td>
<td>B2</td>
<td>+92/169</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Livestock</td>
<td>2030/2050/2070/2100</td>
<td>A2</td>
<td>+174/-80/-160/-287</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2030/2050/2070/2100</td>
<td>B2</td>
<td>+136/182</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Forestry</td>
<td>2030/2050/2070/2100</td>
<td>A2</td>
<td>+15/39/52/19</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2030/2050/2070/2100</td>
<td>B2</td>
<td>+6/+13/18</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Paraguay</strong></td>
<td>Cassava</td>
<td>2020/2050/2080</td>
<td>A2</td>
<td>+16/+22/+22</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(SESA)</td>
<td>Wheat</td>
<td>2020/2050/2080</td>
<td>A2</td>
<td>+4/-9/-13</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>2020/2050/2080</td>
<td>A2</td>
<td>-1/+1/5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soybean</td>
<td>2020/2050/2080</td>
<td>A2</td>
<td>+3/+3/+8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bean</td>
<td>2020/2050/2080</td>
<td>A2</td>
<td>+3/+1/6 A2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Argentina</strong></td>
<td>Maize</td>
<td>2080</td>
<td>A2/B2</td>
<td>-24/-15</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(SESA)</td>
<td>Soybean</td>
<td>2080</td>
<td>A2/B2</td>
<td>+1/0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>2080</td>
<td>A2/B2</td>
<td>-25/-14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soybean</td>
<td>2080</td>
<td>A2/B2</td>
<td>+14/+19</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>2080</td>
<td>A2/B2</td>
<td>-16/-11</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>Rice</td>
<td>2050-2080</td>
<td>A2/B2</td>
<td>+24/+42/+48</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(SESA)</td>
<td></td>
<td>2050-2050-2080</td>
<td>A2/B2</td>
<td>+14/+30/+33</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>2050-2050-2080</td>
<td>A2/B2</td>
<td>+8/+11/+16</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brazi</strong> Sao Pab**</td>
<td>Sugarcane</td>
<td>2040</td>
<td>N</td>
<td>-21%</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(SESA)</td>
<td></td>
<td>2040</td>
<td>Y</td>
<td>+60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td>2050-2080</td>
<td>Y</td>
<td>+30</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2050-2050-2080</td>
<td>N</td>
<td>Up to -30%</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>2050-2050-2080</td>
<td>Y</td>
<td>Up to 45/+75/+90</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>2050-2080</td>
<td>Y</td>
<td>Up to 30%</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2050-2050-2080</td>
<td>N</td>
<td>Near to -15%</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2050-2050-2080</td>
<td>Y</td>
<td>Up to 40/+60/+90</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td><strong>Central America</strong></td>
<td>Arabica coffee</td>
<td>0 to +1°C</td>
<td>Y</td>
<td>+1.5%</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td>(CA)</td>
<td></td>
<td>+1 to +2°C</td>
<td>Y</td>
<td>+15.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+2 to +3°C</td>
<td>Y</td>
<td>+28.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+3 to +4°C</td>
<td>Y</td>
<td>-12.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panamá</strong></td>
<td>Maize</td>
<td>2030</td>
<td>Y</td>
<td>-14 to +2</td>
<td>ECLAC (2010d)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rice</td>
<td>2030</td>
<td>N</td>
<td>-14 to +2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>2030</td>
<td>N</td>
<td>-1 to -8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Crop(s)</td>
<td>Year</td>
<td>Scenario</td>
<td>CO2 Effect</td>
<td>Climate Risk</td>
<td>Reference</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>Colombia</td>
<td>Maize</td>
<td>2050</td>
<td>17GCM-A2</td>
<td>N</td>
<td>0 to -5</td>
<td>Ramirez et al. (2012)</td>
</tr>
<tr>
<td></td>
<td>Maize</td>
<td>2050</td>
<td>17GCM-A2</td>
<td>N</td>
<td>0 to -14</td>
<td>Ramirez et al. (2012)</td>
</tr>
<tr>
<td>Chile</td>
<td>Maize</td>
<td>2050</td>
<td>A1FI</td>
<td>Y</td>
<td>-5% to -10%</td>
<td>Meza and Silva (2009)</td>
</tr>
<tr>
<td></td>
<td>Wheat</td>
<td>2050</td>
<td>A1FI</td>
<td>Y</td>
<td>-10% to -20%</td>
<td>Meza and Silva (2009)</td>
</tr>
</tbody>
</table>

N: Without considering CO2 biological effects; Y: Considering CO2 biological effects

(*1) Huge spatial variability, the values are approximated

(*2) Changes in the percentage of areas with low climate risk
Table 27-6: Comparison of consumption of different energetics in Latin America and the world (in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis).

