Water
to feed the land

Inter-American Institute for Cooperation on Agriculture

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Acronyms

ALIGN	Arable Lands Irrigated and Growing for the Nation (Jamaica)
AMA	Agricultural Management Assistance (NRCS-USDA)
ANA	National Water Agency (Brazil), National Water Authority (Peru)
AQUASTAT-FAO	FAO Global Water Information System
ASA	Interlinking of Semi-arid Regions (Brazil)
ASADA	Association for the Administration of Community Water Supply and Sewerage Systems (Costa Rica)
AWEP	Agricultural Water Enhancement Program (USDA)
AyA	Costa Rican Institute of Water Supply and Sewerage Systems (Costa Rica)
BMZ	Federal Ministry for Economic Cooperation and Development (BMZ)
CAC	Central American Agricultural Council
CAN	Andean Community of Nations
CAS	Southern Agricultural Council
CBD	Convention on Biological Diversity
CCCCC	Caribbean Community Climate Change Centre (Dominica)
CNR	National Irrigation Commission (Chile)
CONAGUA	National Water Commission (Mexico)
CONDESAN	Consortium for the Sustainable Development of the Andean Ecoregion
COOTAD	Organic Code for Land Management, Autonomy and Decentralization (Ecuador)

COSUDE	Swiss Agency for Development and Cooperation
DACC	Project for Development and Adaptation to Climate Change (Uruguay)
DGA	General Water Directorate (Chile)
DGI	General Irrigation Department (Argentina)
DRH/PRONAGRI	Director of Water Resources/National Program for Assistance to Agribusiness (Honduras)
EA-GIRH	Andean Strategy for Integrated Water Resources Management
EC	Executive Committee
ECADERT	Central American Strategy for Rural Area-based Development
ECGIRH	Central American Strategy for Integrated Water Resources Management
ECLAC	Economic Commission for Latin America and the Caribbean
EPA	Environmental Protection Agency (United States of America)
ERAS	Regional Agro-environmental and Health Strategy
ERCC	Regional Climate Change Strategy
EU	European Union
FAO	United Nations Food and Agriculture Organization
GAD	Decentralized autonomous governments (Ecuador)
GDP	Gross domestic product
GIS	Geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (Germany)
GM	Genetically modified
GWP	Global Water Partnership
IABA	Inter-American Board of Agriculture
ICAA	Initiative for Conservation in the Andean Amazon
IFPRI	International Food Policy Research Institute
IHP	International Hydrological Programme
IICA	Inter-American Institute for Cooperation on Agriculture
INTA	National Agricultural Technology Institute (Argentina)
IPCC	Intergovernmental Panel on Climate Change
ISARM	Internationally Shared Aquifer Resources Management Initiative (UNESCO-IAH)

IWRM	Integrated water resources management
LAC	Latin America and the Caribbean
MAG	Ministry of Agriculture and Livestock
MAGA	Ministry of Agriculture and Livestock (Guatemala)
MAGAP	Ministry of Agriculture, Livestock, Aquaculture and Fisheries (Ecuador)
MAPA	Ministry of Agriculture, Livestock and Supply (Brazil)
MGAP	Ministry of Livestock, Agriculture and Fisheries (Uruguay)
MIDA	Ministry of Agricultural Development (Panama)
MINAE	Ministry of Environment and Energy (Costa Rica)
MINAM	Ministry of Environment (Peru)
MMA	Mahaica, Mahaicony, and Abary National Irrigation and Drainage Project (Guyana)
NIDP	National Irrigation Development Programme (Jamaica)
NRCS	Natural Resources Conservation Service (USDA)
OECD	Organization for Economic Cooperation and Development
P1MC	One Million Rural Cisterns Program (Brazil)
PACA	Central American Agricultural Policy
PCGIR	Central American Integrated Risk Management Policy
PISF	Project for the Integration of the Río São Francisco into Watersheds in the Northeast (Brazil)
PRAA	Project for Adaptation to the Impact of the Rapid Retreat of Glaciers in the Tropical Andes
PROCISUR	Cooperative Program for the Development of Agrifood and Agroindustry Technology in the Southern Cone
PROSAP	Provincial Agricultural Services Program
SEAM	Secretariat of the Environment (Paraguay)
SENAGUA	National Water Secretariat (Ecuador)
SENARA	National Groundwater, Irrigation and Drainage Service (Costa Rica)
SICA	Central American Integration System
TAC	Technical Advisory Committee (GWP)
TCP	Technical Cooperation Program (FAO)
UCAR	Unit for Rural Change (Argentina)

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WHO	World Health Organization
WRA/WASA	Water Resources Agency/Water and Sewerage Authority (Trinidad and Tobago)
WTO	World Trade Organization
WWF	World Water Forum

Foreword

Agriculture is called upon to play a key role in the future of humanity, not only because this activity will produce the food, fibers and much of the energy that will be required in the years ahead, but also because of its contribution to the conservation of natural resources and biodiversity.

Water and agriculture are inextricably linked. Ever since human beings began to domesticate plants, they have tried to find ways of making them more productive. Humankind soon discovered that providing plants with regular amounts of good quality water would make them grow better and produce more food. From that moment on, guaranteeing an adequate supply of water for plants and animals, both in terms of quantity and quality, became one of the main concerns for agriculture.

The need to supply water to plants led to the development of great innovations, intended initially to make better use of rainwater, which gradually resulted in the design and construction of irrigation systems and engineering works, as well as important advances in the knowledge of physiology and the genetic improvement of plants and animals. All this resulted in a range of crops, foodstuffs, fibers and other products that are now essential for human existence.

Unfortunately, the progress of humankind has come at a price. Many human activities, whether through lack of awareness, ignorance, need or ambition, have caused serious damage to ecosystems and the irreversible loss of biodiversity.

The negative impacts of agriculture have also been evident in the loss of soils and in pollution of water sources. There are many examples of these impacts, due especially to the unchecked expansion of agriculture and the use of practices that are harmful to the environment.

In addition, the logical consequence of the burgeoning human population, urban expansion and the growth of other economic activities has been competition for natural resources. This, along with the obvious effects of climate change, has created challenges that are unprecedented in human history. One of those challenges is to produce the food, fibers and energy that society needs in a context of decreasing availability of natural resources, greater social pressures for their conservation and more climate variability.

The purpose of this document, produced by the Inter-American Institute for Cooperation on Agriculture (IICA) with contributions from professionals of Argentina, other IICA member countries and a number of institutions, as well as independent experts consulted on the subject, is to inform the ministers of agriculture of IICA's member countries about areas of opportunity that will allow agriculture in the Americas to accomplish the three objectives of guaranteeing the supply of food, contributing to the sustainability of natural resources and promoting inclusive development in the countries of our hemisphere.

We realize that this study addresses only the tip of the iceberg. The complex issue of water in agriculture needs to be explored in greater depth through the coordinated and continuous actions of governments, private enterprise, farmers, water users and society in general.

We are confident that the proposals presented herein will help the ministers of agriculture to consolidate their leadership and promote initiatives that will ensure sustainable supplies of sufficient, good-quality water for the noble activity of agriculture.

Dr. Victor M. Villalobos A.
Director General, IICA

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Executive Summary

Agriculture is called upon to play a key role in the future of humanity, not only by producing the food, fibers and energy that will be required in the years ahead, but also by helping to improve the living conditions of rural dwellers and the use and conservation of natural resources. Given agriculture's dependence on water, it is essential to devise new paradigms that will revitalize agricultural activities in a context of declining availability of water, growing competition for the resource and greater social awareness of the need to conserve it. The purpose of this document is to identify areas of opportunity to develop an agenda for the Americas designed to improve the use of water in agriculture by means of integrated water resource management.

Situation of water in the hemisphere

With a surface area of roughly 42.3 million km^2 and more than 900 million inhabitants, the Americas is endowed with a relative abundance of water (46% of the world's water resources) and average rainfall of 1084 mm per year. However, the distribution of this resource and per capita availability in the region are uneven, with highly seasonal precipitation and per capita water availability rates that vary greatly, both among the countries and within them.

The estimated water extraction rate in the countries of the hemisphere ranges from less than 1% to more than 15%, with around 70% used in agriculture. Given demographic changes and the development of other economic activities, intersectoral competition for the resource has increased in the region, obliging the countries to increase and boost their capabilities for water extraction, collection, conservation, storage, distribution, purification and recycling, and put in place modern and efficiently managed political and institutional arrangements.

The countries of the Americas have an important water management infrastructure, made up of dams, reservoirs, earth dikes, drainage channels and sluice gates. Precise knowledge of the state of this infrastructure, and the improvements needed, is not available, however. It is urgent, therefore, to create a dynamic information system that will make it possible to ascertain the state of the water infrastructure.

The region's underground and transboundary aquifers are an important resource whose management should be a priority, to guarantee their sustainability and prevent them from becoming polluted.

In short, the region's ecological, social, economic, and political wealth and diversity provide an opportunity to identify water management models that can be shared among the countries, enabling them to strengthen their public policies, investment plans and innovation systems.

Water for agriculture: effects of climate change

Climate change is indisputable and poses a global threat, meaning that actions are urgently required to adapt to it and mitigate its impact. The most significant events that can result from climate change and which affect agriculture include floods, droughts, frost, heat waves and hailstorms, as well as variations in the intensity and frequency of hurricanes and in the balance between temperature and rainfall. Latin America and the Caribbean (LAC) is a region that is particularly sensitive to extreme meteorological events.

The problems caused by climate variability will not only affect temperature and precipitation patterns but will also have an impact on the productive capacity of animal and plant species and on the distribution of the human population, which will particularly affect the poor.

Climate change affects agriculture but farming activities also influence the process by producing greenhouse gases (it is estimated that agriculture accounts for around 14% of global emissions of such gases) and their impact on soils, water and biodiversity, altering the carbon and water cycles, and in turn contributing to an increase in the atmospheric temperature. Agriculture also mitigates the effects of climate change, however, since it checks desertification, helps water infiltration, contributes to the conservation of biodiversity and improves carbon capture, among other things.

Climate change is also expected to lead to changes in land use: for example, in hot and humid regions there will be a decrease in the amount of arable land, while in temperate zones it will be possible to grow crops in areas where temperatures do not allow for production at present. The impact of climate change will also vary in relation to the scale and technical capacity of the producer. It is believed that smallholders will be the most affected, with limited access to productive assets and located in vulnerable regions.

Given the above, agriculture needs develop and implement innovative production systems that prioritize water use. According to some scenarios, unless immediate action is taken, food production could fall by more than 25% by 2050.

Use of water in agriculture in the Americas

Many forms of agriculture are practiced in the Americas by a wide variety of farmers: from subsistence and migratory farming to large-scale commercial agriculture. The structure of agriculture in the countries and the property rights that exists influence the way that water is used in agriculture.

It is estimated that more than 390 million hectares of land are farmed under rain-fed systems in this continent. Despite the increase in acreage and the high yields achieved in some crops and regions, the productivity of rain-fed agriculture is lower than that of irrigated agriculture. In the case of cereals, for example, it is estimated that the productivity of rain-fed agriculture is around 65% of what could be achieved with irrigation.

In order to improve the productivity of this type of agriculture, the countries need to introduce innovative cultural practices and technologies, and tap the traditional knowledge that exists in the hemisphere with regard to crop systems that have proven to be effective for achieving a balance between the quantity of water used in agriculture and availability of the resource. Some of the actions that could be taken to improve the productivity of this type of agriculture are: i) promote the harvesting of water, the conservation of water in situ, and integrated rainwater management; ii) continue to invest in scientific and technological research to develop new varieties (particularly ones that can cope better with droughts or excess water and make optimum use of water) and water use and soil conservation practices; and, iii) review and, if necessary, amend public policies on this issue, considering the implementation of incentives based on the sustainability of water resources, the productivity of agriculture and conservation of the setting.

Furthermore, roughly 44 million hectares of land are farmed using irrigation in the Americas, or 12% of the total number of hectares on which crops are grown in the region. Across the board, the efficiency of irrigation water use is less than 40% and irrigation faces complex challenges, despite being one of the many tools that can be used to combat the effects of climate change.

As pressure on water resources has increased, efforts have been made to develop methodologies in order to evaluate and quantify the amount of water used in the human activities, including agriculture, and to provide information that makes it possible to take decisions designed to improve management of the resource, invest more intelligently in this area, improve production processes and promote the design of effective public policies. In general, the water footprint is an empirical indicator of how much water is consumed in a given geographical and temporal space, measured over the entire supply chain of the product. Many estimates of the footprint, for both crop and livestock activities, suggest that opportunities exist for making better use of water in agriculture. However, it is important to note that such measurements are only some of the many tools that can be used to that end.

Agriculture is carried out in a "symbiosis" of land and water and is, simultaneously, both a cause and a victim of the pollution of water resources. It contributes to the problem through the discharge of pollutants and sediments into surface water and groundwater, net soil loss as a result of poor agricultural practices, and the salinization and oversaturation of irrigated land. It is a victim because it makes use of wastewater and because of the pollution of surface water and groundwater by other activities, which affects crops and increases the likelihood of diseases being transmitted to consumers and agricultural workers. Solving these problems calls for technological innovations and also systems of reliable, accurate and up-to-date information and data on the quality and amount of water used. Agricultural institutions and the users of water in agriculture normally do not have access to such data; and any information that does exist is usually inaccurate and out of date.

Innovations to improve the productivity of water in agriculture

Increasing the productivity of water in agriculture is essential to reduce the pressure on water resources, curb environmental degradation and improve food security. Innovations that, thanks to their potential, can be used to generate a common cooperation agenda. The innovations in question correspond to four overarching areas of action: i) use of water by plants, ii) improvements in water use on parcels or production units, iii) improvements in the supply and delivery of water, and iv) innovations in watershed management. Efforts in all these areas will make it possible to address the challenges of physical and economic water shortages.

The evidence suggests that if we continue along the traditional path of genetic improvement, we will soon reach the thresholds of productivity or else the progress made will be too slow, given the urgent need to address the effects of climate change and the demands of production. Faced with this situation, the innovations of the future will come from the "new biology," with the branches of biotechnology, nanotechnology and other specialized fields making significant contributions to improved water productivity and, in the process, releasing supplies of water for other uses.

The second type of innovation developed to improve water use in agriculture is applied at the parcel or farm level. Three general types of actions can be implemented on parcels or farms: i) the application of technologies and techniques aimed at improving soil management (for example, direct planting or zero tillage); ii) improvements in the use of other inputs, particularly fertilizers; and iii) the use of technologies that allow for a more precise and targeted water supply, according to the needs of plants, such as precision irrigation, micro-irrigation and subsurface irrigation. There are also technologies that have proven beneficial in terms of water use, including the techniques generally known as "protected agriculture" and hydroponic crops. The combination of these integrated technologies results in what is termed "precision agriculture." However, many of these technologies are still unknown to farmers, or are economically inaccessible to them due to their cost or scale of application. Therefore, a task is still pending: to bridge the gap between the theoretical availability of these innovations and their practical application in the field, particularly in small-scale agriculture and in family agriculture, which take place on small parcels.

There is also a third type of innovation related to the way in which water is delivered to farmers, which makes it one of the most important interfaces for cooperation between end users and the institutions responsible for the administration of water resources, and offers opportunities to develop hard innovations (in infrastructure) and soft innovations (the way in which resource management is organized).

At the level of river basins, nations and even of transboundary water resources, major efforts have been undertaken to improve the management of this resource. To this end, many countries are now using geo-referencing and geo-measurement technologies, as well as space technologies and computer models. These technologies are being used with four main objectives in mind: a) to ascertain exactly how much water is available, determine its state and develop management models to help address the challenges of meeting current demand and those imposed by climate change and population growth; b) to support decision-making related to the allocation of resources to different users, generally seeking to support water use for those activities that produce the greatest return or are of greatest importance for human development; c) to conserve resources, both in terms of quantity and quality and health; and, d) to establish early warning systems in order to monitor climate conditions, available volumes of water and the levels of water pollution.

Institutional aspects that influence the use of water in agriculture in the Americas

Protecting, conserving and maintaining the integrity of water resources calls for consistent mechanisms that make it possible to ensure the availability and quality of the water required to meet the needs of the growing human population and the economic activities that help to satisfy those needs. The many and varied systems of governance employed for that purpose are designed to contribute to the interests and objectives of national and global development.

In relation to water for agriculture, the way in which the countries administer water for agriculture also varies, with the ministries of agriculture participating to different degrees in various roles, usually limited to the allocation and operation of water for irrigation. However, recognition of the importance of water in mitigating the effects of climate change, increasing agricultural productivity and responding to the pressure for sustainability has led a number of ministries of agriculture to review their structures and functions. As a result, they have included the coordinated management of irrigation water in their functions as part of a State policy. Notable cases are Ecuador, which has a department exclusively devoted to irrigation and now Peru, which recently restructured the Ministry of Agriculture to convert it into the Ministry of Agriculture and Irrigation.

Two aspects that require particular attention, given their importance in instituting new paradigms to promote the integrated and sustainable use of water in agriculture, are ownership of the resource and the right of the different stakeholders in agriculture (including smallholders and indigenous peoples) to have access to it.

Public policies must guarantee access to water for the different types of agriculture that coexist in each country, and recognition of ethnic groups and traditional cultures. In general, processes of that kind are not institutionalized in the hemisphere. In the best of cases, the involvement of the social sectors, agro-entrepreneurs and civil society in the participatory management of water occurs in isolation and almost exclusively at the level of territories. Furthermore, the even-handed application of principles is generally weak, and there is a systemic failure to include traditional principles and customs.

Some of the areas in which the greatest potential for the development of a hemispheric agenda on water governance exists are as follows:

a. Development of long-term, integrated, State policies for the revitalization of water in agriculture based on solid scientific principles that take into account the nature of the resource and the challenges posed by climate change.

b. Construction of an environment that favors the attraction of investments for the modernization of the water and agro-meteorological infrastructure, as well as the incorporation of new technologies.

c. Public sector support for the creation of the conditions required for the development of new innovations, and the implementation of existing cutting-edge innovations, some of which entail geo-referenced monitoring systems, precision agriculture and the use of new technologies for the development of varieties tolerant to water stress.

d. Government promotion of the renewal and strengthening of education systems in agriculture, including, as a priority, skills development programs for women, producers' associations and water users, as new human capabilities are required to apply policies and implement innovations.

e. Establishment of information systems, including early warning systems, that make it possible to take timely decisions related to the design of management policies and tools, and the implementation of actions on farms and in territories and production areas.

