IPCC THIRD ASSESSMENT REPORT WORKING GROUP II – IMPACTS, ADAPTATION, AND VULNERABILITY

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KEY MANDATE

- *This report assesses the vulnerability of ecological systems, socio-economic sectors, and human health to climate change, as well as potential impacts of climate change on these system.*

- *It also examines the feasibility of adaptation to enhance the positive effects of climate change and ameliorate negative effects.*

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KEY FINDINGS

- Climate change will have beneficial and adverse effects on environmental and socio-economic systems. For larger changes, the more adverse effects will predominate;
- Climate change will impact more negatively on developing countries than developed countries, and more on the poor than the wealthy people;
- Adaptation has the potential to reduce the adverse effects of climate change, and can sometimes produce ancillary benefits, but it will not prevent all damages;
- Developing countries will have less adaptive capacity than developed countries;
- Sea-level rise from climate change poses a high threat to human settlements, and is very difficult to adapt to;
- Climate adaptation and sustainability goals can be jointly advanced by changes in policies that lessen pressure on resources, improve management of environmental risks, and enhance adaptive capacity.

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CONTENTS OF THE REPORT

- Scenarios used in the studies;
- Impacts on natural and human systems;
- Regional adaptive capacity, vulnerability and key concerns;
- Adaptation, sustainable development and equity;
- Global issues and synthesis;
- Future work.

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SCENARIOS USED IN THE STUDIES

- Emission scenarios of the Special Report on Emission Scenarios (SRES);
- Socio-economic, land-use, and environmental scenarios;
- Climate scenarios;
- Sea-level rise scenarios.

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Emission scenarios of the Special Report on Emission Scenarios (SRES)

- A1: rapid economic growth, global population that peaks in mid-century and declines thereafter, rapid introduction of new and efficient technologies, and convergence and capacity building among regions. Three sub-groups:
  - A1FI, fossil intensive energy dominant;
  - A1T, non-fossil energy favoured; and
  - A1B, balanced used of fossil and other energy sources.
- A2: a very heterogeneous world, self-reliance and preservation of local identities, economic development is primarily regionally oriented, technological change is fragmented and slower than other scenarios;
- B1: similar to A1, but economic structures become more a service and information economy;
- B2: emphases on local solutions to economic, social and environmental sustainability, and oriented towards environmental protection and social equity.

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Socio-economic, land-use, and environmental scenarios

- Non-climate scenarios describing future socio-economic, land-use and environmental changes are important for characterising the sensitivity of systems to climate change, their vulnerability, and the capacity for adaptation;
- Such scenarios have only recently been widely adopted in impact assessments alongside climate scenarios;
- Socio-economic scenarios have been used more extensively for projecting greenhouse gas emissions than for assessing climate vulnerability and adaptive capacity;
- Most socio-economic scenarios identify several topics or domains, such as population or economic activity, as well as background factors such as governance, social values, and technological changes;
- A great diversity of land-use scenarios have been constructed; however, most of them do not address climate change issues explicitly;
- Environmental scenarios refer to changes in environmental factors other than climate that will occur in the future regardless of climate change; they are progressively being incorporated in integrated assessment methods.

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Climate scenarios

Three main types of climate scenarios have been employed in impact assessments:

- **Incremental scenarios**: these are simple adjustments of the baseline climate according to anticipated future changes, and are mostly used for testing system sensitivity to climate;
- **Analogue scenarios**: these are based on historical climate changes or from data in other regions. They are used to provide insights into impacts of climate conditions outside the present-day range, but are not widely used nowadays;
- **Climate model-based scenarios**: These scenarios use outputs from general circulation models (GCMs) and usually are constructed by adjusting a baseline climate by absolute or proportional changes between the simulated present and future climate;

Most recent impact studies have constructed scenarios on the basis of transient GCM outputs, although some still apply earlier equilibrium results.

