WATER FOR FOOD SECURITY AND WELL-BEING IN LATIN AMERICA AND THE CARIBBEAN

This volume provides an analytical and facts-based overview of the progress achieved in water security in Latin America and the Caribbean (LAC) region during the last decade, and its links to regional development, food security and human well-being. Although the book takes a regional approach, covering a vast amount of data pertaining to most of the LAC region, some chapters focus on seven countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru).

A full understanding of LAC's progress requires framing this region in the global context: an ever more globalized world where LAC has increasing geopolitical power and a growing presence in international food markets. The book's specific objectives are: (1) exploring the improvements and links between water and food security in LAC countries; (2) assessing the role of the socio-economic 'megatrends' in LAC, identifying feedback processes between the region's observed pattern of changes regarding key biophysical, economic and social variables linked to water and food security; and (3) reviewing the critical changes that are taking place in the institutional and governance water spheres, including the role of civil society, which may represent a promising means to advancing towards the goal of improving water security in LAC.

The resulting picture shows a region where recent socioeconomic development has led to important advances in the domains of food and water security. Economic growth in LAC and its increasingly important role in international trade are intense in terms of use of natural resources such as land, water and energy. This poses new and important challenges for sustainable development. The reinforcement of national and global governance schemes and their alignment on the improvement of human well-being is and will remain an inescapable prerequisite to the achievement of long-lasting security. Supporting this bold idea with facts and science-based conclusions is the ultimate goal of the book.

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Water for Food Security and Well-Being in Latin America and the Caribbean
Social and Environmental Implications for a Globalized Economy

Edited by Bárbara A. Willaarts, Alberto Garrido and M. Ramón Llamas

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

earthscan
from Routledge

First published 2014
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

And by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
Water for food security and well-being in Latin America and the Caribbean: social and environmental implications for a globalized economy / edited by Bárbara A. Willaarts, Alberto Garrido, M. Ramón Llamas.
pages cm
Includes bibliographical references and index.
TD227.5.W38 2014
338.1'98–dc23
2013043668

ISBN: 978-0-415-71368-9 (hbk)
ISBN: 978-1-315-88313-7 (ebk)

Typeset in Futura Std light
by M. Carmona

Publisher's note
This book has been prepared from camera-ready copy provided by the authors.

To Eduardo, for his unconditional support, and to Jacques, for his courage
Bárbara A. Willaarts

To my sons, Andrés and David
Alberto Garrido

To Alvaro del Portillo, for his life example and advice
M. Ramón Llamas

Contents

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Tables

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Foreword

In 1964 Marcelino Botín Sanz de Sautuola and his wife Carmen Yllera, founded the Marcelino Botín Foundation to promote social development in Cantabria, in the north of Spain. Today the Foundation, faithful to the spirit of its founders and after nearly 50 years of work, is Spain's number one private foundation both in terms of the investment capacity and social impact of its programmes.

The Botín Foundation's objective is to stimulate the economic, social and cultural development of society. To achieve this, it acts in the fields of art and culture, education, science and rural development, supporting creative, progress-making talent and exploring new ways of generating wealth. Its sphere of action focuses primarily on Spain and especially on the region of Cantabria, but also on Latin America. The main office is located in the city of Santander, the capital of Cantabria, in what used to be the Sanz de Sautuola family´s house. Its exhibition room is located nearby. Two of the city's emblematic buildings, El Promontorio and Villa Iris, are used for official ceremonies, exhibitions and workshops. The Casa Rectoral in Puente Pumar is the Foundation's centre of operations in the Nansa Valley (Cantabria).

Since the end of 2012 a refurbished, former industrial building in the centre of Madrid houses the Foundation's offices in the capital. In 2014, coinciding with its 50th anniversary, the new Botín Centre will be opened in Santander.

In 2008 the Board of the Botín Foundation decided to create a section devoted to water resources within its Trends Observatory, under the title of Water Observatory of the Botín Foundation. The overarching theme of the Water Observatory is improving water management, using innovative approaches, independent thinking and debates. During the last six years, the water programmes of the Foundation have looked at, among others, groundwater issues, water governance, the role of trade in water resources management, water footprint evaluations and water policy. Carrying out independent research and studies, disseminating the findings and engaging in honest debates with stakeholders, politicians and scientists from all over the world have been the main priorities of the Water Observatory. All our publications and seminar materials can be freely accessed from the Foundation's web page.

The Botín Foundation seeks to make a different in the way water resources are managed and governed in Spain and around the world. This book on water and food security in Latin American is the result of two years of collaborative work with dozens of scientists from both sides of the Atlantic and seven prestigious institutions of Argentina, Brazil, Chile, Colombia, Cost Rica, Mexico and Peru. We hope scientists, politicians and stakeholders from all over the world and, especially from Latin America, find in this book useful ideas and inspiration to lead their work in water issues and contribute to a more equitable and sustainable use of this vital resource.

Íñigo Sáenz de Miera y Cárdenas
General Director of the Botín Foundation

Preface

The Botín Foundation was created in 1964, but began its activity in the field of water resources in 1998 when it launched the Groundwater Project (Proyecto Aguas Subterraneas or PAS), one of the first interdisciplinary assessments of groundwater governance. The project, which I was honoured to coordinate, showcased Spain as an example of many of the ethical dilemmas faced by countries across the world, such as the intensive use of groundwater resources for development. This project has been followed by various workshops organized mainly in Santander since 2003, and then published as part of a series of essays under the following titles: *'Water Crisis: myth or reality?'* in 2004; *'Water and Ethics'* in 2007; *'Water and Food Security in a Globalised World: ethical issues'* in 2010; *'Water, Food and Agriculture in Spain: can we square the circle?'* in 2013. The latest workshop on *'Integrated Water Resources Management in the 21st Century: revisiting the paradigm'* took place in Madrid in November 2013, and the book of the proceedings will be published in 2014.

In 2008 the Board of the Botín Foundation decided to create a section devoted to water within its Trends Observatory, under the title of *Observatorio del Agua de la Fundación Botín* (Water Observatory of the Botín Foundation). In the last few years, all the water programmes of the Water Observatory (WO) have focused on three goals: to develop independent research and studies, to disseminate the findings and to create a venue for debate and discussions. A team of twelve researchers, assisted by an active advisory board of three members, has devoted its energies, skills and talent to formulating relevant research questions, obtaining rigorous answers and communicating these findings where the ultimate goal is to enhance the quality and relevance of political decision making with regard to water issues in Spain and around the world.

In virtually all its programmes and activities, the WO has sought to team up and create partnerships with the most respected scholars, public officers, business managers and representatives of international organizations from all over the world. Openness and independence have always been the foundations of the Observatory.

Between 2008 and 2012 most of the publications, seminars, workshops and activities have focused on Spain's water problems. Much of the substantive judgement and most of the recommendations drawn from this line of work were published in 2013 in the essay *'Agriculture and the Environment in Spain: can we square the circle?'* and then in Spanish in a shorter volume called *'El agua en España: bases para un pacto de futuro'* ('Water in Spain: the basis for a future pact'). A single sentence synthesizes this line of work by the Water Observatory: water problems in Spain are not related to physical scarcity, but to poor governance. As the book outlined, recent technological and social advances can help to achieve better governance in a way that is socially and economically acceptable. One of the main efforts of the WO is to create a general awareness of this to the society at large.

A fundamental transformation of Spain's water problems and a change in paradigm, focus and thinking came about when the role that international trade with agricultural commodities was outlined in the WO work *'Water Footprint and Virtual Water Trade in Spain: policy implications'*, published in 2010. By looking thoroughly at water uses and traded commodities since 1996, it emerged that Spain was using significantly more 'virtual water' than real physical water in 2004 and thereafter. Furthermore, most of the virtual water was increasingly and massively imported in the form of low-value products (in economic terms) with high virtual water content (cereals, grains and feeds). Spain is also a big exporter of agricultural products, but principally the exports are in the form of more valuable products in terms of economic productivity (livestock products, wine, olive oil, fruits, vegetables and nuts). Another finding of that work was that Spain increasingly relies, as does the rest of the European Union, on imports from the rain-fed based agriculture in South America.

The results and conclusions of several WO's analyses of the water policy in Spain were innovative and in some respects were against what was generally considered 'politically correct'. Therefore, the WO team deemed it appropriate to test its ideas and methods in other countries with different hydrological and socio-economic conditions.

In view of this, and Latin America being a region of special interest in today's globalized world and an area where the Botín Foundation had already a number of activities, in 2011 the WO decided to launch a new project focusing on Water and Food Security in Latin America. The main, though neither the only nor the last, output of this project is this book.

In order to carry out this project in Latin America, the WO created a partnership with seven other institutions. In Argentina, the work was led by María Josefa Fioriti of the Water Resources Office of the Planning Ministry (Subsecretaria de Recursos Hídricos del Ministerio de Planificación Federal); in Brazil by Prof Pedro R. Jacobi and Dr Vanessa Empinotti from Sao Paulo University (Universidade de São Paulo); in Chile by Prof Guillermo Donoso of the Catholic University of Chile (Universidad Pontifica Católica de Chile); in Colombia by Diego Arévalo, from the Technological Water Institute of Antioquia (Centro Tecnológico del Agua de Antioquia); in Costa Rica by Andrea Suárez and Dr Patricia Phumpiu from the National University (Universidad Nacional Costa Rica) and the Technological Centre of Monterrey (Centro Tecnológico de Monterrey) respectively; in Mexico by Dr Rosario Pérez Espejo of the Autonomous University of Mexico (Universidad Nacional Autónoma de Méjico); and in Peru, by Prof Julio Kuroiwa, of the Hydraulic Laboratory of Engineering University (Labotario de Hidraúlica, Universidad Nacional de Ingeniería). I am very grateful to our Latin American partners and co-authors for the useful and valuable input provided to this book.

Immediately after this partnership was formed, it was clear that the project was a challenging one. Much like playing with matryoshka dolls (Russian dolls), when an issue or topic was addressed, it soon became clear there were others underlying or behind it. The scope of the project continued to widen as we worked and as other key organizations such as the Inter-American Network of Academies of Science (IANAS), the Food and

Agriculture Organization (FAO), the Organization for Economic Cooperation Development (OECD), the World Water Council (WWC), and the Global Water Partnership (GWP) published their reports on the same topics.

On 28 May 2013, in the course of an intense meeting held in Madrid, we were lucky enough to receive comments, criticisms and suggestions from a team of four deeply knowledgeable and world-renowned reviewers, who had read the first manuscript of the book. Our reviewers were Prof Anthony Allan (King's College London, United Kingdom), Prof Ignacio Rodríguez-Iturbe (University of Princeton, USA), Prof Blanca Jiménez Cisneros (UNAM, Mexico, and presently UNESCO) and Maureen Ballestero (Global Water Partnership, Costa Rica). We are indebted to them for their honest and acute criticisms. Their comments guided our work during the summer of 2013 when we thoroughly revised the manuscript. Whatever was left unaddressed will be taken on in our following projects. In any case, the responsibility on the result of that revision is entirely with this book's authors.

The Universidad Politécnica de Madrid (Technical University of Madrid, UPM) also contributed to this project, under the project 'Red Temática UPM-USP-PUC-Análisis de Riesgos Agrarios y Medioambientales: estrategias para mejorar la adaptación y la mitigación al cambio climático (AL12-RT-13)', a joint programme the UPM shares with the Pontificia Universidad Católica de Chile and with the Universidade de São Paulo.

Regarding the project, we had difficulties in deciding the geographical scope of the study. The project began with a special focus on the partner countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru), but then as we gathered larger databases we widened the scope to most of the countries South of the Rio Grande/Rio Bravo. The focus on Latin America was misleading because this is more of a cultural denomination rather than a classification used by the main regional organizations (IDB-Inter-American Development Bank, ECLAC-Economic Commission for Latin America and the Caribbean, or the FAO-Food and Agriculture Organization). In the end we decided to associate the book to the largest and commonest denomination, Latin America and the Caribbean, although we were unable to gather large amounts of data on some of the smallest island states in the Caribbean. Neither the volume nor any book chapter has the ambition to cover the LAC region entirely, but many chapters provide data and draw conclusions covering a large percentage of LAC countries.

Last but not least, I would like to convey my sincere gratitude to Emilio Botín O'Shea, member of the Board of the Botín Foundation. Emilio has always followed and supported our activities since the beginning in 1998.

Prof M. Ramón Llamas
Director of the Water Observatory of the Botín Foundation

(All cited books can be downloadable for free from the Botín Foundation's website: www.fundacionbotin.org/water-observatory_trend-observatory.htm)

Acknowledgments

This book is the product of the project 'Water and Food Security in Latin America' (2010–2013) led by the Water Observatory of the Botín Foundation. This project has been carried out by a consortium of eight partners, including the Water Observatory. The editors would like to express their gratitude to all authors and contributors and their host institutions of Latin America for the exceptional cooperation in the past months.

The book has also received funding from the Universidad Politécnica de Madrid (Technical University of Madrid), under the project "Red Temática UPM-USP-PUC-Análisis de Riesgos Agrarios y Medioambientales: Estrategias para mejorar la adaptación y la mitigación al cambio climático (AL12-RT-13)", which the UPM shares with the Pontificia Universidad Católica de Chile and with the Universidade de São Paulo.

We are deeply grateful to the book reviewers Prof Anthony Allan (King's College London, United Kingdom), Prof Ignacio Rodríguez-Iturbe (University of Princeton, USA), Prof Blanca Jiménez Cisneros (UNAM, Mexico, and presently UNESCO) and Maureen Ballestero (Global Water Partnership, Costa Rica), for the useful and wise advices.

A special mention should be made to our team of editorial assistants. Olga Fedorova, Daniel del Olmo Rovidarcht and Desireé Torrente checked formats, data and consistency tirelessly, enduring large days of work and providing very valuable contributions. Bárbara Soriano managed the data gathering work, assisting many chapters' authors, and becoming the author of some on her own right. Our designer, María Carmona, did a superb work and understood the complexities of the project. Special thanks go to Ruth Cunningham for providing the editorial assistance and correcting the style and language. Also, the editors would like to thank the staff members of CEIGRAM, Esperanza Luque, Katerina Kucerova, Begoña Cadiñanos and Elena Vivas for their constant and valuable support.

We would also like to express our sincere gratitude to Ashley Wright, Alanna Donaldson and Tim Hardwick from Routledge, who have provided us with useful and timely guidance at all times during the book production process.

As always, all members of the Water Observatory are deeply grateful to the Botín Foundation for confiding in our judgement to carry out this and many other projects.

Abbreviations

ACUMAR:Autoridad de Cuenca Matanza-Riachuelo
ADB:Asian Development Bank
ADERASA:Asociación de Entes Reguladores de Agua Potable y Saneamiento de las Américas
ALADI: Asociación Latinoamericana de Integración
ARESEP:Autoridad Reguladora de los Servicios Públicos de Costa Rica
AWWA:American Water-Works Association
AySA:Agua y Saneamientos Argentinos S.A.
CADER:Cámara Argentina de Energías Renovables
CAF:Cooperativa Andina de Fomento
CAN:Comunidad Andina
CATI:Coordenadoria de Assistência Técnica Integral-Brazil
CAWT:Central America Water Tribunal
CDM:Clear Development Mechanism
CDP:Carbon Disclosure Project
CF: Carbon Footprint
CFS:Committee on the World Food Security
CONAGUA:Comisión Nacional del Agua de Mexico
ECLAC/CEPAL: United Nations Economic Commission for Latin America and the Caribbean
ECP:Emissions Compensation Programmes
EF: Ecological footprint
ENSO: El Niño Southern Oscillation
ERS-USDA: Economic Research Service of the United States Department of Agriculture
EPA:Environmental Protection Agency
ES: Ecosytem Services
FAO: United Nations Food and Agriculture Organization
FCCyT: Foro Consultivo Científico y Tecnológico
FCPF:Forest Carbon Partnership Facilities
FNS:Food Nutritional Security
FONAG:Fondo para la protección del Agua
FONAFIFO:Fondo Nacional de Financiamiento Forestal-Costa Rica
FTA:Free Trade Agreements
GDP:Gross Domestic Product
GEF:Global Environment Fund
GFSI:Global Food Security Index
GHI:Global Hunger Index
GMOs:Genetically Modified Organisms
GSM/EDGE:Global System for Mobile communications/Enhanced Data for GSM Evolution
GWP:Global Water Partnership
HDI: Human Development Index
HLTF:High Level Task Force
HRC:Human Rights Council
HRCI:Hunger Reduction Commitment Index
HRWS:Human Right to Water and Sanitation
IANAS:Inter-American Network of Academies of Science
IBGE:Instituto Brasileño de Geografía y Estadística
ICESCR:International Convention on Economic, Social and Cultural Rights
ICT:Information and Communication Technology

IDB:Interamerican Development Bank
IFAD:International Fund for Agricultural Development
IICA:Instituto Interamericano de Cooperación para la Agricultura
IISD:International Institute for Sustainable Development
IMECHE:Institution of Mechanical Engineers
IMF:International Monetary Fund
INPE:National Institute for Space Research
IOM: International Organization for Migration
IPCC: Intergovernmental Panel on Climate Change
IT: Information Technology
IUCN:International Union for Nature Conservation
IWA:International Water Association
IWRM:Integrated Water Resources Management
LAC: Latin American and Caribbean
LAWT:Latin America Water Tribunal
MDG:Millenium Development Goals
MERCOSUR: Common Market of the South
NIC:National Intelligence Council
OAS:Organization of American States
OECD:Organization for Economic Cooperation Development
OHCHR:Office of the United Nations High Commission for Human Rights
OMS/WHO:Organización Mundial de la Salud/World Health Organization
OPEC:Organization of the Petroleum Exporting Countries
PES:Payments for Ecosystem Services
PHI:Poverty and Hunger Index
PTA:Preferential Trade Agreements
RBO:River Basin Organizations
REDD+:Reducing Emissions from Deforestation and Forest Degradation
STEEP: Society-Technology-Economics-Ecology-Politics
TARWR:Total Actual Renewable Water Resources
TL: Trade liberalization
TLC:Trans Latina Companies
UNASUR: South American Nations Union
UNDP: United Nations Development Program
UNEP: United Nations Environment Programme
UNESCO:United Nations Educational, Scientific and Cultural Organization
UNFCCC:United Nations Framework Convention on Climate Change
UNGA:United Nations General Assembly
UNICEF: United Nations Children's Fund
USDA:United States Department of Agriculture
US-EPA:United States Environmental Protection Agency
USGS:United States Geological Survey
VWT:Virtual Water Trade
WBCSD:World Business Council for Sustainable Development
WEC:World Energy Council
WF:Water Footprint
WS:Water Security
WSSD: World Summit on Sustainable Development
WTO: World Trade Organization

Part 1

Introduction

1

WATER AND FOOD SECURITY IN LATIN AMERICA AND THE CARIBBEAN: REGIONAL OPPORTUNITIES TO COPE WITH GLOBAL CHALLENGES

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1.1 Setting the scene

1.1.1 Placing Latin America and the Caribbean in the global context

The world has never been so globalized and interconnected as today. Advances in transportation, logistics, telecommunications and global production systems have attained unprecedented levels of economic integration. Agricultural commodities are transported across hemispheres and trade makes consumers believe that food production no longer respects the traditional seasons. Thanks to technological progress, increasing production specialization, and the wide dissemination of scientific knowledge, world food systems have become more integrated and developed than ever before (Prakash, 2011).

Despite these achievements, important questions still exist as to whether the world's agriculture has the potential to feed a growing population, expected to reach 9 billion by 2050, unless significant improvements are made in production efficiency alongside the promotion of healthier consumption habits. In 2012, 870 million people were still suffering from hunger and malnutrition, equivalent to nearly 12.5% of the global population (FAO, WFP and IFAD, 2012). Furthermore, somewhat ironically, today there are more people overweight than people suffering from hunger globally. According to WHO (2013), in 2008 1.4 billion people were overweight, of which nearly 500 million were obese.

Bridging the hunger gap and addressing the high calorie intake of a growing and wealthier population, demand vast amounts of inputs: water, land, minerals, and energy. The challenge of feeding the world thus becomes particularly acute if it is to be accomplished without adding further pressure on natural resources and surpassing critical environmental tipping points. The National Intelligence Council (NIC) has identified the water–food–energy nexus as one of the four 'megatrends' which is likely to have major impacts on the world's future up to 2030, as an increasing, wealthier and more urbanized population will pose a higher demand on these inextricably linked resources (NIC, 2012).

The NIC report also predicts that the diffusion of power and geopolitical gravity shifts are ongoing megatrends that are likely to influence the world's future in the short term. As Naím (2013) claims, power[1] in the world is decaying as a result of a so-called 'triple-M revolution': the *more* revolution, the *mobility* revolution and the *mentality* revolution. Among the 'more revolution' facts that Naím mentions, a few are worth bearing in mind: the world's economic output has increased fivefold since 1950 and income per capita became 3.5 times greater; between 1990 and 2010, the number of people living on less than US$1.25 a day decreased to 700 million, thus meeting the Millennium Development Goal on halving extreme poverty five years earlier than planned; child mortality has dropped by 17% since 2000; undernourishment decreased from 34% in

1 Naím defines power as the 'ability to direct or prevent the current or future actions of other groups and individuals' (p.16).

1980 to 17% in 2008; the middle class increased from 1 billion in 1980 to 2 billion in 2012, and will likely reach 3 billion in 2020; 84% of the population is literate, up from 75% in 1990; and, last but not least, between 2000 and 2010 the human development index – an overall measure of global human well-being and living standards – has risen everywhere in the world with just a handful of exceptions. This promising picture of countries and citizens progressing, living longer, with healthier lives and improved basic needs, is crucial to understanding today's shifts and redistributions of power, and why it is becoming harder to obtain power and easier to lose it.

