Climate Risk Management for Adaptation to Climate Variability and Change

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ABSTRACT
The warming of the climate system is evident from observations of air and ocean temperatures as well as in melting of snow and ice and rising sea level. Measures are needed to reverse the trends of increased accumulation of greenhouse gases (GHG) in the atmosphere. The two main paths to reverse this trend are: (i) reducing GHG emissions through cleaner energy generation and (ii) removing CO₂ through carbon sequestration. The agricultural and forestry sectors can play a key role in both paths. Carbon markets will likely encourage increased carbon sequestration. However, the implementation of carbon-market projects for small farmers in least developed countries is still a major challenge. Even under the most optimistic scenarios of future GHG emissions adaptive measures are needed to address impacts of the warming due to past and current emissions. Integrating climate change into decision making is complicated by the uncertainty levels of climate scenarios. It is also challenged by a “double conflict of scales”: (i) climate scenarios are available for periods much farther in the future than the ones typically needed for decision making and (ii) spatial scales of the climate scenarios (global to regional) are coarser than the ones often needed for actual decision making (i.e., local level). Introducing the issue of climate change into policy and development agendas can be facilitated by considering the longer-term variations as part of the continuum of total climate variability (seasons to decades to centuries) and generating information at the temporal scales that are relevant and applicable for particular decisions.

THE CLIMATE SYSTEM IS WARMING
Fossil fuel combustion and changes in the land use (including deforestation) have resulted in carbon dioxide (CO₂) accumulation in the atmosphere. The global atmospheric concentration of CO₂ has increased from about 280 ppm (preindustrial) to 379 ppm in 2005. The current atmospheric concentration of carbon dioxide largely exceeds the natural range recorded over the last 650,000 yr (180 to 300 ppm) as determined from ice cores (IPCC, 2007a).

The accumulation of CO₂ and other greenhouse gases is expected to cause observable climatic changes in the 21st century. The International Panel on Climate Change (IPCC) has been publishing assessment reports to governments since the early 1990s. The fourth report, published in 2007, concludes that the global temperature in the last 100 to 150 yr has increased 0.76 ± 0.19°C (IPCC, 2007a). The report also concludes that the warming of the climate system is unequivocal and evident from observed increases in global air and ocean temperatures as well as in melting of snow and ice and rising global sea level (IPCC, 2007a, b). The report includes several evidences of the impact that the observed global warming is already having on biological processes affecting agriculture, forestry, and human health.
The IPCC report finally includes possible scenarios of future climate that would greatly affect agricultural production throughout the world. Research conducted since the late 1980s cited in the four IPCC’s assessment reports has been showing that crop yields in several regions of the world could be severely reduced under warmer conditions due to shorter crop growing seasons and increased pest and disease pressure (see for example Parry and Rosenzweig, 1994; Parry et al., 2004, Rosenzweig and Iglesias, 1994, Baethgen and Magrin, 1995; Schneider et al., 2001). Moreover, agricultural systems that are already fragile under current climate conditions could become unsustainable in the future (e.g., northeast Brazil, the Sahel; Baethgen, 1997). Most of the conducted studies suggest that the most severe impacts on agriculture will be felt around the tropics where most of the least developed countries are located.

POSSIBLE RESPONSES TO CLIMATE WARMING IN THE AGRICULTURAL SECTOR: MITIGATION

Even though it is still difficult to determine how much of the global warming can be attributed to human activity, there is overwhelming agreement that measures should be taken to reverse the current trend of increased accumulation of greenhouse gases (GHG) in the atmosphere. In the jargon of the scientific, technical and policy communities working in the climate change arena, the actions oriented to reverse such trend is generally referred to as “mitigation” of climate change. There are basically two paths to reverse the current trend of increased accumulation of GHG: (i) reducing GHG emissions through cleaner energy generation and (ii) removing CO2 through carbon “sinks” or carbon sequestration.

The agricultural sector in both developed and developing countries can play an important role in helping to reverse the trend. Regarding the reduction of GHG there is increasing interest and growing opportunities to generate energy utilizing biofuels originated in the agricultural and forestry sectors and thus reduce the net emissions of GHG. Hence, several developing countries and some developed countries are investing considerable efforts to increase the generation of energy with crop-produced alcohol (e.g., sugarcane, sweet sorghum, maize), biodiesel produced with oil crops (e.g., oil palm, soybeans, sunflower), and with residues originated in the harvest of annual crops (e.g., rice husks) as well as in the forest harvest and forest industries (Baethgen and Martino, 2004). The observed increased interest in these alternative energy sources is probably rooted mainly in economical, financial, and geopolitical advantages of reducing the countries’ dependence on fossil fuels. However, this is a path that could lead to important reductions in net GHG global emissions (Sims, 2004) and generate important new alternatives for the agricultural sector in the developing world (Hill et al., 2006). On the other hand, several researchers are expressing increased concerns with possible unintended and negative consequences that the production of biofuels could have on increasing world food prices and affecting the global food security (Von Braun, 2008).

