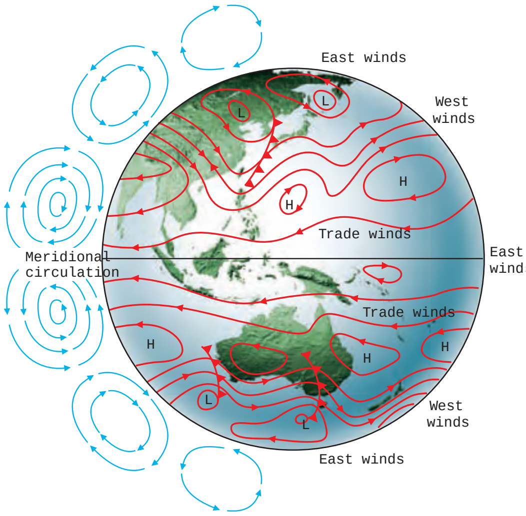
Issue Brief

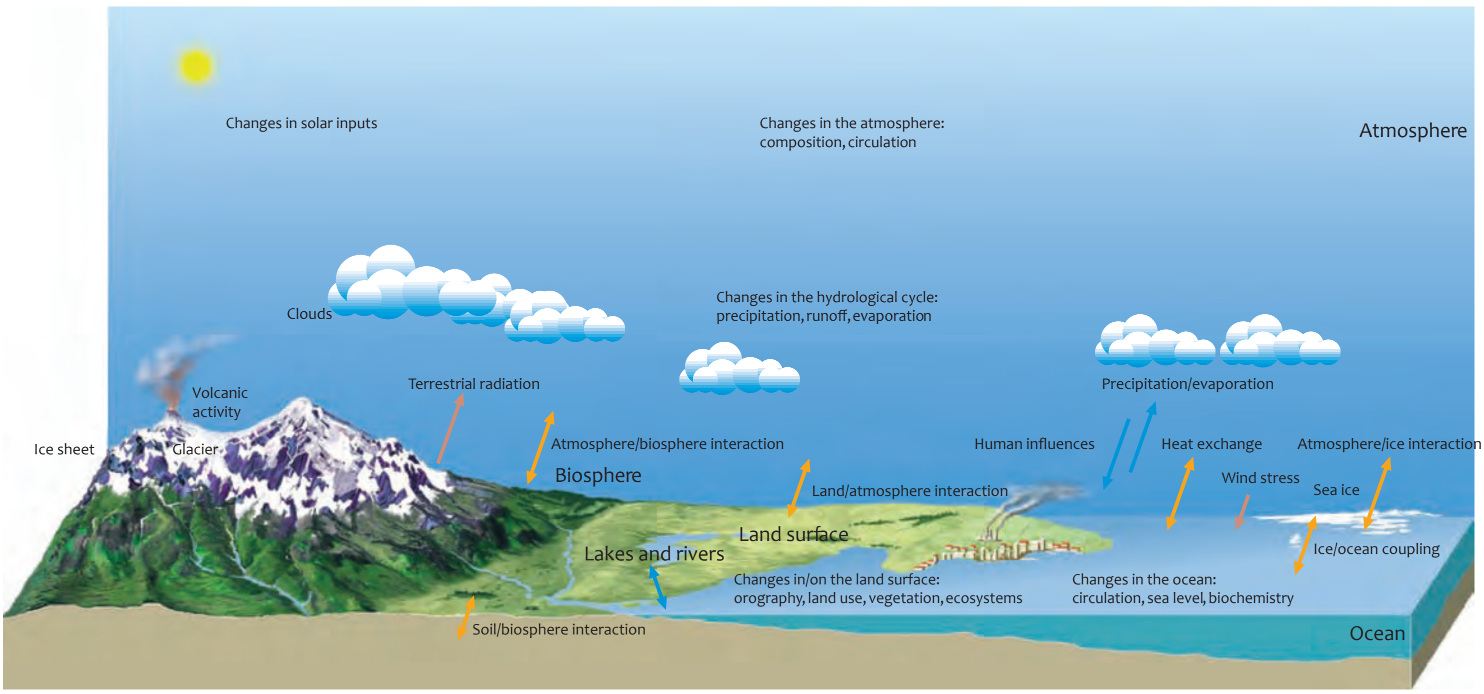
Climate Change: Impacts on Global Agriculture



