Higher temperatures, more variable precipitation, and changes in the frequency and severity of extreme climate events will have significant consequences for food production and food security. However, the frequency of heat stress, drought, and flooding are also expected to increase, even though they cannot be modeled satisfactorily with current climate models. They will undoubtedly have adverse effects on crops and agricultural productivity over and above the effects due to changes in mean variables alone. The impacts of climate change on agriculture are likely to be regionally distinct and highly heterogeneous spatially, requiring sophisticated understanding of causes and effects and careful design and dissemination of appropriate responses.

These changes will challenge the livelihoods of farmers, fishers, and forest-dependent people who are already vulnerable and food insecure. Adapting to these changes, while continuing to feed a world of 9 billion people, requires the formation of a global partnership in science, technology development, and dissemination of results to millions of smallholder farmers, bringing together research workers and resource managers from many fields. To take an international approach to climate change, new partnerships must be forged, linking the agricultural research and climate science communities.

The CGIAR

The Consultative Group on International Agricultural Research (CGIAR) is a strategic partnership, whose members support 15 international centers and five major collaborative programs around the world. The CGIAR plans to contribute its broad-based and multidisciplinary experience in developing-country agriculture to global efforts to adapt to and mitigate climate change through research on agriculture and natural resources. Work already underway that is directly applicable to climate change research includes breeding crops for stress tolerance; developing better practices for sustainable crop and environmental management; gauging the vulnerability of agriculture, natural resources, and rural communities; and supporting the development of policies conducive to sustainable agricultural growth.

The CGIAR’s Consortium for Spatial Information is taking the initiative with other centers of excellence to create a climate information portal for mapping data. The Climate Change Challenge Program is uniting the expertise of the CGIAR with the Earth System Science Partnership to close critical knowledge gaps on how to deal with trade-offs among food security, livelihood, and environmental goals as climate changes.

Challenges in defining the effects of change

Climate modeling and scenario building are important for the global approach to agricultural research, but three challenges must be addressed to achieve practical results. First, we must understand what the local impacts of climate change are likely to be. Uncertainties are involved in scaling down the global climate model output to the high spatial resolutions needed for effective adaptation work at regional and national levels. Some archipelagic and small island countries most at risk from climate change barely figure in global models. Substantiating the local effects of long-term change requires that long-term research and monitoring is supported at key, agro-ecologically defined regional sites. Second, a significant gap exists between the seasonal information we currently have and that on climate change in the long run (2050 and beyond): information about what is likely over the next 3 to 20 years is largely missing. This presents a critical problem, as this time scale is vital for vulnerability assessment, agricultural planning, and political negotiation. Third, convincing the results from modeling scenarios to decision-makers, including farmers and policymakers, will be one of the most significant challenges. Scenarios integrating possible socioeconomic (and climate) futures will therefore be central to exploring and communicating adaptation and mitigation approaches. There must be a long-term approach to building knowledge and capacity at the local scale for effective responses to occur.

Challenges to crop agriculture

The current climate change scenarios demand adaptation to temperature increases, changing amounts of available water, climatic instability and increased frequency of extreme weather events, and rises in sea level and saline intrusion in the coastal zones. Thus future crop farming and food systems will have to be better adapted to a range of abiotic stresses (such as heat or salinity) and biotic stresses (such as pests) to cope with the consequences of a progressively changing climate. In response, the CGIAR is working on gene discovery and improving plant tolerance for heat, drought, and submergence. This work should be expanded to consider the basic energy and water efficiency of plants (improving their photosynthetic capacity and reducing evapotranspiration).

Crop germplasm improvement, natural resource management, and inclusion of enhanced agrobiodiversity have a proven track record of decreasing susceptibility to individual stresses. Breeding and marker-assisted selection are important mechanisms for introducing improved characteristics and achieving yield improvements for most crops. Defining future targeted farming systems and their environments could allow breeding and management programs to be matched with georeferenced data on crop germplasm collections. This would allow the identification of crops and cultivars best suited to predicted conditions, based on the agro-ecological parameters of their places of origin. Improved water-management approaches, with conservation agriculture, are likely to be central to adaptation strategies in both irrigated and dryland agriculture. Work on feed plants (for livestock and aquaculture) should be incorporated into this research approach. However, technical innovations will not be sufficient on their own. Strengthening the adaptive capacities of farmers and other land users requires a variety of strategies ranging from diversification of production systems to improved institutional settings. It is crucial to add value to current investment in agronomic crop management and germplasm improvements by integrating new results and best practices from these fields into adaptation options proposed in the policy domain. There may well be major land use changes, and research will be needed to identify and assess options to support the transitions this will impose on farmers and other actors within the food system.
**Challenges to livestock agriculture**

