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Developing an adaptation strategy for sustainable agriculture

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Abstract—Agriculture is one of the most important economic sectors of global society. Agricultural production continues to expand into forest lands and marginal crop areas in an attempt to keep pace with the ever-increasing world population. Environmental damage is increasing, including erosion, salinity, desertification, deforestation, threats to biodiversity, and water scarcity. Moreover, climate change/variability is having a profound influence on agroecosystems, posing serious threats to food security, human health, and protection of the environment. Thus, comprehensive agrometeorological adaptation policy guidelines, focusing on preparedness, mitigation, and adaptation measures to support sustainable agricultural development, are needed to cope with the impacts of climate change/variability. Adaptation policy can not be an effective “stand alone” strategy, but should be incorporated into a broader policy objective. For example, adaptation to climate change should be a part of a broader socio-economic policy such as agricultural, forest, water resources, natural resources, or coastal-zone management policy. Poorer countries that will require resources to improve capacity in order to cope with impacts, undertake specific adaptation measures.

Key-words: climate change, sustainable agriculture, adaptation, preparedness, policy

1. Introduction

Farmers must cope with natural disasters and extreme weather events as part of their everyday farm management strategy to harvest their crops and raise their livestock. Droughts, floods, heat waves, and tropical cyclones, among other natural hazards, have enormous (and sometimes devastating) impacts on agriculture and the socio-economic well-being of the agricultural community. Thus, an important challenge for agrometeorologists is to develop or improve preparedness and adaptation strategies, especially in vulnerable regions where food and fiber production is most sensitive to vagaries of weather and climate. Equally important, however, are to find the ways and means to translate these

strategies into meaningful products and services for local farming and extension systems; and, to help build the capacity to disseminate appropriate and timely information for the entire user community.

2. Preparedness, mitigation, adaptation, and emergency relief measures

It is within this framework that an effective agrometeorological adaptation policy is needed for the agricultural community to cope with natural disasters and climate change/variability. A disaster can be defined in terms of a natural hazard times the vulnerability. The natural hazard is an extreme weather or climate event such as drought, flood, heat wave, tropical cyclone, or other catastrophe such as wildfire, avalanche, earthquake, or tsunami. Vulnerability represents the social factors including land use practices, environmental degradation, water use trends, technology, urbanization, population growth, and population shifts.

Farmers have to cope with disasters and climate extremes throughout the growing season. Actions can be taken at the farm level to help farmers implement preparedness measures to cope with disasters, including better early warning communication and response systems. Feasible mitigation measures can help reduce vulnerability. Specific mitigation measures implemented by federal, state, or regional governments include drought monitor programs, water supply augmentation, public awareness/education programs, technical assistance on water conservation, water conservation programs, and emergency response programs. Specifically for agriculture, crop irrigation efficiency studies and scheduling, soil moisture monitoring, irrigation technology management, drought-tolerant crops, and innovative cultivation techniques to reduce crop water use are the primary mitigation measures. Adaptation strategies are measures or long-term plans to reduce the vulnerability of the agricultural or coastal communities to the natural hazards. These adaptation strategies need to be both proactive to address long-term coping strategies as well as reactive to provide resilience in the short-term.

A comprehensive framework to cope with natural disasters, which focuses on preparedness, mitigation, and adaptation, as well as emergency relief measures after a disaster strikes, is the ultimate goal of any policy initiative to support sustainable agricultural development efforts. There are other factors involved in this framework that have a significant impact on the ability to recover from climate extreme events. For example, with a shift from productive to marginal agricultural area, the impact of drought or flood on agriculture becomes a much more difficult challenge for climate sensitive farming and ranching, if remedial measures are not taken. The aim of this strategy is to move away from a mainly reactive approach to a disaster event (responding to a natural hazard that turns into a disaster) to a new paradigm based on a more

comprehensive approach that include preventive measures, mainly aimed at reducing the likelihood that a natural hazard translates into a disaster.