<table>
<thead>
<tr>
<th>Energy resource</th>
<th>LATAM</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TFC (non electricity)</td>
<td>TFC (via electricity generation)</td>
</tr>
<tr>
<td>Fossil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal and Peat</td>
<td>9,008</td>
<td>1,398</td>
</tr>
<tr>
<td>Oil</td>
<td>189,313</td>
<td>8,685</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>59,44</td>
<td>9,423</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
<td>1,449</td>
</tr>
<tr>
<td>Renewable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofuels and waste</td>
<td>82,997</td>
<td>2,179</td>
</tr>
<tr>
<td>Hydro</td>
<td>0</td>
<td>45,92</td>
</tr>
<tr>
<td>Geothermal, solar, wind, other renewable</td>
<td>408</td>
<td>364</td>
</tr>
<tr>
<td>TOTAL</td>
<td>341,166</td>
<td>69,418</td>
</tr>
</tbody>
</table>

* TFC: Total final consumption
Source: IEA, 2012
Table 27-7: Overview on local, regional, national and international adaptation programs, projects and initiatives relevant for the region.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Name of Project/ Case Study/ Business Case</th>
<th>Specification of Approach/ Strategy/ Adaptation Area</th>
<th>Platform- NWP (PSI;LCS;EbA;AP)/ weAdapt</th>
<th>Details on platform specification*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Adaptation strategies for the Jujuy model forest in NW Argentina</td>
<td>Adaptation efforts in a forest model in Argentina</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Belize</td>
<td>Adapting to climate change in the Mesoamerican Reef</td>
<td>Assessment of vulnerability; Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Marine and coastal (WWF)</td>
</tr>
<tr>
<td>Belize</td>
<td>Ecosystems, Development and Climate Adaptation: Improving the base for policies, planning and management</td>
<td>Mainstreaming EbA in Belize</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Qhuthañas in Bolivia Collecting and storing rainwater in small dams (qhuthañas)</td>
<td>Rainwater harvesting</td>
<td>NWP- LCS</td>
<td>Hazards: Drought, aridity/ Impacts: Loss of crops; Water shortage</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Enhancing adaptive capacity in semi-arid mountainous regions, Bolivia</td>
<td>Assessment of vulnerability; Improvement in capacity design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Mountain; Forest and woodland (The Netherlands Climate Assistance Programme (NCAP))</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Building Capacity in Vulnerable Mountain Regions</td>
<td>Water Scarcity in Mountain Regions</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Climate Change Adaptation in Practice; Rescuing the Past: Using Indigenous Knowledge to Adapt to Climate Change in Bolivia</td>
<td>Using Indigenous Knowledge to Adapt to Climate Change in Bolivia</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Understanding Adaptation and Mitigation Strategies of Andean People - Bolivia</td>
<td>INCA- Bolivia</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Adaptation strategies for the Chiquitano tropical dry forest in Eastern Bolivia</td>
<td>Adaptation efforts in the tropical dry forest of Bolivia</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Bolivia</td>
<td>Ecosystem-based strategies and innovations in water governance networks for adaptation to climate change in Latin American Landscapes</td>
<td>EcoAdapt</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Brazil</td>
<td>New technologies for climate change adaptation</td>
<td>Food security, agriculture, forestry and fisheries</td>
<td>NWP- PSI</td>
<td>Chemicals (BASF)</td>
</tr>
<tr>
<td>Brazil</td>
<td>Insuring against climate impacts and rewarding sustainable business practices</td>
<td>Business</td>
<td>NWP- PSI</td>
<td>Financial Services (Allianz)</td>
</tr>
<tr>
<td>Brazil</td>
<td>Disaster preparedness, local capacity building, and planning</td>
<td>Science, assessment, monitoring and early warning; Education and training</td>
<td>NWP- PSI</td>
<td>Consulting and Environmental Services (Riverside Technology)</td>
</tr>
<tr>
<td>Country</td>
<td>Project Title</td>
<td>Sector/Industry</td>
<td>Institution/Project</td>
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</tr>
<tr>
<td>---------</td>
<td>-------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>New insurance products and climate risk</td>
