IPCC AR5 WORKING GROUP 2

A Regional Breakdown

INTRODUCTION

This report summarizes the impacts of climate change already being observed, as well as projected climate change impacts from Working Group 2 of the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC). It covers 7 regions across the globe: Africa, Asia, Australia & New Zealand, Europe, North America, Small Islands, and South America. Each regional chapter guides the reader through climate impacts in several categories, such as water availability and public health. Each category starts with a short summary and is followed by more detailed information in bullet points.

This report is composed from information synthesized from the widely available, but not finalized, drafts of the second working group's contribution to the IPCC's fifth assessment report. A final version of the IPCC AR5 WGII report will only be available on March 31 after the Summary for Policy Makers (SPM) is negotiated by government delegates in Yokohama on March 25-29, 2014.

The information in this report has largely been taken from the underlying chapters, which are not expected to change substantially following the SPM negotiations. It has been supplemented with some additional text to further clarify what the implications of the findings might be. It is our intent that this information be used for non-commercial purposes and that the IPCC be acknowledged when appropriate.

AFRICA[1]

AGRICULTURE AND FOOD SECURITY

Climate change has and will continue to increase the vulnerability of agricultural systems throughout Africa, but particularly in the semi-arid regions. Warming temperatures and a shorter wet season could lead to a reduction in cereal crop productivity, which would have strong negative effects on food security. There could also be a shift from mixed crop-livestock to more livestock production because of longer droughts. This would result in a decrease in crop production, putting millions of additional people at risk of food insecurity. Regions where this could occur include West African Sahel, coastal and mid-altitudes areas in eastern and southeastern Africa, which currently support 35 million people and are already chronically food insecure. Climate change is also expected to compound existing environmental and socio-economic drivers, such as land use change, increased damage from agricultural pests, weeds and diseases. This would make it even more difficult to feed the continents' growing population. Fisheries, a major source of protein for many countries, are also closely linked with climate change and are projected to be negatively impacted, especially in West Africa.

Crops

- Overall, climate change will likely have a negative effect on the yield of major cereal crops across Africa, with strong regional variability in the degree of yield reduction.
- Sub-Saharan Africa is predicted to experience decreases of 19% for maize yields, 68% decrease for bean yields and a small increase for fodder grass with a 5 degrees C warming.
- Potential increase in maize production at sites above roughly 1,700 m in elevation in eastern Africa.
- Decreased crop yields of 18% for southern Africa to 22% across sub-Saharan Africa, in excess of 30% for South Africa and Zimbabwe by mid-Century.
- Decrease crop yield of 35% of wheat by mid-century for all regions south of the Sahara and increasingly high vulnerability of wheat production in North Africa.
- Cassava yields in eastern Africa are estimated to moderately increase up to the 2030s but may decline after 2050, however, given cassava's hardiness to climatic extremes relative to many cereal crops, it may be a potential option for crop substitution of cereals as an adaptive response to climate change.
- Reduced bean yields in Eastern Africa are projected by the 2030s.
- Banana and plantain production could decline in West Africa and lowland areas of East Africa, whereas it could increase with temperature rise in highland areas of East Africa.

Livestock

- Drought threatens the loss of livestock and is a critical risk given the extensive rangeland in Africa, especially in regions that are projected to become drier with climate change, such as northern and southern Africa.
- Drought induced water supply issues will also be exacerbated by climate change and would adversely affect livestock populations – for example, the cost of supplying water for cattle from boreholes is projected to increase 23% by 2050 in Botswana.
- Increased water scarcity during dry periods would also decrease the availability of maize feed for cattle in East Africa.

1 Most of the information contained within this brief is directly from IPCC 2014 Working Group 2. In some situations further text that explains the implications has been added to clarify the expected impacts.

- Higher temperatures may reduce stocking of dairy cows and cause a shift from cattle to sheep and goats in lowland areas of Africa – for example, decreased dairy yields of 10-25% are projected in South Africa by 2050.
- Higher temperatures may benefit some livestock farming at higher elevations in East Africa, however, this potential benefit would only last for a limited amount of time as temperatures continue to warm.

Agricultural Pests, Diseases, and Weeds

- Warming in highland regions of eastern Africa could lead to range expansion of crop pests into cold-limited areas – for example, in highland Arabica coffee-producing areas of eastern Africa warming trends may result in the coffee berry borer becoming a serious threat in coffee growing regions of Ethiopia, Kenya, Uganda, Rwanda, and Burundi.
- Increasing temperatures could expand the suitable range of Black Leaf Streak disease of bananas in Angola and Guinea by 2020 and a highly destructive burrowing nematode (*Radopholus similis*) in highland areas of eastern Africa.
- Vector-borne diseases of livestock such as African horse sickness and bluetongue may expand their ranges due to rising temperatures.
- Climate change could lead to an expansion in the distribution of the main tick vector species (*Rhipicephalus appendiculatus*) of East Coast fever disease in cattle, especially in East Africa and South Africa.
- Changes in temperature, rainfall, and seasonality will result in more suitable habitats for striga weed (*Striga hermonthica*), a major cause of cereal yield reduction in central Africa by 2020, but the Sahel region may become less suitable for striga.
- Decreases in the suitable range of major cassava pests – whitefly, cassava brown streak virus, cassava mosaic geminivirus, and cassava mealybug are projected, but with increased suitability in southeast Africa and Madagascar.

Fisheries

- Fisheries are an important source of food security in Africa and contribute over one-third of Africa's total animal protein. Intake and demand are expected to increase substantially over the next few decades. Fisheries, like many natural resources, are tightly linked to changes in climate, with warming water temperatures and drought associated with declining fishery yields.
- Climate change is expected to negatively impact many fisheries throughout Africa from marine to inland fisheries, with some of the most vulnerable countries being Angola, DR Congo, Mauritania and Senegal.
- All coastal countries of West Africa will likely experience significant negative impacts to fisheries with the annual landed value of fish estimated to decline by 21%, resulting in a nearly 50% decline in fisheries-related employment and a total annual loss of US$ 311 million to the region's economy.

HEALTH

Climate change will worsen the incidence of some important health issues in Africa, such as malnutrition, diarrheal diseases, and vector-borne diseases, such as malaria, affecting women and children the most. Warming temperatures and changing precipitation patterns will also affect the geographic range of many of these health issues, spreading into new areas and potentially disappearing in other areas. Cholera, which is primarily associated with poor sanitation, poor governance, and poverty, is projected to worsen in areas of Africa that are expected to get warmer and wetter. Although deaths associated with malaria have continued to slowly decline since 2004 across the continent, data is lacking to assess trends in disease incidence in most affected countries in Africa. Poor populations and rural areas are most vulnerable to climate-induced health issues, and factors that increase vulnerability include inadequate or no mosquito protection and limited access to health care facilities offering effective diagnostic testing and treatment. Regions of Africa with little financial resources, inadequate public health and health care systems, insufficient access to safe water and sanitation, food insecurity, and poor governance will be most affected by climate-induced health issues. Sub-Saharan Africa is particularly vulnerable to climate change's effects on nutrition - 26.8% of the region's population was already undernourished in 2010-2012, a number that climate change will likely increase.

Diseases

- Climate change will undoubtedly increase the incidence of heat-related deaths, with vulnerable populations (i.e., children) most at risk, especially in West and southern Africa. A link between increased mortality and high temperatures has already been identified in Ghana and Burkina Faso.
- Warming temperatures will likely cause some temperate regions, such as mountainous areas of East Africa and Madagascar to become more suitable for tropical vector-borne diseases, such as Rift Valley fever and malaria.
- Cholera outbreaks are likely to increase in frequency and duration, due to heavy rainfall events in coastal West African countries such as Ghana and Senegal, and possibly in other areas (e.g., Zanzibar, Tanzania, Zambia, Zimbabwe, and South Africa).
- Increased precipitation will likely expand the range of diseases, such as schistosomiasis but water resource development (i.e., irrigation dams), which is recommended for adaptation in agriculture, can further amplify the risk as already shown in some places (e.g., Ghana).
- Outbreaks of Rift Valley fever in East Africa are projected to increase in response to increased rainfall and flooding in the region.
- Malaria is greatly impacted by temperature and precipitation and its geographic range and incidence will be affected by climate change – for instance, it is projected that malaria will move into East African highland areas due to warming temperatures.
- Leishmaniasis is a highly neglected disease that has recently become a significant health problem and a rising concern because of co-infection with HIV. Warming temperatures and rainfall may increase leishmaniasis, which is already an endemic disease in northern Africa (e.g., Algeria, Morocco, and Tunisia) and could worsen in West and East Africa.
- Prolonged droughts will likely worsen other health diseases, such as meningococcal meningitis, which is strongly related with the length of the dry season, especially in already dry areas.
- Climate change may shrink the geographic range of the tsetse fly (*Glossina* species), the vector of human and animal trypanosomiasis in Africa.

Nutrition

- Climate change threatens crop productivity in areas that are already food insecure and could lead to declining nutrition across Africa but especially in countries that are more dependent on rain-fed agriculture, such as Kenya.
- The combination of climate change and socio-economic factors is projected to increase the number of under-nourished children under the age of 5 to 52 million by 2050.
- In Mali, nearly 6 million people may experience under-nutrition due to changes in climate, livelihood and demography and three-quarter to one million of this number will be children under five. Further, projections to 2025 suggest approximately 250,000 more children will suffer stunting, nearly 200,000 more will be malnourished, and over 100,000 more will become anemic, assuming constant disease incidence rates.
- Severe child stunting (leading to higher mortality risk) is projected to increase by 31 to 55% across sub-Saharan Africa due to climate change by 2050 without accelerated investment in planned adaptations and could counteract the beneficial consequences of socio-economic development .
- Of the 3.6 million annual childhood deaths in Africa, 11% are due to diarrheal diseases, which could increase due to warming temperatures across the continent.
- Increased food insecurity due to climate change can also lead to increased incidence of malnutrition, affecting the poor and vulnerable the most.

URBANIZATION

African countries are experiencing some of the world's highest urbanization rates and the urban populations in Africa are projected to triple by 2050, increasing by 0.8 billion. As a consequence, many of Africa's evolving cities are growing without planning and therefore have inadequate housing, lack basic services, and have high rates of urban poverty. Climate change will likely compound these issues by driving additional rural-urban migration and further stresses on food and water resources. Large urban centers located on mega-deltas (e.g., Alexandria in Egypt in the Nile delta, and Benin City, Port Harcourt, and Aba in Nigeria in the Niger delta), will also likely experience greater numbers of people vulnerable to coastal climate change impacts. Regions that are projected to experience increased rain during the wet season will likely experience more frequent and severe flooding, and the most expensive damage could occur in urban areas. More than a quarter of Africa's population lives within 100 km of the coast and more than half of Africa's total population living in low-elevation coastal zones is urban, accounting for 11.5% of the total urban population of the continent. Consequently, sea level rise along coastal zones including coastal settlements could disrupt economic activities such as tourism and fishing.

- Climate-induced extreme flooding will likely impact urban areas, as evidence by major flooding events in 2002 and 2006 which forced tens of thousands to leave their homes in Rwanda, Kenya, Burundi, Tanzania, Nigeria, Uganda and Ethiopia.
- Mega-deltas (e.g., Alexandria in Egypt in the Nile delta, and Benin City, Port Harcourt, and Aba in Nigeria in the Niger delta) are projected to experience significant sea-level rise, coastal flooding, larger storm surges, and increased saltwater intrusion.
- Coastal flooding is expected to impact 10,000 to 86,000 people in Kenya alone, with associated economic costs ranging between US$ 7 million to US$ 58 million by 2030.
- Extreme flooding could cost Mombasa US$ 0.68 billion to 1.06 billion and Dar-es-Salaam US$ 35.6 million to US$ 404.1 million in economic loses by 2030.

- Economic impacts of housing and roads due to sea-level rise in the Nile Delta would range between US$ 143 and US$ 287 million in 2030 and upwards of US$ 2.3 billion in 2060.
- Climate change is expected to further stress the limited services provided by small and medium-sized African cities and could lead to more human migration and poverty.

ECOSYSTEMS

Both the direct and indirect effects of climate change will likely compound existing environmental stressors, such as deforestation, forest degradation, land-use change, and pollution and will further degrade terrestrial, freshwater, and coastal ecosystems throughout Africa. For terrestrial ecosystems, it has been observed that deserts have expanded and that vegetated areas have contracted. Further, natural vegetation is declining and humans are increasingly influencing existing vegetated areas through agriculture, livestock grazing, and fuel-wood harvesting. Overall, woody vegetation is decreasing in western Africa and increasing in central, eastern, and southern Africa.

Similar to terrestrial systems, freshwater ecosystems in Africa are also at risk from the compounding effects of climate change, land use change, and increased pollution in addition to over-extraction of water and diversions from rivers and lakes. Climate change has also caused water temperatures to warm as evidenced in lakes such as Kariba, Kivu, Tanganyika, Victoria, and Malawi. These and other environmental changes will likely continue to degrade water quality and adversely affect fisheries throughout Africa.

Coastal and ocean systems are important for the economies and livelihoods of African countries, and climate change will increase challenges from existing stressors, such as overexploitation of resources, habitat degradation, loss of biodiversity, salinization, pollution, and coastal erosion. Coastal systems will experience impacts through sea level rise, increased storm surges, flooding, and ocean acidification. These impacts will affect human lives, livelihoods, food security, property, and economic well-being.