Adaptation can help farmers to minimize or reduce the negative impacts of climate extremes on activities and ecosystems, and, perhaps to take advantage of potential beneficial changes (*Rosenzweig, 2007*). The response that can be taken may be directly by individual farmers based on a set of technology and management decisions available. These systems include shifting the crop calendar (planting, input schedules), cultivar changes, and crop rotation changes. Another response requires a concerted action facilitated by climate-specific regulations and incentives from local, regional, and national policies. These options include land use incentives, irrigation infrastructure, water management, regulations, and germplasm development programs. Both adaptation responses are essential for sustainable agricultural systems.

3. Framework for an adaptation strategy

The development of adaptation policy must begin by identifying both the hazards and vulnerabilities, which then can be used to identify particular disaster scenarios. The disaster scenarios must account for all scales, ranging from actions to managing the local manifestations of global climate disaster, through to global measures to reduce hazards, and to reduce vulnerability. Ways and means of dealing with integrated climate disasters (or natural disasters) need to include the following elements: (1) adaptation to ensure that future developments reduce rather than increase potential disasters; (2) actions to mitigate the losses associated with disasters; and (3) measures to ensure that disasters do not reoccur after a disaster event. These measures should take into account both potential impacts on socio-economic and environmental systems in the local area.

Integrated planning and actions dealing with climate change (or natural disasters) allow the affected community to move beyond preparedness and contingency response and develop adaptation/response strategies to cope with climate change, variability, and extremes. Action must be taken at all governmental levels (international, national, and local) in order to deal with climate disasters and to move the policy from concept to practice. At the international level, an integrated international framework can promote partnerships for coping strategies, which incorporates elements of and builds on existing frameworks for addressing climate change, disaster reduction, desertification and others. At the national level, integrated climate disaster strategies, plans, and programs need to be built on the same institutional and administrative mechanisms as disaster risk management activities in order to address adaptation strategies for climate change (*Sperling and Szekely, 2005*).

Burton et al. (2002) describes a step-by-step formulation of an adaptation policy. The process to develop an adaptation policy for natural disasters and

future climate change begins by assessing current local vulnerabilities to present day climate, including its variability and extremes, and the ways that existing policy and development practice serve to reduce vulnerability.

The assessment of current vulnerability requires an understanding of key background information. What has been the recent pattern in climate variability and extremes? Are there any trends in their recent history of climate variability and extreme events, and if so, are there any discernible atmospheric oceanic features that can be attributed to the trends?

The next step in the policy development process involves the design of policy initiatives and alternatives, and their assessments and prioritization. In evaluating this phase of the exercise, some thought must be given to future conditions, including climate change and changes in the socio-economic environment, based on available evidence and/or sound reasoning. What are the prospects for economic and sustainable agricultural development? What are the prospects for adaptation and how much can vulnerability be reduced? What are the constraints and limitations to public policy for adaptation? What are the costs of adaptation measures and what benefits can be anticipated?

Adaptation policy can not be an effective “stand alone” strategy, but has to be incorporated into a broader policy objective. For example, adaptation to climate change in agriculture should be a part of a broader agricultural policy. The same applies to forests, water resources, coastal zone management, public health, natural ecosystems, infrastructure, and human settlements. Relevant policies are not limited to such socio-economic sectors, but can also include policies for dealing with natural hazards and coping with natural disasters (floods, droughts, tropical and extra-tropical storms, etc.). Governments may have national policies or special policies that are directed to regional developments, including rural and urban-centered regions or river-basins.

An assessment of current policy in agriculture, for example, will normally take into consideration the broad strategic objectives for agriculture in the national socio-economic and development context. Is the aim to expand commercial agriculture for export-led development? How much importance is given to local food security and the maintenance and improvement of agriculture-based livelihoods? Such policies also influence choice of crops and many other agricultural practices at the farm level. Of specific interest in the case of agriculture are other policies in related areas of natural resources and environmental management such as watershed protection and rehabilitation, soil erosion, soil salinity, the use of genetically modified crops, and so forth.

