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Managing Climatic Risks to Combat Land Degradation and Enhance Food security: Key Information Needs

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Abstract

This paper discusses the key information needs to reduce the negative impacts of weather variability and climate change on land degradation and food security, and identifies the opportunities and barriers between the information and services needed. It suggests that vulnerability assessments based on a livelihood concept that includes climate information and key socio-economic variables can overcome the narrow focus of common one-dimensional vulnerability studies. Both current and future climatic risks can be managed better if there is appropriate policy and institutional support together with technological interventions to address the complexities of multiple risks that agriculture has to face. This would require effective partnerships among agencies dealing with meteorological and hydrological services, agricultural research, land degradation and food security issues. In addition a state-of-the-art infrastructure to measure, record, store and disseminate data on weather variables, and access to weather and seasonal climate forecasts at desired spatial and temporal scales would be needed.

Keywords: Acquisition and dissemination of data; vulnerability assessment; management of risks; knowledge base; institutional and policy support; partnerships and capacity enhancement

1. Introduction

Global food grain production has increased from about 850 million tonnes in 1960 to 2.35 billiion tonnes by 2007. As a consequence, despite a rapid increase in human population, per capita availability of food increased from 2 300 kcal/day to more than 2 800 kcal/day in this period. The increase in global food production became possible due to intensification of agriculture in many parts of the world supported by appropriate research, institutions and policies. However, in last few years, the growth in food availability per capita has slowed down; it has become modest to stagnant in regions such as south Asia and even shown a small decline in sub-Saharan Africa.

Although global food production has substantially increased over time, the world's efforts to meet the United Nations Millennium Development Goal of reducing hunger by half by 2015 appears to be beyond reach. The number of people suffering from chronic hunger has increased from under 800 million in 1996 to over a billion now [1]. Most of these hungry people are in south Asia and sub-Saharan Africa (SSA). These regions are highly populated, have widespread poverty and large agricultural areas of low productivity due to a lack of production resources (for example, fertilizers) and high climatic risks. Sub-Saharan Africa's approximately 625 million people are largely dependent on rainfed agriculture; the rural sector employs 70 per cent of the entire work force. This dependence on rainfed agriculture (93 per cent of all agricultural land), combined with high seasonal variability in rainfall, and endemic poverty forcing farmers to avert risks, makes economies in SSA particularly vulnerable.

Globally, over 70 per cent of natural disasters are related to weather and climate, but in some countries or regions, these account for the totality of such disasters. It is very well known that agriculture is inherently sensitive to climate conditions and is among the sectors most vulnerable to weather and climate risks. Variability in weather elements – especially rainfall – has been, and continues to be, the principal source of fluctuations in global food production, particularly in the semi-arid tropical countries of the developing world. Throughout history, extremes of heat and cold, droughts and floods, and various forms of adverse weather have often wreaked havoc on the agricultural systems.

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Climatic variations are also recognized as one of the major factors contributing to land degradation. According to the United Nations Convention to Combat Desertification (UNCCD), over 250 million people are directly affected by land degradation. In addition, some one billion people in over one hundred countries are at risk. Land degradation causes a decline in the quantity and quality of freshwater supplies, and soil productivity leading to greater food insecurities, increased poverty and higher social costs. Droughts, flash floods and forest fires associated with climate change are likely to intensify, leading to further land degradation, loss in human well-being and impacts on global and regional food security.

Next to the increasing frequency of extremes, there are several features of climate and the interactions between climate and society that result in increasing vulnerability. Often weather patterns occur in groups rather than randomly. For instance, in semi-arid areas, dry or wet periods (days, months, years and possibly even decades) tend to be grouped, with "bad" periods following "bad" periods and "good" periods following "good" periods more frequently than alternating "good" and "bad" periods. This has serious implications for food security, as it requires significant food storage capacities to bridge unfavourable periods. It particularly affects livestock as populations decimated during runs of drought years are re-established only slowly during runs of good years and sometimes cannot be re-established fully before the next run of dry years sets in, resulting in decreasing per capita availability of animal products.

In recent times, food insecurity has increased in several regions due to competing claims for land, water, labour and capital, leading to more pressure to improve production per unit of land. Rapid urbanization and industrialization in south Asia, for example, has taken away from agriculture some very productive lands and good quality irrigation water. This leads to increased environmental pressures, compounded by a variable and changing climate exerting even more pressure on scarce resources. According to the Intergovernmental Panel on Climate Change [2], the semi-arid regions of Asia, Africa and Latin America are likely to be warmer during this century, and freshwater availability is projected to decrease. Agricultural productivity in tropical Asia is sensitive not only to changes in the nature and characteristics of monsoons but also to changes in temperature. In the semi-arid tropics of Africa, which are already having difficulty coping with environmental stress, climate change resulting in increased frequencies of drought poses the greatest risk to agriculture. In Latin America, agriculture and water resources are most affected through the impact of extreme temperatures and changes in rainfall.