Much of these socio-economic transitions have occurred in Latin America and the Caribbean (LAC), a region that over the course of the last decade has shown great progress in social, institutional, political and economic spheres. Part of the economic success is due to the region's 'natural dividend', related to the relative and absolute abundance of natural resources, ranging from minerals and energy sources to land and water. As Naím (2013) argues, demand and access to abundant resources are in fact one of the main world drivers of power decay for countries that lack them and of power conquest for those that are well endowed. This partly explains why LAC countries with very little global power until recently are now influential members in the G20 (Argentina, Brazil and Mexico), major world energy providers (Bolivia, Colombia, Ecuador, Venezuela), crucial countries for LAC's overall security (Mexico, Colombia), key EU trading partners (Chile, Peru and Colombia, and the Central American states of Costa Rica, Guatemala, El Salvador, Honduras, Nicaragua and Panama), and leaders of the transpacific cooperation, as four countries (Chile, Peru, Mexico, Colombia) have created the Pacific Alliance to enhance cooperation within the region and across the Pacific with Asia. By all accounts, the LAC region has become a key player in global geopolitics. Exploring how these changes play out in the domain of water and food security contributes to understanding what paths of development this region is following and what are the implications regionally and globally.

1.1.2 Water for regional and global food security

Globally, the largest share of consumptive water use is associated to agricultural production, and just a minor fraction (less than 10% on average) is for cities and industries. Because of the prevalence of rain-fed agriculture over irrigation, the largest share of water consumed in agriculture is *green* water, soil moisture. *Blue* water – water taken from rivers and aquifers – represents a smaller fraction of the agricultural water footprint, although it varies amongst countries. The importance of water for agricultural production and the fact that agriculture is the lion's share of water consumption, renders it relevant and necessary to look at water and food security through the double lens of what Allan (2013) defines as 'food-water' water needed to secure agricultural production, either green or blue- and 'non-food water', which refers to the fraction of blue water providing all other water-related services, beyond food, which are important for human development and well-being.

LAC's agriculture is a strategic sector for rural development and poverty alleviation and it plays a key role in overcoming local and global food insecurities. During the last fifteen years, LAC's agricultural sector has grown considerably, to a large extent driven by trade liberalization policies, which have contributed to turning LAC into an increasingly important competitor in the global agricultural market (for both food and biofuel production). Its weight is not so much in terms of economic value, but in calories and vegetal and animal protein supply, making both developed and emerging economies increasingly more dependent on LAC's output. In recent years, this region has captured an increasing share of the global market of agricultural products, and LAC now controls over 18.4% of the world agricultural trade compared to the 11.4% in 1990 (World Bank, 2013a). Oilseeds, soybean, cereal grain and to a lesser extent livestock products accounted for more than half of this export growth, with a few countries such as Brazil, Argentina and Chile generating over 65% of total LAC exports (*ibid*.).

The expansion of agricultural production and exports has been partially stimulated by the peaks in commodity prices seen in 2007, 2008 and 2012. However, increased price volatility has a lingering effect in the minds of those responsible for managing and governing food systems at international and national levels, even after the price crises subsided. Many governments concluded that relying too much on food imports entailed serious economic and social risks. The notion of food security was thus redefined after the price crises, and food sovereignty is now gaining more prominence to the extent that increasing national food production is becoming an overarching objective in all domains of world and national governance. Nevertheless, under the likely scenario of reaching 9 billion people by 2050, the ongoing process of global urbanization and dietary shifts, the reliance on food imports will remain an indispensable strategy in order to overcome global water and land shortages and cope with future food demand. In this context, it is very likely that LAC will be a major supplier in this long-term scenario as it has already demonstrated over the last decade.

1.1.3 Water for economic development and human well-being

If food-water is essential for achieving food security, non-food water is an equally strategic element for human well-being and social progress. Population growth and the aspiration for higher incomes, greater services and job opportunities, have favoured a rapid and sustained migration flow from rural to urban areas over the last decades. Today, LAC is more urbanized than the average 'high-income' country, with almost 80% of the population living in cities in 2012 (World Bank, 2013b). The region holds four of the largest and most populated cities in the world (the megacities of Mexico D.F., Sao Paulo, Buenos Aires and Rio de Janeiro) and a fast-growing number of middle-size urban areas. This booming process of urbanization, often poorly planned, and the resulting high urban density, pose major challenges for managing water and the delivery of key services to citizens. These include securing access to safe water and sanitation, protection against water hazards such as floods, guaranteeing water provisioning services during drought periods or addressing the growing water pollution problem and environmental degradation of freshwater ecosystems resulting from poor wastewater management policies, amongst other factors.

Non-food water is also a critical input for the industrial sector, including mining, energy production and navigation. Hydropower is the main energy source in the LAC region and still has a large growth potential. Yet its development faces growing physical and socio-economic constraints, including the rights of native and local inhabitants and environmental concerns. Similarly, the growth of the mining sector in LAC, particularly in South America and Mexico, is also generating a growing number of water conflicts. On one hand, because it competes with other economic sectors for sometimes scarce water resources. On the other hand, because of the large pollution problems this sector generates for downstream water users and ecosystems.

1.1.4 Development and sustainability goals: confrontation or alignment?

The strategic value of LAC's natural dividend offers a triple-sided topic of research and inquiry. On the one hand, the role of LAC in the world's current food system and its contribution to global food security cannot be emphasized enough. Interestingly, this crucial role has become a reality in just one decade, and the consequences are now beginning to emerge, in both the political and the scientific spheres. On the other hand, the local, national and regional impacts of this plethora of economic and business opportunities pose enormous challenges for LAC governments. In a time of rapid reconfigurations of power, civil society, NGOs and grassroots organizations have advocated bold reforms at the highest political level (reaching the constitutional one) that enshrine basic rights such as those regarding access to food and water. Last but not least, a fundamental question for the region is whether existing development opportunities and sustainability goals should be framed in terms of trade-offs, or they could also be thought of as win–win opportunities. This dilemma is pertinent worldwide, since decisions concerning to LAC's development and natural resource use will have global consequences for biodiversity, the earth energy balance and the world's climate (Rockström et al., 2009; Gloor et al., 2012).

1.1.5 This book's conceptual approach: linking food and water security

Over the last few years numerous authors and organizations have been looking at the consequences of LAC agricultural growth and globalization. Questions like *What are the socio-economic and environmental implications of this trend for regional development? How does it contribute to local water and food security? and What is the role of LAC in global water and food security?* are of critical importance to the region, but knowledge remains sparse and the overall picture is unclear. Behind all these key questions there are numerous interrelated phenomena and processes at the global, national and local levels that must be jointly analysed in order to provide convincing explanations that allow valid conclusions to be drawn.

The answers to these questions have to be sought in the linkages between regional development, economic globalization, well-being, water resource use (food-water and non-food-water), and the global dimension of water and food systems in LAC. To tackle this complex phenomenon a first and fundamental concern is the biophysical sphere, the realization that no social and economic progress of human beings exists without an adequate *material stratus*. This link is sketched in Figure 1.1. A crucial feature that distinguishes LAC from other regions is that most of its vast agricultural production is obtained in rain-fed systems, relying thus primarily on green water. This green water embedded in agricultural exports are of critical importance for global food and water security. Likewise, LAC's food-water and non-food water are also crucial for regional development and for meeting its growing domestic consumption needs. In the particular case of LAC, with its booming economy and a heavy reliance on natural resources, one can imagine scenarios where the rest of the world's craving for food and natural resources compromises the livelihoods of future LAC's generations and scenarios where the two positively reinforce each other. The latter implies that the booming economy and social progress run along more sustainable paths. This book is an inquiry into the type of path LAC countries seem to be following.

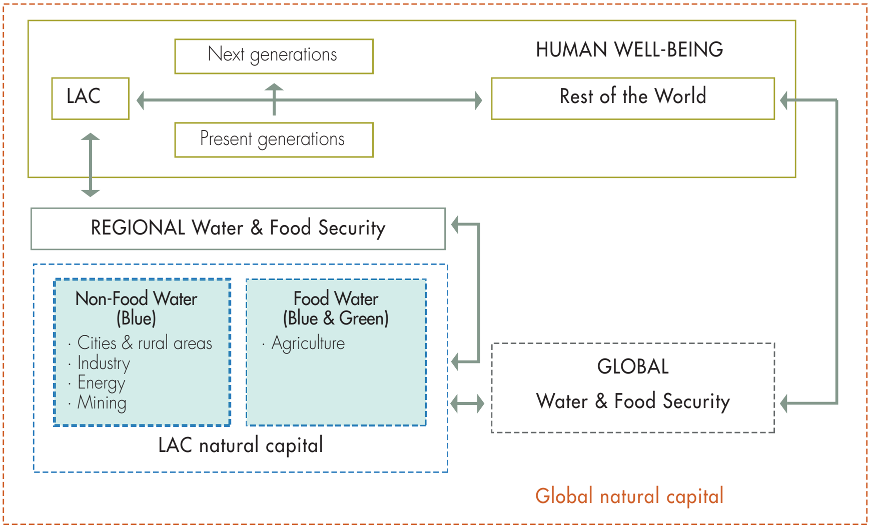

Figure 1.1 Biophysical dimensions of human well-being – water and food security – in LAC and in the rest of the world. *Source: own elaboration.*

A second and equally fundamental concern is the governancel system. If the biosphere represents the material stratus needed for the realization of any kind of security, governance systems represent the *intangible stratus* (Figure 1.2). An underlying theme of this book is that LAC's future depends dramatically on strong governance and institutional frameworks, both within countries and at regional and global levels. Countries' governance systems are where rules for land and water uses are developed and where the bases for water and food security are laid out, as they intervene on how humans interact with the biophysical sphere. Furthermore, the global governance system – e.g. international trade policy, free trade agreements, food safety and sanitary measures – has also become pivotal for food security in LAC and globally. Considering the relatively weak global governance structures of present times, the engagement of national governments in far-seeing and inclusive policies and the demand of citizens of being lead equitably and responsibly are prerequisites for thinking optimistically about the future. This book does not attempt to revise all governance forces operating inside and out of LAC and summarized in Figure 1.2, but to specifically focus on those that have a direct impact on water governance in LAC.

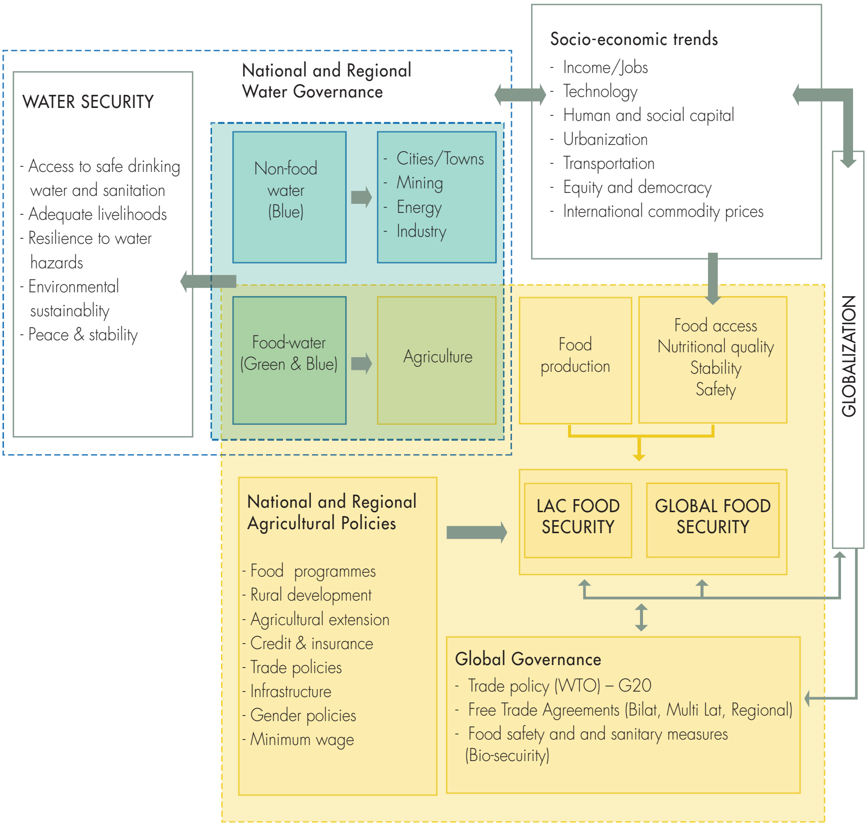

Figure 1.2 The book's framework: topics, inter-dependencies, drivers and focus.
Source: own elaboration.

1.2 The objectives of this book

This book's main goal is to provide an analytical and facts-based view of the progress of LAC's regional water and food security, its contribution to global water and food security and the challenges ahead. A full understanding of these regional changes requires framing LAC in the global picture: a region with increasing geopolitical power in an ever globalized world and a growing presence in global food markets. This overview ultimately aims at facilitating policy debates at national and global levels about these compelling issues. Within this overarching goal, the book has the following specific objectives:

- To diagnose water and food security issues in LAC, using prospective analysis and up-to-date literature. The book pays particular attention to food-water, how it is being used and the links to regional and global food security, without neglecting the importance of non-food water, as it also represents a key asset for development and progress.
- To investigate the role of the socio-economic 'megatrends' in LAC, identifying feedback processes between the region's observed pattern of changes of key biophysical, economic and social variables linked to water and food security.
- To document and analyse the environmental implications linked to the growth of a natural resources-intensive economic model over the last decade, i.e. LAC becoming the world's *food basket* and a key economic actor in domains such as mining and some key industrial products, whilst reviewing the policies in place that have been pursued to mitigate their negative consequences.
- To review the critical changes that are taking place in the institutional and governance water spheres, including the role of civil society, which may represent promising means to advance towards the goal of improving water security in LAC.

Covering a wide array of spheres and databases ranging from biophysical, social and economic variables to detailed records of legal and institutional reform in LAC countries, the book's unique approach offers a complementary view of previous works, including Jiménez-Cisneros and Galizia-Tundisi (2012), Regional Process of the Americas (2012), FAO (2012) and OECD (2013). The first two publications provide considerable updated data on water-related aspects and formulate extremely relevant policy conclusions, while FAO (2012) offers a valuable review of the food security challenges in the LAC region, and OECD (2013) in the world. While this book has a central focus in LAC's water and food challenges, compared to other publications it makes two main contributions: 1) it focuses primarily on the synergies and relationships that both food and water security goals represent for LAC, and 2) it seeks to cover a much vaster domain linking trade and globalization, with water economic uses, pressures on environment and ecosystem services, and water policies, with an overarching view of water and food security for the people and the productive economy in LAC. It does so by first considering international food trade flows and using water accounting techniques to quantify its significance in terms of virtual water movements.

This book will provide an overall picture of LAC's current status and the challenges regarding these compelling issues. But problems and challenges greatly differ across and within countries. LAC is a highly heterogeneous physical territory, even though culturally it is more homogeneous. Whilst this cultural convergence helps in terms of human relations, the different national identities do have an influence on how countries share resources and address common problems, including the widely different standpoint each one has about globalization and the major megatrend. A similar phenomenon can be observed within regions (provinces, states) of the same nation. Thus, although the continental view provides an overall picture, it may also greatly differ from the local vision. It would be impossible to include such a degree of detail within the scope of this book, but in the different chapters some of the striking differences are identified as examples.

1.3 The structure, scope and contents of this volume

This book contains a collection of fifteen essays (including this one) that look at fundamental issues surrounding water for food and human well-being in an increasingly globalized LAC. Most chapters take a regional approach, covering a broad range of data and variables pertaining to most of countries in the region, although a sharper focus is placed in some chapters on seven countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru), as these are the countries represented in the partners' consortium of the project which lead to the present book (see the Foreword). To cover this vast number of issues, the book generates new data, delves into the vast array of already existing literature and datasets about the region and explores linkages among phenomena and trends.

The book is structured in four parts. Part 1 is this introductory chapter. Part 2 sets the scene for the book looking at the biophysical and socio-economic context of LAC. Part 3 describes the main drivers for land and water uses in the region and for the particular case of the seven aforementioned countries. Part 4 presents the economic, legal and institutional context where those uses occur and where water and food security is to be achieved. In the following sections, the topics, data and approaches of each volume's part and chapter are outlined.

1.3.1 Part 2 on the biophysical and socio-economic context

Chapter 2 provides a general overview of the status and trends of water resources in LAC: its spatial and temporal distribution, its uses and the main challenges that those uses pose to the conservation of water and its associated ecosystems.

Chapter 3 describes the status and main pressures on land and ecosystem services and shows that, as a result of the expansion of agricultural and livestock production, LAC has undergone some of the most noteworthy land use changes in modern history. Associated with these changes significant reductions in the provision of ecosystem services have occurred. The chapter discusses the available options to minimize competition between agricultural land and forests.

Chapters 4 and 5 seek to identify the major socio-economic drivers of change within LAC, looking both at endogenous and exogenous global aspects. Chapter 4 describes and documents a wide selection of socio-economic megatrends of LAC including demographic dynamics, economic growth, migration, income growth, disparity and poverty, human development, education, trade and liberalization, food-consumption patterns, technological change, and climate change. Chapter 5 provides an overview of the trends of direct investment, trade flows and policy, and adds further data about the region's connectivity with the rest of the world. The predominance of trading agricultural and mining commodities stands out for its amount, growth and continuity. The chapter also reviews the literature on the impacts of virtual water trade and some of the most serious concerns, anticipating a more complete presentation of data and discussion in Chapter 7.

Chapter 6 explores the meaning of water and food security in the context of LAC countries, taking a wide perspective and trying to account for all those aspects concerning water and food which are important for human well-being beyond its physical availability. It provides a quantitative analysis on the performance of water and food security indicators between 2000 and 2010 with a view to assessing progress and the links between them. This chapter concludes with a final section assessing the influence of socio-economic factors on water and food security advances.

1.3.2 Part 3 on water demand and drivers

Chapter 7 analyses the challenges and opportunities of water management in the region from the perspective of the agricultural sector. The chapter provides detailed data pertaining to water quantity and quality obtained under the framework of the water footprint indicator. Connecting the data on trade presented in Chapter 5, virtual water trade in the LAC region is also analysed with reference to both countries and time. In the final section, the chapter includes a productivity analysis taking into account social and economic aspects.

Chapter 8 focuses on the urban sector. First, it reviews the major challenges associated with the objective of expanding coverage and sanitation to hundreds of large and middle-size cities which are constantly undergoing processes of expansion and economic growth. It further goes on to analyse the challenge of maintaining the existing infrastructure to provide safe water to hundreds of millions of LAC people. This is illustrated in a number of case studies including Sao Paulo, Rio de Janeiro, Mar del Plata, Mexico D.F., Santiago de Chile, Buenos Aires and Lima. In many cases groundwater has a very significant r ole, even if is not a dominant one. It is also remarked upon that some poor natural water quality problems are a concern, especially in small towns and rural areas.

Chapter 9 focuses on mining, energy and industrial sectors. Each of these is reviewed covering the major challenges each faces as water users and potential pollutants. The mining and industrial sectors stand out for having large impacts on the environment, in addition to wastewater discharges from large cities. The mining sector is potentially subject to water shortages since many mines are in desert areas and they compete for scarce water resources with the urban users and the environment.

1.3.3 Part 4 on the economic, legal and institutional context for achieving water and food security

Chapter 10 reviews the efficiency of water resource use in LAC. To this end, it provides the concepts and definitions together with the drivers for water efficiency. Then, it analyses the efficiency of water resources use in Latin America, looking at the different water users: urban and industrial, mining, agriculture, energy and the environment.

Chapter 11 describes fundamental aspects of water governance, including the constitutional provisions in relation to water, water laws, and the recognition of the human right to water and sanitation. The chapter also analyses financial aspects, funding schemes and investments made and needed in order to ensure the enforcement of constitutional and legal mandates on water.

Chapter 12 focuses on different strategies that stakeholders apply in order to influence water governance in LAC. After reviewing the main sources of tensions regarding water in the region, the chapter looks at practices of activism and advocacy often triggered by disputes that represent informal but important spaces for the participation of civil society. Then the chapter discusses means to achieve transparency, accountability and more robust governance, including, the creation of formal venues of participation as a space for negotiation, the role of the private sector, water certification approaches and legal provisions to ensure access to information.

Chapter 13 explores the role of economic instruments in coping with the most pressing challenges of LAC's water problems. The chapter covers pricing policies, as applied to users of natural resources or mere abstraction activities, and to final users in the urban sector or agricultural sectors. It also reports on a few initiatives with pollution charges and the use of payments for ecosystem services. Since Chile is the only country in the region with experience with water markets, the chapter also offers a brief assessment of how they function and mentions the most recent reforms. The chapter concludes with the potential for improving water and food security indicators by using economic instruments.

Chapter 14 explains how LAC countries are confronting the environmental downside of an economic model based on the intensive use of natural resources and the process of urbanization. It reviews the constitutional and legal approaches and economic initiatives meant to address environmental protection that have been implemented in a large number of LAC countries. It then looks at the impediments and the potential effects private rights and ownership could have. It ends with a technical and detailed discussion of the role of payments for ecosystem services, complementing the brief introduction in Chapter 13.

Chapter 15, the last chapter, relates most of the topics and aspects that have been covered in the book with the changing and ambiguous concept of integrated water resources management (IWRM). The reasons for rethinking the concept of IWRM include a number of innovations and recent findings in fields traditionally not placed at the core of water resource sciences, such as non-conventional water resources, climate science and water globalization.

