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Mitigation options for climate change

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ABSTRACT

Climate change is defined as change in climate over time, whether due to natural variability or as a result of human activity. Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences. Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. New options for carbon sequestration in agriculture and forestry as well as changes in land-use such as deforestation contributes respectively to 13 and 17 % of total anthropogenic greenhouse-gas (GHG) emissions. Though the carbon dioxide emissions from agriculture are small, the sector accounts for 60 % of all nitrous oxide (N_2O mainly from fertilizer use) and 50 % of methane (CH_4, emitted mainly from natural and cultivated wetlands and enteric fermentation). The IPCC estimates that the potential of agriculture (excluding forestry) global technical mitigation for will be 5,500 to 6,000 Mt CO_2-equivalent/year by 2030, 89 % of which are assumed to be from carbon sequestration in soils.

Key words : Climate change, Mitigation, Greenhouse gases, Carbon sequestration, Radiative forcings

Climate change will compound the existing food insecurity and vulnerability patterns. Communities must prepare themselves for the possibility of food shortages and make appropriate use of resources to protect their livelihoods as well as lives and property. It is imperative to identify and institutionalize mechanisms that enable the most vulnerable to cope with the impact of climate change. This requires collaborative thinking and response to the challenges generated by the interaction between food supply, climate change and sustainable development. Though, the overall global impact of climate change on agricultural production may be small, regional vulnerabilities to food deficits may increase, due to problems of distribution and marketing of food to specific regions and groups of people. For subsistence farmers, especially for people who now face a shortage of food, lower yields may result not only in measurable economic losses, but also in malnutrition and even famine.

In general, the tropical regions appear to be more vulnerable to climate change than the temperate regions for several reasons. (i) On the bio-physical side, temperate C_3 crops are likely to be more responsive to increasing levels of CO_2; (ii) The tropical crops are closer to their high-temperature optima and experience high temperature stress, despite lower projected amounts of warming; and (iii) insects and diseases, already much more prevalent in warmer and more humid regions, may become even more widespread (Varshneya, 2007).

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Climate change

Climate change in Inter-Governmental Panel on Climate Change (IPCC) usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities or to cope with the consequences.

Vulnerability is the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (Anonymous, 2007).

Greenhouse effect

The greenhouse effect is a natural feature of the climate system. In fact, without the atmosphere (and hence greenhouse effect), the earth's average temperature would be approximately 33°C colder than is observed currently. The atmosphere is more efficient at absorbing long-wave radiation, which is then emitted both upward toward space and downward toward the earth (Fig. 1). This downward emission serves to heat the earth further. This further warming by reradiated long-wave radiation from the atmosphere is known as the greenhouse effect. Same gases in the atmosphere are particularly good at absorbing the long-wave radiation and are known as the greenhouse gases (GHG). Major gases responsible for greenhouse effect and climate change are carbon dioxide (CO_2), methane, (CH_4), nitrous oxide (N_2O), chloro-fluoro-carbons (CFCs), and ozone (O_3) (Table 1). Amongst the GHG, CO_2 is the largest contributor (Fig. 2).

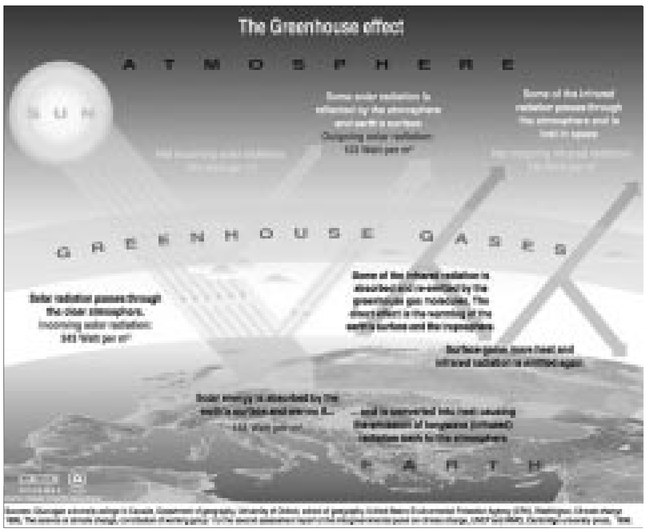


Fig. 1 Greenhouse effect

Global warming

An increase in the earth's temperature is caused by human activities such as burning coal, oil and natural gas that releases GHG into the atmosphere. GHG form a blanket around the earth, trapping heat and raising temperatures on the ground. This is steadily changing our climate.