In devising public policies, governments should adopt a strategy of prioritization and follow-up and a long-term vision, so they do not limit themselves to providing stopgap solutions or adjusting existing policies to the latest trends and currents of opinion.

Recommendations

To ensure that agriculture has the water it needs, in terms of quantity and quality, the ministries of agriculture must strengthen their institutional capabilities against a background of limited human, financial and physical resources. This forces them to set priorities and target their interventions at those areas that offer opportunities to make the greatest impact and obtain better returns in relation to the resources used and in response to the pressing needs of producers and of society in general.

Four recommendations are put forward (three general ones and one that is cross-cutting in nature) that are considered crucial to provide agriculture with the water it needs, both at present and in the future. In making these recommendations, we recognize the steering role and leadership of the ministers of agriculture on the issues of food, competitiveness and sustainability. We consider that the recommendations presented here are the ones that offer the greatest opportunities to generate synergies among the countries and produce positive results in the short and medium term. They also make it possible to target and apply the limited resources available in priority areas and to coordinate and guide the support received from international technical and financial cooperation organizations with clear goals and long-term visions.

A. Recommendation 1: *Promote the institutional strengthening of the ministries of agriculture*

Given the multiplicity of national institutions involved in water management in IICA's member countries, in international forums (for example, the CBD, the UNFCCC and the WTO) and the commitments acquired on the issue of water, the first recommendation is to define a hemispheric program to strengthen the capabilities of the ministries of agriculture and support them in the design and implementation of policies and tools for the integrated management of water in agriculture. This would strengthen their capacity for dialogue and consensus building with other economic sectors in their countries and with the international community.

The main purpose of this recommendation is to improve the management capabilities of the ministries of agriculture in order to: i) ensure that the objectives of producers and populations of rural areas are included in national policies and in international agreements; ii) design and implement investment projects in irrigation systems that meet current demands; and iii) ensure that agriculture is provided with the water it requires, in terms of quality and quantity, for the sustainable and competitive production of food, fibers and energy.

In order to accomplish this objective the following actions are proposed:

a. Analyze the current institutional structure, its strengths and weaknesses and identify the areas or aspects that need strengthening in the ministries of agriculture of IICA's member countries, in relation to water for agriculture.

b. Design, establish and execute an inter-American cooperation program to strengthen the ministries of agriculture.

c. Promote and strengthen existing regional mechanisms for the analysis and definition of common strategies for integrated water resources management in agriculture.

B. Recommendation 2: *Promote integrated water management to achieve sustainability in agriculture and address the challenges of climate change*

One of the greatest challenges in achieving sustainable agriculture is to ensure that the sector adapts to climate change. Water is a crucial resource for this purpose, and therefore the recommendation is to focus efforts on adapting agriculture to climate change, through the integrated management and rational use of water resources, based on solid scientific principles and respecting the legal frameworks, traditions and culture of countries, communities and indigenous peoples.

To achieve this objective the following actions are considered priorities:

a. Strengthen and, where necessary, develop hydro-meteorological information systems, early warning and risk management systems and climatic scenarios, as the essential basis for the design and implementation of adaptation strategies, including prediction, prevention and preparedness programs related to extreme events that consider the incorporation of new satellite technologies as well as telemetry, geo-processing and geo-referencing technologies, etc.

b. Promote the regional integration of hydro-meteorological information and early warning systems, to make it possible to use global models to forecast hydro-meteorological events more accurately.

c. Promote planning processes in agriculture to facilitate adaptation to climate change and water availability; this should include projects for the diversification, reorganization and relocation of crops, among other alternatives.

d. Strengthen agricultural information systems in order to determine the volume of water assigned to the sector (supply) and improve decision-making on water use, in coordination with the national systems responsible for water resources management.

e. Promote investment to revitalize the irrigation infrastructure (water capture, storage and distribution), including the design of new infrastructure projects and the rehabilitation of existing ones, based on clear performance indicators, as well as social inclusion and environmental impact indicators.

f. Promote investment designed to improve the capture, harvesting and use of water rainwater in rain-fed areas.

g. Foster the organization of irrigators for better water management and the implementation of measures to adapt to climate change.

C. **Recommendation 3:** *Strengthen innovation to improve the productivity of water resources in agriculture*

It will not be possible to guarantee the supply of food if the production systems throughout the agrifood chain continue to behave as they have until now, particularly given the declining availability of water resources facing agriculture. It is therefore essential to improve water productivity through innovation, which is the objective of the third recommendation.

To achieve this objective it is essential that the countries focus their efforts on:

a. Developing and consolidating information systems and disseminating innovations to improve water use in agriculture, aimed especially at ensuring that these innovations reach the users. To this end, it is essential to expand the use of new information and communication technologies.

b. Promoting the development of public-private partnerships that make it possible to improve efficiency in water use and reduce pollution of water resources.

c. Strengthening and, where necessary, designing capacity building programs to improve water productivity, paying special attention to the different types of agriculture and the different needs of users, and targeting efforts at the watershed level, as the integrating unit.

d. Focusing efforts on the following areas of innovation:

    i. Identifying, evaluating and disseminating local and traditional technologies for the use of water in agriculture.
    ii. Promoting precision agriculture.
    iii. Generating innovations to improve the knowledge, use and sustainability of the groundwater resources used in agriculture.
    iv. Developing innovations in biotechnology (in agriculture, livestock and food production) to improve water productivity.

v. Evaluate and promote the use of alternative crops, taking advantage of the numerous species that are underutilized and that have demonstrated their capacity to adapt and prosper under water stress conditions.
vi. Promoting innovation to improve the recycling and use of recycled water, which should be combined with production of hydraulic energy.

To accomplish these objectives, the ministers of agriculture are urged to continue working to articulate the agricultural innovation systems, and to exercise proactive leadership in defining the allocation of resources and funds for research on water for agriculture, thereby contributing to achieving the higher goal of developing competitive, sustainable and inclusive agriculture.

D. Recommendation 4: *Strengthen the training of human resources in the new paradigms for agriculture*

To improve the productivity of water in agriculture and achieve integrated water resource management, all the stakeholders must be highly conversant with the new paradigms for agriculture. In that way, they will be equipped to innovate and solve the new problems that have arisen, or that may arise, in the agricultural sector in a context of high price volatility. Accordingly, the ministers of agriculture are urged to:

a. Promote the training of human resources in new paradigms that facilitate the development of a competitive, sustainable and inclusive agricultural sector.

b. Equip producers, especially small and medium-scale farmers, with the skills and expertise required to innovate and thereby achieve the development of intensified and sustainable agriculture.

c. Foster the training of a new generation of agricultural specialists, new scientists and service providers.

d. Recognize the importance of women as key players in integrated water resource management, promoting initiatives that help close gender gaps, improve the inclusion of women in decision-making and achieve full recognition of the rights of rural women, including those related to property, education, and access to productive assets.

I. Introduction

Water is, by its very nature, an essential element of life. Around 70% of the earth's surface is made up of water. In the case of human beings, water accounts for 75% of body weight. In plants, the percentage of water varies from 60% to more than 90%, while in some animals this figure may be over 90%. Without water, there would be no possibility of life on this planet.

By domesticating plants and animals, human beings changed the dynamics of Nature and quickly realized that without water they could not cultivate plants or raise animals for their sustenance. Therefore, one of the first actions taken by humans to modify Nature was to harness, store and deliver water to their crops and animals. Many of the great civilizations flourished in fertile agricultural valleys, where irrigation and water use systems enabled people to produce and trade food in sufficient quantity to permit the development of complex societies.

More than 10,000 years have elapsed since the first plants were domesticated and close to 8000 since the first irrigation systems were designed in Mesopotamia and Egypt. Much has changed on the planet since then. On the one hand, the population has increased to levels that would have been unimaginable a few years ago and, according to most estimates, the population will surpass nine billion inhabitants within the next 40 years.

As civilization has progressed and human activities have expanded, so too has the destruction of the world's renewable and non-renewable natural resources. In addition, the pollution of water, soils and the atmosphere, together with climate change, has reached levels that threaten the future of humankind.

Water is essential to combat poverty and hunger, increase agricultural productivity, ensure sustainability and improve living conditions, both in rural and urban areas. Therefore, any event that alters the hydrological cycle will have an impact on human development.

Agriculture is called upon not only to produce the food, fibers and energy that humanity will require in the medium and long terms, but also to help ensure the sustainability of the planet's natural resources, in order to improve living conditions in rural areas, where the poorest and most vulnerable populations still live, and to contribute to the economic development of people and nations.

On the other hand, agriculture is one of the sectors most vulnerable to climate impacts and highly dependent on natural resources. Changes in rainfall patterns and intensity and other climate phenomena, such as those that are currently responsible for climate change, will severely affect food production. Given agriculture's enormous dependence on water–this sector uses an estimated 70% of the water extracted worldwide–it is essential to develop new paradigms that will revitalize agricultural activities in a context of declining availability of water, growing competition for this liquid and above all, greater social awareness of the need to conserve it.

Discussing and analyzing the subject of water in agriculture is an extremely sensitive and complex matter, given that it spans cultures and social thresholds. It is a public good, but also a private good, and is subject to far-reaching externalities that affect the way in which human beings perceive and interpret the reality that impacts this resource.

New paradigms are required for the future, making it essential that the stakeholders in agriculture rethink the way in which water is being used, as well as the challenges and opportunities this implies. It is also urgent to design actions and strategies, through dialogue and inclusion, to ensure that agriculture is provided with a sufficient quantity of good quality water to produce the goods and services that humankind needs, guarantee the sustainability of natural resources and promote inclusive development in the countries of the hemisphere.

The objective of this document is to identify areas in which there are opportunities for developing a hemispheric agenda for the Americas geared towards improving the use of water in agriculture by means of integrated water resources management (Box 1).

Box 1. Integrated water resources management

Integrated water resources management is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP 2000).

This document is the outcome of collaborative work by professionals of IICA, other institutions and the Institute's member countries, who reviewed and discussed the literature published on this subject and consulted numerous stakeholders and ministries in the Institute's member countries about their policies and priorities, and the contributions of experts who revised this document and commented on its content.

II. Water situation in the Americas

A. Water availability

With a surface area of roughly 42.3 million km^2 and more than 900 million inhabitants, the Americas extend from Canada and the United States to Argentina and Chile, and include the Caribbean island states. It is one of the regions of the world with the greatest biodiversity and ecological and climatic diversity.

It is endowed with a relative abundance of water, which represents approximately 46% of the world's water resources (Sánchez-Albavera 2004), and average precipitation is 1084 mm per year. Taking into account all these resources, the average annual amount of water available per capita is almost 30,000 km^3. However, the distribution of this resource and its availability in the region are uneven, to such an extent that almost two-thirds of the continent's territories are considered arid or semiarid zones. These coexist with some of the world's wettest areas that contain many great rivers–the Amazon, the Mississippi, the Río Bravo/Rio Grande, the Magdalena, the Orinoco, the Sao Francisco, the Paraná, the Uruguay, the Paraguay and the Río de la Plata–and rich reservoirs of water, such as the Great Lakes, and marshlands and river estuaries.

In most of the countries, rainfall is highly seasonal and concentrated in periods of four to five months, during which it is distributed unevenly. For example, in Mexico, Central America and the Caribbean, nearly 50% of the rain falls between August and October, whereas only 7% falls between February and April (WWF 2012). This produces periods with an overabundance of water and others with severe shortages.

Although the average water availability in the Americas would appear to be more than sufficient to guarantee development, the reality is that it varies enormously. There are extreme conditions, such as those prevalent in Haiti and other Caribbean countries, where annual water availability is less than 1700 m^3 per person, a situation that contrasts markedly with that of countries such as Suriname, where annual per capita water availability is put at more than 150,000 m^3. These differences also influence the way in which countries manage their water resources. Demographic growth, increased water pollution, the expansion of cities, agriculture and industry are seriously affecting the availability of this resource.

One region that is in a privileged position as far as its water resources are concerned is Central America, where average annual water availability is roughly 23,000 m^3 per person (ECLAC 2011), almost three times the world average. However, as in other regions, the distribution of this resource is subject to major annual and seasonal geographic variations, which result in periods of (sometimes extreme) scarcity and others of great abundance, in which even floods occur. While the Caribbean coast enjoys abundant rainfall throughout the year, the Pacific coast experiences dry periods lasting five or more months. Table 1 shows water availability in the countries of the Americas.

One aspect that affects the distribution of water resources in the hemisphere is the forest cover lost through deforestation, which is having an impact on the recharge capacity of the region's aquifers, increasing the production of sediment and reducing CO_2 capture.

Eradicating the cultural practices responsible for deforestation in the short term seems to be a complicated task, since such practices are deeply rooted among farmers. This makes the implementation of integrated watershed management difficult. The efforts calls for not only rational water and soil management but also a multi-sectoral approach that would make it possible to focus on aspects such as poverty, the reduction of the gathering and burning of firewood, the promotion and conservation of biodiversity, and the implementation of reforestation programs (Beekman 2011).

Another phenomenon that is affecting the availability of water in the hemisphere is climate change, which will be addressed in Chapter III of this document.

Table 1. Water availability in the Americas

Country	Average precipitation (mm per year)	Total amount of freshwater available annually (in thousands of millions of m3)	Total amount of freshwater available annually (as % of internal resources)	Volume of renewable water (in thousands of millions of m3)	Population	Renewable water per capita m3/ inhab/year
Antigua & Barbuda	1,030	0.005	9.615	0.052	89,612	580.3
Argentina	591	32.570	11.801	276	40,764,561	6,770.6
Bahamas	1,292				347,176	-
Barbados	1,422	0.061	76.125	0.08	273,925	292.1
Belize	1,705	0.150	0.938	16	356,600	44,868.2
Bolivia	1,146	2.027	0.668	303.5	10,088,108	30,084.9
Brazil	1,782	58.070	1.072	5418	196,655,014	27,550.8
Canada	537	45.970	1.613	2850	34,482,779	82,650.0
Chile	1,522	11.340	1.283	884	17,269,525	51,188.4
Colombia	2,612	12.650	0.599	2112	46,927,125	45,006.0
Costa Rica	2,926	2.680	2.384	112.4	4,726,575	23,780.4
Dominica	2,083	0.017			67,675	-
Ecuador	2,087	15.250	3.530	432	14,666.055	29,455.8
El Salvador	1,724	1.376	7.752	17.75	6,227,491	2,850.3
United States of America	715	478.400	16.977	2818	311,591,917	9,043.9
Grenada	2,350	0.010			104,890	-
Guatemala	1,996	2.933	2.686	109.2	14,757,316	7,399.7
Guyana					756,040	-
Haiti	1,440	1.200	9.224	13.01	10,123,787	1,285.1
Honduras	1,976	1.194	1.245	95.93	7,754,687	12,370.6
Jamaica	2,051	0.585	6.218	9.404	2,709,300	3,471.0
Mexico	752	79.800	19.511	409	114,793,341	3,562.9
Nicaragua	2,391	1.288	0.679	189.7	5,869,859	32,317.6
Panama	2,682	0.452	0.306	147.4	3,571,185	41,274.8
Paraguay	1,130	0.490	0.521	94	6,568,290	14,311.2
Peru	1,738	19.340	1.197	1616	29,399,817	54,966.3
Dominican Republic	1,410	3.485	16.595	21	10,056,181	2,088.3
Saint Kitts & Nevis	1,427				53,051	-
Saint Vincent & The Grenadines	1,583	0.010			109,365	-
Saint Lucia	2,301	0.017			179,000	-
Suriname	2,331	0.670	0.761	88	529,419	166,220.0
Trinidad & Tobago	2,200	0.232	6.031	3.84	1,346,350	2,852.2
Uruguay	1,265	3.660	6.203	59	3,368,595	17,514.7
Venezuela	1,875	9.064	1.255	722.4	29,278,000	24,673.8

Source: World Bank 2013.

B. Main uses of water in the hemisphere

The estimated water extraction rate in the Americas is only around 7% (Jouralev 2009), with variations ranging from less than 1% (in Paraguay, for example) to more than 15% in Mexico, the United States and some Caribbean countries. Despite these low levels of water extraction, there are signs that some aquifers in the region are already reaching their extraction limits or are becoming highly polluted as a result of large concentrations of population, increased economic activity, inefficient management of water concessions and exploitation permits, lack of oversight and the application of incentives that distort and promote the irrational use of resources.

Nearly 70% of the volume of water extracted from surface and groundwater sources in Latin America and the Caribbean is used in agriculture, followed by water for domestic use and, lastly, the water used in industry, a sector that accounts for only 10% of water use–almost 50% less than in other more developed regions (Jouralev 2009) (Table 2). However, the percentage of water used in agriculture varies from region to region and from country to country: in the Northern Region, water use for agriculture ranges from 12% to 77%, in the Central Region between 28% and 83%, in

Table 2: Main uses of water extracted in the Americas

Region	Renewable water resources km³/year	Total water extracted km³/year	Water extraction (km³/year)						Extraction as percentage of renewable resources
			Agriculture		Industrial		Domestic urban		
			Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	
Latin America	13,477	252	178	22.5	26	3.3	47	5.9	0.6
Caribbean	93	13	9	1.1	1	0.1	3	0.4	0.1
North America	6,253	525	203	25.7	252	31.9	70	8.9	2.6
Hemisphere	19,823	790	390	49.4	279	35.3	120	15.2	3.3

Source: WWAP 2009.

the Southern Region from 46% to 86%, and in the Caribbean Region between 15% and 83% (percentages estimated based on data from FAO/AQUASTAT 2013).

This data suggests that agriculture is the activity that uses the largest proportion of the water extracted, but a fuller analysis is required taking into account the water that returns to the hydrological cycle, since plants do not use 100% of the water. That undoubtedly means that the real amount of water used by agriculture is less than the figure calculated based on the volumes extracted.

It is estimated that, by 2050, over 75% of the continent's population will live in urban areas. This will generate greater demand for food and water for human consumption, sanitation services, and the production of energy and other satisfiers, a situation that will further increase competition between different sectors for the resource. Agriculture has a leading role to play in ensuring the sustainability of the resource, and could become the key activity for meeting that need. To do so, it must improve the way in which water is used in this activity, in order to release volumes of water for use in other sectors or to reuse the water released by other sectors. These changes in demand will lead to increases in the cost of the resource, so answers will have to be found to the question of how, and by whom, those costs are to be met (Box 2).