A second possible path to reverse the current increased accumulation of GHG in the atmosphere is removing CO2 from the atmosphere. Soil science research evidenced that agricultural lands have the potential for removing 40,000 to 80,000 million tonnes of carbon over the next 50 to 100 yr (Kolshus, 2001; IPCC, 1992). Consequently, soil carbon sequestration in agricultural lands alone might offset the effects of fossil fuel emissions and land use changes for 10 to 20 yr or longer (Post and Kwon, 2000; Lal, 2004).

The agricultural sector can help reduce the enhanced greenhouse effect by introducing agronomic practices that result in increased removal of CO2 from the atmosphere. Carbon dioxide, one of the most important gases that enhance the greenhouse effect, is produced when coal, oil, wood, and other carbon-based fuels are burned. Plants absorb CO2 and through photosynthesis convert it into dry matter (e.g., food, fiber, wood). Carbon fixed by plants can remain in the form of wood for several years and/or return to the soil as plant residues increasing the soil organic matter content. The enhanced carbon sequestration strategy in the agricultural sector cannot be viewed as the permanent solution for the GHG emission problem, but it can be an excellent option for “buying time” and allow for the development and global adoption of new, clean, and safe energy sources.

Past and recent research has evidenced that reduction in atmospheric carbon dioxide content can be achieved by large-scale applications of land management practices (Lal, 2004). Others include: reduced or zero tillage, use of pastures (e.g., clovers, alfalfa) in rotation with annual crops, improved strategies to enhance fertilizer use efficiency, increased efficiency of animal feed and return of animal waste, establishment of forests and grasslands in former croplands and degraded soils. Most importantly, increasing sequestered carbon in the soils provides additional benefits to farmers such as improvement in soil fertility, water holding capacity, and tilth as well as reduction in soil erosion.

Two other gases with greenhouse effect are also important in the agricultural sector: nitrous oxide (N2O) and methane (CH4). The importance of these gases derives from their warming potential which is much higher than that of the CO2; the global warming potential of methane is about 20 times higher and that of nitrous oxide is 300 times higher than that corresponding to CO2 (IPCC, 2007a). Nitrous oxide is mainly produced through transformations in the soil of the nitrogen added as fertilizers and/or plant residues (Mosier et al., 1998). Methane in the agricultural sector is mainly produced as a result of
the enteric fermentation occurring in the digestion process of ruminants and in flooded soils. A second important role of the agricultural sector contributing to reduce the greenhouse effect is therefore to reduce the emissions of these gases. Since the emission of both gases is the result of inefficiencies in the production system, a reduction of the emissions would also lead to better results for the farmers (higher nitrogen use efficiency and more efficient conversion of animal feed into milk, meat, and wool).

The international community has reacted to the increased evidences of global warming by signing the Kyoto Protocol (United Nations Framework Convention for Climate Change [UNFCCC]). The protocol introduced mechanisms to reduce the net greenhouse gas emissions. While Kyoto negotiations are stalled for the time being, the discussions in the UNFCCC have stimulated an impressive amount of activities all over the world, with the increasing involvement of governments, business people, and scientists. In contrast with the slow progress in the government negotiations of the Kyoto Protocol, the results of these side-track activities have been impressive, giving shape to the development of an international carbon market (examples of functioning markets are evident in Australia, Denmark, the United Kingdom, and the United States, among others) (Baethgen and Martino, 2004).

The development of mature carbon markets will probably encourage the establishment of collaborative projects between industry and farmers which will lead the latter to adopt agronomic practices that will result in increased amounts of sequestered carbon and reduced emissions of GHG (such as N₂O and CH₄). This in turn will provide farmers with additional income as well as improve their production systems and natural resource base. On the other hand it will allow the industry to reduce their net GHG emissions during the process of adopting cleaner processes and energy sources. Important challenges, however, remain for the implementation of carbon-market oriented projects in the least developed countries, given the potential difficulties for small farmers (“atomized” carbon offer) to take advantage of the existence of such projects.