1.4 Main book's highlights

While it is not prudent to make generalizations for the entire LAC region, as it is obvious that LAC challenges might differ across and within countries, the following section summarizes the main highlights emerging from this volume, grouping them under six main headings: (1) globalization, trade and the role of LAC in international food and water security; (2) implications for LAC's role in the social and environmental spheres; (3) the performance of LAC's indicators of water and food security; (4) the challenges of urbanization, large cities' water, intensive industrial and mining sectors; (5) progress in water governance; (6) democracy, education and good governance as a basis for LAC's natural resources and social dividends.

1.4.1 Globalization and international trade have changed the way of coping with food and water security challenges and LAC is a key player in this new setting

In 2011 the value of traded goods globally was equivalent to 59% of the world's GDP, up from 49% in 2000, and 39% in 1990. With US$1.356 trillion traded in 2011, agricultural products represent the world's third largest sector in traded value, after fuels and non-pharmaceutical chemicals. LAC's agricultural exports now account for 18.4% of global agricultural exports and in value terms they grew by 21% in 2011, mostly because of the increase in commodity prices. In total, LAC's exports of mining and agricultural products represent between 38% and 40% of all goods exports.

The growth in exports of agricultural and mining products has been a major source of income for the wealthiest nations of LAC. But the region's exports have not been sufficiently diversified and hence un-manufactured and less processed products still account for the largest share of LAC agricultural exports. Within the group of the eleven largest economies of LAC, only Argentina (with automobile exports in the third place) and Mexico (with exports of sound and telecommunication equipment in the third place) had, in 2008, a non-agricultural or non-mining sector amongst the three largest exporting sectors (Dingemans and Ross, 2012).

Because of the abundance of agricultural land and the favourable climate, agricultural production in LAC is primarily rain-fed. International demand for agricultural products is mostly satisfied with green water and thus through the use of vast amounts of land. Over 95% of the production water footprint in LAC ($\approx$1060km^3/year, an average for the time period of 1996–2005) is for food production and nearly 20% of this 'food water' ($\approx$ 203km^3/year) is exported from LAC, mostly to Asia and Europe.[2] The growing

2 According to Dalin et al. (2012), South America exported in 2007 approximately178 km^3 of virtual water outside the LAC region, i.e. to Asian and European countries. This would imply that roughly over 87% of the 'food water' exported annually by LAC countries is meant to meet the demand from other regions, and only 13% is traded regionally.

international demand for protein crops, oilseed, cereal grains, and meat products has contributed to increasing virtual water exports of 37.5% between 2000 and 2010. The remaining 80% of food water consumption is used for to satisfy the internal demand of a growing and wealthier population.

South America's main trading partners are now in Asia, especially China and India, while Central America and the Caribbean still export primarily to North America. Exports from South America to Asia contributed to 30% of the virtual water trade increase between 1986 and 2007, 95% of which is green water. In this context, Brazil and Argentina are now major players in the global markets of agricultural commodities, providing up to 13% of the global annual green water exports. The expansion of transportation infrastructure connecting ports with vast inland regions will probably enhance the effects of globalization in the more remote areas of the region.

Falkenmark and Rockström (2011), Dalin et al., (2012) and OECD (2013) amongst many others conclude that international trade is a basic element for achieving global food and water security, particularly taking into consideration the future global population and the shifting dietary habits. This points to the key role that global governance architecture, including the World Trade Organization as part of its founding elements, should play in ensuring a fair food trade as a necessary premise for global security. It also suggests that, despite the growing importance the food sovereignty discourse is gaining across many countries, agricultural trade will be still necessary, and LAC is likely to remain a key food provider globally.

1.4.2 Pursuing global water and food security intensively taps into LAC's natural capital and has social and environmental trade-offs

The growth of the agricultural sector in LAC is a result of rapid modernization and competitiveness gains, pushed by technology adoption and innovation, infrastructure development and increasing production efficiency, in both physical and economic terms. LAC still has much potential for scaling up its agricultural output owing largely to its rich natural endowment, especially in terms of land and water. Currently, the appropriation of land for agriculture represents 27% of the total LAC area, a figure comparatively lower than the 38% global average. With less than 13% of this land equipped for irrigation (FAO, 2012), the green water dependency of LAC's agriculture is considered a comparative advantage compared to blue water intensive agricultural production systems. However, relying largely on rain-fed agriculture for food security is not exempt from trade-offs since its expansion implies important environmental impacts and the loss of valuable ecosystem services (e.g. deforestation, widespread pollution, carbon emissions, biodiversity loss).

The growth of rain-fed agriculture in LAC has significantly changed land use patterns. Yet, LAC is the second largest deforestation hotspot in the world, only preceded by Southeast Asia. Between 2000 and 2010, close to 1 million km^2 of forest have been transformed into agricultural land, an area equivalent to the size of Venezuela, with large consequences for biodiversity and ecosystem services. Deforestation has been particularly intense in South America, with Brazil accounting for 60% of LAC's forest clearing during the last decade. The great majority of the ongoing deforestation in South America is related to the growing international demand for oilseeds grains. In Mesoamerica, deforestation has advanced at a slower pace, and the drivers seem to be related mainly to the low agricultural productivity, which keeps pushing at the agricultural frontier in order to overcome local food insecurity gaps. Annual deforestation rates peaked between 2000 and 2005 and declined slightly in 2005–2010, but are still higher than in 1995–2000.

The sustainable intensification argument was brought up with enthusiasm, as a 'win–win' solution, which may allow the achievement of the triple goal of ensuring food–water–environmental security. However, gains from this sustainable intensification will be slow and require large investments in research and field trials to avoid falling in the 'intensification trap', since as agriculture intensifies, input demands (e.g. energy, fertilizers, water) also rise, and this has additional environmental consequences (Titonell, 2013). Non-point source pollution of water and soil is, jointly with biodiversity loss and built-in resistance to pests and weeds, the main unwanted consequence of agricultural expansion in LAC. Important causes are the extensive application of pesticides and fertilizers, irrigation-induced salinity and the reuse of insufficiently treated wastewater for irrigation. Improvements in agricultural productivity across many countries in LAC will surely help to spare land and reduce the impacts of deforestation, but important challenges remain in order to mitigate the resource-use dependency of agriculture.

1.4.3 LAC's water and food security indicators have improved, but important goals remain and new challenges are emerging

The buoyant global tailwinds that enabled the remarkable economic development of LAC over the last decade have undoubtedly contributed to social progress in the region. Social advances are obvious in the achievements of LAC countries to meet many of the Millennium Development Goals (MDGs) (see Table 1.1). At the continental level, LAC has made notable advances in alleviating extreme poverty (MGD1a), undernourishment (MDG1c) and improving access to drinking water and sanitation (MDG7). Yet progress achieved upon the rest of MDGs, albeit notable, is still not sufficient to meet the 2015 objectives.

When analysing the achievements made by countries separately, the wide divergences in accomplishing the different MDGs become evident. Overall, high and medium-high income countries (e.g. Southern Cone countries, as well as Brazil, Mexico, Costa Rica, Peru, Panama or Ecuador) are on good track to meet at least those MDGs related to basic indicators of water and food security (MDG1 and MDG7). Goals related to improved education, health, equity and female empowerment are progressing but at a slower pace, and there is a risk that they will not be accomplished by 2015 if the prevailing trend continues. In the Caribbean islands there is a large knowledge gap and the information that is available shows slow progress for the most part. Low-income countries also run the risk of not meeting most of the 2015 goals, except in Bolivia, Nicaragua and Honduras.

Table 1.1 Millennium Development Goals (MDG) progress in Latin America and the Caribbean (LAC) between 1990 and 2010.

Target goals on track to be accomplished by 2015 or earlier are represented in green, observed progress but off track if prevailing trends persist are presented in yellow, and off-target ones in red.

		PROGRESS SCORE							
		MDG 1a	MDG 1c	MDG 2	MDG 3	MDG 4	MDG 5	MDG 7c	
		Extreme poverty	Undernourishment	Completion primary schooling	Gender and women empowerment	Reduction of child mortality	Improve maternal health	Access to safe drinking water	Access to sanitation
Mesoamerica	Honduras	yellow	green	yellow	yellow	yellow	yellow	green	green
	Mexico	yellow	green	yellow	yellow	green	yellow	green	green
	Nicaragua	green	green	yellow	green	yellow	yellow	green	yellow
	Panama	yellow	green	yellow	yellow	yellow	yellow	green	yellow
	Costa Rica	yellow	red	yellow	green	yellow	red	green	yellow
	El Salvador	yellow	yellow	yellow	yellow	green	yellow	green	green
	Guatemala	yellow	red	yellow	yellow	yellow	yellow	green	green
Caribbean	Cuba		green		green	green	red	green	green
	Dominican Republic		green	yellow	yellow	yellow	yellow	red	yellow
	St. Kitts and Nevis		yellow		red	green		green	red
	St. Lucia		red		red	yellow		yellow	yellow
	St. Vincent and the Grenadines		green		red	yellow			
	Haiti		yellow		yellow	yellow	yellow	yellow	red
Andean	Bolivia	green	yellow	green	yellow	yellow	yellow	green	yellow
	Colombia	green	yellow	yellow	yellow	yellow	yellow	yellow	yellow
	Ecuador	green	yellow	yellow	yellow	yellow	yellow	green	green
	Peru	green	green	yellow	yellow	green	green	green	yellow
	Venezuela	yellow	green	yellow	yellow	yellow	yellow	yellow	green
Amazonian	Brazil	green	green	yellow	yellow	green	yellow	green	yellow
South Cone	Chile	green	green	yellow	yellow	yellow	yellow	green	green
	Paraguay	yellow	red	yellow	yellow	yellow	yellow	green	green
	Uruguay	green	green	yellow	yellow	yellow	yellow	green	green
	Argentina	green	green	yellow	green	yellow	red	green	red
LAC countries	**On Target**	**9**	**13**	**1**	**4**	**6**	**1**	**17**	**10**
	Some Progress	**8**	**6**	**17**	**16**	**17**	**16**	**4**	**9**
	Off Target	**0**	**4**	**0**	**3**	**0**	**3**	**1**	**3**

Source: own elaboration based on UN (2013).

These improvements imply that between 1990 and 2012 the percentage of the population living in poverty in LAC has decreased from 49.4% to 28.8%. Still there are 168 million people living in poverty, the majority living in urban areas (ECLAC, 2013). Income distribution inequality is still the Achilles heel of LAC, but a clear downtrend has been evident since the early 2000s. Nevertheless, by 2011, 30% of the population still received over 60% of the total income (*ibid.*).

With regard to food security improvements, the number of people undernourished has decreased from over 65 million in 1990–1992 to 49 million in 2010–2012 (FAO, 2012). The prevalence of stunting in children under five years has also decreased from 19% in 2000 to 14% in 2010, but the problem remains that one in every seven children born in LAC will have stunted growth. In addition to sub-nutrition, LAC is also facing a growing problem of malnutrition. Obesity now affects nearly 18% of the Latin American population (> 110 million people) and overweight up to 33% (> 200 million people) (Finucane et al., 2011). Malnutrition is particularly affecting middle and high income countries like Chile, Brazil, Uruguay, Argentina and Mexico. Current rates of overweight and obesity in LAC are at least double those of other developing regions and comparable to the ones found in Europe.

Regarding water security, LAC boasts the highest renewable water resources per person among the world's regions, but climatic variability, together with urbanization patterns, generates asymmetries between water demands and water availability across the region, and results in water stress in some of the most economically dynamic areas of the region. Over 100 million LAC citizens currently live in basins which face physical water scarcity.

The number of people without access to an improved sanitation facility has decreased from 146.7 million in 1990 to 103.8 million in 2011 (WHO-UNICEF, 2013). The greatest improvements, however, have been achieved in reducing the number of people without access to safe drinking water from 63.8 million in 1990 to 32.8 million by 2011 (WHO-UNICEF, 2013). These figures mask important differences across countries, between urban and rural areas, as well as within urban areas. Overall, and particularly across the poorest countries, water service deficiencies in rural areas are still very significant.

The vulnerability of countries to growing water hazards stands as another important priority when attempting to increase regional water and food security. The frequency of extreme hydro-meteorological events such as floods has quadrupled between 2000 and 2009, compared to the period of 1970–1979 (EM-DAT,2013). The social impacts of floods and storms have remained relatively stable (< 3% of the LAC population affected annually) at the LAC scale, but in countries like Belize, Guyana or Cuba, social exposure risk has increased. The economic impacts have grown considerably, and in 2010 they peaked with damages accounting for almost 2% of LAC's GDP. A major reason for this high vulnerability to floods in LAC is related to accelerated urbanization with little or no urban planning, but also to the fact that many cities are located in very flat areas, where large concentrated rain events may produce serious problems such as the 2013 flooding of La Plata. Hydro-climatic variability, in the form of droughts, also represents a major risk for regional food security. Currently, only 13% of the total agricultural area in LAC is equipped with irrigation (FAO, 2012) which makes the agricultural sector in LAC highly vulnerable to drought. Only some parts of Mexico, Chile, Peru, the Northwest of Argentina, and the Northeast of Brazil rely on irrigation water for food production, mostly for the production of value added products such as fruits and vegetables. The potential to expand irrigation is huge but fairly unrealized: FAO (2013) includes Argentina, Brazil, Colombia, Mexico and Peru in the list of twenty world countries with the largest potential, but only Brazil and Mexico stand among the twenty countries with the largest area already equipped with irrigation. However, groundwater salinity, poor drainage in flatlands and droughts make irrigation developments very risky unless large infrastructure investments are made.

1.4.4 The development and operation of the urban water cycle in large cities, intensive industries and the mining sector pose major environmental challenges

Providing a quality drinking water service, improved sanitation and adequate treatment of wastewater is challenging, especially in LAC where the population, particularly in urban areas, has expanded rapidly. The root of the problem is neither economic (scale economies allow for the provision of good quality and sustainable water services at a reasonable cost) nor technical (current engineering can deal with the most complex problems). Barriers to cope with the already diagnosed problems are mostly the lack of governance and institutional leadership, as well as political agendas that often do not include the universal coverage of water supply and sanitation as key priorities.

During the last decade, infrastructure development for domestic supply has been for the most part orientated towards water service provision while sanitation and wastewater management investments have received less attention. In fact, public and private investment on this front has levelled off recently. Another challenge associated with urban water supply is that initial investments for providing access to water have not been followed by stable funding for maintenance and in fact many water services are currently in dire need of replacement and modernization. This and the large population growth, especially in urban areas, are responsible for the deficient quality of supplied services. Regional Process of the Americas (2012) explicitly highlights among these deficiencies: the insufficient water disinfection, the poor surveillance of water abstractions, discontinuous service, insufficient pressure, high leakage percentage (above 40% in many cases) and the limited wastewater treatment. These are big challenges and making use of economies of scale seems to be the most logical and feasible solution to provide a good quality urban water service to the citizen at the lower possible cost, when all involved costs and long-term economic balances are considered (Cabrera et al., 2013). However, this needs a good administrative structure, political support and remarkable leadership amongst decision makers. Although the main focus of water services in large cities is on domestic supply improvements, natural hazards and pollution are also serious concerns in many rural and small urban areas. These are brought to the attention of national authorities through local political and social representatives.

Although water consumption for energy, industry and mining may only be a small percentage of countries' consumption, it can be locally significant, especially in small basins and in the arid and hyper-arid areas of LAC. This consumption may also be economically and socially important, and therefore water quantity and quality should be guaranteed.

Mining and industrial production are emerging sectors in the region and represent an important share of LAC's economy. Furthermore mining is a key source of income and employment. Nonetheless, industrial activities, and in particular mining, contribute to water resources deterioration, threatening water security locally and downstream. This is due to the disposal of water with high salinity, often containing acids and diverse unwanted and noxious solutes. These unwanted constituents are derived from minerals – diverse heavy metals – or from concentration and processing, such as flotation compounds. Quicksilver (mercury) and cyanide can also be found in the case of the many gold mines in LAC, especially the small and artisanal ones. Pollution management is hindered by financial constraints, as well as by insufficient monitoring programmes and wastewater treatment investments. Yet pressures to maintain and expand mining activities will grow because of the world's demand for metals and non-ferrous products. LAC countries currently supply 51% of the world's silver, 45% of its copper and overall 25% of the world's metal market. The production of lithium, a series of secondary metals and coal are also important, as well as gems. Water productivity in the mining and industrial sector is at least one order of magnitude higher than in the agricultural sector.

1.4.5 In LAC water governance is evolving to address the challenges posed by rapid socio-economic changes, however, as is often the case, the implementation of reforms lags behind

Large unexploited natural resources, coupled with the sustained growth pattern of many LAC countries, contribute to create situations where different needs, interests and understanding of the concept of socio-economic development lead to tensions. Poor legal compliance, insufficient legal instruments and lack of funds are often at the root of significant environmental damages and conflicts. Disputes are mainly related to the construction and operation of water works, water diversion, industrial and mining pollution and the privatization of water supply and sanitation coverage in urban areas. This means that most tensions spin around 'non-food water', i.e. a small fraction of the water actually consumed in the region, as high potential of pollution, new risks of flood and fear to lose the precarious water supply in marginal urban areas act as powerful catalysts for stakeholders concern.

Advocacy networks play a key role in empowering and giving national and international visibility to local populations directly affected by environmental degradation or social unfairness. During the past two decades, the demands from civil society for more inclusive, sustainable, efficient and effective governance, as well as the influence of international organizations and supranational agencies, have triggered significant institutional reforms in the region in the form of much legislative activity.

Common elements in those reforms include: a shift towards decentralization, often complemented with the creation of coordination and supervising bodies at a higher level; the formulation of new water laws and policies that include IWRM principles (environmental sustainability, integration, participation, accountability, transparency, cost recovery); and the creation of water use taxes and tariffs for cost recovery. Additionally, in its search for improved water security, LAC has pioneered the recognition of the right to water and sanitation as a human right.

In most of the countries the focus is now on implementing institutional reforms, where the main challenges are related to the lack of integrated planning of water use, the poor coordination of the main stakeholders (both governmental and non-governmental), insufficient local capacity and the need for management instruments that best fit the specific regional differences.

In the spaces for dialogue and participatory decision making created by reforms (e.g. watershed committees, water councils or customary tribunals), formal participation is mainly limited to water users, usually those representing large-scale economic activities. Some accomplishments in participation deserve to be acknowledged, and there are efforts for refining those formal instruments to make them more inclusive and representative of civil society. Nonetheless, the credibility of participation is often questioned due to stakeholders' unequal capacity to participate and the direct access of strong economic lobbies to decision-makers. Other interests not associated to water rights or the perspectives of indigenous population are often underrepresented and social activism still prevails as the main instrument to voice their demands.

Governance failures at different levels have spurred civil society's claims for higher accountability of elected representatives and public authorities. As a reaction, most LAC countries passed, during the last decade, information transparency laws, which apply also to environmental and water-related public information. The actual implementation of the legal obligations to disclose information, however, is still deficient, thus hindering the process of accountability of public authorities before their constituents.

The progressive deterioration of water resources and the need to finance water services provision have fostered the establishment of economic instruments to implement the 'polluter-pays-principle' and increase cost recovery rates. Environmental taxation has been implemented in some LAC countries, but enforcement and collected revenue are still low and do not act as a true deterrent to polluters. After decades of little or no cost recovery rates in irrigating schemes, some countries, such as Argentina, Mexico, Peru and Brazil, have taken steps to make farmers pay for operation and maintenance costs of the infrastructure supplying their water. This may be a tax on exports to compensate for government investments in infrastructures when the product is sold to other country.

Incentives for environmental conservation like payments for ecosystem services (PES) and PES-like schemes have been developed in LAC over the last few years as a complementary instrument to conventional command-and-control and financial instruments. Yet the most successful initiatives have been orientated towards securing availability and quality of water for urban areas (e.g. Produtor Agua in Brazil or Fondo para la Protección del Agua (FONAG) in Ecuador), and thus are geared towards protecting non-food water for cities. The dependency of many PES schemes on international funds, their often weak financial sustainability and the lack of secure land tenure and property rights, amongst other factors, hinder the implementation and long-term sustainability of many other PES initiatives.

1.4.6 Democracy, education and good governance are the basis for using LAC's large natural and human capital for the achievement of human well-being

At present, in LAC, fertility and birth–death rates have decreased, and the population structure is fairly young, with over 50% of working-age. Such a 'demographic dividend', if maintained and accompanied with the corresponding investments and policies, represents a key asset for assuring LAC's socio-economic development in the decades to come. A deeper democratization, the emergence of a powerful civil society, the rise of a middle class, economic openness, and macro-economic stability are also key elements explaining the recent evolution of LAC societies (World Bank, 2013c).

Economic development and the rapid urbanization process have changed societies in LAC, their needs and the way the population use their natural resources. Economic growth and international trade are contributing to changing the dietary habits of LAC citizens, thus affecting the use of water and land. During the past few decades, globalization and the global trade of goods has opened up new development paths and has triggered dynamics whose implications in terms of water and food security in LAC are still difficult to grasp in full.

The opportunities for LAC to achieve a more sustainable and efficient use of their resources, and facilitate a transition towards a green economy are numerous. In fact, there are already a number of successful cases of application and a window of opportunity for the evaluation of trade-offs whilst identifying the potential for significant improvement. The extraordinary natural endowment coupled with the population dividend represents a unique opportunity to foster LAC's socio-economic development.

