

**Vulnerability to Climate Change in Agricultural Systems  
in Latin America and the Caribbean:  
Building Response Strategies  
(P109730)**

***FINAL REPORT***

**WORLD BANK**

**May 22, 2009**

# **Vulnerability to Climate Change in Agricultural Systems in Latin America and the Caribbean: Building Response Strategies**

## **Final Report**

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We extend our thanks to the lead institutions in Mexico, Peru and Uruguay and the local team members representing those institutions for their work on this study; these efforts are reported on in the separate individual country reports. We wish to acknowledge, in Mexico: Alejandro Castellanos (Universidad de Sonora), Erasmo Valenzuela (INIFAP – Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias), and César Ocaña (COFUPRO – Coordinadora Nacional de las Fundaciones Produce, A.C.); in Peru: Julio Toledo and Miguel Barandarian (INIA – Instituto Nacional de Innovación Agraria), and Carlos Aguirre (private consultant); and in Uruguay: Agustín Giménez, Bruno Lanfranco and Jorge Sawchik (INIA – Instituto Nacional de Investigación Agropecuaria). We also wish to acknowledge the varied contributions to this study on the part of World Bank staff members Indira Ekanayake, Beatriz Franco, Alexandra Horst and Ana Francisca Ramirez. Finally, we extend our thanks to those who reviewed an earlier draft of this study and provided many constructive inputs and suggestions: Jo Albert, Erick Fernandes, Gretel Gambarelli, Michel Kerf, John Nash, Ethel Sennhauser, William Sutton, and Ernesto Viglizzo. The authors assume the responsibility for any errors or omissions.

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## EXECUTIVE SUMMARY

The 2007 Fourth Assessment Report of the International Panel on Climate Change (IPCC, 2007) states that “Warming of the climate system is unequivocal” and documents widespread evidence of global warming and other major climatic changes. The impacts of these changes on agriculture and the farmers, rural households and communities that depend on agriculture worldwide can be expected to be substantial. Not only is agriculture closely tied to its natural resource base, which is expected to undergo climate-related changes, but the livelihoods of many of the world’s rural poor, whose livelihoods are already precarious, can be expected to be made even more vulnerable by these changes. Latin America, like other regions of the world, is significantly affected by climate change, current and future.

This study reports the results of “action research” to identify and prioritize stakeholder driven, locally relevant response options to climate change. These response options comprise the basis of local action plans developed to address agricultural adaptations to climate change in three diverse agroecosystems: the Yaqui Valley in northwestern Mexico, the Mantaro Valley in central Peru, and the western littoral regional of Uruguay. The study has three primary objectives. The first is to develop and apply a pilot methodology for assessing agricultural vulnerability to climate change and for formulating response strategies to inform private and public sector decisions in the Latin America region. The second objective is to formulate recommendations for investments in each of the selected agro-ecosystems in a range of areas including agricultural technology adaptation, infrastructure investments, public and private sectoral support activities, and institutional and policy changes. The final objective is to disseminate the study results in the Latin America region to help increase understanding of the impacts of climate change and alternative adaptation response strategies. This methodology can be used by the Bank to support client countries in defining response strategies, designing related investment projects and formulating policy changes.

The approach taken in this study is based on a formal priority-setting methodology designed to utilize the input of local experts and stakeholders in each of the three regions to develop climate change action plans based on the identification and prioritization of response options that promote adaptation strategies. This methodology translates knowledge about weather variations,

expected climate changes and agricultural systems into a form for decision-making at the local and regional levels. The methodology employs four steps incorporating activities centered around a series of three workshops in each country. *Step 1* involved a comprehensive review by the local country teams of expected climate changes over the next 30+ years and expected regional effects on agriculture in each region. Based on these results, *Step 2* entailed the identification of potential response options to address climate changes and their expected impacts. *Step 3* consisted of the detailed elaboration of these potential response options, the designation and weighting of evaluation criteria for evaluating them, and their assessment and ranking in a formal priority-setting process. The final step, *Step 4*, involved developing a local action plan in each of the three regions based on the prioritized response options for subsequent validation and consideration by policy- and decision-makers.

The key results of this study are several. First, we find that *use of a “bottom-up” participatory priority-setting methodology provides a useful mechanism for the identification and initial design of proactive strategies to improve agricultural sector adaptation and resilience*. The pilot methodology we employed is easy, transparent and relatively costless to apply; is highly participatory and flexible in operation; and it focuses directly on incorporating the views of diverse local stakeholders, the same stakeholders – farmers, landowners, resource managers – whose decisions are at the forefront in actually dealing with climate change at the local level. Moreover, the methodology clearly highlights feasibility considerations and the transition from analysis through decision-making to political acceptance.

Second, although the three production environments were very different agroclimatically, economically and by many other measures, *the response options that emerged across the three countries converged to very similar outcomes*. These included:

- *climate information systems* – e.g., systems for climate predictability (early-warning systems; developing capacity for longer term projections), providing agro-climatological information and enhancing its accessibility by producers;
- *water management technologies* – e.g., water harvesting, drainage, irrigation distribution systems, etc.

- *improvements in the integrated management of natural resources and production systems*, in various forms: water and watershed management, conservation agriculture, crop and pasture rotations, adjustment of planting dates, etc.
- *technological innovations to minimize climate risk*, including plant breeding and biotechnology innovations for drought resistance and pest and disease resistance, and improvements in irrigation infrastructure;
- *institutional innovations*, including: early warning systems for climate and pests and disease, improved policy and regulatory frameworks for water management, agricultural and catastrophic risk insurance, etc.

Given the wide diversity of agricultural production systems in LAC, the similarities in intervention mechanisms identified by local stakeholders in very different settings is a significant finding. These response options can be considered a first approximation to a regional agricultural adaptation strategy in agriculture, one built, at least in part, from the “ground up.”

Third, *a needed role for the public sector was identified in all three country settings*. The bottom-up process inherently prioritizes the responses identified by private resource managers; however, in all three countries, it was widely recognized that private sector responses to climate change can be greatly facilitated by selected public sector interventions. The public sector can play a key role in areas such as infrastructure investment, institutional innovations to help deal with environmental externalities and imperfect markets, and in providing information to facilitate private decision-making.

Fourth, many of the response options identified and prioritized by participants in the workshops in all three countries focused on *decision support and improving the information base* available to farmers through such mechanisms as early warning systems (for climate forecasts, extreme weather events, pests and disease outbreaks, etc.) and climate risk maps and geographic information systems. These are relatively inexpensive options, compared, for example, to major infrastructure investments, and they still leave the key resource allocation decisions in the hands of farmers. Moreover, they directly address the “information externalities” that would otherwise lead to sub-optimal resource use and responses to climate change.

Fifth, *the dissemination of results and the applicability of the priority-setting methodology in other countries and agroecosystems dealing with climate change impacts* would be valuable as one mechanism to deal with climate change adaptations, especially at the local level. With appropriate adjustments based on the specific setting and the “lessons learned” as a result of this study, the pilot approach tested here should be highly applicable to other country and agroecosystem settings. Other priorities for follow-up in terms of implementation and replication include: the closer integration of the local action plans and prioritized response options within national climate change frameworks; the integration of elements addressing mitigation, in addition to the focus here in adaptation; and a more complete reconciling of participatory approaches with modeling inputs and economic evaluation.

Finally, this study reports a number of the practical lessons learned about the priority-setting methodology that should help inform similar efforts elsewhere. We found that developing action plans to address climate change is surrounded with information uncertainty, complexity and an incomplete understanding of causality. A multi-criteria approach such as that employed here helps break up the decision process into manageable parts, acknowledging these sources of uncertainty and reducing the impact of individual assumptions that may subsequently prove inaccurate. Uncertainty also plays a role in shifting the focus of stakeholder driven response options from “climate adaptation” to “climate resilience”. This shift has both advantages – the ability of an agroecosystem to recover from shock and stress induced by climate change – as well as disadvantages, including deemphasizing the importance of mitigation strategies that may address unforeseen future changes. We also conclude that “details matter” in pursuing a priority-setting methodology such as that employed here – that is, the operational and procedural details of using the methodology can make a difference in the outcomes. We found, for example, that the methodology used in this study is more suitable for consensus-building than for conflict resolution; that, as expected, the mix of workshop participants makes a difference in prioritized outcomes; that the quality of workshop facilitation makes a difference in the ability to generate local consensus on response strategies; and that the methodology is compatible with, but not a substitute for, cost-benefit analysis and other economic evaluation and assessment strategies.

## PROLOGUE

Few sectors have more at stake with global climate change than does agriculture. Agriculture is the principal livelihood of the world's poor and at the same time comprises a substantial proportion of the world's land cover. Expected changes in temperature, precipitation and other climatic events over the course of the 21<sup>st</sup> century will create nearly universal challenges of adaption and mitigation for agriculture across the globe, including in Latin America. Although policy and institutional changes to address climate change are commonly formulated at the national and international levels, those ultimately making the micro-level decisions regarding land use and resource allocation are typically farmers and rural households. It is important that the views and priorities of these and other local stakeholders who significantly influence land, water and other resource use decisions be considered in formulating responses to climate change.

This report describes a “bottom-up” approach to identifying and prioritizing agricultural adaptations to climate change among rural stakeholders and local decision-makers in Latin America. The study uses a formal priority-setting methodology to generate local response options to climate change in agriculture. The response options address different sources of uncertainty in local agroecosystems stemming from climate changes – principally in temperature, precipitation and the frequency of extreme events – and their expected effects. The application is to three diverse agroecosystems in Mexico, Peru and Uruguay. In each case, local country project teams involved participants in a series of workshops designed to 1) understand expected climate changes and identify possible response options, 2) prioritize the response options, and 3) develop a climate change action plan that addresses agricultural adaptations to climate change. These response options form the basis for a climate change action plan developed in each case.

Following a brief background and overview of the study, this report discusses the study objectives, the priority-setting methodology employed, and then provides a short description of each of the three study sites. In the main body of the report, each of the four project steps – centered around a series of three workshops in each country – is outlined and discussed. The concluding section summarizes the results and conclusions of the study, the lessons learned regarding the potential application of this methodology elsewhere, and the possible extensions of this study to other countries and contexts.

## I. INTRODUCTION

The recent Fourth Assessment Report of the International Panel on Climate Change (IPCC, 2007) states that “Warming of the climate system is unequivocal” and documents dramatic and widespread evidence of global warming and other climate changes. These impacts include: measured increases in air and ocean temperatures; widespread melting of snow, ice and glaciers and thawing of permafrost regions; an increase in ocean acidification and global average sea levels; and an increase in the frequency and intensity of extreme weather events such as cyclones and tropical storms. Based on extensive observational evidence, the report finds “significant change in many physical and biological systems” – nearly 9 out of 10 of these observed changes are consistent with the climatic changes expected from global warming. The Report concludes that “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.”

The impacts of these, and other, climate changes on agriculture and the farmers, rural households and communities which depend on agriculture can be expected to be particularly significant for two reasons. First, agriculture is directly and closely tied to its physical resource base and natural assets. Major changes in that resource base throughout much of the world widely threaten agricultural production and yields. Among the projected global impacts on agriculture identified in the IPCC Report are: reduced yields in warmer environments due to global warming and the growing incidence of heat waves, increased heat stress, incidence of wildfires, and accompanying land degradation; crop damage, soil erosion and increased water logging due to heavy precipitation events; and saltwater intrusion, soil salinization and loss of coastal farmlands due to higher sea levels.

Second, many of the world’s poor – particularly the rural poor – whose livelihoods are already precarious, are made more vulnerable by climate change for the simple reason that they are disproportionately dependent on agriculture and other natural resources for their livelihoods. More than 2.6 billion people are estimated to be directly dependent on agriculture and 600 million are dependent on livestock production; another 1.6 billion people are estimated to be dependent on forests for at least some portion of their income, and still another 250 million

people closely dependent on marine and inland fisheries (World Resources Institute, 2005; FAO, 2006). The human consequences of climate change for human well-being are enormous, especially when combined with other ongoing sources of ecosystem degradation, as documented in the recent reports of the Millennium Ecosystem Assessment (2005).

Like many other regions of the world, Latin America is significantly affected by climate change, current and future. Although the region accounts for about 12 percent of global greenhouse gas emissions (de la Torre, et al., 2009), the economies of many Latin American countries – and the livelihoods of their people – are heavily dependent on natural resource-based industries, including agriculture. Projected regional impacts of global warming and climate change in Latin America identified by the IPCC include: a transformation of tropical forest to savanna lands in eastern Amazonia; in semi-arid regions, a transition from semi-arid vegetation to arid-land vegetation; and significant biodiversity loss through species extinction in tropical regions. In terms of agriculture specifically, projected effects include: declining productivity of some important crop and livestock systems, with adverse impacts on food security; changes in precipitation patterns and the disappearance of glaciers which will significantly affect water availability for agriculture, human consumption and energy generation; degradation (and loss) of coastal farming systems; and an overall rise in the number of people at risk of hunger. The World Bank's recent study of regional responses to climate change in Latin America (de la Torre, et al., 2009) goes even further, suggesting a “precipitous fall” in agricultural productivity in many regions, with resultant adverse impacts on GDP and rural poverty (although these are likely to be highly region-specific).

Climate changes and their projected impacts create challenges of both *mitigation* and *adaptation*. The capacity to *mitigate* future climatic changes is critical because projections from global circulation models (GCM's) show that future emissions projections significantly influence climate change projections, particularly for the second half of this century. Latin America demonstrates a mixed picture in this regard, in that emissions per unit of energy consumed have declined significantly, but have remained constant when measured on a per capita basis or relative to GDP (de la Torre, et al., 2009). There is considerable capacity to influence future outcomes through emissions decisions made today, particularly regarding the use of fossil fuels

in transportation, energy generation and industrial use. Given that an estimated 13.5% of GHG emissions originate in agriculture, there is also significant scope for mitigation activities in agriculture itself. These include: increasing energy efficiency in agriculture; increasing soil carbon storage through improved land management for crops and grazing; decreasing methane emissions through changes in rice cultivation and livestock and manure management; and improving fertilizer applications to reduce nitrous oxide emissions (IPCC, 2007).

In terms of *adaptation*, a wide variety of strategies can be used in agriculture, where responding to climatic variability has long been a dominant concern of farmers. To maintain production levels and yields, farmers commonly spontaneously adjust practices such as planting dates, the selection of crop varieties, cattle stocking rates, and water use in response to short-term climatic variations. But in addition to these autonomous adjustments by farmers, as climate changes become more severe and pervasive, long-term *planned adaptations* become increasingly important in helping anticipate and minimize the effects of adverse conditions and in responding to long-run projected changes (FAO, 2007). These longer term adaptations include both those immediately relevant at the farm level – the application of new technologies and management techniques, increasing efficiency of water use and distribution systems, innovations in input use (fertilizer, tillage methods, irrigation) – as well as public investments and other broad-based mechanisms for improving adaptation. These include: investments in agricultural research and irrigation infrastructure, information systems for farmers, education and training, biodiversity conservation and wider institutional and policy changes (FAO, 2007). Efforts to build ecosystem resilience to better cope with current climate variability are also a vital and profitable first step towards adapting to future climate challenges (Cooper et al., 2008).

Why are international institutions like the World Bank interested in addressing the effects of climate change in agriculture? There are at least three reasons. First, because agriculture is responsible for generating the livelihoods of most of the world's poor, there is a close and direct connection between maintaining a viable, productive agricultural sector – which rests on underlying climatic and biophysical conditions – and rural poverty alleviation (World Bank, 2007). Second, given the many spatial, intertemporal and country size-related externalities that are created by climate change, international coordination and collaboration with national

governments is critical to generating more sustainable outcomes that would otherwise result from unilateral decisions. Finally, “good development policy is good adaptation policy” (de la Torre, et al., 2009). We know that there exists great scope for reducing the adverse impacts of climate change with informed, fully implemented adaptation strategies (Mendelsohn and Dinar, 1999). Those strategies are much more likely to be effective if developed jointly with governments and local institutions, making use of best available information regarding future projected changes and using a long-term horizon particularly in areas like investing in agricultural research and infrastructure development (e.g., for irrigation), where the long-term payoffs are significant.

## II. STUDY OBJECTIVES

This study has several objectives:

1. *Develop and apply a methodology for assessing agricultural vulnerability to climate change and for formulating response strategies* to inform private and public sector decisions in the Latin America region. The methodology, developed here on a “pilot” basis, translates knowledge about weather variations, expected climate changes and agricultural systems into a form for local and regional decision-making. This methodology can be used by the Bank to support client countries in defining response strategies, designing related investment projects and formulating policy changes.
2. *Formulate recommendations for investments in each of the selected agro-ecosystems* in a range of areas including: agricultural technology adaptation, infrastructure investments, public and private sectoral support activities and institutions (such as insurance, technical assistance, etc.), complementary off-farm income-generating activities, mitigation strategies and policy changes.
3. *Disseminate the study results in the Latin America region* to increase understanding of the impacts of climate change and the costs and benefits of adaptation and mitigation response strategies.

In addressing these objectives, several characteristics of this study should be mentioned. First, the *primary focus of this study is on adaptation to climate change* in Latin American agriculture. As discussed above, mitigation activities – in agriculture and other sectors – are also critical to addressing climate change. This study begins with the observation that farmers and households are already responding to existing climatic variation and longer-term climate changes by making significant behavioral and management changes. The focus of this study is on identifying relevant climate changes in selected agro-ecosystems in Latin America, and formulating adaptive response options that can be used to develop local action plans that will in turn support informed responses in the future. We find that many of these options are in fact consistent with improved mitigation strategies, but the primary focus here is on adaptation.

Second, *the study adopts a “bottom-up” approach*. In a series of three workshops and intervening work by local teams in each country, local stakeholders – farmers, farmer organization representatives, agronomists and technical experts, extensionists and other stakeholders – were closely involved in:

- Identifying current climate changes and their implications for local agricultural systems, rural livelihoods and local people;
- Identifying possible response options – technical, institutional, policy – to support local adaptation strategies to climate change; and
- Prioritizing these possible response options in the form of activities and initiatives that form local action plans.

This bottom-up focus is important for a number of reasons, one of which is that responses to climate change entail changes in the behavior of decision-makers and resource managers at all levels, from farmers and rural households to policy makers. A bottom-up approach – in which response options are identified and prioritized by local stakeholders – makes it much more likely that the response options that are ultimately chosen will be realistic and feasible to those who are most familiar with local circumstances and making resource management decisions.

Third, the study was carried out across *multiple countries and agro-ecosystems* in an effort to identify cross-cutting themes involved in understanding climate changes and their implications, as well as the local responses to those changes. By working at multiple sites, we dealt with a

range of agro-climatic conditions, from highly favorable to highly constrained, and a range of national policy frameworks. This breadth of biophysical and institutional settings is important in addressing adaptation to climate change in a highly diverse region like Latin America.

Fourth, *this study is an example of “action research.”* The applied research undertaken in this study was built around identifying, providing decision support for, and priority-setting of a set of local response options leading to comprise local action plans designed to address climate change and agricultural adaptations. The study reviewed and incorporated existing scientific research on climate changes, forecasts of future climate scenarios and possible agricultural system adaptations to those changes. But the focus was not on conducting new scientific research on either climate changes or their predicted impacts on agriculture and the environment. We took as given existing research results, and focused on the implications of those results for local households and decision-makers who are fundamentally responsible for responding to climate changes at the local level.

Lastly, *this is a “pilot”*. One of the chief objectives of the study was to test the usefulness of a formal priority-setting approach to identifying response options and local action plans to address climate change adaptation. Formal priority-setting approaches have frequently been employed in a variety of other contexts such as agricultural research and public health interventions. We sought to analyze their usefulness for understanding climate change and response options ranked highly by local stakeholders.

Coming to terms with climate change and agriculture requires many different approaches. Effective mitigation strategies – and many adaptation strategies, as well – necessarily entail national level policy changes and a significant degree of “top-down” decision-making. In areas where public goods are involved – assuring adequate water supplies, reducing air and water pollution, maintaining climatic regulatory processes – the public sector has a necessary role. This study is an example of an approach that addresses the local impacts of climate change in agriculture and how to efficiently identify realistic, feasible “bottom-up” strategies that can potentially make local resource management strategies more informed and more effective.