Water Resources

- Climate-induced longer and more frequent droughts will continue to challenge existing water resources especially in southern and western Africa.
- Projected declines in precipitation, particularly during the growing season, will negatively affect rain-fed agriculture in northern Africa and southern Africa.
- All countries within the Zambezi River Basin could contend with increasing water shortages due, in part, to climate change.
- Climate change-induced water shortages will adversely affect people and ecosystems, for example, downstream users that are dependent on the Rozva dam in Zimbabwe.
- Climate change is expected to cause water shortages for the Okavango Delta and the Breede River in South Africa.
- Warmer temperatures and declining rainfall will continue to reduce water resources in Tunisia.
- The combination of warming and declining precipitation will further reduce snowpack in the Atlas Mountains and will lead to more rapid springtime melting. This pattern will reduce supplies of seasonal melt-water for lowland areas of Morocco.
- Warmer temperatures, less precipitation, and increased upstream water development for irrigation and hydropower will reduce water flow in the Nile Basin.

- More intense and frequent heavy rainfalls events will likely lead to flooding and soil erosion, particularly in tropical Africa.
- Climate change is expected to increase flows in the Mara, Nyando, and Tana rivers in Eastern Africa, which could lead to increased flooding, loss of life, and increased damages.
- Decreased rainfall during the dry season would reduce river flows in the Bani River Basin, Mali.
- Climate change is expected to significantly reduce groundwater recharge in already dry locations, such as the Sahel, the Horn of Africa, and southern Africa.

Coastal & Ocean Systems

- Higher sea levels combined with storm swells will lead to increased coastal damage as observed in Durban in March 2007, when storm surge damages were estimated at US$ 100 million.
- Coastal aquifers are additionally vulnerable to climate change because of high rates of groundwater extraction and sea-level rise, both of which lead to saltwater intrusion in aquifers.
- Sea-level rise is expected to decrease the profitability of irrigated agriculture in Morocco due to increased pumping of groundwater and increased salinization risk for aquifers.
- Sea-level rise is also expected to increased flooding of river deltas especially in Egypt, Gabon, Sierra Leone, The Gambia, Nigeria, Cameroon, Tanzania, and Somalia.
- Climate change effects, such as increased ocean acidification and warming ocean temperatures will negatively affect coral reefs and fisheries, and will increase the cost of coastal protection.
- Climate change will likely impact ocean upwelling, an important process that creates some of the most biologically active systems in the world's oceans. For example, the Canary current along the Atlantic coast has warmed since the early 1980s, and there is some evidence that primary production has decreased over the past two decades. The synergies between an increase in water temperature and ocean acidification could also adversely influence a number of important biological processes.

ASIA[1]

AGRICULTURE AND FOOD SECURITY

The impacts of climate change on food production and food security in Asia will vary by region, however, many regions are expected to see a decline in food productivity, with the largest numbers of food-insecure people located in South Asia. For example, higher temperatures are expected to decrease rice yields as a result of shorter growing periods. Overall, studies indicate that crop production will likely shift northwards with benefits to colder areas and negative consequences to warmer areas. Cereal production in Central Asia (i.e., northern and eastern Kazakhstan) could benefit from longer growing seasons, warmer winters and a slight increase in winter precipitation. In contrast, frequent droughts could negatively affect cotton production, increase water demand for irrigation, and exacerbate desertification in other areas, such as western Turkmenistan and Uzbekistan. Sea level rise also threatens many Asian coastal areas and is projected to inundate low lying areas which would negatively affect rice growing regions. Fisheries, a major source of livelihoods and protein for many countries, are also projected to be negatively impacted by climate change, especially in South and Southeast Asia.

Crops

- Central Asia is expected to become warmer in the coming decades and increasingly arid, especially in the western parts of Turkmenistan, Uzbekistan, and Kazakhstan.
- A longer growing season, warmer winters, and a slight increase in winter precipitation could benefit cereal production in northern and eastern Kazakhstan.
- Frequent droughts could negatively affect cotton production, increase already extremely high water demands for irrigation, and exacerbate the already existing water crisis and human-induced desertification in western Turkmenistan and Uzbekistan.
- The Indo-Gangetic Plains (India), which produce about 14-15% of global wheat, could suffer significant reductions due to climate change-induced heat stress, affecting about 200 million people (based on the current population).
- Decreased precipitation would negatively affect rain-fed agriculture in semi-arid and arid regions of western Asia.
- Changes in temperature and precipitation are expected to reduce sorghum grain yield by 2-14% by 2020.
- Warming temperatures may adversely affect rice and other crops growing near their heat stress limits in places such as Pakistan/North India (during October), South India (April-August), East India/Bangladesh (March-June), Myanmar/Thailand/Laos/Cambodia (March-June), Vietnam (April-August), Philippines (April-June), Indonesia (August) and China (July-August).
- The most vulnerable regions for reduced rice yield is projected for western Japan, eastern China, the southern part of the Indochina peninsula, and the northern part of South Asia.
- Sea-level rise threatens coastal and deltaic rice production areas in Asia, such as those in Bangladesh, Myanmar, and the Mekong River Delta. For example, about 7% of Vietnam's agricultural land may be submerged due to sea-level rise.
- Winter wheat yields could increase in some areas, such as Huang-Huai-Hai Plain, China's most productive wheat growing region, due to warmer nighttime temperatures and higher precipitation.

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- Maize yield could decrease by 25% by the 2080s (compared to 1961-1990) in the North China Plain.
- Winter wheat yields could increase with warming temperatures in the northern portion of its production (northern Pakistan), however, extreme weather events could counter some of these gains.

Fisheries

- Climate change will compound existing threats, including overfishing, pollution, dam construction, etc. For example, rising temperatures, reduced precipitation, and increased droughts will decrease river flow regimes in some areas, which in turn would adversely affect fish reproduction. Additionally, increased precipitation and floods will scour rivers and also adversely affect fish reproduction.
- Coldwater fish will be threatened as rising water temperatures make much of their current habitat unsuitable.
- Habitats that depend on seasonal inundation, including floodplain grasslands and freshwater swamp forests would be adversely affected by reduced precipitation and droughts.
- Reduced dry season flows together with sea-level rise will increase saltwater intrusion into many Asian deltas, compound existing threats, and negatively impact both capture fisheries and aquaculture production.
- Modeling studies indicate that climate change may lead to a massive redistribution of the ability to harvest marine fish, with large increases in high-latitude regions, including Asian Russia, and large declines in the tropics, particularly Indonesia.
- Warming ocean temperatures, ocean acidification, and the loss of coral reefs would greatly decrease the abundance of marine fisheries, negatively affecting many countries in south and southeast Asia.

HUMAN SETTLEMENTS, INDUSTRY, AND INFRASTRUCTURE

By the middle of this century, Asia's urban population will increase by 1.4 billion and will account for over 50% of the global population. South and Southwest Asia have the highest urban population growth rates within Asia at an average of 2.4% per year during 2005-2010. Needless to say, climate change will compound the many stresses caused by rapid urbanization, industrialization, and economic development. Furthermore, climate change is expected to adversely affect the sustainable development capabilities of most Asian developing countries by aggravating pressures on natural resources and the environment. Asia experienced the highest number of weather- and climate-related disasters in the world during the period from 2000-2008 and suffered huge economic losses, accounting for the second highest proportion (27.5%) of the total global economic loss. A large proportion of Asia's population lives in low elevation coastal zones that are particularly at risk from climate change hazards, including sea-level rise, storm surges, and typhoons. Half to two-thirds of Asia's cities with 1 million or more inhabitants are exposed to one or multiple hazards, with floods and cyclones being the most important. Climate change will also impact industry both directly by affecting industrial production and indirectly by affecting the cost of infrastructure and potential damages. Climate change will likely reinforce existing inequalities, disrupt the social fabric of communities and cities, and exacerbate poverty.

Floodplains and Coastal Areas

- Three of the world's five most populated cities (Tokyo, Delhi, and Shanghai) are located in areas with high risk of floods and climate change threatens to increase their frequency and intensity.
- Climate change-induced floods also threaten vulnerable regions that have high concentrations of people and infrastructure in India, Bangladesh, and China.
- Reduced precipitation will also likely exacerbate existing water shortages, which would negatively affect socioeconomic, agricultural, and environmental conditions, particularly in East Asia.
- Climate change threatens large parts of south, east and southeast Asia, which are already exposed to a high degree of cumulative climate-related risks. For example, Asia has more than 90% of the global population exposed to tropical cyclones and more powerful tropical cyclones would result in more loss of life and destruction as illustrated by Super Typhoon Haiyan, in the Philippines in 2013.
- By the 2070s, the top Asian cities in terms of population exposure (including all environmental and socioeconomic factors) to coastal flooding are expected to be Kolkata, Mumbai, Dhaka, Guangzhou, Ho Chi Minh City, Shanghai, Bangkok, Rangoon, and Hai Phòng. The top Asian cities in terms of assets exposed are expected to be Guangdong, Kolkata, Shanghai, Mumbai, Tianjin, Tokyo, Hong Kong, and Bangkok.
- Asia includes 15 of the global top 20 cities for projected population exposure and 13 of the top 20 for asset exposure.
- The combined effect of climate change and over-withdrawal of groundwater in many Asian cities, such as Bangkok, Manila and Tianjin will likely result in land subsidence and may increase hazard exposure due to coastal inundation and sea-level rise.

Industry & Infrastructure

- Extreme events will likely have a greater impact on large and medium-sized construction projects due to the costs of infrastructure deterioration and associated repairs.
- Extreme events are expected to be more catastrophic in losses in areas with poor infrastructure and development, such as the east coast of India.
- Climate change threatens to disrupt basic services such as water supply, sanitation, energy provision, and transportation systems, which has serious implications for local economies and in some cases could lead to mass migration.
- Climate-smart improvements may reduce future losses for some industries. For example, it is estimated that upgrading the drainage system in Mumbai today, could reduce losses associated with a 1-in-100 year flood event by as much as 70% and reduce the indirect effects of flooding by half, speeding recovery after such events significantly.

HUMAN HEALTH, SECURITY, LIVELIHOODS, AND POVERTY

The majority of Asians live in rural areas and heavy depend on natural resources that are directly influenced by changes in weather and climate. However, climate change impacts are not limited to rural populations and will impact urban populations. Furthermore, extreme climate events will have an increasing impact on human health, security, livelihoods, and poverty. For instance, more frequent and intense heat-waves in Asia will increase mortality and morbidity in vulnerable groups. Increases in heavy rain and temperature will increase the risk of diarrheal diseases, dengue fever, and malaria. Increases in floods and droughts will exacerbate rural poverty in parts of Asia due to negative impacts on some crops (e.g., rice), resulting in increases in food prices and the cost of living. Climate change impacts on water resources, agriculture, coastal areas, resource-dependent livelihoods, and urban settlements and infrastructure will have implications for human health and well-being and ultimately affect human security in Asia.

Floods and Health

- Climate change impacts such as increased flooding and extreme weather events will likely lead to deteriorated drinking water quality, mosquito proliferation, increased exposure to rodent-borne pathogens and intermediate snail hosts of Schistosoma, and increased disease epidemics.
- Floods are projected to increase in central and eastern Siberia and parts of south-east Asia including India.
- Flooding-induced contamination of urban water supplies will likely increased exposure to pathogens and toxic compounds.
- Extreme flooding may also increase mental disorders and posttraumatic stress syndrome, which have been previously observed in disaster-prone areas in India.

Heat and Health

- Warmer temperatures and more heat waves will likely to lead increased mortality and morbidity especially in vulnerable populations, such as the elderly, children, the poor, and people with cardiovascular and respiratory disorders. This phenomenon has already been documented in populations in India, Thailand, and several cities in East Asia.
- Climate change will likely increase the frequency of heat stress disorders among workers, leading to productivity losses.
- More cold events associated with extreme weather will also likely lead to increased mortality, particularly in rural environments.
- Climate change will affect the local transmission of many climate-sensitive diseases. Increases in heavy rain and temperature are projected to increase the risk of diarrheal diseases in, for example, China.
- Climate change is also expected to affect the distribution of dengue fever and schistosomiasis, for example, it is projected that the latter will increase its distribution in northern China due to climate change.
- Severe child stunting because of malnutrition is projected to increase by 62% in South Asia by 2050 without accelerated investment in planned adaptation.
- The incidence in mosquito-borne diseases, such as dengue fever, Japanese encephalitis, and Chikungunya fever are likely to increase with warming temperatures and precipitation changes in some areas.

Livelihood and Poverty

- Floods, droughts and changes in seasonal rainfall patterns are expected to negatively impact crop yields, food security and livelihoods in vulnerable areas, especially in Southeast Asia.
- Climate change will likely exacerbate rural poverty in parts of Asia due to impacts to important crops, such as rice, and increases in food prices and the cost of living.
- If climate change reduces crop productivity as expected, producers in food exporting countries, such as Indonesia, the Philippines, and Thailand, would benefit from global food price rises and reduce poverty, while countries such as Bangladesh would experience a net increase in poverty of 15% by 2030.
- Climate and food impacts will also vary within food exporting countries, with disproportionate negative impacts on farm laborers and the urban poor.
- Reduction in the amount of precipitation during the growing season for rice would have negative impacts on the welfare of farmers in places such as Indonesia, and these impacts may lead to global mass migration and related conflicts.
- Drought-induced fires will increase the vulnerability of agriculture, forestry and human settlements, particularly in peatland areas in Indonesia.
- In North Asia, climate-driven changes in tundra and forest-tundra vegetation may influence indigenous peoples who depend on nomadic tundra pastoralism, fishing, and hunting.