Nevertheless many challenges still need to be faced, as in several cases economic growth in LAC has been achieved at the expense of land use, energy and water resources intensification, combined with an increase in the levels of pollution and the loss of ecosystems and biodiversity. The reinforcement of national and global governance schemes and their alignment on the achievement of true and universal human well-being, under ethical and moral principles, and will remain an inescapable prerequisite to facing these challenges.

References

Allan, J.A. (2013). Food-water security: beyond water resources and the water sector. In: Lankford B., Bakker, K., Zeitoun, M. and Conway, D. (eds). *Water security: principles, perspectives and practices*, London, Earthscan. In press.

Cabrera, E., Cobacho, R., Espert, V. & Soriano J. (2013). Assessing the full economic impact of domestic water tanks. International Conference on *Asset Management for Enhancing Energy Efficiency in Water and Wastewater Systems*. Marbella, Spain, IWA.

Dalin, C., Konar, M., Hanasaki, N., Rinaldo, A. & Rodriguez-Iturbe, I. (2012) Evolution of the global virtual water trade network. *Proceedings of the National Academy of Sciences of the United States of America* 109 (16): 5989–5994.

Dingemans, A. & Ross, C. (2012). Free trade agreements in Latin America since 1990: an evaluation of export diversification.CEPAL *Review,* 108: 27–48.

ECLAC (2013). Economic Comission for Latin America and the Caribbean. *Social Panorama of Latin America 2012*. Technical Report. 238 pp.

EM-DAT (2013). Emergency Events Database on Disasters. World Health Organization and Centre for Research on the Epidemiology of Disasters Database. [Online] Available from: www.emdat.be/ [Accessed May, 2013].

Falkenmark, M. & Rockström, J. (2011). Back to basics on water as constraint for global food production: opportunities and limitations. In: Garrido, A. and H. Ingram (eds). *Water for Food in a Changing World. 2nd*–Rosenberg Volume Series. London, Routledge Publishers. pp.103–116.

FAO (2012). Food and Agriculture Organization of the United Nations. *Panorama de la Seguridad Alimentaria y Nutricional 2012 en América Latina y el Caribe*. Rome, FAO. 150 pp.

FAO, WFP and IFAD (2012). *The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition*. Rome, FAO. 65 pp.

FAO (2013). Food and Agriculture Organization of the United Nations. FAOSTAT *Database*. [Online] Available at: www.faostat.fao.org/ [Accessed in September, 2013].

Finucane M.M., Stevens, G.A., Cowan, M.J., Danaei, G., Lin, J.K., Paciorek, C.J., Singh, G.M., Gutierrez, H.R., Lu, Y., Bahalim, A.N., Farzadfar, F., Riley, L.M. & Ezzati, M. (2011). Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Body Mass Index) national, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9·1 million participants. *Lancet* 377: 557–567.

Gloor, M., Gatti, L., Brienen, R.J.W., Feldpausch, T., Phillips, O., Miller, J., Ometto, J.P., Ribeiro da Rocha, H., Baker, T., Houghton, R., Malhi, Y., Aragao, L., Guyot, J.L., Zhao, K., Jackson, R., Peylin, P., Sitch, S., Poulter, B., Lomas, M., Zaehle, S., Huntingford, C. & Lloyd, J. (2012). The carbon balance of South America: status, decadal trends and main determinants. *Biogeosciences Discussions,* 9(1): 627–671.

Jiménez-Cisneros, B. & Galizia-Tundisi, J (Coord.) (2012). *Diagnóstico del Agua en las Américas*. Red Interamericana de Academias de Ciencias (IANAS) and Foro Consultivo Científico y Tecnológico (FCCyT). [Online] Available from: www.foroconsultivo.org.mx/home/index.php/libros-publicados/diagnosticos-y-analisis-de-cti/991-diagnostico-del-aguaen-las-americas. [Accessed February, 2013].

Naím, M. (2013). *The end of power: from boardrooms to battlefields and churches to states, why being in charge isn't what it used to be*. New York, Basic Books.

NIC (2012). National Intelligence Council of US. *Global Trends 2030: Alternative Worlds* [Online] Available from: www.dni.gov/files/documents/GlobalTrends_2030.pdf [Accessed September, 2013].

OECD (2013). Organisation for Economic Co-operation and Development. *Global food security: challenges for the food and agricultural system.* Paris, OECD Publishing. 160 pp.

Prakash, A. (2011). *Safeguarding food security in volatile global markets*. Rome, FAO. 619 pp.

Regional Process of the America (2012). *Americas' water agenda: targets, solutions and the paths to improving water resources management.* February 2012. Available at: www.gwp.org/Global/GWP-CAm_Files/Americas'%20Water%20Agenda.pdf

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., Wit, C.A. de, Hughes, T., Leeuw, S. van der, Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V. J., Hansen, J., Walker, B. & Liverman, D. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society,* 14 (2).

Tittonell, P.A. (2013). *Farming systems ecology towards ecological intensification of world agriculture*. Inaugural lecture upon taking up the position of Chair in Farming Systems Ecology. Wageningen University. Available at: www.wageningenur.nl/upload_mm/8/3/e/8b4f46f7-4656-4f68-bb11-905534c6946c_Inaugural%20lecture%20Pablo%20Tittonell.pdf [Accessed June, 2013].

UN (2013). United Nations. *Sustainable development in Latin America and the Caribbean: follow-up to the United Nations development agenda beyond 2015 and to Rio+20*. Preliminary version. Available at: www.eclac.org/rio20/noticias/paginas/8/43798/2013-273_Rev.1_Sustainable_Development_in_Latin_America_and_the_Caribbean_WEB.pdf [Accessed August, 2013].

World Bank (2013a). *Agricultural exports from Latin America and the Caribbean: harnessing trade to feed the world and promote development.* Washington DC, World Bank.

World Bank (2013b). *World Development Indicator Database*. [Online] Available at: databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators [Accessed March, 2013].

World Bank (2013c). *Shifting gears to accelerate shared prosperity in Latin America and the Caribbean*. Washington DC, World Bank. [Online] Available at: www.worldbank.org/content/dam/Worldbank/document/LAC/PLB%20Shared%20Prosperity%20FINAL.pdf [Accessed September, 2013].

WHO (2013).World Health Organization. *Obesity and Overweight* Fact sheet No. 311. [Online] Available at: www.who.int/mediacentre/factsheets/fs311/en/ [Accessed October, 2013].

WHO-UNICEF (2013). Joint Monitoring Programme (JMP) for Water Supply and Sanitation data. [Online] Available at: www.wssinfo.org/data-estimates/table/ [Accessed July 2013].

Part 2

Setting the scene

2

WATER RESOURCES ASSESSMENT

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Highlights

- Latin America boasts some of the world's largest rivers, lakes and aquifers. Overall, these store and yield more water per person than any other region in the planet.
- Climatic variability, together with urbanization patterns, generates strong asymmetries between water demands and water availability across the region. This results in severe water stress in some of the most economically dynamic areas.
- Despite the abundance of surface water resources, groundwater use is gradually increasing. This is partly because of the growing costs associated with surface water storage and treatment, and partly because the advantages of groundwater use are becoming better known and accepted.
- Water quality poses a major cause for concern across the region. Pollution management is complicated by financial constraints, as well as by the absence of adequate monitoring programmes and wastewater treatment facilities.
- A much needed step towards protecting the environment and the health of water-related ecosystems is to implement integral management systems that cater for the maintenance of forests, wetlands, lagoon systems and coastal estuaries.
- Latin American water resources face threats derived from population growth, urbanization, changes in land use patterns and climate change.

2.1 Introduction

The Latin America and Caribbean region is water-abundant. It boasts some of the world's largest rivers, lakes and aquifers, which yield more water per person than any other region in the planet. However, water is irregularly distributed in time and space due to climatic variability. While heavy rainfall takes place across the year in the Amazon rain-forests, it barely ever rains in the Atacama Desert. Besides, the majority of the population is concentrated in cities. This generates strong asymmetries between water demands and water availability. Largely as a result, many freshwater ecosystems are endangered by a wide array of different pressures. Adaptation to climate change, universal access to water and sanitation services, pollution control and an integrated approach to transboundary water resources management are the main challenges ahead.

2.2 Water availability

Latin America only accounts for 13% of the total emerged lands and 6% of the global population, but it produces over one-third of the world's total runoff (Table 2.1). This region is home to some of the world's most important rivers, including the Amazon, Parana, Orinoco, and Magdalena, as well as some of the largest lakes. Take for instance the Titicaca Lake in Bolivia and Peru, the Nicaragua Lake, and Lake Chapala in Mexico. Surface water accounts for over 80% of Latin America's renewable resources, but the region is also endowed with abundant groundwater (Table 2.2). This includes the Guarani aquifers which are shared by Argentina, Brazil, Paraguay and Uruguay. Groundwater also represents a strong environmental element, discharging an estimated 3,700km^3/year into Latin America's rivers. From an economic viewpoint, groundwater storage is particularly important because it remains relatively stable over time and is comparatively better protected from domestic, agricultural and industrial pollution sources (Rebouças, 1999).

Looking at these facts one would think that water scarcity is hardly a matter of concern in Latin America. Overall figures are, however, misleading, as Latin America is diverse within itself. The irregular distribution of water, in both time and space, natural quality problems and an asymmetric occupation of the land imply that the above situation is not representative of all basins across the region. As a result, some are subject to mounting pressures, if not already confronted with water scarcity. For instance, the basins of the Gulf of Mexico, the South Atlantic and the Río de la Plata cover some 25% of Latin America's territory and are home to more than 40% of the population, but contain just 10% of the available water resources (WWC, 2000). Meanwhile, about 53% of the region's total renewable water supply comes from just the one river, the Amazon.

Table 2.1 Approximate amount of annual precipitation, evaporation and runoff per continent in relation to the water footprint

REGION	SURFACE (1000 km^2)	POPULATION (million)	AVERAGE RAINFALL (mm)	TOTAL RAINFALL (km^3)	AVG.EVAP. (mm)	TOTAL EVAP. (km^3)	RUNOFF (km^3)	WATER FOOTPRINT (km^3)	WATER FOOTPRINT (% of rainfall)
Asia	43,820	4,216	650	28,500	410	18,000	10,500	4,850	17.0
Africa	30,370	1,072	740	22,500	630	19,000	3,500	1,400	6.2
North America	24,490	346	800	19,500	470	11,500	8,000	970	5.0
South America	17,840	596	1,600	28,500	900	16,000	12,500	1,130	4.0
Europe	10,180	740	820	8,400	590	6,000	2,400	1,250	15.0
Oceania	9,010	37	440	4,000	400	3,500	500	45	1.1

Source: Martínez-Santos et al. (2014)

Table 2.2 **Renewable water resources and storage capacity in selected countries in Latin America**

COUNTRY	RENEWABLE SURFACE WATER (km^3/yr)	RENEWABLE GROUNDWATER (km^3/yr)	RESERVOIR STORAGE CAPACITY (km^3)
Belize	19	8	–
Mexico	409	139	180
Costa Rica	75	37	–
El Salvador	25	6	–
Guatemala	103	3	–
Honduras	87	39	9
Nicaragua	193	59	0.5
Panama	145	21	–
Guyana	241	103	–
Suriname	122	80	22.7
Bolivia	596	130	0.3
Colombia	2,132	510	–
Ecuador	424	134	–
Peru	1,913	303	3.9
Venezuela	1,211	227	164.1
Brazil	8,233	1,874	513.1
Argentina	814	128	–
Chile	922	140	4.7
Paraguay	336	41	37.7
Uruguay	139	23	18.8
Total	18,139	4,005	955

Source: FAO (2013)

Brazil alone generates 37% of Latin America's surface runoff, while no other country reaches 10%. In contrast, arid zones have no surface runoff, except during rare and extreme rainfall events. Rainfall averages 1,600mm/year across the region (Figure 2.1), but ranges from 20mm/yr in the Atacama Desert to over 2,000mm/yr in the mountains of southern Chile (Box 2.1). Rainfall is also characterized by its strong seasonal component. Take for instance Central America, where about half of the precipitation occurs from August to October, and only 7% between February and April. In South America, 35% of stream flows take place between May and July, whilst only 17% corresponds to the November–January period (Shiklomanov, 1999).

Seasonal variability is influenced by cyclic atmospheric phenomena known as El Niño and La Niña. Both are associated with major temperature fluctuations in the tropical Pacific Ocean. El Niño is an abnormal warming of the sea surface temperature, whereas La Niña is a cool ocean phase. During El Niño, droughts take place along the Pacific coast of Central America. Conversely, higher precipitations occur in the Caribbean coasts. In South America, El Niño generates the opposite response. In the Pacific and Southern Atlantic coasts, rains become more intense, whereas in the tropical Atlantic coast drought frequency increases. The cold phase La Niña causes different patterns. Rain events increase along the Pacific coast of Central America. The same occurs with the frequency of hurricanes in the Caribbean Sea. Along the Southern Pacific coast of South America, droughts tend to become more frequent and temperatures drop. Overall, El Niño events are more frequent than La Niña. In the last decades a higher frequency of El Niño events has been recorded, leading some experts to contend that this might be related to climate change (Magrin et al., 2007).

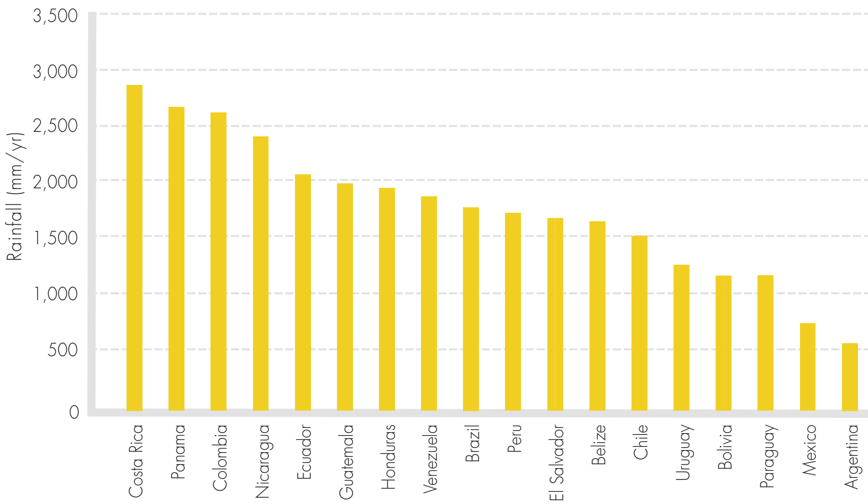

Figure 2.1 Long-term annual rainfall in selected Latin American countries. *Source: FAO (2013)*

Overall, water availability per capita has steadily decreased over the last decades, mostly due to the fact that the population has grown from 420 to 550 million inhabitants between 1992 and 2011. Currently, water availability ranges from Mexico's 3,500m^3/person/yr to Peru's 55,000m^3/person/yr (Figure 2.2). In other words, all of Latin America's countries are safely located above Falkenmark's 1,700m^3/person/yr threshold for water scarcity. The regional average is around 25,000m^3/person/yr, well above Europe's 8,500m^3/person/yr or Asia's 3,600m^3/person/yr. However, while most standard indicators underline Latin America's privileged position in terms of water resources, water scarcity does occur at the regional scale. This is because water resources are mostly located in the inland, while urbanization and land development followed the path of decisions made in colonial times. Thus, cities and economic activities were concentrated either near the coast to facilitate exports to Spain and Portugal, or close to the main cities of the Aztec and Inca empires to take advantage of the abundant labour (Mejía, 2010). In practice, this means that large countries such as Venezuela, Mexico and Peru show strong asymmetries between water availability and population density (Box 2.2).

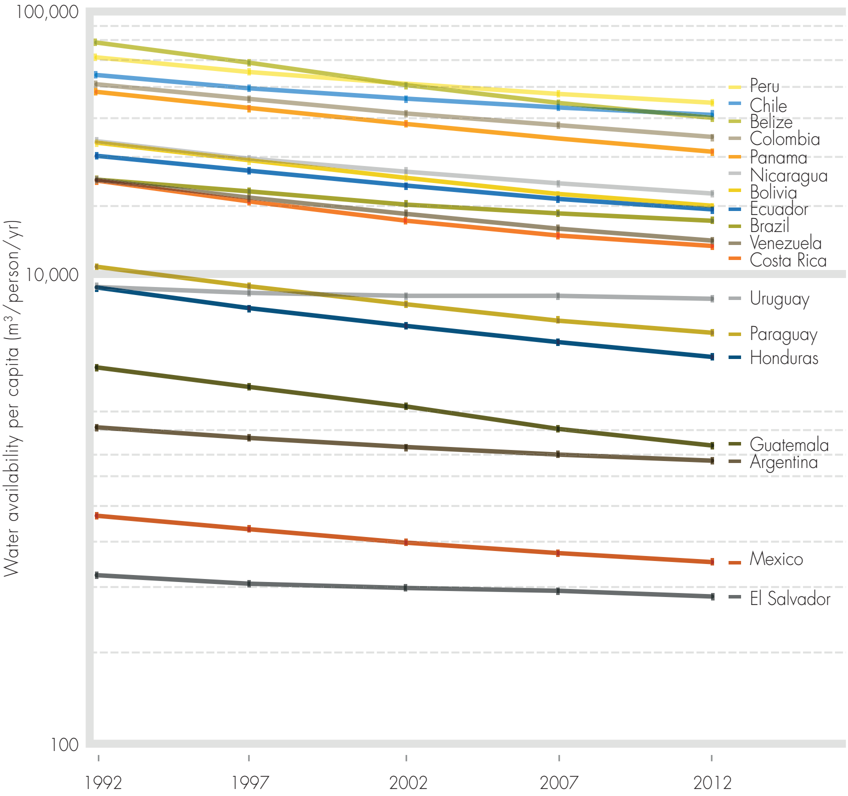

Figure 2.2 Renewable resources per capita over the last twenty years in selected countries.
Source: FAO (2013)

Box 2.1 Large countries are naturally diverse: rainfall variability in Chile

Although Latin America is best described as a water-rich region, average water availability is decreasing. Chile is an excellent example since the country's unique geography, including a number of short river valleys running from the Andes to the Pacific Ocean, provides a variety of climatic conditions. Two primary mountain ranges, the Andes and the Coastal Mountains, span the length of Chile and provide the limits between the coastal plain and the central valley. Average precipitation ranges from near zero in the north to about 2,000mm/yr in the south (Figure 2.3).

The rainy season is in winter, from June to September, and much of the precipitation is stored in the snowpack of the Andes. Water flows in most river basins have a mixed origin, since waters come from winter precipitations and summer snow melt, presenting highest flows in summer (November–February) due to said snow melt, and pronounced reductions in winter (from April to June). Additionally, rainfall fluctuations show greater variability in the arid and semi-arid north (between the Arica-Parinacota Region and the Coquimbo Region). South of 37°S latitude, rainfall becomes more uniform. Therefore, the hydrological regime of Chile is rather irregular.

Within the global context, Chile as a whole may be considered privileged in terms of water resources. The total runoff is on average equivalent to 53,000m^3/person/yr (World Bank, 2011a), a value considerably higher than the world average (6,600m^3/person/yr). However, there exist significant regional differences: north of the city of Santiago, arid conditions prevail with average water availability below 800m^3/person/yr, while south of Santiago the water availability is significantly higher, reaching over 10,000m^3/capita/yr.

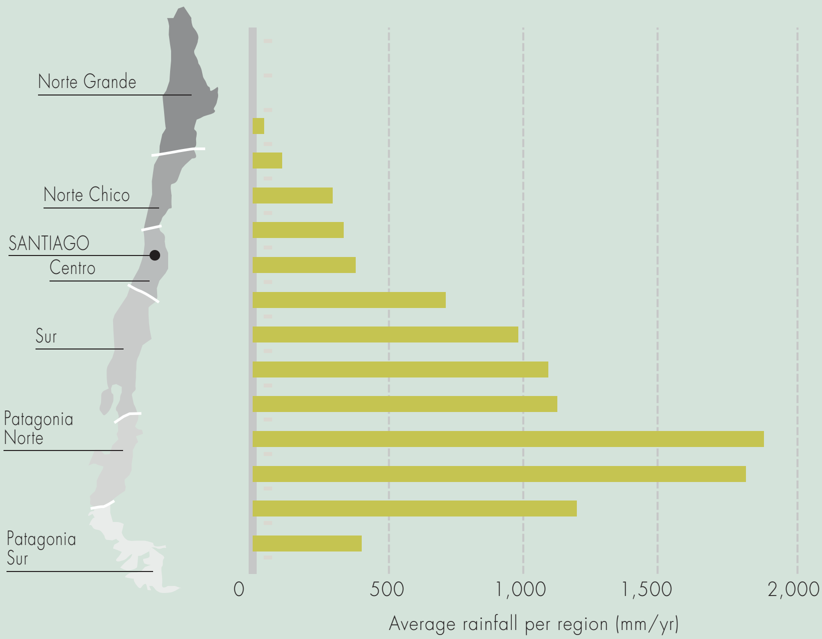

Figure 2.3 Regional rainfall variability in Chile. *Source: modified from Donoso (2014)*

Box 2.2 Water and population asymmetries: Mexico, Peru and Venezuela

Many Latin American countries show a significant disparity between water resources abailavility and the population distribution. Take for instance Mexico. In this country, 77% of the population, 84% of the economic activity and 82% of the irrigated land is located in the central and northern plateaus, some 1,000 metres above sea level. In contrast, 72% of water availability occurs in the south and below that altitude. Another example is Venezuela, where 90% of population and economic activity is located in the north of the country with less than 10% of water availability. In contrast, most of the water availability is found south of the Orinoco River away from the northern coast. But perhaps the most startling case is Peru. Rainfall in the Peruvian part of the Amazon basin, which is home to 30% of the country's population, accounts for 97.5% of the country's surface water. Conversely, the Pacific basin hosts 65% of the population and produces only 1.8% of the water resources of the nation. Rainfall in the capital, Lima, is 10mm/yr or lower. This asymmetry makes the most economically dynamic regions of Peru severely water stressed.