### III. PRIORITY-SETTING METHODOLOGY

One of the constraints in dealing with adaptations to climate change, as in most other areas, is that resources are constrained. Even given the severity of climate change-related problems in agriculture, there are inherent resource limitations faced by farmers, landowners and resource managers, as well as the private and public sector institutions that support them. As in any environment where resources are constrained, a formal priority-setting methodology may be used to establish priorities among competing alternatives to order to meet private or social objectives. But whose priorities? Depending on the application, they might be those of farmers, households, researchers, extension personnel, non-governmental associations, government authorities, or external donors. Priority-setting methodologies have been employed in many areas, including the allocation of resources in research programs in agriculture, biotechnology and health; establishing priorities for public health expenditures, such as in malaria interventions; allocating amongst competing demands in public sector budgets; and even in prioritizing needs in building maintenance. Due to the relevance of the experience with agricultural research to the objectives of this study, we draw most heavily from the priority-setting literature in agricultural research.

A variety of priority-setting methods have been used in agricultural research and related fields (Alston, et al., 1995; Lattre-Gasquet, 2006). Among the alternative approaches are:

- *Congruence methods*, which rank alternative choices on the basis of a single measure;
- *Scoring methods*, which rank alternative choices according to multiple criteria;
- *Benefit-cost models* (benefit-cost ratios, net present value, internal rate of return), which rank alternative choices by quantitative measures that assess the present value of a stream of economic benefits and costs over time;
- *Economic surplus models* which use applied welfare measures based on the price responsiveness of consumers, producers, input suppliers and government, and the resulting net benefits, and their distribution, among different groups.
- *Foresight models* which base resource allocation decisions (for example, in research or technology development) on assessing the relative economic and social benefits of alternative measures vis-à-vis their ability to generate future expected or desired outcomes.

There are advantages and disadvantages to each of these approaches as they apply to addressing adaptation to climate change. The exceptionally high degree of complexity and uncertainty in priority-setting for climate change adaptations has been previously noted (FAO, 2008): the multiple sources of uncertainty; the vulnerability of the poor; the many actors (local, national, international) and their relative, and sometimes conflicting, roles; the lengthy time-scale of changes and impacts. Given the simplicity of congruence methods, and the limitations of benefit-cost, economic surplus and foresight models as applied to climate change (see below), it was determined early in this study to use a scoring method approach.

Typically, scoring methods involve the assessment (via scoring or ranking) by individual actors of alternative choices using a number of different criteria. This may be done by “matrix ranking” (evaluating multiple choices by multiple criteria) or by pair-wise ranking, in which a ranking of options is established by a sequential evaluation of all possible pairs. Scoring methods used in priority-setting have both advantages and disadvantages (Alston, et al., 1995; Manicad, 1997). Advantages include the fact that the method is easy to administer, transparent, it allows for active involvement by diverse participants, and the method does not require advanced quantitative skills (unlike benefit-cost and economic surplus methods, for example). Disadvantages include the simplicity of the method and that it does not quantify or often make explicit economic (including welfare) measures, the results are dependent on those who are doing the scoring, and there can be problems and inconsistency in the definition of objectives and evaluation criteria.

However, the limitations of benefit-cost and other conventional economic assessment approaches in the context of climate change also deserve brief note. Conventional economic evaluation approaches such as benefit-cost analysis work best in a deterministic environment where the sources of uncertainty are minimized, or at least expected values based on distributions associated with possible outcomes are known (Environmental Assessment Institute, 2006). Such is not the case with climate change and agriculture, where the sources of uncertainty are many and ubiquitous – uncertainty stemming from climate change outcomes themselves, their impacts on agricultural production and the natural resource base underlying agriculture, the geographic distribution and time-paths of those effects, and the wide variety of human responses to climate

changes that are yet to unfold – for example, regarding mitigation measures and the outcomes they have yet to determine in the latter half of the current century. Even given information on the expected distributions of costs and benefits under alternative climate change scenarios, the costs, time and resources necessary to conduct a full-blown benefit-cost or economic surplus assessment given the multiplicity of possible outcomes, the lengthy time-scale of analysis, and the many remaining unknowns – such as the outcomes of future commodity prices – make these conventional approaches problematic. That said, the plan in this study, from the outset, was to incorporate estimates of costs and benefits of possible climate change response options within the priority-setting methodology so that they would be prominent in the evaluation process.<sup>1</sup>

The use of scoring methods to address climate change is applied in this study within a broader priority-setting framework that we have adapted from the regional research planning and priority-setting methodology developed by Janssen and Kissi (1997), for application to agricultural productivity and natural resource management research. Our approach also draws from the participatory “Interactive Bottom-up” approach (see Commandeur, 1997) and the “stepped agro-ecological” approach (Thiombiano and Andriessse, 1998), both developed in the Netherlands to address priority-setting in the areas of agricultural biotechnology and agro-ecological research, respectively. These approaches emphasize a sequential approach that is built fundamentally around needs assessments by local stakeholders and that also incorporates:

- formation of a multi-disciplinary local team;
- collection of information (scientific, institutional, policy) by the team early in the study;
- sharing of this information with stakeholders at a workshop(s) as background for subsequent priority-setting exercises; and
- a process of substantiation and validation of the priority-setting process that focuses on policy and implementation.

The Janssen-Kissi methodology is the most comprehensive and entails additional steps, including an explicit focus on identifying local constraints and potentials, the incorporation of explicit quantitative criteria to use in priority-setting (benefits, costs, adoption), and the identification of

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<sup>1</sup> Further discussion on this study’s experience with the priority-setting methodology applied to climate change is given in Section VI, Box 2.

human resource needs for implementation. In the application of this study to climate change, several aspects suggested pursuing a more streamlined application of this methodology: the degree of uncertainty characterizing both causes and impacts, the level of technical knowledge required to understand highly complex issues, the study focus beyond simply marketable commodities, and the frequent lack of locally-relevant quantifiable decision criteria. Details on the methodological approach as it was applied here are discussed in Section V.

#### **IV. OVERVIEW OF THE THREE REGIONS**

As indicated above, one of the key objectives of this pilot study was to apply the priority-setting approach in several different regions reflecting the diversity of agro-ecosystems, institutional and policy frameworks that are represented across Latin America. The three regions selected for this study were:

- the Yaqui Valley in the State of Sonora, in northwestern Mexico;
- the Mantaro Valley in the central Andean highlands of Peru; and
- the western littoral region of Uruguay, including the Departments of Colonia, Soriano, and Río Negro.

Within these three regions, the study incorporated a highly diverse set of agro-ecosystems. The Yaqui Valley is a dry but intensively irrigated and highly productive agricultural system, home to the “Green Revolution” in wheat production. The Mantaro Valley in Peru is a productive Andean highland valley surrounded by steep hills and mountains and characterized by mostly small producers and highly diversified farming systems. The western littoral region of Uruguay is part of the flat pampas region, with rangelands and croplands producing a variety of cereals and oilseeds, and characterized by medium to large farms. The farming systems of each of these regions are briefly described in this section. Further details are available in the individual country studies accompanying this report. Some of the aspects of the national policy and institutional environment dealing with climate change in each country are also briefly discussed.

**Figure 1. The Yaqui Valley of Northwestern Mexico**



A. The Yaqui Valley of Northwestern Mexico<sup>2</sup>

The Yaqui Valley, located in northwestern Mexico, is one of the most highly productive wheat-based farming systems in the world and was the original site of the 20<sup>th</sup> century “Green Revolution” in wheat production. The Valley watershed encompasses 71,452 km<sup>2</sup>, divided into three major sub-watersheds. Located in the semi-arid coastal plain of the Sonora Desert, the Valley has an annual rainfall of only 512 mm/year in the upper watershed and about 350 mm/year in its lower regions. A high degree of inter-annual variability in rainfall has been experienced in recent decades. Rainfall is highly seasonal with most precipitation in the summer months of July to October. Average monthly temperatures range between 17° C (January) and 31° C (July-August); however, the temperature extremes are much wider, ranging between an average minimum monthly temperature of 7° C (January) and 25° C (July-August) and average maximum monthly temperatures of 25-26° C in December through February to 45° C in August.

<sup>2</sup> Unless otherwise indicated, the material in this section is drawn from Castellanos, et al., 2009..

About a quarter million hectares of irrigated crops are grown in the Valley (252,000 hectares in 2007), valued at over \$4 billion (2007). A wide variety of crops is grown, although most land, currently 70-75%, is devoted to wheat production. The Valley is not only the most important wheat-producing area in Mexico's State of Sonora, but it accounts for about 40% of wheat production in Mexico as a whole. Other major crops include safflower, corn, sorghum, garbanzo beans, potatoes, and cotton. A large number of vegetable crops are also produced including tomatoes, chilis, broccoli and lettuce. The cattle industry is also an important industry overall in the State of Sonora.

The high productivity of the region's irrigated agriculture is mostly attributable to its extensive irrigation system and the broad availability of irrigation water. The three major reservoirs in the Valley – the Angostura (built in 1941), the Oviáchic (1952) and the Novillo (1965) – provide a storage capacity of 7,168 hm<sup>3</sup> and generate water availability of 2.2-3.2 billion m<sup>3</sup> annually. The intensive use of irrigation water and other purchased inputs (improved seeds, fertilizers, etc.) makes for very high yields. Yields of eight major crops (not including wheat) were estimated at 161-293% of national average levels in 2007 (SAGARPA, 2008). In recent years, as water scarcity has grown, groundwater sources have increasingly been used for supplementary irrigation especially during periods of drought. This is the case even though the cost of irrigation water from groundwater sources is much higher to farmers than that from surface water sources. Approximately 320 irrigation wells exist in the Valley, of which about 113 are in private hands.

### B. The Mantaro Valley of Central Peru<sup>3</sup>

The Mantaro Valley is located in the central Andes of Peru at an altitude of between 3000 and 3400 masl. The Valley extends 53 km in length and ranges between 4 km and 21 km in width, covering a total of 34,500 km<sup>2</sup> (Figure 2). Farming occurs both in the productive valley bottomlands as well as the much less productive steep hillsides on the margins of the watershed.

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<sup>3</sup> Except where indicated, this section draws from Cuellar, 2008.

**Figure 2. The Mantaro Valley of Central Peru.**



The local economy is highly diversified; although agriculture accounts for 25-35% of employment, the manufacturing, commerce and service sectors all generate roughly equivalent proportions of economic activity. The climate is mild and dry, although with a high, and increasing, degree of climatic variability (Silva, et al., n.d.). Average annual rainfall is 760 mm although it is highly seasonal; most rainfall is between October and March (the “big season” in which agriculture is rainfed), while the months from April to September are typically very dry. Farmers with access to irrigation water can produce a second (“little season”) crop in the latter months. The annual average temperature is 12°C, with an annual minimum temperature of 1°C and an average maximum of 20°C (Instituto Geofísico del Perú, n.d.).

Agriculture in the Mantaro Valley is primarily oriented toward small-scale, diversified subsistence production. Rural poverty is widespread; in a recent survey of nearly 300 potato-producing households in the region, the incidence of monetary poverty (using a <\$2/day poverty line) was 73% (Escobal and Caverro, 2007). Agriculture is primarily rainfed, with only

about 20-25% of land under small-scale irrigation (Silva, et al., n.d.). It has estimated that only about one-third of agricultural production is destined for market (primarily potatoes), while most production is used for family consumption. In addition to potatoes (19,234 ha in 2008), the primary crops are maize (7,383 ha), the traditional sweet corn *choclo* (6,554 ha), barley (6,512 ha), peas (4,354 ha), and carrots (1,844 ha). The native high-value *quinoa* grain is widely grown (over 900 hectares planted in 2007-08) and Andean tuber crops – especially *oca*, *olluco* and *mashua* – are also popular, especially on hillside farms. Agrobiodiversity is very important to the region: there are an estimated 300+ varieties of potato and 200+ varieties of *olluco* in Peru, and these and other tuber crops are an essential component of consumers' diets not only locally, but also in urban Peru.

Most farms in the Mantaro Valley range in size between 0.5 and 4.9 ha, with 62.9% of producers farming less than 3.0 ha. Although farms of greater than 50 ha account for only 2.6% of farms, they account for more than three-quarters (76.7%) of total farmland (MINAG, n.d.). A variety of problems characterize agriculture in the Valley: soil erosion, given the steep hillsides surrounding much of the valley; soil degradation, in large part due to overgrazing; poor land use practices; and deforestation. However, the main overall factor limiting agriculture is water. Even with contributions from the meltwaters of rapidly retreating glaciers on the Huaytapallana mountain range (5,557 masl) due to climate change, the region's three main reservoirs – Lasuntay, Chuspicocha and Duraznuyoc – as well as many smaller reservoirs were well below capacity in late 2008. Water quality is also a significant problem throughout the watershed due to untreated industrial, mining, agricultural and human waste. The waters of the Mantaro River have been found to contain high concentrations of arsenic, cadmium, zinc, copper and lead, almost wholly attributable to the long history of mining in the region.

**Figure 3. The Western Littoral Region of Uruguay.**



### C. The Western Littoral Region of Uruguay

The third region included in this study is the western littoral region of Uruguay. This region extends north and west from the mouth of the Rio de la Plata, and encompasses the Departments of Colonia, Soriano and Río Negro (see Figure 3). This zone is a highly productive agricultural region, representing much of the traditional rainfed agriculture of Uruguay and accounting for approximately 65-70% of Uruguay's total production area. Soils in the western halves of these Departments are alluvial and fertile, while toward the east, the land is more varied with a diversified agriculture, including wheat, dairy and citrus. Average annual precipitation is around 1200 mm, but is highly seasonal, with high rainfall especially in the summer months; the highest average monthly rainfall is in February (108 mm), while the lowest average rainfall is in August (70 mm). The average annual temperature is 18° C, but this is also highly seasonal. The mean monthly temperature ranges from 7° C in July to 31° C in January.

Farms in the western littoral region have traditionally been mixed crop-livestock farms, with the great majority of farmland in a long-term rotation of 2-3 years of crops and 3-4 years of pastures (Ferrari, 2008). In recent years, global commodity price trends have increasingly favored crop production, resulting in a relatively greater devotion to crop production. Land devoted to soybeans, in particular, has increased sharply. Winter pastureland has declined, while that devoted to crops, primarily wheat, has also increased. In 2007-08, of more than 3.2 million hectares of total landholdings, about 25% (769,000 hectares) was in cropland or pastureland (Ferrari, 2008). Over 350,000 hectares were planted to winter crops, principally wheat (193,400 ha.), barley (127,400 ha.), and oats (27,500 ha). About 614,200 ha were planted to summer crops, including soybeans (461,900 ha.), maize (80,600), sorghum (37,700 ha.) and sunflower (34,000 ha.).

The mild climatic conditions of the region allow for double-cropping and mixed crop-livestock production. These characteristics are important with respect to climate change adaptation in that they permit farmers a great deal of flexibility in responding to both market conditions and changing agroclimatic conditions (Giménez, 2006). A major constraint is soils, however. Although soils are of high quality, they are often degraded. Farmers consistently identify soil erosion as a major and increasingly important constraint to agriculture in the region (Ferrari, 2008). The causes of erosion identified by farmers include adverse climatic events, the use of fallows without groundcover, and the reduction of pastures in the conventional crop-pasture rotation.

The region's 7,500+ crop producers average about 101 hectares in size, however, the size distribution of production is highly bimodal (Ferrari, 2008): over three-fourths (77%) of producers cultivate less than 20 hectares and account for less than 2% of total agricultural area. On the other hand, 4% of producers (an estimated 321 producers) own or operate more than 500 hectares each and collectively farm more than 75% of the total land in the region. With the increasing trend away from mixed crop-livestock systems and toward crops, structural changes in agriculture in the region are occurring with an increasing shift toward very large-scale production, e.g., plantings in excess of 1,000 has (Ferrari, 2008)

#### D. Summary of National Climate Change Policy Frameworks<sup>4</sup>

This section briefly summarizes the national policy frameworks addressing climate change in the three countries.

Mexico. With three submitted National Communications to the United National Framework Convention on Climate Change (UNFCCC) and a fourth under preparation, Mexico is a leader among developing countries in its commitment to the global policy dialogue on climate change. The contribution of the agricultural sector in the country's GHG emissions is small compared to other countries in the region; agriculture accounted for 11% of emissions and land-use changes and forestry accounted for another 14% in 2000. However, around 24 million people comprising 23% of the country's total population, live in rural areas (WDI, 2007), and many of them derive their livelihoods from agriculture. Given current and predicted climate changes, they are increasingly vulnerable to adverse weather conditions (see discussion below).

Mexico released its National Climate Change Strategy (ENACC) in 2007, which identifies opportunities for emissions reductions on a voluntary basis, as well as measures for the development of necessary national and local capacity for response and adaptation. The Strategy proposes concrete adaptation and mitigation measures for all sectors. In agriculture and forestry, these measures include significant increases in reforestation, soil restoration, and commercial plantations. In addition, renewable energy sources in rural areas and changes in crop production are expected to contribute to reducing emissions. The country is also unveiling a new Special Climate Change Program (PECC) to make the Strategy operational by identifying priority actions across sectors and required sources of funding, both domestic and international. The PECC establishes specific actions and measurable goals for mitigation and adaptation across sectors. Climate change is also identified as a strategic area in Mexico's Agricultural Sector Program 2007-2012 and the National Water Program 2007-2012.

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<sup>4</sup> The discussion in this section is substantially drawn from the World Bank's "Climate Change Aspects in Agriculture" Country Notes series (<http://go.worldbank.org/Q1YTC1WII0>)

Peru. Peru is estimated to contribute only about 0.3% of global greenhouse gas emissions and agriculture contributes only about 13% of total national emissions. However, nearly three-fourths of the country's emissions are due to changes in land-use and forestry, which are closely tied to extensification of the agricultural frontier (although not in the Mantaro Valley). So agriculture, both directly and indirectly, and the natural resource sector in general have a large stake in the country's performance with respect to GHG emissions. One of the unique impacts of climate change in Peru, as discussed below, is the rapid disappearance of its tropical glaciers. Glacial meltwater is a major source of water in the mountains of central Peru, including the Mantaro Valley, serving agriculture, human populations and hydropower generation. The loss of these glaciers – predicted by some experts to be no more than 20 years away – will contribute substantially to increasing water scarcity in the region.

There is strong commitment for pursuing climate change adaptation in Peru. Peru's national submission to the UNFCCC in 2001 established the national GHG Inventory, a necessary first step to improved national monitoring of emissions. A second communication to the UNFCCC is planned for 2009. Peru formulated its National Climate Change Strategy (ENCC) in 2003, with the objectives of promoting and developing policies and measures enhance adaptation capacity to climate change and therein reduce vulnerability. Included in the strategy are the improved management of GHG emissions, increasing carbon sequestration in forests, and improved public education about climate change. The same year (2003), Peru also formulated its National Strategy Study for the Clean Development Mechanism (NSS), which was intended to identify potential greenhouse gas abatement projects and investments, and to foster participation in the CDM. As of January 2009, Peru had 16 CDM-registered projects, one of which is in agriculture.

At the regional level, it is noteworthy that the 2002 Organic Law of Regional Governments, which establishes the framework for the transfer of functions from the central government to the regions, requires each region to elaborate its Regional Climate Change Strategy. This in part reflects the awareness that in a large and geographically diverse country such as Peru, action plans in agriculture can be better developed and implemented at the sub-national level, provided the regions have sufficient resources. The Regional Government of Junín – within which the Mantaro Valley is located – was the first in Peru to elaborate such a strategy, in 2007,

with a 2007-2021 time horizon. This followed the creation two years before of a multi-sector and regional working group on climate change, vulnerability and adaptation.

Uruguay. The net contribution of the agricultural sector to total GHG emissions in the country is large (50% in 2000, including the effects of afforestation and reforestation efforts in the country) and it is among the largest in the region. This is mainly due to methane emissions from enteric fermentation and manure from farm animals. Though generally better predisposed to climate change adaptations than many countries in the lower latitudes, Uruguay's agriculture is increasingly vulnerable to variability in precipitation patterns, as well as the incidence of extreme events like the recent drought.

With two submitted National Communications to the UNFCCC and a third one under preparation, Uruguay is among the leading developing countries to actively participate in the global climate change policy dialogue. Uruguay has formulated a national climate change program, the General Program for Mitigation and Adaptation (PMEGEMA), which proposes a set of response measures for climate change mitigation and adaptation. These are to be applied to the most relevant sectors of the economy, including agriculture, forestry, water resources, fisheries and biodiversity. To date, some measures have been undertaken, particularly on the mitigation side, with funds from the Global Environment Facility and the U.N. Development Program.