ECOSYSTEMS

Terrestrial systems in many parts of Asia have responded to recent climate change with shifts in the timing of blooming, growth rates, the distributions of plant species. Permafrost degradation, and future climate change are expected to further increase these impacts. Boreal trees will likely invade treeless arctic vegetation, while evergreen conifers will likely invade deciduous larch forests. Although these changes will impact the species that inhabit in these areas, they will also impact humans who rely on ecosystems services, such as water regulation. Large ecosystem changes may also occur in arid and semiarid areas with substantial impacts, but uncertainties in precipitation projections make these more difficult to predict. Changes in animal distributions and species migrations have also been projected, in response to both direct impacts of climate change and indirect impacts through changes in the availability of suitable habitats.

Coastal and marine systems in Asia are under increasing stress from both climatic and non-climatic threats. Sea-level rise will likely contribute to coastal erosion, especially in the Asian Arctic, where rising sea levels are expected to interact with melting permafrost and a lengthening of the ice-free season. In South and Southeast Asia, mangroves, salt marshes, and seagrass beds may shrink due to sea-level rise, while coastal freshwater swamps and marshes will be vulnerable to saltwater intrusion. These are important habitats for a plethora of species, including many economically important fish species. Warming ocean temperatures and ocean acidification are expected to continue to damage to coral reefs with substantial impacts to regional livelihoods and economies. Marine biodiversity is expected to increase at temperate latitudes as warm water species expand their ranges northwards, but may decrease in the tropics if thermal tolerance limits are exceeded.

Vegetation & Animals

- Earlier spring greening and longer growing seasons are expected to continue in humid temperate and boreal forest areas and this may increase the distribution of pests and diseases.
- Boreal forests are expected to expand northward and eastward at the expense of the tundra.
- Species composition changes, such as declines of larch and increases in darker colored evergreen conifers into the tundra would decrease albedo and cause additional regional warming.
- Alpine vegetation may be largely replaced by forest/shrubland on the Tibetan Plateau.
- Bamboo is projected to decline in the Qinling Mountains, with potentially adverse consequences for the giant pandas that rely on them for food.
- Reduced precipitation in already dry regions will adversely impact species and resources (water, wood, soil) and the people who rely on them.
- Snow leopard habitat in the Himalayas is expected to contract by up to 30% as forests replace open habitats.
- The biodiversity of isolated mountains may also be particularly vulnerable to warming, because many species already have small geographical ranges that will shrink further.
- Increased drought stress will likely impact much of interior Asia, especially already dry regions like Mongolia.
- Increased droughts will also impact lowland Southeast Asia, and together with logging and fire, could greatly increase the vulnerability of this already fragmented landscape to fire, smoke, and air pollution.

Marine & Coastal Systems

- Fish species are projected to shift their ranges northwards in response to rising sea surface temperatures and the combined effects of changes in distribution, abundance, and physiology may reduce the body size of marine fishes, particularly in the tropics and intermediate latitudes.
- Continuation of current trends in sea-surface temperatures and ocean acidification would result in large declines in coral-dominated reefs by mid-century.
- Coastal freshwater wetlands may be vulnerable to saltwater intrusion with rising sea-levels, but in most river deltas local subsidence for non-climatic reasons will be more important.
- Cyclone intensification and sea-level rise could increase coastal flooding and would be further exacerbated by the loss of coral reefs and mangrove forests which reduce wave damage.
- Permafrost is projected to decrease 20-90% by 2100 in North Asia and the Qinghai-Tibet Plateau, which will have substantial impacts to erosion, infrastructure, and livelihoods.
- Sea-level rise of 0.5 m over this century is projected to erode coastlines that are composed of loose permafrost rocks, such as along the Laptev Sea, East Siberian Sea, and West Yamal in the Kara Sea.

ASIA

WATER SECURITY

Water resources are critically important in Asia due to the massive population, which is reported to be about 4.3 billion in 2013, or approximately 60% of the world population. In addition to climate change, increased water demand and lack of good management will increase the scarcity of freshwater for large portions of Asia. It is also expected that population growth and increasing demand arising from higher standards of living would worsen water security in many parts in Asia and affect many more people in future. Declines in rainfall and river runoff will undoubtedly affect millions of people and may lead to increased tension due to water scarcity in some regions, especially arid areas. Integrated water management strategies could help adapt to climate change, including developing water saving technologies, increasing water productivity, and water reuse.

- Drought will likely compound the mismanagement of water resources and add to existing tensions especially in arid regions of Asia.
- Climate change may further complicate the unsustainable consumption of groundwater for irrigation and other uses in some locations, such as the Indian states of Rajasthan, Punjab, and Haryana.
- Decreasing precipitation will exacerbate the growing population and expanding water withdrawal, ultimately leading to more water scarcity in northern China
- Climate change will challenge water supply issues in south Asia and may adversely affect agricultural and livestock sustainability.

AUSTRALIA & NEW ZEALAND[1]

WATER RESOURCES

Climate change impacts on water resources represent a cross-cutting issue affecting people, agriculture, industries and ecosystems. The challenge of satisfying multiple demands with a limited resource is exacerbated by the variability of river flows, particularly in Australia. The unprecedented decline in river flows during the 1997-2009 'Millennium' drought in south-eastern Australia resulted in low irrigation water allocations, severe water restrictions in urban centers, suspension of water sharing arrangements and serious environmental impacts. Climate induced changes in precipitation will significantly affect how much and when water flows in rivers and wetlands, and could further exacerbate impacts from human water use in developed river basins.

- River flows tend to be decreasing in southern Australia and increasing in northern Australia.
- Freshwater resources in far south-eastern and far south-west Australia are projected to decline further (up to 70%, for 2°C warming) due to the reduction in winter precipitation.
- Warmer temperatures and associated evaporation will exacerbate existing stresses to water resources such as interceptions from farm dams and less surface-groundwater connectivity in long dry spells.
- Heavy rainfalls are likely to become more intense and frequent during the 21st century in many parts of the region, which may lead to more intense soil erosion (projected to increase by as much as 40-50% in Australia), negatively impacting agriculture, drinking water quality, and ecosystems.
- An increase in the frequency and intensity of bushfires will also lead to increased soil erosion and degraded water quality.
- In New Zealand, precipitation changes are projected to lead to increased runoff in the west and south of the South Island and reduced runoff in the north-east of the South Island, and the east and north of the North Island.
- Annual flows of eastward flowing rivers with headwaters in the Southern Alps (New Zealand) are projected to increase by 5-10% by 2040 in response to more alpine precipitation. Most of the increases occur in winter and spring, as more precipitation falls as rain and snow melts earlier.
- The Ashley River, which is near Christchurch, New Zealand, is projected to increase in winter river flows but decrease in summer flows, which could have serious impacts to the one of the largest and least modified estuaries in New Zealand. These changes could significantly affect many migratory birds that use this estuary.
- Climate change will affect groundwater through changes in recharge rates and the relationship between surface waters and aquifers. Groundwater recharge is projected to decrease to less than 50% of the 1990s value by 2050 because of the decline in precipitation in most of western, central and southern Australia, and increase in the north and some parts of the east because of projected increase in extreme rainfall intensity.
- In New Zealand, groundwater recharge in the Canterbury Plains is projected to decrease by about 10% by 2040.

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ECOSYSTEMS

Terrestrial and freshwater ecosystems have suffered high rates of habitat loss and species extinctions since European settlement in both Australia and New Zealand and as a result many reserves are small and isolated and some key ecosystems and species are now under-represented. Under-represented ecosystems and species may have a negative domino effect further disrupting ecosystem processes, functions, and services. These effects would undoubtedly impact several key sectors, such as agriculture and tourism and indigenous peoples. Climate change has led to some recently observed changes in the distribution, genetics and phenology of individual species, and in the structure and composition of some ecological communities in Australian terrestrial systems. Existing environmental stresses will interact with, and in many cases be exacerbated by, shifts in climatic conditions and associated change in the frequency or intensity of extreme events, especially fire, drought and floods. Extreme heat and reduced water availability, either singly or in combination, will be significant drivers of future population losses and will increase the risk of local species extinctions in many areas. Many freshwater ecosystems are currently stressed from over-allocation and pollution, especially in southern and eastern coastal regions in Australia. Adding to this, additional stresses include erosion, changes in nutrients and fire regimes, mining, invasive species, grazing and increasing salinity. These stresses compound and increase the vulnerability to rapid climate change, providing significant challenges for both autonomous and managed adaptation. The marine ecosystems of both countries are considered hotspots of global marine biodiversity with many rare, endemic and commercially important species. Climate change will likely compound the increasing density of coastal populations and stressors such as pollution and sedimentation from settlements and agriculture. Climate change also threatens coastal habitats, which provide many ecosystem services including coastal protection and carbon storage, particularly in seagrass, saltmarsh, and mangroves.

- Recent drought-related mortality has been observed for amphibians in south-east Australia, savannah trees in north-east Australia, Mediterranean-type eucalypt forest in southwest Western Australia, and eucalypts in sub-alpine regions in Tasmania.
- Mass die-offs of flying foxes and cockatoos have been observed during heat-waves.
- Range contractions are projected for many Australian native species, such as koalas, platypus, Western Australian Banksia spp., native rats, greater gliders, quokkas, northern macropods, and a number of birds and fish.
- Species distribution models project the complete loss of climatically suitable habitat for some species within a few decades, and therefore increased risk of local and, perhaps, global extinction.
- Alpine areas are one of the most vulnerable Australian ecosystems due to loss of snow cover, invasions by exotic species, and changed species interactions.
- Coastal wetlands, such as Kakadu National Park (Australia), face substantial risks to saline intrusion.
- Tropical savannas face risks due to changed fire regimes.
- Inland freshwater and groundwater systems face risks from drought, over-allocation, and altered timing of floods.
- Peat-forming wetlands along the east coast of Australia face risks from drying.
- Biodiversity-rich regions, such as southwest Western Australia and tropical and sub-tropical rainforests in Queensland, face risks from drying and warming.
- Climate change threatens to exacerbate existing stresses, such as invasive species and habitat loss in New Zealand. For example, the rich biota of the alpine zone in New Zealand is at risk through increasing shrub growth and loss of herbs, especially if combined with increased establishment of invasive species.

- Some cold water-adapted freshwater fish and invertebrates are vulnerable to warming and increased spring flooding may increase risks for some bird species.
- Suitable habitat may increase with warming for some restricted native species (e.g. native frogs), although range expansion will be limited by low dispersal ability.
- Warming temperatures may increase the ratio of males to females in tuatara populations, although this trend is not necessarily supported by paleo records.
- Freshwater ecosystems in Mediterranean-montane ecoregions (e.g., Australia) are projected to experience a shortened wet season and prolonged, warmer summer season, increasing the vulnerability of fish communities to drought and floods.
- Shifts in hydrologic regimes in snow-melt systems, including earlier runoff and declining base flows in summer, are projected to alter freshwater ecosystems, through changes in physical habitat and water quality.
- Declining rainfall and increased inter-annual variability will most likely increase low-flow and dry-spell duration in dryland regions, leading to reduced water quality in remnant pools, reduction in floodplain egg- and seed-banks, the loss of permanent aquatic refugia for fully aquatic species and water birds, altered freshwater food webs, and drying out of wetlands.
- Climate change is already affecting coastal and ocean systems around Australia and New Zealand, with climate zones shifting south by more than 200 km along the northeast and about 100 km along the northwest Australian coasts since 1950 and 350 km along the southeast Australia coast.
- Warming oceans have led to changes in phytoplankton productivity, species abundance of macroalgae, growth rates of abalone, southern rock lobster, coastal fish and coral, seabirds, sub-tidal seaweeds, plankton, fish, sea urchins, and intertidal invertebrates.
- Climate change may cause mangroves to expand inland at the expense of saltmarshes.
- Extreme events have the potential to negatively impacts coastal habitats and species and ocean acidification and an increase in bleaching events will adversely impact coral in places such as the Great Barrier Reef. Continued loss of this habitat will reverberate through the marine systems and affect tourism and coastal protection.

INDUSTRIES

There are a number of key industries in Australia and New Zealand that have already been impacted by climate change and are expected to be further affected. Industries covered here include, forestry, agriculture, mining, energy supply, demand, and transmission, and tourism. Some industries, in some locations, have the potential to benefit from projected changes in climate and increasing atmospheric CO_2. For example, there may be reduced energy demand for winter heating in New Zealand and southern parts of Australia, and forest growth may increase in cooler regions. However, it is expected that the adverse impacts will likely outweigh the positive effects with long-term climate change. Climatic changes to some industries will impact world supply, for example, the region produces over 40% of the world trade in dairy products. This implies that climate change impacts could have consequences for food security not just locally but even globally.

Forestry

- Forestry contributes around A$7 billion annually to Australia's GDP and it is projected that tree growth will be reduced by temperature increases in hotter regions and declining precipitation in dry regions, especially where species are grown at the upper range of their tolerances. For example, plantations in south-west Western Australia are most at risk.

- In cooler regions where water is not limiting, higher temperatures could benefit forestry production. For instance, warming is expected to increase P. radiate growth in New Zealand's cooler south, however, temperature increases may reduce productivity in the warmer north.
- Climate change is expected to cause more frequent and perhaps more intense fires, which poses serious risks to forestry in both countries, but especially for the commercial forestry plantations in the southern winter-rainfall regions.
- Climate-induced changes to pests and diseases, such as Dothistroma blight, a serious pine disease in New Zealand, will also be affected and could have negative impacts to some regions.