<td>Business; Transport, infrastructure and human settlements</td>
<td>Financial Services (HSBC)</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Community Reforestation in Rio de Janeiro, Brazil; Preventing soil erosion and landslides</td>
<td>Soil conservation; Natural resource management</td>
<td>NWP- LCS</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Babassu Palms in Brazil Harvesting the fruits for oil and protein</td>
<td>Diet diversification</td>
<td>NWP- LCS</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Tires walls in Rio de Janeiro, Brazil Building retaining walls from crape tires</td>
<td>Soil conservation</td>
<td>NWP- LCS</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Rio de Janeiro's Community Reforestation Project</td>
<td>Improvement in capacity; design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Ecosystem-Based Adaptation in Marine, Terrestrial and Coastal Regions as a Means of Improving Livelihoods and Conserving Biodiversity in the Face of Climate Change</td>
<td>Improvement in capacity; design and policy measures; Implementation of EBA measures</td>
<td>Marine and coastal; forest and woodland; agriculture; inland water (Federal Environment Ministry of Germany, Conservation International Foundation)</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Adaptive management of pirarucu (Arapaima gigas)</td>
<td>Adaptive management</td>
<td>weAdapt</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>Promotion of drought resistant native fruits</td>
<td>Resistance to droughts</td>
<td>weAdapt</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>SMCE/NAIADE: Evaluating the effects of the Alumysa Project in the Aysen Region in Chile</td>
<td>Adaptation tools, case study SMCE/NAIADE</td>
<td>weAdapt</td>
<td></td>
</tr>
<tr>
<td>Chile</td>
<td>Adaptation strategies for the Alto Malleco model forest in Chile</td>
<td>Adaptation efforts in a forest model in Chile</td>
<td>weAdapt</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>Adaptation program to support ecosystem services</td>
<td>Water resources</td>
<td>NWP- PSI</td>
<td></td>
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<tr>
<td>Colombia</td>
<td>Integrated National Adaptation Plan - Colombia highland ecosystems</td>
<td>Assessment of vulnerability; Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>Mountain; Inland Water (GEF; World Bank; Conservation International)</td>
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<tr>
<td>Colombia</td>
<td>Orito Ingi Ande Medicinal Plants Sanctuary</td>
<td>Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
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<tr>
<td>Colombia</td>
<td>Implementing Climate Adaptation Strategies in the World's Most Outstanding Natural Places</td>
<td>Delivering Adaptation</td>
<td>weAdapt</td>
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<tr>
<td>Colombia</td>
<td>Building Capacity in the Colombian coastal area</td>
<td>Integrated Coastal Management for Adaptation</td>
<td>weAdapt</td>
<td></td>
</tr>
<tr>
<td>Country, Region</td>
<td>Project Description</td>
<td>Approach Area</td>
<td>Type of Adaptation</td>
<td>Hazard/Impact</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------</td>
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<tr>
<td>Colombia, El Salvador, Nicaragua</td>
<td>Integrating Climate Change Risks and Opportunities into National Development Processes and United Nations Country Programming (UNDP)</td>
<td>not specified</td>
<td>NWP- AP</td>
<td>Academic, Governmental, Intergovernmental</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>Flood preparedness in Costa Rica Implementing a community training programme</td>
<td>Disaster risk management</td>
<td>NWP- LCS</td>
<td>Hazard: Floods/ Impact: Damage to human settlements</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>Hurricane-resistant housing in Costa Rica Constructing low-cost reinforced bamboo houses</td>
<td>Improved housing design</td>
<td>NWP- LCS</td>
<td>Hazard: Storms/ Impact: Damage to human settlements</td>
</tr>
<tr>
<td>Ecuador</td>
<td>Providing farming training and assistance</td>
<td>Education and training; Food security, agriculture, forestry and fisheries; Water resources</td>
<td>NWP- PSI</td>
<td>Food and Beverages (Nestlé)</td>
</tr>
<tr>
<td>Ecuador</td>