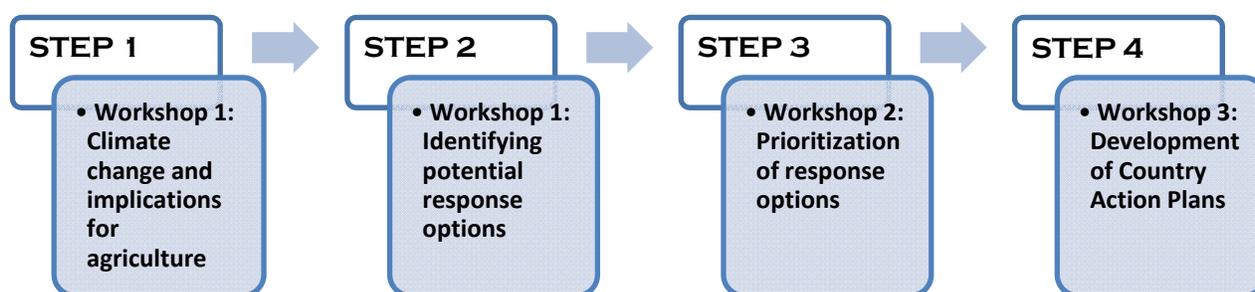
Recently, in March 2009, President Vazquez reaffirmed the commitment at the highest political levels for pursuing climate change adaptation in the country. He called attention to the need for further work in establishing a fund for climate-related disasters and weather emergencies, highlighted the need for better management of water resources, and called for greater information sharing and institutional coordination. The latter is to include creation of a fund designed to address weather emergencies, and creation of a national working group on risk prevention and adaptation to climate change, with representation from the Executive Branch and the Congress of Governors, along with an advisory committee of scientists and experts.

## V. STUDY DESCRIPTION

### A. Introduction

This study was carried out in four steps, each incorporating activities centered around a series of three workshops in each country. All study activities were designed to lead to a successful culmination in the final step – the development of local Action Plans to address the effects of climate change adaptation in agriculture in each of the three regions. The general methodology of the study follows that outlined in Section III above. That is, we tested the application of a streamlined version of the priority-setting methodology outlined in Janssen and Kissi (1997) – previously applied to agricultural and natural resource management research – to priority-setting for local adaptations to climate change. The applications were to prospective climate change impacts in the three highly heterogeneous agroecosystems in Mexico, Peru and Uruguay described in the previous section.

**Figure 4. Study Steps**



The four steps of the study are summarized in Figure 4. These were as follows:

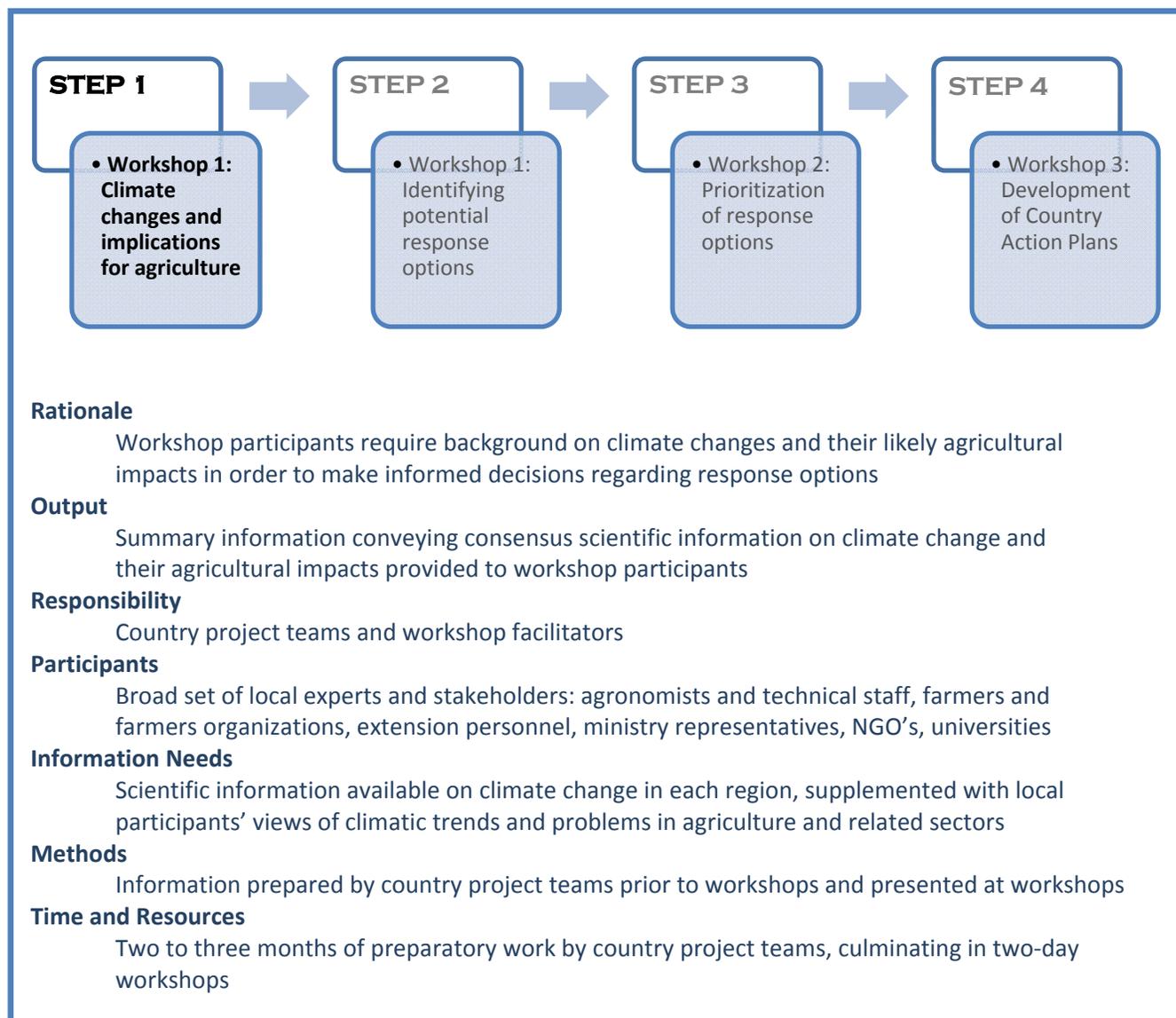
1. **Step 1** involved a comprehensive review by the local teams of expected climate changes over the next 30+ years in the three regions, and the identification of major future implications for agricultural adaptations confronting each region.
2. **Step 2** entailed the identification of potential response options to the climate changes and their implications identified in Step 1.
3. **Step 3** consisted of the further elaboration of the potential response options identified in Step 2, the formal designation and weighting of evaluation criteria for assessing these response options, and finally, the prioritization of the response options.

4. **Step 4** involved the translation of these prioritized response options into an Action Plan for consideration by policy- and decision-makers in each of the three regions.

These steps were executed in a series of three workshops in each country, the details of which are described in the following sections. The specific activities and the organization of each series of workshops were led by a multidisciplinary local team in each country. In Mexico, the leadership of the study was shared by the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP), the Universidad Nacional de Sonora and the Coordinadora Nacional de Fundaciones Produce (COPFUPRO). In Peru, the study was coordinated by the Instituto Nacional de Innovación Agraria (INIA). In Uruguay, leadership was provided by the Instituto Nacional de Investigación Agropecuaria (INIA). Activities were in each case carried out by the staff of these organizations and other national collaborators and consultants. External assistance was provided by World Bank staff and consultants from Cornell University (U.S.).

Most of the study's activities involved the preparation of materials, the presentation of those materials and discussions with, and decisions by, participants in the series of workshops held in each country. Participation in the workshops was sought from a variety of stakeholders knowledgeable about climate change, their agricultural impacts and local conditions. This included agronomists, crop specialists and other technical staff from the national agricultural research organizations (INIFAP in Mexico, INIA in Peru and Uruguay), farmers and representatives of farmers' organizations, and other participants representing relevant government ministries, local universities, local and regional governments, non-governmental organizations and other institutions. The third workshop in each country involved discussion and validation of the draft Action Plans; for this reason, workshop participation was broadened to include representation from a greater breadth of local and national institutions. The workshops were held as follows: Workshop 1 – September and October, 2008; Workshop 2 – January and February, 2009; and Workshop 3 – March and April, 2009. Other details regarding the content of and participation in these workshops are summarized below and are described in more detail in the individual country reports.

## B. STEP 1 – Workshop 1: Expected Climate Changes and Their Implications



In the first step of this study, prior to the initial country workshops, the local teams reviewed the existing scientific literature on climate changes and potential agricultural impacts in each of the three regions. This included results from regional and global studies, such as the 2006 regional Assessments of Impacts and Adaptations to Climate Change (AIACC (Giménez, 2006)), the 2007 reports of the Intergovernmental Panel on Climate Change (IPCC), and other climate studies. In addition, the research literature on biophysical responses to climate change (current

and future) was also reviewed in order to identify key anticipated problems and opportunities that are likely to affect agricultural systems in the targeted regions in the first half of this century.

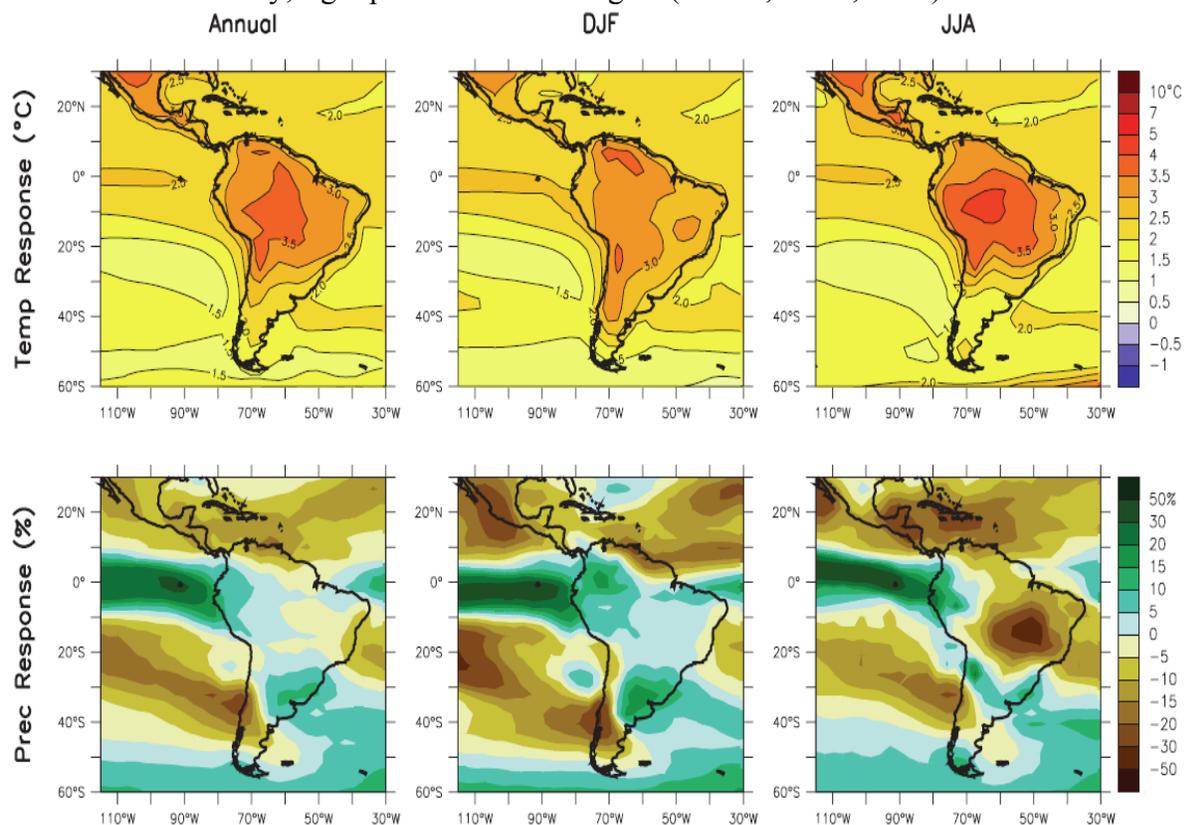
In the first set of country workshops, summary results were reported in a series of presentations by the local team and collaborators, and were widely discussed by workshop participants. The workshops were organized to maximize opportunities for small group discussion and the development of consensus views on future climate changes and their likely effects on the production environment facing agriculture. Participation (excluding workshop organizers) was as follows: Mexico – 32; Perú – 66; Uruguay – 24. The mix of participants varied by country, with farmers and farmer organizations' representatives heavily represented in Mexico and Uruguay, and agronomists, agricultural extensionists and other technical personnel particularly well represented in Peru. Some of the key results regarding climate changes and their expected impacts are summarized here for each country.

### **B.1. Overview of climate change and impact projections from the 2007 IPCC assessment**

A common thread across all three cases was the presentation of results from the 2007 report of the Intergovernmental Panel on Climate Change – and other scientific results as well, which differed by country – to workshop participants. Given their extensive nature, their prominence in the recent literature on climate change and their regional relevance, we briefly review here some of the key results from the 2007 IPCC assessment.

A key outcome from multi-model simulations – 21 global circulation models (GCMs) – of future global climate conducted as part of the IPCC assessment is the recognition that projected changes are not spatially uniform. There is general agreement among GCM model projections that Northwest Mexico will be significantly drier by the end of the century whereas Uruguay is likely to be significantly wetter (see Figure 5, December-January-February (DJF) precipitation trends). Much of northern and central Peru is also likely to experience an increase in precipitation. *In all cases, the magnitude of forecasted change is sensitive to the individual GCM model, assumptions about future greenhouse gas emissions, the time period of interest, and within-year seasonal differences.* In general, there is a higher level of agreement among model projections for temperature than precipitation in most regions. Within the timeframe of interest

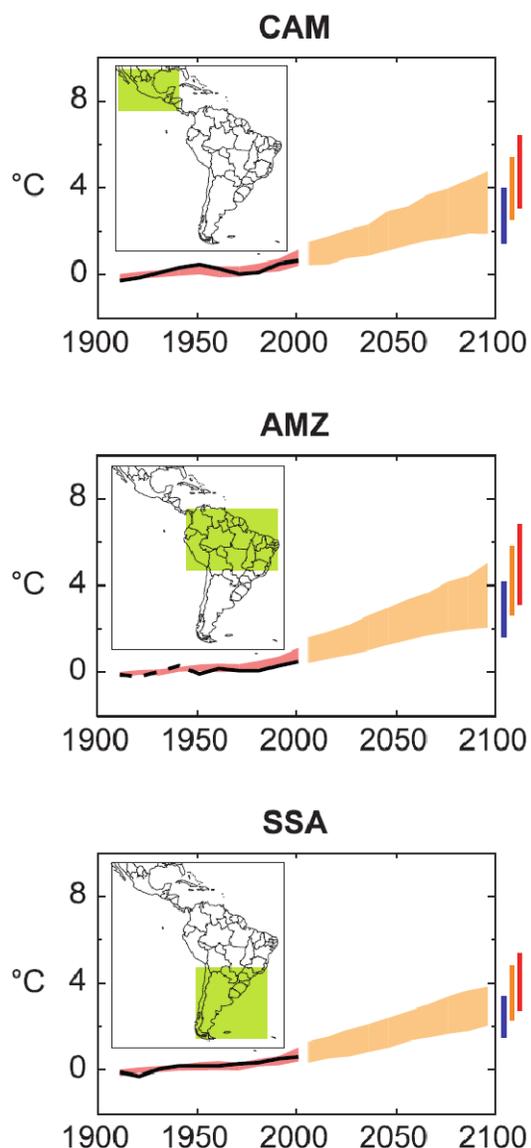
**Figure 5. Multi-model simulations of temperature and precipitation changes towards the end of the century compared to historical averages.** Left panel – annual mean; middle panel – December to February; right panel – June to August (Ch. 11, IPCC, 2007).



to this study (e.g. roughly the next 30 years, to 2039), average annual temperatures are likely to increase by around  $1^{\circ}\text{C}$  over historical means (Ruosteenoja et al., 2003). Under all emission scenarios, global and regional temperatures are projected to increase over time (Figure 6). Table 1 summarizes the plausible range of seasonally-adjusted changes to temperature and precipitation that are expected by 2020, 2050, and 2080 in different areas of Latin America.

There is also a growing consensus that changes in the frequency and severity of extreme events are likely to have more impacts on agricultural systems than are changes in longer-term climate means (Porter and Semenov, 2005). While progress has been made towards identifying and predicting trends in extreme events, much uncertainty remains in current projections especially in the tropics (see Ch. 11, IPCC, 2007). On an historical basis, there is a general trend in many areas of Latin America towards an increase in heavy rainfall events as well as the number of

**Figure 6. Multi-model projections of temperature increases for different regions of Latin America** (orange envelope for the A1B emissions scenario). Bars at the right of the graph indicate the range of projected temperatures at the end of the century with lower (blue) or higher (red) greenhouse gas emissions (Ch. 11, IPCC, 2007).



consecutive dry days (Ch. 13, IPCC, 2007). These trends are consistent with the intensification of the hydrological cycle that can be attributed to global warming.

Just as changes to the climate systems will not be uniform, the impacts on agriculture will be spatially, temporally, and enterprise-specific. (This is one of the primary reasons for the multiple sites chosen for this study). As summarized in Chapter 13 (Latin America) of the IPCC report,

**Table 1. Regional changes in temperature and precipitation for 2020, 2050, and 2080 in Latin America (Ch. 13, IPCC, 2007)**

		2020	2050	2080
<b>Changes in temperature (°C)</b>				
<b>Central America</b>	Dry season	+0.4 to +1.1	+1.0 to +3.0	+1.0 to +5.0
	Wet season	+0.5 to +1.7	+1.0 to +4.0	+1.3 to +6.6
<b>Amazonia</b>	Dry season	+0.7 to +1.8	+1.0 to +4.0	+1.8 to +7.5
	Wet season	+0.5 to +1.5	+1.0 to +4.0	+1.6 to +6.0
<b>Southern South America</b>	Winter (JJA)	+0.6 to +1.1	+1.0 to +2.9	+1.8 to +4.5
	Summer (DJF)	+0.8 to +1.2	+1.0 to +3.0	+1.8 to +4.5
<b>Change in precipitation (%)</b>				
<b>Central America</b>	Dry season	-7 to +7	-12 to +5	-20 to +8
	Wet season	-10 to +4	-15 to +3	-30 to +5
<b>Amazonia</b>	Dry season	-10 to +4	-20 to +10	-40 to +10
	Wet season	-3 to +6	-5 to +10	-10 to +10
<b>Southern South America</b>	Winter (JJA)	-5 to +3	-12 to +10	-12 to +12
	Summer (DJF)	-3 to +5	-5 to +10	-10 to +10

crop yield responses from a variety of impact studies ranged from -38% to +50% depending on crop type, time period, geographic location, emission scenario, and choice of crop and climate models.

In general, moderate warming (to 3° C) is expected to benefit crop productivity in the mid to high latitude regions, but any amount of warming in lower latitudes may significantly reduce yields for crops like wheat (Ch. 5, IPCC, 2007). It is important to recognize, however, that these types of generalizations undervalue potential changes in extreme events and precipitation. Only a few climate change studies to date have assessed the impact of future trends in climate variability on crop productivity (Tubiello et al., 2007).

While much uncertainty surrounds projections of future climate and its associated impacts on regional and local agricultural systems (Barros, 2006), there is a growing recognition that we are committed to a certain amount of warming in the coming decades and that this will inevitably affect agriculture (Howden et al., 2007). Thus agricultural adaptations are inevitable, and indeed are already occurring. We turn now to a brief consideration of key changes in each of the three study regions.

## **B.2 The Yaqui Valley, Mexico**

The average annual precipitation in the lower reaches of the Yaqui Valley is around 350 mm, with most rainfall concentrated in the summer months between July to October when heat-sensitive crops like wheat are not cultivated. Annual potential evapotranspiration is around 2000 mm. In the absence of irrigation, the Yaqui Valley would be dominated by subsistence farming as was the case prior to the early 1940's when large surface water impoundments and the irrigation infrastructure to tap these waters were first completed (Schoups et al., 2006). Nearly 70 years later, the Yaqui Valley now provides up to 40% of the irrigated wheat production in Mexico, and constitutes the dominant land use in the Valley's approximately 250,000 ha of irrigated land. However, the vulnerabilities evident during the severe historical drought conditions that persisted from 1996 – 2004 are indicative of the types of impacts that may become more common if climate change forecasts of significantly reduced precipitation in Northwest Mexico are realized.