Despite these increasing pressures on agriculture, agricultural output needs to increase to support growing demand for food. It is estimated that global food production must double by 2050 to meet the demand caused by a growing population. Most of this increase has to come in Asia and Africa where the population pressures are likely to be more intense. Management of current as well as future climatic risks, which could be a major source of food insecurity to millions, needs to be adequately addressed by all stakeholders. Understanding the risks posed by the current season-to-season variability of rainfall and its multiple impacts, and having clearly defined risk management frameworks to cope with it are therefore most important. This includes both risk assessment and specific actions taken to reduce, hedge, transfer or mitigate risk. It is also essential to develop and integrate agriculture mitigation and adaptation frameworks for climate change into sustainable development planning at national and regional levels to cope with projected impacts of climate change. This paper briefly discusses the key information needs to reduce the negative impacts of weather variability and climate change on land degradation and food security, identifies the opportunities and barriers between the information and services needed and comments on what is available and areas that are weak.

2. Acquisition and wider dissemination of climatic data

There are several opportunities available today that can facilitate management of climatic risks in agriculture from local to global scales such as early warning systems, and real-time agro-advisories for farmers, policy planners, industry and other stakeholders. The prerequisites in the provision of these products and services are a state-of-the-art infrastructure to measure and record weather variables; standardized data protocols; systems for data storage, assimilation and dissemination; and access to short-, medium- and extended-range weather forecasts and seasonal climate forecasts at desired spatial and temporal scales. Good quality and reliable weather and climate data are also essential for climate risk assessment, and mapping of crop distribution, phenology, yield potential and vulnerability indicators including adaptation capacity, land suitability and surface and groundwater availability. Fortunately, advanced tools such as automatic weather stations, global circulation models, regional climate models, numerical weather prediction models, and downscaling techniques have become more widely available to address stakeholder needs for value-added information.

The United States Drought Monitor [3], established in 1999, is a good example of value-added agro-climatic product developed from a rich information stream, including climate indices, numerical models, and the input of regional and local experts to the national level. It is an operational tool for monitoring drought conditions, including aerial extent, severity and type around the country. Similarly, the Drought Monitoring Centre in Nairobi operates a service for application and dissemination of climate information in Africa. It monitors weather and climate data, uses numerical weather prediction products and provides weather and climate advisories including early warnings on droughts, floods and other extreme weather events. The Centre also provides monthly and decadal impact assessment of extreme climate anomalies on various socio-economic activities. In India, the India Meteorological Department, in collaboration with agricultural research institutes, Farmers' Science Centres, the Department of Agriculture, non-governmental organizations, and media agencies are providing weather-based crop and livestock advisory services regularly for the whole country. The dissemination of agrometeorological advisories is achieved through multichannel systems (newspapers, TV, telephone, SMS) at local, state and national levels. There are plans to greatly increase Internet services in rural India, and this will further accelerate dissemination of value-added agrometeorological products.

Sharing such agrometeorological information among countries is critical for strengthening national weather services, enhanced accuracy of weather/climate forecast models and for agro-advisories. The World Meteorological Organization has evolved the concept of Core AgroMeteorological Stations to facilitate such exchange and to provide more value-added services to end-users. It also established a Web portal named as World AgroMeteorological Information Service (WAMIS) in 2002 to provide a dedicated Web server for disseminating agrometeorological products issued by WMO members. This Service is helping users to quickly and easily evaluate the various bulletins, and to gain valuable insight into improving their own bulletins. The Website also hosts training modules to further help Members improve the quality and presentation of their agrometeorological bulletins.

Although meteorological infrastructure is continuously increasing and upgrading around the world, much remains be done with respect to wider dissemination of weather and climate data. Free and open exchange of climate data needs to be encouraged since data are public goods and wider availability of data would encourage the development of useful products and information for the user community. This lack of climate data has been the main constraint for a wider application of simulation models at the farm level. The ill-perceived notion by some governments and/or government agencies that the costs of collecting climate data need to be recouped through the sale of those data needs to be strongly opposed. Instead, we advocate for a far greater emphasis on adding value to such data through targeted applications resulting in benefits that far outweigh the original costs of data collection.