Agriculture

- A 3°C temperature increase (from a 1980-99 baseline) is expected to have a 4% reduction in gross value of the beef, sheep and the wool sector in Australia.
- Dairy output is projected to decline in all regions of Australia other than Tasmania under a 1°C increase by 2030.
- Shorter growing season due to changes in both rainfall and temperature is projected to decrease profitability of sheep and beef production in southern Australia and parts of New Zealand by 2050.
- Heat stress for animals increased from 1960-2008 in the Murray Dairy region of Australia and is expected to increase further with reductions in milk production.
- Wheat yields in New Zealand may increase with climate change, but only with the appropriate choices of cultivars and sowing dates. In Australia, the selection of appropriate cultivars and sowing times are also projected to increase wheat yields in high rainfall areas such as southern Victoria. However, scenarios of extreme low rainfall in these areas could change these projections and under some scenarios, Australia could become a net importer of wheat.
- Climate change impacts on water availability will strongly impact the production of rice and sugercane in Australia with declines in precipitation and warming temperatures adversely affecting production.
- Observed trends and modelling for wine-grapes suggest that climate change will lead to earlier budburst, ripening and harvest for most regions and scenarios. However, without adequate adaptation, reduced quality is expected in all Australian regions. Change in cultivar suitability in specific regions is expected, with potential for development of cooler or more elevated sites within some regions and/or expansion to new regions, with some growers in Australia already relocating (e.g. to Tasmania).

Mining

- Australia is the world's largest exporter of coking coal and iron ore and has the world's largest resources of brown coal, nickel, uranium, lead and zinc. Recent events demonstrated significant vulnerability to climate extremes: the 2011 floods reduced coal exports by 25-54 million tones and led to A$5-9 billion revenue lost in that year and tropical cyclones have regularly disrupted mining operations over the past decade.
- Flooding also affects mining and road and rail transport to major shipping ports and may get worse with climate change.
- Projected changes in climate extremes will likely increase mining vulnerability and competition for energy and water for other users, but it is perceived that the adaptive capacity of the industry is high.

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Energy, Supply, Demand, and Transmission

- Australia's predominantly thermal power generation is vulnerable to drought-induced water restrictions, which could require dry-cooling and increased water use efficiency where rainfall declines.
- Depending on carbon price and technology costs, renewable electricity generation in Australia is projected to increase from 10% in 2010/11 to ~33-50% by 2030, but few studies have explored the vulnerability of these new energy sources to climate change.
- New Zealand's predominantly hydroelectric power generation is vulnerable to precipitation variability. Increasing winter precipitation and snow melt, and a shift from snowfall to rainfall will reduce this vulnerability as winter/spring inflows to main hydro lakes are projected to increase by 5-10% over the next few decades. Further reductions in seasonal snow and glacial melt as glaciers diminish, however, would compromise this benefit.
- Increasing wind power generation would benefit from projected increases in mean westerly winds but face increased risk of damages and shut-down during extreme winds.
- Increased summer peak demand, particularly in Australia, will place additional stress on energy networks and can result in black-outs. For example, during the 2009 Victorian heat wave demand rose by 24% but electrical losses from transmission lines increased by 53% due to higher peak currents, and successive failures of the overloaded network temporarily left more than 500,000 people without power.
- Climate change will likely increase the risk of failure of energy distribution networks in most Australian states by 2031-2070 due to increased bushfire risk and potential strengthening and southward shift of severe cyclones in tropical regions. Adaptation costs have been estimated at A$2.5 billion to 2015, with more than half to meet increasing demand for air conditioning and the remainder to increase resilience to climate-related hazards. For example, underground cabling would reduce bushfire risk but has large investment costs that are not included above.
- Increasing high winds and temperatures are the most relevant risks to electric transmission in New Zealand.

Tourism

- Tourism contributes 2.6-4% of GDP to the economies of Australia and New Zealand, and most tourism is or will be impacted by climate change with some destinations being highly sensitive to extreme events.
- Tropical Cyclone Yasi and the associated floods in 2011 cost the Queensland tourism industry about A$590 million, mainly due to cancellations and damage to the Great Barrier Reef. Drought in the Murray-Darling Basin caused an estimated A$70 million loss in 2008 because of reduced visitor days.
- Climate change is expected to degrade the Great Barrier Reef and reduce its attractiveness.
- Ski tourism is expected to decline in the Australian Alps due to reduced snow cover.
- Increased temperature extremes in the Northern Territory are projected to increase heat stress and adversely affect tourism.
- Warmer and drier conditions in New Zealand may benefit tourism in some areas but wetter conditions and extreme climate events could compromise tourism.

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HUMAN HEALTH

Extreme events are expected to get worse with climate change and will have increasingly severe impacts to human health, especially among the most vulnerable. Extreme hot weather, particularly in Australia, increases mortality, with exceptional heat wave conditions being associated with substantial increases in mortality and hospital admissions in several regional towns and capital cities. For example, during the heat wave in 2009 in south-eastern Australia, total emergency cases increased by 46% over the three hottest days. Direct heat-related health problems increased 34-fold, 61% of these being in people aged 75 years or older, and there were an estimated 374 excess deaths, a 62% increase in mortality. Mental health admissions also increased across all age groups by 7.3% in metropolitan South Australia during heatwaves (1993-2006).

- Climate change is projected to result in 11% fewer temperature-related deaths in both 2050 and 2100 in Australia with strong mitigation, but 14% and 100% more deaths in 2050 and 2100, respectively, without mitigation under a hot, dry scenario. The hardest hit areas will be in Queensland.
- The number of hot days when physical labor in the sun becomes dangerous is projected to increase substantially in Australia by 2070 and could lead to economic costs from lost productivity, increased hospitalizations and deaths.
- Water- and food-borne diseases are projected to increase due to climate change but specific projections are relatively uncertain.
- For Australia, up to 870,000 new cases of bacterial gastroenteritis are projected by 2100, under a range of emission scenarios.
- Climate change may impact water-borne diseases, such as cryptosporidiosis and giardia.
- The area climatically suitable for transmission of dengue will expand throughout the region, but changes in socio-economic factors, especially domestic water-storage may have a more important influence on disease incidence than climate.
- Climate change is expected to increase significant mental health risks associated with climate-related disasters, in particular persistent and severe drought, floods and storms; climate impacts may be especially acute in rural communities where climate change places additional stresses on livelihoods.

CENTRAL & SOUTH AMERICA[1]

WATER AVAILABILITY

Central and South America have an extremely uneven distribution of water availability, ranging from excessively wet areas in the tropical rainforests to excessively dry areas in the high Andes. The main user of water is agriculture followed by human use by the region's 580 million inhabitants. According to the International Energy Agency, the region meets 60% of its electricity demand through hydropower generation, which contrasts with the 20% average contribution of other regions in the world. Given the use and dependency of Central and South America on water resources, climate change-induced changes will undoubtedly have substantial impacts that will reverberate through the regions' economies and affect human well being. For instance, changes in stream flow and water availability have already been observed and are projected to continue in the future, affecting already vulnerable regions. Ice and glaciers in the Andes are retreating at an alarming rate, affecting the seasonal timing and volume of streamflows. There are increasing runoffs in the La Plata River basin (Brazil, Paraguay, Argentina, Uruguay) and decreasing runoffs in the Central Andes (Chile, Argentina) and in Central America. For areas that are already semi-arid, the risk of water supply shortage will increase due to decreasing precipitation and increasing evapotranspiration, thus affecting water supply for cities, hydropower generation, and agriculture.

- Tropical glacier retreat has accelerated, losing between 20-50% in area since the late 1970s. Although this melting increased streamflow initially, it has now decreased as evidenced in the Cordillera Blanca of Peru.
- Glaciers, icefields, and snowpacks in the extra tropical Andes (Central-South Chile, Argentina) are expected to shrink even more, with reduced flows in dry seasons and increasing flows during wet seasons expected.
- Reduced precipitation and increasing evapotranspiration will likely lead to reduced runoff for most of the Central American region, including a 20% reduction in runoff projected for the Lempa River basin, one of the largest basins in Central America, covering portions of Guatemala, Honduras, and El Salvador. This amount of change in runoff could have large and serious implications to hydropower generation in the region.
- Tropical Andes glaciers are also expected to melt more and some permanent glaciers may disappear entirely within 20 to 50 years, with continued declines of water availability during the dry months. For example, it is estimated that complete glacial melt in the Peruvian Andes would result in 2-30% reduction in annual discharge, further exacerbating vulnerability to drought.
- Loss of hydropower generation related to glacial melt is projected to be 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.
- Decreased precipitation and associated runoff in south-central Chile and Argentina are expected to continue with significant declines in freshwater availability.
- Decreased water availability would substantially affect agriculture with economic impacts that could potentially drive full-scale migrations in the Brazilian northeast region.

ECOSYSTEMS & BIODIVERSITY

Central and South America contain a diverse array of unique ecosystems and the highest biodiversity in the planet. Unfortunately, this natural wealth is threatened by the compounding stresses of climate change and increasing agriculture and industrialization. Although conversion of natural ecosystems is the main cause of

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biodiversity and ecosystem loss in the region (especially for hotspots: Mesoamerica, Chocó-Darien-Western Ecuador, Tropical Andes, Central Chile, Brazilian Atlantic forest, and Brazilian Cerrado), climate change is expected to increase the rates of species extinction. The combination of land-use change, warming temperatures, and changing precipitation patterns will likely drive species from their current habitats, with some facing extinction. For instance, in Brazil, the distribution of some groups of birds and plants will be pushed southwards, where there are fewer natural habitats remaining.

- In combination with other stressors like deforestation, reduced rainfall, higher temperatures and water stress may lead to an abrupt and irreversible replacement of Amazon forests by savanna-like vegetation by mid to late century with large-scale impacts on climate, biodiversity, and local inhabitants.
- Plant and animal species are rapidly declining in Central and South America, in part due to climate change. Brazil is among the countries with the greatest number of threatened bird and mammal species and a large percent of in-land fish species with restricted distributions, which are highly likely to be affected by a changing climate.
- High-elevation species in the Andes and Sierra Madre are especially vulnerable to climate change because of their small geographic ranges and high energetic and area requirements.
- In Brazil, projections for Atlantic forest birds, endemic bird species, and plant species of the Cerrado indicate that species will need to shift their distributions south and southeast, precisely where fragmentation and habitat loss are worse.
- Warming temperatures and changes in water availability will likely adversely affect freshwater fish due to impacts on physiology and life histories.
- Interactions between and among species will also be affected by climate change. For example, changes in the timing of flowering, breeding and migration, the structure and composition of ecosystems, predator-preys interactions and interactions among organisms are all expected with climate change and will impact some species more than others. Highly vulnerable species may disappear altogether.
- High Andean ecosystems, especially those within the tropics, provide a series of crucial ecosystem services for millions people and are expected to face exceptionally strong climate change effects during the 21st century. Consequently, socio-economic well-being, especially for vulnerable communities, will be negatively affected by changes to biodiversity in the region.

COASTAL AND MARINE SYSTEMS

Sea-level rise has and will continue to impact coastal and marine systems throughout Central and South America. For instance, coastal states of Latin America and the Caribbean have a population of more than 610 million, 75% of who live within 200 km of the coast and could be affected with climate change. Furthermore, El Salvador, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, and Ecuador have more than 30% of their population living in coastal areas that are directly exposed to climatic events. Marine ecosystems adjacent to large coastal populations are also undergoing significant transformations due to the combined effect of climate change and non-climatic stressors. Sea-level rise and human activities on coastal and marine ecosystems pose serious threats to fish stocks, corals, mangroves, recreation and tourism, and disease control. The combination of climate change and overfishing, pollution, invasive species, and habitat destruction could negatively impact biodiversity and the delivery of ecosystem services, and could lead to losses that pose significant challenges and costs for societies, particularly in developing countries. Frequent coral bleaching events associated to ocean warming and acidification occur in many places, but are especially prevalent in the Mesoamerican Coral Reef and throughout the Caribbean.

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- Locations that have had more than 40% of change in sea-level rise are expected to experience increased flooding in the future and include: the south coasts of Cuba, Dominican Republic, Haiti, and the north coasts of Jamaica, Cayman Islands, Honduras, Nicaragua, Costa Rica, Panama, Colombia, and Venezuela.
- The greatest flooding levels in the region are found in the Rio de La Plata, an estuary formed by the confluence of the Uruguay River and the Paraná River on the border between Argentina and Uruguay and is expected to increase here with climate change.
- Urban areas along the east coast of Brazil have also experienced some of the greatest increases in coastal flooding levels and are projected to experience more in the future.
- Beach erosion is a serious problem for many coastal countries and will worsen with increased sea-level rise and coastal flooding. Locations that are at particularly high risk include the north coast of Cuba, Haiti, Dominican Republic, the east coast of Antigua and Barbuda, Dominica, St. Lucia, Barbados, Guyana, Suriname, French Guiana, portions of Brazil, and portions of the west coast of Chile, Mexico, and Colombia.
- Larger and stronger waves induced by sea-level rise could significantly affect infrastructure and coastal structures in some cities along the west coast of Central and South America.
- Warming ocean temperatures, ocean acidification, and the loss of coral reefs would greatly decrease the abundance of marine fisheries negatively affecting livelihoods and communities in coastal areas. For instance, some projections indicate that that the Mesoamerican coral reef could collapse by mid-century (between 2050 and 2070), causing major economic losses in the region, especially for Belize, Guatemala, and Honduras. Through marine-based tourism, fisheries, and coastal protection, the Mesoamerican reef contributes an estimated US$ 395-US$ 559 million annually in Belize.
- Many ecologically and economically important mangrove forests, especially along the Atlantic and Pacific coasts of Central America, could be lost in the next 100 years if current climate and non-climatic threats, such as deforestation, land conversion, and shrimp ponds continue.
- Continued mangrove forest loss and degradation will likely result in in ecosystem collapse, fisheries reduction and serious impacts on livelihoods in Central America countries, Brazil, French Guiana, and Colombia.
- Peru and Colombia are two of the eight most vulnerable countries to climate change impacts on fisheries, due to the following: the combined effect of observed and projected warming, species and productivity shifts in upwelling systems, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities.