<td>Flood-Resistant Housing in Ecuador Constructing elevated bamboo houses</td>
<td>Improved housing design</td>
<td>NWP- LCS</td>
<td>Hazard: Floods/ Impact: Damage to human settlements</td>
</tr>
<tr>
<td>Ecuador and Peru</td>
<td>The CEIBA-PILARES project</td>
<td>Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Forest and woodland (Nature and Culture International)</td>
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<tr>
<td>El Salvador</td>
<td>Vulnerability and Capacity Analysis of Communities Amando López and Octavio Ortiz in the Lower Lempa Valley</td>
<td>Vulnerability and Capacity Analysis of Communities in El Salvador</td>
<td>weAdapt</td>
<td>n.a.</td>
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<td>El Salvador, Costa Rica, Panama</td>
<td>Climate Change Governance Capacity: Building Regionally and Nationally Tailored Ecosystem-Based Adaptation in Mesoamerica</td>
<td>Assessment of vulnerability; Improvement in capacity design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Marine and coastal; Agriculture; Inland waters (Federal Environment Ministry of Germany, International Union for Conservation of Nature)</td>
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<td>El Salvador; Guatemala; Nicaragua</td>
<td>Coffee Under Pressure: Climate Change and Adaptation in Mesoamerica (CUP)</td>
<td>Food security, agriculture, forestry and fisheries</td>
<td>NWP- PSI</td>
<td>Food and Beverages; Agriculture (Green Mountain Coffee Roasters (GMCR); International Center for Tropical Agriculture (CIAT); Catholic Relief Services (CRS))</td>
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<td>El Salvador</td>
<td>Drought-resistant agriculture in El-Salvador</td>
<td>Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Agriculture (Red Cross; World Food Programme)</td>
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<tr>
<td>Guatemala</td>
<td>Finding Points of Engagement to Integrate Climate Change Adaptation into Water Management Planning</td>
<td>Integrating Climate Adaptation into National Policy (NCAP)</td>
<td>weAdapt</td>
<td>n.a.</td>
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<tr>
<td>Guyana</td>
<td>Participatory school and community-based disaster preparedness</td>
<td>Community-based disaster preparedness</td>
<td>weAdapt</td>
<td>n.a.</td>
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<tr>
<td>Honduras</td>
<td>FORCC: Using forests to enhance resilience to climate change</td>
<td>FORCC Honduras</td>
<td>weAdapt</td>
<td>n.a.</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>Reduction of risks and vulnerability from floods and droughts in the Estero Real</td>
<td>Adaptation fund: reducing floods and droughts</td>
<td>weAdapt</td>
<td>n.a.</td>
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<tr>
<td>watershed</td>
<td>Improvement in capacity, design and policy measures; Implementation of EBA measures</td>
<td>NWP- EbA</td>
<td>Forest and woodland; Agriculture (Maya Nut Institute)</td>
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<td>Nicaragua, Guatemala, El Salvador</td>
<td>Using the Maya Nut Tree to increase tropical agroecosystem resilience to climate change in Central America and Mexico</td>
<td>NWP- PSI</td>
<td>Food and Beverages (Cafédirect; GIZ)</td>
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<td>Peru</td>
<td>Adaptation for Smallholders to Climate Change (AdapCC)</td>
<td>NWP- LCS</td>
<td>Hazards: Drought, aridity; Floods/ Impact: Loss of crops</td>
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<tr>
<td>Peru</td>
<td>Waru Waru in Peru; Utilizing an ancient irrigation and drainage system</td>
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<td>Peru</td>
<td>Understanding Adaptation and Mitigation Strategies of Andean People - Peru</td>
<td>INCA- Peru</td>
<td>weAdapt n.a.</td>
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<td>Peru</td>
<td>Response to impacts of glacial retreats</td>
<td>Response to impacts of glacial retreats</td>
<td>weAdapt</td>
<td>n.a.</td>
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<td>Suriname</td>
<td>Sustainable Livelihoods in the Coastal Zone of Suriname</td>
<td>Local Adaptation in Coasts</td>
<td>weAdapt n.a.</td>
<td></td>
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<tr>
<td>Central America</td>
<td>Hurricane guarantees and waivers</td>
<td>Tourism</td>