During the 2003-4 growing season, useful reservoir storage was depleted and only 17% of the agricultural lands in the Yaqui were irrigated (Schoups et al., 2006). This reduction had a major impact on the aggregate production of wheat and other crops. In the previous season, irrigation supplies were also limited and Lobell et al. (2005) identified the delayed application of irrigation water as the principal source of variability between high and low yielding fields. The latter phenomenon is suggestive of the distributional considerations that may need to be accounted for when conducting climate change impact assessments. Several studies also suggest that rising temperatures in a changing climate will intensify evaporative demand, thereby increasing crop water requirements and exacerbating the impact of irrigation shortages in years when supplies are limiting (see Tubiello et al., 2007).

In addition to irrigation, there are several other issues that may impact the future productivity and value of crops in the Yaqui Valley. For example, wheat has the C<sub>3</sub> photosynthetic pathway and is expected to have favorable growth responses to future increases in atmospheric CO<sub>2</sub>. However, the magnitude of this response is not expected to be large in the coming decades (Parry et al., 2004) and there is increasing recognition that benefits from CO<sub>2</sub> fertilization will also be contingent on concomitant changes to temperature and other potential environmental

stresses including insufficient stocks of soil nutrients (Asseng et al., 2004). In some cases, countervailing stresses may overwhelm any potential yield increases from increasing atmospheric CO<sub>2</sub>. Other research suggests that increasing CO<sub>2</sub> may reduce the nutritional and baking qualities of wheat and that adjustments to agronomic practices and crop genetic resources will be required (e.g. regarding protein content, see discussion in Porter and Semenov, 2005).

Work by Lobell et al. (2005) has highlighted the importance of temperature conditions to wheat productivity in the Yaqui Valley. Specifically, cooler nights in tandem with higher solar radiation levels are historically associated with higher yields. Even discounting the possibility of more thermal stress during critical development periods like flowering, a general increase in temperature with climate change will likely have a negative impact on processes such as night respiration rates that, in turn, can reduce yields.

Climate change is not the only important future challenge to the agricultural systems in the Yaqui Valley. Over the last 50 years, productivity gains achieved by farmers have been impressive with average yields increasing from 1.5 to 5.5 metric tons per hectare. However, wheat yields have stagnated over the last decade (Ortiz et al., 2008). In part this can be attributed to a lack of genetic gain in the physiological yield potential of wheat. Even without climate change, meeting future food security goals in the face of increasing demand will not be easy. The Yaqui Valley is now home to approximately half a million people. Conflicts between urban and agricultural uses of water may intensify with rising sea levels and its impacts on coastal aquifers further complicating efforts to develop groundwater resources as a hedge against more variable or reduced surface water availability (see Schoups et al., 2006).

### **B.3 The Mantaro Valley, Peru**

The climate in the Mantaro Valley exhibits a distinct seasonality (Lagos and Sanchez, 2008). Average monthly rainfall ranges from 10-15 mm in June and July to 120-130 mm in January through March, with 83% of annual rainfall occurring between October and April (Silva, et al., 2006). Rainfall is highly variable across the watershed, ranging from 550 mm/yr in the lowest southeastern parts of the river basin, to 1,000 mm/yr in the northwestern and southwestern

highlands, to 1,600 mm/yr in the rainforest near the confluence of the Mantaro and Ene Rivers (Silva, 2006). The average annual minimum temperature ranges from 1°-2°C in June-July to 6°-7°C in January-March. The average maximum monthly temperature of 19°-20°C is typically reached in November with monthly lows of 17°-18° in February (Instituto Geofísico del Perú, n.d.). Here again, however, significant geographic variation occurs, with average annual minimum temperatures ranging from -2° in the western highlands (above 4,600 masl) to 8°C in the lower southeastern part of the basin and average annual maximum temperatures ranging from 12° in the western and central eastern parts of the basin to 28°C in the easternmost part (Silva, et al., 2006).

Recent climatic trends over the 1964-2003 period suggest that the Mantaro Valley has gradually become dryer, hotter and experienced more variability (Silva, et al., 2006); precipitation declines are also confirmed for southern Peru in general over roughly this same period (Haylock, et al., 2006). A gradual reduction in rainfall (3% every decade) has occurred in the northern and central parts of the river basin, including the Valley, with a slightly positive increase in rainfall in the western and southern central part of the basin<sup>5</sup>. The maximum temperature has shown a distinct positive trend over this period of 1.3°C (+.24°C per decade), while the minimum temperature has shown considerable seasonal and inter-annual variability. The frequency of frosts has generally increased over this same period by an average of 8 days per decade during the September to April period.

There is considerable uncertainty and inconsistency among climate change projections for Peru, including the Mantaro Valley. The IPCC 2007 report projects mean warming to the end of this century of 1-4 degrees for Peru, as throughout much of South America, and an increased frequency of weather and climate extremes. Predicted changes in precipitation by the end of the century are modestly positive (5-10%). Ensemble forecasts reported by Marengo (2008) show a similar range of predicted temperature increases (1°-3°C) and extreme rainfall and temperature events are also forecast to be more frequent. However, other sources (Silva, et al., 2006 and

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<sup>5</sup> It is unclear from the evidence whether these differences sum to zero.

IGP, 2005a-c) report somewhat different climatic scenarios to the year 2050, downscaled<sup>6</sup> from the National Center for Atmospheric Research's RegCM<sub>2</sub> regional climate model and other models. These results include:

- Increase in the average temperatures in summer of 1.3°C.
- Diminution in the relative humidity in summer of 6%.
- Diminution (rather than increases) in precipitation in the north, central and southern regions of the river basin of 10%, 19% and 14%, respectively.
- Increase in the diurnal amplitude of temperature of approximately 1°C.

Alternatively, projections from the Hadley Center's HadRM3P climate model<sup>7</sup> (U.K.), reported by Lagos and Sanchez (2008) forecast changes of only +0.6° to 1° C changes from 1990-99 to 2046-2055, but more severe cumulative temperature increases of up to 3°-4°C by 2071-2100 (compared to 1961-1990). Although these sources differ in their predictions for future precipitation, there is a consensus that the region is expected to become hotter, and that the variability of climatic events (floods, droughts, frosts) will increase.

There is another area where there is little disagreement: glacial melting is expected to continue, indeed it has already reached "critical" levels (IPCC LA, 2007). Tropical glaciers, such as those in Peru, are especially affected by temperature increases induced by climate change (Vergara, et al., 2007b). The retreat of the glaciers on Huaytapallana peak is one of the chief factors that is expected to result in increasing water scarcity in the future in the Mantaro Valley. It is estimated that, just between 1970 and 1997, Peru's glaciers declined from 2,041 km to 1,595 km, or 22% (GEF, 2007). Anecdotal evidence suggests that the ice cap on Huaytapallana receded more than 1,000 feet in the past five years (Fraser, 2007). The IPCC report states that the melting of tropical glaciers is accelerating and that Andean inter-tropical glaciers shall disappear in the next several decades. Glacial meltwater plays two important roles in the Mantaro Valley, both of which can be expected to be negatively affected in the future as the glaciers continue to retreat: first, as a

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<sup>6</sup> As Marengo and Ambrizzi (2006) acknowledge: "Downscaled scenarios may reveal smaller scale phenomena (e.g. associated with topographical features)... but in general the uncertainty associated with using different GCMs as input is a dominant presence in the downscaled scenarios."

<sup>7</sup> The Hadley Center model frequently has contradictory results from most of the other GCMs whose results are reported in this study.

source of irrigation water on which the Valley's agriculture depends, and second, as a significant generator of hydropower which is produced in the Valley.

Although Peru doesn't contribute much to greenhouse gas production (0.4% of global production), it is vulnerable to many sources of risk, indeed, the country is said to be one of three countries of the world most prone to natural hazards: earthquakes, floods, landslides, melting glaciers, and events associated with the periodic El Niño Southern Oscillation pattern (ENSO). Increasing climatic variability is suggested by the increased El Niño disturbances over the last three decades with major events in 1982-83 and 1997-98 and other severe climatic extremes that have had major impacts on human populations: floods, droughts and landslides. However, the IPCC report (Ch. 11, 2007) indicates that the effects of climate change on the amplitude or period of El Niño events are indeterminate.

Potatoes are by far the most important crop grown in the Mantaro Valley. Hijmans (2003) estimated the likely impacts of climate change on potato yields globally, and projected average yield decreases in the range of 18%-32% without adaptation and 9%-18% with adaptive measures. These model estimates do not include the potential growth benefits from increased atmospheric CO<sub>2</sub> (Fleisher et al., 2008). In Peru, the impact of climate change is expected to be much lower ranging from -5% (without adaptation) to +5% (with adaptation). At high latitudes or at the higher altitudes in the tropics, adaptation measures to the higher temperatures accompanying climate change will likely include changes in the time of planting, the use of longer duration varieties, and a shift of the location of potato production into areas that are not suitable for cultivation at present due to low temperature constraints. While these types of strategies should preserve aggregate potato production in the Mantaro Valley, smallholder farms dominate and the impacts and opportunities for adaptation are likely to be uneven. Moreover, Peru is a center of genetic diversity for potato (Brush, et al., 1995) and some of the landraces now cultivated may not be favored in a changing climate. This brings into question the viability of *in situ* conservation of potato genetic resources in places like the Mantaro Valley.

The IPCC reports (2007) that the high rainfall and humidity accompanying the most recent El Niño event led to increased incidence of several fungal diseases in maize, potato, wheat and

beans in Peru. In other regions of the world, studies have shown that in places where wetter and warmer microclimates are projected to occur during the crop growing season, the risk of diseases like potato late blight are significantly increased (Baker et al., 2005). If the ensemble projections from the IPCC (2007) reports are correct that the prime summer growing season in the Mantaro Valley will be both warmer and wetter, the occurrence rates of fungal diseases are likely to increase.

Potato is sensitive to water stress and in areas of water shortages this can significantly lower yields (Fleisher et al., 2008; Pliska, 2008). The higher temperatures accompanying climate change may lead to increased crop irrigation requirements. This is particularly important given the dependence of the Mantaro Valley's water resources on glacial melt waters, especially during the winter months when rainfall is low and glaciers are the primary source of water to sustain flows in most Andean rivers. Vuille et al. (2008) estimate that by mid-century, river flows during these months may be 20-40% lower than the historical average. It is also probable that in the near-term as melt rates and glacial retreat accelerate, river flows will substantially increase. While these ephemeral increases may be beneficial, they also bring the risk that communities and individual producers may assume that increased river flows are the new norm and make investments or planning decisions accordingly.

#### **B.4 Uruguay**

In terms of historical climate trends, the Assessments of Impacts and Adaptations to Climate Change regional assessment (AIACC Project LA-27, Giménez, 2006) for the Pampas region extending from northeastern Argentina to southern Brazil, including all of Uruguay, analyzed observed trends in climate change and agricultural adaptations over the 1930-2002 period. The results from this report are instructive (and complement the climate forecasts from the IPCC). The AIACC report compares climate changes in the Uruguay region of the Pampas occurring between 1931-1960 and 1970-2000, and concludes:

- Absolute maximum temperatures in those sites showing significant changes increased by an average of 4.3°C in 2000 compared with 1930, while absolute minimum temperatures rose by an average 1.9° over the whole year. However, a decrease in the average maximum temperature during January and February was also reported.

- Average annual precipitation has increased, especially in spring and summer (October to February).
- The average length of the period of frost has fallen and the average temperature during this period has risen – the average date of the first frost is later by one week, while the average date of the last frost is 3.5 weeks earlier by 2000 compared to 1930. In short, the frost-free period suitable for cropping has lengthened.
- There is still a high amount of inter-annual variability, so that in any given year, the trend (increases or decreases) may or may not be observed. Comparing 1930-1964 to 1965-2000, there is a higher variability in rainfall between September and February.

In terms of future projections, the IPCC (Ch. 13, 2007) reports that for the Southern South America (SSA) region in which southwestern Uruguay is located (p. 894, regional report), between 1980-1999 and 2080-2099, temperatures are projected to increase 1.7° C to 3.9° C (half of models projected temperature increases in the range of 2.3° to 3.1° C., with a median of 2.5° C.). An IPCC Background Paper using earlier (2001) IPCC estimates (see Giménez, et al., 2008) breaks these longer trends down for Uruguay: predicted average temperatures increase by 0.3–0.5°C by 2020 and 1.0–1.8°C by 2050. These changes are more moderate than for the SSA region as a whole.

A continuing poleward shift in Atlantic storm tracking is forecast to make the Rio del Plata region wetter in the future (IPCC Background Paper, 2008). For the winter months, changes in precipitation of -5% to 3% are predicted to 2020, -12% to + 10% for 2050, and -12% to + 12% for 2080). For the summer months, the predicted changes are -3% to +5% to 2020; -5% to 10% to 2050, and -10% to +10% for 2080. The net annual effects of these changes are unclear. It is the summer season that will likely continue to experience the greatest increases in precipitation. Estimates from the AIACC project suggest October to March precipitation changes of between +10 mm/month (HadCM3 model) to +50-60 mm/month (LARS model) by 2020.

Recent work by Magrin et al. (2005) used a simulation modeling approach to explore the theoretical contribution of climate changes to agricultural productivity documented in the Pampas in the later decades of the 20<sup>th</sup> century. In comparison to 1950 – 1970, these authors

determine that yield increases for soybean (38%), maize (18%), wheat (13%), and sunflower (12%) could be attributed to climate factors. In large part, these trends are linked to increases in summer precipitation and, perhaps to a lesser degree, a decrease in maximum summer temperatures. Following on this type of simulation approach, other recent work has explored the potential impact of projected climate changes on the productivity of maize, soybean, and pasture systems in the Pampas region (Giménez, 2006; Travasso et al., 2006), including specifically for a location in Uruguay (la Estanzuela). With increases in ambient CO<sub>2</sub> and adaptive measures that included adjusted planting dates and nitrogen fertilizer rates, mean maize yields in the Pampas region are expected to significantly increase under both high and lower GHG emission scenarios. Specifically, increases of 14%, 23% and 31% were simulated for 30-year climatology centered on 2020, 2050 and 2080 under high emissions. The response of soybeans, a C<sub>3</sub> species, was even more dramatic with simulated gains of 35%, 52%, and 63% for the same time periods. In all cases, pasture yields were only marginally affected. Without the influence of increased CO<sub>2</sub> on crop growth, yields were projected as modest declines for maize and soybeans.

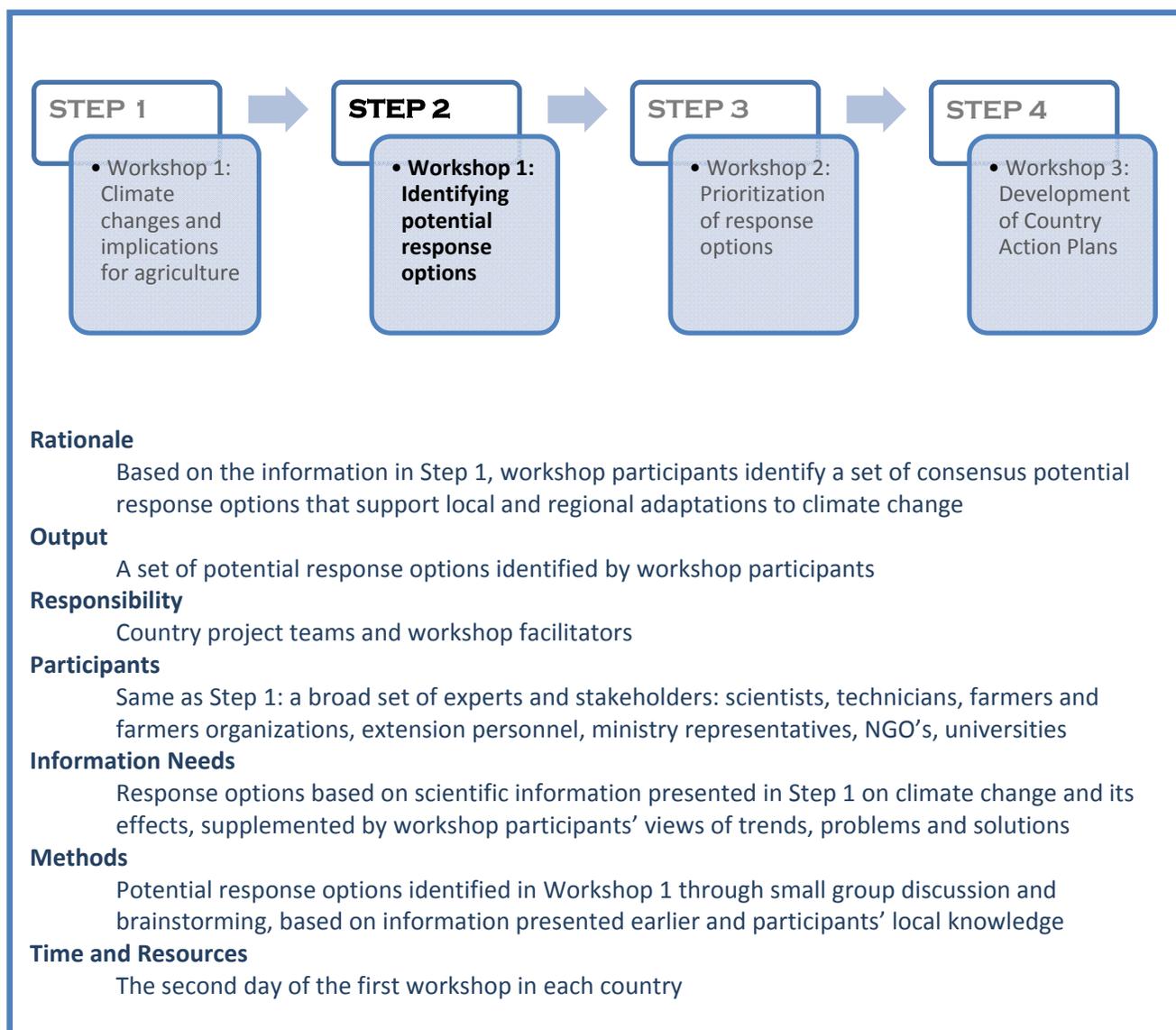
It should be noted that in recent years, there has been a significant amount of controversy regarding the impact of elevated CO<sub>2</sub> on crop growth. Although there remains substantial uncertainty about CO<sub>2</sub> impact on the field performance of crops, the most recent synthesis suggests that earlier response estimates, especially for C<sub>3</sub> species, are valid and that significant yield benefits are likely – all other factors being equal – with elevated CO<sub>2</sub> (Tubiello et al., 2007; Ziska and Bunce, 2007).

The warmer, wetter conditions projected for the Pampas will not be without climate-related hazards. Giménez (2006) linked crop growth simulations with a disease incidence model of *Fusarium* head blight in wheat. This disease can cause dangerous levels of mycotoxin contamination which may result in the wheat crop being unsuitable for sale. In all of their climate change simulations, the risk of head blight increased.

Like Brazil and Argentina, Uruguay has recently experienced a rapid expansion of cultivated area together with an intensification of existing agricultural systems away from pastures and long-term rotations. For example, soybean acreage expanded dramatically from 8,900 ha in

2000 to 366,000 ha in 2007 (FAOSTATS, 2009). This trend may continue; FAO (2000) estimates that Uruguay has more exploitable land reserves (on a proportional basis) than any other country. Intensified cultivation of row crops in the Pampas has raised concerns for soil quality, vulnerability to erosion, and environmental pollution (see Travasso et al., 2006). The increased precipitation expected with climate change, especially if it is associated with more extreme rainfall events and flooding, may exacerbate existing problems with erosion and soil quality (Garbrecht et al., 2007). Moreover, the extended cropping calendar enabled by the longer frost-free growing periods projected with climate change may encourage the type of intensification through double cropping that is already expanding in Uruguay (Monzon, et al., 2007).

## C. STEP 2 – Workshop 1: Identification of Possible Response Options to Climate Changes



The study's second step, also conducted during the first workshop, consisted of the identification of potential response options to address the effects of climate change. The primary predicted climate changes affecting each country were, as discussed above, identified in Step 1 and a consensus developed among workshop participants of the likely effects of climate change on agricultural production systems, barring any steps to mitigate or remediate those effects. The

process then followed in each workshop was to identify a set of possible options to counteract those effects, whether on the part of farmers, government institutions, or other stakeholders.

The process used to identify these response options generally consisted of small group discussion in breakout groups, participants' use of cards to identify possible response options, which were then clustered around common themes, and general "brainstorming" on the basis of participants' familiarity with the region and the challenges facing agriculture, farmers and rural households. In each case, after identification of a large number of possible response options, the workshop moderator led the participants through a discussion process to identify related options, eliminate duplication and, through extended discussion among all workshop participants, arrive at a group consensus of a limited number of possible response options for further refinement and analysis. Workshop participation was the same in Step 2 as in Step 1.