THE NEED OF SOCIETIES TO ADAPT TO A CHANGING CLIMATE

Even under the most optimistic scenarios of globally coordinated actions to drastically reduce the net emissions of greenhouse gases (GHG) during the next decades, climate science confirms that warming is already unavoidable due to past emissions. As indicated by IPCC’s Fourth Assessment Report (IPCC, 2007a, b), granting that the atmospheric GHG concentrations remain at 2000 levels, the inertia of past emissions is estimated to cause some unavoidable warming and consequent changes in climate. Accordingly, even under this unrealistically optimistic scenario, adaptation will be necessary to address the impacts resulting from the warming that is already unavoidable due to past and current emissions. More realistic scenarios of GHG emissions and atmospheric concentrations impose more aggressive needs of the different socioeconomic sectors including the agricultural sector, to further develop adaptive strategies to the already changing climate.

CLIMATE CHANGE ADAPTATION AND DECISION MAKING: UNCERTAINTIES AND CONFLICT OF SCALES

Decision makers (including those involved in policy) working in the public and private sectors of developing countries typically confront the pressure to act in response to problems that require immediate action. Moreover, the effect of such actions must also be evident during the usually short terms in which those decision makers operate (often a maximum of 2–5 yr, sometimes up to 10 yr). Consequently, relatively lower priority is assigned to issues that deal with the long term, such as 50 to 100 yr in the future.

On the other hand, the scientific community has focused research on climate change and its impacts on societies mainly by proposing climate scenarios expected for the next decades (typically 70–100 yr in the future). This research approach and the communicated results have been crucial to raise the awareness of the general public on the climate change issue in both developed and developing countries. The research outcomes and the resulting increased public awareness have also contributed to current efforts to promote the use of cleaner energy sources, encourage practices that enhance carbon sequestration, and in general support actions conducive to reduce net GHG emissions.

At the same time, this research approach based almost exclusively in possible scenarios expected 70 to 100 yr in the future has also placed the issue of climate change as a problem that will affect societies in the future and in a timeframe that is far beyond the one in which policymakers and decision makers operate. In addition, the possible scenarios of future climate produced with the best available scientific methods include uncertainty levels that often impose further challenges to be considered in actual decision-making and planning activities. These uncertainties are partially due to limitations of the scientific knowledge included in the climate models that are used to produce the scenarios. Some uncertainty is just inherent in the climate system even with perfect knowledge and representation of the physical processes and climate feedbacks. Uncertainties are also the result of assumptions that need to be made about the characteristics of different socioeconomic scenarios used to estimate the GHG emission levels that drive the climate models. Thus the socioeconomic scenarios include a wide range of assumptions dealing with trade, energy sources, technology transfer, etc., for the next 70 to 100 yr that inevitably embrace uncertainties.
Uncertainties are larger for establishing possible scenarios of rainfall as compared to those of global temperatures and even much larger for the climate scenarios at regional or local scales (as opposed to global scale) that are the ones typically needed for planning and decision making. With respect to the latter, some recent methods allow the downscaling of global model runs to regional or even local levels. However, it should be noted that these methods do not reduce the uncertainty levels associated with the global scenarios. In fact, these downscaled climate change scenarios can be viewed as scenarios with higher level of detail of the same (and often larger) level of uncertainty.

The challenge of effectively incorporating the information resulting from the research in climate change into decision making is thus complicated by the uncertainty levels as well as by the frequent “double conflict of scales.” On the one hand the temporal scales of climate change scenarios are much farther in the future than the ones often needed for decision making and planning. On the other hand the spatial scales of the climate scenarios that can be established with the currently best available tools and methods still have a larger spatial scale (global to regional level) than the ones often needed for actual decision making (regional to local level).

**A COMPLEMENTARY APPROACH TO ADAPTATION TO CLIMATE CHANGE**

The earth’s climate system includes processes that cause variability at different temporal and spatial scales. Some processes are local and act in the short or immediate term (a few days) and cause the variability of “weather.” Other processes are affected by the interaction of the atmosphere with the oceans and the land surface. Some of these processes result in variations of climate at the scale of months to seasons (e.g., those processes affected by El Niño). Still other phenomena depend on natural and anthropogenic factors that affect the chemical composition of the atmosphere and cause variability of the climate at the scale of several decades to centuries. The latter includes the variability of climate that is commonly referred to as climate change.