There are several other barriers to greater and effective uptake of the meteorological data. One key issue is that in several developing countries there still remains a large gap in the scientific capacity to analyse data, interpret results and add value by developing products for use by the stakeholders. Extension workers and others concerned are not trained enough to utilize these products. Often data are made available in formats and at times that are not appropriate. Gridded General Circulation Model output of monthly mean rainfall, for example, might not be particularly useful for a smallholder maize farmer in Kenya. Similarly, the probabilistic onset date of the first rains of the wet season is often far more important for farmers for crop sowing than the onset date of the meteorologically defined monsoon. Agencies responsible for meteorological data collection, analysis and interpretation must ensure that such data are made available to the stakeholders in a form that they can understand and at a time when they can utilize them.

Considering the foregoing, we recommend that National Meteorological Services be helped to move “centre-stage” in the field of agricultural research and development though building their capacity in (a) climate data collection and management, (b) enhanced ability to use statistical software and climate driven simulation models, such as crop growth models, in order to provide relevant products and (c) through helping them develop more collaborative attitudes with regard to data sharing and genuine partnerships.

3. Climatic vulnerability assessment

Societies have always been subject to climate “shocks” such as floods, droughts and cyclones, and have suffered their impacts in the form of food insecurity, infrastructure destruction and disease outbreaks. Concerns about climate-related risks have rapidly escalated and have been drastically fueled by recent and generalized concerns about a changing climate. Many of the world’s leading development organizations (the United Nations Development Programme, the World Bank, regional banks, multilaterals) have recognized the direct effect of climate on social and economic development and are now reviewing their programs to explicitly include climate risk assessment and management.

A vast amount of relevant information is now available. The IPCC has been producing authoritative assessments of the current climate and possible future climate scenarios. Several centres throughout the world are producing routine monitoring information, and seasonal-to-interannual climate forecasts are being developed and disseminated through regular Regional Climate Outlook Forums. However, one continuing issue is the translation of the probabilistic forecast information in terms that can effectively assist in making decisions and that can be explicitly incorporated into public policies for the different socio-economic sectors. Consequently, relatively little uptake of the climate information has been achieved and livelihoods and economies remain vulnerable to current climate-induced risks.

There are multiple reasons for this failure, including many institutional, knowledge and interdisciplinary barriers resulting in the current supply of climate information not being matched by a corresponding demand, and often climatic data not being easily accessible. This is in spite of great scientific advances for improving both climate monitoring and climate predictability at intra-seasonal to multi-decadal scales.

A key element to define priorities for implementing climate risk management actions, inform decisions and establish policy is the assessment of socio-economic vulnerabilities. Although huge efforts have been made to establish such vulnerability assessments, it has been extremely challenging to effectively link them to actual decisions and policies. In the case of vulnerability to climate change, one of the reasons for these difficulties is that the climate science community has often focused on providing climate scenarios for periods that are too far in the future (for example, 2080–2100) to stimulate immediate action. In addition, the best available climate scenarios present large uncertainty levels and coarse spatial resolution, imposing even larger challenges for incorporating them into actual policies. Although it is very important to inform people about the intrinsic uncertainties associated with climate projections, it is important to ensure that these uncertainties are not used as an excuse for inaction. Although the exact magnitude of future changes is uncertain, most climate studies agree that future climate conditions will be more unstable and that climate variability will increase. Consequently, recent efforts are proposing to concentrate on improving the management of current climate-induced risks as a first step to build capacity to adapt to future climate changes [4][5][6].

There is a wealth of scientific articles available that report on approaches and methods to assess the vulnerability of socio-economic sectors to climate variability and change. One approach that has been commonly used to assess such vulnerability, is to focus on crop production in a given country or region, and to assume that these effects would have direct or indirect impacts on the food security situation of that country or region. Although this approach can be easily applied to different regions throughout the developing world, it provides very limited information on the actual risks of food insecurity since it covers only one component of the issue, namely the food availability.

Researchers, especially those working in biophysical sciences, often focus on this type of one-dimensional approach to manage climate risks and assess vulnerability, and tend to provide scale-specific, detailed and technical information for clearly identified and somewhat predictable sources of risk. On the other hand, decision-makers usually manage risk holistically and often intuitively [7][8]. The narrow focus on specific risks commonly used by the scientific community can have the unintended consequence of under-emphasising longer-term and more holistic opportunities to build adaptive capacity [9][10]. Hence the demand for science input is often broad, general and vague, while the supply is narrow, specific and precise, creating a (perceived) lack of science relevance [11].