Table 2.3 Water availability in Peru's hydrographic regions

BASIN	AREA (1,000km^2)	RAINFALL (mm/yr)	WATER AVAILABILITY (hm^3/yr)	WATER AVAILABILITY (% of total)	POPULATION (million)	POPULATION (% of total)	WATER AVAILABILITY (m^3/person/yr)
Pacific	279.7	274	37,363	1.8	18,315,276	65	2,040
Amazon	958.5	2,061	1,998,752	97.7	8,579,112	30	232,979
Titicaca	47.2	814	10,172	0.5	1,1326,376	5	7,669
Total	**1,285.20**		**2,046,268**	**100**	**28,220,764**	**100**	**72,510**

Source: Kuroiwa et al. (2014)

Development of non-conventional water resources remains relatively uncommon. Take for instance desalination. Peru and Chile are Latin America's premier users of desalinated seawater, on which they rely for specific developments. Most of the investments in Chilean desalination projects are located in the dry north of the country. These have been designed to underpin mining activities, as well as urban supply. In coastal Peru, desalination provides water for the industrial sector, households and agriculture.

Drinking water and sanitation services reach a relatively large share of the Latin American population. Total coverage amounts to 87% in the case of water supply and 78% in the case of sanitation. However, these figures hide an uneven distribution. For instance, important variations in drinking water coverage are observed across countries.

In Brazil, Mexico, Costa Rica, and Colombia, this figure exceeds 90%, whereas in Peru it is lower than 75%. In terms of rural areas, only Mexico and Costa Rica exceed 85%. Few other countries reach 60%. Sanitation systems are largely insufficient to meet demands. Coverage is similar to that of water supply, exceeding 80% in some urban agglomerations, but rural areas rarely ever reach 50%. Chile poses a remarkable exception, having increased its water services dramatically over the last decade (World Bank, 2011a). Currently, it exceeds 95% in terms of water supply and sanitation coverage in urban areas and 60% in rural regions. The vast majority of sewage goes untreated, thus generating downstream pressures. Less than 40% of sewage is treated in countries such as Argentina, Brazil or Colombia. All these issues will be discussed in more depth in Chapters 6 and 8.

2.3 Water uses

The available water data mostly refer to water withdrawals within each country. In other words, it does not distinguish between water use for production, for domestic consumption or for producing goods for exportation, and exclude virtual water. Moreover the lack of sufficient data on climate, soils and growing seasons in most countries is often the factor limiting the ability to produce meaningful information on consumptive uses. This is most often due to inadequate databases or to the absence of data. In this sense, it is important to distinguish between consumptive uses and withdrawals. Not all water withdrawals result in consumptive water use. This is due to the fact that a large share of withdrawn waters goes back into the hydrological cycle in the form of pipeline losses, wastewater or irrigation returns. On the other hand, not all consumptive uses stem directly from withdrawals. Rain-fed agriculture, for instance, represents a significant fraction of the total water use without being responsible for any direct extraction from the water cycle.

Despite these clarifications, which apply to water figures across the world, Latin America is known to be less water-stressed than other regions (Figure 2.4). Unlike Asia, where a significant part of the water resources are already in use, a large share of Latin America's waters remains untapped. Figure 2.5 shows the distribution of water withdrawals per sector and sub region in Latin American and Caribbean regions. Agriculture comprises irrigation and livestock. Consumption due to water uses such as hydropower, navigation, fishing or recreation is considered negligible for practical purposes.

Rainwater can be split into 'green' and 'blue' water. Green water refers to the share of rainwater that stays in the soil rather than running off or recharging groundwater. In other words, green water is that which underpins rain-fed agriculture. On the other hand, blue water refers to the water in rivers, lakes, reservoirs, ponds and aquifers. Irrigated agriculture uses blue water as a supplement to rainfall. As will be discussed in Chapters 6 and 7, green and blue water have different implications for the purpose of water and food security.

The water footprint provides a useful indicator of water use. As shown in Table 2.4, green water agriculture accounts for the largest share of the region's water footprint (Mekonnen and Hoekstra, 2011). Blue water follows in magnitude, well ahead of industrial and domestic use. Irrigation efficiency is however low. Efficiency is measured by taking into account the difference between the volume of water captured and the actual delivery to the farms, and is mostly dependent on the type of irrigation system. In many Latin American countries, irrigation efficiency ranges between 30% and 40% (San Martín, 2002). Inefficient irrigation technologies do not necessarily imply a wasteful water use, as the losses return to the hydrological cycle. However, these rank among the main causes behind the loss of fertile soils and are largely a consequence of policies that promote production. This represents one of the main threats to agricultural sustainability across the region.

Table 2.4 Blue and green water footprint of countries in the Latin America and Caribbean region (those with more than one million inhabitants). All consumption figures are rounded to the nearest decimal.

COUNTRY	POPULATION (million)	CONSUMPTION OF AGRICULTURAL PRODUCTS				CONSUMPTION OF INDUSTRIAL PRODUCTS		DOMESTIC WATER CONSUMPTION
		INTERNAL (hm³/yr)		EXTERNAL (hm³/yr)		INTERNAL (hm³/yr)	EXTERNAL (hm³/yr)	(hm³/yr)
		GREEN	BLUE	GREEN	BLUE	BLUE	BLUE	BLUE
Argentina	37.1	47,746	3,258	1,298	146	116	61	491
Bolivia	8.4	25,764	377	2,489	124	4	4	18
Brazil	175.3	288,345	8,498	27,981	2,075	420	147	1,202
Chile	15.5	6,994	2,101	5,071	278	93	32	142
Colombia	40.1	35,863	1,386	9,101	716	16	33	539
Costa Rica	4	2,725	148	1,381	187	12	11	79
Cuba	11.1	13,194	831	1,944	130	47	9	156
Dominican Rep.	8.9	6,590	826	3,263	211	2	13	109
Ecuador	12.4	17,175	1,440	2,464	134	33	12	212
El Salvador	5.9	3,441	42	1,482	215	7	7	32
Guatemala	11.4	8,137	149	1,553	202	10	13	13
Haiti	8.7	6,809	225	1,230	434	0	2	5
Honduras	6.3	5,754	113	777	172	2	4	7
Jamaica	2.6	2,162	45	1,510	164	3	6	14
Mexico	99.8	83,841	8,654	65,986	8,475	135	358	1,359
Nicaragua	5.1	3,498	134	536	99	1	4	19
Panama	3	2,226	54	928	95	1	8	55
Paraguay	5.4	9,673	214	14,	59	2	6	10
Peru	26.2	13,142	3,299	8,050	404	74	18	168
Trinidad & Tobago	1.3	0	1,588	115	2	4	21	1,590
Uruguay	3.3	177	1,286	13	2	8	8	1,268
Venezuela	24.6	21,551	1,194	12,985	547	16	21	381

Source: Mekonnen and Hoekstra (2011)

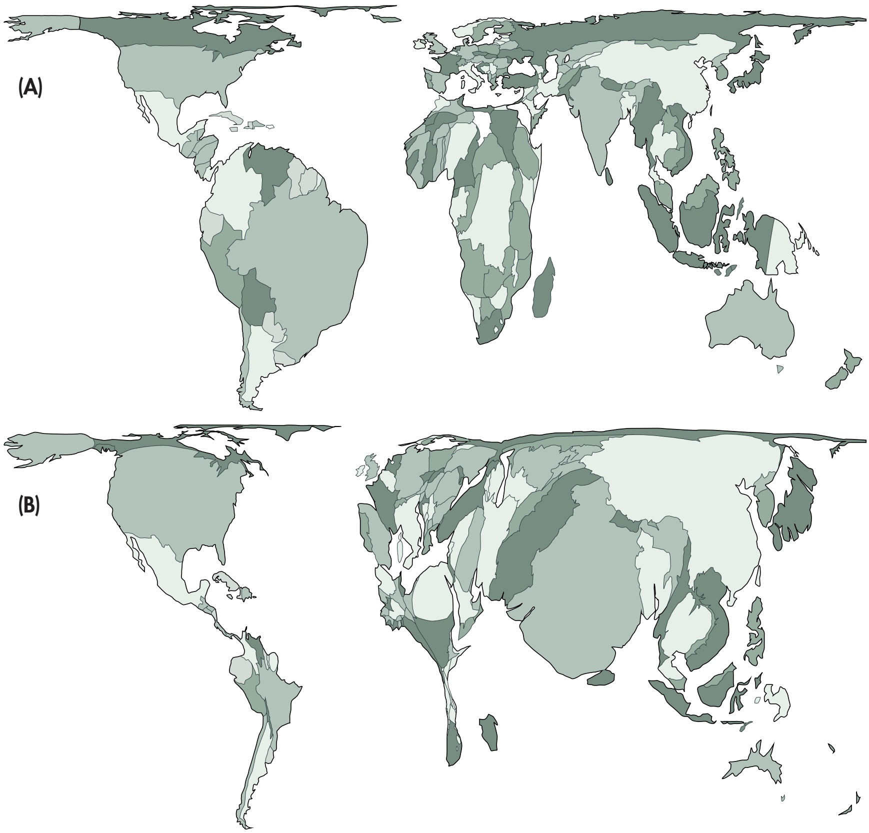

Figure 2.4 **(A) Total annual rainfall (av. period 1961–1990) and (B) Water use across the world.** Country areas are deformed as a function of total rainfall and water use, i.e. the larger the country is represented, the larger is its proportional share relative to other countries. Source: *modified from Sasi Group (University of Sheffield) and Mark Newman (University of Michigan)*

Industry uses relatively little water in comparison with other sectors. Water-intensive industries include food processing, pulp and paper, petro-chemical and textile sectors. These demand raw materials that are abundant in the region, creating significant multiplier effects in the local and national economies (San Martín, 2002). However, industries are responsible for environmental degradation by dumping untreated sewage into rivers and aquifers. This is particularly true of the mining industry, whose water use is relatively low, but which is considered one of the main water polluters across the region (Chapter 9).

While surface water is the preferred source of water in the region, groundwater use has increased in recent decades (Box 2.3). This is partly because of the growing costs associated with surface water storage and treatment and partly because the advantages of groundwater use are becoming more accepted (Llamas and Martínez-Santos, 2005). Most of the existing groundwater-based developments are concentrated in areas of economic or political interest, or where surface water is under stress. In contrast, fundamental hydrogeological knowledge is still under development in many parts of Latin America and there are vast regions where groundwater data are scarce or non-existent (Ballestero et al., 2007). Besides, natural water quality problems, such as elevated concentrations of arsenic, are yet to be fully assessed in countries such as Argentina, Bolivia, Chile, Ecuador, El Salvador, Mexico, Nicaragua and Peru.

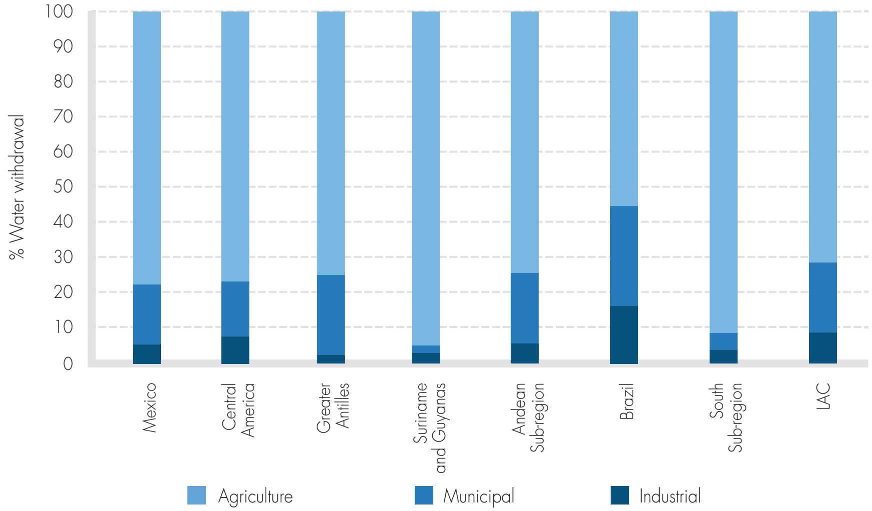

Figure 2.5 Water withdrawals per sector in the Latin American and Caribbean region. Central America comprises Costa Rica, Honduras, Guatemala, Belize, El Salvador, Panama and Nicaragua; the Greater Antilles include Cuba, Haiti, the Dominican Republic and Jamaica; the Andean sub-region refers to Colombia, Ecuador, Venezuela, Bolivia and Peru; and the South sub-region includes Paraguay, Uruguay, Argentina and Chile. *Source: FAO (2013)*

Groundwater use is especially relevant in Argentina, where it accounts for 30% of the total water withdrawals. Likewise in Chile, where it is of particular importance in the mining sector. In this country, 63% of the water used in mining and 46% of domestic water supply comes from aquifer sources. Groundwater is also the primary source for human consumption in Costa Rica and in Mexico, where groundwater accounts for 50% of industrial demands, 70% of domestic supply in cities and practically all domestic supply in rural areas.

The wealth of water resources in Latin America is reflected in the region's natural resources and the environmental services that these provide (UNEP, 2003). Natural forests cover 47% of the total surface area of the region, the northern part of the Amazon and the Guyana area being home to the largest expansion of virgin forest in the world. About 95% of the green surface corresponds to the tropical rainforests of Central America, the Caribbean and the South American sub-tropics. The remainder is located in temperate South America, primarily Argentina, Chile and Uruguay.

Box 2.3 Groundwater mining in Latin America

[By Prof Emilio Custodio (Universitat Politècnica de Catalunya, Spain)]

As is the case of diverse regions of the world, and especially in arid and semi-arid areas (Custodio, 2010, 2011), in some of the driest areas of Latin America groundwater reserves are being depleted due to intensive exploitation, at a rate much higher than they are being replenished. Groundwater mining is mostly produced in two areas. One corresponds to the hyper-arid areas of the Andean Region, comprising coastal Peru, northern Chile, southwestern Bolivia and northwestern Argentina, where groundwater renewal is scarce to nil. Groundwater abstraction takes place primarily to supply the mining of metal ores and also for brine extraction in terminal salt lakes ('salares') in order to exploit some solutes such as lithium, potassium and nitrate. The sustainability of small springs and groundwater discharges that are important for some human settlements, tourism in the area and have a significant ecological value, such as the high altitude wetlands ('bofedales'), is of special concern. Rainfall in the intermediate depressions is a few mm/yr on average and the limited replenishment is occasionally produced by some sporadic floods in gullies whose headwaters are in the highlands ('Altiplano'). Albeit rainfall in the Altiplano is scarce, a combination of almost bare soil with low humidity retention (mostly acidic ignimbrites) and rainfall retention in the seasonal snow cover favour some recharge. This manages to sustain some springs that yield water with a very long turnover time. Although mining may deplete groundwater reserves and their recovery may take centuries, there are no specific studies on groundwater reserve depletion.

Other groundwater mining areas can be found in the dry areas of Mexico, where reserves are being depleted at a rate greater than recharge, even if recharge is still significant. In this case groundwater is mostly used for irrigation, but also for mining and industrial activities. In some coastal areas freshwater in the aquifer is being replaced by laterally or vertically intruding saline water, as in Sonora's coastal aquifers. In Mexico, 104 of the existing aquifer systems are considered over-exploited by the Federal Water Authority (Comisión Nacional del Agua). Even though this is a small fraction of the existing aquifers receiving a groundwater recharge of 2,500m^3/s, these aquifers yield 800m^3/s. This amounts to 80% of used groundwater (Jiménez-Cisneros and Galizia-Tundisi (2012). About 20–25% of groundwater reserves, equivalent to171m^3/s, have been ruined, which is equivalent to about half the water used for public supply.

Some cases of groundwater resources depletion are located in the agricultural valleys of western Peru, such as Ica–Villacurí. The main problem here is the integrated management of water resources and the adequate use of the aquifer as a storage reservoir. A key issue is the mixing of freshwater and old saline water. Similar problems are found in the dry northeast of Brazil and also in the dry areas of the Argentinean Pampas (the Chaco-Pampean region), where arsenic and fluoride groundwater quality problems and deep-seated relict saline water upcoming add to periodic, non-permanent depletion of water reserves.

Other well-known groundwater problems, such as seawater intrusion in Mar del Plata and Recife, or land subsidence around Mexico City or Queretaro, are better described as they hydrodynamic results of intensive groundwater development, rather than as groundwater mining problems.

Computing environmental requirements for ecosystems is a recurrent stumbling block for academics and managers across the world. Latin America's ecosystems are no exception. Although the importance of marine and coastal flora and fauna is widely acknowledged (WSSD, 2003), there is less recognition of water needs to support ecosystems, which are themselves legitimate water users (UNEP, 2012). Ecosystems, which provide life-supporting goods and services, need water of adequate quantity and quality. Appropriate timing is also crucial in many cases. A much needed step towards protecting the environment and health of water-related ecosystems is to implement integral management systems that cater for the maintenance of forests, wetlands, lagoon systems and coastal estuaries.

Hydropower is the main non-consumptive use across the region. Take for instance Chile, whose hydropower sector has grown to account for 38% of its total energy production, and whose current flow rate is in the order of 4,190m^3/s (Ayala, 2010). This is largely explained by sustained economic growth over the last three decades, which has led to a significant increase in energy demands. About 82% of Colombia's reservoirs are devoted to energy generation, but even so, it is estimated that the country is only taking advantage of 10% of its potential for producing energy, since many of its rivers are still unregulated. Mid- and long-term developments are therefore expected, the main challenge being the need to balance environmental, social and economic constraints. Hydropower is an important water user in several other countries, including Brazil. In Costa Rica, this industry holds 82% of the water licenses.

Due to the size of many Latin American rivers, navigation is another relevant user. It is particularly important in countries such as Argentina, which operates along the Paraguay-Paraná and Alto Paraná waterways. Buenos Aires boasts South America's most important harbour. Maintaining adequate navigation conditions implies continuous work on the Río de la Plata. The Patagonian harbours, to the south of the country, have experienced notable development over the last decades in order to favour tourism.

Fishing is an important activity in many regions, allowing for the economic subsistence of local communities. It is also an established industry and features highly among tourist destinations. However, this sector has experienced setbacks in recent years due to the construction of reservoirs, over-fishing, the introduction of exotic species and contamination. Water pollution has proved particularly detrimental to recreational uses. Indeed, poor or non-existent treatment of wastewater effluents has endangered tourism and ecosystems in freshwater bodies across the region. Many Latin American lakes, including Lake Chapala in Mexico and Lake Titicaca in Bolivia and Peru, are at present severely polluted.

Water demands are leading to increasingly important conflicts between users (Chapters 11 and 15). In terms of consumptive uses, agriculture is usually displaced by the domestic and industrial sectors. In most cases, however, the environment is the net loser. There is a general consensus that contamination due to untreated wastewater, industrial and mining effluents, and widely dispersed agricultural pollutants are serious problems in many areas across the region.

2.4 Water quality

Water pollution in Latin America is caused by human activities and refers in general to the presence of pollutants from anthropogenic sources. In addition, natural phenomena such as volcanic activities, storms or earthquakes cause changes in water quality. Pollutants may cause water to be unfit for human consumption or to sustain aquatic life.

Water quality is associated with the use it is given. García (2006) explains that a water body is polluted when it contains substances that make it inadequate for certain uses, and contaminated when it contains substances that endanger human health. Therefore, a water body may be polluted and not contaminated. Conversely, if it is contaminated, it is polluted. Due to its capability to dissolve chemicals, natural and residual waters, as well as water for human consumption, always contain dissolved substances. Depending on their concentrations, all pollutants have the potential to become contaminants.

Water pollutants include both organic and inorganic chemical substances as well as pathogens. These substances can be man-made or of natural origin, such as plant residues. Some are found naturally in Latin American water bodies and their concentrations may assist in defining their natural origin or classification as contaminants. Many chemicals are toxic and some of them are biodegradable, thus consuming oxygen dissolved in water.

In Latin America pollutants are frequently discharged into water bodies from both point and non-point sources, producing physical, chemical, and biological changes that cause adverse effects in humans and in ecosystems. Point source pollutants are those that enter water bodies through discharge pipes or channels. They include municipal and industrial wastewater discharges, with or without previous treatment, and urban runoff drains. Diffuse source pollution does not come from a single source but is the accumulation of pollutants after runoff from areas with diverse land uses. This type of pollution is the main cause of water eutrophication, which refers to the increase in concentration of nutrients. This, in turn, may increase the primary production in water bodies, causing anoxia and decreased water quality, affecting ecosystems and other water uses.

Land uses in Latin American watersheds and water uses for human purposes introduce changes in the natural cycle of precipitation, absorption, water flow, infiltration, and evapotranspiration. While part of the used water is consumed, part is returned to the water bodies but most often with different quality. While agricultural use return flows contain salts, nutrients, pesticides, and organic matter, industrial discharges contain organic matter, metal ions, chemical residues and salts and what's more, at higher temperatures. Domestic discharges carry grease, detergents, dissolved solids, bacteria, and viruses (García, 2006).