FOOD PRODUCTION & LAND-USE CHANGE

The Central and South American region is playing an increasingly key role in the world economy as countries like Brazil, Chile, Colombia, and Panama are rapidly developing and becoming economically important. However, the region is also increasingly exposed to pressures related to expanding land-use change, industrialization, and a growing need for food. Much of the region's natural wealth is already threatened by development as well as rapidly growing agricultural, cattle, and bioenergy production. Climate change threatens to add further stress. Deforestation and land degradation also exacerbates the negative impacts of climate change and is leading to environmental degradation throughout the region. Climate change is expected to impact agricultural productivity, which would have significant consequences for food security in some parts

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of the region. For example, in southeastern South America, climate projections indicate more rainfall, leading to sustained or increased productivity until mid-century. In contrast, Central America, northeast Brazil, and parts of the Andean region are projected to get warmer with reduced precipitation and could experience a decrease in productivity, threatening the food security, especially for the poor. Crops and zones most affected by increases in temperature and heat stress will likely include rice in Southeast Brazil, maize throughout the Central and South American region, and soybeans in Central Brazil. Climate change has the potential to severely affect the poorest populations and their food security by increasing the current rate of chronic malnutrition. Currently, Guatemala is the most food insecure country in the region by percentage of the population (30.4%) and the problem has been increasing in recent years.

- Increased precipitation and soil moisture has led to improved summer crops and pasture productivity and expanded agricultural areas in southeastern South America. For example, wetter conditions observed during 1970-2000 (in relation to 1930-1960) led to increases in maize and soybean yields (9% to 58%) in Argentina, Uruguay and Southern Brazil, a trend that could continue in the future.
- Warmer and wetter conditions may benefit crops towards the southern and western zone of the Pampas and in South Brazil, irrigated rice yield and bean productivity is expected to increase.
- Sugarcane production could benefit as warming could allow the expansion of planted areas towards the south, where low temperatures are a limiting factor.
- Increases in crop productivity could reach 6% in São Paulo state by 2040; however, more mixed results are projected for yields of soybean, maize and wheat in Paraguay.
- Declines in precipitation would threaten the sustainability of agricultural systems in regions that are already marginal and continued agricultural practices in these areas could produce severe dust storms, cattle mortality, crop failure, and rural migration.
- In Chile and western Argentina, yields could be reduced by water limitations. In central Chile temperature increases, reduction in chilling hours and water shortages may reduce productivity of winter crops, fruits, vines and Radiata pine (*Pinus radiate*).
- Decreased precipitation and subsequent reductions in the average flows in the Neuquén River basin, (northern Patagonia, Argentina), could negatively affect fruit and vegetable production.
- In the northern portion of the Mendoza basin (Argentina), the combination of climate change and increases in water demand, due to population growth, could compromise the availability of subterranean water for irrigation and potentially force many farmers out of agriculture by 2030.
- Increasing temperatures during the growing season in parts of tropical South America, east of the Andes, and Central America will likely adversely affect agricultural productivity and human welfare.
- Declining crop yields in subsistence crops such as beans, corn, and cassava are projected in northeast Brazil and areas currently favorable to cowpea bean will likely shrink.
- Coffee production may be unfeasible for high temperature scenarios in Minas Gerais and São Paulo (southeast Brazil) and therefore may have to be transferred to more. southern regions where temperatures are lower and frost risk is less. For example, with +3ºC, Arabica coffee is expected to expand in the extreme south of Brazil, near the Uruguayan border, and northern Argentina.

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- Coffee production is highly sensitive to changes in climate and at least 1.4 million people in Guatemala, El Salvador, Honduras and Nicaragua depend on the coffee sector for their livelihoods.
- Climate change may shrink the suitable habitat for the Pequi tree (*Caryocar brasiliense*; an economically important Cerrado fruit tree), affecting the poorest communities in Central Brazil.
- Worst case scenarios project a 44% reduction in soybean yields by 2050 in the Amazon region.

HUMAN HEALTH

Changes in weather and climatic patterns are negatively affecting human health in Central and South America by increasing morbidity, mortality, and disabilities, and through the emergence of diseases in previously non-endemic areas. Climate-related drivers (temperature and precipitation changes) are associated with respiratory and cardiovascular diseases, vector- and water-borne diseases (malaria, dengue, yellow fever, leishmaniasis, cholera, and other diarrheal diseases), Hantaviruses and Rotaviruses, chronic kidney diseases, and psychological trauma. Vulnerabilities vary with geography, age, gender, race, ethnicity, and socio-economic status, and are rising in large cities. Climate change will exacerbate current and future risks to health especially given the region's high population growth rates and existing vulnerabilities in health, water, sanitation and waste collection systems, nutrition, pollution, and food production in poor regions.

- Climate-induced hurricanes and flooding has the potential to affect the health and survival of thousands of people in the region as evidenced in 1998 when outbreaks of vector- and water-borne diseases were triggered by Hurricane Mitch and also in the Colombian floods of 2010-2012, when hundreds of people died and thousands were displaced.
- The number of cases of malaria has increased in Colombia and in other urban and rural Amazonian regions during the last five decades. Without significant prevention, cases of malaria will continue to increase with climate change.
- Malaria transmission is also climbing in elevation in the Bolivian Andes, and vectors are found at higher altitudes from Venezuela to Bolivia.
- The incidence of dengue fever, also affected by climatic conditions, has risen in tropical America in the last 25 years, causing annual economic losses of US$ 2.1 billion.
- Despite large vaccination campaigns, the risk of Yellow Fever outbreaks has increased mostly in tropical America's densely populated poor urban settings.
- Schistosomiasis is likely to increase with a warmer climate, especially in rural areas of Suriname, Venezuela, the Andean highlands, and rural and peripheral urbanized regions of Brazil.
- Higher temperatures and deteriorating air quality in urban settings are increasing chronic respiratory and cardiovascular diseases, and morbidity from asthma and rhinitis.
- Other diseases, such as cholera, Chagas disease, cutaneous leishmaniasis, and visceral leishmaniasis, are affected by climatic variations such as El Niño and La Niña events and may worsen with climate change.

EUROPE[1]

PRODUCTION SYSTEMS AND PHYSICAL INFRASTRUCTURE

Settlements

European countries are diverse in both demographic and economic trends. The overall health of the population and social welfare has improved, with reductions in adult and child mortality rates. However, social inequalities both within and between countries persist. The population has increased in most EU27 countries, primarily due to net immigration, although population growth is slow. The risk of extreme events, such as coastal and river flooding will likely increase with climate change and coastal flood risk will remain a key challenge for several European cities, port facilities and other infrastructure.

- With no adaptation, coastal flooding in the 2080s is projected to affect an additional 775,000 (B2 scenario) and 5.5 million (A2 scenario) people per year in the EU27, with the Atlantic, Northern and Southern European regions most affected.
- The direct costs from sea-level rise in the EU27 without adaptation could reach 17 billion Euros per year by 2100, with Netherlands, Germany, France, Belgium, Denmark, Spain, and Italy incurring high damage costs.
- A 1m sea-level rise in Turkey could affect 3 million additional people and put $US 12 billion capital value at risk.
- In Poland, up to 240,000 people would be affected by increasing flood risk on the Baltic coast.
- The increasing cost of insurance and unwillingness of investors to place assets in affected areas is a potential growth impediment to coastal and island economies
- There has been an observed increase in river flood events and damages in Europe. While this is partly attributed to the increased exposure of people and property, climate change will likely further increase the flooding risk in the future.
- In the EU15, river flooding could affect 250,000-400,000 additional people by the 2080s and more than double annual average damages, with Central and Northern Europe and the UK most affected.
- When economic growth is included, economic flood losses in Europe could increase 17-fold under some scenarios.
- Climate change may increase the frequency and perhaps intensity of storms in northwest Europe, which would incur economic and insurance losses.

Built Environment

Built infrastructure in Europe is vulnerable to extreme weather events, such as the overheating of buildings (houses, hospitals, schools) during hot weather. Buildings that were originally designed for historical weather conditions will need to function in warmer climates in the future. Climate change in Europe is expected to increase cooling energy demand, especially in large cities that have strong urban heat island effects. However, modification of the built environment, via enhanced urban greening, for example, can reduce temperatures in urban areas, and have co-benefits for health and well being. Climate change may also increase the frequency and intensity of drought-induced soil subsidence and associated damage to dwellings in some areas.

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Transport

- Severe accidents caused by extreme weather are projected to decrease by 63-70% in 2040-2070 compared to 2007 as a result of changes to climate and expected developments in vehicle technology and emergency systems.
- Increased rail buckling in summer, as occurred in 2003 in the UK, is expected to increase the average annual cost of heat-related delays in some regions, while decreases are expected for ice and snow-related delays.
- An increase in extreme precipitation in some regions would cause more rail delays.
- An increase in high water levels during the winter and low water levels during the summer will complicate transportation on inland waterways. For instance, low water levels will reduce the load factor of inland ships and consequently increase transport prices, as experienced in the Rhine and Moselle Rivers in 2003.

Energy Production, Transmission, and Use

- Wind energy potential in northern, continental, and most of Atlantic Europe may increase during winter and decrease in summer after 2050.
- For southern Europe, a decrease in wind energy potential is expected during both seasons, except for the Aegean Sea and Adriatic coast where a significant increase during summer is possible.
- For hydropower, electricity production in Scandinavia is expected to increase by 5-14% during 2071-2100 compared to historical levels and increases by 1-20% were estimated for 2021-2050.
- In continental, and part of alpine Europe, reductions in electricity production by 6-36% are estimated.
- Energy production is expected to decrease by 5-15% in 2050 compared to 2005, for Southern Europe and net annual electricity generation cost will increase in most of the Mediterranean (while decreasing in the rest of Europe).

Tourism

- Climate change may improve tourism during summer and less during autumn and spring in northern continental Europe, Finland, southern Scandinavia and southern England especially after 2070.
- For the Mediterranean, climatic conditions for light outdoor tourist activities are expected to deteriorate in summer mainly after 2050, but improve during spring and autumn.
- Tourism in mountainous areas may benefit from improved climatic conditions in summer. However, natural snow reliability and thus ski season length will be adversely affected, especially where artificial snowmaking is limited. Lower elevation areas will be the most vulnerable.

Insurance and Banking

- Banking is potentially affected by climate change because of physical impacts to assets and investments and because of changing demands in the sustainability of investments and lending portfolios.
- Windstorm losses are well covered in Europe by building and motor policies, thus creating a large exposure to the insurance sector of extreme weather events.

- Flood losses in the UK in 2000, 2007 and 2009 have put the insurance market under further pressure, with increasing need for the government to reduce risk.
- Other risks of concern to the European insurance industry are building subsidence related to drought, and hail damage to buildings and crops.

AGRICULTURE, LIVESTOCK, FISHERIES AND FORESTRY PRODUCTION

Climate change impacts on the production of major crops have been observed in parts of Europe, including decreases during summer heat waves. For instance, summer heat waves during 2003 and 2010 resulted in grain-harvest losses of 20 and 30% in affected regions of Europe and Russia, respectively. Additionally, cereals production fell on average by 40% in the Iberian Peninsula during the intense 2004/2005 drought and is generally below potential in many rain-fed areas in Europe. The regional distribution of climate change impacts on agricultural production is likely to vary widely. However, continued warming, reductions in precipitation, and increased frequency of extreme events could result in productivity declines in some areas, particularly southern Europe by the end of the 21st Century. Europe is a global supplier of food and productivity declines would therefore affect food security globally.

Plant (Food) Production

- High temperatures and droughts have contributed to the lack of yield increase of winter wheat in France despite improvements in crop breeding.
- Warming has favored an increase in potato yields since 1960 in eastern Scotland.
- In northeast Spain, grape yields have been reduced by an increased water deficit since the 1960s.
- A 5.4 °C regional warming under the A2 scenario could reduce mean yields by 10% which would have serious impacts on food security.
- Under the A2 and B2 scenarios, crop production shortfalls, defined as years with production below 50% of its average climate normal production, would double by 2020 and triple by 2070 in the most productive southern European regions of Russia.
- Southern Europe would experience the largest yield losses (-25 % by 2080 under a 5.4 °C warming), with increased risks of rain-fed summer crop failure.
- Warmer and drier conditions by 2050 would cause moderate declines in crop yields in Central Europe regions.
- In western Europe, increased heat stress around flowering could cause considerable yield losses in wheat.
- For northern Europe, positive yield changes combined with the expansion of climatically suitable areas could lead to crop production increases. However, increased climatic variability would limit winter crops expansion and cause high risk of cereal yield loss at high latitudes.
- With generally warmer and drier conditions, deep rooted weeds and C4 weed species could pose a more serious threat to crops than shallow rooted C3 weeds.
- Arthropod-borne diseases (viruses and phytoplasmas), winter infection root and stem diseases (phoma stem canker of oilseed rape and eyespot of wheat), Fusarium blight, grapevine moth, and black rot fungus in fruit trees could create increasing damages in Europe under climate change.

Livestock Production

- Livestock production is particularly sensitive to heat stress. Temperatures above 18 and 21°C have been shown to reduce intensive dairy production of cows and growth performance of pigs.
- High temperature and air humidity during breeding increased cattle mortality risk by 60% in Italy.
- For grass-based livestock systems, model simulations show increases in potential dairy production in Ireland and France. However higher risks of summer and autumn production failures in central Europe and at French sites are expected by 2100.
- Reduced rainfall during dry summer months may increase weed pressure from tap-rooted forbs on grasslands and pastures. However, Mediterranean genotypes could be used to breed more resilient and better adapted forage plant material for livestock production.
- The spread of bluetongue virus in sheep across Europe has been partly attributed to climate change and although the distribution of this vector is unlikely to expand in the future, its abundance could increase in Southern Europe.
- Ticks, which cause Lyme disease and tick-borne encephalitis, have moved towards higher altitudes and latitudes with climate change.