In many parts of the world, water resources are already under great pressure. However, the demand for more water will continue to increase, to cover the additional need for food, energy, services and drinking water, so that competition for water is inevitable and is bound to intensify. There is concern that water sources will be reduced even further in regions where water availability has already reached critical levels because of climate change (UN 2011), which will exacerbate poverty and food insecurity.

As part of this effort, the countries of the Americas must improve water conservation, recycling and purification capabilities, and implement modern and efficient political and institutional arrangements for management of the resource.

Box 2. Water in rural areas with agricultural and mining activities

One of the biggest conflicts that occurs between agriculture and mining is related to the use of water, which is accentuated because mining normally takes place in territories with high levels of poverty and low levels of development, in which almost no public services are provided. In such areas, mining companies are usually the first to collect or extract water, affecting its quality and the volumes available for agriculture, especially when farming activities are carried out downstream of mining operations, altering the way in which crop and stock farming are carried out.

With the recognition of these conflicts and growing social awareness of the importance of all sectors having access to the water they need, some mining operations are implementing good water management practices and improving their interaction with agriculture. This has been accompanied by the development of new civil society organizations that monitor the situation with regard to the resource. However, the State needs to implement effective regulatory measures and promote close coordination between the public and private sectors to resolve such conflicts.

Some of the actions that could be implemented to ensure that more efficient use is made of water in agriculture include increased recognition of environmental services, greater use of recycled water, the implementation of better agricultural practices and training for producers with regard to the amount of water that crops actually need during their different phenological stages.

Bilateral treaties and the support of international organizations have made it possible for countries to reach agreement on water use for mutual benefit. In North America, institutional arrangements have been established for Canada-United States and United States-Mexico river basins. In South America, a number of binational agreements are in place, some for the development of hydroelectric projects, including those of Salto Grande (Argentina and Uruguay), Itaipú (Brazil and Paraguay) and Yacyretá (Paraguay and Argentina). It is also important to mention the Amazon Cooperation Treaty, signed by eight countries, as well as the Agreement on the Guaraní Aquifer, signed by Argentina, Brazil, Paraguay and Uruguay, aimed at contributing to the aquifer's conservation and management.

C. Infrastructure and storage

In the countries of the Americas, irrigation infrastructure generally includes reservoirs or dams, earth dikes, wells, drainage channels, sluice gates and secondary channels that deliver water to users. A high percentage of the water used for irrigation is extracted from groundwater tables but there are a large number of works constructed to store surface water, including 68 dams with structures measuring more than 130 meters in height, providing an annual reservoir capacity of 2721 km^3. Most of these works are located in the Northern Region. Very little information is available about small reservoirs used to store water for irrigating small parcels.

It is difficult to provide accurate data on the status of the region's water infrastructure, since complete information is only available for a handful of countries, notably in the Northern Region. The Andean Region has reliable data for Peru, Ecuador and Colombia, while the Southern Region data is available for Brazil, Argentina and Chile. This reflects the urgency of developing dynamic information systems to determine the status of the continent's water infrastructure. In the case of the Caribbean Region, there is an evident lack of infrastructure for managing water in agriculture.

During the last 20 years, the number of hectares incorporated into irrigated agriculture in the region has declined markedly, from nearly 12 million new hectares under irrigation during the 1970s, to just six million in the first decade of this century. The reasons for these changes are not clear but they could be due, among other things, to the limited attention that the countryside has received over the last 20 years, insecure land ownership and the low rate of return on investments in the sector. It is not easy to obtain and verify clear data on investments of this kind, confirming the need to make the respective information systems more transparent and effective.

Investment in the maintenance of irrigation infrastructure also seems to have declined. This may be inferred from the fact that, in theory, the continent has the infrastructure to irrigate 48 million hectares, but only 39 million hectares are irrigated, due in part to damage in water supply and delivery systems.

As to the type of irrigation infrastructure in place, analysis of the available information shows that nearly 75% of irrigated parcels have infrastructure for surface irrigation, 22% for sprinkler irrigation and only 3% for localized irrigation. Other types of problems exist where the use of surface water for agriculture is concerned, such as the over-allocation of rights and water pollution.

D. Groundwater and transboundary aquifers

The challenges faced in integrating and managing surface water are relatively simple, when compared with those associated with managing groundwater reservoirs, which are a valuable asset for this continent and play an increasingly strategic role in national development. Agriculture continues to be the main user of groundwater; for example, in the United States the sector uses approximately 50% of the groundwater extracted, while in Mexico groundwater is used for one-third of the total irrigated area. Increased pollution of surface water in the hemisphere means that many urban centers increasingly depend on groundwater to meet their needs, but often with inadequate or unreliable supply systems. One of the great challenges facing the countries of the Americas is to develop a system that integrates groundwater and surface water management, and ensures that this is done in a sustainable way.

The application of diverse, and often inconsistent, public policies for the management of groundwater, has given rise to numerous conflicts. Efforts to redistribute groundwater concessions and restrict water extraction activities within sustainable and economically viable limits have been two of the main forces driving the legal and institutional reforms introduced in a number of countries in the region. (Narishan 2008, Jarvis 2006). The case of Mexico stands out, because, historically, in some cases the country granted concessions for more water than it had available, obliging the authorities to adopt a strategy aimed at striking a balance between the quantity available and the amount used, based on the temporary suspension of the free extraction of water throughout the country.

The overexploitation of groundwater leads to other types of problems, such as land subsidence (sinkholes) and salinization, which eventually undermine the good quality of such water.

According to the inventory of transboundary aquifers of the Americas (Puri and Aurelli 2009), there are at least 67 transboundary aquifers in the Americas: 27 in South America, 19 in North America (Canada, Mexico and United States), 12 in Central America and 4 in the Caribbean (Dominican Republic-Haiti). One third of those aquifers are located in arid or semiarid zones.

An assessment of underground aquifers shows that 20 transboundary aquifers have been intensively exploited, while 16 that are located in areas with intensive agriculture or in industrial zones, have high salinity rates.

Given the situation, one priority is the need to ensure the sustainable management of transboundary aquifers in areas with water scarcity, particularly in arid and semiarid areas throughout the continent. An example of such areas is the Gran Chaco Americano, the largest semiarid plain in South America, where nearly 80% of the rural population has no access to drinking water, and the problems associated with water scarcity are further compounded by a growing population, intensified soil use and the lack of investment.

Sharing transboundary water resources and ensuring their quality are issues of major importance for inter-American relations. This calls for efforts to strengthen bilateral relations, joint research, information sharing, the development of dispute settlement mechanisms and the signing of new treaties and agreements, as is already occurring in some regions of the hemisphere (e.g., in the Caribbean Region, where the ministers responsible for water meet every year to find joint solutions).

The analysis of the water situation in the Americas confirms that it is impossible for the region to be considered homogeneous and an area where one-size-fits-all measures can be applied. Annex 1 of this document contains a detailed description of the water situation in each subregion of the continent, with emphasis on water management for agriculture.

The region's ecological, social, economic and political richness and diversity offer an opportunity to identify water resource management models that could be shared by countries to strengthen their public policies, investment plans, and innovation systems.

The information analyzed also makes it possible to suggest that certain common problems exist that could be resolved working together, so that future generations are guaranteed sufficient water of good quality to live a full life. For example, reliable databases operating in real time could be created and actions undertaken to regulate competition between different sectors of the economy and the water needed for human consumption.

III. Water for agriculture: impacts of climate change

The Stern Review (2006) warns that climate change poses very serious global risks that call for an urgent global response. The Fourth Report of the Inter-governmental Panel on Climate Change (IPPC 2007) confirms that "warming of the climate system is unequivocal," that it will affect all the nations of the world, and that urgent action is needed to mitigate and adapt to the new conditions resulting from that process.

The most important extreme events that can result from climate change and which affect agriculture include floods, droughts, frosts, heat waves and hailstorms, as well as variations in the intensity and frequency of hurricanes and in the balance between temperature and precipitation. Latin America and the Caribbean (LAC) is a region that is particularly sensitive to extreme meteorological events (Beekman 2007).

Extreme phenomena–especially more numerous periods of warm nights, intense precipitation and successions of dry days–have seriously impacted LAC in recent years. In this region, "the occurrence of climate-related disasters increased by 2.4 times between 1970-1999 and 2000-2005, continuing the trend observed during the 1990s. Only 19% of the events between 2000 and 2005 have been economically quantified, representing losses of nearly USD 20 billion," (Williams and Nuttall 2007).

Another effect of climate change is the reduction in rainfall, particularly in areas where it is already insufficient, which would have a serious impact on surface water and groundwater sources. This change will impact how new infrastructure is designed and operated, since using historical models will be of no use in forecasting what may happen in the future (ONU 2011).

The problems caused by climate variability will not only affect temperature and precipitation patterns but also have an impact on the productive capacity of animal and plant species and on the distribution of the human population, which will particularly affect the poor.

Higher temperatures, less precipitation and unstable rainfall patterns, rising sea levels and the intensification of extreme weather events–such as droughts and hurricanes–will have an impact on production, infrastructure, livelihoods and the health and security of the population. Furthermore, the changes will weaken Nature's capacity to provide us with vital resources and services, and ensure the viability of agriculture. In the case of South America, the situation could become more serious, given the disappearance of glaciers and the potential reduction in the volume of flow of the Amazon River.

Among the factors that affect climate variability in Latin America, and which are likely to be accentuated by climate change, are the "twin" events known as El Niño and La Niña, which affect the pattern and intensity of rainfall throughout the continent. In 1997-1998, El Niño increased the frequency of floods, droughts and landslides. Future occurrences of El Niño/La Niña are expected to bring about bigger alterations in rainfall patterns and increase the number of extreme events.

Climate change affects agriculture but farming activities also influence the process by producing greenhouse gases (the World Future Council [2013] estimates that agriculture accounts for around 14% of global emissions of such gases) and their impact on soils, water and biodiversity, altering the carbon and water cycles, and in turn contributing to an increase in the atmospheric temperature. Agriculture also mitigates the effects of climate change, however, since it checks desertification, helps water infiltration, conserves biodiversity and improves carbon capture, among other things.

Most of the climate scenarios constructed to understand the risks and challenges posed by climate change clearly suggest that, unless we adopt the necessary measures and act immediately, agriculture will not be in a position to provide the food, fibers and energy products that society will need in the future. According to an Inter-Ameriscan Development Bank report (Vergara *et al.* 2013), LAC will need between USD 17 billion and USD 27 billion to adapt to the impacts of climate change that are already inevitable and a further USD100 billion per year to maintain the climate stable. The main impacts of climate change on agriculture and human well-being include: i) changes in crop yields, ii) repercussions on prices, and iii) changes in consumption that can increase food insecurity in entire regions. Some scenarios predict that calorie availability in 2050 will be lower than it was in 2000 as a consequence of climate change (Nelson *et al.* 2009). Other estimates suggest that, in order to prepare adequately to address the risks posed by climate change, investments equivalent to 2-3% of the hemisphere's current GDP will be required (Stern 2006).

In response to this situation, agriculture must develop and implement innovative production systems that prioritize water use. According to some scenarios, unless immediate action is taken, food production could fall by more than 25% by 2050.

Fortunately, most countries in the Americas have already taken steps in this direction, implementing a number of initiatives that have shown that better water management is an excellent measure for adapting agriculture to climate change (Annex 2).

The availability of water for energy generation will also be affected by climate change, further increasing competition with agriculture for a progressively more limited resource. The Andean glaciers in Argentina, Bolivia, Chile, Colombia, Ecuador and Peru have lost 20% of their volume, affecting the supply of water and energy in South America. In addition, hydroelectric power provides at least 50% of the Andean Community's energy supply and farmers in many rural areas of these countries are highly dependent on water from the glaciers. Rising temperatures in the Andes are altering hydrological cycles as well as the habitats of mountainous areas, where variations in rainfall patterns are already affecting the quality of water sources and the water supply (Ortiz 2011).

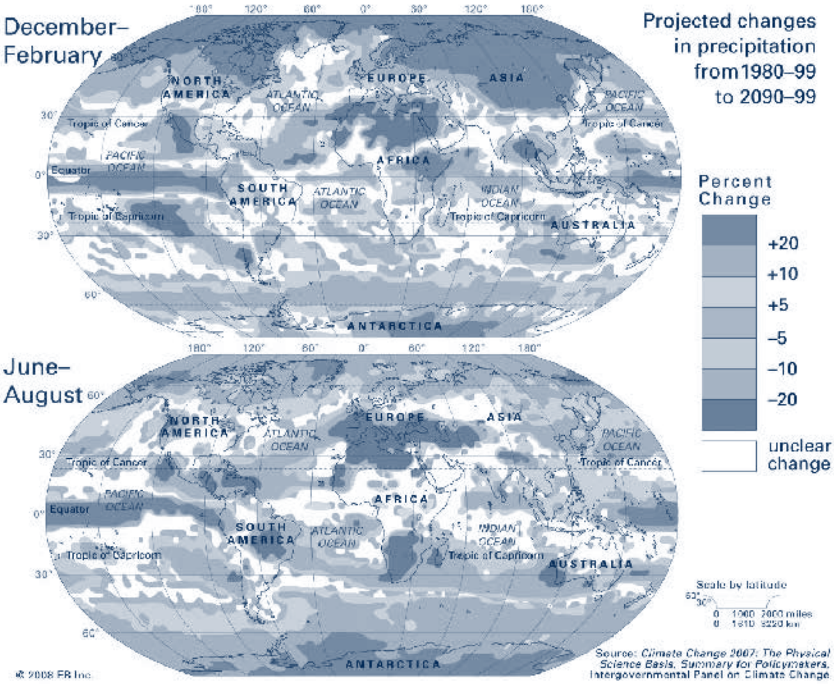
The outlook for demographic growth suggests that the demand for food will increase. Combined with the growth of cities and other industrial activities, that increases the likelihood of growing water scarcity in large parts of the globe and competition for water resources among agricultural, industrial and municipal users.

The impact of climate change will vary according to the geographic location of the countries, while its effects on their agricultural sectors will also vary depending on the type of agricultural production system and the technology used. Coastal regions and small island states will be affected most, and the negative effects of the changes will include a reduction in the quantity and quality of water sources.

Climate change is also expected to lead to changes in land use: for example, in hot and humid regions there will be a decrease in the amount of arable land, while in temperate zones, it will be possible to grow crops in areas where temperatures do not allow for production at present. Equatorial regions are considered extremely vulnerable to climate change, because temperatures there have almost reached the maximum that many crops can tolerate.

The impact of climate change will vary according to the scale and the technological capacity of the producer. Small-scale rural producers

Figure 1. Projected changes in precipitation toward the end of the 21st century as a consequence of climate change



Source: IPPC 2007b.

are more vulnerable (in socioeconomic and environmental terms) and warrant special attention. The adaptability of such communities is usually extremely low, partly due to poverty levels and also because of adverse climatic conditions that affect both the availability of water (for human consumption and use in production) and land yields and the survival of cattle (impact of both regular droughts and floods).

Therefore, it is vitally important to transfer to these producers the tools and technologies they need to improve their capacity to respond to the intensification of climate phenomena. Failure to act will lead, among other things, to migration to pockets of urban poverty and even slower development of the poorest and most vulnerable regions.

The way in which water has been managed until now is no longer a good guide for the future. At this point, we need new approaches to water management adapted to climate change. The institutions and legal frameworks governing the use of water were designed based on a seasonal vision of the hydrological cycle; these arrangements must now be reviewed in order to achieve the flexibility required to face an uncertain climatic future. In each location, according to the projected variability, it is necessary to assess the requirements and adapt the infrastructure–both natural and manmade–in order to maintain production. It is also necessary to provide the social actors and native populations with training that will enable them to meet those challenges.

IV. Use of water in agriculture in the Americas

The production of food, fibers and energy will have to double over the next 40 years if it is to meet the demand created by a burgeoning world population, improved economic conditions and changes in lifestyles. Given this trend and the demand for renewable energy sources, agricultural production will have to rise considerably. Some projections (FAO 2009) suggest that production will have to increase nearly 70% by 2050 simply to keep pace with the demand for food, i.e., excluding the fibers and agricultural products required to produce renewable energy.

Such an increase will only be achieved if productivity is improved. For practical purposes, that means producing more on the same amount of land with fewer inputs–particularly water–and applying sustainable methods. Increasing production by extending the agricultural frontier is practically impossible in the Americas, apart from certain areas, particularly in the Southern Region, where unused land is still available (FAO 2011; IICA, ECLAC and FAO 2011).

Two constraints to higher productivity will be the availability of water for agriculture and its use in the sector. Therefore, it is necessary to redefine the way in which agriculture is conducted, both under rain-fed and irrigated conditions, and acknowledge the existence of many kinds of agriculture, from subsistence and migratory farming to large-scale commercial agriculture, and the different types of family farming.

The diverse nature of agriculture and the people involved in it calls for broad and transparent general frameworks for regulating the use of water, and specific actions to meet the particular needs of each type of agriculture. At the same time, efforts must be made to preserve national cultures and traditions, which often seem to be at odds and are always complex.

The agrarian structure of the countries, as well as the land tenure situation in each one, also impact the use of water in agriculture. In general, both the fragmentation of farmland and its concentration in a few hands affect the way in which policies and instruments for comprehensive water management can be implemented.

This chapter provides a brief analysis of the situation of water in agriculture in the Americas, with emphasis on the Latin American and Caribbean countries. It contributes new data designed to complement the detailed studies that have been carried out in each country and those published by a number of organizations and professionals, especially *Riego en los países del Sur* (IICA and PROCISUR 2010), *Irrigation in Latin America and the Caribbean in Figures* (FAO 2000) and the work on irrigation in the Central Region that IICA has been promoting since 2012. The analysis excludes the management of coastal waters and the use of water in aquaculture and animal production in general.

It is vital for the Americas to find technological and other alternatives that would allow the region to maintain its productive and competitive capability, as it is the most important area of the world for food production and accounts for the largest share of global food exports.

The development of water resources for agriculture over the last 50 years has been swift. Dams, large areas of irrigation and community schemes have been built to supply water for food production. As the world's population grew from 2.5 billion in 1950 to 6.5 billion at the beginning of the 21st century, the surface area under irrigation doubled and water extraction tripled. In the countries of the Americas, the amount of cropland under irrigation rose from less than eight million hectares in 1967 to more than 20 million in the year 2000, with annual rates of growth of close to 4% during the 1960s and 1970s. The rate fell to around one percent in 2000, reflecting the changes in priorities that occurred in the countries of the region at that time.