Climates of the past billion years have been about 13°C warmer to 5° C cooler than the current climate (Schneider *et al.*, 1990). Data of past 130 years indicate that there has been a 0.3 to 0.6°C warming of the earth surface since the late 19th century (Jones *et al.*, 1994,1999). During the last 150 years the rate of increase of temperature was 0.045°C, for last 100 years 0.074°C, for the last 50 years 0.128°C and for the last 25 years 0.177°C per decade (Fig. 3), indicating that the recent rate of increase of temperature was the highest compared with that of previous years (Manning, 2007).

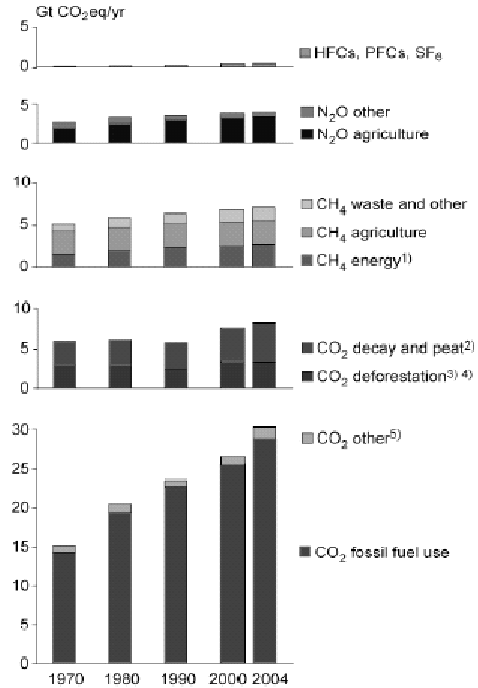


Fig. 2. Contribution of different gases in greenhouse effect

Context of climate adaptation

The vulnerability to food insecurity shocks has grown global. The vulnerability patterns of global and local food security will be modified by the climate change. Small-scale rainfed farming systems, pastoralist systems, inland

Table 1. Main Greenhouse gases and their global warming potential.

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)	Anthropogenic sources	Global warming potential (GWP)
Carbon dioxide	CO_2	278000 ppbv	358000 ppbv	Variable	Fossil fuel combustion, land use conversion, cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12.2	Fossil fuel, rice paddies, waste dumps, livestock	21
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer, industrial processes combustion	310
CFC-12	CCl_2F_2	0	0.503 ppbv	102	Liquid coolants, foams	6200-7100
HCFC-22	$CHClF_2$	0	0.105 ppbv	121	Liquid coolants	1300-1400
Perfluoro-methane	CF_4	0	0.070 ppbv	50, 000	Production of aluminum	6500
Sulphur Hexafluoride	SF_6	0	0.032 ppbv	3200	Dielectric fluid	23900

Temperature (°C) during 1961-1990

Fig. 3. Global average temperature during 1860-2000

and coastal fishing and aquaculture communities, and forest-based systems are particularly vulnerable to climate change. Moreover, the urban poor, particularly in coastal cities and flood-plain settlements, face increasing risks. It is urgent to build resilient communities living off agricultural, forestry and fisheries or aquaculture systems that have high capacity to adapt to stress and disturbances.

Attempts to improve the resilience to future and uncertain impacts through anticipatory and planned adaptation and innovation will have both immediate and future costs with trade-offs between optimizing current conditions and minimizing vulnerability to future shocks. Adaptation to climate change must also focus on prevention and removal of mal-adaptive practices that may not succeed in reducing vulnerability but instead, could increase it.