Tables 2, 3 and 4 show the results of this process as it was conducted in each of the country workshops. The response options identified in Step 2 are explained in greater detail below in the context of Step 3, where they are further elaborated. It is clear that there are numerous commonalities in the response options identified, including in all three countries a focus on:

- *Soil and water management*, particularly in the context of integrated systems of watershed management;
- *Crop management*, including the identification of *best management practices* which respond to climate changes;
- *Improving weather prediction and monitoring*, and disseminating results to stakeholders;
- *Agricultural technology innovation*, including everything from improved irrigation and water storage, to fertilization technologies, to biotechnology; and
- *Institutional and policy innovations*, including market feasibility analysis, agricultural insurance mechanisms, improved frameworks for biotechnology regulation, and overall institutional strengthening to deal with expected climate changes in agriculture.

**Table 2. Selected Climate Change Response Options: Mexico**

1. Agricultural technology revalidation:
  - Conservation agriculture
  - Best management practices, including: optimal planting dates, crop residue management and incorporation of organic matter in soils, use and management of pesticides, fertilization, precision farming
  - Integrated pest management
2. Integrated watershed management:
  - Efficient use of irrigation water (from Mocúzaro reservoir)
  - Best management practices in water use and management, including agriculture, urban and industrial uses
  - Better long-term planning of water demands
3. Irrigation technology: improve efficiency in the management and distribution of irrigation water
4. Improve weather prediction systems: early alert systems
5. Market feasibility studies and socio-economic studies
  - Economic viability studies
  - New options for integrated farming systems
  - Integrated project for ferti-irrigation
6. Agricultural technology innovation
  - Non-governmental institution for regulating the use of transgenics: revision and/or appropriateness of regulatory framework; involvement of stakeholders;
  - Technological innovations for “clean” technologies in agriculture.

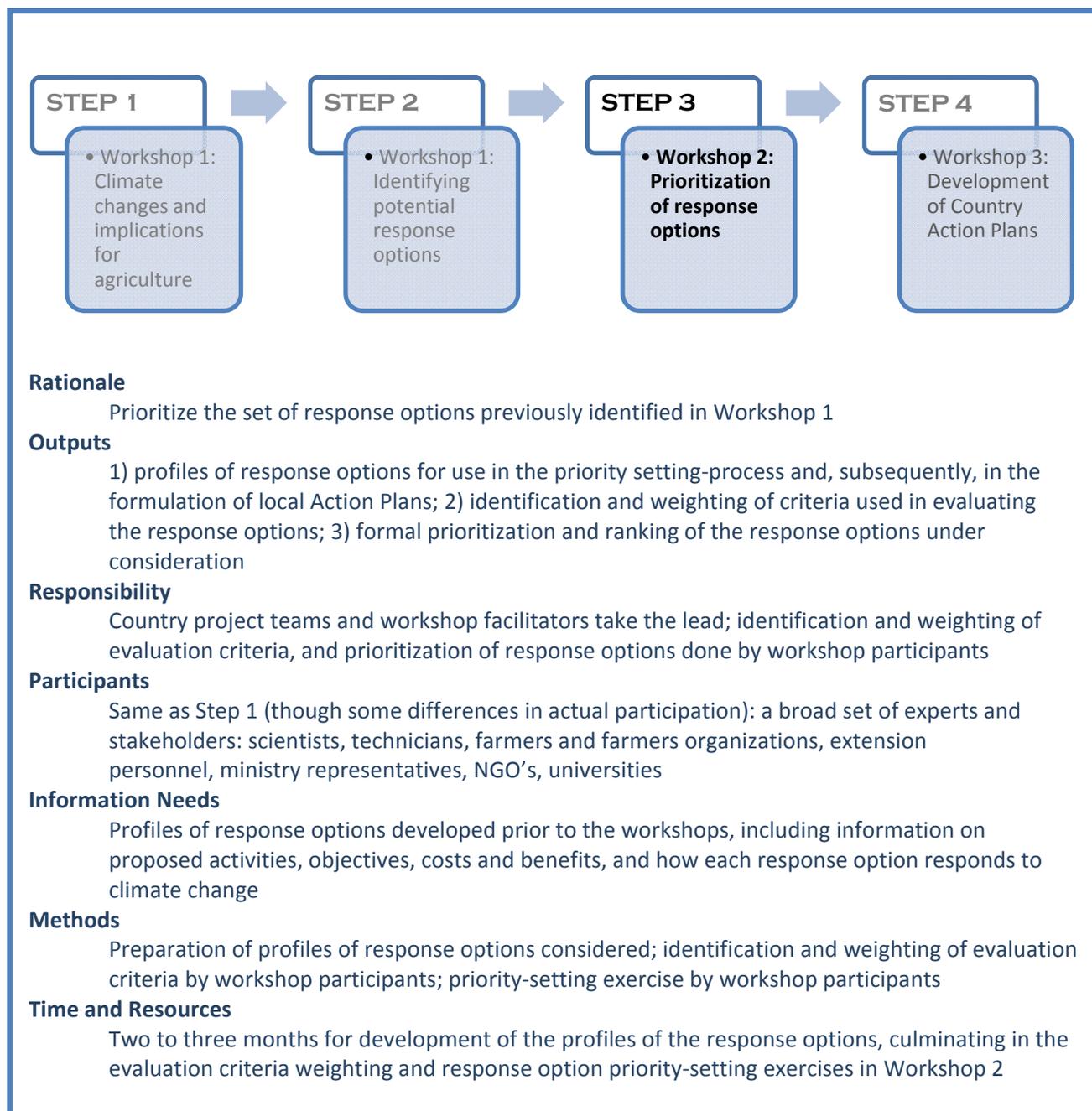
**Table 3. Selected Climate Change Response Options: Peru**

1. Integrated, sustainable and participatory management of micro-watersheds vulnerable to climate change in the Mantaro Valley
2. Monitoring of agrobiodiversity in native potatoes in light of climate change in the Mantaro Valley.
3. Institutional strengthening and regional and local regulatory improvements for effective adaptation to climate change.
4. Adaptation of agricultural management technologies to conditions of climate change.
5. Adaptation of livestock management technologies to conditions of climate change
6. Construction of mini-water storage reservoirs and their use in supplementary irrigation during periods of drought in the micro-watersheds of Cajas and Hualhuas.

**Table 4. Selected Climate Change Response Options: Uruguay**

1. Decision information and support system
  - Agroclimatic information and agricultural monitoring to meet demands of producers and the public sector
  - Information for decision-support in agricultural insurance systems: quantification of risks, improve calculations of premiums, etc.
2. Traditional genetic improvement and use of biotechnology in the development of drought resistance, conditions of excess water, etc.
3. Improve weather prediction, short- and long-term
4. Water management: water harvesting, improve systematization of plots, drainage, etc.
5. Research on and design of production systems that reduce climatic risk: best management practices such as crop and pasture rotations, timing of soybean cultivation, etc.
6. Insurance:
  - Stimulate insurance programs, including those based on climatic indices
  - Catastrophic crop insurance
7. Support for information and technology transfer (including information under #1)
8. Stimulate best practices in agriculture – soil and water conservation, crop rotation, crop diversification – including through use of credit and differential interest rates.

## D. STEP 3 – Workshop 2: Prioritization of Response Options to Climate Change



The third step of this study involved priority-setting of the individual response options identified in Step 2. Participation in the second series of workshops was as follows: Mexico – 63; Peru – 81; Uruguay – 21. Participation varied over the course of each workshop, however, and not all participants participated in the criteria-ranking or priority-setting exercises. The completion of the third step involved three components:

1. Identification and weighting of the criteria subsequently used in subsequent evaluation the response options;
2. Elaboration of the characteristics of each response options; and finally
3. Scoring of each of the criteria as applied to each of the response options, to generate a final prioritized ranking of the response options.

We describe each of these steps in turn.

#### D.1 Identification and Weighting of Evaluation Criteria

In Step 1, during the first workshop, the workshop organizers presented a draft list of evaluation criteria to participants in each country workshop for subsequent use in scoring and ranking the final response options. These included several proposed *impact criteria* to assess the potential impacts of each response option in addressing the local effects of climate change in each of the three country sites, and several proposed *viability criteria* to assess the viability of each response option. These criteria were discussed among participants during Workshop 1; criteria were added, deleted and revised. Following the first series of workshops, the country study leaders, Bank staff and external consultant engaged in a dialogue by email prior to the second workshop to refine the list of criteria – subject to final input and confirmation in Workshop 2 – to be proposed for the final priority-setting exercise. At the beginning of Workshop 2, the draft list of criteria was presented to all workshop participants at each country workshop for discussion and any final changes prior to the weighting exercise conducted in each country.

In the weighting exercise, participants in each country workshop were asked to allocate 100 points among eight impact criteria (seven in Uruguay) and another 100 points among six viability criteria. Table 5 shows the final list of criteria used in the priority-setting exercises in each country and their associated average weights as assigned by participants in the second series of workshops. The number of participants in the second workshop (e.g. those involved in the criteria weighting exercise) represented a subset of workshop participants: 53 in Mexico, 44 in Peru, and 18 in Uruguay. There were only minor differences among the three sets of criteria; this was due to the effort at developing consensus over their selection beginning with the first workshops in each country.

**Table 5. Impact and Viability Criteria, and Average Weights Assigned by Workshop Participants, Used in Priority-Setting**

<b>Impact Criteria</b>	<b>Mexico (n=53)</b>	<b>Perú (n=44)</b>	<b>Uruguay (n=18)</b>
1. Economic benefits of the response option (including both private benefits and broader benefits of the product or activity to the local economy)	22.5	16.7	30.6
2. Economic costs of the response option	12.0	14.0	13.9
3. Spillover effects in other regions or sectors	6.9	7.1	11.1
4. Importance of the response option to the local poor and indigenous groups*	10.8	13.7	8.1
5. Adaptation potential: potential of the response option to promote adaptation to climate change	13.1	10.5	15.3
6. Mitigation potential: potential of the response option to promote mitigation of climatic change	12.5	10.6	9.7
7. Capacity to reduce damage resulting from extreme events induced by climate change	11.4	11.9	11.4
8. Other environmental effects: maintaining biodiversity, etc.	10.8	15.6	n/a
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>
<b><u>Viability Criteria</u></b>			
1. Technical viability of the response option	23.4	21.8	32.5
2. Availability and confidence in the information necessary to evaluate the response option	17.2	16.7	17.2
3. Compatibility of response option with country's climate change strategy	14.8	17.1	10.0
4. Potential public support and general public acceptance	18.0	15.7	16.4
5. Necessity of public sector intervention	16.3	17.4	13.6
6. Existing level of development of response option at regional and national levels	10.3	11.2	10.3
<b>TOTAL</b>	<b>100.0</b>	<b>100.0</b>	<b>100.0</b>

\*and in Peru (only), aspects of gender.

The weights of the evaluation criteria show both similarities and differences across the three countries. In all three countries, the perceived economic benefits of the response option were weighted the highest among the impact criteria. In both Mexico and Uruguay, the potential of the response option to contribute to adaptation to climate change was ranked second highest, while in Peru, “other environmental effects” (notably, biodiversity preservation) received the second highest weight among workshop participants. The economic costs of each response option were ranked highly as an evaluative criterion in all countries. The importance of the response option to local poor and indigenous groups was more highly weighted among participants in the Peru workshop, reflecting the much smaller farms in the Mantaro Valley compared to the other two study areas, and the much greater prevalence of poverty. Among the viability criteria, in all three countries, the technical viability of the response option was by far the most heavily weighted criterion, while in both Mexico and Uruguay, potential public support and public acceptance ranked second. In Peru, participants’ weights of the other viability criteria were more evenly distributed.

## D.2 Elaboration of Response Options

Between the first set of country workshops in September-October, 2008 and the second set of workshops in January-February, 2009, the teams in each country developed “profiles” of each of the response options identified for subsequent analysis. These profiles contained detailed information used subsequently by participants in Workshop 2 in evaluating the different response options and scoring them by various impact and viability criteria. These profiles were rounded out in further detail in the development of the Action Plans (see Step 4 below). The profiles included information on: underlying need for the response option; technical characteristics of the proposed components; costs and benefits (only selectively developed); and likely impacts. These profiles are outlined in detail in the individual country reports; some of the key points contained in each are briefly summarized here for each country.

Mexico: The response options developed for the third workshop, discussed at the workshop, and subsequently evaluated in the priority-setting exercise included the following:

1. Integrated management of the Yaqui Valley watershed
  - Principal objective: promote adaptation to climate change based on optimal use of water and improved decision-making based on the sustainable functioning of the different agroecosystems in the watershed: agriculture, livestock, natural environment and urban areas
  - A primary focus on adaptation to drought and extreme climatic events, in part to avoid migration to urban areas and urbanization of the countryside. Water availability, storage and use are the key limiting factors in the watershed, affecting both agriculture and socio-economic development.
  - Proposed projects on: watershed conservation and management planning; reforestation and revegetation; building water retention ponds and reservoirs; use of best management practices for water use; ferti-irrigation; improved monitoring of water supply and use.
  
2. Improve water use efficiency in irrigation in Yaqui Valley Irrigation District 041
  - Objective is improving (ideally, doubling) water use efficiency and economic feasibility of water use in irrigation.
  - Specific proposed actions in improving irrigation management practices, including greater efficiency of water use, use of ferti-irrigation, conservation tillage and other practices.
  - Urge modernization and government reinvestment in irrigation infrastructure, main and feeder canals, serving 7,500 hectares (with detailed cost estimates).
  
3. Climate early warning system
  - Goal is to reduce risks to farmers arising from drought, extreme weather events and pest and disease outbreaks
  - Components include: risk mapping; monitoring and forecasting of weather events and pest and disease outbreaks; system of disseminating information through alerts to producers, municipal officials and the population at large; adoption of appropriate methods to respond to these alerts.
  
4. Crop genetic improvement
  - Principal focus on adaptation to drought and improving productivity
  - Obtain advanced genetic lines for crop varietal improvement
  - Develop varieties with drought tolerance and resistance to rust disease (wheat), bushy stunt mycoplasma (maize) and other pests and diseases.
  - Develop experimental varieties for field and farmer trials
  
5. Agricultural technology development
  - Major objective is to improve adaptation to drought and improve productivity
  - Alternatives include: technologies to improve irrigation efficiency, ferti-irrigation, conservation tillage, retention and storage ponds for water, promotion of best management practices in irrigation and land management, technologies for monitoring and improving water quality

#### 6. Market feasibility studies for fair trade products

- With both climate change and reduced profitability of basic agricultural commodities (maize, wheat), examine potential market feasibility of high-value “fair trade” products which are facing high demand in international markets
- Lots of interest among producer groups, already 50 producer groups in Mexico are certified for fair trade production; fair trade products should potentially benefit smallholders in the Valley due to significant potential to generate revenues on small landholdings; one objective is to improve incomes of smallholders and deter rural to urban migration;
- Products to examine include: Yori muni beans, potatoes, honey, etc.

#### 7. Economic feasibility studies for market diversification

- Wheat production in the Yaqui Valley faces many present and future constraints: climate change and water availability; maintaining high yields in an intensive system; slow growth in demand; growing international competition in wheat production; etc. Thus diversification into other products and markets, particularly those with prospects for high market demands is desirable.
- Options include: grains – corn, sorghum, rice; oilseeds – safflower, canola (rapeseed), soybeans; legumes: beans, garbanzo, sesame; vegetables: potato, tomato (red and green), chiles, watermelon, melon, eggplant, pepper, broccoli; biocombustibles: agave, sugarcane and beet, sweet sorghum, castor bean, jatropha, crambe; fruits: pineapple, mango, oranges, mandarins, grapefruit, lemons, olives; pastures: alfalfa, zacates (long grass).

Peru: Profiles were developed for the following consensus response options:

#### 1. Integrated, sustainable and participatory management (MISP) of micro-watersheds in the Mantaro Valley vulnerable to climate change

- Development of a system of micro-watershed monitoring for indicators relevant to climate change
- Formation of a MISP plan for two pilot micro-watersheds including local committees, participatory needs assessment and development of a micro-watershed plan
- Afforestation and reforestation activities in the selected micro-watersheds
- Soil and hillside conservation investments to promote water conservation and retention (promoting construction of infiltration ditches, terraces, etc.)

#### 2. Construction of water retention ponds for use in supplementary irrigation in periods of drought in two pilot areas: micro-watersheds of Cajas and Hualhuas.

- Construction of water retention ponds
- Formation of water user groups for operating irrigation systems
- Construction of irrigation canals and water distribution systems
- Provide training in organization, management and operation of systems

3. Monitoring of agrobiodiversity in native potato species in pilot area of Comas district, Concepción Province
  - Develop agrobiodiversity monitoring system
  - Develop inventory of potato biodiversity in six communities, with follow-up and registry
  - Develop system for participatory monitoring, including manual and training
4. Institutional strengthening and regulatory improvements to promote adaptation to climate change in the Mantaro Valley
  - Develop a climate change information system
  - Develop early alert indicators for agriculture and livestock
  - Develop a geographic information system for mapping zones of vulnerability to climate change
  - Improve adaptation and application of regional policy to facilitate adaptation to climate change
5. Design, development and implementation of technologies for climate change adaptation in agricultural production systems
  - Monitoring and evaluation of pests and diseases
  - Develop an early alert system for agroclimatic risk and pests and diseases
  - Develop crop varieties that are tolerant to climate change factors (e.g., drought tolerance, etc.)
  - Integrated pest management
6. Design, development and implementation of technologies for climate change adaptation in livestock production systems
  - Evaluate vulnerability of traditional systems for raising cattle and cuyes
  - Improvements in natural and improved pastures, including seed production
  - Organize field schools (and materials) for animal health improvement (cattle, cuyes)
  - Evaluate and monitor responses of camelids (llamas, alpacas, etc.) to climate changes (feeds, animal health, etc.) and develop mechanisms for maintaining population viability, genetic diversity, etc.

Uruguay: Profiles were developed for the following response options identified in Workshop 1:

1. Information and decision support system (SISTD)
  - Identify specific vulnerabilities and opportunities in agricultural systems created by climate change
  - Reduce risk and uncertainty by climatic and agricultural systems monitoring
  - Technologies and appropriate practices for reducing vulnerability to climate change (e.g. crop diversification, improved crop, water and soil management, improved crop varieties, etc.)

- Institutional and policy responses to reduce climatic risk: early alert systems, risk transfer mechanisms (crop insurance, directed credit, etc.)
2. Genetic improvement and use of biotechnology to reduce risks created by climate change
    - Multiple focus on traditional breeding, biotechnology and improving nitrogen fixation
    - Key crops with high payoffs: rice, wheat, barley, soybeans, forage crops
  3. Improve climate forecasting for improved decision-making
    - Improve climate modeling and climate systems modeling, with a focus on using these models for improved support in private sector decisions.
  4. Improved water management
    - Improve management of surface water resources, including better use of runoff
    - Monitoring of supply, quality and management of water resources
    - Improve spatial, environmental and land use planning, especially in water management
    - Development of new methods of irrigation measurement and control
    - Identification and development of techniques and tools for prevention and mitigation of water excesses and deficits.
  5. Design of new production systems to reduce climate risk
    - Emphasis on improved information for water management.
    - Validation of irrigation technology for more efficient water use for extensive systems.
    - Impact of different irrigation systems for production under varying environmental (soil-climate) settings
    - Development of tools for water management that can be used in via the WWW.
  6. New insurance instruments to reduce climatic risk
    - Agricultural insurance
    - Catastrophic risk insurance
    - Create a public-private Insurance Compensation Fund to help cover risks not otherwise covered through private insurance
  7. Support for information and technology transfer (of the information developed in #1)
    - Form “technology roundtables” (based on previous use of this model) as a means to bring producers, researchers and public sector institutions together, focused on common needs in agro-industrial chains
    - Specialized training (at all levels) in management of water resources, water management, land and systematization of different irrigation techniques.

- Promote development of information technologies and communications (ITC), applied by distance learning tools.
- Strengthening of producer organizations, cooperatives, public and private institutions, etc. which transfer technology and information.

8. Stimulate and support Best Management Practices in agriculture

- Financing of investment for implementation of conservation techniques for water and soil management
- Targeting of investments in irrigation technology, improved soil management, etc.
- Implementation and financing of projects for integrated management of natural resources and irrigation development
- Market development of greenhouse gas abatement certificates and creation of public-private partnerships to validate carbon certificates.
- Implementation of tax and other incentives for production systems that have rotations with pasture and that increased carbon sequestration capacity.
- Dissemination of good agricultural practices and carbon market options.