A. Rain-fed agriculture

It is calculated that rain-fed agriculture is practiced on nearly 1.5 billion hectares of land worldwide, including 70% of the total surface area used to produce cereals, contributing roughly 58% of total global grain production (Rosegrant *et. al.* 2002, World Bank 2008). Contrary to what might be expected, rain-fed agriculture is used to produce more cereals in the developed countries, where it is practiced on nearly 80% of land used to grow such crops (Rosegrant *et. al.* 2002), than in the developing nations. Table 3 shows the surface area used for rain-fed agricultural activities in American Continent. It can be seen that, as in the rest of the world, this production system is utilized on most arable land.

Despite the increase in the area under cultivation and the high yields achieved in some crops and regions, the productivity of rain-fed agriculture is lower than that of irrigated agriculture. In the case of cereals, for example, it is estimated that the productivity of rain-fed agriculture is around 65% of what could be achieved with irrigation.

There are also differences between countries with respect to the productivity of rain-fed agriculture. General data summarized in Rosegrant *et al.* (2002) shows that in developing countries the productivity of cereal production under rain-fed agriculture is lower than in developed countries. A case in point is that of parts of the U.S. Midwest and some countries in Europe, in which corn yields under rain-fed agriculture are similar to those achieved in developing countries under irrigated agriculture.

Table 3. Irrigated and rain-fed cropland in selected countries of the Americas (data circa 2010)

Country	Total cropland (in thousands of ha)	Irrigated cropland (in thousands of ha)	Rain-fed cropland (in thousands of ha)
	A	B	C = (A-B)
Antigua & Barbuda	5.00	0.03	4.97
Argentina	39,048.00	1,550.00	37,498.00
Bahamas	13.00		13.00
Barbados	17.00	5.44	11.57
Belize	107.00	3.00	104.00
Bolivia	4,055.00	128.20	3,926.80
Brazil	79,030.00	5,400.00	73,630.00
Canada	47,894.00	869.90	47,024.10
Chile	1,774.00	1,199.00	575.00
Colombia	3,998.00	1,087.00	2,911.00
Costa Rica	580.00	103.10	476.90
Dominica	24.00		24.00
Ecuador	2,536.00	853.40	1,682.60
El Salvador	895.00	44.99	850.01
United States of America	162,762.00	26,644.00	136,118.00
Grenada	10.00	0.22	9.78
Guatemala	2,445.00	312.10	2,132.90
Guyana	447.00	150.10	296.90
Haiti	1,280.00	97.00	1,183.00
Honduras	1,460.00	87.85	1,372.15
Jamaica	220.00	25.22	194.78
Mexico	28,166.00	6460.00	21,706.00
Nicaragua	2,130.00	94.24	2,035.76
Panama	729.00	34.62	694.38
Paraguay	3,990.00	67.00	3,923.00
Peru	4,500.00	1,196.00	3,304.00
Dominican Republic	1,250.00	306.50	943.50
Saint Kitts & Nevis	5.10	0.02	5.08
Saint Vincent & The Grenadines	8.00		8.00
Saint Lucia	10.00	3.00	7.00
Suriname	65.00	51.18	13.82
Trinidad & Tobago	47.00	3.60	43.40
Uruguay	1,846.00	181.00	1,665.00
Venezuela	3,250.00	1,055.00	2,195.00
Totales	394,596.10	48,012.70	346,583.40

Source: FAO 2103 (http://www.fao.org/nr/water/aquastat/main/index.stm, consulted April 29, 2103).

For the developing countries, where the productivity of this type of agriculture is low, the adoption of, and adaptation to, cultural and technological practices similar to those used in developed countries, where the percentage of rain-fed production is high, would appear to be a viable option, to help raise production rapidly and close the gaps in productivity observed between countries. However, care must be exercised in transferring such practices, given the different ecological conditions of the countries. For example, it is quite clear that technology applied in temperate areas has little immediate application in tropical areas.

To improve the productivity of this type of agriculture, efforts are also needed to collect the traditional knowledge that exists in many regions of the Americas, which have proven to be effective in striking a balance between the use of water for plants and the availability of the water resource. All these processes of technology transfer, adaptation and adoption call for the strengthening of inter-American cooperation on this matter, and innovation programs capable of identifying the technologies used by indigenous producers and populations in the hemisphere.

In theory, the expansion of rain-fed agriculture is a real alternative, to compensate for the lack of investment in irrigated agriculture. Things are not that simple, however, as the two forms of agriculture are quite different and any vision that fails to take into account the purposes of rain-fed agriculture could have serious implications for environmental sustainability. Promoting the expansion of this type of agriculture could be interpreted as a recommendation to expand the agricultural frontier too far, with the resulting loss of biodiversity and natural resources, and expansion toward sensitive and vulnerable areas, such as slopes and mountain valleys, which would lead to the loss of soil and biodiversity.

Therefore, the countries must seek technological options that would allow them to improve the productivity of this type of agriculture and, at the same time, prevent the implementation of incentives that encourage the expansion of the surface area under cultivation or promote the extraction of groundwater, as has already occurred in several countries. Some of the interventions to improve the productivity of this type of agriculture are: i) foster the harvesting of water, the conservation of water in situ, and integrated rainwater management; ii) continue to invest in scientific and technological research to develop new varieties (particularly ones that can cope better with droughts or excessive water and optimize their use) and water use and soil conservation practices; and, iii) review and, if necessary, amend public policies on this issue, considering the implementation of positive incentives based on the sustainability of water resources, the productivity of agriculture and the conservation of the setting.

With regard to policies, efforts must be made to ensure that producers, especially smallholders and family farmers, have competitive access to transparent input markets. Schemes offering recognition of the environmental services that those kinds of farmers could provide should also be considered. Such services include micro-watershed management, the supply of good-quality water, carbon sequestration and the conservation of biodiversity or the landscape, which could be developed based on analytical criteria keyed to the composition of ecosystems. Under a broad vision, such initiatives should form part of a strategy designed to enable rural producers to diversify their income.

Special attention should be paid to the implementation of risk management programs, particularly agricultural insurance initiatives, as a mechanism to support such producers, who are heavily dependent on the cycles of nature.

B. Irrigated agriculture

Throughout history, human beings have attempted to compensate for fluctuations in the availability of rainwater by delivering water to crops from other sources. This gave rise to what is known today as irrigated agriculture. Everyone is familiar with the ingenious irrigation systems developed in ancient times that helped the great civilizations of the Americas and other parts of the world to prosper, because such systems helped to produce the food needed for complex societies to develop.

Currently there are more than 277 million hectares of land under irrigation. That figure includes, according to the AQUASTAT database

(FAO 2103), over 44 million in the Americas (see Table 3, Annex 3), or roughly 12% of the land under cultivation in this region, whose productivity, as has already been mentioned, is higher than that of land farmed under rain-fed systems.

It is also estimated that this area will continue to grow, given the need to increase food production and respond to the challenges posed by climate change, since irrigation is one of the many tools that will help agriculture to meet those challenges. Irrigation will also grow thanks to technological advances that make it possible to expand the surface area under irrigation, without increasing the total amount of water supplied to the sector.

The efficiency of irrigation water use (the amount of water that a plant actually uses compared to the total amount extracted for irrigation) currently stands at less than 40%, so there is plenty of room for improvement. Making irrigation more efficient would save a large amount of water, bearing in mind that per hectare use in the hemisphere is between 9000 m^3/year and 14,000 m^3/year.

Irrigation has undoubtedly played a key role in ensuring availability of the food we enjoy today and, when combined with integrated water resources management, will continue to be a very useful tool to support agriculture in finding more efficient ways of meeting the challenges of development and climate change, and helping to guarantee the food security of a growing population.

Today, irrigation must overcome a series of obstacles to achieve these objectives; however these obstacles can also been seen as opportunities for innovation and for the definition of a hemispheric agenda of common commitments. Some of the most important challenges currently faced by irrigated agriculture in the region are.

a. High extraction rates, which have led to the overexploitation of many aquifers, encouraged by “negative incentives” that promote the use of water based on volume rather than the productivity of water in agriculture.
b. Inefficient utilization of water in irrigation systems, because of users’ lack of expertise, the irrigation technologies, infrastructure

and methods employed, and the type of crops and species or varieties grown.

c. The pollution of aquifers by crop and livestock farming, industrial and domestic activities.
d. The existence of a multi-institutional framework that regulates, and in some cases over-regulates, the use of water, which affects the performance of agriculture.
e. The need for modern infrastructure and the rehabilitation of damaged and obsolete structures.
f. Environmental degradation, which affects the availability of water and the recharge of aquifers, manifested mainly in the salinization and, in some cases, the oversaturation of soils and in reservoir sedimentation.
g. The failure of many major irrigation infrastructure projects and the need to garner and take advantage of ancestral knowledge.
h. The need for trained and qualified human resources to meet current and future challenges.
i. Water rights and ownership; the legal status of groundwater; the conflicting interests of farmers, which often hinder the implementation of such rights; water ownership problems and the establishment of maximum extraction volumes are common issues in areas where pump irrigation is used.
j. The exclusion of certain social groups or groups of producers.
k. Inefficient utilization of rainfall in rain-fed systems and poor strategic use of irrigation at certain critical moments during the year (complementary irrigation).

An important issue for irrigated agriculture is the need to promote the recycling of water, in particular water used for domestic or industrial purposes. This practice has been implemented under diverse conditions in different countries, with varying degrees of success.

In theory, recycling water increases the amount of the resource available, protects river basins and coastal areas, and contributes nutrients to crops, thus reducing the need for fertilizers. However, in practice it presents serious limitations, particularly due to chemical pollution, which cannot always be eliminated, and biological pollution, which can affect food production. Therefore, recycled water is more suited to the production of grains rather than fruits and vegetables.

In the area of agricultural irrigation, attention should be paid to drainage, especially in areas where agriculture is intensive and excess water causes water tables to rise, in some cases due to the natural water logging of the soil, and in others to the induction of water as a result of ineffective irrigation practices, poor soil management, the application of poor quality irrigation water, or a combination of all of these factors, which creates a major problem in the areas under cultivation. The most harmful effects of excess moisture on the soil and crops are a reduction in root-zone aeration and damage to the structure of the soil. In short, irrigated agriculture cannot be efficient if the question of drainage is not taken into account.

Another recurring problem in irrigated agricultural soils is salinization, which has become a threat for highly productive irrigated land. It will also be a growing environmental problem in areas where climate change is expected to lead to greater aridity or in coastal areas affected by rising sea levels.

Salinity affects the structure of soils, due to the formation of aggregates by the flocculation and cementation of colloids. In plants, the impact of salinization is seen two main ways: an increase in osmotic pressure and a direct toxic effect. As the saline concentration of the solution in the soil rises, the osmotic pressure also increases to the point where the roots of plants are unable to absorb water.

In sum, irrigated agriculture is at a crossroads today. Regardless of the type of agriculture involved, farmers and other actors in development must achieve a rational balance between the use of water and crop productivity, and do so in a way that ensures environmental, economic, and social sustainability.

C. The water footprint of agricultural activities

As the pressures on the water resource have increased, efforts have been made to develop methodologies for evaluating and quantifying the amount of water used by human activities, including agriculture, and to provide input on which to base decisions aimed at improving the management of the resource, investing more intelligently, enhancing productive processes and promoting the design of appropriate public policies.

One of the methodologies is the so-called “water footprint,” initially proposed in 1990 by Ress (1992) and subsequently by Allan (1998). The concept is now widely disseminated throughout society, but it is often used with little analysis of its advantages, implications and limitations.

In general, the “water footprint” is… “an empirical indicator of how much water is consumed and polluted, when and where, measured over the entire supply chain of the product... The water footprint of an individual, community or business, is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business...” (Hoekstra *et al.* 2011). With these criteria, today there are estimates of the water footprint of nearly all agricultural products and services, and many countries have launched programs to determine their own water footprints.

Table 4 shows data on the water footprint of several crops, while Table 5 presents data for the water footprint of a number of animal products.

It is important to point out that in decision-making the water footprint is only one of the many methodologies that can be used for integrated water resources management. It is also worth mentioning that, until now, water footprint measurement has had only a limited impact on the establishment of public policies (Chapagain and Tickner 2012) and its role in trade has not been clearly defined. If the measurement of the water footprint is used properly, it can help to improve knowledge of the interrelationships that exist among water use, economic development, business practices and social and environmental risks (Chapagain and Tickner 2012).

Table 4. Average global water footprint for some of the principal agricultural crops

Type of crop		Water footprint (m^3/ton)
Cereals		
	Total cereals	1644
	Wheat	1827
	Corn	1222
Vegetable oils		
	Cotton	3800
	Soybean	4200
	Palm	5000
	Sunflower	6800
	Olive	14 500
Fruits		
	Watermelon	235
	Pineapple	255
	Papaya	460
	Apple	820
Juices		
	Tomato	270
	Orange	1000

Source: Mekonnen and Hoekstra 2011.

Table 5. Average global water footprint of the principal animal products

Product	Water footprint (m^3/ton)
Beef (grazing)	21 829
Beef (intensive)	10 244
Sheep meat (grazing)	16 311
Sheep meat (intensive)	5623
Pig meat	5988
Chicken meat	4325
Chicken eggs (grazing)	7644
Chicken eggs (intensive)	2874
Cow's milk (grazing)	1191
Cow's milk (intensive)	1207

Source: Mekonnen and Hoekstra 2012.

D. Management of water pollution caused by agriculture

Agriculture is carried out in a symbiosis of land and water and, as a result, "appropriate steps must be taken to ensure that agricultural activities do not adversely affect water quality so that subsequent uses of water for different purposes are not impaired" (FAO 1990). However, recent WHO reports suggest that agricultural pollution has triggered an important rise in nitrogen levels in groundwater, which could increase further if agricultural activities are intensified (WHO 2006).

Extraction has nearly reached the threshold for the renewal of water resources, and in some cases has already exceeded it, causing damage to ecosystems and threatening river courses. Usually, when water availability is low, demand increases, and shortages and conflicts occur. This trend is accompanied by degradation of the quality of surface water and groundwater, as a result of the combined waste from cities and industrial and agricultural activities.

Agriculture is carried out in a symbiosis of land and water and is, simultaneously, both a cause and a victim of the pollution of water resources. It contributes to the problem through the discharge of pollutants and sediments into surface water and groundwater, net soil loss as a result of poor agricultural practices, and the salinization and oversaturation of irrigated land. It is a victim because it makes use of wastewater and because of the pollution of surface water and groundwater by other activities, which affects crops and increases the likelihood of diseases being transmitted to consumers and agricultural workers (Beekman and Biswas 1998).

For those reasons, water pollution and its relationship to agriculture have to be considered from two standpoints. Firstly, from the perspective of the pollution that agriculture causes in water resources, resulting from the use of fertilizers and pesticides, waste from livestock or aquaculture operations, and soil loss and salinization. Secondly, in terms of the effects of water pollution on agriculture–on productivity and, ultimately, on food safety and consumer health.

Part of the solution lies in creating information systems and providing users with reliable, precise and up-to-date data on the quality and amount of water utilized. Agricultural institutions and water users in agriculture do not usually have access to such data and, even when it is available, it is largely inaccurate and out of date. Therefore, ministries of agriculture need to strengthen their actions aimed at establishing systems for monitoring and supplying information about the quantity and quality of the water used in agriculture, harnessing new technologies and innovations that use models with spatial and geo-referenced measurements.

V. Innovations to improve water productivity in agriculture

A. Productivity of water in agriculture

Increasing water productivity in agriculture is essential in order to reduce the pressure on water resources, reduce environmental degradation and improve food security (Box 3). However, this is not a simple process and there is no "magic" solution to achieve it, since improving water productivity requires interventions in all the links of the "water use chain." This implies many improvements – from efficiency in the way in which plants use water to the manner in which international trade affects the productivity of its use.

This chapter offers a brief description of some innovations that, given their potential to improve the use of water in agriculture, could be taken into account in developing a common agenda for cooperation. The innovations in question are related to four overarching areas

Box 3. Water Productivity

"Improving water productivity in agriculture will help to reduce pressure on water resources, environmental degradation and will contribute to food security by "releasing" water for other uses and sectors. The term water productivity has many interpretations and definitions that depend on the level of measurement and the user. For some, it means increased production per unit of water transpired; for others, it implies greater production per amount of water supplied, and for yet others, it means improvements in well-being per total amount of water used..."

Molden *et al.* 2003

of action: i) use of water by plants, ii) improvements in water use in parcels or production units, iii) improvements in the supply and delivery of water and iv) innovations in watershed management. Efforts undertaken in all these areas will make it possible to address the challenges of physical and economic water shortages.

Two factors are key to the successful implementation of these innovations. The first is to recognize that innovations are the result of advances in scientific knowledge, thanks to which we now have a better understanding of the hydrological cycle, the way in which plants use water, the relationship between soil and water and the complex interactions between water, climate and biodiversity. Therefore, the construction of a hemispheric cooperation agenda must be based on a commitment to encourage comprehensive research and innovation, with a particular emphasis on those disciplines that provide practical solutions to integrated water management.

The second key factor for improving water productivity is the participation of the actors of agriculture, particularly farmers (large, medium and small-scale), who are ultimately responsible for the use of this resource and have the greatest stake in safeguarding its conservation and quality. In this sense, it is important to recover the traditional and ancestral knowledge which, when combined with modern knowledge and technologies, can guarantee the comprehensive management of water resources.

B. Improvements in plant water-use efficiency

Ultimately, water productivity is determined by the efficiency with which plants use this resource, as a result of the absorption, metabolism and evapotranspiration, which is a physiological manifestation in plants. Over the last 50 years, significant progress has been made in improving water use efficiency in plants. Another important advancement has been the release of new varieties of short-cycle and higher-yielding crops that require the same amount of water as lower-yielding varieties. This has not always been the result of greater efficiency in water productivity, but rather of changes in the biomass of plants and their relationship with grain production. There are numerous vegetable species domesticated many centuries ago that are underutilized and marginalized, despite being tolerant to limited water availability, since they have C4 or CAM photosynthetic mechanisms that made them more efficient that traditional crops for water utilization. Furthermore, the development of plant species and varieties that are better adapted to conditions of limited water availability, such as varieties with a smaller leaf surface, has enabled crops to withstand water stress better.