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Sea-level rise scenarios

- Sea-level rise scenarios are required to evaluate a diverse range of threats to human settlements, natural ecosystems, and landscapes in the coastal zone;
- Relative sea-level scenarios (i.e. sea-level rise with reference to movements of the local land surface) are of most interest for impact and adaptation assessments;
- Although some components of future sea-level can be modelled regionally by using coupled ocean-atmosphere models, the most common method of obtaining scenarios is to apply global mean estimates from simple models;
- Changes in the occurrence of extreme events such as storm surges can be investigated by superimposing historically observed events onto a rising mean sea level;
- Recently, some studies have begun to express future sea-level rise in probabilistic terms, enabling rising levels to be evaluated in terms of the risk of exceeding a critical threshold of impact.

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IMPACTS ON NATURAL AND HUMAN SYSTEMS

- Water resources;
- Agriculture and food security;
- Terrestrial and freshwater ecosystems;
- Coastal zones and marine ecosystems;
- Human settlements, energy, and industry;
- Insurance and other financial services;
- Human health.

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Impacts on natural and human systems: Water Resources

- Climate change challenges existing water resources management practices by adding stress and uncertainty;
- Widespread accelerated glacier retreat and shifts in the timing of stream flow associated with observed increase in temperature significantly affect water supply strategies;
- Peak stream flow will move from spring to winter in many areas where snowfall currently is an important component of the water balance;
- Water quality generally will be degraded by higher water temperature;
- Flood magnitude and frequency are likely to increase in most regions, and low flows are also likely to decrease in many regions;
- Non-climate changes (such as population growth and development) may have a greater impact on water resources than climate change.

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Impacts on natural and human systems: Agriculture and Food Supply

- Degradation of soil and water resources is one of the major challenges for global agriculture;
- The impact of climate change on crop yields varies widely, depending on the species, cultivar, soil conditions, treatment of CO_2 effects, and locations;
- A few degrees of projected warming will lead to increases in temperate crop yields; at larger amounts of warming, most temperate crop yield responses become negative;
- In the tropics, where some crops are near their maximum temperature tolerance and where dry-land agriculture predominates, yields will decrease with even minimal changes in temperature;
- Advances in research since the Second Assessment Report (SAR) on the direct effects of CO_2 on crops suggest that beneficial effects may be greater under certain stress conditions, including warmer temperature and droughts.
- Extreme events are likely to increase heat stress-related livestock deaths, although winter warming may reduce deaths at temperate latitudes.

Impacts on natural and human systems: Terrestrial and Freshwater Ecosystems

- Recent modelling studies continue to show potential for significant disruption of ecosystems under climate change;
- Populations of many species are already threatened and are expected to be placed at greater risk by climate change;
- However, vegetation distribution models since the SAR suggest that mass ecosystem or biome movement is most unlikely to occur;
- Increasing CO_2 concentration will increase net primary productivity in most systems, whereas increasing temperature may have positive or negative effects;
- In arid or semi-arid areas (rangelands, dry forests/woodlands) where climate change is likely to decrease available soil moisture, productivity is expected to decrease;
- Climate change will lead to pole-ward movement of the southern and northern boundaries of fish distributions, loss of habitat for cold-water fish, and gain in habitat for warm-water fish;
- Contrary to the SAR, global timber market studies suggest that climate change will increase global timber supply.

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Impacts on natural and human systems: Coastal Zones and Marine Ecosystems

- Global climate change will result in increases in sea-surface temperature and sea level, decreases in sea-ice cover, and changes in salinity and ocean circulation;
- Many coastal areas are already experiencing increased levels of sea flooding, accelerated coastal erosion, and seawater intrusion into freshwater sources. These processes will be exacerbated by sea-level rise;
- Low-latitude tropical and subtropical coastlines, particularly in areas where there is significant human population pressure, are highly susceptible to climate change impact;
- High-latitude (polar) coastlines also are susceptible to climate warming impacts, although these impacts have been less studied;
- Coastal ecosystems such as coral reefs and atolls, salt marshes and mangrove forests will be impacted by sea-level rise, warming sea-surface temperature, and changes in storm frequency and intensity;
- If El Niños increase in frequency, plankton biomass and fish larvae abundance will decline and adversely impact fish, marine mammals, seabirds, and ocean biodiversity.