As a result of the limitations of one-dimensional vulnerability assessments, some research institutions have established multidisciplinary teams of biophysical and social scientists, and have started producing a vast number of new vulnerability studies. A typical approach used in this type of study is to define a set of indicators. For example, the United States Agency for International Development Famine Early Warning System (FEWS) programme defines indices, based on selected variables, to measure the vulnerability to food insecurity in Africa (http://www.fews.net). This approach considers data on crop risk (for example, length and variability of growing season), income risk, (for example, average cash crop production) and coping strategies (for example, staple food production, access to infrastructure). Other institutions using this type of approach include the Pacific Northwest Laboratory, which uses an index composed of 16 variables (for example, Moss et al.[12]) and the South Pacific Applied Geoscience Commission (SOPAC), which defines an environmental vulnerability index with a composite of 54 independent variables [13].

Even though the index approach is very valuable for studying trends within the same region, it is likely to be less robust for comparing the vulnerability of different regions. The main reason for this limitation is that the variables that are selected to create the vulnerability indicators may be more important in some regions than in others. Further limitations of the index approach include the subjectivity in selecting the variables and the frequent lack of good information on all the variables required to establish the index. Frequently, index-based approaches end up measuring what they can, rather than what they should [9][10].

These limitations have led researchers such as Luers et al. [14] to move away from the quantification of the vulnerability of a site or a region to assessing the vulnerability of a set of selected variables to specific stressors. This new approach for assessing vulnerability first studies the sensitivity of a given system to different stressors and identifies a threshold at which the system is considered to be damaged. Then the susceptibility is measured in terms of the system's sensitivity to and exposure to stressors. The approach finally estimates the system's ability to modify its vulnerable conditions by adapting and responding to changing circumstances. A salient advantage of this approach is that it explicitly allows for the consideration of the great untapped adaptive potential historically found in places such as Africa, south Asia or the Andes, where societies have shown to be able to adapt, respond and survive to extremely severe climate-related challenges.

These new approaches to assess vulnerability are based on a livelihood concept that includes climate information but also key socio-economic variables, thereby overcoming the narrow focus of one-dimensional vulnerability studies [10]. Still, in order to make science more relevant it is imperative to embed the scientific approaches within context-specific, multi-stakeholder dialogues that match the most suitable tools and approaches to the issues at hand. Such participatory processes can translate scientific information, including vulnerability assessments into real life action by paying attention to salience, credibility and legitimacy, as proposed by Cash and others [15].

4. Management of multiple risks

Risk management strategies in agriculture could involve [16]:

(a) Avoiding the dangers;

(b) Preventing/reducing the frequency of impacts;

(c) Controlling/reducing the consequences (coping and adaptation measures);

(d) Transferring the risk (for example, insurance);

(e) Responding appropriately to incidents/accidents (for example, disaster management);

(f) Recovering or rehabilitating as soon as possible (for example, media response).

The major natural disasters include hurricanes/tropical cyclones/typhoons; floods; droughts; extra-tropical storms; tsunamis and storm surges; tornadoes; sand and dust storms; extreme temperatures; weather-related fires; and pests and diseases of crops and livestock. Most countries have some degree of plans relating to some or all of the above for addressing climatic risks. Yet, losses due to climatic risks are generally huge everywhere. The disasters cause many deaths and economic losses amounting to billions of dollars each year. According to Munich Reinsurance Company, 2008 was third worst year on record for natural disasters, with overall losses of US$ 200 billion, up from US$ 82 billion in 2007 (www.munichre.com). Insured losses in 2008 were US$ 45 billion, up roughly 50 per cent from 2007.

In the future, climate change will likely modify many equilibria and tensions as we know them today, because the ecological and energy efficiency of activities will shift, as will the economic profitability and sustainability, and because of changing demand patterns due, among other reasons, to population pressure and urbanization. Some examples of typical equilibria include land used for crops versus land used for livestock; water used for agriculture versus water used for industry and human settlements; and food crops versus energy crops. Yield, production and price risks may further change due to globalization of agriculture and other activities, accelerated land degradation, migration of population for economic reasons and many other socio-economic factors. In such situations, high preparedness, prior knowledge of the timing and magnitude of weather events and climatic anomalies and effective recovery plans will do much to reduce the impact on production levels, on land resources and on other assets such as structures and infrastructure and natural ecosystems that are integral to agricultural operations. When user-focused weather and climate information is readily available, and used wisely by farmers and others in the agriculture sector, losses resulting from adverse weather and climatic conditions can be minimized, thereby improving the yield and quality of agricultural products [17].