There is evidence that if we continue along the traditional path of genetic improvement, we will soon reach the thresholds of productivity or else the progress made will be too slow, given the urgency of addressing the effects of climate change and the demands of production. Faced with this situation, the innovations of the future will come from the "new biology," with the branches of biotechnology and nanotechnology making significant contributions to improved water productivity and, therefore, to the "release" from agriculture of water that could be used for other purposes. Box 4 summarizes some of the main contributions of biotechnology to improving water productivity. As is evident, not all those contributions are associated with plant efficiency; some are also related to interventions that improve post-harvest processes or the health of soils.

These observations confirm the importance of continuing to strengthen biological and agronomic research in order to find plant species that can produce more by using water more efficiently or by adapting to extreme climatic conditions, including limited water availability and high salinity. Recent studies to determine how plants function have identified certain genes that could eventually be incorporated into food crops to give them a greater tolerance to water stress, which will generate savings of this vital resource.

C. Improved water use on production units

The second type of innovation developed to improve water use in agriculture has to do with the way in which water is used at the production unit (parcel or farm) level. In most cases, these are combinations of technologies and techniques aimed at enhancing the productivity of all the resources available to farmers.

There are three general types of interventions that can be used on parcels or farms: i) the application of technologies and techniques aimed at improving soil management (for example, direct planting or zero tillage); ii) improvements in the use of other inputs, particularly fertilizers and iii) the use of technologies that allow for a more precise and targeted water supply, according to the needs of plants, such as precision irrigation, micro-irrigation and subsurface irrigation. There are also technologies that have proven beneficial in terms of water use, including the techniques generally known as "protected agriculture" and hydroponic crops.

The combination of these integrated interventions results in what is termed "precision agriculture." The most advanced examples of this type of agriculture use computerized systems that detect the water requirements of plants throughout their biological cycle and which,

Box 4. Biotechnology: contributions to improve water productivity

1. Production of drought-tolerant plants through traditional improvement techniques and genetic modification

    a. Drought-tolerant rice, wheat and sorghum obtained through plant breeding
    b. Drought-tolerant GM corn deregulated by the USDA in 2011
    c. At present, tests to assess biosafety in GM maize, soybean and cotton based on events generated in Argentina

2. Use of biotechnological techniques such as bioremediation to clean water

    a. Microbial bioremediation to treat water contaminated with hydrocarbons or heavy metals (from mining)
    b. Treatment of wastewater from agriculture and livestock production (pigs, poultry and cattle) oxidation ponds, commonly used on golf courses, production of turf, ornamental plants and non-horticultural crops, and from irrigation of plants used for animal consumption, such as forage grasses and alfalfa

3. Cleaning and purification technique using “algal turf”

4. Obtaining plants tolerant to salt water

    a. VImproved varieties of rice irrigated with salt water
    b. VTesting of plants genetically modified to tolerate salinity

5. Improved agricultural practices: covering soil with agricultural or harvest waste to conserve moisture in the soil.

with the support of satellite measurement systems, make it possible to supply, at the right time, the exact amount of water and other inputs required by an individual plant or a group of plants grown on a very small piece of land.

When we speak of improving water use in parcels, we cannot ignore the enormous importance of soil management, since soil health goes hand in hand with water productivity. According to some recent data, the development prospects of more than 1500 million people are threatened by the effects of soil degradation.

Given that agricultural innovation systems and the private sector have placed emphasis on the development of these types of knowledge and methodologies, the market offers a large number of alternatives that can help farmers increase their yields, while at the same time improving the overall management of their parcels.

However, many of these technologies are still unknown to farmers, or else are economically inaccessible to them due to their cost or scale of application. Therefore, a task is still pending: to bridge the gap between the theoretical availability of these innovations and their practical application in the field, particularly in small-scale agriculture and in family agriculture, which take place on small parcels. This underscores the urgency felt by the Latin American and Caribbean countries to build and strengthen their knowledge transfer systems and to modernize what are traditionally known as "agricultural extension systems."

D. Improvements in the conveyance and distribution of water

There is also a third type of innovation related to the way in which water is delivered to farmers, which makes it one of the most important interfaces for cooperation between end users and the institutions responsible for the administration of water resources, and offers opportunities to develop hard innovations (in infrastructure) and soft innovations (the way in which resource management is organized).

By way of a summary, the greatest efforts in this regard have focused on:

a. Improving the operation of irrigation systems: the main purpose of these interventions, which include not only improvements in canals and pipeline systems, but also in organization for management, is to ensure that farms or production units receive a timely supply of the water they require, both in terms of quantity and quality, without delays in delivery and losses in the pipeline.

b. Reduce water evaporation: to this end efforts have focused on redesigning channels, redefining distribution routes, avoiding the conveyance of water through unproductive land, modifying the types of crops grown by eliminating species that use water less efficiently and controlling weeds that compete with crops for water and nutrients.

c. Reduce filtration, run-off and leaching (displacement of soluble or dispersible substances, such as clay, salts, iron and humus) caused by the movement of water in the soil, which is characteristic of wet climates. This causes some layers of soil to lose their nutritional compounds and become more acid; sometimes it also generates toxicity.

d. Minimize water pollution and salinization of soils.

e. Promote recycling and reutilization of water.

Two actions that have had positive results in enhancing all of these interventions are the involvement of users in all these processes and facilitating community-based management of water resources, particularly in territories with deeply rooted cultural and community traditions.

E. Innovation in watershed management

At the level of river basins, nations and even of transboundary water resources, major efforts have been undertaken to improve the management of this resource. To this end, many countries are now using geo-referencing and geo-measurement technologies, as well as space technologies and computer models.

These technologies are being used with four main objectives in mind. The first is to find out exactly how much water is available, determine its state and develop management models to help address the challenges of meeting current demand and those imposed by climate change and population growth. In this regard, countries must work to strengthen their national capabilities and establish international cooperation programs to build databases and models that will enable them to guarantee water availability.

The second objective of innovations at the level of river basins is to support decision-making related to the allocation of resources to different users, generally seeking to support water use for those activities that produce the greatest return or are of greatest importance for human development.

The third objective of innovations at the level of river basins has to do with the need to conserve resources, both in terms of quantity and quality and health. In these types of interventions we include innovations in business models that involve users and reward or compensate them for the ecosystemic services they provide.

The fourth objective of these innovations is to establish early warning systems in order to monitor climate conditions, available volumes of water and the levels of water contamination.

It is clear that improving water productivity and ensuring an integrated approach to water resources management is a responsibility shared at all levels, and therefore requires the participation of researchers, producers, local communities, countries and the international community to guarantee the availability and integrity of this vital resource. Undoubtedly, an individual action by a farmer, a community, a government or a researcher will be insufficient to guarantee the availability of water required by agriculture in the near future.

VI. Institutional aspects that influence the use of water in agriculture in the Americas

Protecting, conserving and maintaining the integrity of water resources calls for consistent mechanisms that make it possible to ensure the availability and quality of the water required to meet the needs of the growing human population and the economic activities that help to satisfy those needs. The many and varied systems of governance employed for that purpose are designed to contribute to the interests and objectives of national and global development (Box 5).

Box 5. Governance in water resources management

Water governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society (GWP 2002).

Given the intrinsic characteristics of integrated water resources management, solid regulatory frameworks are required to ensure the availability of water for future generations, balance the demand for and pressures placed on the resource by different economic sectors and human activities, and effectively coordinate investment in infrastructure, innovation, and technologies.

The public sector has the specific responsibility of spearheading, overseeing and coordinating the development and implementation of consistent policies that will ensure the attainment of the overarching goals of development, such as food security and poverty reduction, as well as the specific objectives of improving agricultural productivity and conserving resources for future generations, with water being one of the most important among them.

Consistent, integrated policies make it possible to balance society's water needs (consumption and health) with the conservation of landscapes and watersheds, and the improvement of the productivity of agriculture and other economic sectors (including energy and transport). Similarly, consistent policies are also vital for the development of plans and strategies to meet the challenges posed by climate change and population growth.

In the American Continent, the issue of water and its relationship with agriculture and food security is a priority on the agendas of all the countries, one that is addressed and managed by means of a wide range of institutional arrangements and a large number of instruments.

IICA's efforts to describe the institutional duties and responsibilities related to water in LAC revealed that responsibilities are assigned in a wide variety of ways in the different countries. They also confirmed the findings of previous studies, especially one conducted by the OECD (Akhmouch 2012) that found that, in the Americas, a number of ministries and levels of government are involved in water management, for which a range of policy mechanisms and management instruments are used. Annexes 4 and 5 contain a brief summary of such arrangements in selected countries of the hemisphere.

The diversity of institutions, policies and rules and regulations, coupled with the multiplicity of users, creates problems for the coordination of the implementation and articulation of actions, especially at the level of territories. In many cases, this leads to confusion and chaotic situations involving users.

To try to correct such shortcomings and improve coordination among the different entities involved in water management, some countries have set up specific mechanisms, usually at the federal or national government level, with varying degrees of success.

The way in which the countries administer water for agriculture also varies, with the ministries of agriculture participating to different degrees in various roles, usually limited to the allocation and operation of water for irrigation. However, recognition of the importance of water in mitigating the effects of climate change, increasing agricultural productivity and responding to the pressure for sustainability has led a number of ministries of agriculture to review their structures and functions. As a result, they have included the coordinated management of irrigation water in their functions as part of a State policy. Notable cases are Ecuador, which has a department exclusively devoted to irrigation and now Peru, which recently restructured the Ministry of Agriculture to convert it into the Ministry of Agriculture and Irrigation (Box 6).

Box 6. Changes carried out within Peru's Ministry of Agriculture that highlight the importance of water in agriculture

On April 3, 2013, Peru's Cabinet approved the creation of the Ministry of Agriculture and Irrigation, modifying the functions and structure of the previous Ministry of Agriculture to meet the new needs and challenges. The new structure will include a Deputy Minister's Office devoted exclusively to integrated water management for irrigation. These changes are in line with the trend observed in countries such as Ecuador, which has a Department of Irrigation and Drainage under the purview of the Deputy Minister of Rural Development.

In other cases, the use of water by agriculture is promoted under specific projects or programs that usually focus on improving the integrated management of irrigation water, attracting investment and promoting technological innovations at the territorial or provincial level (Box 7).

Contrary to the efforts being made in the countries with respect to the management of irrigation water, the participation of the ministries of agriculture in the management and development of rain-fed agriculture, an area in which the main need is for policies and incentives to improve the collection and conservation of rainwater, does not seem to be clearly defined. This suggests that there are opportunities for improvement, since rain-fed agriculture is used on most farms in the countries of the hemisphere, and millions of producers, some

Box 7. Argentina: focusing efforts at the provincial and territorial level to improve integrated water management in agriculture

- The Provincial Agricultural Services Program (PROSAP), overseen by the Rural Change Unit (UCAR) of the Ministry of Agriculture, Livestock and Fisheries, whose purpose is to design and implement public investment projects, at the provincial and national levels, that are socially and environmentally sustainable (including irrigation and drainage projects) aimed at increasing the coverage and quality of the rural infrastructure and agrifood services.

- The Project for the Sustainable Management of Water Resources for the Agricultural Sector, carried out under the Strategic Area of Natural Resources of the National Agricultural Technology Institute (INTA), which includes the following subprojects:

  - Development of Technologies for Optimization of Irrigation
  - Dynamics of Water Supply for the Agricultural and Forestry Sector of Argentina
  - Integrated Water Management for Family Agriculture and Producers in Rain-fed Areas
  - Hydrological Modeling for Watershed Planning, whose objectives are as follows:

    a. strengthen the internal and inter-institutional network;
    b. increase the training of human resources;
    c. creation of a database and estimation of the water footprint of products and services;
    d. update the characterization of different agricultural uses;
    e. develop, update, and validate methodologies for forecasting availability;
    f. apply hydrological models to different geomorphological situations;
    g. incorporate the use of remote sensing to characterize and determine performance indicators for the regional level; and,
    h. develop and validate technologies for the collection and use of water by different types of producers in crop, livestock and forestry production.

working in highly precarious and vulnerable conditions, depend on rainwater for their production activities.

To revitalize the use of water in agriculture, it is necessary to enhance the capabilities of the ministries responsible for agricultural production and rural development, so they can coordinate their work with that of other ministries involved in water management and achieve more integrated public policies, safeguard the sector's interests, ensure that agriculture makes a positive contribution to water conservation (in terms of both quantity and quality), and define the research and innovation goals and priorities with regard to the management and use of water in agriculture.

Various public policy instruments exist that are associated with water, instruments that impact the way in which agriculture uses water and that are used by the countries to promote or discourage its use, conservation, quality and recycling.

The use of such instruments is reflected, in most cases, in the price paid for water and the way in which it is charged; it is also manifested in the form of domestic support and subsidizing of the energy required to extract and use water. Each country applies them in accordance with its particular development models and political, social and economic principles.

Two aspects that require particular attention, given their importance in instituting new paradigms to promote the integrated and sustainable use of water in agriculture, are ownership of the resource and the right of the different stakeholders in agriculture (including smallholders and indigenous peoples) to have access to it.

The general consensus is that, ultimately, water belongs to the countries and all human beings are entitled to have access to it. That consensus is clear in the case of waters located within national territorial limits but becomes confusing and conflicting when transboundary waters are involved, since actions in one country can affect the development and, therefore, the agriculture, of its neighbors. As pointed out in section D of Chapter II, a number of transboundary bodies of water exist in the Americas that are managed in a coordinated way by two or more countries that share the river basins in question.

Furthermore, it is important that the countries of the hemisphere analyze the implications that the purchasing of land by countries outside the region could have on this resource.

The agriculture of a given country is made up of many forms of production and types of farming, which should all enjoy the same equitable and universal right to access the water they need. This raises special issues that must be addressed by means of public policies designed to ensure that the resource is managed in a participatory manner, that users are involved in decision-making at the different levels, and that plural management of the resource is promoted.

Similarly, public policies must guarantee access to water for the different 'agricultures' that coexist in each country, and recognition of ethnic groups and traditional cultures (Allaverdian *et al.* 2012). In general, processes of that kind are not institutionalized in the hemisphere. In the best of cases, the involvement of the social and agribusiness sectors and civil society in the participatory management of the water occurs in isolation and almost exclusively at the level of territories. Furthermore, the even-handed application of principles is generally weak, and there is a systemic failure to include traditional principles and customs (FAO 2011). In the United States of America, it is common for the private sector and other segments of society to be actively involved in the democratic decisions taken at the county level.

Furthermore, the settlement of disputes related to water in agriculture does not include the participation of specific courts in most countries. When conflicts occur, they are resolved through the application of generic laws by courts that are not conversant with the specifics of the subject, often resulting in wrong decisions that are detrimental to agriculture, especially when the plaintiffs have no negotiating power or are poorly represented.

The current state of governance in relation to water and water resources in the hemisphere offers opportunities for individual and coordinated action at the hemispheric level, and for international technical cooperation. Some of the areas in which the greatest potential for the development of a hemispheric agenda on water governance exists are as follows:

a. Development of long-term, integrated, State policies for the revitalization of water in agriculture that are consistent with the geographical conditions, uses, users and agricultural policies instituted by the countries to meet the challenges of agriculture. Those policies should be based on solid scientific principles that take into account the nature of the resource and the challenges posed by climate change.

b. Construction of an environment that will attract investments for the modernization of the water and agro-meteorological infrastructure, as well as the incorporation of new technologies (including space and communication technologies) as mechanisms for the efficient management of water.

c. Public sector support for the creation of the conditions required for the development of new innovations, and the implementation of existing cutting-edge innovations, some of which call for geo-referenced monitoring systems, precision agriculture and the use of new technologies for the development of varieties tolerant to water stress.

d. Government promotion of the renewal and strengthening of education systems in agriculture, including, as a priority, skills development programs for women, producers' associations and water users, as new human capabilities are required to apply policies and implement innovations.

e. Establishment of information systems, including early warning systems, that make it possible to take timely decisions related to the design of management policies and tools, and the implementation of actions on farms and in territories and production areas.

In devising public policies, governments should adopt a strategy of prioritization and follow-up and a long-term vision, so they do not limit themselves to providing stopgap solutions or adjusting existing policies to the latest trends and currents of opinion.

VII. Recommendations

The analysis carried out in the preceding chapters highlights the major problems facing agriculture with respect to water. It also identifies a number of opportunities for joint action that, if fully taken advantage of, would ensure that the agriculture of today, and of the future, has the necessary water, in terms of quantity and quality, to produce the food, fibers and energy required by humanity. It also underscores the importance of implementing integrated water resources management to ensure the development and sustainability of agriculture.

The same analysis suggests that the Ministers of Agriculture face numerous challenges in the short, medium and long term. One of the most important is the need to guarantee the volumes and quality of water required by agriculture, in a context of growing competition for this resource, which is becoming increasingly complex and difficult.

To ensure that agriculture has the water it needs, in terms of quantity and quality, the ministries of agriculture must strengthen their institutional capabilities against a background of limited human, financial and physical resources. This forces them to set priorities and target their interventions at those areas that offer opportunities to make the greatest impact and obtain better returns in relation to the resources used and in response to the pressing needs of producers and of society in general.

In this chapter, four recommendations are put forward (three general ones and one that is cross-cutting in nature) that are considered crucial to provide agriculture with the water it needs, both at present and in the future. These recommendations can be used to build a hemispheric cooperation agenda designed to improve the integrated use of water resources in agriculture. In making these recommendations, we recognize the steering role and leadership of the ministers of agriculture on the issues of production, food, competitiveness and sustainability.

In making these recommendations, we recognize that there are numerous opportunities for action; however, we consider that the proposals presented here are the ones that offer the greatest opportunities to generate synergies among the countries and produce positive results in the short and medium term. They also make it possible to target and apply the limited resources available in priority areas and to coordinate and guide the support received from international technical and financial cooperation organizations with clear goals and long-term visions.

A. Recommendation 1: *Promote the institutional strengthening of the ministries of agriculture*

Given the multiplicity of national institutions involved in water management in IICA's member countries, in international forums (for example, the CBD, the UNFCCC and the WTO, among others) and the commitments acquired on the issue of water, the first recommendation is to define a hemispheric program to strengthen the capabilities of the ministries of agriculture and support them in the design and implementation of policies and tools for the integrated management of water in agriculture. This would strengthen their capacity for dialogue and consensus building with other economic sectors in their countries and with the international community.

The main purpose of this recommendation is to improve the management capabilities of the ministries of agriculture in order to: i) ensure that the objectives of producers and populations of rural areas are included in national policies and in international agreements; ii) design and implement investment projects related to irrigation systems and the management and conservation of rainwater for rain-fed agriculture that are in line with current needs; and iii) ensure that agriculture is provided with the water it requires, in terms of quality and quantity, for the sustainable and competitive production of food, fibers and energy.