Water Resources and Agriculture

The impacts of climate change on water resources will be very different between northern and southern Europe. In southern Europe, soil water content will decline, saturation conditions and drainage will be increasingly rare and restricted to periods in winter and spring, snow accumulation will likely decline, and melting will increase, especially in the mid-elevations. Across most of northern and continental Europe, there is an increase in flood hazards, which could increase damages to crops and plant growth, complicate soil workability, and increase yield variability. Groundwater recharge and/or water table level is projected to decline significantly by the end of the century for river basins located in southern Italy, Spain, northern France and Belgium. Less precipitation in summer and higher rainfall during winter could increase nitrate leaching with negative impacts on water quality in places such as the Seine river basin (France). Climate-induced declines in the suitability for rain-fed agricultural production together with declines in total runoff and groundwater resources will increase water demand for crop irrigation in some areas of Europe, especially in the Mediterranean area and in over-allocated catchments.

Forestry

Observed and future responses of forests to climate change include changes in growth rates, phenology, composition of animal and plant communities, increased fire and storm damage, and increased insect and pathogen damage. Tree mortality and forest decline due to severe drought events were observed in forests in Southern Europe, Cyprus, and Greece as well as in Belgium, Switzerland and the pre-Alps in France. Declines have also been observed in wet forests not normally considered at risk of drought. An increase in forest productivity has been observed in Russia.

- Higher temperatures and increasing atmospheric CO_2 are expected to increase forest growth and wood production in northern and Atlantic Europe, at least in the short to medium term.
- Increasing drought and disturbance risks would cause adverse effects and declines in productivity in southern and eastern Europe.

- Climate change is expected to reduce the economic value of European forest land by 2100 leading to a potential loss of several hundred billion Euros (depending on interest rate and climate scenario).
- In southern Europe, fire frequency and wildfire extent significantly increased after the 1970s due to fuel accumulation, climate change, and extreme weather events. For example, severe winds during hot, dry periods have led to substantial losses in France, Greece, Italy, Portugal, Spain, and Turkey in 2010.
- Megafires, triggered by extreme climate events, caused a record amount of burnt areas in some Mediterranean countries during last decades and future wildfire risk is projected to increase in southern Europe.
- Under the A2 scenario, annual burned area is projected to increase by a factor of 3 to 5 in southern Europe compared to the present by 2100. However, in northern Europe, fires are projected to become less frequent due to increased humidity.
- Wind storm damage to forests in Europe has recently increased and increased storm losses of 8-19% are projected in Western Germany, with the largest impacts in the mountainous regions.
- Boreal forests will become more vulnerable to autumn and early spring storm damage due to expected decrease in period of frozen soil.
- An increase in the incidence of diseases has been observed in many European forests and species of fungi will likely benefit from milder winters in continental Europe.
- Bark beetles are projected to increase in Scandinavia, in lowland parts of central Europe and Austria due to late summer warming temperatures.

Fisheries and Aquaculture

- Climate change is likely to cause fish species to shift north and down in ocean depth with warming temperatures. This may result in an increase in the production of marine fisheries in the North Atlantic.
- In British waters, the lesser sandeel (*Ammodytes marinus*), which is a key link in the food web, has shown declining numbers since 2002 and is projected to further decline in the future.
- In the Baltic Sea, some new species are expected to arrive because of an expected increase in sea temperatures, however, only a few of these species would be able to successfully colonize the Baltic because of its low salinity.
- In response to climate change and intensive fishing, widespread reductions in fish body size and in the mean size of zooplankton have been observed over time, affecting the sustainability of fisheries.
- Sea-level rise may reduce the available habitat appropriate for aquaculture.
- Warmer water temperatures have adversely affected both wild and farmed freshwater salmon production in the southern part of their distribution.
- Ocean acidification will likely disrupt the early developmental stages of shellfish with serious implications to the shellfish industry.
- The combination of climate change and overfishing has resulted in the decline of the North Sea cod during the 1980-2000.
- In North Sea and Celtic Seas, there has been a steep decline in boreal fish species and an increase in the southern (Lusitanian) species.
- As water temperatures increase, a number of endemic diseases and exotic pathogens of both wild and farmed salmon populations are likely to increase.

EUROPE

HUMAN HEALTH

Climate change is likely to have a range of health effects in Europe, with an increase of future heat-related effects on mortality and morbidity, particularly in older people and those with chronic diseases. Populations in southern Europe appear to be most sensitive to hot weather and will experience the highest heat exposures. However, populations in continental and northern Europe are also vulnerable to heat wave events. For most countries in Europe, the current burden of cold-related mortality is greater than the burden of heat mortality and climate change is likely to reduce future cold-related mortality. Although future mortality rates due to flooding are highly uncertain, it is expected that sea-level rise and an increase in extreme precipitation events will increase risks to people in some locations, particularly northern Europe. An increase in extreme events, such as flooding and heat waves, could also impact critical infrastructure (e.g., power distribution network and hospitals).

Climate change will also affect the current distributions and risk of some diseases. For example, the Asian tiger mosquito (a vector of dengue and Chikungunya) is currently present in southern Europe and may extend eastward and northward under climate change. The risk of introduction of dengue remains very low because it would depend partially on effective vector control measures. Climate change may facilitate the expansion of visceral and cutaneous leishmaniasis (currently present in the Mediterranean region), northwards in 15-20 years. Suitable climatic conditions for malaria may also expand with a warmer, wetter climate; however, disease re-emergence would depend upon many other factors including: the introduction of a large population of infectious people or mosquitoes or high levels of people-vector contact resulting from significant land-use changes.

ECOSYSTEMS & BIODIVERSITY

Terrestrial Systems

Current and future climatic changes including CO_2 increase are negatively impacting many ecosystems and species. Observed changes in plant communities in European mountainous regions show a shift of species to higher altitudes, resulting in an increase in species richness in boreal-temperate mountain regions and decrease in Mediterranean mountain regions. In southern Europe, decreases in the diversity of plant, bird and mammal communities are projected to occur at most low elevations. Climate change has altered breeding seasons, the timing of spring migration, breeding habitats, latitudinal distribution, and the migratory behavior of birds throughout Europe. In general, a northward shift in bird community composition has been observed. Climate change can affect trophic interactions, as co-occurring species that may not react in a similar manner and novel ecosystems composed of new species assemblages may occur. Climate change can exacerbate the threat posed by invasive species to biodiversity in Europe amplifying the effects of native and exotic pests and diseases.

- Projected habitat loss is greater for species at higher elevations. Suitable habitats for Europe's breeding birds are projected to shift nearly 550 km northeast by the end of the century.
- Aquatic habitats and habitat connectivity in river networks may become increasingly fragmented.
- Large range contractions due to climate change are projected for several populations of pine tree (e.g., *Pinus cembra* and *Pinus Sylvestris*).

- Range expansion is projected for the dominant Mediterranean tree species, Holm oak. However, changes in disturbance regimes and human impacts, such as land-use change, increase its vulnerability.
- Common species of European birds with a low thermal tolerance have showed the sharpest declines between 1980 and 2005, a trend likely to continue.
- Projections for 120 native European mammals suggest that 5-9% are at risk of extinction, assuming no migration, during the 21st century due to climate change. 70-78% may be severely threatened under A1 and B2 climatic scenarios.
- Species that are not able to migrate fast enough in response to climate change, such as amphibians and reptiles, may also decline or experience ecological mismatches in the future.

Coastal & Marine Systems

Climate change will affect Europe's coastal and marine ecosystems by altering the biodiversity, functional dynamics and ecosystem services of coastal wetlands, dunes, inter-tidal and subtidal habitats, offshore shelves, seamounts, and currents. Impacts will occur through changes in invasive species, species range shifts, changes in fish stocks and habitat loss. Warming is affecting food chains and changing phenological rates and the distribution of fisheries in all seas over the past 30 years. Dune systems will be lost in some places due to coastal erosion from combined storm surge and sea level rise, requiring restoration. In the North Sea, the Iberian coast, and Bay of Biscay, a combination of coastal erosion, infrastructure development and sea defenses may lead to narrower coastal zones ("coastal squeeze").

- Europe's northern seas are experiencing greater increases in sea surface temperatures (SSTs) than the southern seas, with the Baltic, North and Black seas warming at 2-4 times the mean global rate.
- In the Baltic, decreased sea ice will expose coastal areas to more storms, changing the coastal geomorphology.
- Warming sea surface temperatures will influence biodiversity and drive change in depth and latitudinal range for intertidal and sub-tidal marine communities, particularly in the North and Celtic sea.
- Changes in the timing and location of phytoplankton and zooplankton are affecting North Sea cod larvae.
- Warmer waters increase the rate of the establishment and spread of invasive species, further altering trophic dynamics and the productivity of coastal marine ecosystems.
- In the Mediterranean, invasive species have arrived in recent years at the rate of one introduction every 4 to 5 weeks. While in this case the distribution of endemic species has remained stable, most non-native species have spread northward by an average of 300 km since the 1980s, resulting in an area of spatial overlap with invasive species replacing natives by nearly 25% in 20 years.

NORTH AMERICA[1]

WATER RESOURCES

Water resources are already stressed in many parts of North America due to non-climate stressors, and are expected to become further stressed due to future climatic changes. Decreases in snowpacks are already influencing seasonal stream flows with negative implications to humans and ecosystems. Recent floods, droughts, and changes in stream flow (although not yet attributed to climate change in some places), are a sign of future climate impacts. Climate projections include decreases in water quality and increases in urban drainage flooding throughout most of North America as well as a decrease in in-stream uses such as hydropower in some regions. Additionally, there will be decreases in water supplies for urban areas and irrigation in North America, except perhaps for southern tropical Mexico, northwest coastal US, and west coastal Canada. These expected decreases in water supplies will compound the fact that water withdrawals are already exceeding stressful levels in many regions of North America such as the southwest U.S., northern and central Mexico (particularly Mexico City), southern Ontario and the southern Canadian Prairies. Declines in water quality is also a concern with 10% to 30% of the surface monitoring sites in Mexico having polluted water, and about 44% of assessed stream miles and 64% of assessed lake areas in the US not clean enough to adequately support their uses. Water management infrastructure in most areas of North America is in need of repair, replacement or expansion and climate change, land use changes, and population growth and demand will add to these threats.

- Annual precipitation and stream runoff increases have been observed in the midwestern and northwestern U.S., and decreases have been observed in southern U.S.
- Warmer temperatures have led to earlier peak flow of snowmelt run-off in snow-dominated streams and rivers in western North America.
- Water supplies are projected to be further stressed by climate change, resulting in less water availability and increased drought conditions in arid and semi-arid western U.S. and Canada and in most of Mexico, except the southern tropical area. Compounding these conditions are other non-climatic factors such as salt water intrusion and increased groundwater and surface water pollution.
- The combination of climate change-induced decreases in water availability together with growing water demand and water transfers to urban and industrial users will further stress ecosystems and irrigation in the US southwest and southeast. These impacts will likely have economic, environmental, social, and cultural impacts that vary by water user and vulnerability.
- Crop irrigation requirements for pasture grass are projected to increase by 20% by 2040 and by 31% by 2070 in the Colorado River Basin.
- In the Rio Grande basin of New Mexico, runoff is projected decrease by 8%-30% by 2080 due to climate change.
- In Mexico, water shortages combined with increased water demands are projected to increase surface and groundwater overexploitation.
- The vulnerability of water resources in the tropical southern region of Mexico is projected to be low through 2050, with precipitation decreases from 10%-5% in the summer and no precipitation changes in the winter. However, after 2050, greater winter precipitation is projected, increasing the possibility of damage to hydropower and water storage damns by floods. Precipitation is projected to decrease by 40%-35% in the summer, which could negatively impact agriculture and vulnerable populations.

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- Water supply systems in the eastern U.S. will be negatively impacted by lost snowpack storage, rising sea levels contributing to increased storm intensities and salt water intrusion, potentially lower stream-flows, land use and population changes, and other stresses.
- Approximately two-thirds of Canadian irrigated land is located in southern Alberta, and this area is projected to experience declines in mean annual stream flow, especially during the summer, negatively affecting agriculture.
- Increases in rainfall and wet weather lead to higher rates of inflow and infiltration, negatively impacting wastewater treatment plants. Higher sea levels and increased river and coastal flooding could also threaten sewage collection systems.
- Climate change induced flooding could affect sectors ranging from agriculture and livestock in southern tropical Mexico to urban and water infrastructure in areas such as Dayton, Ohio, metro Boston and the Californian Bay-Delta region. Increased urbanization will compound these impacts.
- Hydropower generation is projected to decrease in arid and semi-arid areas of Mexico, the Great Lakes region, and in the U.S. Pacific Northwest.
- Navigation on the Great Lakes, Mississippi River and other inland waterways may benefit from less ice cover but will be hindered by increased floods and low water levels during droughts.