All of these processes act simultaneously and result in the observed earth’s total climate variability. The magnitude of climate variability at these temporal scales is different and the relative magnitude also varies among regions of the world. An example of the relative magnitude of climate variability at different time scales is shown in Fig. 1. The figure was constructed by partitioning the total variability observed in annual rainfall in the Sahel for the period 1900 to 2006. Panel (a) shows the rainfall variability at the long-term (linear trend in the last 100 yr, which is a crude representation of the man-made climate change signal), the scale that is usually called climate change. The second panel (b) shows the variations of rainfall measured at the decadal scale (after removing the linear trend) and reveals decades when rainfall tended to be above average (e.g., the 1950s and the early 1960s) and decades when rainfall tended to be below average (e.g., the 1970s and 1980s). Finally, panel (c) shows the variability of rainfall in the year-to-year time scale that remains after removing the linear and the decadal trends. The figure shows the relative magnitude of the rainfall variability at these three temporal scales as measured by the percent of the total variance explained by each temporal scale. The proportion of total variance explained by the short-term (interannual) variability is three times greater than the corresponding to the long-term variability (climate change) and two times greater than that of the decadal variability.

In other regions of the world the relative magnitude of the variability of climate at the various temporal scales (long-term, decadal, and interannual) is different. For example in southeastern South America the long-term, linear trend in the observed changes in rainfall seems to be much larger that the multidecadal variability (data not shown).

The slow and persistent forcing of increasing GHGs is producing noticeable changes in the mean climate on which shorter-term variability is superimposed. Increasing GHGs may also change the magnitude of the short-term variability, for example by enhancing the strength of the hydrological cycle. Changes in the mean state, the variability, or both will alter the statistical distribution of climate and weather and will likely result in more frequent extreme events that can have devastating socioeconomic and environmental impacts. Consequently, an effective manner for assisting societies to be better prepared and adapt to possible climate change scenarios is by assisting them to cope better with current climate variability.

Thus, a possible approach to introduce the issue of “adaptation to climate change” into the policy and development agendas is to consider the longer-term variations (climate change) as part of the continuum of the total climate variability, from seasons to decades to centuries, and generate information at the temporal scale that is relevant and applicable for the particular time frames or planning horizons of the different decisions. This approach allows considering climate change as a problem of the present (as opposed to a problem of the future) and aims to inform the decision-making, planning, and policy-making processes to reduce current and potential future vulnerabilities to climate variability and change.

One of the key premises of this approach to engage in adaptation to climate change is that improving year-to-year planning activities and decisions lead to societies that are better adapted to longer term climate change (Hansen et al., 2007). However, there are situations in the different socioeconomic sectors where important issues require fundamentally different approaches and activities. Thus, several important decisions need information and climate projections at temporal scales of 10 to 30 yr (e.g., transportation
infrastructure projects, water reservoir design, long-term business plans, etc.). Therefore, focus is also needed on climate risk management work for adaptation to “near-term” climate change, that is, 10 to 30 yr. These time frames require the consideration of “decadal climate variability,” which is still posing important scientific challenges and the climate science community is investing huge efforts in exploring ways to improve the ability to predict it. In the meantime much can be gained by interpreting and characterizing the decadal trends in the observed historic records and on methods for producing seasonal forecasts under a changing climatic baseline (as opposed to the “static” baseline).

An advantage of this approach is that it provides immediate assistance to the public and private sector: while it helps stakeholders to confront possible future climate scenarios, it identifies immediate actions needed to manage the climate variability that is currently affecting societies. Furthermore, the impacts of the taken actions and interventions are also evident and verifiable in the short term making them more attractive to policymakers and decision makers. Research organizations such as the IRI (International Research Institute for Climate and Society) are focusing on this approach and labeling it Climate Risk Management (CRM).

FOUR PILLARS OF IRI’S CLIMATE RISK MANAGEMENT APPROACH

The outcome of socioeconomic activities (agriculture and water resource management) as affected by climate can be represented by probabilistic curves (Fig. 2). Thus, a few years present very unfavorable climatic conditions (droughts, floods, and hurricanes) and the socioeconomic impacts are extremely negative (“Disasters”). The damage caused by these relatively infrequent years can be so large that planning is often designed with the priority of avoiding or minimizing such damage. For example, farmers often prefer to use “precautionary” technologies that do not have expectation of high yields but that reduce the chances of high losses in unfavorable conditions. In the water sector, managers often prefer very conservative strategies to minimize the chances of not being able to supply water for all intended uses in very dry years.