At the same time, we need to be cognizant that real risk management considers all sources of risk simultaneously. Often, climate-based information might make only a partial contribution to the overall risk management. However, even within the "family" of climatic risks, differences are large, and their importance is very context specific. There is a need for documenting success stories from around the world, including indigenous traditional knowledge that has been used at local and community levels to cope with multiple risks. Research to understand the complexities of multiple risks and coping strategies for such situations need to be promoted. This would involve a thorough quantitative assessment of the potentials and constraints of land based on the available scientific knowledge, resource characterizations, socio-economic conditions and the interests of various stakeholders to identify the most efficient and sustainable risk management solutions. The current availability of simulation models and other systems research tools provides an opportunity for an interdisciplinary approach [18]. Capacity for such research will need to be enhanced through international collaboration.

Risk transfer approaches, such as weather derivatives, are increasingly being used as a viable solution for many types of risks. While these have been reasonably successful in the developed world, there still is a lot of work to be done before their large-scale adoption in developing countries. The poor section of society is either not aware of these tools or does not have the capacity to pay the premiums. One needs to examine and perhaps evolve new models of North-South cooperation in such risk transfers and innovative private–public cooperation for overall global, regional and local benefits.

5. Advancing the knowledge base for adaptation

Global climate change is likely to increase the problems of food security, hunger and malnutrition for millions of people especially in south Asia, Sub-Saharan Africa and small islands [19] and also further aggravate the current trends in land degradation, especially in the semi-arid tropical regions [20]. Adaptation to climate change is, therefore, central to future food security at local, national and global levels. Climate change, besides change in climatic means, also involves increased variability and extremes, which are likely to increase production variability significantly. We need to analyse the possible options that could assist in increasing the adaptive capacity. In the regions that experience substantial climatic risks, considerable traditional expertise exists that is underutilized and that could be valuable even today as a starting point to build more effective strategies for adapting to climate change. Sharing such experiences accumulated over centuries could be useful at the household, community as well as regional levels in many parts of the world.

Several regions have minimized their exposure to climatic stresses by resorting to mixed cropping, by changing varieties and planting times, by diversifying sources of income for farmers and by maintaining buffer stocks of food for managing periods of scarcity. These management strategies would also help in the future climate change scenarios but may not be enough in view of the increasing intensity of climatic risks and pressure on land to produce more food with much higher efficiency. In some parts of the world, recurring extreme events, such as cyclones and floods in Bangladesh, have almost become a rule. In such instances, traditional risk minimization approaches might no longer apply; instead a focus on adaptation action is needed. This would require considerable investment to increase resilience of the communities through the development of flood control structures, the greater use of new technologies (such as cultivation of recently released flood tolerant rice varieties) and crop insurance.

Climatic risks such as drought, cyclones and floods often result in destruction of standing crops and loss of livestock. In such events, farmers need food for themselves, forage for their surviving livestock and seeds to replant. Since such activities cost money and individual farmers may not be able to manage them on their own, communities of farmers could group together and establish their own stocks of food, forage and seeds. Such self-help groups will require technical and financial support from governments and other development partners, at least in the initial stages.

In many developing countries, including those at greater risk of climatic extremes that affect food security, there is a large gap between potential farm yields and actual yields harvested. For example, the national average yields of rice and wheat crops are less than 4 t ha^{-1} today, whereas climatic factors in the region allow much higher yield potential of most crops. For example, in the productive Indo-Gangetic plains, potential rice and wheat yields are estimated to be 10 and 8 t ha^{-1} respectively [21] indicating large yield gaps. Such yield gaps exist in all crops and across all ecosystems and bridging them could ensure meeting increased food demands of the future. A fragile seed sector, poor technology dissemination mechanisms, the lack of adequate capital for inputs such as fertilizers, poor markets and inadequate infrastructure are the key reasons for yield gaps [22]. Reducing even some of the yield gap could strengthen the food security in a region and reduce the vulnerability of the populations to climate change.

Developing an effective adaptation response requires a comprehensive understanding of the impacts and vulnerabilities of different agricultural commodities, and of microbes and pests. A large part of the current understanding of impacts in developing countries is based on generic global- scale assessments since there are relatively few national, regional or even local level studies. Locally relevant research is needed to understand the probable impacts of climatic risks, and adaptation strategies, especially in relation to subsistence agriculture, and native crops such as legumes, oilseeds, plantations and fish and livestock species. To enhance our adaptive capacity, future crop breeding should address multiple stresses – droughts, floods, heatwaves, salinity and pest load – imposed by the changing global climate. There will be a need to stack several adaptive traits in a suitable agronomic background. This requires substantial breeding efforts, including collection, conservation and distribution of appropriate genetic material among breeders and other researchers.

6. Enabling institutional and policy support

Producing enough food sustainably in order to satisfy an ever-increasing demand against the background of scarce resources and a changing climate is a formidable task. Addressing climate change is central for future food security and attainment of the Millennium Development Goals, especially those related to poverty alleviation.