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Impacts on natural and human systems: Human Settlements, Energy, and Industry

- The most widespread direct risk to human settlements from climate change is flooding and landslides, driven by projected increases in rainfall intensity and, in coastal areas, sea-level rise;
- Population may be directly affected through extreme weather, changes in health status, or migration;
- A serious threat is from tropical cyclones which may increase in peak intensity in a warmer world;
- Global warming is expected to result in increased energy demand for space cooling and in decreased energy use for space heating, but the net effect is scenario- and location-dependent;
- Industrial, transportation, and commercial infrastructure is generally vulnerable to the same hazards as settlement infrastructure.

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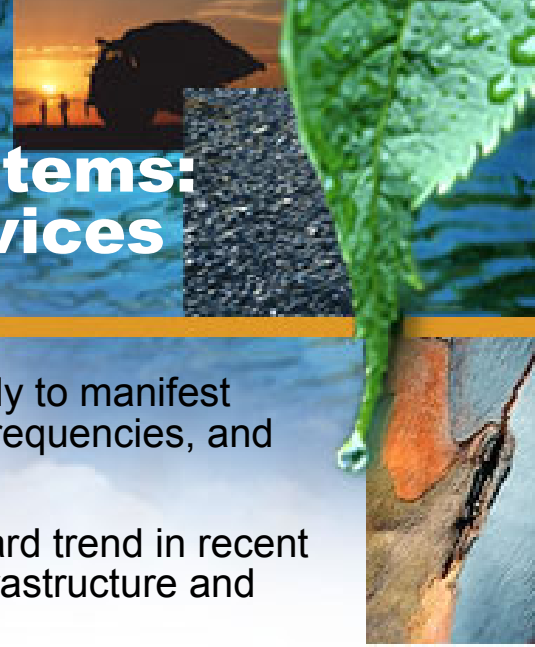
Impacts on natural and human systems: Insurance and other Financial Services



- The effects of climate change on financial services sector are likely to manifest themselves primarily through changes in the spatial distribution, frequencies, and intensities of extreme weather events;
- The costs of extreme weather events have exhibited a rapid upward trend in recent decades, despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness;
- Part of the observed upward trend in disaster losses is linked to socio-economic factors such as population growth and increased wealth, and part is linked to climate factors such as changes in precipitation, flooding, and droughts;
- Recent cases have shown that weather-related losses can stress insurance companies to the point of impaired profitability, consumer price increases, and elevated demand for publicly funded compensation and relief;
- The financial services sector as a whole is expected to be able to cope with the impacts of future climate change, although low-probability, high-impact events or multiple closely spaced events may severely affect parts of the sector;
- Equity issues and development constraints will arise if weather-related risks become uninsurable, insurance prices increase, or the availability of insurance or financing becomes limited.

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Impacts on natural and human systems: Human Health

- Global climate change will have diverse impacts on human health – some positive, most negative;
- Changes in the frequencies of extreme heat and cold, floods and droughts will affect population health directly;
- Other health impacts will result from the impacts of climate change on ecological and social systems, including infectious disease, local food production, population displacement and economic disruption;
- If heat waves increase in frequency and intensity, the risk of death and serious illness will increase, principally in older age groups and the urban poor;
- Climate change will decrease air quality in urban areas with air pollution problems;
- Higher temperatures, changes in precipitation and climate variability will extend the range and season for some infectious diseases;
- Changes in food supply resulting from climate change could affect the nutrition and health of the poor in some regions of the world.

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REGIONAL ADAPTIVE CAPACITY, VULNERABILITY AND KEY CONCERNS

- Africa;
- Asia;
- Australia and New Zealand;
- Europe;
- Latin America;
- North America;
- Polar regions;
- Small Island States.