This type of strategies heavily influenced by the risk aversion of decision makers may be effective in reducing losses in extreme conditions but they also imply missing opportunities that can be critical for development. Thus, near normal or favorable conditions (about two-thirds to the right of the curve in Fig. 2), which are much more frequent than the disastrous conditions, offer the possibility to for example optimize agricultural income through higher productivity. Near normal or favorable years are much more frequent than the disastrous years, and therefore the sum of missed opportunities can have much greater impacts on the economies and on development. However, since the impacts of even a single extreme negative event can be so devastating that decision makers rightly adopt precautionary strategies to protect against those impacts. There is a cost associated with such an approach, namely the lost opportunities of the more frequent favorable years that could be captured if we could protect against the negative extremes.

The CRM approach as understood in the IRI seeks managing the entire range of climate-related risks: from the very unfavorable conditions (extreme left area of Fig. 2) up to the “risk of missing opportunities” (e.g., about two-thirds of the area to the right of Fig. 2). Managing the entire risk range is based on four main pillars:
if the forecast leads to an ex-post "incorrect" decision.

that a skillful forecast is provided and that protections are in place above average years, additional income can be generated given modalities of insurance can cover this residual risk. Finally, in years, improved technology is not sufficient, and so different modalities of insurance can cover this residual risk. Finally, in above average years, additional income can be generated given that a skillful forecast is provided and that protections are in place if the forecast leads to an ex-post "incorrect" decision.

1. **Identify vulnerabilities and potential opportunities** due to climate variability and/or change for a given water, agriculture, or health system. This process begins with stakeholder analysis, as they identify their climate challenges, and then proceeds with modeling of the system being analyzed to identify other vulnerabilities and/or opportunities that stakeholders may not identify.

2. **Quantify uncertainties in “climate information”** to reduce uncertainties in using that information. A better understanding of the climate aspects of these vulnerabilities, challenges and opportunities, such as predictability, expected recurrence, and possible long-term changes requires: (i) understanding climate variability at different time scales and assessing the socioeconomic impacts observed in the past, (ii) monitoring the present conditions of relevant environmental factors (climate, vegetation, water, diseases, etc.), and (iii) providing the best possible climate information of the future, from seasons to decades depending on the relevance for different decisions and activities.

3. **Identify technologies and practices** that optimize results in normal or favorable years as well as technologies and practices that reduce vulnerabilities to climate variability and change (examples in agriculture include crop diversification, crop rotations, improved tillage systems, increased water soil storage, improved crop water use efficiency, drought-resistant cultivars).

4. **Identify interventions, institutional arrangements and best practices** that reduce exposure to climate vulnerabilities and enable the opportunistic exploitation of favorable climate conditions. Exposure reduction can be achieved through, for example: (i) improved early warning and response to crisis (e.g., improved emergency systems) and (ii) transferring portions of the existing risks (e.g., different modalities of rural insurance, supervised or differential credit programs, etc.). Risk-transfer instruments require efforts to characterize and quantify the different risk levels (“Disasters,” “Harm,” etc.) which vary for different production systems and for different regions of the world. Such characterization and quantification of risk levels is in turn a key input for institutions that design insurance (and reinsurance) policies.

Typically a portfolio of approaches will be necessary, for example, insurance covering extreme negative events, diversification covering moderately negative events, and forecast or scenario use and access to the means to capture good year opportunities (e.g., fertilizer, improved crop seeds in agriculture) to take advantage of favorable climate conditions given the downside risk is covered by other parts of the portfolio (Fig. 2).

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International agencies and development banks are increasingly adopting this approach as a means to effectively incorporate adaptive measures into policies and development plans. For example, Mr. Warren Evans, Environment Director at the World Bank, addressing the Global Environmental Fund Assembly in Cape Town (August, 2006, Cape Town) stated that: “adaptation to climate risks needs to be treated as a major economic and social risk to national economies, not just as a long-term environment problem. By enhancing climate risk management, development institutions and their partner countries will be able to better address the growing risks from climate change and, at the same time, make current development investments more resilient to climate variability and extreme weather events.”

1. The temporal scale (seasons, years, or decades) of the information that is needed is defined by the needs of the stakeholders demanding it. Farmers usually demand information at seasonal to inter-annual scales; development banks, foresters, and water reservoir builders may be interested in the likelihood of decades with frequent droughts or floods; and national authorities negotiating in the UNFCCC may require climate scenarios for the next 50 or more years.
References