Livestock are a critical component of agriculture, particularly for the income and nutrition of the poor in developing countries. However, the magnitude of the changes that are likely to befall livestock systems is a relatively neglected research area. Little is known about the interactions of climate and increasing climate variability with other drivers of change in livestock systems and in broader development trends. While opportunities may exist for some households to take advantage of more conducive rangeland and cropping conditions, for example, the changes projected will pose very serious problems for many other households. Furthermore, ruminant livestock themselves have important impacts on climate, through the emission of methane and through the land-use change that may be brought about by livestock keepers. Nevertheless, meeting anticipated demand for meat and milk and other necessary livestock products in the coming decades will require attention to the supply of livestock feeds. Climate change sharpens the edge of the production dilemma among human food, animal feed, and (potentially) energy on a finite amount of land. The issue of temperature and other abiotic stresses will have to be as carefully addressed in feed plants as in human crops. Critically, altered climate regimes will alter the ranges of insect pests and vectors; a major risk of climate change is that it will change or extend the range of current diseases or, through unknown effects, create the conditions for the spread of new diseases to the livestock population. Human health would also be threatened by an increase in zoonotic diseases. Since the impacts of climate change on livestock disease may be extremely complex, integrated approaches must go well beyond climate and risk mapping and will require epidemiological reassessment, new diagnostic reagents, adapted or new livestock genotypes, and new veterinary and public health management services.

**Challenges to forests and forestry**

Major recent fora on forestry have concluded that integrated approaches to adaptive forest management are a central component of the global response to climate change. Within global approaches, there is the opportunity to both reduce forest destruction and potentially to sequester carbon (atmospheric CO₂) as a climate change mitigation measure. Test cases for the payment for environmental services approach are being tried in the forestry sector (for example, Reduced Emissions from Deforestation (REDD) payment schemes). There should be continuous scientific, economic, and social evaluation of Payments for Environmental Services (PES) schemes so that their true value to the environment and to the lives of the poor are put on an evidence-based footing.

**Challenges to fisheries**

Fisheries are key natural resources ensuring food security for large numbers of people. Successful fisheries depend upon coherent marine and freshwater ecosystems, which are at risk of disruption by climate change. As temperatures change, fisheries are likely to gradually be displaced or migratory patterns may become erratic, affecting fish supplies for both human consumption and aquaculture and livestock feeds. There could be long-term effects on coral reefs (which are very susceptible to small changes in temperature). The rise in coastal sea levels could disrupt livelihoods and cause salt water intrusion into agricultural land. Like livestock industries, aquaculture competes for feed resources (from aquatic or terrestrial sources). A broad set of tasks, linking research assessment and monitoring of fisheries to the design of adaptive measures and appropriate policies, must be addressed to sustain poor communities through the expected changes. Aquaculture will require that particular attention be given to the breeding of robust genotypes and the design of sustainable feed resource policies.

These tasks will require cooperative approaches among research providers across the fields of agricultural and climate change science. New collaborative arrangements will need to be implemented, with each organization playing its part according to its comparative advantage.

**Suggested negotiating outcomes:**

- The world currently has imperfect knowledge of agriculture–climate change interactions. In order to effectively plan and implement adaptation strategies, funds must be made available to increase knowledge in this area, particularly for determining more precise climate change effects on developing-country agriculture, forestry, and fisheries.
- The development of adaptation strategies for developing-country agriculture should be a key element of any adaptation fund. International exchange of information and collaboration among science groups in different sectors should be fostered and supported. Implementation of integrated strategies for adaptation to climate change that affect farmers will require funding for indirect adaptation expenditures, such as improvements to national agricultural research and extension services, as well as international research and project-specific funding.
- Mitigation strategies should primarily address global energy policy. However, some sectors of agriculture are net contributors to global greenhouse gas (GHG) emissions. Investigation into whether there is potential for low-cost effective sequestration of GHGs by agricultural systems should be supported.


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