As discussed in an earlier section, the collection, maintenance and wider dissemination of good quality and reliable weather data in real time remain a major constraint in the application of farm models. Policies and institutions that promote the collection, assimilation and dissemination of quality climatic data and products need to be strengthened, and systematic research efforts are needed to understand the likely impacts on agricultural activities.

Although the scientific community has recommended a number of adaptation options, there is very limited knowledge available today on the costs associated with these. Action on part of governments and other donor agencies will perhaps be higher if scientific estimates of costs and benefits of investments in a competitive environment at different scales for the vulnerable regions could be made available to the decision-makers.

Integrating perspectives on climatic risks in current national policies and programs in different sectors such as disaster management, water resources management, land use, biodiversity conservation and agricultural development will lead to increased adaptive capacity to current as well as future climatic variability. Such an effort requires multidisciplinary research and multi-institutional participation involving scientific, development and user communities on the same platform. At present such models do not exist; most of our institutions remain largely disciplinary and insular.

Both current and future climatic risks can be managed better if there is appropriate policy and institutional support together with technological interventions. Incentives should be provided to the farmers and industry for following scientific agricultural practices leading to increased resilience of food production systems such as those related to efficiency of water, fertilizer and energy use, and to sequestration of carbon. Necessary provisions need to be included in the development plans to address the issues of attaining multiple objectives of poverty alleviation, income growth and environmental sustainability. The United Nations Framework Convention on Climate Change (UNFCCC) Conference at Bali (COP13) in 2007 saw some progress in cooperative action by all countries for meeting these challenges. The Bali Action Plan calls for enhanced action on mitigation and adaptation by nationally appropriate commitments and actions, technology development and transfer and the provision of financial investments and resources to support these (www.unfccc.int). The Food and Agriculture Organization of the United Nations organized a conference in June 2008 on "World Food Security: The Challenges of Climate Change and Bioenergy". It urged governments to explore how farmers, smallholders in particular, could adapt and assist in mitigation through the global financial mechanisms and investment flows, and technology development and transfer [23].

The Intergovernmental Panel on Climate Change does a voluminous and commendable effort of compiling, analysing and assessing global information on climate change impacts, adaptation and mitigation. This has certainly raised awareness to a large extent and has started promoting some action, but much remains to be done. A similar intergovernmental effort is needed to address climate variability and to provide a roadmap for region- and sector-specific action plans in a given time frame. Perhaps the mandate of IPCC could be broadened to explicitly include climate variability to facilitate greater uptake of its recommendations.

7. Partnerships and capacity enhancement

Resource-poor farmers of the developing world do not have any voice in international negotiations on climate change. Although their contribution to global warming is miniscule, their vulnerability to climate change is large. While negotiators in climate change meetings need to be sensitized to this issue, partnerships between developing country groups, FAO and UNFCCC would be useful in addressing the goal of poverty alleviation and hunger through adaptation and mitigation in agriculture. Such partnerships should ensure that funds start flowing to ensure that food supplies become "climate robust", particularly in vulnerable regions. They should also strengthen adaptation-related infrastructure in vulnerable developing countries, implement weather-related risk insurance programs, enhance research capacity and secure patented knowledge/technologies related to adaptation, including germplasm/genes from various sources.

Climate and land degradation are intimately linked, agricultural productivity is being threatened by land degradation and a slower growth rate in agricultural productivity is threatening food security. Hence strong partnerships are needed among three groups: WMO and the National Meteorological and Hydrological Services dealing with climate issues; UNCCD, CGIAR, National Agricultural Research Systems and Extension Services, and Soil Conservation Services dealing with land degradation and agriculture issues; and FAO and national entities dealing with the food security issues. The issues are very broad and need a comprehensive approach to find solutions, but compartmentalization and lack of effective partnerships are constraining the design of a comprehensive approach. The need is to promote open dialogue, identify the issues, prepare an effective implementation plan and develop partnerships to implement actions on the ground with the full involvement of the affected communities. Capacity enhancement must place emphasis on building locally relevant skills that address problems of land degradation and agricultural productivity. This should encompass education and research to promote the search for innovative solutions while taking advantage of local traditional knowledge, as well as appropriate field applications involving local communities.