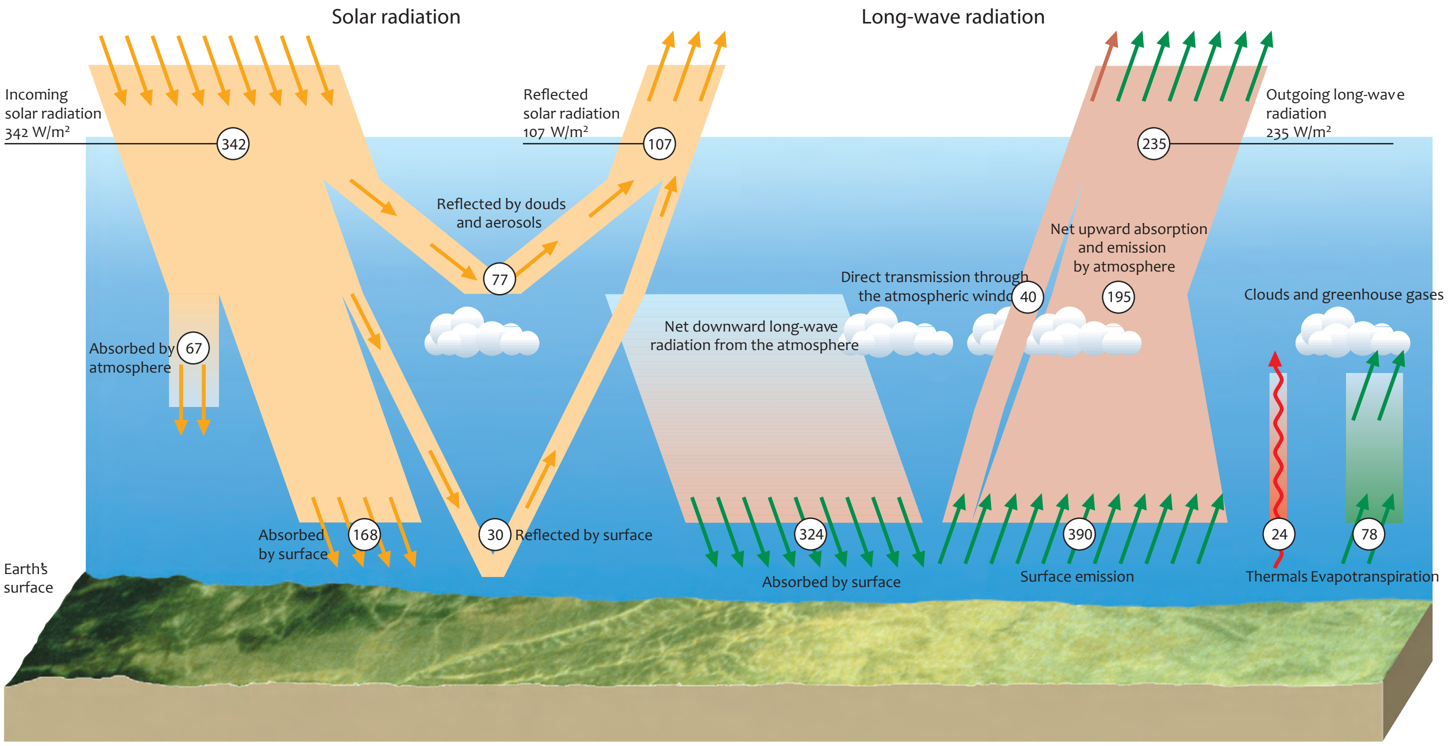
At the simplest level, weather is what is happening to the atmosphere at any given time. Climate is a measure of what to expect in any month, season or year, and is arrived at using statistics built up from observations over many years. All aspects of the Earth's climate – the wind, rain, clouds and temperature – are the result of energy transfers and transformations within the atmosphere, at the Earth's surface and in the oceans.