An example of a typical response option developed for Step 3 of this study is presented in Box 1. This Box presents some of the details for one of seven response options developed for Mexico – the genetic improvement of wheat, maize and oilseeds. This response option was ultimately ranked as the top response option for Mexico in the prioritization exercise described below, and was one of the key components of the Action Plan developed for the Yaqui Valley in Step 4 (see below). This is drawn from Castellanos, et al., 2009.

### Box 1. Proposed Response Option for Mexico: Genetic Improvement of Wheat, Maize and Oilseeds

One of the prioritized response options identified by workshop participants in Mexico aimed to reduce the impacts of climate change (higher temperature, dryer climate) and improve agricultural adaptations by fostering continued yield growth for three key Yaqui Valley crops – wheat, maize and oilseeds. Participants in the second workshop ultimately ranked this as the top priority option in the priority-setting exercise conducted, and it was a key part of one of the four components of the Action Plan developed in Step 4 of the study.

**Objective:** Genetic improvement and varietal development through plant breeding and applications of biotechnology (including use of molecular markers), in order to maintain a competitive and viable commercial agriculture.

*Wheat* has been the dominant crop during the development of the Yaqui Valley for the last several decades, accounting for 70-75% of irrigated land. Climate change may threaten the dominant role of wheat in the Yaqui Valley, a crop which is important both to the regional economy and to meeting the food security needs of Mexico. Crop diversification is important and should be pursued, but developing improved varieties of wheat which will thrive in a hotter, dryer climate and which are disease and insect resistant is critical. A priority is to develop wheat varieties which can grow well as part of new and evolving production cycles and which have the capacity to respond to new climatic conditions.

*Maize* is often identified as an alternative crop with equal or superior yield potential to that of wheat. Meeting the challenges of climate change will entail maize varietal improvements which can resist high temperatures and aridity, while also achieving better efficiency in water and nitrogen use. The challenge for the summer cycle is to obtain maize hybrids which would permit reaching a productivity level of 8 ton/ha, while being resistant to rust, micoplasmosis and fungus.

*Oilseeds* have significant potential in the face of rising temperatures and decreasing precipitation, as they are characterized by relatively low water needs and a high adaptation capacity in different production cycles (autumn-winter and spring-summer). In order to pursue this option, a crop improvement program needs to create varieties and hybrids adapted to the agroecological conditions of the Yaqui Valley, as well as other parts of the country.

**Costs and Benefits.** The following table shows estimated research costs and impacts:

Crop	Research Costs 2010-2025 (1,000 Pesos)		Impact on Farmers Returns (Pesos)
	Equipment	Operation	
Maize	5,889	21,744	663,750
Oilseeds	5,889	21,985	656,250
Wheat	5,889	27,603	1,375,000
Subtotal	17,666	71,332	
Total	88,997		2,695,000

/cont.

### **Box 1. Mexico: Genetic Improvement of Wheat, Maize and Oilseeds (cont.)**

#### **Goals:**

- After 15 years, three white maize and three yellow maize varieties tolerant to high temperatures and hydrological stress, permitting the improvement of Yaqui Valley average crop yields at least +1 ton/ha above current averages. This would reach experimental levels of 9.0 ton/ha during the summer cycle and up to 12.0 ton/ha during the autumn-winter cycle.
- After 15 years, obtain five new varieties of safflower, canola and soybeans with a potential yield at or above 4.0 ton/ha for safflower and canola, and 3.5 ton/ha for soybeans.
- After 15 years obtain at least eight new varieties of wheat, allowing the maintenance of current yield and quality levels, even in the face climate change.

The economic benefits derived from research would contribute to sustainable development of the region by improving the economic, social and environmental viability of agriculture. Moreover, the impacts of grain production in the region will remain key in terms of contributing to food security in Mexico.

**Institutions and partnerships.** This response option and action plan are based on the potential for a strategic alliance between the federal and state governments, producers associations and research and training institutions.

**Impacts and other social aspects.** It should be possible to genetically improve the soybean crop which disappeared from the Yaqui Valley during the 1990s by creating a summer planting level of 30,000 ha. This would help improve the profitability of the land now planted to less productive or profitable crops. Total oilseeds planting of up to 50,000 ha are possible even under projected water constraints.

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Source: Adapted from Castellanos, et al., 2009.

### D.3 Prioritization of Response Options

Given the criteria identified and weighted for use in evaluating the individual response options (Section D.1) and the elaboration of the potential response options in each country (Section D.2), the remaining step was the actual priority-setting process. At the conclusion of the second workshop in each country, following the presentation and general discussion of the full set of response options, a priority-setting exercise was undertaken in which the individual response options were evaluated by workshop participants according to the previously determined criteria.

In each workshop, participants were given a matrix and asked to assign a value from 1 to 10 based on the extent to which they believed each evaluation criterion was effectively addressed by each response option. The participants' ratings of each response option by criterion were then weighted by the criteria weights previously calculated: the impact criteria were proportionately assigned 50% of the overall score and the other 50% assigned proportionately to the viability criteria. After averaging across all workshop participants at each workshop, the results were then multiplied by 100 to normalize the weighted average rankings to a maximum value of 100.

The final results are shown in Tables 6-8. The differences in scores across the response options in each country are relatively modest; these are weighted average scores, so this is not surprising. Although the full sets of response options bear many similarities across the three cases, the options that ranked highest in each country were quite different. However, in all cases, integrated management of water and watershed resources ranked among the top two priorities.

The Annex to this report contains a detailed summary of the priority-setting approach as it was applied in one country, Uruguay, to assist in understanding the entire process.

**Table 6. Results of Priority-setting Process for Climate Change Response**  
Options: Mexico

<u>Response option</u>	<u>Final Score (max = 100)</u> (n=27)
1. Genetic improvement – wheat, maize, oilseeds	83.0
2. Integrated watershed management	81.0
3. Improvement to irrigation systems	77.2
4. Revalidation of agricultural technologies	77.0
5. Early alert system	75.7
6. Feasibility study for crop diversification	72.0
7. Feasibility study for “fair trade” products	67.8

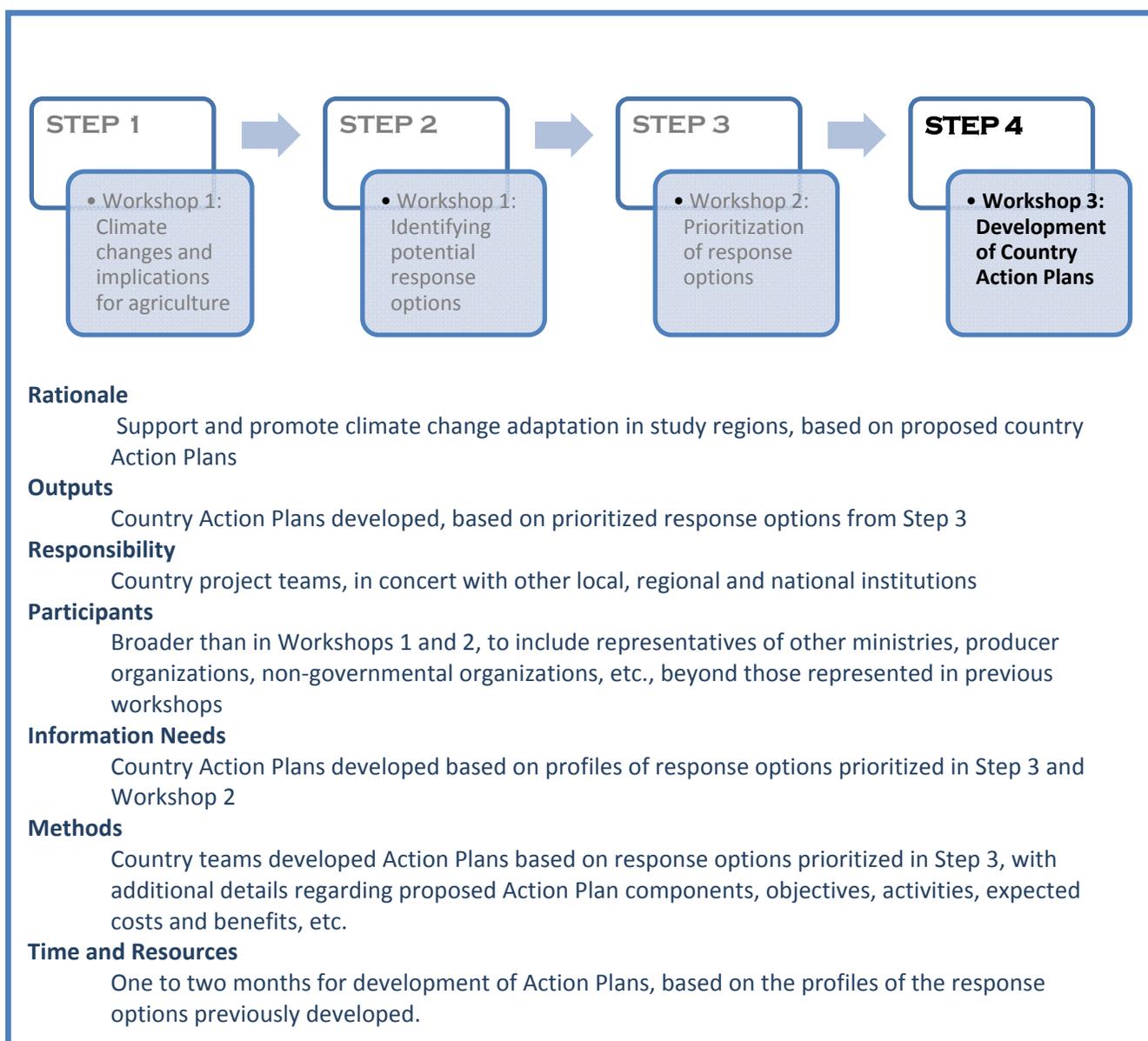
**Table 7. Results of Priority-setting Process for Climate Change Response**  
Options: Perú

<u>Response option</u>	<u>Final Score (max = 100)</u>
	(n=44)
1. Integrated sustainable management of micro-watersheds	76.6
2. Mini-reservoirs for water storage and training	74.7
3. Technology adaptation for crop production and management	69.4
4. Technology adaptation for livestock production and management	67.0
5. Agro-biodiversity monitoring of native potato varieties	63.3
6. Strengthening of institutions and regulatory framework	62.1

**Table 8. Results of Priority-setting Process for Climate Change Response**  
Options: Uruguay

<u>Response option</u>	<u>Final Score (max = 100)</u>
	(n=18)
1. Information and decision support systems	78.9
2. Water management	77.2
3. Agricultural insurance	75.3
4. Support for technology and information transfer	72.9
5. Stimulating best management practices in agriculture	69.9
6. Improving climate forecasts	69.2
7. Design of production systems to reduce climate risk	67.2
8. Traditional crop genetic improvement and use of biotechnology	63.8

## E. Step 4 (Workshop 3): Development of Country Action Plans



The final step of this study involved, first, the translation of the climate change response options prioritized in Step 3 into a local Action Plan in each country. This was accomplished by the local project team in each country. While the Action Plan was built around the prioritized response options, significant attention was also given to possible overlap of the response options as well as strategic local institutional and policy considerations. In some cases, these aspects necessitated the reframing and recombination of the response options in different ways to enhance the likelihood of the acceptability to local and national authorities, and if developed in a project

format, of being of potential interest to donors. The key components of the three Action Plans are listed in Tables 9-11. Further details are provided in the individual country reports that are a part of this study. As the Action Plans were derived directly from the response options developed in the previous step of the study, there is a significant overlap with those options, which have been previously described.

At the third workshop in each country, the Action Plans were presented to participants for discussion and debate. The objective was to validate and critique the Action Plans from the standpoint of broader criteria than were necessarily reflected in the first two workshops, which focused primarily on technical considerations. Participation in the third workshops was, by intent, from a wide set of local and national institutions – Ministries of Agriculture and the Environment; key government agencies with responsibilities for climate change policy, water, forest and land management; local and national producer associations; local and regional governments; and other organizations. Many of these organizations had been represented in the first two workshops, but in general, participation in the third workshop was broader, with the objective of soliciting broad feedback.

Attention was also given in each workshop to plans for follow-up activities, with the objective of carrying the components of the Action Plans forward. In at least two of the countries, Mexico and Peru, specific plans for follow-up were developed at the workshop, and in the case of Mexico, a committee of interested institutions was formed to spearhead these follow-up activities. Additional details regarding the activities of the third workshops and plans for follow-up are given below.

Mexico. Workshop 3 in Mexico involved more than 70 participants representing a wide variety of regional and national institutions, both public and private. These included: the Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA); Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) – including the National Water Commission (CONAGUA) and the National Forestry Commission (CONOFOR); the National Council on Science and Technology (CONACYT); the International Maize and Wheat Improvement Center (CIMMYT); the Instituto Nacional de Investigaciones Forestales, Agrícolas

**Table 9. Summary of Climate Change Action Plan: Yaqui Valley, Mexico.**

<b>Climate Change Action Plan for Yaqui Valley, Mexico: Major Components</b>	
<b>1. Integrated management of the Río Yaqui watershed: Efficient use of watershed resources and long-term planning for water demands</b>	<ul style="list-style-type: none"> <li>a. Establish a plan for integrated management of watershed resources, including norms and regulations for environmental management, and including natural areas.</li> <li>b. Improve monitoring and management of natural resources and valuation of ecosystem services in the watershed, with a major focus on forest ecosystems to improve maintenance of water and biodiversity resources</li> <li>c. Institutional strengthening and planning, monitoring and simulation modeling, with a focus on water resources</li> <li>d. Improve efficiency, management and use of water resources</li> </ul>
<b>2. Early warning system to confront climate and phytosanitary risk (SIATVY)</b>	<ul style="list-style-type: none"> <li>a. Develop an automated network of meteorological stations in the Valley</li> <li>b. Use models to estimate climate risks and effects on agricultura (pests, disease, etc.)</li> <li>c. Use improved information to support decision-making and reduce climate and economic risk</li> <li>d. Dissemination of agro-meteorological information</li> <li>e. Dissemination of information and maps identifying climate, yield and phytosanitary risk.</li> </ul>
<b>3. Transformation of agriculture in the Yaqui Valley through genetic improvement and improvement of irrigation systems.</b>	<ul style="list-style-type: none"> <li>a. Genetic improvement of cereals and oilseeds (wheat , maize, canola, safflower, and soybeans), especially for drought and heat tolerance</li> <li>b. Improvements in the irrigation system: investments to modernize infrastructure; improve water use efficiency; promote conservation tillage</li> </ul>
<b>4. Market diversification and new options for crop farming in the Yaqui Valley</b> (specific crops under consideration identified in Section D.2)	

y Pecuarias (INIFAP), including both national and regional representatives; the Sonoran Agricultural Research and Experiment Organization (PIEAES); the Fundaciones Produce and their National Coordinating Organization (COFUPRO); the Universidad de Sonora and the Technological Institute of Sonora; the Cajeme Agricultural Credit Union (UCAC); and others.

The implementation of specific climate change adaptation and mitigation measures will be guided by the Special Climate Change Program (PECC). The PECC establishes specific actions and measurable goals for mitigation and adaptation across sectors, following in the steps of the National Climate Change Strategy (ENACC). In the case of adaptation in agriculture, several priority actions have been identified by sub-sector. Among the Adaptation for Productive Agriculture measures are those focusing on sustainable production systems, efficient use of water resources, production potential of crops, etc. The Action Plan for Yaqui Valley closely adheres to the established Federal measures for climate change adaptation in the agricultural sector. It also provides a sub-national perspective for implementation of these measures. The measurable goals established in the PECC will be met through existent sectoral programs, with no additional budget allocated to them. Thus, additional funds will be needed for implementation of the actions to ensure an effective and timely pursuit of the established goals.

Follow-up to the final workshop entailed the formation of an inter-agency committee among the organizations represented at the workshop to work toward implementation of the Action Plan in the context of the PECC. Discussion at the workshop centered, in part, on the Yaqui Valley as a regional pilot, which could subsequently be extended to other sectors or regions. Early in 2009, the World Bank approved a \$500 million Development Policy Loan to Mexico to address climate change investments, which may provide a potential funding mechanism for initiatives of the type outlined in the Action Plan.

Peru: About eighty participants attend Workshop 3. These included representatives from the Ministry of Agriculture and its Technical Group for Food Security and Climate Change (GTTSACC), SENAMHI (National Service of Meteorology and Hydrology of Peru), IGP (Peruvian Geophysical Institute), SENASA (National Service of Agricultural Health), PSI (Irrigation Sub-sector Program), GRADE (Group of Analysis for Development), other NGOs and producers' organizations, regional and local governments, including the Irrigation Board of Junín and a representative of the Presidency of the Regional Government of Junin. A full list of participating organizations is contained in the Peru country report.

**Table 10. Summary of Climate Change Action Plan: Mantaro Valley, Peru.**

<p><b>Climate Change Action Plan for Mantaro Valley, Peru: Major Components</b></p> <ol style="list-style-type: none"> <li><b>1. Improving legal and institutional frameworks, and information systems</b> <ol style="list-style-type: none"> <li>a. Establish an integrated regional database on natural resources, climate, and vulnerability</li> <li>b. Integrate the different existing early warning systems to enhance inter-institutional collaboration to manage emergency situations</li> <li>c. Align the national and regional institutional and legal frameworks to deal with the expected effects of climate change in the Mantaro Valley.</li> </ol> </li> <li><b>2. Improving the management of natural resources and related infrastructure to reduce vulnerability</b> <ol style="list-style-type: none"> <li>a. Integrated and sustainable management to reduce vulnerability to climate change in selected small watersheds – Shullcas, Yacus, Achamayo and Cunas – including reforestation, soil conservation, terrace management, monitoring systems, and capacity building of communities</li> <li>b. Construction of small structures for water storage and distribution, and improved infrastructure and management of irrigated areas (in Hualhuas and Cajas watersheds).</li> </ol> </li> <li><b>3. Adaptation of Mantaro Valley agricultural and livestock production systems to climate change impacts</b> <ol style="list-style-type: none"> <li>a. Monitor and conserve the rich biodiversity of native potato varieties in the district of Comas</li> <li>b. Design and implement integrated pest management practices and monitoring systems to deal with the emergence of new crop diseases and pests</li> <li>c. Design and implementation of agricultural techniques and practices for livestock systems, including improved pastures and fodder conservation.</li> </ol> </li> </ol>
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The Regional Government representatives from Junín expressed strong interest in the action plan developed in this study, in its alignment with the region’s climate change strategy (*Enfrentando el Cambio – Estrategia Regional de Cambio Climático – 2007*), and in its concrete project proposals to promote agricultural sector adaptation to climate change. They consider the regional

strategy as a dynamic document that needs to be flexible and that must link concrete proposals with the participatory budget and public investment process in order to turn the strategy into action. At the workshop, a plan was developed to present the Action Plan to the President of the Regional Government of Junín at an upcoming meeting, which will also involve representation from INIA, the regional offices of the Ministries of Agriculture and the Environment, and producers' organizations. The focus will be on discussing the potential for incorporating the proposed adaptation activities and projects outlined in the Action Plan in the regional public investment process. Workshop participants also discussed the importance of disseminating the experience acquired on climate change and agriculture beyond the Mantaro Valley, which is viewed as a reference region in Peru for dealing with climate change issues, and possibly replicating it elsewhere. INIA will develop a dissemination plan for the country report, including a presentation within the Ministry of Agriculture's Technical Group for Food Security and Climate Change (GTTSACC), as well as formal sharing of the results with other regional governments, and dissemination via the web.

Uruguay: Approximately 35 participants participated in Workshop 3, including representation from: the Instituto Nacional de Investigación Agropecuaria (INIA); the Ministerio de Ganadería, Agricultura y Pesca (MGAP), including the Programs and Policy Office (OPYPA) and the Renewable Natural Resources Office (RENARE); the Ministry of the Environment, including the Climate Change Unit in the National Environment Office (DINAMA) and the National Water and Sanitation Office (DINASA); the National Emergency System; and the Office of Projects and Programs in the Office of the Presidency. The private sector and producer groups were also well represented, with participation by representatives from FUCREA (Federación Uruguaya de los Grupos CREA), the National Agrarian Cooperative (COPAGRAN), the Federated Agricultural Cooperatives (CAF), and the Rural Association of Uruguay (ARU).