Costs of production are likely to rise in a changing climate, as producers adjust crop varieties and species, scheduling of operations, and land and water management techniques. Successful adaptation to climate change/variability may involve significant changes to current agricultural systems in order to maintain sustainability. Some of these changes may be costly. There may be a need for investment in new technologies and infrastructure; new irrigation

systems may be required for aridity or precipitation instability, damages from flooding may increase in many regions, there may be greater application and/or development of new agricultural chemicals, particularly herbicides and pesticides. However, with respect to agricultural chemicals, environmental concerns and increasing problems with chemical pollution (discussed earlier) limit its successful application.

Adaptation is, in fundamental ways, inherently local, meaning that both natural disasters and climate change/extremes have their direct impacts mostly at the local level. Thus, response measures must be tailored to local circumstances. However, for these efforts to be robust, or, in many cases, even possible, they must be acted upon, guided, and supported by the national policies and strategies. For some countries, these, in turn, need to be facilitated through international measures.

The adaptation strategy for a country refers to a general plan of action for addressing the impacts of natural disasters and climate change and climate variability, including extremes. This requires a combination of coordinated policies and measures with the primary objective of reducing the country's vulnerability. The comprehensive strategy should be aimed at the national level, but addressing adaptation factors across all sectors, regions and vulnerable populations of the country. Policies refer to objectives, together with the means of implementation, with the goal to strengthen food security, for example.

Ways and means to achieve this objective may be to enhance farmer advice and information services, improved application of agricultural research and development, better seasonal climate forecasting services for agricultural applications, and sustainable agricultural development systems. Measures are focused actions aimed at specific issues. Measures can be individual interventions or they can consist of packages of related measures. Specific measures might include actions that promote the chosen policy directions such as implementing an irrigation project, setting up a farmer information, advice, and early-warning programme, developing a new scheme for crop insurance, establishing a system of grain storage to protect against drought or crop failure, or providing incentives to grow a specific crop. Each of these measures may contribute to the local, regional, and national goal of food security.

Easterling et al. (2004) discussed the strategy of “proactive adaptation” as opposed to reactive adaptation. In the reactive strategy, measures take effect after the climate event or disaster strike. In the reactive approach, coping with disasters or climate change/extremes can be very costly in terms of emergency response measures. For example, there is the possibility that irreversible impacts such as species extinction or unrecoverable ecosystem changes can occur. Unacceptable high agricultural losses and damages that expose lives and property to intense storm damages can also occur.

Proactive adaptation, unlike reactive adaptation, is forward-thinking and takes into account the inherent uncertainties associated with anticipated change.

Successful proactive adaptation strategies are, therefore, flexible; i.e., they are designed to be effective under a wide variety of potential climate conditions, to be economically justifiable (i.e., benefits exceed costs) and to increase adaptive capacity. Preparedness is the cornerstone for a proactive adaptation strategy.

4. Formulation of an adaptation strategy for sustainable agriculture

All countries should have national adaptation strategies with a broad view of future development paths and expected impacts of climate on agriculture, forests, fisheries, and other natural resources. The policy review needs to include the management of extreme weather events as well. It must be proactive, emphasize risk management, and preparedness as the cornerstone of its strategy, but must include emergency relief measures as fail-safe response steps.

Developed countries are well advanced in both resources and planning for adaptation strategies. However, even in the developed countries, there is a wide range of progress, with some very limited action plans to a few with well developed national adaptation strategies. Developing countries are more vulnerable and less able to adapt to changing climate. They also have a greater dependence on agriculture and natural resources for subsistence-level economies. There is a tendency for many of these nations to have larger variations in weather; lower availability of critical resources such as water, productive land, production inputs, and capital. These vulnerabilities and limitations pose serious constraints on the ability of developing countries to cope with climate change and natural disaster issues.

The key issue is how governments and the international community can work together to assist developing countries with adaptation strategies and measures that are effective for local communities. The constraints are numerous, including expense, lack of knowledge on how to implement measures, and countervailing beliefs and cultural practices (Yohe *et al.*, 2007). Notwithstanding these impediments, farmers and others at risk in the local community from changing climate and natural disasters can be provided with external help. The provision of technical information, advice or guidance can be made more readily available through extension services in agricultural services; the provision of weather and seasonal climate forecasts and warnings can be improved; drought and flood emergency relief measures can be readily implemented; and insurance or other forms of risk management measures can be instituted. Adaptation measures need to be formulated into public policy. For example, with agricultural policies in place on crop and livelihood diversification, how drought and other climate variability or climate change influences agriculture can be factored into policy choices.