The Sun's energy is a power source that drives the Earth's climate system. Our knowledge of the climate system is based on the physical laws of emission and absorption of electromagnetic radiation and how these relate to incoming solar radiation and outgoing terrestrial radiation. The other part of our understanding of the radiation 'budget' is how atmospheric gases and other components of the climate system (like the Earth's surface, clouds, aerosols and particulates) absorb and re-radiate radiation. At a fundamental level, the system is dependent on how much solar energy is absorbed by the Earth and how this energy is re-radiated at longer wavelengths to space in the form of infrared terrestrial radiation. Over time, the Earth's climate system remains largely stable, because the energy received is equal to that lost. The Earth only absorbs about 70 percent of the radiation from the Sun, while the rest is reflected back into space.

In theory, the Earth's average surface temperature might be expected to be around -19°C, much lower than the observed value of about 14°C. The reason for this difference is the Earth's atmosphere, which itself absorbs and re-emits energy. This naturally occurring process is commonly known as the Greenhouse Effect, which plays a significant role in setting the Earth's surface and atmospheric temperatures. Water vapor is the most important greenhouse gas.



The climate system is made up of the processes and interactions of the Earth's atmosphere, oceans, land surfaces, ice sheets, and its plants and animals which use the incoming radiation from the Sun, which in turn is balanced by heat radiated back to space.



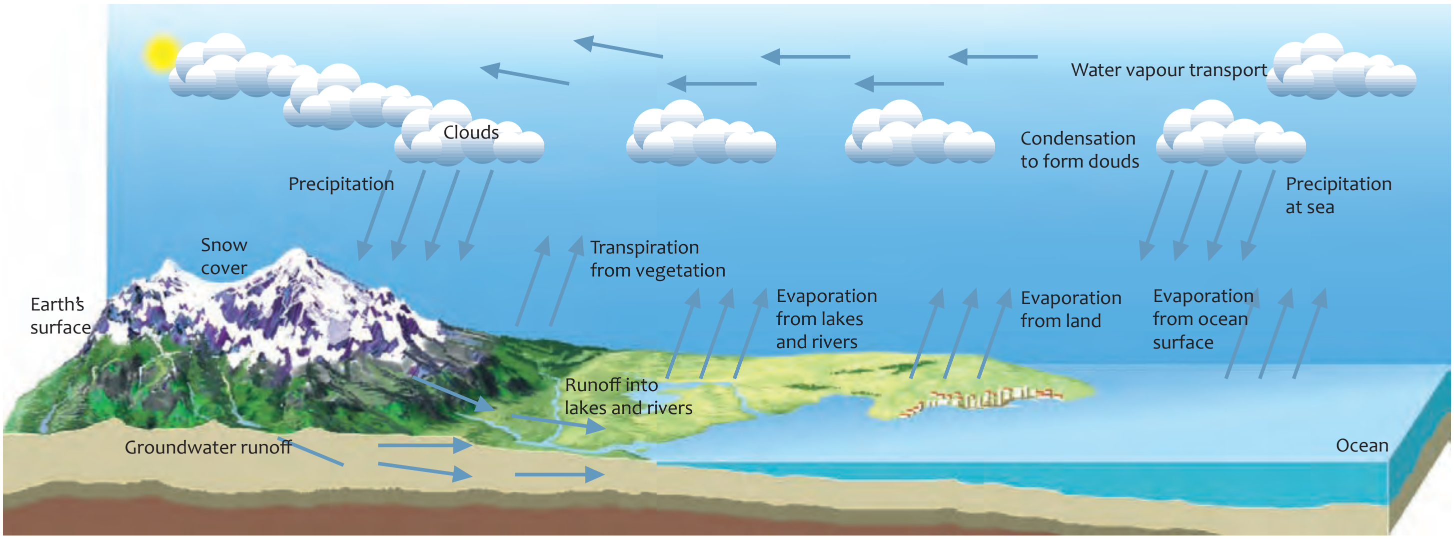
However, because of the abundance of water, there is virtually no direct human influence on the amount in the atmosphere. In contrast, human activities alter the concentrations of greenhouse gases such as CO2, Methane, n2o, and the release of chlorofluorocarbons (CFCs). As the concentrations of greenhouse gases in the atmosphere increase, the amount of solar energy absorbed at the surface remains almost unchanged, but the lower levels of the atmosphere absorb more outgoing terrestrial radiation. This warms the lower atmosphere a little, which then emits a little more infrared radiation, both upwards and downwards. As incoming and outgoing radiation are balanced, the surface and the lower atmosphere warm, and the upper atmosphere cools. In consequence, the surface warms up and the atmosphere, as a whole, effectively radiates from a higher and cooler level.