**Table 11. Summary of Climate Change Action Plan: Western Littoral Region, Uruguay.**

<b>Climate Change Action Plan for Western Littoral Region, Uruguay</b>	
<b>1. <u>Information and decision support system (SISTD)</u></b>	<ul style="list-style-type: none"> <li>• Define agroecological zones through climate and land-use mapping that distinguish different economically productive activities</li> <li>• Quantify agroclimatic risk through analysis of physical and economic factors influencing variability of production systems and causes of extreme climatic events</li> <li>• Crop modeling, incorporating agroclimatic and management factors, to enable improved modeling and reduction of risks associated with climate change.</li> <li>• Permanent monitoring of climatic and agronomic factors, to support an early alert and decision support system</li> <li>• Develop climatic and economic indicators for use in the establishment and implementation of insurance and other risk management systems.</li> <li>• Implement an early alert and monitoring system to assist the government in forecasting and responding to emergencies</li> </ul>
<b>2. <u>Improved water management</u></b>	<ul style="list-style-type: none"> <li>• Institutional strengthening for improved water management, especially at the watershed level; also, improved institutional support for irrigation management and land-use planning</li> <li>• Use of new technologies, tools and information for improved and more efficient water management, including supplemental irrigation, and improved production systems</li> <li>• Human capital development, including specialized training, for water management</li> <li>• Improved technology transfer through private and public institutions, including “technology roundtables”</li> </ul>
<b>3. <u>Insurance and other financial instruments for risk management</u></b>	<ul style="list-style-type: none"> <li>• Stimulate the development and use of conventional agricultural insurance for improved risk management, as well as catastrophic risk insurance based on improved measurement of agroclimatic risk, including the use of index-based mechanisms.</li> <li>• Create an emergency or contingency disaster compensation fund to supplement and help cover risks not otherwise covered by private.</li> </ul>

The general strategy of the local team in Uruguay led by INIA is to work to incorporate the response options contained in the Action Plan for Southwestern Uruguay (summarized in Table 11) in an implementation strategy built around the principles of the national climate change strategy (PMEGEMA). The Plan identified action steps for the agricultural sector that are highly consistent with the new directions announced in March 2009 by Uruguay President Vazquez to promote national attention to climate change adaptation – a fund for climate-related disasters,

improved management of water resources, creation of a national working group on risk prevention and climate change adaptation, with broad governmental and scientific representation. The implementation of these actions will require institutional coordination both across agricultural stakeholders as well as between and within layers of government. In response to the President newly announced initiatives, in May 2009, the national working group was formed to coordinate existing knowledge and propose specific measures to deal with climate change in the country. These are important political steps in taking the climate change debate further. The Action Plan developed in this study can facilitate, and help speed up, the knowledge generation and implementation process within the agricultural sector. It can also serve as a solid ground for identifying much needed financial backing that can translate climate change concerns into action for Uruguay's agricultural sector.

## **VI. CONCLUSIONS**

### **A. Study Results and Conclusions**

As outlined in the ESW and in Section II above, this study had three primary objectives:

- a) *Develop and apply a methodology for assessing agricultural vulnerability to climate change and for formulating “bottom-up” response strategies to inform policy investments and policy changes across three contrasting agricultural production systems representative of the Latin America region;*
- b) *Formulate recommendations for investments in each of the selected agroecosystems including agricultural technology adaptation, infrastructure investments, public and private sectoral support activities and institutions (insurance, technical assistance, etc.), complementary off-farm income-generating activities, mitigation strategies and policy changes.*
- c) *Disseminate the study results in the Latin America region to increase understanding of the impacts of climate change and the costs and benefits of adaptation and mitigation response strategies.*

With these objectives in mind, it is possible to identify a number of primary conclusions emerging from this study:

First, *the use of a “bottom-up” participatory priority-setting methodology provides a good starting point in the design of proactive adaptation strategies in agriculture.* We found that use of a formal priority-setting methodology provides a useful mechanism in the identification and initial design of strategies to improve agricultural sector adaptation and improve its resilience.

The priority-setting methodology

- is easy, transparent and relatively costless to apply;
- is highly participatory and flexible in operation; and
- it focuses directly on incorporating the views of diverse local stakeholders, the same stakeholders – farmers, landowners, resource managers – whose decisions are at the forefront in actually dealing with climate change at the local level.

In Box 2, we address in detail several of the specific experiences, advantages and limitations we encountered with the methodology. We find that the priority-setting methodology has a number of advantages when applied under conditions of significant complexity and uncertainty, as in the case of climate change and its effects. Under such conditions, more deterministic, quantitative assessments (such as cost-benefit analysis and economic welfare analysis) may be more problematic, both conceptually and in practice. A multi-criteria approach such as that employed here helps break up the decision process into manageable parts, adapting to multiple sources of uncertainty and reducing the impact of individual assumptions that may later prove inaccurate. Uncertainty also likely played a role in the shift we observed among many workshop participants from viewing response options from the perspective of “climate adaptation” to one of “climate resilience”. This shift has an advantage in that it places an emphasis on the ability of an agroecosystem to recover from shocks and stresses induced by climate change (e.g., “resilience”). However, such a shift may also deemphasize the focus on unforeseen but potentially critically important future changes that may necessitate mitigation measures.

As noted in Box 2, we believe that pursuing a priority-setting approach such as that used here is compatible under most circumstances with benefit-cost and other standard economic assessment

## Box 2. Experience with the Priority-Setting Methodology

The multi-criteria, participatory priority-setting approach we used in this study we found to have a number of advantages as well as several limitations. Some of the more important of these are summarized here.

*Response to uncertainty.* One of the most distinctive aspects of climate change is the high degree of uncertainty surrounding it (CBO, 2005). In agriculture, these sources of uncertainty are many, including: the types and magnitudes of climate changes themselves, their environmental and biophysical impacts on production agriculture, the geographic and temporal distribution of both climate changes and their impacts, and the economic impacts both in terms of costs and benefits (which are in turn dependent on unknown future prices). In an environment of such uncertainty and in the absence of reliable data on key biophysical and economic variables, the use of cost-benefit analysis and other conventional methodologies is fraught with difficulties and the resulting policy recommendations can be highly varied, even contradictory (Pizer, 2005). The use of a “bottom-up” priority-setting approach – *at least as a first-step approximation to framing response options* – has a number of advantages, including its flexibility in incorporating a diverse set of evaluation criteria (see Section V); the direct focus of the approach on feasibility and viability of response options; and its potential for incorporating economic assessment of costs and benefits. In addition, the participatory process allows assessment of outcomes by groups of participants, thereby increasing the likely robustness of responses.

*Compatibility with economic analysis.* In principle, there are few limitations to including conventional economic analysis of the costs and benefits of proposed response options as part of the priority-setting methodology used in this study. This does not necessarily mean, however, that the two approaches necessarily generate the same outcomes; the priority-setting methodology used here incorporates a broader set of criteria, including non-quantitative criteria, compared to cost-benefit analysis which focuses on numerical estimates of economic criteria. Cost-benefit analysis is also most effective in a deterministic setting (EAI, 2006), which rarely characterizes matters related to climate change. Estimates of the costs and benefits were planned from the outset to be included in Step 3 for a selected number of response options in each country (Section V). This was indeed accomplished in both the Mexico and Peru cases, although these estimates are at a rougher and more preliminary level than originally planned (see, for example, Box 1, which outlines a typical response option for Mexico). Economic costs and benefits from each of the response options were also explicitly included among the evaluation criteria used to assess each response option in the priority-setting process (see Table 5). In addition, we would urge that any major potential investment – for example, in the modernization and renovation of the irrigation system in the Yaqui Valley, identified in the priority-setting process for Mexico – undergo a standard comprehensive cost-benefit analysis prior to major investment of public funds.

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**Box 2. Experience with the Priority-Setting Methodology (cont.)**

In practice, our experience in integrating economic analysis in the priority-setting methodology encountered several limitations. First, the high degree of uncertainty characterizing climate change effects means that economic assessments would ideally have to be conducted for a wide variety of possible response options. This was not feasible in a pilot study like this. Second, even with the limited number of response options considered in Step 2 of this study (see Section V), conducting a full-blown cost-benefit analysis under a wide variety of climate change scenarios would be difficult to accomplish under the resource constraints realistically facing most projects. Finally, we found that the estimated costs of response options are much easier to estimate than the estimated benefits. In the latter case, many outcomes are unknown, such as the net yield effects of higher CO<sub>2</sub> levels in the atmosphere and economic benefits resulting from unknown future prices. Notwithstanding these limitations, given adequate time and resources, it is possible to do a more complete job in integrating economic cost and benefit considerations in a priority-setting approach than proved possible in this pilot study.

*Prioritizing specific response options.* One of the key findings of this study, described in Section VI, is the similarity of response options identified and prioritized in the three country case studies. Workshop participants identified key climate change response strategies to include climate information systems, improved water management technologies and practices, technology innovations and investments (research, infrastructure, etc.), improvements in integrated natural resource management and agricultural systems management, and a variety of institutional innovations. These are largely “no regrets” options which make sense under widely different climate change outcomes. This was not a coincidence. Although the specifics differ by region, the overall challenges created by climate change in each region centered around many of the same issues – water availability and quality, changes in the natural resource base and cropping systems, the need for better information and public investments to backstop private decision-making, and so forth. At the same time, it is likely that the focus on *local* agroecosystem constraints associated with the “bottom-up” focus of this study on agricultural adaptation may have resulted in a lesser emphasis on other potential response options that might be prioritized in other regions or circumstances. For example, response options designed to address climate change mitigation might well have emerged given a greater focus in this study on mitigation aspects. Further, if conducted at a national rather than a regional level, reforms in tenure systems and rights to land, water and other natural resources – factors which are widely acknowledged to influence resource access and use by farmers and rural households – might have figured prominently among response options identified. The same might be said with regard to other potential response options.

/cont.

### **Box 2. Experience with the Priority-Setting Methodology (cont.)**

*Limitations of the priority-setting approach.* In spite of its advantages, we found the priority-setting methodology to be characterized by a number of limitations, in particular the sensitivity of the outcomes to some key study components. Under this approach, the composition of the workshop participants both in Workshops 1 and 2 played a key role in identifying and prioritizing the specific response options. Given this central role, it is important that the composition of the group represent a balanced representation of stakeholders representing different interests in the region. Similarly, the experience and skills of the workshop moderators played a key role in generating consensus in the selection of potential response options, particularly in Workshop 1; less experienced or capable workshop moderators might not have been able to guide participants to these consensus views. In addition, the priority-setting methodology is itself inherently oriented toward consensus-building; it is less able to deal with conflict and resolving conflict. Finally, the weights associated with the evaluation criteria reported in Table 5 played a central role in the prioritization of the individual response options. Though they were by design differentiated by country, reflecting the priority criteria designated by country-level participants, different weighting criteria have the potential to affect the ranking of prioritized outcomes.

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Congressional Budget Office. *Uncertainty in Analyzing Climate Change: Policy Implications*. U.S. Congress, Washington, DC. January 2005.

Environmental Assessment Institute. *Risk and Uncertainty in Cost-Benefit Analysis: A Toolbox Paper*. Copenhagen, Denmark. 2006.

Pizer, W. "Climate Policy Design Under Uncertainty." *Discussion Paper 05-44*, Resources for the Future, Washington, DC. October 2005.

measures (though the results may differ). Indeed, we sought from the outset to integrate estimates of costs and benefits in the evaluation of most of the response options considered in this study. As it turned out, there was a range of outcomes in seeking to accomplish this, with the most comprehensive examples being in the case of Mexico. In addition, in keeping with the notion that the priority-setting methodology is especially effective at providing a first step in identifying feasible local response options, we stress that future public investments, particularly expensive ones such for irrigation infrastructure, will need the application of more comprehensive economic assessments of benefits and costs before proceeding. Thus the two

types of approaches are typically highly compatible. Many of the operational limitations encountered are practical ones of time and available resources.

One aspect of the methodology – the use of climate change and crop models in Steps 1 and 3 of the study – turned out differently than originally planned. The reasons for this are explained in detail in Box 3. As with the use of cost-benefit and other economic models in Box 2, the high level of uncertainty characterizing climate change and its biophysical effects, as well as related practical limitations of time and available resources, substantially accounted for our experiences in this aspect of the study.

A second overall conclusion of this study is that, although the three production environments were very different in many respects – agroclimatic characteristics, crops grown, farm size and structure, etc. – *the response options that emerged across the three countries were highly similar*. In each country, response options were identified in this study that focused on:

- *climate information systems* – e.g., systems for climate predictability (early-warning systems; developing capacity for longer term projections), agro-climatological information and its accessibility by producers;
- *water management technologies* (e.g. water harvesting, drainage, irrigation distribution systems, etc.)
- *technological innovations to minimize climate risk*; these innovations range from the use of conventional plant breeding and biotechnology for drought resistance and pest and disease resistance, to improvements in irrigation infrastructure;
- *improvement in the integrated management of natural resources and production systems* in various forms: water and watershed management, conservation agriculture, crop and pasture rotations, adjustment of planting dates, etc.
- *institutional innovations* of many varieties, including: early warning systems for climate and pests and disease, improved policy and regulatory frameworks for water management, agricultural and catastrophic risk insurance, etc.

### Box 3: Use of Climate Change and Crop Models

The original plan was to use the results of climate change and crop models at two points in the study. The first was in Step 1, to identify key climate changes and their likely agricultural impacts in the three study regions in order to share these impacts with workshop participants. The second was in Step 3, to quantitatively assess the efficacy of different response options that were identified in the first workshop.

In Step 1, we used the outputs of climate change models (from the 2007 IPCC report and other regional studies) to describe “consensus” climate changes in each of the three study regions in terms of temperature, precipitation, frequency of extreme events, etc. Reporting consensus *impacts* of these climate changes on agriculture proved to be a more challenging task. Potential climate change affects on agricultural systems have been assessed with increasing levels of sophistication for more than 30 years (Tubiello et al., 2007). However, most of these studies either focus very narrowly (e.g. CO<sub>2</sub> impacts on crop yield), very generally (e.g. country-scale crop production), or for time periods that were not relevant to the timeframe of this project (30+ years). Hence for the three geographic areas of interest, it was not possible to quantify all the relevant agricultural impacts of climate change from existing studies.

In Step 3, the time and resources necessary to conduct new simulations to assess the effectiveness of different response options were simply too great to accomplish as originally envisioned. This was particularly the case where there is a significant lack of agreement among climate change projections from different models (e.g. precipitation in central Peru). In light of this type of uncertainty, there is increasing recognition that crop simulations should be conducted with a range of scenarios that reflect the diversity of climate change projections for a region (Tebaldi and Lobell, 2008). While this is the preferred approach, it is also much more costly and time consuming than utilizing climate change projections from a single model.

In a future project like this, closer integration of regionally-specific climate change and crop modeling results into a priority-setting exercise could be accomplished if the following are available: 1) adequate time and sequencing of project steps; 2) a sufficiently multi-disciplinary project team with the requisite expertise in climatology, crop modeling, and associated technical areas; and 3) adequate project resources to support this effort.

From the standpoint of workshop participants in this study and their perceptions of the outcomes of climate change models, we learned several things:

- Many participants commonly confused “climatic variation” with “climate change”. Familiar climatic variations – seasonal, annual, etc. – are often understood to represent future climatic change, when the two need not be the same.

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### Box 3: Use of Climate Change and Crop Models (cont'd)

- Many participants, particularly those with less formal education or with less scientific training, tended to generalize from personal experiences to future perceptions of climate change. It was often quite difficult for workshop participants to see beyond personal experience and anecdotal evidence to perceive what scientists might mean by “climatic change”.

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Tebaldi, C., Lobell, D.B. 2008. “Towards probabilistic projections of climate change impacts on global crop yields.” *Geophysical Research Letters* 35: L08705.

Tubiello, F.N., Soussana, J.F., Howden, S.M., 2007. “Crop and pasture response to climate change.” *PNAS* 104, 19686–19690.

Given the wide diversity of agricultural production systems in LAC, the similarity in adaptation mechanisms, as identified by local stakeholders in very different settings, is a significant result of the study. These response options could thus be considered a first approximation to a regional adaptation strategy in agriculture, one built, at least in part, from the “ground up.” The required interventions are similar, though differences do exist and their implementation will vary across countries.

Third, *a needed role for the public sector was identified in all three country settings.* The bottom-up priority-setting process that is the centerpiece of this study inherently prioritizes the responses identified by private resource managers. However, in all three countries, even in Mexico and Uruguay where the private sector exhibits strong leadership in agricultural resource management and policy, it was widely recognized that the private sector is challenged in responding to climate change and that those responses can be greatly facilitated by selected public sector investments and institutional and policy changes. The public sector can play a key role, at a minimum, in three areas: 1) infrastructure investment, such as with regard to irrigation systems (this was a high priority in Mexico); 2) providing information to facilitate private decision-making, such as through climate change information systems and early warning systems; and 3) institutional innovations to help deal with environmental externalities and imperfect markets. Specific alternatives that were identified as priority response options that

might be provided by, or facilitated through, the public sector included climate change information systems; agricultural and catastrophic risk insurance; investments in integrated watershed management; market feasibility studies to encourage crop diversification, including higher-value products; agricultural research targeting new crop varieties, best management practices, and other priority needs; and policy and institutional reforms to deal with such issues as water access rights, intellectual property and climate change mitigation.

Fourth, it is worth emphasizing that many of the response options identified and prioritized by workshop participants in all three countries focused on *decision support systems and improving the information base available to farmers and land managers*. Mechanisms include early warning and climate information systems (for climate forecasts, extreme weather events, pests and disease outbreaks, etc.) and climate risk maps and geographic information systems. By comparison with major infrastructure investments, such as the modernization and reinvestment in irrigation systems prioritized in the Yaqui Valley, these are relatively inexpensive options. They still leave the key resource allocation decisions in the hands of farmers but focus on solving the information externalities, and other constraints, that would otherwise lead to sub-optimal resource use and climate change responses. These alternatives confirm from the “bottom up” recommendations from a variety of global and regional institutions (UNFCCC, UNDP, World Bank, Stockholm Environment Institute, CSIRO-Australia, and others) that have prioritized improved information provision and decision support as a key way to address climate change adaptation.

Fifth, we found that “*details matter*” – the operational and procedural details of using a priority-setting methodology can influence the outcomes. The use of any methodology has various advantages and disadvantages. In this case, the outcomes of the priority-setting approach were dependent on a number of key factors, in part related to the functioning of the country workshops that were a centerpiece of this study. In addition to those discussed above (Box 2 and Box 3), some of the key operational factors encountered in this study are addressed further in the next section and in Box 4.

Finally, the applicability of the priority-setting methodology in other countries and the dissemination of the results of this study can be useful and instructive as one mechanism to deal

with climate change adaptations. In general, we found the overall approach we undertook as a pilot has much to recommend it and, with appropriate adjustments based on the local setting and the “lessons learned” elsewhere, should be highly applicable to other country and agroecosystem settings in responding to the challenges created by climate change.

## **B. “Lessons Learned” Regarding Application of the Priority-Setting Methodology**

We found that many of the operational and procedural “details” involved in the application of the priority-setting methodology made a substantial difference in the outcomes. Given that this effort was originally conceived as a “pilot”, we identify some of these operational experiences below and present them in the form of recommendations for future applications. Further details and elaboration are given in Box 4.

### *1. Actors*

Given the technical complexity of the subject matter (climate change and agriculture), a diverse team with several counterparts having varying expertise, differentiated tasks, and representing different institutions is recommended. The optimal mix is a government agricultural research institution (bringing technical and experimental knowledge and a familiarity with local agricultural conditions), a university (bringing technical capacity, a research-based focus and in some cases, technical modeling capacity), and a farmer organization (representing the needs and views of producers). Early attention should be paid by the local team to connecting with representatives of farmers organizations, key national government agencies, local and regional governments, and other stakeholder groups that otherwise might not be formally brought into the process until the final workshop.