8. Conclusions and Recommendationns

Agricultural systems are subject to a wide range of risks and uncertainties in most parts of the world. Climatic risks have been historically responsible for widespread droughts, floods, migration, famines and poverty. Increasing climatic risks in the future would further compound the problem. Addressing risks in agriculture, especially in the context of climate change is, therefore, essential for ensuring future food security and attainment of the Millennium Development Goals, especially on poverty alleviation, in the developing countries. In this paper, we have discussed some of the key actions relating to research, risk analysis and management, climatic data application, institutions and policies, partnerships and capacity enhancement, actions that can assist in reducing the negative impacts of weather variability and climate change on land degradation and food security. There is a need to recognize that in places such as Africa, south Asia or the Andes, societies have shown to be able to adapt, respond and survive, and these can provide several lessons for the future We conclude that there is an urgent need to strengthen locally relevant research efforts in the vulnerable regions to understand the probable biophysical and economic impacts of, and adaptation to, increasing climatic risks, especially on subsistence agriculture, and on native foods such as millets, legumes, oilseeds, plantations and local species of fish and livestock. One can expect some action on the part of governments and other donor agencies only once such understanding is available.

For enhancing our adaptive capacity to climatic risks, there is a great and urgent need for policies and infrastructure that promote weather data collection, management and dissemination in the developing world. This will improve our understanding of climatic impacts on land degradation and agricultural production, and lead to identification of the potential coping/adaptive strategies. We conclude that besides these efforts, new and innovative models of cooperation and partnerships are needed for adaptation research and development, and to secure global adaptation funds for reducing the exposure of agriculture to multiple risks. Indeed, the Bali Action Plan (www.unfccc.int) calls for cooperative action by all countries for enhanced action on mitigation and adaptation through nationally appropriate commitments and actions, technology development and transfer and provision of financial investments and resources to support these.

8.1 Recommendations

(a) National Meteorological Services must be helped to move "centre-stage" in the field of agricultural research and development though building their capacity in (a) climate data collection and management, (b) enhanced ability to use statistical software and climate driven simulation models in order to provide relevant products and (c) through helping them develop more collaborative attitudes with regard to data sharing and genuine partnerships.

(b) Vulnerability assessments must consider the adaptive potential historically found in places such as Africa, south Asia or the Andes where societies have shown to be able to adapt, respond and survive. Such assessments must be embedded within context-specific, multi-stakeholder dialogues through participatory processes that can translate the vulnerability assessments into real life action.

(c) There is a need to strengthen research to understand the complexities of multiple risks and coping strategies for such situations in agriculture. Locally relevant research in the vulnerable regions is needed to understand the probable biophysical and economic impacts of, and adaptation to, increasing climatic risks, especially on subsistence agriculture and on native foods such as millets, legumes, oilseeds, plantations and local species of fish and livestock. The understanding resulting from such research is needed to initiate concrete action on the part of governments and other donor agencies.

(d) The Intergovernmental Panel on Climate Change does a voluminous and commendable effort of compiling, analysing and assessing global information on climate change impacts, adaptation and mitigation. A similar intergovernmental effort is needed to address climatic/weather variability and to provide a road map for region- and sector-specific action plans in a given time frame for food security and poverty alleviation.

(e) For a holistic management of climatic risks in agriculture, new and innovative models of cooperation and partnerships are needed among three groups: (a) the World Meteorological Organization and the National Meteorological and Hydrological Services dealing with climate issues; (b) the Consultative Group on International Agricultural Research, National Agricultural Research Systems and Extension Services, the United Nations Convention to Combat Desertification, and Soil Conservation Services dealing with land degradation and agriculture technologies; and (c) the Food and Agriculture Organization of the United Nations and national entities dealing with agriculture, food security and policy issues. Such partnerships should explore securing global adaptation funds for research and development activities relating to reducing exposure of agriculture to multiple risks, providing incentives to farmers for resource conservation, ensuring food security and poverty alleviation, and other associated local, national and global benefits.

References

[1] Food and Agriculture Organization of the United Nations (FAO), Note by the Food and Agriculture Organization of the United Nations (FAO) for the G8 Summit, L'Aquila, 8−10 July 2009. http://www.fao.org/fileadmin/user_upload/newsroom/docs/FAO_G8_backgrounder.pdf.

[2] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. (M. Parry, O. Canziani, J. Palutikof, P. van der Linden and C. Hanson, eds). IPCC, Geneva, 2007.

[3] Svoboda, M., D. LeComte, M. Hayes, R. Heim, K. Gleason, J. Angel, B. Rippey, R. Tinker, M. Palecki, D. Stooksbury, D. Miskus and S. Stephens. The Drought Monitor. Bulletin of the American Meteorological Society 83 (2002) 1181.

[4] Baethgen, W.E., Climate changes in the agricultural sector of developing countries: Mitigation, adaptation and decision making. Multiciencia. 8 (2007) 122.