Hydrological cycle

The continual recycling of water between the oceans, land surface, underground aquifers, rivers and the atmosphere (the hydrological cycle) is an essential part of the climate system. Ice requires much energy to melt (latent heat of fusion) and water needs even more energy to evaporate (latent heat of vaporization), so the cycling of water through the atmosphere by evaporation and its subsequent precipitation is a significant mechanism through which energy is transported throughout the climate system. How much and where water is absorbed into the atmosphere, the nature and form of the clouds it creates, and how quickly it is precipitated out again, are all processes of the climate system. Over the oceans, the temperature of the surface is generally the dominant factor in evaporation, with wind speed playing a secondary role. However, the fierce winds associated with tropical cyclones and other storms markedly accelerate evaporation from the ocean and feed more energy into the weather systems. Over land the presence of living matter complicates the issue considerably. The amount of water vapour passing into the atmosphere over land is a combination of evaporation of available moisture directly from the soil and transpiration from plants, defined as evapotranspiration. The amount of water vapour in the atmosphere affects its radiative properties and is a critical factor affecting the climate system.

Greenhouse Gases and Agriculture

Human activities—primarily burning of fossil fuels and changes in land cover—are modifying the concentration of atmospheric constituents or properties of the Earth's surface that absorb or scatter radiant energy. Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed preindustrial values determined from ice cores spanning many thousands of years. The global atmospheric concentration of carbon dioxide increased from a pre-industrial value of about 280 ppm (parts per million) to 381 ppm in 2006, an increase of 36%. CO2 is responsible for 63% of the global warming effect due to long-lived greenhouse gases affected by human activities. Methane (CH4) contributes 18.6 % of the global warming effect due to long-lived greenhouse gases affected by human activities. Methane has increased from a pre-industrial value of about 715 ppb (parts per billion) to 1782 ppb in 2006, an increase of 155%. Nitrous oxide (N2O) contributes 6.2% of the global warming effect from long



Water vapor is continually evaporating from the oceans, freshwater sources and soils and through transpiration from plants, forming clouds and eventually precipitating as rain or snow. This precipitation often returns quickly to rivers and oceans as surface runoff, but can remain for some time as soil moisture in groundwater, or as ice or snow.

lived greenhouse gases. The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 320 ppb in 2006, an increase of 19%. The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land use change (deforestation) providing another significant but smaller contribution. It is very likely that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture.

For 2005, agriculture accounted for an estimated emission for about 10–12% of total global human-based emissions of GHGs. Of global human-based emissions in 2005, agriculture accounted for about 60% of N2O and about 50% of CH4. Despite large annual exchanges of CO2 between the atmosphere and agricultural lands, the net flux is estimated to be approximately balanced, with CO2 emissions being very low (emissions from electricity and fuel use in agriculture are covered in the buildings and transport sector respectively).

Without additional policies, agricultural N2O and CH4 emissions are projected to increase by 35–60% and ~60%, respectively, to 2030, thus increasing more rapidly than the 14% increase of non-CO2 GHG observed from 1990 to 2005.

Current Observations of Climate Change

According to the WMO/UNEP Intergovernmental Panel Climate Change (IPCC) Fourth Assessment report which was released last year, the warming of the climate system is unequivocal. Eleven of the last twelve years (1995-2006) rank among the 12 warmest years in the instrumental record of global surface temperature. The 100-year trend (1906-2005) is 0.74°C. The linear warming trend over the last 50 years (0.13°C per decade) is nearly twice that for the last 100 years. At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

The IPCC further notes that there has been an increasing trend in the extreme events observed during the last 50 years, particularly heavy precipitation events, hot days, hot nights and heat waves. Climate change projections indicate it to be very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. The combination of these events can have an enormous impact on agricultural production, quality and subsequently farmer's incomes.

Future Climate Change Impacts on Global Agriculture

The IPCC expects the warming in the 21st century to be greatest over land and at the highest northern latitudes. For the next two decades a warming of about 0.2°C per decade is projected. Increases in the amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions. Drought-affected areas will likely increase in extent. It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. Given these projections of future climate change, there will be increased land degradation owing to droughts and increased soil erosion owing to heavy rainfall events.