Knowledge is fundamental to any adaptation strategy. Knowledge is dynamic; it accumulates through observation, monitoring, and analysis; it can

also degrade over time if the learning process is neglected; and research and development must be continually supported to ensure literacy and education levels improve and/or basic societal infrastructure does not decay. Education raises awareness, and over time, it changes societal values. Examples are consumer information, public awareness campaigns, and professional development. Monitoring, observation, and communication systems have to be created or strengthened for climate-related parameters, for indicators of climate change and impacts (e.g., sea-level rise, changes in species composition of ecosystems, extreme events monitoring, and for enhanced agroclimatic observations).

Technological change is a principal route of many recent human adaptations. Innovations in transportation, agriculture, and information systems have advanced adaptive capacity. However, while these advances have taken place in developed countries, developing countries have not benefited from these innovations. Thus, a major gap is still to be bridged. Science, research, and development (R&D) and technological innovations are needed to enable responses to natural disasters/climate change in general, and to enable specific responses to extreme events/climate variability, including economic valuation of adaptations, technological adaptations (development of drought or salt-resistant crop varieties), and investigations of new sources of groundwater and better resource management. It may be necessary to adapt existing technologies to fit with the adaptation demands; e.g., the development of more energy-efficient, low-cost desalination plants and new technologies to combat saltwater intrusion.

Adaptations can be divided into two categories: autonomous and planned adaptations (*Easterling et al, 2007*). Autonomous adaptation is the ongoing implementation of existing knowledge and technology in response to the changes in climate experienced, and planned adaptation is the increase in adaptive capacity by mobilizing institutions and policies to establish or strengthen conditions favorable for effective adaptation and investment in new technologies and infrastructure.

Examples of autonomous adaptation options include: altering inputs such as varieties and/or species to those with more appropriate thermal time and vernalization requirements; wider use of technologies to “harvest” water, conserve soil moisture and to use water more effectively; water management to prevent waterlogging, erosion, and nutrient leaching in areas with rainfall increases; altering the time or location of cropping activities, diversifying income by integrating other farming activities such as livestock raising; improving the effectiveness of pest, disease, and weed management practices through wider use of integrated pest and pathogen management; and, using seasonal climate forecasting to reduce production risk.

Options for effective planning and capacity building for adaptation include: policies to maintain climate monitoring and for effective communication of this information, including surveillance of pests, diseases, and other factors directly

affected by climate; policies to support research, systems analysis, extension capacity, and industry and regional networks that provide information; need to invest in or develop technical options to respond to projected changes; where there are major land use changes, there may be a role for governments to support any transition; and, developing new infrastructure, policies and institutions to support management and land use arrangements by addressing climate change in development programs.

Risk and disaster management is another essential component of proactive adaptation. Proactive adaptation may necessitate periodic reassessment of the adequacy and preparedness of relief systems and programs, particularly in light of changing frequency and intensity of extreme events. Governments and insurance companies provide relief for such extreme climate events as hurricanes and tropical cyclones, floods, and droughts. Emergency plans, extreme events relief, and recovery measures also belong to this type of adaptation measure. Updating risk insurance rate tables may require anticipation of future climate/natural disaster risk changes. Proactive adaptation, therefore, may include fire mitigation programs such as prescribed burns and land use controls.