In order to accomplish this objective the following actions are proposed:

a. Analyze the current institutional structure, its strengths and weaknesses and identify the areas or aspects that need strengthening in the ministries of agriculture of IICA's member countries, in relation to water for agriculture.

b. Design, establish and execute an inter-American cooperation program to strengthen the ministries of agriculture.

c. Promote and strengthen existing regional mechanisms for the analysis and definition of common strategies for integrated water resources management in agriculture.

B. Recommendation 2: *Promote integrated water management to achieve sustainability in agriculture and address the challenges of climate change*

One of the greatest challenges in achieving sustainable agriculture is to ensure that the sector adapts to, and helps mitigate, climate change. Water is a crucial resource for this purpose, and therefore the recommendation is to focus efforts on adapting agriculture to climate change, through the integrated management and rational use of water resources, based on solid scientific principles and respecting the legal frameworks, traditions and culture of countries, communities and indigenous peoples.

To achieve this objective the following actions are considered priorities:

a. Strengthen and, where necessary, develop hydro-meteorological information, early warning, risk management and climate scenarios systems, as the essential basis for the design and implementation of adaptation strategies, including prediction, prevention and preparedness programs related to extreme events that consider the incorporation of new satellite technologies as well as telemetry, geo-processing and geo-referencing technologies, etc.

b. Promote the regional integration of hydro-meteorological information systems and early warning systems to make it possible to use global models for making more accurate forecasts of hydro-meteorological events.

c. Promote planning processes in agriculture to facilitate adaptation to climate change and water availability; this should include projects for the diversification, reorganization and relocation of crops, among other alternatives.

d. Strengthen agricultural information systems in order to determine the volume of water assigned to the sector (supply) and improve decision-making on water use, in coordination with the national systems responsible for water resources management.

e. Promote investment to revitalize the irrigation infrastructure (water capture, storage and distribution), including the design of new infrastructure projects and the rehabilitation of existing ones, based on clear performance indicators, as well as social inclusion and environmental impact indicators.

f. Promote investment to improve the capture, harvesting and use of rainwater in rain-fed areas.

g. Foster the organization of irrigators to improve water management and the implementation of measures for adaptation to climate change.

C. Recommendation 3: *Strengthen innovation to improve the productivity of water resources in agriculture*

It will not be possible to guarantee the supply of food if the production systems throughout the agrifood chain continue to behave as they have until now, particularly given the declining availability of water resources facing agriculture. It is therefore essential to improve water productivity through innovation, which is the objective of the third recommendation.

To achieve this objective it is essential that the countries focus their efforts on:

a. Developing and consolidating information systems and disseminating innovations to improve water use in agriculture, aimed especially at ensuring that these innovations reach the users. To this end, it is essential to expand the use of new information and communication technologies.

b. Promoting the development of public-private partnerships that make it possible to improve efficiency in water use and reduce pollution of water resources.

c. Strengthening and, where necessary, designing capacity building programs to improve water productivity, paying special attention to the different types of agriculture and the different needs of users, and targeting efforts at the watershed level, as the integrating unit.

d. Focusing efforts on the following areas of innovation:

    i. Identify, evaluate and disseminate local and traditional technologies for the use of water in agriculture.

ii. Promoting precision agriculture.
iii. Generating innovations to improve the knowledge, use and sustainability of the groundwater resources used in agriculture.
iv. Developing innovations in biotechnology (in agriculture, livestock and food production) to improve water productivity.
v. Evaluate and promote the use of alternative crops, taking advantage of the numerous species that are underutilized and that have demonstrated their capacity to adapt and prosper under water stress conditions
vi. Promoting innovation to improve the recycling and use of recycled water, which should be combined with the production of hydraulic energy.

To accomplish these objectives, the ministers of agriculture are urged to continue working to articulate the agricultural innovation systems, and to exercise proactive leadership in defining the allocation of resources and funds for research on water for agriculture, thereby contributing to achieving the higher goal of developing competitive, sustainable and inclusive agriculture.

D. Recommendation 4: *Strengthen the training of human resources in the new paradigms for agriculture*

To improve the productivity of water in agriculture and achieve integrated water resource management, all the stakeholders must be highly conversant with the new paradigms for agriculture. In that way, they will be equipped to innovate and solve the new problems that have arisen, or that may arise, in the agricultural sector in a context of high price volatility. Accordingly, the ministers of agriculture are urged to:

a. Promote the training of human resources in new paradigms that facilitate the development of a competitive, sustainable and inclusive agricultural sector.

b. Equip producers, especially small and medium-scale farmers, with the skills and expertise required to innovate and thereby achieve the development of intensified and sustainable agriculture.

c. Foster the training of a new generation of agricultural specialists, new scientists and service providers.

d. Recognize the importance of women as key players in integrated water resource management, promoting initiatives that help close gender gaps, improve the inclusion of women in decision-making and achieve full recognition of the rights of rural women, including those related to property, education, and access to productive assets.

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Annexes

Annex 1
REGIONAL CHARACTERIZATION OF WATER FOR AGRICULTURE

Central American Region

Annual per capita water availability in Central America is approximately 23,000 m^3, distributed heterogeneously both between and within countries due to differences in rainfall patterns and the distribution systems that exist. In the Central American isthmus, annual precipitation rates range from 1150 mm to 5000 mm. In addition, marked seasonality is evident on the Pacific slope, with well-defined dry periods (December-April) and rainy periods (May-November), while on the Caribbean slope there is a continuous rainy period, with only small decreases in rainfall during April and October. Central America's water resources are climate dependent. The Caribbean slope has approximately 70% of the region's water resources while the Pacific has roughly 30%, the opposite of the situation vis-à-vis the concentration of population and productive activities.

Although Central America has sufficient water resources, their availability for agriculture is affected by the irregular spatial and temporal distribution of rainfall, by insufficient water regulation works, by the degradation of river basins and by the poor quality of water. These factors also influence the region's productive capacity. With respect to water use, Central America follows the global trend: approximately 70% of its water is used for agriculture.

Since the 1970s, the number of extreme hydrometeorological events has risen, with the most severe flooding occurring in the north of the region. Extreme temperatures, droughts and forest fires have increased since the 1990s. A highly vulnerable dry corridor spans the entire region, mainly on the Pacific slope.

A pending task for the countries of the isthmus is the joint use of water resources in shared river basins, which account for 37% of Central America's territory. This region has 23 river basins shared by two or more countries, 13 of which contain rivers that mark national boundaries. Transboundary river basins cover 36.9% of its territory (191,449 km^2), an area larger than that of any of its countries. The river basin of the San Juan River is the largest in Central America.

Central America has developed specific policies and strategies for water resource management, and sectoral and intersectoral instruments that address the issue of water for agriculture, such as the following: the Central American Strategy for Integrated Water Resources Management (ECGIRH), the Central American Agricultural Policy (PACA), the Regional Agro-environmental and Health Strategy (ERAS), the Central American Strategy for Rural Area-based Development (ECADERT), the Regional Climate Change Strategy (ERCC), and the Central American Policy on Comprehensive Disaster Risk Management (PCGIR). The Central American Integration System (SICA) has set up the Interagency Group on Water for the purpose of reaching consensus on a regional water resources management program. In this group, the agricultural sector is represented by the Central American Agricultural Council (CAC), the regional body of the ministers of agriculture of the isthmus.

The most important regional initiatives underway at the time of writing this document are as follows: i) the Training Program in Rainwater Harvesting and Use Systems, supported by the Postgraduate College of Mexico and the Secretariat of the CAC; and, ii) the Central American Program on Water Resources for Irrigation and Drainage, endorsed by the CAC and supported by IICA. It is important to note that in the context of SICA the secretariats of the councils of ministers (including the CAC) and specialized institutions meet three times a year to discuss and assess the outlook for weather conditions. Based on the data available, they identify opportunities and hydrometeorological threats (droughts, floods, irregular rainfall patterns), anticipate their impacts on the different sectors, including agriculture, and formulate recommendations for prevention and mitigation purposes.

Central America has great potential in terms of water use for irrigation in agriculture. At present, the estimated area under irrigation is around 500,000 hectares but the potentially irrigable area exceeds 1.5 million hectares. Implementing irrigation systems based on integrated water resources management is one of the most effective ways of promoting efficient water use, helping the agricultural sector to adapt production to the effects of climate change, enhancing efforts to combat drought as well as improving productivity, the quality of products, risk management and food security in the region. Irrigation would also make it possible to release land for the protection of river basins and the provision of environmental services.

In order to make better use of water and increase its potential for agriculture in this region, it is necessary to: i) strengthen the institutional framework to ensure the efficient application of laws and regulations, ii) intensify river basin initiatives, iii) expand the areas under irrigation and use irrigation systems efficiently, iv) strengthen water users' organizations and improve the management of irrigation systems, v) design and apply measures to regulate water use, vi) promote policies and financial products to encourage the use of irrigation, vii) promote innovation in irrigation through capacity building and training of human resources, and viii) promote the harvesting and use of rainwater.

Andean Region

The Andean region has an enormous wealth of hydrological resources that is capable of providing a powerful engine for development and social well-being, if managed and used in a sustainable way. Average rainfall in this region is 1853 mm/year, just over double the global average. The Andean region has vast water reserves with important transboundary river basins that cover a significant area of territory, offering opportunities for joint management. However, the region's great water potential is limited by the impacts and pressures of supply and demand for this resource, climate change, the El Niño/La Niña phenomenon, the expansion of mining activities, and the location of the growing population.

The Andean Community of Nations (CAN) has developed the Andean Strategy for Integrated Water Resources Management (EA-GIRH), published in 2012 and approved that same year through Resolution No. 763, adopted at the Third Regular Meeting of the Andean Council of Ministers of Foreign Relations. This decision establishes a supranational standard that is a mandatory requirement for the governments of Bolivia, Colombia, Ecuador and Peru. However, it should be noted that the Strategy focuses on the concept of integrated water resource management and does not specify activities of a sectoral nature, for example in agriculture. Responsibility for implementing the Strategy rests with the Council of Ministers of Environment and Sustainable Development of the CAN and the national water authorities of the member countries, in coordination with the General Secretariat of the CAN.

The EA-GIRH prioritizes the following lines of action: i) knowledge management, ii) strengthening of governance, iii) subregional and international cooperation for the implementation of the EA-GIRH, iv) conservation and sustainable use of water resources in member countries, v) actions in response to the effects of climate change on water resources, vi) integrated management of water resources in transboundary river basins, and vii) guidelines and actions for implementing the GIRH by member countries within the Amazon basin.

At the Andean Amazon Regional Dialogue on Water, held in 2012 with the participation of civil society organizations, governments and indigenous peoples of Bolivia, Colombia, Ecuador and Peru, and organized by the Consortium for the Sustainable Development of the Andean Eco-region (CONDESAN) and the Initiative for the Conservation of the Andean Amazon (ICAA), the following six actions were identified and prioritized: i) define a comprehensive approach to land use planning in the Andean Amazon, ii) promote the creation of a regional fund for the protection and conservation of water and associated ecosystems in the Andean Amazon, iii) identify ecosystems, their status, uses and users in each transboundary river basin, iv) design a monitoring system, compatible with the measurement standards used in the different countries of the Andean Amazon, v) identify sources of funding and secure resources for transboundary initiatives, and vi) make an inventory with information on the water supply, regulatory mechanisms and land use planning.

The most significant regional initiatives related to the issue of water for agriculture are as follows: i) good agricultural practices and improvements in irrigation systems as measures for adapting to climate change, an activity of the Adaptation to the Impact of Rapid Glacier Retreat in the Tropical Andes Project (PRAA), aimed at improving water management in agriculture; ii) the Program for Adaptation to Climate Change in the Andean Region (CAN, GIZ, BMZ), which promotes joint measures for adaptation to climate change in agriculture to contribute to food security; iii) the Challenge Program on Water and Food, in which CONDESAN participates, aimed at increasing water productivity and reducing conflicts over water use through the establishment of mechanisms that allow for an equitable distribution of benefits; and, iv) the Investment in Water Protection-Forest Trends Project, backed by the Swiss Agency for Development and Cooperation (COSUDE) with the participation of the Payment Mechanisms Incubator for Ecosystem Services (MINAM/CONDESAN), for Peru, and the Natura Foundation, for Bolivia.

In order to improve and increase the potential of water for agriculture in this region, the first step is to implement the actions of the EA-GIRH. Subsequently, it will be necessary to promote efficient management of water resources through better coordination between water authorities and those of the agricultural sector, improve the management and conservation of watersheds, take advantage of opportunities afforded by transboundary river basins and promote the harvesting and use of rainwater. It is of particular interest to establish equitable agreements on water use between agriculture and other economic activities, particularly mining.

Southern Region

The Southern region is known as one of the world's breadbaskets, and particularly as a leading producer and exporter of soybean, maize and cereals, a great variety of fruits of temperate, tropical and subtropical climates, as well as beef, lamb and poultry products. Commercial agriculture is highly mechanized with an intensive use of irrigation. This region covers a vast area and has a wide range of ecosystems– from the driest deserts to some of the rainiest parts of the world, along with extreme conditions in terms of supply and demand for water resources and water for agriculture.

Average annual rates of water availability in the arid and semiarid regions of Argentina, which comprise 76% of the national territory, amount to less than 14% of the country's surface water resources, 60% of which are found in the Patagonia region. Chile is currently suffering one of the worst droughts of the last 100 years, a situation that has seriously affected the country's production of fruit trees for export from regions III and VII, and seen systems of reservoirs or dams practically dry up. Meanwhile, in Uruguay, an estimated 90% of rainwater ends up in rivers but is lost as it flows out to sea. In most countries of the region, there have been intersectoral conflicts over the use of water, especially between agricultural groups, the hydroelectric energy sector and mining.

Some of the most recurrent problems and constraints identified in the region with regard to water management are the following: i) institutional weaknesses in water planning and management, including the provision of support services, ii) the need to strengthen strategic policies for the management of water resources in order to achieve a balanced use in the different processes and territories, iii) constraints on increasing the quantity and quality of the sustainable water supply, iv) weak or ineffective intersectoral coordination and articulation, v) water scarcity and lack of infrastructure for water storage, vi) lack of regulation of water use for different purposes and rights of access to and use of water by vulnerable groups, vii) poor management of groundwater, viii) limited management capacity among users' organizations and little participation by citizens, and ix) intersectoral conflicts over water use.

However, this region has the advantage of a regional mechanism on water for agriculture that could coordinate efforts aimed at ensuring the integrated management of water resources. At the Twenty-fifth Regular Meeting of the Council of Ministers of Agriculture of the Southern Region, held in Buenos Aires from March 14-15, 2013, the ministers agreed to create an ad hoc group of specialists and technicians of the CAS countries in order to address these issues and exchange relevant experiences.

The Southern region's potential in relation to water for agriculture will be realized if it strengthens its institutional framework with the aim of defining responsibilities and designs more efficient policies for improving water use by increasing and enhancing capacity for planning and management of water resources. The following actions are especially important: i) develop and expand water infrastructure in general, and in particular, facilitate access to water for family agriculture, ii) promote efficient use of water in irrigation agriculture, iii) promote capacity building at all levels, iv) ensure inter-institutional coordination and articulation between the public and private sectors, v) improve regulation of water use and protect water rights, vi) undertake efforts to tackle pollution and degradation of water resources, vii) promote the application of the water footprint, viii) improve institutional information systems and information for users, and ix) improve management of groundwater resources, in order to guarantee their sustainability.

Northern Region

The extensive territories that comprise the Northern Region, which includes Canada, the United States and Mexico, contain a wide variety of climates and extreme conditions of supply and demand for water. In general, the region experiences droughts and floods, but conditions vary greatly in the three countries. While in Canada it is difficult to find any evidence of water scarcity, in the arid regions of northwestern and central Mexico, which are home to 77% of the country's population and generate 85% of the its gross domestic product (GDP), water availability is very limited. That situation contrasts with areas of southern Mexico, where most of the water resources are to be found, but which are home to some of the poorest populations. In many territories of the Northern Region, particularly in Mexico, the aquifers have been over-exploited and polluted, resulting in insufficient water availability, which does not contribute to economic development or environmental sustainability.

The main problems and constraints identified in this region include the following: i) lack of coordination among different government institutions involved in water management, which affects the design and implementation of policies; ii) conflicts between different sectors over water use (irrigation, energy generation, water supply for the population, others); iii) the need to modernize water infrastructure, particularly in the case of Mexico; iv) agricultural practices that still rely on large quantities of water; v) increased water scarcity and growing competition and conflict over water among the sectors that need it; vi) poor water quality, which implies risks for food safety and animal health; and, vii) inefficient conservation practices.

Given the type of political and legal organization prevalent in the countries of the Northern region (federal and state systems in the United States and Mexico, and federal and provincial systems in Canada), there is a high degree of decentralization and autonomy. As a result, water resources management is generally decentralized and most of the decisions in this regard remain in the hands of states, and even of municipalities, counties and provinces, which sometimes makes it difficult to ensure an integrated approach to management in the many economic sectors and regions of the countries.

Although the Northern region has a solid institutional framework, certain reforms may help it to consolidate its leadership in sustainable water management. Some of the areas that offer opportunities are as follows: i) strengthen the institutional framework in order to improve participation by the ministries of agriculture in the management and design of water policies; ii) implement hydro-agricultural projects for water harvesting and conservation, expansion of the water supply, and improved management of surface water resources; iii) promote more intensive actions to adapt agriculture to or mitigate the effects of climate change and provide water for agriculture; iv) design approaches for managing intersectoral conflicts related to water use; v) promote knowledge management and information on good practices in water management for agriculture; vi) support research studies and validate them to improve technologies and innovation in the management of water for agriculture; and, vii) construct the infrastructure works required for the extraction and use of water in agriculture.

This region also has an opportunity to strengthen North-South cooperation to promote the transfer of knowledge, technologies and innovations in water management.

Caribbean Region

The Caribbean region is comprised of 14 countries, which, in addition to the island nations, include Guyana and Suriname. All these countries have different characteristics but share common objectives and problems. They show varying degrees of development in terms of integrated water resources management. Achieving a dependable supply of freshwater is one of the major changes facing the governments of this region. The annual per capita water availability of many of the countries is less than 1000 m^3, a level close to the minimum limits for human development. The Caribbean region uses both surface and underground water, with the form of extraction varying from country to country. In situations where the topography is a constraint to accessing water and demand outstrips the supply, the practice of collecting (or harvesting) rainwater and the desalinization of seawater are common practices.