ECOSYSTEMS

North American ecosystems are under increasing stress from rising temperatures, CO_2 concentrations, and sea levels, and are particularly vulnerable to climate extremes. Climate stresses occur alongside other human influences on ecosystems, including land-use changes, non-native species, and pollution, and in many cases will exacerbate these pressures. Ecosystems are increasingly vulnerable to multiple and interacting climate stresses. For instance, in forest ecosystems, wildfire activity, regional drought, high temperatures, and infestations increase vulnerability. In coastal zones, increasing temperatures, ocean acidification, coral reef bleaching, increased sediment load in run-off, sea-level rise, storms, and storm surges increase vulnerability. Warming temperatures have led to changes in physiology, phenology and distributions in North American ecosystems, particularly in the U.S. and Canada. In general, plant, mammal, bird, lizard, and insect species' distributions have shifted northward and upwards in the western United States and eastern Mexico. Climate change also adds risks from sea-level rise, warming, ocean acidification, extratropical cyclones, altered upwelling, and hurricanes and other storms to highly productive estuaries, coastal marshes and mangrove ecosystems, which are present along the Gulf coast and the East and West coasts of North America. These ecosystems are also subject to a wide range of non-climate stressors, including urban and tourist developments and the indirect effects of overfishing.

- Droughts of unusual severity, extent, and duration have affected large parts of western and southwestern North America and resulted in regional-scale forest dieback in Canada, the U.S., and Mexico. Forest dieback is projected to increase in the future with higher vegetation mortality and an increase of biological agents, such as beetles, insect borers, pathogenic fungi, budworms, and other pests.
- Climate change and drought index projections show increases in wildfire risk during the summer and fall on the southeast Pacific coast, Northern Plains and the Rocky Mountains. In places like the Sierra Nevada, mixed conifer forests, which have a natural cycle of small, non-crown fires, are projected to have massive crown-fires. Wildfires also pose a direct threat to human lives, property and health, including respiratory effects from smoke inhalation.

NORTH AMERICA

- Extreme temperatures and severe droughts have led to forest dieback in northern and central Mexico during 2011 and 2012 and events such as these can alter ecosystem structure and function.
- Climate change will likely compound the impacts of disturbance, such as wildfires and insect outbreaks, which could have a major influence on North American ecosystems and economy in a changing climate. In terms of carbon stores, these outbreaks have the potential to turn forests into carbon sources.
- Warm winters in western Canada and U.S. have increased winter survival of the larvae of bark beetles, helping drive large-scale forest infestations and forest die-off in western North America since the early 2000s. Beginning in 1994, mountain pine beetle outbreaks have severely affected over 18 million hectares (44.5 million acres) of pine forests in British Columbia, and outbreaks are expanding northwards.
- More frequent droughts in tropical forests may change forest structure and regional distribution, favoring a higher prevalence of deciduous species in the forests of Mexico.
- Shifts in climate are expected to lead to changes in forest infestation, including shifts of insect and pathogen distributions into higher latitudes and elevations. For instance, warming is expected to increase bark beetle developmental rates, increase the number of generations per year, and change the suitable habitat in the western United States, western Canada, and northern Mexico.
- Sea-level rise, which has not been uniform across the coasts of North America, is directly related to flooding and loss of coastal dunes and wetlands, oyster beds, seagrass, and mangroves. Projected increases, particularly along the coastlines of Florida, Louisiana, North Carolina, and Texas, will threaten many plants in coastal ecosystems through increased inundation, erosion, and salinity levels. In settings where landward shifts are not possible, a 1 m rise in sea level will result in loss of wetlands and mangroves along the Gulf of Mexico of 20% (in Tamaulipas) to 94% (in Veracruz).
- Increases in sea surface temperature in estuaries alter metabolism, threatening species, especially cold water fish and further increases will contract cold-water fish habitat and expand warm-water fish habitat.
- Historical warm periods have coincided with low salmon abundance and restriction of fisheries in Alaska. Future projections indicate that Chinook salmon in the Pacific Northwest may decline by 20 to 50% by 2040-50.
- North Atlantic cetaceans, and tropical coral reefs in the Gulf of California and the Caribbean have been affected by increases in the incidence of diseases associated with warm waters and low water quality.
- Increased concentrations of CO_2 in the atmosphere due to human emissions are causing ocean acidification and in conjunction with high temperatures have been identified as a serious threat to coral reefs and other marine ecosystems in the Bahamas and the Gulf of California. Continuing ocean acidification will decrease coral growth and interactions with temperature increases will lead to increased risk of coral bleaching, leading to declines in coral ecosystem biodiversity.
- Tropical storms and hurricanes can substantial affect coral reef and mangrove ecosystems, and an increase in the frequency of category 4 and 5 storms could have profound impacts.

NORTH AMERICA

AGRICULTURE AND FOOD SECURITY

Effects of temperature and climate variability on yields of major crops have been observed throughout North America and include yield increases in some northern locations (Canada and the U.S.). However, continued warming, reductions in precipitation, and increased frequency of extreme events would result in net productivity declines in major North American crops by the end of the 21st Century without adaptation. Given that North America is a significant source of global food supplies, projected productivity declines here may affect global food security. Canada and the U.S. are relatively food secure, although households living in poverty are vulnerable. Much of Mexico's landbase is already marginal for two of the country's major agricultural products: corn and beef and climate change threatens to compound the already present severe desertification and further compromise agricultural productivity. Many of Mexico's agricultural communities are considered highly vulnerable and 17.6% of Mexicans are food insecure because the agriculture sector consists primarily of small farmers, who face high livelihood risks due to limited access to credit and insurance. Indigenous peoples are highly vulnerable due to high reliance on subsistence.

- Overall yields of major crops in North America are projected to decline modestly by mid-century and more steeply by 2100 without adequate adaptation.
- Warmer temperatures may increase agricultural productivity in northern regions (Canada, U.S.) and where water is not projected to be a limiting factor.
- Higher temperatures and a shortage of water availability are expected to significantly decrease productivity in some southern regions (Mexico).
- Extreme weather events threaten crop yields in most locations and could reverse the projected gains in some regions.
- Yields of several important North American agriculture sectors—including grains, forage, livestock and dairy are projected to decline significantly above critical temperature thresholds.
- Temperature increases affect product quality as well –e.g., coffee, wine grapes, wheat, fruits and nuts, and cattle forage.
- Projected temperature increases would reduce corn, soy, and cotton yields by 2020, with declines ranging from 30-82% by 2099 depending on crop and scenario.
- The productivity of California crops are projected decline from 9-29% by 2097, with large declines in suitable land for grape and wine production.
- Heat-induced livestock stress, combined with reduced forage quality, would reduce milk production and weight gain in cattle.
- Reduced soil moisture and water availability will likely adversely impact crops and productivity in the U.S. West/Southwest, the Western Prairies in Canada, and central and northern Mexico.
- Based on a combined exposure and consumptive water use the U.S. Great Plains is one of four global hotspots for future vulnerability of water availability from the 2030s and beyond, where anticipated water withdrawals would exceed 40% of freshwater resources. This would have substantial impacts to agriculture and food security.
- Projected earlier spring snowmelt and reduced snowpack would negatively affect productivity in western U.S. and Canada, as water availability in summer and fall are reduced.

- Projected increases in extreme heat, drought and storms are projected to adversely affect productivity throughout North America, but especially in Central North America, which is projected to be among the globe's regions of highest risk of heat stress by 2070.
- Corn and wheat production is projected to be negatively impacted in the northeastern and southeastern U.S.
- Land classified suitable for rain-fed corn is projected to decrease from 6.2% currently to between 3% and 4.3% by 2050 in Mexico.
- Precipitation is projected to decline 0-30% over Mexico by 2040, with the largest declines in northwestern Mexico, the primary region of irrigated grain farming. Although these declines may have the side effect of increasing rangeland productivity in some regions, the effects of projected maximum summer temperatures on livestock heat stress are expected to reach the "danger level" (at which losses can occur) by 2020 and continue to thereafter.
- Coffee, an economically important crop supporting 500,000 people, many indigenous, is projected to decline by 34% in Veracruz by 2020.

HUMAN HEALTH

Extreme events, which are expected to get worse with climate change, will have increasingly severe impacts to human health. For instance, extreme heat events currently cause increases in mortality and morbidity throughout North America. Impacts vary by age, location and socioeconomic factors. Extreme coastal storm events, such as hurricanes and flooding, can cause excess mortality and morbidity, particularly along the East coast of the U.S., and the Gulf coast of both Mexico and the U.S. Coastal and low-lying infrastructure and populations are vulnerable to flood-related interruptions in communications, healthcare access, and mobility. However, the magnitude of storm impacts depends on interactions between exposure and characteristics of affected communities. A range of water-, food-, and vector-borne infectious diseases, air pollutants, and airborne pollens are influenced by climate variability and change and are expected to get worse. Extreme events and flooding can create breeding sites for vectors and contaminate food and water resources, elevate mold levels and cause mental health impacts. Further climate warming will also impose additional stresses on the health sector through more severe extreme events such as heat waves and coastal storms, as well as more gradual changes in climate and CO_2 levels.

- High temperatures have been shown to increase the mortality and/or morbidity and climate warming will lead to continuing health stresses related to extreme high temperatures, particularly for the northern parts of North America.
- Extremely cold temperatures have also been associated with increased mortality and may increase with more frequent extreme events in some places.
- Temperature, humidity, and wind speed and direction have been linked with adverse air quality and health effects in many locations in North America. Climate change may also make it harder to achieve some air quality goals with worsening air pollution emissions, particularly ozone.
- Climate-induced forest fires are a source of particle emissions and can lead to increased cardiac and respiratory-disease incidence, as well as direct mortality and are expected to increase in western North America (U.S. and Canada).
- Warming temperatures and changes in vegetation are expected to change the seasonal timing and length of pollen release, with potentially adverse effects to people with respiratory issues, asthma, and allergies.

- Water-borne infections, such as cholera, may get worse in some locations, particularly in Mexico, especially among the poor, infants, elderly, pregnant women, and immune-compromised individuals.
- Severe storms have been shown to play a role in water-borne disease risks in Canada and could increase in the future.
- More flooding events could increase the potential for runoff to carry sediment and pollutants to water supplies, leading to more water-borne illnesses, as evidenced in the central State of Mexico.
- Climate change may impact the current range and possibly the incidence of vector-borne diseases, including Lyme disease, dengue fever, West Nile virus, and Rocky Mountain spotted fever. However, socio-economic and socio-cultural factors, prioritization of vector control, access to health care and land-use change will likely have bigger effects.
- Climate change will increase the risk from invasive vector-borne pathogens, such as chikungunya and Rift Valley fever viruses.
- There have been an increasing number of cases of Lyme disease in Canada and Lyme disease vectors are spreading along climate-determined trajectories.

KEY ECONOMIC SECTORS AND SERVICES

Observed impacts on livelihoods, economic activities, and infrastructure in North American have been attributed to sea-level rise, changes in temperature and precipitation, and occurrences of such extreme events as heat waves, droughts and storms. Among the most vulnerable are indigenous peoples due to their complex relationship with their ancestral lands and higher reliance on subsistence economies, and urban centers where high concentrations of populations and economic activities in risk-prone areas combine with several socio-economic and environmental sources of vulnerability. For instance, much of North American infrastructure is currently vulnerable to extreme weather events and, unless investments are made to strengthen them, will be even more vulnerable in the face of climate change. Water resources and transportation infrastructure are in many cases deteriorating. Extreme events have caused significant damage to infrastructure in many parts of North America and risks to infrastructure are particularly acute in Mexico, but are a big concern in all three countries. Most sectors of the North American economy have been affected by and have responded to extreme weather, including hurricanes, flooding, and intense rainfall, and there is an emerging concern that dislocation in one sector of the economy may have an adverse impact on other sectors due to supply chain interdependency. Slow onset perils – like sea level rise, drought, and permafrost thaw – are an emerging concern and are expected to get worse with climate change.

- Energy demand for cooling has increased as air conditioning demand has increased, a trend likely to continue with warming temperatures, especially in warmer climates such as the southern U.S. and Mexico. Demand for winter heating is projected to decrease but overall total energy demand in North America is projected to increase due to climate and non-climatic factors.
- Extreme weather currently poses risk to the energy system, for example, Hurricane Sandy resulted in a loss of power to 8.5 million customers in the Northeast U.S.
- Energy consumption is a major user of water resources in North America, with 49% of the water withdrawals in the U.S. for thermoelectric power.

NORTH AMERICA

- Transportation infrastructure across North America is aging, or inadequate (Mexico) making it more vulnerable to damage from extreme events and climate change. Approximately 11% of all US bridges are structurally deficient, 20% of airport runways are in fair or poor condition, and more than half of all locks are more than 50 years old and more than US$2 trillion is needed to bring infrastructure in the U.S. up to "good condition". Evidence of damage from previous storms is compelling and future risks are highest to coastal transportation infrastructure.
- Less ice cover could benefit marine and lake transportation in high latitudes.
- One-meter sea level rise combined with a 7-meter storm surge could inundate over half of the highways, arterials, and rail lines in the U.S. Gulf coast.
- Declining water levels in the Great Lakes would increase shipping costs by restricting vessel drafts and reducing vessel cargo volume. In southern Canada by the 2050s, cracking of roads from freeze and thaw may decrease but higher extreme temperatures could increase rutting and related maintenance and rehabilitation costs.
- 10,000 to over 100,000 bridges in the U.S. could be vulnerable to increasing peak river flows in the mid-and late-21st Century and strengthening bridges to be less vulnerable to climate change is estimated to cost approximately US$ 100 to US$ 250 billion.
- Increased heavy precipitation events could adversely affect mining, especially in Canada.
- Drier conditions would present challenges for manufacturing, especially in regions already experiencing water stress and could lead to increased conflicts over water between sectors and regions.
- Higher temperatures and humidity could lead to decreased productivity and increased occupational health risks.
- Insurance claims have and are expected to increase significantly due to climate change as more people and assets are located in areas of high risk, especially along coasts. Consequently, the price of insurance has increased in regions where the risk of loss and damage has increased.