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Adaptive capacity, vulnerability and key concerns: Africa

- Adaptive capacity of human systems is low due to lack of resources; vulnerability is high as a result of heavy reliance on rain-fed agriculture;
- Grain yields are projected to decrease, diminishing food security;
- Major rivers are highly sensitive to climate variation;
- Extension of ranges of vector-borne infectious diseases will adversely affect human health;
- Desertification will be exacerbated by reductions in average annual rainfall, runoff and soil moisture;
- Increases in droughts, floods, and other extreme events will add to stresses on water resources, food security, health and development;
- Significant extinctions of plant and animal species are projected;
- Coastal settlements will be adversely impacted by sea-level rise through inundation and coastal erosion.

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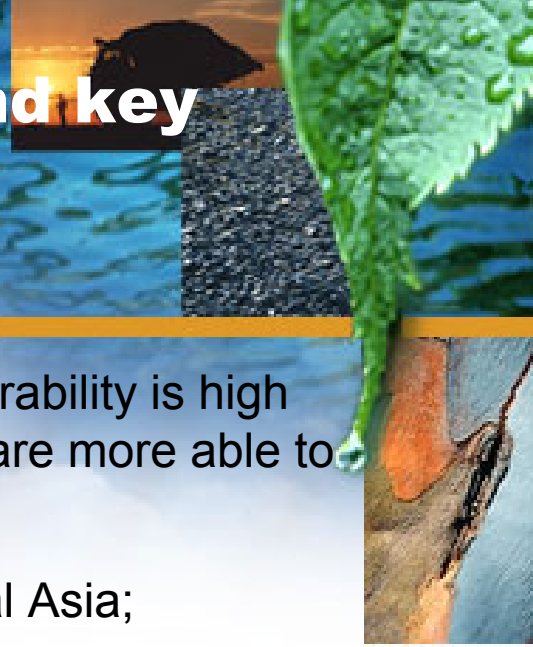
Adaptive capacity, vulnerability and key concerns: Asia



- Adaptive capacity of human systems is low and vulnerability is high in the developing countries; the developed countries are more able to adapt and less vulnerable;
- Extreme events will increase in temperate and tropical Asia;
- Decreases in agricultural productivity and aquaculture will occur in many countries; with increases in northern areas;
- Human health will be threatened by vector-borne infectious diseases and heat stress in parts of Asia;
- Sea-level rise and increases in tropical cyclones could displace tens of millions of people in low-lying coastal areas;
- Climate change will increase energy demand;
- Climate change will exacerbate threats to biodiversity due to land-use change and population pressure.

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Adaptive capacity, vulnerability and key concerns: Australia and New Zealand

- Adaptive capacity of human systems is generally high, but some indigenous peoples may have low capacity to adapt and consequently high vulnerability;
- The net impact on some crops may initially be beneficial, but this balance is expected to become negative with further climate change;
- Water is likely to be a key issue due to projected overall drying trends and change to a more El Niño-like average state;
- Increases in the intensity of heavy rains and cyclones will alter the risks to life, property and ecosystems from flooding, storm surges and wind damage;
- Some species could become endangered or extinct;
- Australian ecosystems that are particularly vulnerable include coral reefs, and arid and semi-arid habitats;
- Freshwater wetlands are vulnerable.

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Adaptive capacity, vulnerability and key concerns: Europe

- Adaptive capacity of human systems is generally high; southern Europe and the European Arctic are more vulnerable than other parts;
- Water availability and soil moisture are likely to decrease in southern Europe;
- Half of alpine glaciers and large permafrost areas could disappear by end of the 21st century;
- River flood hazard will increase across much of Europe;
- There will be some broadly positive effects on agriculture in northern Europe; productivity will decrease in southern and eastern Europe;
- Upward and northward shift in biotic zones will take place; loss of important habitats will threaten some species;
- Higher temperatures and heat waves may affect summer and winter tourism.