*a. Multidisciplinary team.* Addressing climate change and adaptation in agriculture is an inherently complex undertaking. The subject matter is complex, wide-ranging, inherently multidisciplinary and addresses highly contentious issues. It is very helpful to have a multidisciplinary local team to work on the preparation of background materials for the study, workshop presentations and other components where diverse technical expertise is called for. This diversity of backgrounds, disciplinary training and viewpoints is also

#### Box 4: People and Processes in Developing Country Action Plans

In order to develop a collective action plan, a consensus must be reached among the different stakeholders of likely local climate changes, their expected effects and the proposed adaptation actions and strategies. This box describes several aspects of the consensus building process as experienced in the series of three workshops held in each country, in particular, the role of the different people behind the action plan, as well as the process of planning and leading the workshops:

1. The **list of participants** was established well in advance of each workshop and included farmers and other agricultural practitioners, agricultural researchers, and policy-makers dealing with climate change in the studied agro-ecosystem. In addition to farmers, agricultural practitioners included agricultural extensionists and representatives of agricultural producers organizations. Researchers and technicians included climatologists, agronomists, soil scientists, sociologists, forestry and water specialists, etc. Other participants included representatives from local and regional governments, non-governmental organizations, and national government ministries. The workshops typically consisted of 30 to 70 participants. We found that a minimum representation of 30% of farmers and farmers' organization representatives was necessary to generate the desired input by practitioners.
2. A good **continuity of key participants** from the three main groups (i.e. practitioners, researchers and technical personnel, policy-makers and NGO representatives) throughout the series of three workshops is highly desirable. This continuity helps create a continuing commitment among participants, makes workshop planning and execution more efficient, and helps create local ownership of the final action plan. Participation in all three workshops created commitment and a strong ownership of the final action plan. For example, in Peru, 70-80% of the participants in the third workshop had also taken part in the two previous workshops.
3. **A fluent exchange of information between researchers and non-experts** was facilitated by the workshop moderators through developing and sharing background material and providing guidance in the group discussions. *The input of researchers* was key in explaining in simplified language the basic concepts of climate change and climate change scenarios (e.g. changes in CO<sub>2</sub>, temperature and rainfall) as well as in characterizing the agro-ecosystems. *The input of agricultural practitioners* related mainly to their practical experience about incorporating climatic uncertainties in their production strategies and farming practices and their perceptions of possible effects of climate change in the medium term and required adaptations. The interaction of these different points of view permitted the generation of a group consensus regarding climate changes, their expected effects and the appropriateness and feasibility of proposed adaptation options.

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**Box 4: People and Processes in Developing Country Action Plans (cont.)**

4. **Participation and group work** (via small group discussion) facilitated the elaboration of climate change response options and facilitated the creation of local ownership. In the first workshop, we found that maximum participation of 10-12 individuals in each small group discussion helped to maximize participation, kept the discussion balanced and permitted diverse viewpoints to emerge regarding the alternative response options needed to address climate change in agriculture. A preliminary consensus on these issues was easily reached by the wider group after a collective discussion and comparison about the outputs of each small group. In the second workshops, small group discussion helped in elaborating the details and technical depth of each adaptation response under consideration.
5. **Policy makers** (also including government and ministry representatives, trade associations, non-governmental organizations, etc.) – in particular those with an agricultural and environmental mandate – were involved from the very first workshop on. This was important in helping them better understand the inclusive and “bottom-up” approach used in the elaboration of the action plans. Their input was key in providing the relevant institutional, legal and policy context to assist participants in proposing politically and institutionally viable mechanisms to implement the action plan. Especially during the final series of country workshops, it was important to give policy makers the opportunity to express interest in and comment on the action plans, and to commit to concrete follow-up actions – e.g., making institutional commitments, linking the action plans to local planning processes, etc.
6. Having an **experienced workshop moderator** is indispensable in helping steer the group dynamics towards a collective agreement at various junctures in the series of workshops: identifying consensus local impacts of climate change, identifying feasible response options, and finally, in helping prioritize these options. Workshop moderators also played a key role in ensuring that participants understood the basic concepts of climate change and adaptation before engaging in the small group discussions. In the context of a technically complicated subject like climate change, an experienced workshop moderator should also be knowledgeable about the local agroecosystem and climate change issues, sensitive to social, economic and gender issues, as well as the participatory and priority-setting methodology.
7. The **implementing partners** included the national agricultural research organizations in each country, and in Mexico, university and producer organization collaborators. This diversity of collaborators is desirable to helpful at several levels: in assuring adequate technical capacity to deal with a complex subject like climate change; in fostering the diverse types of public and private sector linkages to adequately deal with the challenges created by climate change; and simply in assisting in the operational details associated with organizing a series of workshops with diverse participation. It was also felt that they gained credibility throughout the process as reliable and committed institutions in using a bottom-up approach on adaptation to climate change, and fostering new partnerships.

highly advantageous in an area where even experts often disagree. A multidisciplinary team is also useful for improving networking amongst different stakeholder groups and achieving “buy-in” at the end of the study across diverse stakeholders. Ideally, a local team would consist of members (or individuals who could be called upon) with expertise in: meteorology and climatology; agronomy, crop and soil science; animal science and livestock management; forestry; hydrology and water resources; ecology and environmental science; economics and policy analysis; and someone with comprehensive knowledge of local farmers, farming systems and communities. A diverse local team also helps in organizing the technical and logistical aspects of the workshops. Realistically, resources may not permit this wide-ranging a local team in many applications, but a diverse multidisciplinary team should be the goal.

- b. *Mix of workshop participants.* Much of the work of this study was built around the series of three workshops in each country and the activities contained therein. Therefore the number and mix of local participants at each workshop was critical to all parts of the study including: in identifying possible response options to address climate change; defining and weighting criteria with which to evaluate the final response options; prioritizing the response options; and reacting to the Action Plans the defined the scope for implementation. Although our focus was on agriculture (here primarily defined to involve mostly crop production), in retrospect, we should have had wider representation from livestock, water, and forestry sectors, in particular. In addition, it would have been advantageous to have other specialists that work indirectly with agriculture (e.g. the insurance industry), as well as the private agribusiness sector (input suppliers, processors, etc.). With careful targeting of participants, a group of 30-40 people is a manageable size. Above that number, unless carefully managed, it becomes difficult to involve everyone in the workshop deliberations and to acknowledge all participants’ views.

Above all, it is important to have a “critical mass” of producers and representatives of farmers’ organizations participate. This necessitates specific attention as to how to best contact, invite and assure farmer participation in each case (mechanisms will vary in different contexts). In some cases, this critical mass of producers was present, in other cases, it was not. Having a wide and diverse mix of participants improves the process at all stages, and in

particular, assures that the priorities emerging at the end of the process are truly representative of the wide local community of practitioners.

## 2. *Workshops*

In the prioritization exercise held in Workshop 2, the different response options that were evaluated by participants were chosen from a narrow set of alternatives that had been identified and selected by consensus in Workshop 1. Then (as discussed below), after Workshop 2, the ranking of the response options was subsequently followed by a process of reorganizing, reframing and recombining the different response options into “packages.” Thus, it turned out that the original list of possible response options from Workshop 1 became the “short list” from which the priorities were selected in Workshop 2 (which in turn framed the Action Plan in Workshop 3). As a result, the original identification of possible response options in Workshop 1 and the process of arriving at a consensus selection of those options which deserve further analysis for consideration in Workshops 2 and 3, is a critical step in the entire methodology. While we recognized this beforehand, we didn’t fully appreciate its significance. This suggests the importance of assuring a widely representative participation of stakeholders in Workshop 1 (as in the other workshops), and that the consensus-driven identification of possible response options in Workshop 1 be managed systematically and deliberately, ideally by an experienced workshop leader. Other workshop-specific comments are as follows:

- a. *Workshop 1:* In the synthesis of the available climatic information and impacts before and during Workshop 1, and in the identification of the possible response options, we found several aspects to be particularly important:
  - 1) It is highly desirable to provide the *general country context* on climate change strategies, national and regional-level programs, and on-going projects and activities pertaining to climate change and agriculture. We found that only selective information on these important contextual matters was available at the first country workshops. This should be built in during the planning stages. This early exposure of workshop participants – and study leaders – to the policy and institutional framework relevant to climate change and agriculture is important not only in providing context at the outset of the study, but it becomes important again toward the end of the study in framing the Action Plan.

- 2) It is important that *comprehensive baseline physical, climatic and climate change forecasts and their potential impacts* be prepared by the local team prior to the first workshop and clearly and systematically presented to all participants. Although this information was, in all cases, provided in this study, the treatment was not always uniform in its comprehensiveness or in its reliance on the underlying science. We discovered that many workshop participants confuse *short-term climatic variation* with *long-term climate change*, and that this confusion persisted over the first two workshops. Many participants also implicitly used historical analogues in considering future climatic changes, when the two need not necessarily be the same. It should not be assumed that the many subtleties involved in the interpretation of complex climate change models will be self-evident to workshop participants and other laypeople lacking scientific backgrounds or prior knowledge of these models.
  - 3) It is important in the organization of, and presentations at, the workshop to distinguish between 1) *climate changes* (e.g. in temperature, precipitation, etc.) and 2) their *likely effects in agriculture and ecosystems* (yields, incidence of pests and disease, etc.). As discussed in Box 3, the latter proved particularly difficult to discuss at the workshops due to the frequent lack of regional-relevant scientific results, and even if these were available, the considerable work involved in ferreting these out before the workshop and presenting these findings. This is a technically difficult and time-consuming step, and adequate time and resources should be made available for, and devoted to, completing this important component.
- b. *Workshop 2*: Before any prioritization exercise is completed, the identified response options should ideally be further discussed, redefined and re-grouped. Some of this was done by the local teams prior to Workshop 2 and was reflected in the options evaluated at the workshop. But the options identified in Workshop 1, in some cases, still had substantial overlaps. Additionally, important strategic issues and political constraints were brought up by Workshop 2 participants that had implications for framing the response options. This created some problems in effectively applying the prioritization exercise since there was not sufficient time during the second workshops – nor could there be, given the time required – to carefully fine-tune each of the response options prior to the priority-setting exercise.

Ideally, a consensus should be reached early in Workshop 2 regarding the scope of each proposed option, and whether it is to stand alone or to be combined with the remaining options. The more specific the options, the easier this process is. Using broad themes (which is how we typically began), tends to lead to overlap among options and, although a general idea of the direction of possible interventions is possible, it does not necessarily lead to a precise specification of what activities will be involved.

The other aspect of Workshop 2 that is key to its success is based on the fact that, given the methodology employed, the final set of priorities identified in Workshop 2 – which then defined the components of the Action Plan in Workshop 3 – is wholly dependent on the rankings and assessments of Workshop 2 participants. Thus, again, it is critical to assure that a widely representative set of participants are involved in both the criteria identification and weighting exercise, and the prioritization of the response options.

- c. *Workshop 3.* Having an established format for the framing of the Action Plan would have facilitated turning the prioritized response options from Workshop 2 into the Action Plan discussed and validated in Workshop 3. The study leaders wanted to allow for plenty of flexibility and leeway for the local teams to frame the Action Plans as they felt would best meet local requirements. However, this flexibility created some uncertainty, which was addressed by the study leaders developing and sharing guidelines for the development of the Action Plans (based on the response options) with the local teams. It turns out that providing guidance in the format and content for the framing of the Action Plans from the beginning of the study, would likely help ensure more consistent results across countries and, within a country, across the response options.

### 3. *Use of Priority-setting Approach*

The priority-setting methodology has been discussed above and in Box 2. One additional point also deserves mention. The priority-setting exercise, while a critical step in this study, was only one part in the formulation of the response options and Action Plans. If the results of the priority-setting exercise had been followed strictly (disaggregated, and in rank order), this might tend to lead to an overly “mechanical” development of the Action Plans. We found, throughout the workshop discussions, that other strategic elements pertaining to local institutional capabilities,

changes in the policy environment, local and national political concerns, and the priorities of potential funding organizations were often given major attention by participants. This was true in the validation phase of the study (Workshop 3) as planned, in the evaluation of the response options (Workshop 2), and even, to some extent, in their initial definition (Workshop 1). In all three countries, the country teams (and workshop participants) recognized the importance of these strategic considerations, and the priority-setting and formulation of the Action Plans took these aspects into account. Nonetheless, this indicates one limitation of too strict a reliance on the priority-setting methodology. This can be addressed early on in the process by providing more background information on the country policy context during Workshop 1 (as suggested above). This would enable participants to better frame their suggested response options taking into consideration the broader institutional and policy context.

### **C. Options for Future Follow-up**

Section V.E (above) outlines the specific mechanisms for follow-up to this study in each of the three countries in the context of the development of the local Action Plans. In addition, there are a number of other avenues for possible follow-up based on the experience of this study:

- *Application to climate change in other country settings.* Given the experience of this study in formulating and executing an overall approach to priority-setting for climate change adaptation and the practical experience gained in the three country sites, we are now in an excellent position to apply this approach (or a suitably revised version) to other country settings. In doing so, we have learned both the strengths and limitations of applying priority-setting methods to the climate change problem, as well as the additional complexities and challenges involved compared to other traditional areas of action research on priority-setting (agricultural research, public health, etc.).
- *Extension to climate change mitigation.* Although this study focused primarily on adaptation strategies to climate change, we recognize that mitigation strategies are also extremely important, given the role of agriculture in generating greenhouse gases directly as well as indirect effects, for example, through land clearing and deforestation which are a major contributor to greenhouse gas emissions in Latin America. We further recognize that mitigation strategies are unlikely to be effective without a dominant role and

commitment of national governments. Mitigation activities in most countries need to first target primary emitting sectors such as transportation, energy, and industrial development. However, as climate changes accumulate and their impacts on the agricultural sector intensify, it will be important for agriculture-oriented strategies – including bottom-up strategies applied at the micro-level – to have a mitigation focus as well. *Most, if not all, of the adaptation strategies prioritized in this study are consistent with those that emphasize mitigation.* The framework pursued in this study could however be easily adapted with a more explicit focus on priority-setting for mitigation as well as adaptation strategies in agriculture and natural resource management, although again, a focus on mitigation is unlikely to be as effective with a micro-oriented strategy.

- *Policy and institutional mechanisms to promote climate change adaptation and mitigation.* Many of the response options identified in this study focus on land, water and resource management at the farm level, by design. Others of the response options require institutional commitments and/or policy changes in order to be implemented: integrated watershed management, biodiversity monitoring, investments in irrigation infrastructure and management, public information and early alert systems, new insurance instruments for risk reduction, etc. As climate change intensifies and its impacts become more pervasive, there is likely to be increasing pressure on farmers, landowners and resource managers everywhere to significantly modify their management practices. That will be difficult to accomplish on a wide scale without more innovative institutional mechanisms designed to promote climate change adaptation and mitigation at regional and national levels. Attention needs to be given to new policies and instruments that provide incentives for farmers to modify land and resource use. In addition to regulatory and enforcement (“command and control”) approaches which are often ineffective in developing country settings, attention should be given to a host of other approaches, including some borrowed from industrialized countries. Some of the alternatives include: taxes and subsidies; input pricing that reflects true scarcity values (e.g., for water) and that fully incorporates environmental externalities (e.g., fertilizer); innovative payments for environmental services (PES) programs; expanding agriculture’s role in CDM (Clean Development Mechanism) projects; carbon taxes; agricultural offsets to cap and trade

programs; emissions trading; better monitoring of greenhouse gas emissions in crop and animal systems; and closer harmonizing of production-oriented agricultural programs with environmental regulations.

- *Climate change sourcebook.* Another possible extension of this work is to include this priority-setting approach and the lessons learned along with other different approaches to facilitating climate change adaptation in the form of a “sourcebook” which would catalog a variety of possible approaches, case studies, and the pro’s, con’s and “lessons learned” from each (the World Bank has previously published sourcebook on Environmental Assessment, Participation, Poverty Reduction Strategies, Agricultural Investment and Gender in Agriculture, for example). This sourcebook could draw from the growing number of innovative experiences in promoting climate change adaptation and mitigation strategies and, while drawing from research and applied research, could be made highly applied and “actionable”. Given the complexity of climate change and associated strategies, such a sourcebook could address many possible topics: land use changes, water and irrigation management, climate information systems (early alert, GIS, decision support, etc.), crop and livestock management (especially in such climate-sensitive areas as water management and pest and disease management), as well as broader concerns related to local economic development, employment, rural to urban migration, etc.

## ANNEX

### Using the Priority Setting Approach in Uruguay

This Annex summarizes the priority-setting approach as it was applied in one country, Uruguay, and the activities that were involved at each step. The methodology for prioritizing the proposed climate change interventions was applied over a series of three workshops, as described above, and most of the study activities occurred in preparation for, during, or as follow-up to these workshops. The Uruguay experience was closely paralleled by that in Peru and Mexico, although with adjustments in each country to reflect local circumstances and constraints.

#### Workshop 1

An outline of the priority-setting methodology was presented during the first workshop and reviewed and discussed by the workshop participants. This was both to solicit their feedback on the process to be followed and to ensure that they understood the process that was to be followed over the entire series of workshops. Following this review, numerous presentations were given, leading to extended discussion, on predicted climate changes and their likely effects on agriculture in Uruguay, drawing extensively from the available scientific literature. These presentations emphasized crops, sectors and issues of particular relevance to the southwestern part of the country, the chief region of interest to this study. Organizers also brought up the suitability of several proposed impact and feasibility criteria for eventual use, in Workshop 2, in evaluating the response options (at that point, the response options were yet to be defined).

Following a series of presentations on climate changes and their likely impacts, Small group discussions were held to identify a list of potential response options in the country. The results of these small group discussions were then shared with the entire group. With guidance by an experienced facilitator, the results from the group discussions were then combined and “bundled” into major common themes to reduce overlap and eliminate “outlier” responses. This was done with the agreement of all participants. The end result was a reduced list of specific potential response options representative of the discussions of all of the groups, and emphasizing those response options that were generally acknowledged to be the most important.

## Workshop 2

The major results from the first workshop carried over to the second were: 1) the list of eight major potential response options, for which “profiles” were developed by the local study team prior to the second workshop, and 2) general agreement on a set of evaluation criteria – “impact” criteria and “feasibility” criteria – to be applied to the assessment of the response options.

The first part of Workshop 2 was dedicated to a review of the entire methodology (as several participants had not attended the first workshop), a review of the key technical results of the first workshop, and reaching final agreement on the choice of evaluation criteria. Workshop participants were asked to provide their independent assessments of the relative importance of seven “impact criteria” and six “feasibility criteria” (given below) by weighting them. Participants were asked to do this individually on a sheet of paper on which all criteria were listed. They were asked to distribute 100 total points among each group, reflecting their individual views regarding the relative importance of each criterion. The individual weights were then tallied and the average weighting scheme calculated. The results are as follows:

### Impact criteria (total = 100%)

Economic benefits of the response option	30.6%
Economic costs of implementation	13.9%
The scope of the response beyond the focus of the project	11.1%
The importance of the activity for poor groups	8.1%
Adaptation potential	15.3%
Mitigation potential	9.7%
Capacity to reduce damage caused by extreme events	11.4%

### Feasibility criteria (total = 100%)

Technical viability of the response option	32.5%
The level of available information for impact evaluation	17.2%
Compatibility/coherence of the option with PMEGEMA	10.0%
Potential public support and general acceptance	16.4%
Need for public sector intervention	13.6%
Existing development of the response option at the national or regional level	10.3%

It should be noted that this same process was followed in the second workshops in each country. Some minor changes were made in Peru in response to the discussions of evaluation criteria, and they were modified accordingly.

Following the determination of the evaluation weighting scheme, extended presentations were given by workshop organizers of each of the potential response options identified in the first workshop. Detailed information was given regarding such things as: proposed projects and activities, their connection to climate change response, their estimated costs and impacts, etc. The objectives was to enable participants to make informed decisions in their assessments of the individual response options.

Finally, at the close of the workshop, each participant was given a matrix summarizing the chosen response options (listed in the columns) and the 13 evaluation criteria (listed in the rows). Each participant was asked to score each response option on a 1 (low) to 10 (high) basis, based on his/her individual assessment of the potential of each response option to successfully address each criterion. The total score for each response option weighted by each criterion (with the weights as given above), was calculated following the workshop. Impact criteria were collectively assigned a 50% weight (individual criteria weighted proportionately), with the other 50% assigned to the feasibility criteria (again, with individual criteria weighted proportionately). The results were then averaged across all workshop participants, and normalized on a base of 100 = maximum score. The results were as follows:

<b>Response option</b>	<b>Final score (100 = maximum)</b>
1. Information system for decision making (SISTD)	78.9
2. Water management	77.2
3. Insurance	75.3
4. Support for the transfer of information and technology	72.9
5. Stimulus for best practices in agriculture	69.9
6. Improvement in climate predictability	69.2
7. Design of production systems to reduce climate risk	67.2
8. Genetic improvement (traditional and use of biotechnology)	63.8

### **Workshop 3**

The original plan of the study was that the top-ranked response options of the prioritization process conducted in Workshop 2 would provide the primary content of the Action Plans developed for presentation, validation and discussion in Workshop 3. As a practical matter, all of the response options for which profiles were developed and which were formally evaluated in Workshop 2 had strong arguments behind them and support among workshop participants. In all three countries, the prioritization process yield average scores for many response options that were often relatively close. In addition, for strategic reasons – institutional support, political considerations, the prospect of achieving external funding – there was, in all three countries, a “bundling” of response options to generate the final Action Plans. While the scoring of the response options reported above did not directly translate into the components of the Action Plans as originally envisioned, the prioritization process did directly feed into the elaboration of the Action Plans.

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