Water resources are inextricably linked with climate. Annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics. The report detailed many impacts on global and regional agriculture and the impacts depended on the specific location and the magnitude of the warming. Here is summary of some of the potential impacts of future climate change on global agriculture:

- In general, the report states that **increases in the frequency of droughts** and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes.
- Globally, the **potential for food production is projected to increase** with increases in local average temperature over a range of 1-3°C, but above this range, food production is projected to decrease.
- At lower latitudes, especially in the seasonally dry and tropical regions, **crop productivity is projected to decrease** for even small local temperature increases (1-2°C), which would increase risk of hunger.
- Crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions.
- With the virtually certain likelihood of warmer and more frequent hot days and nights, there are projected to be increased insect outbreaks impacting agriculture, forestry and ecosystems.
- Adaptations such as altered cultivars and planting times allow low- and mid- to high-latitude cereal yields to be maintained at or above baseline yields for modest warming.

What does adaptation mean to farmers?

The IPCC (2007) defines adaptation as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Various types of adaptation can be distinguished, including anticipatory, **autonomous and planned adaptation**.

With the IPCC AR4, there has been a focus on climate change, future impacts, and potential adaptation strategies. However, the main determinant of agricultural production is still the seasonal variation of temperature, precipitation, sunshine, etc. Droughts, floods, frost-freezes, and heatwaves stress both crops and livestock. It is the changing frequency of these events due to climate change that is the concern.

There are many regional specific potential climate change impacts on agricultural production.

In many **African regions**, the area suitable for agriculture, the length of growing seasons and yield potential, particularly along the margins of semi-arid and arid areas, are expected to decrease. In some countries, yields from rainfed agriculture could be reduced by up to 50% by 2020.

It is projected that crop yields could increase up to 20% in **East** and **Southeast Asia** while they could decrease up to 30% in **Central and South Asia** by the mid-21st century.

In drier areas of **Latin America**, climate change is expected to lead to salinisation and desertification of agricultural land. Productivity of some important crops is projected to decrease and livestock productivity to decline, with adverse consequences for food security. In temperate zones, soybean yields are projected to increase.

Production from agriculture and forestry by 2030 is projected to decline over much of **southern and eastern Australia, and over parts of eastern New Zealand**, due to increased drought and fire. However, in New Zealand, initial benefits are projected in western and southern areas and close to major rivers due to a longer growing season, less frost and increased rainfall.

In **North America**, moderate climate change in the early decades of the century is projected to increase aggregate yields of rain-fed agriculture by 5-20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or depend on highly utilized water resources. Also in this region, disturbances from pests, diseases, and fire are projected to have increasing impacts on forests, with an extended period of high fire risk and large increases in area burned.

In **Southern Europe**, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity. In **Central and Eastern Europe**, summer precipitation is projected to decrease, causing higher water stress. Forest productivity is expected to decline and the frequency of peatland fires to increase. In **Northern Europe**, climate change is initially projected to bring mixed effects, including some benefits such as reduced demand for heating, increased crop yields and increased forest growth. However, as climate change continues, its negative impacts (including more frequent winter floods, endangered ecosystems and increasing ground instability) are likely to outweigh its benefits.

Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. Climate change is projected by the mid-century to reduce water resources in many small islands, e.g., in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low rainfall periods.

There are several adaptation measures that the agricultural sector can undertake to cope with these future changes.

These include:

- Changing planting dates;
- Planting different varieties or crop species;
- Development and promotion of alternative crops;
- Developing new drought and heat-resistant varieties;
- More use of intercropping;
- Using sustainable fertilizer and tillage practices (improving soil drainage, no-till, etc)
- Improved crop residue and weed management;
- More use of water harvesting techniques,
- Better pest and disease control for crops;
- Implementing new or improving existing irrigation systems (Reducing water leakage, soil moisture conservation - mulching);
- Improved livestock management (Providing housing and shade, change to heat-tolerant breeds, change in stocking rate, altered grazing and rotation of pasture);
- More use of agroforestry practices;
- Improved forest fire management (altered stand layout; landscape planning; dead timber salvaging; clearing undergrowth; insect control through prescribed burning);
- Development of early-warning systems and protection measures for natural disasters (droughts, floods, tropical cyclones, etc);

What is mitigation?