[5] Cooper, P.J.M., J. Dimes, K.P.C. Rao, B. Shapiro, B. Shiferaw and S. Twomlow, Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? . Agriculture, Ecosystems and Environment. 126 (2008) 24.

[6] Twomlow, S., F.T. Mugabe, M. Mwale, R. Delve, D. Nanja, P. Carberry and M. Howden, Building adaptive capacity to cope with increasing vulnerability due to climatic change in Africa – A new approach. Physics and Chemistry of the Earth. 33 (2008) 780.

[7] Meinke, H., R. Nelson, P. Kokic, R. Stone, R. Selvaraju and W. Baethgen, Actionable climate knowledge – from analysis to synthesis. Climate Research. 33 (2006) 101.

[8] Schwartz, B. and K.E. Sharpe, Practical wisdom: Aristotle meets positive psychology. Journal of Happiness Studies 7 (2006) 377.

[9] Nelson, R., P. Kokic, S. Crimp, H. Meinke and S.M. Howden, The vulnerability of Australian rural communities to climate variability and change: Part I – Conceptualising and measuring vulnerability. Environmental Science and Policy. 13(2010a) 8.

[10] Nelson, R., P. Kokic, S. Crimp, P. Martin, H. Meinke, S.M. Howden, P. deVoil, G. McKeon and U. Nidumolu, The vulnerability of Australian rural communities to climate variability and change: Part II – Integrating impacts with adaptive capacity. Environmental Science and Policy. 13(2010b)18.

[11] Meinke, H., S.M. Howden, P.C. Struik, R. Nelson, D. Rodriguez and S.C. Chapman, Adaptation science for agricultural and natural resource management – Urgency and theoretical basis. Current Opinion in Environmental Sustainability. 1 (2009) 69.

[12] Moss, R.H., A.L. Brenkert and E.L. Malone, Vulnerability to climate change: A quantitative approach, Prepared for the US Department of Energy. PNNL-SA-33642, 2002. http://www.globalchange.umd.edu/data/publications/Vulnerability_to_Climate_Change.PDF.

[13] Kaly, U.K., C.R. Pratt and R. Howorth, A framework for managing environmental vulnerability in Small Island Developing States. Development Bulletin. 58 (2002) 33.

[14] Luers, A.L., D.B. Lobell, L.S. Sklar, C.L. Addams and P.A. Matson, A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change. 13 (2003) 255.

[15] Cash, D.W., W.C. Clark, F. Alcock, N.M. Dickson, N. Eckley, D.H. Guston, J. Jäger and R.B. Mitchell, Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences. 100 (2003) 8086.

[16] Sivakumar, M.V.K. and R.P. Motha, Managing weather and climate risks in agriculture – A synthesis. In: Managing Weather and Climate Risks in Agriculture (M.V.K. Sivakumar and R.P. Motha, eds.). Berlin, Springer, 2007.

[17] Hay, J., Extreme weather and climate events and farming risks, in: Managing Weather and Climate Risks in Agriculture (M.V.K. Sivakumar and R.P. Motha, eds.), Berlin, Springer, 2008.

[18] Roetter, R.P., M. van den Berg, A.G. Laborte, H. Hengsdijk, J. Wolf, M.K. van Ittersum, H. van Keulen, E.O. Agustin, T.T. Son and N.X. Lai, Combining farm and regional level modelling for Integrated Resource Management in East and South-east Asia, Environmental Modelling and Software. 22 (2007) 149.
a
[19] Easterling, W.E., P.K. Aggarwal, P. Batima, K.M. Brander, L. Erda, S.M. Howden, A. Kirilenko, J. Morton, J.-F. Soussana, J. Schmidhuber and F.N. Tubiello, Food, fibre and forest products, in: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds), Cambridge, Cambridge University Press, 2007.

[20] Sivakumar, M.V.K. and N. Ndiang´ui, eds., Climate and Land Degradation, Environmental Science and Engineering, Berlin, Springer, 2007.

[21] Aggarwal, P.K., K.K. Talukdar and R.K. Mall, Potential yields of rice-wheat system in the Indo-Gangetic plains of India. Rice-Wheat Consortium Paper Series 10. New Delhi, India. RWCIGP, CIMMYT, 2000.

[22] Aggarwal, P.K., P.K. Joshi, J.S.I. Ingram and R.K. Gupta, Adapting food systems of the Indo-Gangetic plains to global environmental change: Key information needs to improve policy formulation. Environmental Science and Policy. 7 (2004) 487.

[23] Food and Agriculture Organization of the United Nations (FAO), High-Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy. FAO, Rome, 2008. ftp://ftp.fao.org/docrep/fao/meeting/013/k2359e.pdf.