Agricultural effects on water quality are mostly due to chemical contamination of fertilizers and pesticides that accumulate in some aquifers, and reuse of sewage effluents for irrigation that can transmit a number of pathogens, even after secondary water treatments (World Bank, 2011b). Significant water pollution due to irrigation has been reported in Barbados, Mexico, Nicaragua, Panama, Peru, Dominican Republic and Venezuela (Biswas and Tortajada, 2006; FAO 2004; LA-Mexico, 2012).

Salinity due to irrigation has been a serious constraint in countries such as Argentina, Cuba, Mexico, and Peru, and, to a lesser extent, in the arid regions of northeastern Brazil, north and central Chile and some small areas of Central America (ibid). The reuse of domestic wastewater for irrigation has been established as a common practice on the outskirts of the cities located in arid and semi-arid areas, where intense competition for water for agriculture and urban uses often occurs.

Arsenic and fluoride pose groundwater quality concerns in several parts of the region. Arsenic content in groundwater is sometimes natural, but can also be attributed to economic activities such as gold or lead mining or to industrial effluents. High arsenic concentrations are known to be a problem in parts of Mexico, the Andean range and Argentina. High fluoride concentrations are often associated to sodium-bicarbonate waters found in weathered alkaline and metamorphic rocks, coastal aquifers affected by cation exchange or aquifers affected by evaporation. Thus, high fluoride concentrations have been observed in parts of Brazil and the Andes.

As indicated by Biswas and Tortajada (2006), water is becoming increasingly polluted in Latin America. Such pressures vary in the different sub-regions, and some sectors, such as mining and agriculture as well as large cities, are quite conspicuous, representing specific local water quality concerns for both surface and groundwater (Box 2.4). While large mining companies recycle and treat discharges, most small and artisanal mining companies do not have control and measures of their water pollution, and constitute important sources of contaminants to adjacent water bodies (World Bank, 2011b).

Box 2.4 Pollution by metals, metalloids and other contaminants in Chile

Rivers in the north of Chile have relatively high concentrations of metals from both natural sources and mining activities. Recent studies address the variation in concentration of heavy metals and sulphates, which is also a by-product of mining, in eleven rivers in the north of Chile. These show high concentrations of heavy metals and sulphates that in many cases exceed Chilean regulations. Arsenic is an important contaminant related to natural pollution in Chile. High evaporation and increased extraction of water have caused higher contents of salts in water. Aluminium is also an important pollutant in the central zone of the country. In order to control changes in waters quality, regulations of discharges must be fulfilled and norms are being developed that specify water quality limits for these releases to aquatic systems, considering the specific conditions of the receiving water bodies (Jiménez-Cisneros and Galizia-Tundisi, 2012).

Barrios (2006) points out that water quality management is not a substitute for efficient water management but a strategic issue that requires the integration of water quantity, pollution control, efficient use of water, environmental considerations and human health implications. Since Latin American countries are heterogeneous in terms of physical, climatic, economic, social, institutional, and environmental conditions (Biswas and Tortajada, 2006), water quality management should be specifically planned and developed and be an integral component of water management policies. The region's water quality management is complicated by the lack of wastewater treatment, financial constraints, difficulties in complying with standards and criteria of receiving waters, and the lack of monitoring programmes (García, 2006).

Not all of Latin America faces the same water quality problems, since these vary according to development and types of economic activity. While standards have been established to control point source pollution, García (2006) affirms that the resulting water quality is still not adequate. Among the problems are the disposal of sewage and lack of wastewater treatment. Besides, the attention has mostly been towards industrial discharges, ignoring municipal and non-point source pollution. The lack of monitoring and assessment has prevented the development and application of receiving waters criteria for more efficient basin-wide approaches to cope with such problems.

Given the magnitude of non-point source pollution's contribution to water quality losses, there is widespread agreement that many water quality goals cannot be reached without reducing this type of pollution. The cost-effectiveness of controlling non-point source pollution is generally recognized as opposed to narrowing regulations so that tertiary treatments of point source discharges are required (Russell and Clark, 2006).

Hoekstra et al. (2011) developed the Water Pollution Level (WPL) as an indicator of the level of water pollution. WPL is defined as the ratio between the total grey water footprint in an area or a watershed to the actual runoff. In Latin America, the overall WPL related to nitrogen (N) that are close to or higher than 1.0 are widespread over the entire region (Figure 2.6), while those related to phosphorus (P) that are close to or higher than 1.0 are mostly in Mexico and to the south and east of the region (Figure 2.7).

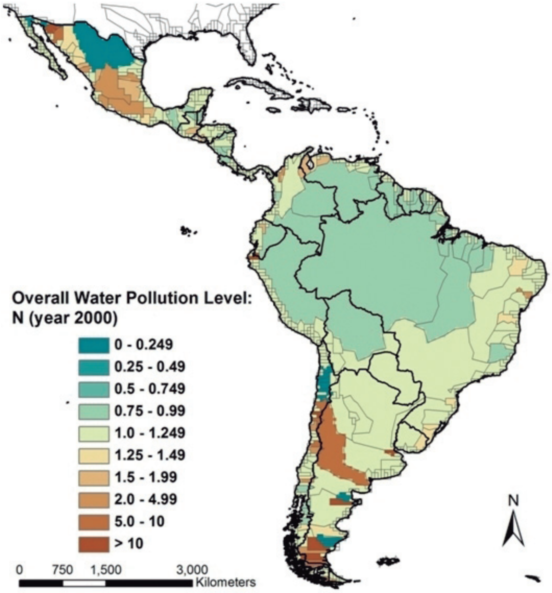

Figure 2.6 **Water Pollution Level for nitrogen (N) per river basin in Latin America (year 2000).** *Source: Liu et al. (2012)*

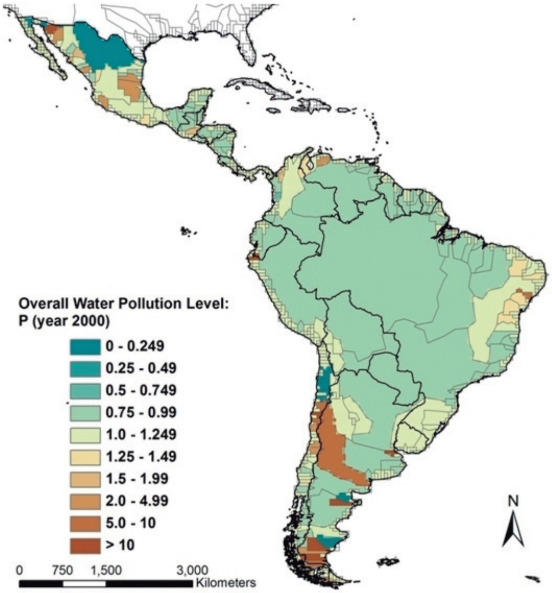

Figure 2.7 **Water Pollution Level for phosphorus (P) per river basin in Latin America (year 2000).** *Source: Liu et al. (2012)*

Water quality is acquiring great relevance because of the role of water in transporting contaminants and the growing concern over emergent forms of pollution such as endocrine-disrupting substances, in addition to persistent organic pollutants and other toxic compounds. Very few developing countries are prepared to face these concerns (Barrios, 2006) and, although there are specific case studies in Latin America that relate to the presence of these pollutants, to date there is no general overview of their presence in water bodies of the region. No permanent programmes exist for the monitoring of persistent organic pollutants, emerging pollutants, and other toxic compounds, and there are therefore no inventories or formal valuations of the exposure and risks associated with these substances (Box 2.5).

Box 2.5 Water quality policies in Mexico

The priorities of the Mexican water policy are to assure enough water of appropriate quality, recognize the strategic value of water, efficient use of water, protect water bodies, and to ensure the sustainable development and environmental conservation (CONAGUA, 2008).

The National Water Law (DOF, 2012) establishes the water quality requirements depending on its use, with the priority on human consumption relative to other uses of water. The norm NOM-127-SSA1-1994 (permissible limits of water quality and treatments for water purification) and NOM-179-SSA1-1998 (monitoring and evaluation of water quality control for human use and consumption, of water distributed by public supply systems), establish limits for human use and consumption. On the other hand, NOM-001-SEMARNAT-1996 establishes the limits for discharges to waters and national properties and NOM-002-SEMARNAT-1996 establishes the limits for discharges to municipal and urban sewage systems. The ecological criteria for water quality, CE-CCA-001/89, include limits for urban public use, recreation with direct contact, irrigation, livestock and aquatic life.

Currently, the evaluation of water quality in Mexico is based on three basic indicators: biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS). In 2009, twenty-one of 1,471 river basins were classified as heavily contaminated according at least one of these indicators. Nearly 13% of the Mexican surface water was polluted owing to BOD, 31%, to COD, and 7.5%, to TSS.

Hansen and Corzo-Juárez (2011) highlighted the priorities and requirements for the evaluation of pollution of watersheds, referring to the policy of water management in Mexico, and the above-mentioned regulations. They remark that the national programme for monitoring and evaluation of toxic persistent and bioaccumulable substances (STPB) is recently being implemented and up until now there had been no formal valuations or cataloguing of the substances and the associated risks. A proposed list of substances to be included in a monitoring program of STPB in watersheds and aquifers has been presented by Hansen (2012).

Water quality problems are not only solved by constructing and operating wastewater treatment plants. Water quality management should include the formulation and implementation of water policies, monitoring and evaluation of water quality, installation of appropriate legal and institutional frameworks, capacity building, and evaluation and control of non-point sources pollutants.

2.5 Transboundary resources

A significant number of the region's basins are shared by two or more countries. These transboundary basins cover an area where a relatively large fraction of the population is concentrated. Take for instance South America, where there are thirty-eight international water basins that cover almost 60% of the continent area and that are home to more than one hundred million people (nearly 30% the population) (UNEP, 2007). Despite this, only four transboundary basins in South America have transboundary agreements in place (La Plata, Titicaca, Amazon and Lagoon Mirim). Remarkably, the Orinoco and Essequibo basins, i.e. the third and fourth largest of the continent, are not governed by international treaties (De Stefano et al., 2012).

Another important factor influencing the territorial structure of water management is that four of the largest countries in the continent are federal (Brazil, Mexico, Argentina and Venezuela). This means that most transboundary basins are directly or indirectly influenced by federalism. In those cases, strong state-level authorities will determine land and water use based on social, economic and political interests that may not take into account the interests of upstream or downstream users.

The distribution of water management responsibilities in Latin American countries is diverse (Table 2.5). Water resources commissions and river basin organizations have often demonstrated themselves to be useful bodies to coordinate inputs from sectors and stakeholders acting at the chosen management scale. This can be seen in the institutional evolution of several countries in Latin America. In Mexico, for example, management units include basins and sub-basins, and basin organizations at both scales. Mexico together with Brazil and Argentina have a tradition of river basin organizations, whereas in other countries, e.g. Peru, such entities are still being set up. River basin organizations have had deficiencies since their creation, partly due to weak institutional and policy frameworks, weak investment or financing methods (Dourojeanni, 2011). Take for instance Argentina, where the lack of financial autonomy of the river basin committees makes them highly dependent on provincial and local governments (OECD, 2012). In some cases, decentralized watershed management exists but is isolated and not formally recognized, stemming from local initiatives or pursued by sub-national authorities through informal processes and without the support of national political elites (see for instance Ecuador, Kauffman, 2011). Dourojeanni (2001) identified several challenges for river basin organizations, including the clarification of their role (and the potential competition with other authorities), economic viability and funding.

Table 2.5 Distribution of water responsibilities in selected countries

COUNTRY	WATER RESOURCES	DOMESTIC SUPPLY	RIVER BASIN ORGANIZATIONS	WATER USER ASSOCIATIONS
Argentina	Provinces	Provinces, municipalities	Yes	Yes
Brazil	Central Government, Water-specific bodies, RBO	Municipalities	Yes	Yes
Chile	Central Government	Central Government, water-specific bodies, local rural, committees	No	Yes
Costa Rica	Central Government	Municipalities	No	No
El Salvador	None	Municipalities, inter-municipal bodies, water-specific bodies, RBOs	n/a	No
Guatemala	RBOs	Municipalities	Yes	Yes
Honduras	Municipalities, inter-municipal bodies, water-specific bodies	Municipalities, inter-municipal bodies, water-specific bodies	n/a	No
Mexico	Regions, municipalities, inter-municipal bodies, RBOs	Regions, municipalities, inter-municipal bodies, RBOs	Yes	Yes
Nicaragua	Regions, municipalities, inter-municipal bodies, water-specific bodies, RBOs	Regions, municipalities, RBOs	Yes	Yes
Panama	None	Municipalities, others	n/a	No
Peru	Regions, municipalities, water-specific bodies, RBOs	Regions, municipalities, water-specific bodies, RBOs	Yes	Yes

Source: OECD (2012); OECD (2011); LA–Chile (2012); LA–Costa Rica (2012)

2.6 Climate change and water resources

Many countries of LAC have reported multiple evidences of a changing climate.[1] The most frequent impacts reported include an increase in average temperature, higher frequency of extreme rainfalls, sea level rise and coastal retreat, droughts, hurricanes and strong winds, and glacier melting. The magnitude and importance of each impact differs across regions and within countries (see Figure 2.8).

Based on the number and frequency of recorded impacts, the Andean region is the most vulnerable zone to climate change. Mean temperature has increased in all countries,

1 Most of the information under this heading stems from National Communication reports (NCs) in compliance with the United Framework Convention on Climate Chagne (UNFCCC) by twenty LAC countries (Non-annex I parties), including: Mexico, Belize, Guatemala, Honduras, El Salvador, Costa Rica, Panama, Nicaragua, Peru, Bolivia, Colombia, Ecuador, Venezuela, Brazil, Suriname, Guyana, Chile, Argentina, Paraguay and Uruguay.

most importantly in the higher altitudes, e.g. in the Bolivian Andean altiplano (between 1.1 to 1.7°C) and in the high Colombian plains (up to 1°C). In these parts of the Andes rainfall has decreased and droughts are becoming more frequent. Such trends are probably behind observed glacier melts, particularly in Peru and Colombia. In contrast, the Andean lowlands are becoming wetter and more prone to extreme rainfall. These changes have been linked to the intensification of El Niño events.

The South Cone also appears to be suffering important changes. The most frequently recorded phenomenon is an increase in extreme rainfall events, particularly in the northern part of the region. In central and northern Argentina the number of extreme rainfalls has increased fourfold since the 1960s. Also, a sea level rise of up to 4mm/year has been recorded on the coast of Rio de la Plata during the last two decades. The persistence of both trends is worrisome given the population density in this area. Elsewhere, along the Andean mountains of Chile and Argentina, the frequency and length of droughts have increased. Dryness has been associated with the intensification of La Niña. In Chile for instance, the number of dry years has increased substantially over the last century, e.g. during the first quarter of the 20th century the frequency of dry years was 15%, during the last fifty years, the frequency has increased to 50%. In the South Cone, an increase in mean temperature has mostly occurred in the Patagonian region (up to 1°C) and the Andean Mountains (+0.25°C) but not along the coastal areas. Eighty-seven out of one hundred glaciers under study along the Andean region have receded during the last century.

The intensification of El Niño events has been linked to the increasing frequency of extreme rainfall events and hurricanes along the Caribbean Coast. In Belize, for instance, four out of the eight major storms recorded during the 20th century have occurred in the last twenty five years. Likewise, Honduras is the third country in the world with the highest record of extreme event occurrence between 1990 and 2008. Extreme rainfall has caused nearly sixty floods in Costa Rica over the last six decades. While the Caribbean coast is becoming wetter and rain events more extreme, droughts are increasing along much of the Pacific coast of Central America. In the north of Costa Rica the frequency of dry years has increased remarkably between 1960 and 2005, and the average reduction in precipitation during these dry years surpasses 32% of the mean annual precipitation.

These observed trends largely coincide with the climate projections made by the Intergovernmental Panel on Climate Change (IPCC) for the region (Figure 2.8). According to Galindo et al. (2010), 2100 climate projections show an increasing frequency of hurricanes in the Caribbean and Central America, as well as a higher drought frequency and a reduction in annual rainfall. Glacier melting will continue along much of the Andean tropical glaciers of Colombia, Ecuador, Peru, as well as in Chile and Argentina.

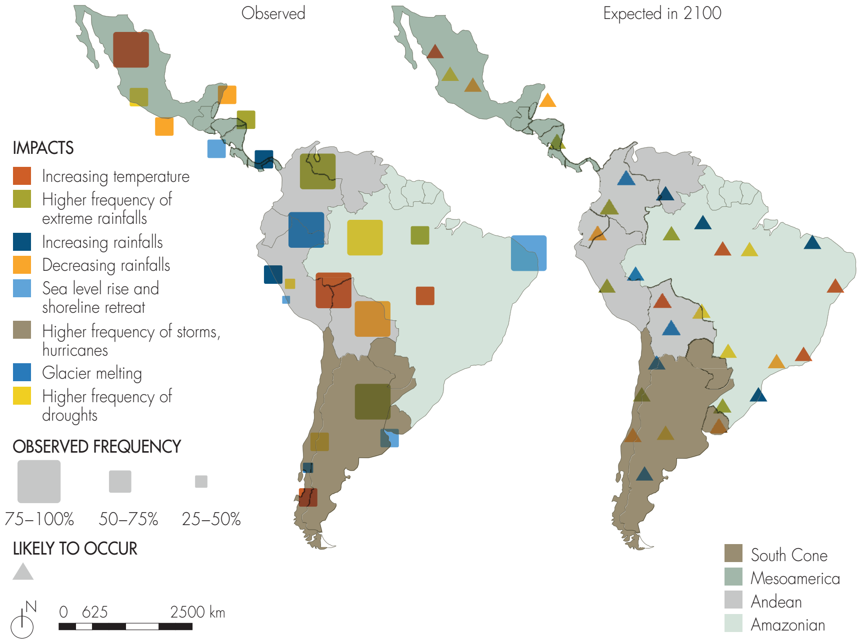

Figure 2.8 Observed (left) and expected (right) impacts linked to Climate Change in Latin America. *Source: own elaboration based on the information on observed impacts recorded from the National Communications (NCs) performed by twenty Latin American countries and summarized by major regions (UNFCCC, 2013); and expected climate change impact projections for the year 2100 in LAC as summarized in Galindo et al. (2010).*

2.7 Future challenges

Latin American water resources face important threats derived from population growth, urbanization, land use patterns and climate change, among others (Jones and Scarpati, 2007). United Nations' estimates suggest that the population will increase significantly in the coming years. By 2030, the population in northwest South America, from Venezuela to Bolivia, is expected to grow by one-third. Countries such as Brazil, Argentina or Chile will experience a demographic growth of about 20%. In addition, Latin America is experiencing other changes, namely, the shift of population from the countryside into the cities. As a result, per capita water consumption is rising dramatically in urban areas (see Chapter 8). This increases the pressure on local resources, such as Mexico City's aquifer, leading to problems of groundwater quality degradation, aquifer depletion and subsidence. Besides, the increase in paved areas, coupled with inadequate drainage, favours devastating floods such as the ones that have occurred in Sao Paulo, Mexico City, Rio de Janeiro or Buenos Aires in the recent past (Regional Process of the Americas, 2012).

Climate change is likely to cause increasing variability in precipitation and runoff, in both time and space, resulting in the excess or scarcity of water, and extreme events.

Inevitably this will cause changes in hydropower generation, agriculture, industry and domestic water supply. Some of the practical effects of climate change include the gradual substitution of Amazon rainforest with savannahs, changes in crop patterns and yields across the region, increased vulnerability to floods and droughts in Central and South America, augmented effects of the El Niño and La Niña oscillation phenomena and glacier melting in the Andes (EuropeAid, 2009).

In a context of unevenly distributed water resources and increasing drought in some regions and precipitation in others, enhanced water efficiency and management poses a major challenge, not only for direct water users and managers, but also for indirect water users such as policy makers, businesses, agricultural commodity trading companies and consumers. In contrast, consistent water accounting systems are yet to be developed. Quantifying and accounting for water flows within the economy (including environmental needs) and related impacts on the appropriate time and spatial scales would allow transparent information to be attained and thus contribute to the development of robust allocation and management systems needed to underpin a green economy (UNEP, 2010).

Deteriorating water quality due to urban and agricultural waste has long threatened public health and ecosystems. Full integration of water quality into the management debate is needed in order to ensure the preservation of water resources for the future. In this regard, systematic water quality monitoring, pollution control and wastewater treatment programmes are perceived as both urgent and essential.

Although some encouraging steps have been taken in the last few years, integrated water resources management is still absent in most countries (Chapter 15). Water governance opportunities are associated with the administration of water resources, the need to broaden and strengthen the capacity of public institutions, the establishment of clear and effective regulations for the provision of efficient services or the formulation and implementation of effective policies, with the subsidiary action of governments and with the participation of all water users including public–private cooperation strategies at local, sub-national and national levels (Regional Process of the Americas, 2012). Amongst all the challenges not least is the need to devise adequate governance frameworks for shared basins.

References

Ayala, L. (2010). *Aspectos Técnicos de la Gestión Integrada de las Aguas (GIRH). Primera etapa: Diagnóstico.* Informe preparado para el diagnóstico de la gestión de los recursos hídricos, Santiago, Chile.

Ballestero, M., Reyes, V. & Astorga, Y. (2007). Groundwater in Central America: its importance, development and uses, with particular reference to its role in irrigated agricultures. In: Giordano, M. & Villholth, K.G. (eds). *The Agricultural Groundwater Revolution: Opportunities and Threats to Development,* London, CAB International. pp.100–128.