According the IPCC, mitigation is the technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks. Improved agricultural management can reduce net GHG emissions, often affecting more than one GHG. The effectiveness of these practices depends on factors such as climate, soil type and farming system. About 90% of the total mitigation arises from soil carbon sequestration and about 10% from emission reduction. The most prominent mitigation options in agriculture are:

- restoration of cultivated organic soils;
- improved cropland management (including agronomy, nutrient management, tillage/residue management and water management (including irrigation and drainage) and set-aside / agro-forestry
- improved grazing land management (including grazing intensity, increased productivity, nutrient management, fire management and species introduction);
- restoration of degraded lands (using erosion control, organic amendments and nutrient amendments.

Lower, but still substantial mitigation potential is provided by:

- rice management;
- livestock management (including improved feeding practices, dietary additives, breeding and other structural changes, and improved manure management (improved storage and handling and anaerobic digestion)

Forestry

Global forest cover is 3952 million ha, about 30% of the world's land area. Most relevant for the carbon cycle is that between 2000 and 2005 gross deforestation continued at a rate of 12.9 million ha/yr, mainly as a result of converting forests to agricultural land, but also due to expansion of settlements and infrastructure. Due to afforestation, landscape restoration and natural expansion of forests, the net loss of forest between 2000 and 2005 was 7.3 million ha/yr, with the largest losses in South America, Africa and Southeast Asia. On the global scale, during the last decade of the 20th century, deforestation in the tropics and forest regrowth in the temperate zone and parts of the boreal zone remained the major factors responsible for CO_2 emissions and removals, respectively.

Options available to reduce emissions by sources and/or increase removals by sinks in the forest sector are grouped into four general categories:

- maintaining or increasing the forest area;
- maintaining or increasing the site-level carbon density;
- maintaining or increasing the landscape-level carbon density and
- increasing off-site carbon stocks in wood products and enhancing product and fuel substitution.

The multilateral process and the involvement of farmers

The United Nations Framework Convention on Climate Change is the overall framework for intergovernmental efforts to address the challenges posed by climate change. Governments gather and share information on greenhouse gas emissions, national policies and best practices, launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries and cooperate in preparing for adaptation to the impacts of climate change. (http://unfccc.int/essential_background/items/2877.php); Navigating the COP/MOP ; A guide to the COP/MOP process: http://www.centrehelios.org/en/climate change.

Kyoto Protocol

The Kyoto Protocol (KP) was adopted in 1997, in the framework of the UNFCCC. The KP aims for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". Since the treaty is legally binding, signatories commit to reduce greenhouse gases or engage in emissions trading. Each country much reach its targets of GHG emissions reduction between 2008 and 2012, on top of a total cut in GHG emissions of at least 5% against the baseline of 1990. Developed countries bear a heavier responsibility in the Protocol. (http://unfccc.int/kyoto_protocol/items/2830.php)

Clean Development Mechanism

Parties to the Protocol have several mechanisms at their disposal to reach their targets: Emissions Trading, Joint Implementation and the Clean Development Mechanism (CDM). Under CDM, parties can earn and trade emissions credits through projects implemented either in other developed countries or in developing countries. Developing host countries benefit from technology transfer and assistance in achieving sustainable development. These projects help identify lowest-cost opportunities for emissions reductions and attract private sector participation in emission reduction efforts. (http://cdm.unfccc.int/index.html)

The Bali Action plan or "road map"

The Bali Action Plan, adopted after COP/MOP13 in Bali In December 2007, includes four building blocks: adaptation, mitigation, technology transfer and financing. Adaptation has been identified as vital, as impacts of climate change are already happening. Developing countries require international assistance to support adaptation. This includes funding, technology transfer and insurance, reducing the risk of disasters and raises the resilience of communities to increasing extreme events such as droughts, floods and tropical cyclones. Funding for adaptation is provided through the financial mechanism of the Convention, currently operated by the Global Environment Facility (GEF).
(http://unfccc.int/adaptation/items/4159.php)