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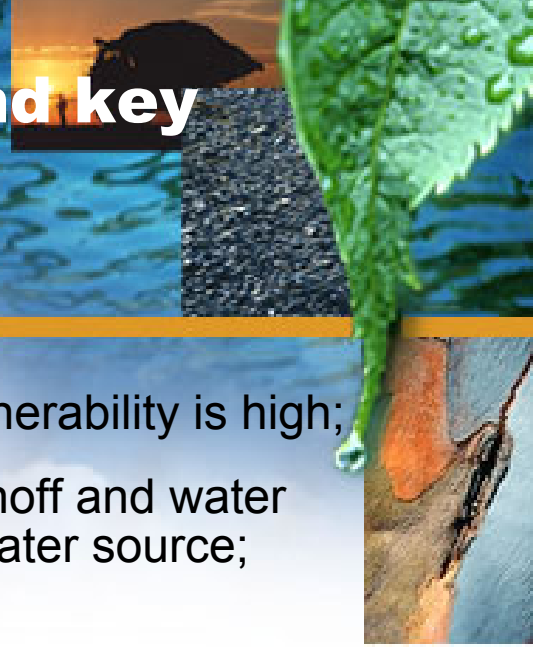
Adaptive capacity, vulnerability and key concerns: Latin America



- Adaptive capacity of human systems is low, and vulnerability is high;
- Loss and retreat of glaciers will adversely impact runoff and water supply in areas where glacier melt is an important water source;
- Floods and droughts will become more frequent;
- Increases in intensity of tropical cyclones will alter the risks to life, property, and ecosystems;
- Yields of important crops are projected to decrease in many locations, even when the effects of CO_2 are taken into account;
- The distribution of vector-borne infectious diseases will expand pole-ward and to higher elevations;
- Coastal human settlements will be negatively affected by sea-level rise;
- The rate of biodiversity loss will increase.

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Adaptive capacity, vulnerability and key concerns: North America

- Adaptive capacity of human systems is generally high and vulnerability is low, but some communities are more vulnerable;
- Some crops will benefit from modest warming accompanied by increasing CO_2, but effects will vary among crops and regions;
- However, benefits for crops will decline at an increasing rate and possibly become a net loss with further warming;
- Some natural ecosystems will be at risk and effective adaptation is unlikely;
- Sea-level rise will have a negative impact, particularly in Florida and the U.S. Atlantic coast;
- Weather-related insured losses and disaster relief payments have been increasing;
- Vector-borne diseases may expand their ranges in North America.

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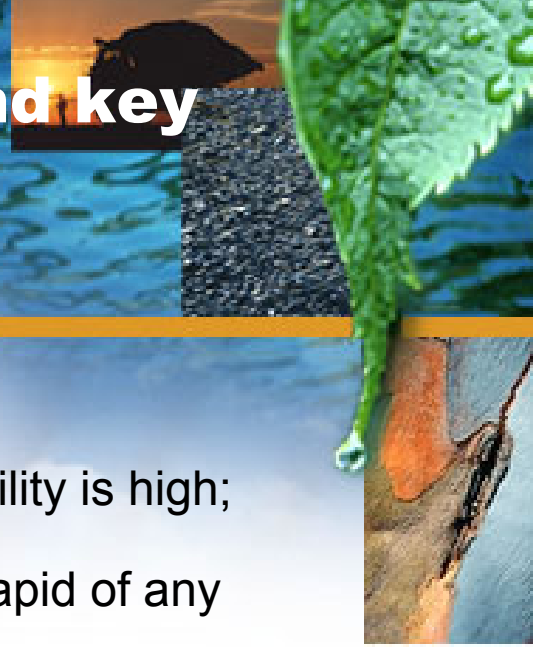
Adaptive capacity, vulnerability and key concerns: Polar Regions



- Adaptive capacity of ecosystems is low, and vulnerability is high;
- Climate change in the regions is large and the most rapid of any region on Earth, and will cause major impacts;
- Climate change has altered the distribution and abundance of species in these regions;
- Some polar ecosystems may adapt through eventual replacement by migration of species, and changing species composition.