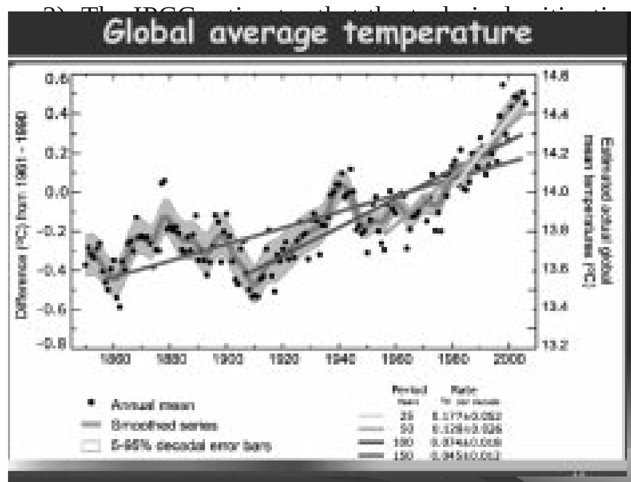
Technical adaptation measures range from temporal and spatial variations in production systems (e.g. adjusting planting or fishing dates, rotations, multiple cropping or species diversification, crop-livestock-pisciculture systems, agro-forestry) to confer better protection against temperature changes, changing rainfall variability and patterns, salinization through rise in sea level and pest attacks for investment in soil, water and bio-diversity conservation and development (e.g. building soil biomass, restoring degraded lands, rehabilitating rangelands, harvesting and recycling water, planting trees, developing adapted cultivars and breeds, protecting aquatic ecosystems) in order to maintain long-term productivity (Anonymous, 2008).

Adaptation measures also include establishing disaster risk management plans and risk transfer mechanisms, such as crop insurance and diversified livelihood systems. For example, integrated aquaculture-agriculture systems will allow activities to shift in response to changes in the suitability of land and availability of water to produce food. In cases where benefits of diversification are limited, such as those that affect all aspects of the food production systems, social safety nets are required. An important caveat is that there are limits to adaptation. Due to changing climate, the frequency of floods and droughts may increase so much that agriculture, fisheries and forestry will no longer be sustainable. Diversification to other economic activities and relocation will need to be considered under such conditions.

Mitigation

Agriculture and land-use change such as deforestation contribute to respectively 13 and 17 % of the total anthropogenic greenhouse gas (GHG) emissions. Though the carbon dioxide emissions from agriculture are small, the sector accounts for 60 % of all nitrous oxide (N_2O, mainly from fertilizer use) and 50 % of methane (CH_4, emitted mainly from natural and cultivated wetlands and enteric fermentation). The GHG impact through radiative forcing of N_2O is 300 times that of CO_2. Methane and nitrous oxide emissions are projected to further increase by 35 to 60 % by 2030, driven by growing nitrogen fertilizer use and increased livestock production in response to growing food demand.

Mitigation of climate change is a global responsibility. Agriculture, forestry, fisheries or aquaculture provide, in principle, a significant potential for GHG mitigation (Table



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tation), and improved soil fertility leads to better yields (production and income generation). However, sequestration of CO_2 in soils is not included in the Clean Development Mechanism (CDM) agreed to in Kyoto Protocol. The scope of the successor of the CDM could be improved for increasing the carbon sinks in the soil and in above- and below-ground biomass, and thus can contribute to removing the methodological barriers to operationalizing soil-carbon sequestration under the Post-2012 climate-change regime. The FAO should play a leading role in this process, including the establishment of a Global Soil Carbon Sequestration Initiative, entrusted with the promotion of agricultural technologies that restore carbon pools and soil quality (e.g. organic agriculture, conservation agriculture) and to create tools to measure, monitor and verify soil-carbon pools and fluxes of greenhouse-gas emissions (viz. nitrous oxide) from agricultural soils, including crop lands and pastures.

Reduction in emissions from deforestation and forest degradation in developing countries : As the UN agency with the mandate for forestry and a comprehensive programme covering all aspects of forestry as well as agriculture, FAO can play a leading role in: (i) providing technical information and support for the development of methodological and policy options for reduction in emissions from deforstation and forest degradation in developing (REDD), strengthening the capacity for countries undertaking REDD programmes, including development of systems for monitoring changes in forest carbon; and addressing the underlying causes of deforestation and forest degradation rooted in both agriculture and forest sectors. In addition, FAO can launch a comprehensive REDD-support effort for the developing countries.

Knowledge base

Strengthening of IPCC and UNFCCC on agriculture and food-related issues: The IPCC could improve its assessments on the impacts of climate change on food security. The establishment of a Global Food Security Observing System (GFSOS) is seen as an extension of the FAO's Global Information and Early Warning System. It is also a technically feasible option to set up permanent monitoring of the effects of current and future climate on food security. Global studies must be complemented by comprehensive national assessments of the impact of climate change on agriculture and food security. Local impacts are badly needed to support national and subnational decision-making. Though existing studies focus mainly on the effect of downscaled climate-change scenarios on major crops and aquatic species, future studies should look at a wider range of crops and also take into account the local farming dynamics and resource base, food-marketing chains and delivery systems, the greater international connectedness, food prices, the implications of agricultural policy and possible development pathways.