Barrios, J.E. (2006). Water quality management: missing concepts for developing countries. In: Biswas, A.K., Tortajada, C., Braga, B. & Rodriguez, D.J. (eds). *Water Quality Management in the Americas. Water Resources Development and Management*, The Netherlands, Springer. pp. 137–146.

Biswas, A.K. & Tortajada, C. (2006). Preface. In: Biswas, A.K., Tortajada, C., Braga, B. & Rodriguez, D.J. (eds). *Water Quality Management in the Americas. Water Resources Development and Management,* The Netherlands, Springer. pp. 5–9.

CONAGUA (2008). Comisión Nacional del Agua. *Programa Nacional Hídrico 2007–2012. Secretaría del Medio Ambiente y Recursos Naturales.* [Online] Available from: www.conagua.gob.mx/CONAGUA07/ Contenido/Documentos/PNH_05-08.pdf [Accessed July, 2013].

Custodio, E. (2010). Intensive groundwater development: a water cycle transformation, a social revolution, a management challenge. In: Martínez-Cortina, L., Garrido, A. & López-Gunn, E. (eds). *Rethinking Water and Food Security,* Boca Raton,FL, CRC Press/Balkema. pp. 259–298.

Custodio, E. (2011). Hidrogeología en regiones áridas y semiáridas. VII Congreso Argentino de Hidrología. Temas Actuales de la Hidrología Subterránea/Hidrogeología Regional y Exploración Hidrogeológica. *Salta*: 1–17.

De Stefano, L., Duncan, J., Dinar, S., Stahl, K., Strzepek, K. & Wolf, A.T. (2012). Climate change and the institutional resilience of international river basins. *Journal of Peace Research*, 49(1): 193–209.

DOF (2012). Diario Oficial de la Federación. *Ley de Aguas Nacionales.* Latest reform published on June 8, 2012. pp. 1–106.

Donoso, G. (2014). Integrated water management in Chile. In: Martínez-Santos, P., Aldaya, M.M. & Llamas, M.R. (eds). *Integrated Water Resources Management in the 21st Century: Revisting the paradigm.* Boca Raton,FL, CRC Press. Forthcoming.

Dourojeanni, A. (2001). Water management at the river basin level: challenges in Latin America. Serie Recursos Naturales e Infraestructura: ECLAC. Report No. 29.

Dourojeanni , A. (2011). El error de crear organizaciones de cuenca sin las atribuciones necesarias para cumplir sus roles. *Revista Virtual REDESMA* [Online] 5(1). Available from: www.cebem.org/cmsfiles/articulos/REDESMA_11_art05.pdf [Accessed September, 2013].

EuropeAid (2009). *Climate change in Latin America.* AGRIFOR consult Group. [Online] Available from: ec.europa.eu/europaid/index_en.htm [Accessed July, 2013].

FAO (2004). Food and Agriculture Organization of the United Nations. AQUASTAT. [Online] Available from: www.fao.org/ag/agl/aglw/aquastat. [Accessed February, 2013].

FAO (2013). Food and Agriculture Organization of the United Nations. AQUASTAT. [Online] Available from: www.fao.org/ag/agl/aglw/aquastat. [Accessed February, 2013].

Galindo, L.M., de Miguel, C. & Ferrer, J. (2010). *Gráficos vitales del cambio climático para América Latina y el Caribe.* Edición especial para la CP16/CP-RP 6, México. Ciudad de Panamá. [Online] Available from: www.cridlac.org/digitalizacion/pdf/spa/doc18216/doc18216.htm [Accessed February, 2013].

García, L.E. (2006). Water quality issues in Latin America. In: Biswas, A.K., Tortajada, C., Braga, B. & Rodriguez, D.J. (eds). *Water Quality Management in the Americas*, Berlin, Springer. pp. 1–15.

Hansen, A.M. (2012). Programa de monitoreo y evaluación de STPB en cuencas hidrológicas y acuíferos. *Tecnología y Ciencias del Agua*, III (4): 167–195.

Hansen, A.M. & Corzo-Juárez, C. (2011). Evaluation of pollution in hydrological basins: priorities and necessities. In: Oswald-Spring, U. (ed). In: *Water Resources in Mexico. Scarcity, Degradation, Stress, Conflicts, Management, and Policy.* Berlin-Heidelberg, Germany, Springer. pp. 201-230.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. & Mekonnen, M.M. (2011). *The Water Footprint Assessment Manual: Setting the global standard*. London, UK, Earthscan.

Jiménez-Cisneros, B. & Galizia-Tundisi, J (Coord.) (2012). *Diagnóstico del Agua en las Américas*. Mexico. Mexico, Red Interamericana de Academias de Ciencias (IANAS) and Foro Consultivo Científico y Tecnológico (FCCyT). [Online] Available from: www.foroconsultivo.org.mx/home/index.php/libros-publicados/diagnosticos-y-analisis-de-cti/991-diagnostico-del-agua-en-las-americas [Accessed February, 2013].

Jones, J.A. & Scarpati, O.E. (2007). Water resources issues in South America. *GeoJournal*, 70: 227–231.

Kauffman, C. (2011). *Transnational Actors and the Power of Weak Laws: Decentralizing Watershed Management Without the State*. Paper presented at the 2011 Annual Meeting of the American Political Science Association. Seattle, Washington, September 1–4, 2011.

Kuroiwa, J.M., Castro, L.F., Lucen, M.N. & Montenegro, J.I. (2014). Integrated water resources management in Peru: the long road ahead. In: Martínez-Santos, P., Aldaya, M.M & Llamas, M.R. (eds). *Integrated Water Resources Management in the 21st Century: Revisting the paradigm*. Boca Raton, FL, CRC-Press. Forthcoming.

LA–Chile (2012). *Report of Chile*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project. Madrid, Spain, Fundación Botín.

LA–Costa Rica (2012). *Report of Costa Rica*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project. Madrid, Spain, Fundación Botín.

LA–Mexico (2012). *Report of Mexico*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project. Madrid, Spain, Fundación Botín.

Liu, C., Kroeze. C., Hoekstra. A.Y. & Gerbens-Leenes, W. (2012). Past and future trends in grey water footprints of anthropogenic nitrogen and phosphorus inputs to major world rivers. *Ecological Indicators,* 18: 42–49.

Llamas, M.R. & Martínez-Santos, P. (2005). Intensive groundwater use: silent revolution and potential source of social conflict. *Journal of Water Resources Planning and Management*, 131(5): 337–341.

Magrin, G., Gay García, C., Cruz Choque, D., Giménez, J.C., Moreno, A.R., Nagy, G.J., Nobre, C. & Villamizar, A. (2007). Latin America. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden P.J. and Hanson, C.E. (eds) *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, Cambridge University Press. pp. 581–615.

Martínez-Santos, P., Aldaya, M.M., Llamas, M.R (2014). Integrated water resources management in Peru: state of the art and the way forward. In: Martínez-Santos P., Aldaya M.M. & Llamas M.R (eds). *Integrated Water Resources Management in the 21st Century: Revisting the paradigm*. Boca Raton FL, CRC-Press. Forthcoming.

Mejía, A. (2010). *Water For The Americas: Challenges & Opportunities*. Rosenberg International Forum on Water Policy. Buenos Aires, Argentina.

Mekonnen, M.M. & Hoekstra, A.Y. (2011). *National Water Footprint Accounts: The green, blue and grey water footprint of production and consumption*. UNESCO-IHE, Value of Water Research Report Series No. 50.

OECD (2011). Organisation for Economic and Cooperation Development. *Water Governance in OECD Countries A Multi-level Approach OECD Studies on Water*. Paris, OECD Publishing.

OECD (2012). Organisation for Economic and Cooperation Development. *Water Governance in Latin America and the Caribbean: A Multi-level Approach, OECD Studies on Water*. Paris, OECD Publishing.

Rebouças, A. (1999). Groundwater resources in South America. *Episodes*, 22(3): 232–237.

Regional Process of the Americas (2012). *Americas' Water Agenda. Targets, Solutions and the Paths to Improving Water Resources Management,* Marseille, 6th World Water Forum, [Online] Available from: www.unesco.org.uy/phi/fileadmin/phi/infocus/Americas__Water_Agenda.pdf Accessed July, 2013].

Russell, C.S. & Clark, C.D. (2006). Economic instruments and non-point source water pollution. In: Biswas, A.K., Tortajada, C., Braga, B., Rodriguez , D.J.(eds.) *Water Quality Management in the Americas*. Berlin, Springer. pp. 17–45.

San Martín, O. (2002). *Water Resources in Latin America and the Caribbean: Issues and Options*. Inter-American Development Bank. Technical Report No. 65.

Shiklomanov, I.A. (1999). *World Water Resources at the Beginning of the 21st Century.* UNESCO/IHP.

UNEP (2003). United Nations Environment Programme. *Water Resources Management in Latin America and the Caribbean*. Technical Report No. 26.

UNEP (2007). United Nations Environment Programme. *Hydropolitical Vulnerability and Resilience along International Waters. Latin America and the Caribbean*. Nairobi, UNEP.

UNEP (2010). United Nations Environment Programme. *Measuring Water Use in a Green Economy. A Report of the Working Group on Water Efficiency to the International Resource Panel*. Technical Report No. 91.

UNEP (2012). United Nations Environment Programme. *Global Environmental Outlook 5* (GEO5). Technical Report No. 591.

UNFCCC (2013). United Nations Framework Convention on Climate Change. *National Communications of non-Annex I parties of United Nation Framework. Convention on Climate Change*. [Online] Available from: unfccc.int/national_reports/non-annex_i_natcom/items/2979.php [Accessed May, 2013].

World Bank (2011a). *Chile: Diagnóstico de la gestión de los recursos hídricos. Departamento de Medio Ambiente y Desarrollo Sostenible para América Latina y el Caribe*. Santiago, Chile. [Online] Available from: www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2011/ 07/21/000020953_20110721091658/Rendered/PDF/633920ESW0SPAN0le0GRH0final0DR0REV.0doc.pdf. [Accessed April, 2013].

World Bank (2011b). *Water and Sanitation Program. American Water, a window of information to support water and sanitation sector.* [Online] Available from: www.wsp.org/featuresevents/features/agua-latina-window-access-knowledge-and-information [Accessed April, 2013].

WSSD (2002). World Summit on Sustainable Development. *Johannesburg Plan of Implementation. World Summit on Sustainable Development. JPOI Response Strategy.* [Online] Available from: www.cooperazioneallosviluppo.esteri.it/pdgcs/documentazione/AttiConvegni/2003-01-01_JohannesburgPlanImplementation.pdf [Accessed April, 2013].

WWC (2000). World Water Council. *World Water Vision: Making Water Everybody's Business*. London, Earthscan, [Online] Available from: www.worldwatercouncil.org/library/archives/world-water-vision/vision-report/ [Accessed June, 2013].

3

TRENDS IN LAND USE AND ECOSYSTEM SERVICES

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Highlights

- The land used for agricultural production in Latin America and the Caribbean (LAC) comprises 26% of its total surface area: 10% for crops and 16% for livestock grazing. This share still remains below the global average land appropriation (38%).
- Between 1990 and 2010 LAC lost approximately 92 million hectares of forests, becoming the second most important deforestation hotspot worldwide, only preceded by Southeast Asia. Some 88% of this forest loss has occurred in South America and 12% in Mesoamerica. Brazil alone accounts for 60% of LAC's deforestation. In the Caribbean forest area has increased.
- Agriculture is the major driver of deforestation in LAC. In South America the cultivation of agricultural commodities, mostly oilseeds and grains, underpin much of the ongoing deforestation together with the sharp expansion of the livestock sector. In Mesoamerica, the low agricultural productivity keeps pushing the agricultural frontier in order to overcome national food in security problems.
- LAC has outstanding natural capital and contributes to the provision of multiple ecosystem services on a wide range of scales. Yet, land use changes are a major driver of ecosystem services loss even above climate change.
- The deep transformations that have occurred in LAC over the last two decades have had important impacts on the provision of key ecosystem services. Regulating services such as carbon sequestration and biodiversity conservation have experienced the largest impacts, with an average loss of 9%. Also, native agro-diversity has shrunk almost 6%. Cultural services like ecotourism has grown over 150% and provisioning services like forestry and water provision have also increased (35% and 6%, respectively).
- Deforestation rates are slowing down. Yet, the growth of agriculture in LAC is increasingly being decoupled from expanding the agricultural frontier and more based on increases in agricultural yields.
- To cope with the increasing world food demand while ensuring the conservation of LAC's natural capital and ecosystem services, it is necessary to develop integrated land use approaches, including agricultural oriented measures (e.g. land sparing and land sharing) and conservation initiatives (e.g. Reducing Emissions from Deforestation and Forest Degradation- REDD+).

3.1 Introduction

Latin America and the Caribbean region (LAC) is currently facing a daunting challenge: producing food, fibre, and fuel to satisfy an increasing internal and international demand and at the same time preserve its outstanding natural capital and related ecosystem services (ES) (Martinelli, 2012). Compared to other regions, LAC has a major advantage to achieve this double goal due to its rich natural endowment in terms of land, water and its low population density.

Ongoing pressure on LAC natural resources is linked to internal development but also to economic globalization, population growth and principally changing diets throughout the world. FAO (2009) estimates that by 2050 agricultural production will need to double in order to satisfy the increasing world food and biofuel demand. This future demand can partly be met by intensifying existing agricultural land and improving resource use efficiency (e.g. bridging the yield gap, the development of genetically modified crops-GMOs, etc.), however, most experts agree that between 50 and 450 million hectares of additional agricultural land will also be required (FAO, 2009; Fisher et al., 2009; Lambin and Meyfroidt, 2011). This additional land demand is most likely to be absorbed by developing countries that have the greatest land availability, primarily sub-Saharan Africa and LAC (Smith et al., 2010).

Food and fibre are key provisioning ES to LAC as they provide important benefits which are contributing to overcome local and global food insecurity gaps and at the same time allow for regional economic development. By 2011 annual gross revenues of LAC's agriculture accounted for over 120,000 million US$ (FAO, 2013), and generated approximately 18% of the employment (World Bank, 2013). In some of the major agricultural producing countries, like Brazil, agro-industry accounted for 22% of the national GDP in 2011 (CEPEA, 2013). A large part of this agricultural market expansion is taking place at the expenses of replacing natural ecosystems, mostly tropical savannahs and forests. The ecosystem productivity of these tropical forests ranks among the highest in the world due to their extension and quality, particularly along the Amazon basin and much of Central America (Pfister et al., 2011). Their replacement entails important trade-offs for the provision of other key non-market ES, like carbon sequestration, pollination, water flow regulation or biodiversity conservation. Balancing these ES trade-offs are key to LAC but also globally since the Amazon tropical forests play a key role in the global carbon and water cycle (Rockström et al., 2009; Gloor et al., 2012).

Despite the pressure, significant improvements in agricultural production have been achieved in many LAC countries, in an attempt to increase efficiency, decouple production from water and land resource consumption and thus minimize existing ES trade-offs. Efforts in this direction are critical since deforestation, as opposed to climate change, causes abrupt changes in ecosystems, limiting and often precluding opportunities for adaptation.

Accordingly, this chapter aims to explore: 1) what major changes in land use have occurred in LAC during the last two decades of significant economic changes; 2) what are the drivers behind these land changes; 3) how are those changes influencing the flow of ES across the region; and 4) what policy options are in place to safeguard LAC's natural capital while contributing to global food security.

3.2 What have been the main land use trends over the last decades?

As Chapters 4 and 5 describe, LAC has experienced significant changes over the last decades as a result of its great economic acceleration and the strong development of its agricultural sector. This growth has been accompanied by the expansion of LAC's agricultural area by almost 57 million hectares (see Figure 3.1). Such increase is related to the expansion of pastures for livestock production and arable land. Likewise, shrublands and secondary forests have also experienced an important area increase (≈ +27 million hectares). Much of these land uses have grown at the expense of replacing natural meadows and even more notably, natural forests, which have shrunk 92 million hectares, an area equivalent to the size of Venezuela. This forest reduction represents 46% of the total forest losses occurred in the southern hemisphere over the last two decades (FAO, 2010; Rademaekers et al., 2010), demonstrating that LAC, and particularly South America, is one of the most important global deforestation hotspots.

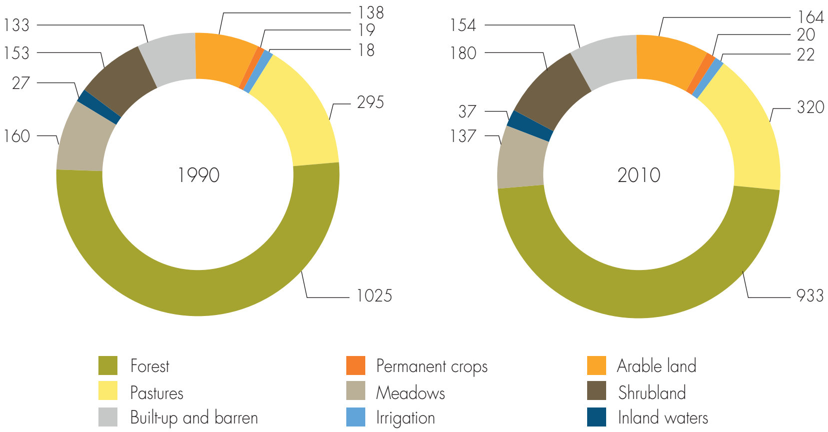

Figure 3.1 Land uses in Latin America and the Caribbean (LAC) in 1990 and 2010 (in million hectares). *Source: own elaboration based on FAO (2013)*

Within LAC, the most important deforestation hotspots are located in Brazil and to a lesser extent in Venezuela, Bolivia and Argentina (Table 3.1). Since 1990, Brazil alone has lost over 55 million hectares, although the rates of deforestation have slowed down significantly over the last years. According to the National Institute for Space Research (INPE) deforestation rates in the Brazilian Legal Amazon have diminished from about 2.9 million hectares per year in 2004 to 0.47million hectares per year in 2012

(INPE, 2012). Deforestation rates in other Brazilian biomes (e.g. Cerrado, the Brazilian savannah) remain high, but overall it is patent the progressive regression of deforestation on a national level. This slow down in forest cover loss has not been observed yet in Venezuela, Bolivia and Ecuador, where deforestation rates have remained stable or even increased in the last years. In Mesoamerica, the largest forest losses have occurred in Mexico, Honduras, Nicaragua and Guatemala. In the Caribbean region the trend points into a different direction, since forest area has increased over 10,300 hectares between 2000 and 2010 (FAO, 2010).

Table 3.1 Deforestation rates across Latin America between 1990 and 2010. Figures have been rouded to the nearest decimal.

	ANNUAL RATE OF DEFORESTATION (million ha/yr)			TOTAL DEFORESTATION (million ha)
COUNTRY	1990–2000	2000–2005	2005–2010	1990–2010
BRAZIL	2.9	3.1	2.2	55.3
VENEZUELA	0.3	0.3	0.3	5.8
BOLIVIA	0.3	0.3	0.3	5.6
ARGENTINA	0.3	0.3	0.2	5.4
ECUADOR	0.2	0.2	0.2	4.0
PARAGUAY	0.12	0.2	0.2	3.6
PERU	0.1	0.1	0.2	2.2
COLOMBIA	0.1	0.1	0.1	2.0
MEXICO	3.5	1.2	0.8	5.5
HONDURAS	1.7	0.6	0.6	2.9
NICARAGUA	0.7	0.4	0.4	1.4
GUATEMALA	0.5	0.3	0.3	1.1

Source: FAO (2010)

Figure 3.2 shows the prevailing land use trends across LAC's territory since the 90s.[1] Overall, LAC's territory has been very dynamic during the last two decades, with 40% of the territory (over 900 million hectares) experiencing either a change in land use or in land cover. This dynamism is the result of two major trends: (1) a pronounced reduction of the forest cover, either due to large-scale deforestation for cultivation or through small to

1 The land use trends have been obtained from the land use transition matrix created by combining the 1993 Global Land cover (USGS 2008) and the 2009 Glob Cover Map (ESA 2010) for LAC. Map sources have different spatial resolutions and legends, therefore figures on land use trends need to be considered as a first gross approximation to the real size of ongoing land use trends in LAC.

medium-scale forest clearing for cattle, mining and subsistence agriculture; and (2) a less pronounced but growing trend of reforestation, which combines processes of secondary natural succession, human-induced afforestation and woody encroachment on previous cultivated areas.

Deforestation and expansion of the agricultural frontier has been the dominant trend in LAC in the last two decades (Figure 3.2). The greatest expansion of pastures and arable land has occurred in South America, mostly in Brazil, Argentina and Paraguay. In Mesoamerica, countries like Nicaragua, Honduras, Panama and Guatemala have also seen an increase of their agricultural area, mostly arable land but also permanent pastures for grazing.

Although less intensive, the progressive trend of forest degradation observed in many parts of the region is still important. This can be seen along the northern part of Mexico, in the region of Los Llanos in Venezuela, northwest of Colombia, the Amazonian belt in Brazil, and along much of the Andean region of Peru, Ecuador and Colombia. This trend of forest degradation comes from the clearing of natural forest and shrubs to be turned into pastures. The underlying reasons of this trend might be diverse but some common causes include the extended practice of slash and burn agriculture, extensive livestock grazing, gold mining, illegal logging and crop plantation.