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Adaptive capacity, vulnerability and key concerns: Small Island States

- Adaptive capacity of human systems is generally low, and vulnerability is high;
- Small island states are likely to be among the countries most seriously impacted by climate change;
- The projected sea-level rise will have high negative impacts, and will require high expenditure to respond and adapt to these changes;
- Coral reefs will be negatively affected by bleaching and by reduced calcification rates due to higher CO_2 levels;
- Declines in coastal ecosystems will negatively impact reef fish and threaten reef fisheries;
- Limited arable land, and soil salinisation, makes agriculture in small island states highly vulnerable to climate change;
- Tourism will face severe disruption.

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ADAPTATION, SUSTAINABLE DEVELOPMENT AND EQUITY

- Adaptation and adaptive capacity in sectors:
  - Water Resources;
  - Ecosystems and their services;
  - Coastal zones;
  - Human settlements, energy, and industry;
  - Insurance and other financial sectors;
  - Human health.
- Relationship between adaptation, sustainability development and equity.

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Adaptation and adaptive capacity in sectors: Water Resources

- Climate change is just one of numerous pressures facing water management;
- Adaptation can involve management on the supply side (e.g. altering infrastructure or institutional arrangements) and on the demand side. Numerous no-regret options exists, which will generate net social benefits regardless of climate change;
- Estimates of the economic costs of climate change impacts on water resources depend strongly on assumptions made about adaptation; economically optimum adaptation may be prevented by constraints associated with uncertainty, institutions, and equity;
- Ability to adapt is affected by institutional capacity, wealth, management philosophy, planning time scale, organisational and legal framework, technology, and population mobility;
- Water resource conservation needs research and management tools aimed at adapting to uncertainty and change, rather than improving climate scenarios.

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Adaptation and adaptive capacity in sectors: Ecosystems and their services

- Adaptation to losses in managed ecosystems may be possible; adaptation to losses in wild ecosystems and biodiversity may be difficult or impossible;
- There is considerable capacity for adaptation in agriculture, but adaptation to evolving climate change and inter-annual variability is uncertain;
- In countries where rangelands are important, lack of infrastructure and investment in resource management limit the options for adaptation;
- Commercial forestry is adaptable, reflecting a history of long-term management decisions under uncertainty; adaptations are expected in land-use management (species-selection silviculture) and product management (process-marketing);
- Adaptation in developed countries will be easier, while that in developing countries will be more difficult.

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Adaptation and adaptive capacity in sectors: Coastal Zones

- Without adaptation, the consequences of global warming and sea-level rise will be disastrous in coastal zones;
- Coastal adaptation entails more than just selecting one of the technical options to respond to sea-level rise; it is a complex and iterative process rather than a single choice;
- Adaptation options are more acceptable and effective when they are incorporated into land-use planning, disaster management, and sustainable development strategies;
- Adaptation choices will be conditioned by existing policies and development objectives, requiring researchers and policy makers to work towards a commonly acceptable framework for adaptation;
- Enhancing resilience is a particularly appropriate adaptive strategy given future uncertainties and the desire to maintain development opportunities.

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Adaptation and adaptive capacity in sectors: Human Settlement, Energy, and Industry

- Many adaptation options are available to reduce the vulnerability of settlements;
- Lack of financial resources, weak institutions, and inadequate or inappropriate planning are major barriers to adaptation in human settlements;
- Successful environmental adaptation cannot occur without locally based, technically competent, and politically supported leadership;
- Uncertainty with respect to capacity and the will to respond hinder the assessment of, and progress in, adaptation initiatives.

(Note: This Working Group II Report places more emphasis on human settlement issues; further information on energy and industry is provided in the Working Group III Report.)

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Adaptation and adaptive capacity in sectors: Insurance and other Financial Services

- Adaptation in financial and insurance services in the short term is likely to involve coping with changes in frequencies and intensities of extreme weather events;
- Increasing risk could lead to the development of new financial risk management products;
- Financial services have adaptability to external shocks, but there is little evidence that climate change is being incorporated into investment decisions;
- The adaptive capacity of the financial sector is influenced by regulatory involvement, the ability of firms to withdraw from at-risk markets, and fiscal policies regarding catastrophe reserves;
- Adaptation will involve changes in the role of private and public insurance.
- Insurers' adaptations include raising prices, non-renewal of policies, etc., - actions that can seriously affect investment in developing countries.