Intergovernmental Panel on Climate Change (IPCC)

The IPCC is a scientific intergovernmental body set up by the World Meteorological Organisation (WMO) and the UN Environmental programme (UNEP). It was established in 1988 to provide "on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and option for adaptation and mitigation". IPCC provides its reports at regular intervals and, after having played a decisive role in the establishment of the UNFCCC and providing key input for the Kyoto Protocol, continues to be a major source of information for the negotiations under the UNFCCC.
(http://www.ipcc.ch/about/index.htm and http://www.ipcc.ch/pdf/10th-anniversary/anniversary-brochure.pdf)

The Farmers' Voice at the World Level

FIPA IFAP

INTERNATIONAL FEDERATION
OF AGRICULTURAL PRODUCERS
60, rue Saint-Lazare
75009 Paris, France
Phone: +33 1 45 26 05 53
Fax: +33 1 48 74 72 12
E-mail: ifap@ifap.org
www.ifap.org

World Meteorological Organization
Weather • Climate • Water

WORLD METEOROLOGICAL
ORGANIZATION
7 bis, Avenue de la Paix
P.O. Box 2300
CH 1211 Geneva 2
Switzerland
Phone: +41 (0) 22 730 81 11
Fax: +41 (0) 22 730 81 81
E-mail: wmo@wmo.int
www.wmo.int

WMO is the United Nations system's authoritative voice on weather, climate, and water.

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How can IFAP and the WMO help farmers deal with Climate Change?

- **Capacity building to benefit farmers in developing countries**
- **Working on adaptation and risk management tools**

With many of the adaptation practices listed above, the use of weather and climate information can assist agricultural communities in making better decisions. A number of measures are being taken by WMO to address these weather- and climate- related issues in relation to agricultural production.

Capacity building in drought management

WMO contributes to global understanding through dedicated observations of the climate system; improvements in the application of agrometeorological methods and the proper assessment and management of water resources; advances in climate science and prediction; and promotion of capacity building in the application of meteorological and hydrological data and information in drought preparedness and management.

Capacity building in climate predictions and regional models

There is a need for climate predictions on a seasonal and decadal time frame for enabling better decision-making by agricultural communities. Seasonal climate predictions will allow farmers to adjust planting dates, varieties, crops, and management systems for crops and livestock and reduce the vulnerability of the agriculture to floods and droughts caused by such phenomena like ENSO. Regional climate models provide more useful local information needed by policy makers and planners on adaptation policies. Since fine resolution climate change information for use in impact studies can also be obtained via sophisticated statistical downscaling methods, coordinated efforts must also be undertaken to use these methods to develop and implement useful and plausible regional scale climate scenarios. The agricultural and climate communities need to work closer together in order to develop and determine the potential future impacts on food security.

Disaster Risk management tools and preparedness

To cope with existing climate variability and future climate changes, disaster risk management (DRM) is another useful adaptation strategy. For agriculture, the hazards to focus on are droughts, floods, sand/wind storms, locusts, tropical and extra-tropical storms. Examples of such tools include weather derivatives, catastrophe bonds and different types of insurance. DRM decisions at the national level include prevention and mitigation as well as emergency preparedness, response, recovery and reconstruction. With the threat of the climate change and its potential impacts on the trends and severity of natural hazards, the latest knowledge and capacities in climate need to be translated into operational products that would enable countries to enhance their capacities in climate-related risk management.

The WMO provided financial support to the NMHS's of Ethiopia, Colombia, and India to organize Roving Seminars on Weather, Climate, and Farmers. These seminars were developed by NMHSs with WMO guidance to increase the interaction between NMHSs and the agricultural community. The overall goal is to make farmers more self-reliant by helping them become better informed with weather and climate issues that influence their agricultural production. This kind of information can improve the farmer's risk management and ensure sustainable use of natural resources for agricultural production. The one-day seminars focussed on basic weather and climate information provided by NMHSs experts, applications of weather and climate in agricultural decision-making, and pest and disease control provided by agricultural extension agents. With funding from the State Agency for Meteorology in Spain, these seminars will held in 2008 and 2009 to improve the interaction between National Meteorological Services and agricultural communities in the West African countries of Burkina Faso, Mali, Mauritania, Niger, and Sénégal.