The recent food crisis and high price variability, which have significantly affected the finances of these countries given their strong dependence on imported food, have forced the region to conduct an in-depth review of all its agricultural and food policies. The Jagdeo Initiative proposes to transform agricultural activities in the region in order to guarantee its food supply and at the same time conserve the natural resource base. The Initiative clearly recognizes that these objectives can only be achieved with the participation of the private sector.

The implementation of this effort and the reactivation of agriculture in the region will generate increased pressure for water, primarily for irrigation. It is therefore urgent to devise policies and strengthen the institutional framework of the ministries of agriculture to coordinate the implementation of the Initiative, guarantee the water supply and prevent pollution (Vergara *et al.* 2013). Investments will also be needed to improve the harvesting and conservation of water. The institutionalization of water use in the Caribbean region is a continuous process. The countries in the region with the most advanced polices are Grenada, Jamaica and Barbados. Other countries are promoting integrated water resources management, including the management of coastal areas and the incorporation of early warning systems. Despite the progress made in recent years, the region does not have a good record as far as the management of river basins and groundwater are concerned. The situation is made more difficult by the topography of the islands, which makes them all but highly vulnerable isolated watersheds, so that phenomena that under other conditions would be localized, are felt throughout the island.

The main recurring problems and constraints identified in this region include the following: i) lack of institutional structures required for the management of water resources (policies, modern legislation, management systems at the national level); ii) urgent need for comprehensive water management strategies for agriculture; iii) failure to devise strategies that would provide a balanced response to demand for water by different economic sectors, without adversely affecting agricultural productivity; and, iv) growing conflicts over the use of water.

The Caribbean region will be able to realize its potential in relation to water for agriculture if the following actions are implemented: i) development of legal instruments to encourage cooperation among water users, ii) training for human resources to promote technical approaches to water use in agriculture, iii) strengthening of government institutions to improve integrated water resources management, and iv) implementation of strategic projects for the efficient use of water for agriculture.

Annex 2
EXPERIENCES IN COUNTRIES OF THE AMERICAS THAT SHOW AN INTEGRATED USE OF WATER IN AGRICULTURE IN PREPARATION FOR CLIMATE CHANGE

Country	Initiatives
Ecuador	• Initiative 1 - National Irrigation and Drainage Plan 2012-2027, MAGAP, of national scope. • Initiative 2 - National Strategy for Climate Change, Ministry of the Environment.
Belize	• Establishment of an irrigation unit in the context of the Agricultural Enterprise Project.
Costa Rica	• Initiative 1 - Design of a National Water Agenda, which includes a chapter on agriculture. • Initiative 2 - Programs for the use and administration of micro-basins. • Initiative 3 - Municipalities with environmental services. • Initiative 4 - Rational water use plans to be implemented by SENARA.
El Salvador	• Initiative 1 - Agro-productive development in irrigation zones through implementation of irrigation technologies for efficient use of water (drip or sprinkler irrigation). The aim is to optimize water use in agriculture through appropriate irrigation technologies. Executed by the MAG through the Division of Irrigation and Drainage, with funding from the Government of Japan. • Initiative 2 - Expansion of agricultural areas under irrigation using systems operated with renewable photovoltaic energy, to be executed in 250 hectares. The aim is to modernize irrigation agriculture and minimize the operating costs of water users. This initiative is executed by the MAG through the Division of Irrigation and Drainage with funding from the Government of Korea. • Initiative 3 - Installation of water treatment plants in irrigation districts for reutilization of wastewaters. The aim is to improve the quality of water for agricultural use and increase its availability for irrigation. Executed by the MAG through the Division of Irrigation and Drainage and water users' associations, and is financed by the Government of El Salvador. • Initiative 4 - Formulation of a regulatory and institutional framework for water use in agriculture (policy and law on irrigation and drainage). Its purpose is to regulate and guide the development of irrigated agriculture. The project is under the responsibility of the MAG and the Technical Secretariat of the Presidency.

Guatemala	• Initiative 1 - National Irrigation Policy. Its objectives are to increase efficiency in production, promote the environmental sustainability of irrigation, expand the area under irrigated agriculture, increase food productivity and net food production, improve governance of water use, increase the competitiveness of small and medium-sized farmers and promote the equitable distribution of benefits stemming from access to irrigation. The institution responsible is the Ministry of Agriculture, Livestock and Food (MAGA). • Initiative 2 - Policy on Agriculture, Livestock, Forestry and Hydro-biological Production. Its aim is to implement sustainable and culturally appropriate production models in agriculture, livestock production, forestry and hydro-biological production, in order to promote comprehensive human development in rural communities. The institution in charge of this initiative is the MAGA. • Initiative 3 - Socio-environmental Policy. Its purpose is to guarantee the environmental sustainability of policies aimed at developing the rural economy.
Honduras	• Initiative 1 - Integrated water resources management (DRH/PRONAGRI). • Initiative 2 - Implementation of investment policies in water storage infrastructure (reservoirs and/or ponds) and distribution of water for irrigation (DRH/PRONAGRI). • Initiative 3 - Administration of technical and financial assistance with international cooperation (DRH/PRONAGRI). • Initiative 4 - Implementation of irrigation projects and programs of different scales (DRH/PRONAGRI). • Initiative 5 - Consolidation of existing large, medium and small-scale irrigation systems (DRH/PRONAGRI).
Nicaragua	• Initiative 1 - Policies to encourage private investment in infrastructure for the capture and distribution of water for irrigation. • Initiative 2 - Policies for environmental fees and penalties. • Initiative 3 - Policies on groundwater resources. • Initiative 4 - Policies on research and extension. • Initiative 5 - Policies for financing private investment.
Panama	• Initiative 1 - Consultations with the private sector. • Initiative 2 - Establishment of four work teams to support the private sector. • Initiative 3 - Geographic Information Systems (GIS). • Initiative 4 - Bank of irrigation projects. • Initiative 5 - Strategic studies, training center on modern irrigation techniques, improvements in the scientific and technical capabilities of MIDA.

Canada	• Improving efficiency in the use of water for agriculture. • Irrigation technologies and innovations for water and energy conservation. • Climate monitoring and programming irrigation systems in real time. • Technologies to improve water quality and treatment for agricultural uses. • Treatment of wastewater from agriculture to reduce the impacts of agricultural activities. • Water footprint of agriculture. • Development of tools to support decision-making in agriculture and facilitate adaptation to climate variability and climate change.
United States	• USDA's Environmental Quality Incentives Program: its purpose is to provide technical, financial and educational assistance to implement management practices, works and "*vegetative practices*" (use of wetlands to remove pollutants from surface run-off and reduce potential for erosion). • Conservation Reserve and Conservation Reserve Enhancement Programs, of the USDA: financial initiatives to encourage farmers and cattle ranchers to protect water, flora, fauna and soil resources voluntarily. • Agricultural Management Assistance (AMA), of the USDA's Natural Resources Conservation Service (NRCS): the aim is to provide technical and financial assistance to rural producers to voluntarily address issues such as water resources management, water quality and erosion control through the adoption of conservation measures in production processes. • The USDA´s Agricultural Water Enhancement Program (AWEP): promotes partnerships between federal, state and local governments, indigenous authorities and non-governmental organizations for water management in watersheds. This incentive program seeks to encourage voluntary conservation through technical and financial assistance to farmers, included in multiyear agreements. • Clean Water Act, Section 319(h) – EPA: the objective is to provide funding to indigenous and state agencies to implement approved programs and activities that are non-specific sources of contamination, such as agriculture.
Argentina	• Initiative 1 - Provincial Agricultural Services Program (PROSAP), managed by the Unit for Rural Change (UCAR) of the Ministry of Agriculture, Livestock and Fisheries. The aim is to design and implement socially and environmentally sustainable public investment programs at the provincial and national levels (including irrigation and drainage projects), in order to increase the coverage and quality of rural infrastructure and agrifood services.

Argentina *(Continued)*	• Initiative 2 - Sustainable Water Resources Management Project for the Agricultural Sector, implemented in the context of the Strategic Area of Natural Resources of the National Agricultural Technology Institute (INTA), which in turn includes the following specific projects: - Technology Development for the Optimization of Irrigation. - Dynamics of the Water Supply for the Agriculture and Forestry Sectors of Argentina. - Integrated Water Management for Family Agriculture and Producers in Rain-fed Areas. - Hydrological Modeling for Watershed Planning: the main objectives are: a) to strengthen internal and inter-institutional networks; b) to increase training of human resources; c) to develop a database and a mechanism for determining the water footprint of products and services; d) to update the characterization of different agricultural uses; e) to develop, update and validate methodologies for predicting water availability; f) to apply hydrological models to different geo-morphological conditions; g) to incorporate the use of remote sensors for the characterization and definition of performance indicators at the regional level; and h) to develop and validate technologies for water harvesting and use in agriculture, livestock production and forestry for different types of producers.
Brazil	• Initiative 1 - Project for the Integration of the São Francisco River with the Hydrographic Basins of the Northeast (PISF): this initiative involves integrating the São Francisco river with the basins of the seasonal rivers in the semi-arid region, through the continuous extraction of 26.4 m^3/s of water, equivalent to 1.4% of the volume of water from the Sobradinho dam (1850 m^3/s) in the stretch of the river where the water will be captured. This volume of water will be earmarked for consumption by urban communities in 390 municipalities of the regions of Agreste and the Sertão, in the four states of the Northeast. During the years when the Sobradinho dam is generating water, the volume captured can be increased up to 127 m^3/s, thereby helping to guarantee the water supply for multiple uses (Ministry of National Integration). • Initiative 2 - Program 2013 – Irrigated Agriculture. Its objectives are: a) to complete implementation of the stages necessary to make existing public irrigation projects viable, b) to revitalize the public infrastructure and c) to promote exploration of areas where projects have already been implemented according to environmental legislation, with a view to transferring their management. The goals are the following: a) to promote technical assistance and rural extension services in areas with irrigated agriculture, seeking to promote the rational use of soil and water and effective crop management; b) to promote training on irrigated agriculture in conjunction with governmental, non-governmental institutions and the private sector; c) to promote the implementation of new projects in areas with potential for irrigated agriculture and expand

Brazil *(Continued)*	agricultural production with greater value added; and d) to reformulate the legal framework of the National Irrigation Policy, prepare the National Irrigation Plan and restructure the management of irrigated agriculture in coordination with relevant public policies. Institution responsible: Ministry of National Integration. • Initiative 3 - Water Producer: the objective is to reduce erosion and sedimentation in water springs in rural areas. This voluntary program contemplates technical and financial support for the execution of water and soil conservation efforts, e.g. through the construction of terraces and infiltration (recharge) basins, improvement of rural roads, restoration and protection of water sources, reforestation of permanent protection areas and legal reserves, environmental sanitation, etc. It also contemplates the payment of incentives (or some form of financial compensation) for rural producers who contribute to the protection and recovery of springs, thereby generating benefits for the watershed and the population. The incentives are delivered only after the partial or full implementation of previously agreed conservation actions and practices and the amounts paid are based on the results obtained: control of erosion and sedimentation, reduction of contamination and increased water infiltration in the soil. Institution responsible: ANA. • Initiative 4 - Incentives Program for Irrigation and Storage (Moderinfra): the Ministry of Agriculture, Livestock and Food Supply (MAPA) supports the use of irrigated agriculture. In addition to generating income for producers, the rational use of water for irrigation helps preserve the environment, making this technique sustainable and profitable. The MAPA has policies to promote this technique, which is already known to farmers, together with specific credit lines, such as the Incentives Program for Irrigation and Storage (Moderinfra), to encourage the use of irrigation on small, medium and large farms. During the current sugar cane harvest, Moderinfra is offering producers R$1000 million in funds to join the program. This financing, with an annual interest rate of 6.75%, allows for repayment over a 12-year period. By promoting the use of irrigated agriculture, the federal government believes that farmers will be better prepared to address climatic phenomena that affect the agricultural sector, not only in the semi-arid region, but also in other parts of the country where irrigation is required. As a complement to this practice, agricultural drainage systems should be included in irrigation projects, given the importance of controlling excess water and reducing the process of salinization in irrigated lands. Institution responsible: MAPA. • Initiative 5 - One Million Cisterns Program (*Programa Um Milhão of Cisternas*)(P1MC) and One Earth Two Waters Program (*Programa Uma Terra e Duas Aguas*) (P1+2): - The P1MC aims to provide nearly five million inhabitants of Brazil's semiarid region with water for drinking and cooking through the construction of one million cisterns, which together would create a

Brazil *(Continued)*	decentralized water supply infrastructure with capacity to deliver 16,000 million liters of water. Institution responsible: Articulação do Semiárido (ASA). - The objective of P1+2 is to go beyond the harvesting of rainwater for human consumption, and move toward sustainable land use and integrated water resources management for food production (livestock and crops) thereby promoting food security and generating income. In the Northeast region, a national strategy is being implemented to focus actions on resolving the problems of water scarcity, while in other regions (North, Western-central, South and Southeast Brazil) the main objective is to guarantee water quality.
Chile	• Initiative 1 - Reservoir Plan, sets priorities for new regulation works that will generate new rights and water security (Council of Ministers of the National Irrigation Commission - CNR). • Initiative 2 - Regulations on Environmental Flows, which includes environmental variables in granting water rights (Directorate General of Waters, DGA - Ministry of Environment). • Initiative 3 - Groundwater Regulations, for the coordination of infiltration projects (DGA). • Initiative 4 - Water Resources Strategy, which defines strategic guidelines for the country's future water management actions (DGA) and Amendment of the Water Code, which increases the penalties for unauthorized water use and theft, increases the authority and supervisory powers of the DGA and facilitates registration of water users' organizations (DGA). • Initiative 5 - Amendment of Law 18.450, which will allow financial incentives for medium-scale works, thereby increasing the current number of beneficiaries (CNR).
Paraguay	• Initiative 1 - Strategy: Cultivating Good Water. The aim is to promote the sustainable management of water, biodiversity and soils in the Parana River Basin, taking into account all communities in the area. A total of 29 municipalities benefit from this strategy, which consists of 20 programs and 63 projects. A total of 2146 organizations are participating with a view to promoting sustainable development in the region through environmental education and citizen participation, which is one of the key aspects of the strategy. • Initiative 2 - Project for the Modernization of the Water and Sanitation Sector in the Oriental Region of Paraguay, coordinated by the Secretariat for the Environment (SEAM). Its purpose is to map and codify Paraguay's hydrographic resources. • Initiative 3 - Watershed-based Management Program, coordinated by Itaipú. In large watersheds, the health of a river is the direct consequence of measures used to control surface run-off and promote water infiltration in the soil, prevent erosion, reduce the amount of sediments and nutrients and preserve biodiversity in the watershed, ensuring connectivity between different micro-basins.

Paraguay *(Continued)*	• Initiative 4 - Project for the Modernization of the Water and Drainage Sector in the Oriental Region of Paraguay. • Initiative 5 - The Itaipú Technological Park and the United Nations Educational, Scientific and Cultural Organization (UNESCO) are preparing to establish the International Hydro-informatics Center in Foz do Iguaçu, an initiative that involves Paraguayan and Brazilian institutions and government bodies. The first international contacts are already been made by representatives in LAC universities.
Uruguay	• Initiative 1 - Chapter 5 - Lines of Action "Towards a National Integrated Water Resources Management Plan." • Initiative 2 - Call for draft projects involving irrigation and associative use of water for production (MGAP). • Initiative 3 - Irrigation Projects of the Department of Natural Resources and of the Ministry. • Development and Adaptation to Climate Change Project (DACC). "Sustainable Natural Resources Management and Adaptation to Climate Change" (IBRD loan 8099-UY).
Dominica	• FAO/TCP: Feasibility study for small-scale irrigation projects, 1998. • Penville Savanne Irrigation Project (less than 40 acres), FAO, 2008. • Castle Bruce Irrigation Scheme (250 acres), funded by the European Union (EU), 2005. • Calibishie Irrigation Project (320 acres), funded by the EU, 2010. • Milton and Syndicate Irrigation Project (50 acres), Caribbean Community Climate Change Centre (CCCCC)/World Bank, 2011.
Guyana	• Takuma Conservancy (reservoir), to provide water for irrigation (Region 2). • Boerasine Conservancy, for irrigation purposes (Region 3). • East Demerara Conservancy, for irrigation purposes (Region 4). • Mahaica, Mahaicony and Abary (MMA) National Irrigation and Drainage Project. • Black Bush Polder irrigation and drainage system.
Haiti	• Initiative 1 - Water users' committee. • Initiative 2 - Benefits for water users' committees. • Initiative 3 - Improve seed availability for water users' committees. • Initiative 4 - Training.
Jamaica	• National Irrigation Development Programme (NDIP), with 51 irrigation projects nationwide. • Small-Scale Irrigation System Supported by Rainwater Harvesting Techniques - Drip Irrigation Project. • Program "Arable Lands Irrigated and Growing for the Nation" (ALIGN).
St. Vincent and the Grenadines	• Establishment of a centralized micro-irrigation system covering 1700 acres (nearly 688 ha), 1998-2003

Trinidad and Tobago	• National Sugar Adaptation Strategy, reform of the sugar cane sector, Ministry of Food Production. • On Farm Water Management (IWRM Stakeholder Forum), water use efficiency and pollution management in the agricultural sector, WRA/ WASA. • Model Farm, demonstration of closed loop system for water use in agricultural activities, PCS Nitrogen. • Mega Farms to encourage cooperatives, Ministry of Food Production. • Strategy for Improved Water Use, WRA.