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Adaptation and adaptive capacity in sectors: Human Health

- Adaptation involves changes in society, institutions, technology or behaviour to reduce potentially negative impacts or increase positive ones;
- There are numerous adaptation options, which may occur at the population, community, or personal levels;
- The most important and cost-effective adaptation measure is to rebuild public health infrastructure which has declined in much of the world in recent years.
- Many diseases and health problems that may be exacerbated by climate change can be effectively prevented with adequate financial and human public health resources;
- Adaptation effectiveness will depend on timing, quality of health infrastructure, and pre-existing burden of disease.

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Relationship between adaptation, sustainable development and equity

- Activities required for enhancement of adaptive capacity are essentially equivalent to those promoting sustainable development;
- Enhancement of adaptive capacity is a necessary condition for reducing vulnerability, particularly for the most vulnerable groups;
- Inclusion of climate risks in the design and implementation of development initiatives is necessary to reduce vulnerability and enhance sustainability;
- Climate adaptation and sustainability goals can be jointly advanced by changes in policies that lessen pressure on resources, improve management of environmental risks, and enhance adaptive capacity;
- Climate adaptation and equity goals can be jointly pursued through initiatives that promote the welfare of the poor – e.g. by improving food security, access to water and health care, and access to other resources.

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GLOBAL ISSUES AND SYNTHESIS

- Detection of climate impacts;
- Major reasons for concern;
  - Impacts on unique and threatened systems;
  - Aggregated impacts;
  - Distribution of impacts;
  - Extreme weather events;
  - Large-scale singular events.

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Detection of climate impacts

- Observational evidence indicates that climate change in the 20th century already has affected a diverse set of physical and biological systems;
- The presence of multiple causal factors (e.g. land-use change, pollution) makes attribution of many observed impacts to climate change a complex challenge;
- Nonetheless, based on observed changes, there is high confidence that 20th century climate change has had a discernible impact on many physical and biological systems;
- High sensitivity of biological systems to long-term climate change is also demonstrated by paleo-records;
- Signals of climate change impacts are clearer in physical and biotic systems than in social and economic systems, which are simultaneously undergoing many complex non-climate related stresses, such as population growth and urbanisation.

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Major reasons for concern

- *Impacts on unique and threatened systems*, including: critically endangered species and species with restricted habitat requirements;
- *Aggregated impacts*: with a small temperature increase, aggregated impact could be plus or minus a few percent of GDP. With medium to higher temperature increases, benefits tend to decrease and damages increases, so the net change in economic welfare becomes negative;
- *Distribution of impacts*: Developing countries are expected to suffer more adverse impact than developed countries;
- *Extreme weather events*: the large damage potential of extreme events arises from their severity, suddenness and unpredictability, which make them difficult to adapt to;
- *Large-scale singular events*: these have the potential to trigger large-scale changes in Earth systems that could have severe consequences at regional or global scales.

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FUTURE WORK

Although progress has been made, considerable gaps of knowledge remain regarding sensitivity, adaptability, and vulnerability of physical and social systems to climate changes. Further work is required in:

- Quantitative assessment of the sensitivity, adaptive capacity, and vulnerability of natural and human systems to climate change, particularly those related to extreme climate events;
- Assessment of possible thresholds at which strongly discontinuous responses to projected climate change will be triggered;
- Understanding dynamic responses of ecosystems to multiple stresses, including climate change, at global, regional and finer scales;
- Development of approaches to adaptation responses, estimation of the effectiveness and costs of adaptation options;
- Improving tools for integrated assessment;
- Use of scientific information on impacts, vulnerability and adaptation in decision making processes, risk management, and sustainable development initiatives;

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