Improving data collection and impact-assessment capacity: Improvement in data collection and sharing of results at national, regional and international levels will improve the local weather forecasts, seasonal climate forecasts and the assessment of risk and impact. It can also increase the detail of assessment of climate impact to a scale that is meaningful for optimizing the adaptation and mitigation measures, and operating nearly real-time early warning and hot-spots warning systems for food security, agriculture, forestry and fisheries.

Agro-ecological research: Research will provide the backbone for adaptation and mitigation methodologies. However, research for a rapidly changing situation is different from that for stable ecological conditions. Traditional knowledge and local bio-diversity are a suitable entry points, but likely to be insufficient in a rapidly changing situation. In addition, methodologies, crops and crop varieties need to be developed for future conditions, because their applicability cannot be assessed at the location where they may be used in future. Research results need to be public in an enabling environment, in which methods, germplasm, crop varieties and animal breeds are accessible for use and introduction in adaptation programmes. To implement national climate-change and food-security policies, there is need for in-depth knowledge of appropriate methods and tools as well as awareness of available funding mechanisms, such as the carbon market and adaptation funds established under the IPCC.

Capacity building: The capacity to identify, collect and

Table 2. Ways to reduce greenhouse-gas emissions

Sector	Key mitigation technologies and practices currently commercially available
Energy	Supply efficiency, fuel switching, nuclear power, renewable resources (hydro-power, solar, wind, geothermal and bio-energy), combined heat and power, early applications of CO_2 capture and storage
Transport	More fuel-efficient vehicles, hybrid vehicles, bio-fuels, modal shifts from road transport to rail and public transport systems, cycling, walking, land-use planning
Buildings	Efficient lighting, efficient appliances and air-conditioners, improved insulation, solar heating and cooling, alternatives for fluorinated gases in insulation and appliances
Industry	More efficient electrical equipment, heat and power recovery, material recycling, control of non-CO_2 gas emissions
Agriculture	Land management to increase soil carbon storage, restoration of degraded lands, improved rice cultivation techniques, improved nitrogen fertilizer application, dedicated energy crops
Forests	Aforestation, reforestation, forest management, reduced deforestation, use of forestry products for bio-energy
Waste	Land-fill methane recovery, incineration of waste with energy recovery, composting, recycling and waste minimization

share data, use information and methods, and build knowledge relevant for adaptation, and mitigation of climate-change and food security is critical owing to the rapidly changing climatic, environmental and socio-economic conditions. Extension services and mechanisms have been weakened greatly over the last two decades. Extension will need to be strengthened substantially in order to address adaptation and mitigation for providing an efficient interface between policy-makers and the farming community. Recognizing that climate change will alter many existing equilibriums, socio-economic dynamics must be considered, and the role of all the partners may need to be re-examined or redefined.

Weakness of capacities in adaptation development in food sectors include: vulnerability of infrastructure (e.g. irrigation, means to cope with flood, protection from sea-water incursion), non-structural measures (*e.g.* legislation, insurance and capacities to integrate adaptation into development planning at all levels), transportation, food storage and distribution systems to climate vagaries; lack of crop varieties, animal and aquatic species or breeds, and of trees and forests adapted to climate change; lack of climate-related knowledge in research and extension; lack of standard tools to assess the main vulnerability patterns that can be tailored to national circumstances; lack of monitoring and forecasting of variable food availability; insufficient knowledge of rural development and of the roles of markets, trade, migration, refugees, and urbanization, and their linkage to climate change and food security; lack of understanding of social dimensions of vulnerability and resilience, such as how climate change will require shifts in use of, and access to, natural resources (land, water), credit and education, and Insufficient institutional capacities and integration.

Regional co-operation: Countries can pool their resources to inventories and share traditional and innovative solutions. They can also take advantage of developing regionalized markets for reducing the greenhouse-gas emissions and transport costs and increase the benefits and rural incomes.

(a.) Changes in lifestyle and behavior patterns can contribute to mitigation in climate change across all sectors. Management practices can also have a positive role.