National drought policy has taken on even more importance with severe drought episodes in the late 1980's. Adaptation measures can also be grouped according to whether they are focused on one or more economic sectors (i.e., agriculture or multiple sectors). An example of a sectoral measure would be the introduction of improved agricultural varieties. In agriculture, for example, reduced rainfall and higher evaporation may call for drought tolerant crop varieties in a growing area. It may require a local, regional, and national drought policy to be implemented for long-term planning. Multi-sectoral measures include the use of improved watershed and coastal management methods, and more efficient irrigation management techniques. Multi-sectoral measures relate to the management of natural resources that span sectors; e.g. agricultural, water management, or river basin management. A third adaptation measure is called cross-sectoral measures, which includes such measures as the promotion of public awareness, agroclimatic research, and data collection. Sectoral measures may relate to specific adaptations that could be affected by natural disasters/climate change.

Science and technology have provided the knowledge and tools for the development of adaptation strategy formulation; a key component in the ultimate success in this framework is the engagement of stakeholders; i.e., individuals, local community groups, organizations (governmental agencies or non-governmental organizations and their networks). Relevant stakeholders need to be brought together to identify the most appropriate forms of adaptation. Furthermore, understanding the role of stakeholders in the decision-making process will assist in the implementation of adaptation policies.

Thus, an outline of an adaptation strategy for agriculture considers the following issues:

- (1) Complete monitoring systems will allow policymakers to develop and adjust adaptation strategies based on sound observational data bases. Agrometeorologists can take a more active role in this aspect, as noted earlier in the discussion of the socialization of agrometeorology. It is becoming increasingly important to communicate and disseminate meaningful and appropriate information to the user community at the right time and in the right format for decision-making.
- (2) Risk/disaster management measures include the development of early warning systems, in particular for extreme events like cyclones, droughts, floods, and ENSO occurrences. The success of this type of measure depends upon good communication systems and cooperation among users.
- (3) In many cases, flexibility, durability, and resiliency to climatic variability and change can be enhanced via changes in infrastructure design characteristics. Agriculture extension services can be more proactive with farmers to inform them about changes in crop varieties and practices that may be better suited to changing climate conditions.
- (4) Adopt preparedness measures and emergency response measures to help mitigate the impact of climate extremes and climate change.
- (5) Avoid agricultural expansion into marginal lands, coastal lowlands, or other poor cropping areas that are prone to desertification, coastal erosion, or prone to flooding.
- (6) Promote technological innovations that fit adaptation demands and will benefit both developed and developing countries, if possible.
- (7) Public policy provides substantial guidance in adaptation formulation and strategy at the national level, and, planning and implementations at the local level. Coordination at all levels is absolutely essential for emergency preparedness and disaster planning.
- (8) In summary, the ecosystem approach to adaptation measures involves the integrated management of land, water and other resources that promotes their conservation and sustainable use in an equitable way.

5. Education and training

It is essential to promote greater community education and training opportunities to meet the needs of the public, which correspond with the development of more robust warning systems, the increasing capacity to respond rapidly to disasters, and the recognition for comprehensive adaptation strategies in the community to

cope with natural disasters and climate change. Some general focus areas include:

- Develop community awareness and self-management programs in relation to hazard management. The emphasis is on equipping community groups exposed to certain types of hazards with the knowledge to manage that hazard;
- Provide training programs in the effective use of agro-climate information, including climate predictions (which have the potential not only to help minimize heavy losses in poor years, but also to maximize yields in good years) and vulnerability scenarios;
- Promote communication strategies between stakeholders, including effective use of the media. Good services and methodologies are ineffective unless the user understands and applies the information provided. At the same time, it is important that users be able to feed back how the information can be improved (*Wright, 2005*).

Finally, the introduction of natural disaster/climate change and climate variability issues at different levels of the educational system must be in an ongoing process to help build capacity among stakeholders to support adaptation in the future and to develop appropriate research activities and a greater awareness among citizens. Furthermore, campaigns to raise public awareness and disseminate information in order to involve a broad array of stakeholders are necessary. These campaigns can also be an opportunity for adaptation decision-makers to better understand the perception and views of the public on the issues.

6. Conclusion

There are many illustrations of potential coping strategies each with challenges and uncertainties. There can be no generic strategy that can be formulated as a suitable solution for wide applications in diverse areas. However, the goal is to establish guidelines to meet the specific needs of the user community that be incorporated in the development of adaptation policy framework and adaptation measures.

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