<td>Tourism and Recreation (Apple Vacations; Club Med; Sandals; SuperClubs; TNT Vacations)</td>
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<tr>
<td>Multiple</td>
<td>Provision of solar energy builds resilience of rural population</td>
<td>Renewable energy systems</td>
<td>NWP- PSI</td>
<td>Energy and Utilities (HiNation AB)</td>
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<tr>
<td>Multiple</td>
<td>SkyHydrant Water Purification Technology</td>
<td>Water resources</td>
<td>NWP- PSI</td>
<td>Science and Technology (Siemens)</td>
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<tr>
<td>Multiple</td>
<td>Adapting to Climate Changes for Potato Production in The Andes</td>
<td>Water resources</td>
<td>NWP- PSI</td>
<td>Food and Beverages (PepsiCo South America, Caribbean and Central America Foods)</td>
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<tr>
<td>Multiple</td>
<td>Product solutions for a future of more constrained resources</td>
<td>Water resources</td>
<td>NWP- PSI</td>
<td>Consumer Packaged Goods (Unilever)</td>
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<tr>
<td>Multiple</td>
<td>Boosting crop yield for every drop of water</td>
<td>Capacity building, education and training; Finance and insurance; Food, agriculture, forestry and fisheries; Technology and Information &amp;Communications Technology (ICT); Water resources</td>
<td>NWP- PSI</td>
<td>Agriculture (Syngenta)</td>
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<tr>
<td>Multiple</td>
<td>The Latin American Water Funds Partnership</td>
<td>Capacity building, education and training; Finance and insurance; Science, assessment, monitoring and early warning; Water resources</td>
<td>NWP- PSI</td>
<td>Food and Beverages (Femsa Foundation)</td>
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<tr>
<td>not specified</td>
<td>Partners for Resilience</td>
<td>Capacity building; Communication and awareness raising; Knowledge management</td>
<td>NWP- AP</td>
<td>Non-Governmental</td>
</tr>
<tr>
<td>not specified</td>
<td>Assessment of Impacts and Adaptations to Climate Change in Multiple Regions and Sectors (AICCC)</td>
<td>Education; communication and awareness raising; financial support</td>
<td>NWP- AP</td>
<td>Intergovernmental</td>
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<td>not specified</td>
<td>BASIC project</td>
<td>Education; communication and awareness raising; knowledge management</td>
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<td>Academic</td>
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<td>not specified</td>
<td>Iberoamerican Network of Climate Change Bureaus (RIOCC)</td>
<td>Knowledge management, education; training</td>
<td>NWP- AP</td>
<td>Intergovernmental</td>
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<tr>
<td>not specified</td>
<td>Inter-American Development Bank Activities (IDB)</td>
<td>Financial support</td>
<td>NWP- AP</td>
<td>Intergovernmental</td>
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<td>not specified</td>
<td>Oficina de Riesgo Agropecuario (ORA) - República Argentina Activities</td>
<td>Education</td>
<td>NWP- AP</td>
<td>Governmental</td>
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<td>not specified</td>
<td>Practical Action Activities</td>
<td>Pilot adaptation programmes/projects</td>
<td>NWP- AP</td>
<td>Non-Governmental</td>
</tr>
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<td>not specified</td>
<td>ProVentium Consortium Activities</td>
<td>Education, training; knowledge management</td>
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<td>Non-Governmental</td>
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<td>The Netherlands Climate Assistance Programme</td>
<td>Communication and awareness raising; training; education</td>
<td>NWP- AP</td>
<td>Non-Governmental</td>
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<tr>
<td>not specified</td>
<td>Water Center for the Humid Tropics of Latin America and the Caribbean Activities (CATHALAC)</td>
<td>Communication and awareness raising; training; education</td>
<td>NWP- AP</td>
<td>Academic</td>
</tr>
</tbody>
</table>

* Details are provided for NWP platforms and comprehend for PSI, business sector/ company; for LCS, hazard/impact; for EbA, ES/ implementing institution; and for AP, the type of organization (see also NWP interface, UNFCCC, 2012xx).