SMALL ISLANDS[1]

SEA-LEVEL RISE, INUNDATION, AND SHORELINE CHANGE

Sea-level rise poses one of the most widely recognized climate change threats to low-lying coastal areas on islands and atolls. It is virtually certain that global mean sea-level rise rates are accelerating, with some areas increasing at much higher rates than others. Projected increases to the year 2100 superimposed on extreme sea-level events (e.g. swell waves, storm surges, El Niño-Southern Oscillation (ENSO) events) present severe flooding and erosion risks for low-lying coastal areas and atoll islands. Likewise, there is high confidence that storm surges and swell waves will degrade freshwater resources and that rising sea surface temperatures will result in increased coral bleaching and reef degradation. Given the dependence of island communities on coral reef ecosystems for a range of services including coastal protection, subsistence fisheries and tourism, there is high confidence that coral reef ecosystem degradation will negatively impact island communities and livelihoods.

- Over much of the 20th Century, global mean sea level rose at a rate between 1.3 to 1.7 mm per year. Since 1993 it has increased at a rate between 2.8 to 3.6 mm per year.
- Rates of sea-level rise have been significantly higher than the global average in some areas of the Indian Ocean and tropical Pacific.
- Rates up to four times the global average (approximately 12 mm per year) have been reported in the tropical western Pacific between 1993 and 2009. Although these rates are generally associated with climate phenomena such as El Niño-Southern Oscillation, they predispose island communities to higher vulnerability.
- Rates of relative sea-level rise at Funafuti Atoll, Tuvalu from 1950-2009 have been approximately three times higher than the global average and saline flooding of internal low-lying areas occurs regularly. This flooding is expected to become more frequent and extensive in the future.
- Sea-level rise will exacerbate existing stresses, such as vertical subsidence, engineering works, development activities and beach mining and will lead to increased coastal inundation and erosion.
- Extreme events that are superimposed on a rising sea-level baseline are the main threats to the habitability of low-lying islands as sea levels continue to rise.

CORAL REEFS AND COASTAL WETLANDS

Coral reefs are an important resource in small tropical islands and the well being of many island communities is linked to their ongoing functioning and productivity. Reefs play a significant role in supplying sediment to island shores and in dissipating wave energy thus reducing the potential for shore erosion. They also provide habitat for a host of marine species upon which many island communities are dependent for subsistence foods as well as underpinning beach- and reef-based tourism and economic activity. Increased coral bleaching and reduced reef calcification rates due to thermal stress and increasing CO_2 concentrations are expected to affect the functioning and viability of living reef systems. Globally, the incidence and implications of temperature-related coral bleaching in small islands is well documented. Combined with the effects of increasing ocean acidification, these stressors threaten the function and persistence of island coral reef ecosystems.

- Unprecedented bleaching events have been recorded in the remote Phoenix Islands (Kiribati) with nearly 100% coral mortality in the lagoon and 62%mortality on the outer leeward slopes of the otherwise pristine reefs of Kanton Atoll during 2002-2003.

1 Most of the information contained within this brief is directly from IPCC 2014 Working Group 2. In some situations further text that explains the implications has been added to clarify the expected impacts.

- In 2005, extensive bleaching was recorded at 22 sites around Rodrigues Island in the western Indian Ocean with up to 75% of the dominant species affected in some areas.
- Studies of the severe 1998 El Niño bleaching event in the tropical Indian Ocean showed reefs in the Maldives, Seychelles, and Chagos Islands were among the most impacted.
- In 2005 a reef survey around Barbados following a Caribbean regional bleaching event revealed the most severe bleaching ever recorded with approximately 70% of corals impacted.
- The loss of coral reef habitat has detrimental implications for coastal fisheries in small islands where reef-based subsistence and tourism activities are often critical to the wellbeing and economies of islands.
- Higher temperatures have also been implicated in negatively affecting the spawning of adult reef species.
- Like coral reefs, mangroves and sea grass environments provide a range of ecosystem goods and services. Both habitats play a significant role in the wellbeing of small island communities.
- Mangroves in particular serve a host of commercial and subsistence uses as well as providing natural coastal protection from erosion and storm events.
- Sea-level rise is reported as the most significant climate change threat to the survival of mangroves. For example, loss of mangroves at Hungry Bay, Bermuda has been attributed to sea-level rise and the inability of mangroves to tolerate increased water depth at the seaward margin.
- Over half of the world's coral reefs may experience harmfully frequent thermal stress by 2080.
- The likelihood of a severe mass coral bleaching events (occurring more than once every 5 years) is estimated to occur by 2074 in the Caribbean, 2088 in the western Indian Ocean, 2082 in the central Indian Ocean, 2065 in Micronesia, 2051 in the central Pacific, 2094 in Polynesia and 2073 in the eastern Pacific small islands regions.

ISLAND BIODIVERSITY AND WATER RESOURCES

Climate change impacts on terrestrial biodiversity on islands frequently interacts with several other drivers and falls into three general categories: (1) ecosystem and species compositional shifts; (2) altitudinal species range shifts and decline mainly due to temperature increase on high islands; and (3) exotic and pest species range expansion and increased invasions mainly due to temperature increase in high latitude islands. Due to the limited area and isolated nature of most islands, these effects are generally magnified compared to continental areas and may cause species loss especially in tropical islands with high numbers of endemic species. Sea-level rise has been observed to threaten the long-term persistence of freshwater-dependent ecosystems within low-lying islands such as in the Florida Keys. For example, on Sugarloaf Key, pine forest area declined from 88 to 30 hectares from 1935 to 1991 due to increasing salinization and rising ground water, with vegetation transitioning to more saline tolerant species such as mangroves.

- Increasing global temperatures will likely lead to altitudinal species range shifts and contractions within high islands with an upward creep of the tree line and associated fauna.
- There has been an altitudinal shift of 3.4 m per year for plant species on sub-Antarctic Marion Island.

- Fire-adapted grasses have expanded upward along a warming tropical elevation in Hawaii Volcano National Park over a 40-year period from 1966-67 to 2008.
- Reduction in the numbers and sizes of endemic populations caused by habitat contraction and changes in species composition in mountain systems may result in the demise and possibly extinction of endemic species.
- Altitudinal temperature change has been reported to influence the distribution for disease vectors such as mosquitoes, potentially threatening biota unaccustomed to such vectors.
- Rapidly growing demand, land use change, urbanization, and tourism are already placing significant strain on the limited freshwater reserves in small island environments. These issues will be exacerbated by decreasing rainfall and increasing temperatures.
- Rainfall records averaged over the Caribbean region for 100 years (1900-2000) show a consistent 0.18 mm per year reduction, a trend that is projected to continue and will impact rain-fed agriculture.
- In contrast, rainfall in the Seychelles has shown an increase, but is mostly related to ENSO variability.
- Long-term reduction in streamflow (median reduction of 22-23%) has been detected in the Hawaiian Islands over the period 1913-2008, resulting in reduced freshwater availability for both human use and ecological processes.
- Increasing sea levels will likely lead to more saline (sea-water) intrusion into fresh groundwater reserves with wave overtopping and wash-over being major agents of intrusion. For instance, on Pukapuka Atoll, Cook Islands, storm surge over-wash caused the freshwater lenses to become immediately brackish in 2005 and it took 11 months to recover to levels appropriate for humans.
- It is estimated that 37 island endemic species in the tropical Pacific region risk complete inundation due to a 1 meter rise in sea levels.
- The movement of aquatic and terrestrial invasive fauna within and across regions will almost certainly exacerbate the threat posed by climate change in island regions, and could impose significant environmental, economic and social costs. For example, the invasion of the Indo-Pacific lionfish (*Pterois volitans*) into Caribbean Sea has led to a significant decline in marine herbivores and increases in algal dominance in coral and sponge communities.

ISLAND SETTLEMENTS AND TOURISM

The majority of settlement, infrastructure, and development are located on lowlands along the coastal fringe of small islands. In the case of atoll islands, all development and settlement are essentially coastal. It follows that populations, infrastructure, agricultural areas, and fresh groundwater supplies are all vulnerable to extreme tides, wave and surge events, and sea-level rise. Population drift from outer islands or from inland, together with rapid population growth in main centers and a lack of accommodation space drives growing populations into ever more vulnerable locations. Additionally, without adequate resources and planning, engineering solutions such as shoreline reclamation also place communities and infrastructure in positions of increased risk.

- Many socially vulnerable island communities are in places of high risk and these pre-existing conditions of vulnerability add to the threat of climate change.
- The issue of 'coastal squeeze' remains a concern for many small islands as there is a constant struggle to manage the requirements for physical development against the need to maintain ecological balance.

- In some places like Martinique in the Caribbean, physical infrastructure prevents the beach and wetlands from retreating landward in response to increased rates of coastal erosion.
- Moreover, intensive coastal development in the limited coastal zone combined with population growth and tourism has placed great stress on the coast of some islands and has resulted in dense aggregations of infrastructure and people in potentially vulnerable locations.
- Tourism is an important weather- and climate-sensitive sector on many small islands and severe weather-related events can deter visitation, as has been shown in the past with heavy, persistent rainfall in Martinique and Hurricanes in Anguilla.
- Beach erosion and coral bleaching have also been found to negatively impact the perception of destination attractiveness in various locations, for example in Martinique and Barbados and Bonaire, and especially for dive tourists.
- Freshwater is limited on many small islands, and changes in its availability or quality during drought events linked to climate change have adverse impacts on tourism operations. Tourism is a seasonally significant water user in many island destinations and in times of drought, concerns over limited supply for residents and other economic activities become heightened.
- It is estimated that 49-60% of tourist resort properties in the Caribbean would be damaged from 1 meter of sea-level rise, potentially transforming the competitive position and sustainability of coastal tourism destinations in the region.

HUMAN HEALTH

The effects of climate change on human health are expected to exacerbate existing health risks, especially in the most vulnerable communities where the burden of disease is already high. Most small island nations are in tropical areas with weather conducive to the transmission of diseases and currently suffer from climate-sensitive health problems, including morbidity and mortality from extreme weather events, certain vector and food- and water-borne diseases. Extreme weather and climate events such as tropical cyclones, storm surges, flooding, and drought can have both short- and long-term effects on human health, including drowning, injuries, increased disease transmission, and health problems associated with deterioration of water quality and quantity.

- Leptospirosis incidence is affected by climatic changes and can increase substantially during La Niña events (negative phase of ENSO), as has been shown in places such as Guadeloupe and Trinidad.
- The Caribbean has been identified as a 'highly endemic zone for leptospirosis' with Trinidad and Tobago, Barbados, and Jamaica representing the highest annual incidence (12, 10 and 7.8 cases per 100,000 population) in the world with only the Seychelles being higher (43.2 per 100,000 population).
- In Pacific islands the incidence of diseases such as malaria and dengue fever has been increasing, especially endemic dengue in Samoa, Tonga and Kiribati. Incidence of these diseases is projected to increase in the future.
- Dengue incidence is also a major health concern in other small island countries, including Trinidad and Tobago, Singapore, Cape Verde, Comoros and Mauritius. It is expected to increase in the future.
- Climate change will likely exacerbate current stressors to human health, such as lack of access to adequate, safe, freshwater and adequate nutrition.

- Many of the anticipated health effects of climate change are expected to be indirect, connected to the increased stress and declining well-being that comes with property damage, loss of economic livelihood and threatened communities.
- More intense droughts and storms could lead to fresh water scarcity and result in the deterioration of sanitation standards and hygiene in places such as the Caribbean and Pacific and Indian oceans. This could then lead to increased exposure to a range of health risks including communicable (transmissible) diseases.
- Warming water temperatures associated with climate change could increase the incidence of Ciguatera fish poisoning, the most common non-bacterial food-borne illness associated with consumption of fish, in tropical regions such as the island regions of the Caribbean (e.g., Lesser Antilles), Pacific (e.g., Tokelau, Tuvalu, Kiribati, Cook Islands and Vanuatu), the Mediterranean, and the Canary Islands in the Atlantic.
- The influence of climatic factors on malaria vector density and parasite development is well established, and while the present incidence of malaria on small islands is not reported to be high, favorable environmental and social circumstances for the spread of the disease are present in some island regions and are expected to increase with projected changes in climate in Papua New Guinea, Guyana, Suriname, and French Guyana.

ISLAND ECONOMIES

The economic vulnerabilities of small islands states are often the result of a high degree of exposure to economic conditions outside of their control, and are exacerbated by dependence on a narrow range of exports and strategic imports, such as food and fuel. This leads to economic volatility, which can be exacerbated by climate change. There are also some economic downsides associated with the small size and insularity of many small islands. For instance, small geographic area and population can lead to high overhead cost per capita, particularly in infrastructural outlays. This is of major relevance to climate change adaptation that often requires upgrades and redesign of island infrastructure. Insularity leads to high cost of transport per unit, associated with purchases of raw materials and industrial supplies in small quantities, and sales of locally produced products to distant markets. These disadvantages are associated with the inability of small islands to reap the benefits of economies of scale resulting in a high cost of doing business in small islands. High costs are also associated with extreme events such as hurricanes and droughts. On small islands such events often disrupt most of the territory, especially on single-island states, and have a very large negative impact on GDP, in comparison with larger and more populous states where individual events generally only affect a small proportion of the country and have a small impact on their GDP. For instance, the top ten most GDP-impacted areas due to sea-level rise are small islands from the Pacific (Federated States of Micronesia, Palau, Marshall Islands, Nauru) and Caribbean (Bahamas). Moreover, many small islands are highly dependent on a limited number of climate-sensitive economic sectors such as tourism, fisheries, and agricultural crops. Simply put, the damage costs related to climate change for small island states are enormous in relation to the size of their economies.