(i) Lifestyle changes can reduce GHG emissions. Changes in life-styles and consumption patterns that emphasize resource conservation can help develop a low-carbon economy that is both equitable and sustainable;
(ii) Education and training programmes can help overcome barriers to the market acceptance of energy efficiency, particularly in combination with other measures;
(iii) Changes in occupant behaviour, cultural patterns and consumer choice as well as the use of technologies can result in considerable reduction in CO_2 emissions related to energy use in buildings;
(iv) Transport Demand Management, which includes urban planning (that can reduce the demand for travel) and provision of information and educational techniques (that can reduce car usage and lead to an efficient driving style) can support GHG mitigation; and
(v) In industry, management tools that include staff training, reward systems, regular feedback, and documentation of existing practices can help overcome the barriers in industrial organization and reduce the energy use and GHG emissions.

(b.) Investments in new energy infrastructure in the developing countries, upgradation of energy infrastructure in the industrialized countries, and policies that promote energy security, can in many cases create opportunities to reduce GHG emission compared with the baseline scenarios.

(i) Decisions on investment in future energy infrastructure, expected to total over 20 trillion US$ between now and 2030, will have a long-term impact on GHG emissions, owing to the long life-times of energy plants and other infrastructure capital stock. The wide-spread diffusion of low-carbon technologies may take many decades even if early investments in these technologies are made attractive. Initial estimates show that returning global energy-related CO_2 emissions to 2005 levels by 2030 would require a large shift in the pattern of investment, although the net additional investment required ranges from negligible to 5-10%.
(ii) It is often more cost-effective to invest in the end-use energy efficiency than in increasing the energy supply to satisfy the demand for energy services. Efficiency improvement has a positive effect on energy security, abatement of local and regional air pollution, and employment.
(iii) Renewable energy generally has a positive effect on energy security, employment and air quality. Given costs relative to other supply options, renewable electricity, which accounted for 18% of the electricity supply in 2005, can have a 30-35% share of the total electricity supply in 2030 at carbon prices up to 50 US$/t CO_2-eq.
(iv) Given costs relative to other supply options, nuclear power, which accounted for 16% of the electricity supply in 2005, can have an 18% share of the total electricity supply in 2030 at carbon prices up to 50

US$/t CO_2-eq, but the safety, weapon proliferation and waste remain the major constraints; and

(v) Carbon Capture and Storage (CCS) in underground geological formations is a new technology with the potential to make an important contribution to mitigation by 2030. Technical, economic and regulatory developments will affect the actual contribution.

(c.) There are multiple mitigation options in the transport sector, but their effect may be counteracted by growth in this sector by: (i) Improved vehicle-efficiency measures, leading to fuel saving; (ii) Bio-fuels might play an important role in addressing GHG emissions in the transport sector. Bio-fuels used as gasoline and diesel fuel additives or substitutes are projected to grow to 3% of the total transport-energy demand in the baseline in 2030. This could increase to 5-10%, depending on the future oil and carbon prices, improvements in vehicle efficiency and the success of technologies to utilize cellulose biomass; (iii) Modal shifts from road to rail and to inland and coastal shipping as well as from low-occupancy to high occupancy passenger transportation, besides land use, urban planning and non-motorized transport offer opportunities for GHG mitigation, depending on local conditions and policies; (iv) Medium-term mitigation potential for CO_2 emissions from the aviation sector can come from improved fuel efficiency; and (v) Realization that emissions reduction of emission in the transport sector is often a co-benefit of addressing traffic congestion, air quality and energy security.

(d.) Options regarding energy efficiency for new and existing buildings could considerably reduce CO_2 emissions with net economic benefit.

By 2030 about 30% of the projected GHG emissions in the building sector can be avoided with net economic growth.

It is concluded that plantation should be increased on the foot-hills of Himalayas, Sahyadri ranges, coastal area and barren land. In Gujarat the forest area should increase from 9.5% to 20% in the next decade or by 2020 AD. For controlling methane emission from rice field, the appropriate water-saving technology should be used instead of transplanting and submerged method of paddy cultivation. Shelter-belts should be created near sea shore to check salinity and salt nuclei in atmosphere that changes the rainfall pattern. The simulation results indicate that increase in temperature and decrease in solar radiation levels pose a serious threat in decreasing the growth and yield of agricultural crops. Increased CO_2 levels are expected to favour growth and increase the crop yields, and therefore will be helpful in counteracting the adverse effects of temperature rise in future.

The future needs are : In many studies the impact of climate change on crop growth and yield is analysed using crop- simulation models. A proper analysis of the performance of such models should be made to verify their reliability in the projected conditions of changed atmospheric composition and changed climate, Further identify regional variations and sensitivity (with respect to climate change), Impacts would be analysed mainly for Crop yields and variability, and Shifts in relative productivity and production

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