Annex 3. WATER INFRASTRUCTURE IN COUNTRIES OF THE AMERICAS

A) Area under water management: area equipped for irrigation

	Full control irrigation					
Country	Surface irrigation (1000 ha)	Sprinkler irrigation (1000 ha)	Localized irrigation (1000 ha)	Total area equipped for irrigation (1000 ha)	As percentage of cultivated area (%)	Area actually irrigated (1000 ha)
Antigua and Barbuda	0.003	0.03	0.10	0.13	2.60	
Argentina	1390.00	65.21	0.00	1550.00	5.47	1356.00
Bahamas						
Barbados				5.44	31.97	
Belize				3.00	3.06	
Bolivia	127.90	0.31	0.00	128.20	3.91	128.20
Brazil	1860.00	2413.00	328.00	5400.00	6.83	4454.00
Canada	180.90	683.00	6.03	869.90	1.74	
Chile				1199.00	44.31	1094.00
Colombia		37.27	6.04	1087.00	27.19	
Costa Rica	85.48	3.90	13.70	103.10	21.04	101.50
Dominica						
Ecuador	663.90	170.10	19.40	853.40	32.82	619.90
El Salvador	40.04	4.95	0.00	44.99	5.51	
United States of America				26 644.00	16.20	22 229.00
Grenada	0.00	0.03	0.19	0.22	1.99	
Guatemala	198.60	94.43	19.08	312.10	12.41	312.20
Guyana	150.10	0.00	0.00	150.10	29.78	
Haiti	91.50	0.00	0.00	97.00	7.58	65.42
Honduras	73.21	0.00	0.00	87.85	6.02	61.00
Jamaica	19.04	4.41	1.76	25.22	9.70	25.22
Mexico	5802.00	310.80	143.10	6460.00	22.94	5439.00
Nicaragua	61.37	0.00	0.10	94.24	4.22	50.93
Panama	25.73	8.32	0.57	34.62	5.22	27.48
Paraguay				67.00	2.03	
Peru	1176.00	11.98	7.70	1196.00	28.08	1109.00
Dominican Republic	269.70	0.00	0.00	306.50	24.52	269.70
Saint Kitts and Nevis	0.00	0.00	0.02	0.02	0.26	
Saint Vincent and the Grenadines						
Saint Lucia				3.00	30.00	
Suriname	50.32	0.86	0.00	51.18	98.42	51.18
Trinidad & Tobago	2.89	0.71	0.12	3.60	5.54	3.06
Uruguay	181.00	0.00	0.00	181.00	13.90	181.00
Venezuela	356.10	72.80	20.80	1055.00	32.46	978.80

Source: FAO 2013 (http://www.fao.org/nr/aquastat/).
This information corresponds to the most recent data, obtained during the period 1997-2011.
1 ha = 1 hectare = 10,000 m²

B) Infrastructure: area equipped for irrigation and percentage of cultivated area

Continent/ region	Sub-region	Surface equipped for irrigation (millions of hectares)			By groundwater		Percentage of cultivated area equipped for irrigation		
					Area	Percentage of total			
		Years							
		1970	1990	2009	2009	2009	1970	1990	2009
North America		**20.0**	**27.2**	**30.2**	**17.6**	**58.4**	**7.5**	**10.2**	**12.3**
	United States and Canada	16.4	21.6	23.9	15.0	62.9	6.7	9.0	11.0
	Mexico	3.6	5.6	6.3	2.6	41.3	15.5	21.3	22.6
Central America and the Caribbean		**0.9**	**1.7**	**1.8**	**0.6**	**33.9**	**7.8**	**11.9**	**12.0**
	Central America	0.2	0.4	0.5	0.1	21.4	3.8	5.6	6.6
	Caribbean - Greater Antilles	0.7	1.3	1.3	0.5	39.5	12.5	18.9	18.4
	Caribbean – Lesser Antilles and Bahamas	0.0	0.0	0.0	0.0	25.5	2.5	7.6	13.9
South America		**5.7**	**9.4**	**12.4**	**2.0**	**16.5**	**6.3**	**8.6**	**9.8**
	Guyana	0.1	0.2	0.2	0.0	0.0	34.9	32.8	40.7
	Andes	2.2	3.3	3.8	0.6	16.5	14.0	18.4	21.5
	Brazil	0.8	2.7	4.5	1.0	21.7	1.9	4.7	6.6
	South America	2.6	3.3	3.8	0.4	11.4	7.6	9.6	9.7
Americas total		**26.6**	**38.3**	**44.4**	**20.3**	**45.7**	**7.2**	**9.8**	**11.5**

Source: FAO 2013 (http://www.fao.org/nr/aquastat/).

C) Area equipped for full control irrigation

Country	Irrigation by surface water (1000 ha)	Irrigation by groundwater (1000 ha)	Irrigation by mixed groundwater and surface water (1000 ha)	Percentage of area irrigated with surface water	Percentage of area irrigated with groundwater
Antigua and Barbuda					
Argentina					
Bahamas					
Barbados					
Belize					
Bolivia	119.30	8.90	0.00	93.06	6.94
Brazil	2325.00	545.30	0.00	80.79	18.95
Canada					
Chile	1841.00	58.90	0.00	96.90	3.10
Colombia					
Costa Rica	85.60	17.52	0.00	83.03	16.99
Dominica					
Ecuador	853.90	9.50	0.00	98.90	1.10
El Salvador				97.00	3.00
United States of America		10 835.00			40.11
Grenada					
Guatemala	122.30	7.50	0.00	94.22	5.78
Guyana					
Haiti					
Honduras					
Jamaica					
Mexico	4129.00	1689.00	437.90	66.00	27.00
Nicaragua	18.41	42.96	0.00	30.00	70.00
Panama	34.27	0.35	0.00	98.99	1.00
Paraguay					
Peru	1064.00	131.50	0.00	88.96	10.99
Dominican Republic	210.40	59.33	0.00	78.01	22.00
Saint Kitts and Nevis					
Saint Vincent and the Grenadines					
Saint Lucia					
Suriname	51.18	0.00	0.00	100.00	0.00
Trinidad and Tobago					
Uruguay	174.00	7.25	0.00	96.00	4.00
Venezuela	440.70	8.99	0.00	98.00	2.00
Total	**11 469.06**	**13 422.00**	**437.90**	**86.66**	**14.56**

Source: FAO 2013 (http://www.fao.org/nr/aquastat/; consulted on April 9, 2013).

D) Infrastructure: Tallest dams in the Americas (more than 130 m high)

No.	Country	Name of dam	River	Location	Year (service)	Height (m)	Width (m)
1	Argentina	Piedra del Águila	Limay	Provinces of Río Negro and Neuquén	1992	170	820
2	Argentina	Presa de Alicurá	Limay	Patagonia	1985	135	880
3	Brazil	Presa Campos Novos	Canoas	Campos Novos	2006	202	600
4	Brazil	Represa de Itaipú	Paraná		1984	196	7760
5	Brazil	Represa de Barra Grande	Canoas	Rio Grande do Sul	2005	185	665
6	Brazil	Presa Emborcação	Paranaíba	Araguari, Minas Gerais	1983	158	1507
7	Brazil	Serra da Mesa	Tocantins		1998	154	1544
8	Brazil	Represa de Foz de Areia	Iguazú	Paraná State	1980	153	828
9	Brazil	Gobernador Ney Braga	Iguazú	Segredo, Paraná	1992	145	700
10	Brazil	Presa de Xingó	São Francisco	Alagoas and Sergipe	1994	140	830
11	Canada	Mica Dam	Columbia	Revelstoke, British Columbia	1961	243	792
12	Canada	Daniel-Johnson Dam (Manic 5)	Manicouagan	Quebec	1970	214	1314
13	Canada	W. A. C. Bennett Dam	Peace	British Columbia	1968	190.5	2040
14	Canada	Revelstoke Dam	Columbia	British Columbia	1984	174	1630
15	Canada	Denis-Perron Dam (Sainte-Marguerite-3)	Sainte-Marguerite	Quebec	2001	171	378
16	Canada	Robert Bourassa	La Grande Rivière	Quebec	1981	168	2826
17	Chile	Presa Ralco	Bío Bío	Bío Bío Region	2002	155	360
18	Colombia	Presa de El Guavío	Guavío	Department of Cundinamarca	1992	243	390
19	Colombia	Presa del embalse La Esmeralda	Batá	Department of Boyacá	1998	237	310
20	Colombia	Presa Ituango	Cauca	Ituango, Department of Antioquia	2018	225	
21	Colombia	Presa Lengupá	Lengupá			215	660
22	Colombia	Presa Andaquí	Caquetá			206	800
23	Colombia	Presa Sogamoso	Sogamoso	Bucaramanga, Department of Santander	2013	190	
24	Colombia	Presa Miel I (o Patángoras)	La Miel	Norcasia	2003	188	200
25	Colombia	Represa Salvajina	Cauca	Department of Cauca	1985	154	400
26	Colombia	Presa Porce III	Porce	Department of Antioquia	2011	151	426
27	Ecuador	Represa de Paute (o Daniel Palacios)	Paute		1991	170	420
28	Ecuador	Ingapata	Paute			166	

No.	Country	Name of dam	River	Location	Year (service)	Height (m)	Width (m)
29	Ecuador	Guayllabamba	Guayllabamba	Province of Pichincha		165	413
30	Ecuador	Presa Paute-Mazar	Mazar		2010	165	310
31	United States	Oroville Dam	Feather	Oroville, Butte County, California	1968	235	2317
32	United States	Hoover Dam	Colorado		1935	221.46	379.2
33	United States	Dworshak Dam	Clearwater (North Fork)	Clearwater County, Idaho	1973	218.6	1002
34	United States	Glen Canyon Dam	Colorado		1966	216.4	475.4
35	United States	New Bullards Bar Dam	Yuba (North Fork)	Yuba County, California	1969	196.6	789
36	United States	Seven Oaks Dam	Santa Ana	Mentone, San Bernardino County, California	2000	193	910
37	United States	New Melones Dam	Stanislaus	Jamestown, California	1979	190.5	475.5
38	United States	Swift Dam	Lewis	Skamania County, Washington	1958	186	640
39	United States	Mossyrock Dam	Cowlitz	Lewis County, Washington	1968	184.7	502
40	United States	Shasta Dam	Sacramento	Shasta County, California	1945	183.5	1054.5
41	United States	New Don Pedro Dam	Tuolumne	La Grange, California	1971	178	853
42	United States	Hungry Horse Dam	Flathead	Flathead County, Montana	1953	171.9	645
43	United States	Arroyo Bruno Irrigation Reservoir	Arroyo Bruno	Custer County, Idaho	1983	168	
44	United States	Grand Coulee Dam	Columbia	Grant y Okanogan Counties, Washington	1942	167.6	1592
45	United States	Ross Dam	Skagit	Whatcom County, Washington	1949	165	396
46	United States	Trinity Dam	Trinity	Weaverville, California	1962	164	793
47	United States	Yellowtail Dam	Big Horn	Big Horn County, Montana	1967	160	451
48	United States	Cougar Dam	McKenzie (South Fork)	Lane County, Oregon	1964	158	488
49	United States	Flaming Gorge Reservoir	Green	Daggett County, Utah	1964	153	360
50	United States	Morrow Point Dam	Gunnison	Cimarron, Gunnison County, Colorado	1968	143	211
51	United States	Bath County PS Upper Dam	Creek	Bath County, Virginia	1985	140	
52	United States	Carters Dam	Coosawattee	Chatsworth, Murray County, Georgia	1977	136	
53	Honduras	Presa El Cajón Dam	Humuya	Department of Cortés	1985	234	382
54	Mexico	Presa Chicoasén	Grijalva	Chiapas	1980	261	485

No.	Country	Name of dam	River	Location	Year (service)	Height (m)	Width (m)
55	Mexico	Presa Álvaro Obregón	Mextiquic	Sonora	1952	260	88
56	Mexico	Presa La Yesca	Grande de Santiago	La Yesca, Nayarit	2012	220	628
57	Mexico	Presa Zimapán	San Juan, Tula y Moctezuma	States of Hidalgo and Querétaro	1993	203	50?
58	Mexico	Presa Aguamilpa	Grande de Santiago	Nayarit	1994	187	660
59	Mexico	Presa El Cajón	Grande de Santiago	Nayarit	2007	178	640
60	Mexico	Presa Huites (o Luis Donaldo Colosio)	Fuerte	Sinaloa State	1995	155	430
61	Mexico	Presa Infiernillo	Balsas	Guerrero State, Michoacán	1964	149	350
62	Mexico	Presa La Angostura (o Belisario Domínguez)	Grijalva	Chiapas	1974	144	300
63	Mexico	Presa Malpaso (o Netzahualcóyotl)	Grijalva	Chiapas	1964	137,5	478
64	Mexico	Embalse El Novillo (Plutarco Elías Calles)	Yaqui	Sonora	1964		188
65	Paraguay						
66	Peru	Presa de Antamina	(balsa de relaves)	Huaraz, Ancash Region	2001	209	1 050
67	Venezuela	Represa del Guri	Caroní	Bolívar	1978	162	7 426
68	Venezuela	Presa Ing. José María Ochoa Pile	Yacambú	Lara		162	?

Source: Wikipedia 2013.

Annex 4
EXAMPLES OF THE INSTITUTIONAL FRAMEWORK THAT REGULATES WATER USE IN AGRICULTURE IN SELECTED COUNTRIES OF THE AMERICAS

Country	Institutions, laws, decrees and regulations
Argentina	• The National Constitution of 1994 establishes that "the provinces hold the original right of property over the natural resources existing in their territory." • Argentina currently has no national water act. • The present national legislation consists basically of the provisions contained in the Civil Code, the Commercial Code, the Mining Code and the Criminal Code, as well as various federal laws such as those on energy, navigation, transport, ports, protection of the environment and natural resources, etc., which include provisions directly or indirectly related to water. • Law No. 25.688 (2002), Environmental Water Management System. • At the provincial level, the legal situation varies considerably. Some provinces have no specific legislation, while others have a highly developed regulatory framework. • Provincial water laws: the first of these was the law of Mendoza Province (1884), which created the General Department of Irrigation (DGI), the body currently responsible for water management, and instituted the participation of irrigators in water use. • The Sub-secretariat of Water Resources, in its capacity as a national coordination body on water policy, together with the Federal Water Council, led the process to draft the National Federal Water Resources Plan. The general objective of this Plan is to promote integrated water resources management (IWRM) through a participatory process that facilitates coordination and cooperation among all water and non-water organizations that have an impact on water management.
Brazil	• National Council for Water Resources • National Water Agency • State and Federal Water Councils • Watershed Committees • Ministry of Planning, Budget and Management • Ministry of Agriculture, Livestock and Food Supply • Ministry of the Environment • Ministry for National Integration • Valle do San Francisco Development Company

Ecuador	• The Constitution of Ecuador establishes that the sole authority responsible for water in the country is the National Water Secretariat (SENAGUA). Its mission is to oversee the comprehensive and integrated management of water resources throughout the national territory through the implementation of policies, standards and decentralized mechanisms of control and management, which result in the efficient administration and use of water. SENAGUA forms part of the Ministry for the Coordination of Strategic Sectors. • Ministries, government agencies and institutions recognize SENAGUA as the only authority responsible for water in the country. • In agriculture, responsibility for the treatment of water for irrigation rests with the Ministry of Agriculture, Livestock, Aquaculture and Fisheries (MAGAP) and the Provincial Decentralized Autonomous Governments (provincial GADs), under the authority of SENAGUA. The GADs have specific responsibility for irrigation, in accordance with the General Code of Territorial Organization, Autonomy and Decentralization (COOTAD). • SENAGUA has the necessary policy instruments for the integrated management of irrigation. • The country has policies for watersheds and for water use rights. • Efforts have also been made to develop information and tariff systems (volumetric rate: SENAGUA; basic rate: GAD). • Some systems are administered, operated and maintained by rural communities, to which SENAGUA transfers its authority. • The Sub-secretariat of Irrigation and Drainage of MAGAP coordinates its actions through the National Irrigation and Drainage Plan, which is under the general coordination of the Secretary of Irrigation and Drainage.
Costa Rica	• Law 276 of 1942, Water Law. • Law 2726 of 1961, Creation of the Costa Rican Institute of Aqueducts and Sewers (AyA). • Law 6877 of 1983, Creation of the National Groundwater, Irrigation and Drainage Service (SENARA). • MINAE Executive Decree No. 32529-S of February 2, 2005, Regulations for Associations that Administer Community Aqueducts and Sewer Systems (ASADAS). • National Groundwater, Irrigation and Drainage Service (SENARA). • Costa Rican Institute of Aqueducts and Sewers (AyA). • Associations that Administer Community Aqueducts and Sewer Systems (ASADAS).
United States	• No integrated system exists for the management of water resources. • Integrated water resources management is carried out through federal laws and regulations, state-level statutes, federal and state institutions and guidelines and policies issued by government agencies that promote inter-sectoral cooperation.

United States *(Continued)*	• There is much confusion regarding the roles and responsibilities of each institution in the management of water resources, due to the large number of government agencies involved in this sector. • U.S. Army Corps of Engineers and Department of the Interior's Bureau of Reclamation: water infrastructure. • U.S. Geological Survey: information on water availability and water use. • Environmental Protection Agency, Department of Commerce's National Marine Fisheries Service, U.S. Fish and Wildlife Service: administration of laws related to clean water and the protection of flora and fauna. • Other institutions involved in water management include: the Farm Service Agency, Economic Research Service, Forest Service, Natural Resources Conservation Service, Rural Utilities Service (all under the United States Department of Agriculture, USDA); Economic Development Administration, National Oceanic and Atmospheric Administration (both under the Department of Trade; Food and Drug Administration, Centers for Disease Control and Prevention. • Most water management activities are carried out by state or local agencies and institutions. • No single federal agency is responsible for water resources management; in most cases, responsibility rests mainly with state authorities, except on some issues such as the definition of quality standards for federal water projects and the settlement of disputes between indigenous groups over water use.
Canada	• Responsibility for the management of water resources is shared among federal, provincial and municipal governments, as well as the governments of native peoples. • Federal Government: is responsible for the conservation and protection of oceans and their resources; other water resources under the responsibility of the federal government include cross-border water resources that Canada shares with the United States. • Provincial governments: are responsible for certain legal aspects related mainly to the management and protection of water resources. • Municipal (local) governments: are responsible for the treatment and distribution of water and for the collection and treatment of wastewater in urban areas. • Ministry of the Environment of Canada: is responsible for licensing activities that could alter the beds/banks of rivers that flow through the territory of Canada and the United States. • Department of Fisheries and Oceans: responsible for the management of fisheries and the protection of oceans. • Health Canada: establishes water quality standards for potable water and is responsible for science and research on health issues in Canada. • First Nations: shared management with indigenous peoples of the development of Northern Canada.

Peru	• Water Resources Act: establishes the National Water Authority and integrated and multi-sectoral water management. • Regulations of the Water Resources Act. • General guidelines for the creation of Water Councils for Watersheds — National Water Authority (ANA) 2011—. • Guides and manuals for assessments of water resources prepared by the ANA. • Enactment of State Policy on Water Resources as part of the National Agreement. • Environmental Services Act, aimed at promoting integrated watershed management.

About the Authors

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