Source: Authors based on UNFCCC (2012b) and weAdapt (2012)
Table 27-8: Cases of government-funded PES schemes in CA and SA.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Level</th>
<th>Start</th>
<th>Name</th>
<th>Benefits</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costa Rica</td>
<td>National</td>
<td>1997</td>
<td>FONAFIFO fund</td>
<td>PES is a strong incentive for reforestation and, for agroforestry ecosystems alone, over 7,000 contracts have been set since 2003, and nearly 2 million trees were planted.</td>
<td>Montagnini and Finney (2011)</td>
</tr>
<tr>
<td>Ecuador</td>
<td>National</td>
<td>2008</td>
<td><em>Socio-Bosque</em></td>
<td>By 2010, the program already included more than half a million hectares of natural ecosystems protected and has over 60,000 beneficiaries.</td>
<td>De Koning <em>et al.</em> (2011)</td>
</tr>
<tr>
<td>Guatemala</td>
<td>National</td>
<td>1997</td>
<td>Programa de Incentivos Forestales, PINFOR</td>
<td>By 2009, the program included 4,174 beneficiaries who planted 94,151 hectares of forest. In addition, 155,790 hectares of natural forest were under protection with monetary incentives.</td>
<td>Instituto Nacional de Estadística (2011)</td>
</tr>
</tbody>
</table>
Figure 27-1: Observed and simulated variations in past and projected future annual average temperature over land areas of the Central and South American "SREX regions". Black lines show several estimates from observational measurements. Shading denotes the 5-95 percentile range of climate model simulations driven with "historical" changes in anthropogenic and natural drivers (68 simulations), historical changes in "natural" drivers only (30), the "RCP4.5" emissions scenario (68), and the "RCP8.5" (68). Data are anomalies from the 1986-2006 average of the individual observational data (for the observational time series) or of the corresponding historical all-forcing simulations. Further details are given in Box 21-3.
Figure 27-2: Area deforested per year for selected countries in CA and SA (2005-2010). Notice three countries listed with a positive change in forest cover (based on data from FAO, 2010).

Figure 27-3: Deforestation rates in the Brazilian Amazonia (km²/year) based on measurements by the PRODES INPE project (see also INPE, 2011).
Figure 27-4: Evolution of GDP per capita and poverty from 1990-2011: CA and SA (US-Dollars per inhabitant at 2005 prices and percentages) (ECLAC on the basis of CEPALSTAT (2012) and ECLAC (2011))

Figure 27-5: Current and predicted coastal impacts and coastal dynamics in response to climate change (elaborated by Iñigo Losada, ECLAC)
Figure 27-6: Soy teleconnections and major effects in SA. Economic growth giant consumers as China pressurize the soy production system in SA, increasing the production of biodiesel, but demanding more energy in general. (partly based on Nepstad and Stickler (2008), and Tomei and Upham (2009))
Figure 27-7: Summary of observed changes in climate and other environmental factors in representative regions of CA and SA. The boundaries of the regions in the map are conceptual (not precise geographic nor political) and follow those developed in Figure 3-1 of the IPCC SREX (IPCC, 2012). Information and references to changes provided are presented in different sections of the chapter.
Figure 27-8: Observed impacts of climate variations and attribution of causes in CA and SA.