Despite this reduction in LAC's forest area, symptoms of forest recovery, the so-called 'forest transitions' (Mather, 1992), are emerging in some areas. The clearest example of this forest transition is the emergence of new forests on previously cultivated areas or pastures. These new forests are either naturally regenerated or planted (afforested). Such trend is widespread in the southeast and northeast of Brazil and across various areas of northern Mexico (Figure 3.2). Another important reforestation trend is the development of new shrub areas in previously cultivated or grazed areas. The development of this woody vegetation is a natural ecological response to the abandonment of agriculture or grazing activities. In grasslands the ceasing of agriculture normally ends with the encroachment of shrubs, whereas in forest areas, the appearance of this woody vegetation could represent an early successional stage of forest regeneration. Across LAC, this shrub encroachment has mostly occurred in the central-north region of Brazil and in the Argentinean Pampa. These processes of forest recovery largely overlap with the reforestation hotspots identified by Aide et al. (2012), although the size of the reforestation trends seem to be greater in our study. Differences in methodologies, scales and data sources might explain the divergences found across both studies, highlighting the need for further investigation and the difficulties in providing precise figures. Overall, according to our analysis, reforestation in all its forms i.e. through forest natural succession, afforestation, or woody development represents at least 20% of the current forest area in LAC. The extent to which these new 'secondary' forests have or fulfil the same ecological processes as those of primary forests remains unclear and needs further investigation (Lambin and Meyfroidt, 2011).

Grau and Aide (2008) argue that a main driver underpinning reforestation in LAC is related to the industrialization of agriculture, which has contributed to the concentration of production to the most fertile areas, while marginal agriculture has progressively been abandoned, leading to ecosystem recovery. In addition to the changes in the agricultural production system, the strong rural–urban migration flow together with the implementation of conservation policies in many rural areas (*ibid.*) has also favoured forest regeneration. Such evolution of the land use pattern, in which agricultural areas have become highly intensified on the most fertile or suitable lands, and natural areas tend to stand along the slopes or less accessible zones, resembles the land use path followed by other regions such as Europe. Box 3.1 summarizes the complexity of the factors underlying forest transitions and reforestation processes in southeast Brazil.

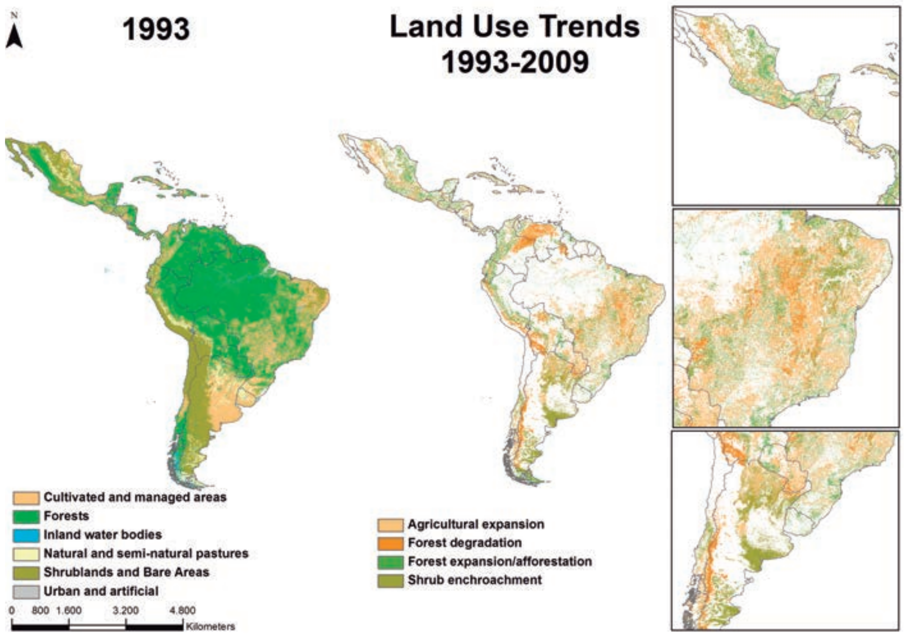

Figure 3.2 Land use and land cover changes occurred in Latin America and the Caribbean between 1993 and 2009. *Source: own elaboration based on 1993 Global Land cover (USGS, 2008) and the 2009 Glob Cover Map (ESA, 2010)*

Overall, agricultural expansion is the predominant land use trend in LAC, although deforestation rates seem to be slowing down and in some cases even reversing. As described in Chapters 1, 5 and 7, the growth of the agricultural sector in LAC is largely related to a growing internal demand for food and energy and ongoing dietary shifts, but is also driven by the rising international demand for oilseeds and cereal grains. To understand past, but foremost, future land use decisions in LAC and develop possible solutions for curbing deforestation and environmental degradation, it is crucial to understand the drivers underpinning the increasing need for agricultural land in this part of the world.

Box 3.1 Drivers of forest transition: theory and practice in São Paulo, southeastern Brazil

Forest transitions – the change in land use characteristics from a period of constant reduction of forest cover to a period of net forest increase – have diverse drivers, including a variety of socio-economic, cultural and political factors. In the last decades some 'pathways' have been proposed to explain the processes and factors behind observed forest recovery across countries (see e.g. Rudel et al., 2005; Lambin and Meyfroidt, 2010). The most common argument is the so-called 'economic development' pathway: economic development associated with industrialization, urbanization, and land use intensification results in agricultural land abandonment and reforestation through secondary succession or tree planting. Also, forest transition would occur when a lack of forest products prompts governments and landowners to plant trees – the 'forest scarcity' pathway (Rudel et al., 2005).

Much of the research conducted in LAC countries like Argentina (Grau and Aide, 2008), Brazil (Perz and Skole, 2003; Baptista, 2008; Walker, 2012), El Salvador (Hecht et al., 2006), and Mexico (Klooster, 2003; Bray and Klepeis, 2005), raised doubts about the broad applicability of forest transition models based on economic development or forest scarcity, emphasizing the importance of a variety of factors linked in a complex network of institutional, social, biological, cultural and physical interactions. In this sense, Lambin and Meyfroidt (2010) proposed the 'globalization', the 'state forest policies' and the 'smallholder, tree-based land use intensification' pathways, which offer more refined explanations of processes involved in forest transitions.

In Brazil, although deforestation rates are greater than forest recovery, forest increase seems to be occurring in some regions. In São Paulo, a southeastern state, evidence suggests that a forest transition took place in the 1990s at the state level, which coincides with a period of overall economic growth in the country (Farinaci and Batistella, 2012) (see Figure 3.3).

Considering only a broad scale, it would be reasonable to explain the forest transition in São Paulo in terms of the 'economic development' pathway, as the state became increasingly urbanized, industrialized and wealthy. However, analysing the processes occurring on a smaller spatial scale, Farinaci (2012) concluded that the transitions observed in municipalities in eastern São Paulo were more influenced by crises and economic stagnation in late 1980s and 1990s – a period in which sustainable development became part of the political discourse in different sectors of society – than by the acceleration of economic growth during the 2000s. Moreover, at the intra-municipality level, forest recovery was not driven by local economic development or agricultural adjustment, but rather by the failure of production systems to ensure the livelihoods of rural population. In São Luiz do Paraitinga, which exemplifies changes occurring in rural areas in eastern São Paulo over the last few decades, the decline of dairy farming was the most important factor influencing recovery of native forest,

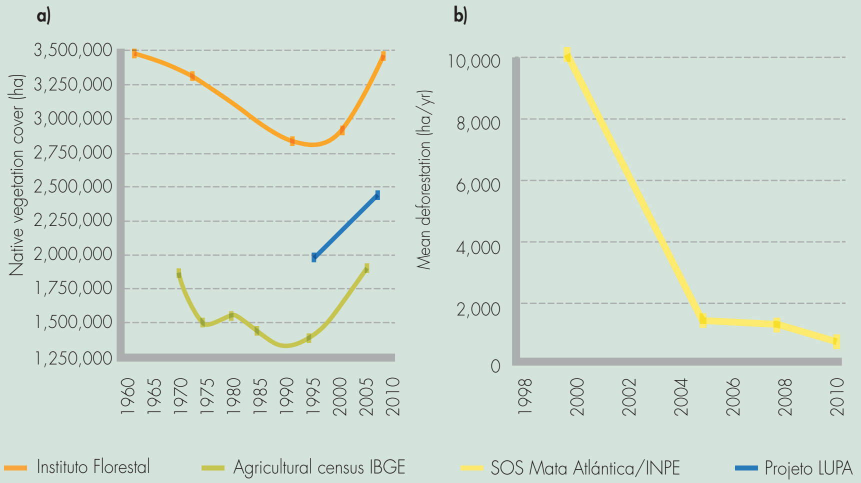

Figure 3.3 Evidence of forest transition in São Paulo State (Brazil) according to four different data sources. *(a) Temporal variation on native vegetation cover (b) Deforestation rates between 2000 and 2010 (annual mean values for each period) - (Sources: Kronka et al., 1993, 2005; SIFESP, 2010; Fundação SOS Mata Atlântica and INPE, 2008, 2009, 2010; IBGE (2009); SAA, CATI and IEA (2009).*

predominantly via secondary succession. Modernization of the dairy sector, shortage of rural jobs, lack of public investment on rural infrastructure, and competition with other regions contributed to a decline in dairy farming. Moreover a reduction in soil fertility and rugged relief restricted the possibilities for alternative land uses. Concurrently, an increasing number of people who are willing to purchase land for second residences or tourism activities, often motivated by conservation values, favoured forest recovery. In addition, laws restricting tree cutting and hunting, improvement of fire monitoring systems, and protected areas were important prompters of forest conservation and reforestation. When smaller-scale processes are considered, and put into socio-economic, political and cultural contexts, it is clear that the 'globalization' pathway in association with the 'state forest policies' pathway, as proposed by Lambin and Meyfroidt (2010), provide more comprehensive explanations of the processes leading to forest transitions as observed by Farinaci (2012) in São Paulo.

3.3 What are the drivers of the observed deforestation trends?

Deforestation and land appropriation is an ancient and constant process throughout human history, although driving forces have evolved over time. Around the tropics, deforestation between the 1970s and the early 1990s was largely 'state-driven' to promote rural development (Rudel, 2007). Government policies varied from region to region, but generally provided incentives for the colonization of remote forests, such as cheap land, and investments in infrastructure (e.g., road building) in order to foster the development process. In the case of LAC, since the 1990s different structural adjustment programmes endorsed by the World Bank, International Monetary Fund (IMF) and other international donors favoured the development of trade liberalization policies. Ever since then, deforestation in LAC has been primarily 'enterprise-driven', particularly by large multinationals (Rudel, 2007). Yet, governments still contribute to these efforts indirectly, e.g. through tax incentives for businesses to settle and also by developing infrastructures, which facilitate and speed up the transportation of goods and natural resources to the nearest harbours (Rudel et al., 2009; DeFries et al., 2010). Tree felling, agricultural industrialization, trade, mining and biofuel are the dominant drivers of current deforestation in many tropical countries (Butler and Laurance, 2008).

Figure 3.4 summarizes some of the main drivers explaining ongoing deforestation trends in LAC.[2] Economic globalization (Factor 1), and particularly the specialization of LAC's economies in the exportation of agricultural commodities (e.g. cereals and oilseeds), explains approximately 21% of the observed forest losses in LAC between 1990 and 2010. This factor is the underlying reason for most of the deforestation in South American countries like Brazil, Bolivia, Argentina, Ecuador and Paraguay. Despite the migration of rural population to the cities, the ongoing efforts to increase the area under protection and the yield improvements, deforestation in these countries has not halted. Whether deforestation is likely to continue in LAC is very much linked to the major drivers underpinning the expansion of agriculture (e.g. international food and biofuel demand, agricultural specialization) and undoubtedly the set of policy instruments and economic incentives (e.g. increases in agricultural productivity, Reduced Emissions from Deforestation and Forest Degradation – REDD+) that may be put in place to reverse deforestation and promote a greener economy. According to FAO (2010), Brazil is responsible for almost 60% of current LAC deforestation, therefore this country is called on to play a key role in this respect, and more recent data suggests that government measures are starting to be effective (Table 3.1).

Nevertheless, the globalization of LAC's economies does not always lead to deforestation. In fact those countries with a high GDP per capita, high agricultural productivity, greater agricultural investments (e.g. in machinery) and with a powerful forestry sector (e.g. Chile or Uruguay) have experienced a net forest area increase despite their strong exporting policies. The extent to which these new secondary forests provide an equivalent flow of ES as the native ones requires further investigation as was mentioned previously.

2 To assess the factors underpinning ongoing land use trends in LAC we conducted a multivariate factor analysis (FA) by combining information from twenty-four different socio-economic variables. All variables represent national values for the time period 1990–2010.

Another critical factor of LAC deforestation beyond globalization is the high reliance of many countries on a primary-based economy (see Figure 3.4. Factor 2). High rates of deforestation overlap with countries where agriculture and mining represent a large percentage of their GDP. This factor could explain much of the deforestation observed in Mesoamerican countries like Guatemala, Honduras or Nicaragua, where around 23% of their national GDP is linked to agriculture. These countries have low yields and are mostly land stressed, i.e. they have a low land per capita availability and over 67% of the actual agricultural area is used to produce staples like maize, beans and export crops like coffee. Deforestation in these countries is probably less related to the growth of agricultural exports, and more influenced by the expansion of agriculture to overcome food insecurity problems. The development of the mining industry, mostly in South American countries like Brazil, Peru, Colombia and Ecuador, also appears to be influencing deforestation. Likewise, the development of the livestock sector is an important driver of tropical deforestation. The majority of cattle in LAC is produced extensively in pastures, making the growth of this sector highly dependent on land availability. Since 1990 livestock production has increased 21% in the Caribbean, 44% in South America and 53% in Mesoamerica (FAO, 2012). The value of livestock products in two decades has increased by almost 10,000 million US$ in Mesoamerica and up to 32,000 million US$ in South America (World Bank, 2013). In the Caribbean region, the predominance of a service-oriented economy largely relying on fuel exports and tourism has contributed to preserve and even augment the forest area.

Nevertheless, and despite the importance of the two drivers mentioned above, agricultural expansion and forest area change are also influenced by many other socio-political and legal aspects. For instance, in Colombia much of the reforestation observed between 2001 and 2010 (about 1.7 million hectares) is due to the coca crops eradication programmes enforced by the government (Sánchez-Cuervo et al., 2012). Land tenure and undefined property rights may also be a driver on land use change and its influence will depend on site specific socio-economic dimensions. In Mexico, Bonilla-Moheno et al. (2013) show that the private-common-pool dichotomy was not the dominant explanatory dimension for deforestation; since the greatest differences occurred between types of common-pool systems. Physical variables like altitudinal differences, usually not included in most models of deforestation, can also play an important role in identifying intraregional drivers. One example can be seen in the differences between lowland and montane forest cover changes in Colombia, due in part to the accessibility of forests and differences in wealth and economic activities (Armenteras et al., 2010). The energy sector (e.g. dam construction) is most likely to be an important driver of actual deforestation but no data was found to include this variable in the assessment. All these factors need to be jointly considered in order to identify sustainable land use options at the local level and hence providing opportunities for development and the minimization of environmental trade-offs.

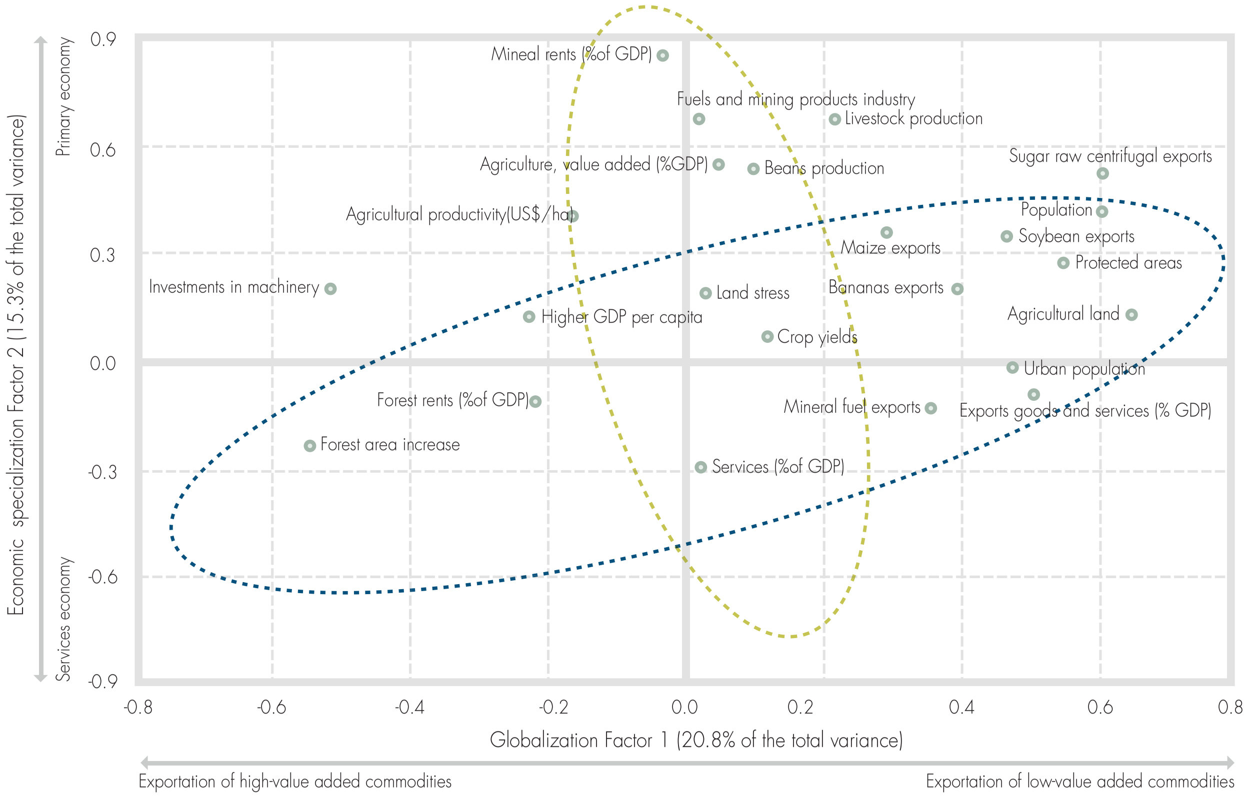

Figure 3.4 Factor analysis explaining drivers of forest area change in Latin America and the Caribbean between 1990 and 2010. Factors I and II explain the percentage of total variance. Variables' values represent the correlation with the two factors. *Source: own elaboration based on FAO (2012) and World Bank (2013)*

3.4 Impacts of land use changes on ecosystem services

The observed changes in land use in LAC have deep implications for the provision of ES. Yet knowledge of the performance of ES in LAC is sparse across countries but overall significant (Balvanera et al., 2012). Much of the existing knowledge on ES is primarily focused on provisioning services, e.g. timber production and freshwater provisioning and regulating services such as water flow regulation or carbon sequestration (*ibid.*). However, less knowledge is available on other key ES, e.g. pollination and pest regulation. Figure 3.5 summarizes the quantification of six ES at the national scale and their trends between 1990 and 2010.

3.4.1 Carbon sequestration

Carbon (C) stocks vary depending on the type of biome and the management practices. Across LAC, the largest aboveground C pools are found in the native tropical forests of Brazil, Peru, Colombia, Venezuela and Bolivia (FAO, 2010). Together these countries store 87,280MtC (million tons of carbon); around 84% of the total aboveground C stock of LAC. The importance of these stocks is related to the extension of their tropical forests but also to the average C content per hectare (>105t/ha), which is above the LAC average.

Between 1990 and 2010 approximately 8,600t C have been lost which is equivalent to 10% of LAC's total C stock. Some 80% of these C emissions have occurred in the aforementioned countries (Brazil, Peru, Colombia, Venezuela and Bolivia). Nowadays land use changes, and particularly deforestation, is the most important source of green house gas emissions (GHG) across most LAC countries, and therefore represents a major driver of climate change (see Figure 3.6). Among some of the most important initiatives currently under negotiation to halt deforestation and mitigate climate change in LAC is through the Reducing Emissions from Deforestation and Forest Degradation (REDD+) (see Box 3.2).

Box 3.2 Enhancing forest conservation through Reducing Emissions from Deforestation and Forest Degradation (REDD+)

Since the end of 2006 negotiations have been held under the United Nations Framework Convention on Climate Change (UNFCCC) to support developing countries in reducing greenhouse gas emissions (GHG) and enhancing forest carbon sinks as a key mitigation strategy. Initially only emission reductions from deforestation and forest degradation were considered, the so-called REDD strategy. But soon given the different national circumstances and the position on the forest transition curve (Perz, 2007a and b) of tropical developing countries, in addition to reducing emissions from deforestation and degradation, the negotiations expanded to further include the conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks. This wider scope was agreed upon to allow broad non-Annex I parties (mostly developing countries), based on differing national circumstances, and was renamed REDD+. This climate change solution for developing countries has been endorsed by different initiatives (e.g. the UN-REDD programme, the Forest Carbon Partnership Facility (FCPF) and the Forest Investment Program (FIP), hosted by the World Bank). Currently the UN-REDD programme supports different activities in forty-six countries, including Bolivia, Panama and Ecuador.

Negotiations relating to REDD+ can be traced back to the 11th session of the UNFCCC Conference of Parties (COP) in Montreal (2005), where it was raised as an agenda item that later initiated a two-year process under the UNFCCC's Subsidiary Body for Scientific and Technological Advice (SBSTA), including several technical workshops on the issue. This lead to the introduction of REDD+ as part of the Bali Action Plan at COP13 in 2007, as Decision 2/CP.13, that also provided some early methodological guidance. At COP 15 (Copenhagen in 2009), several principles and methodological guidelines were defined further (Decision 4/CP.15). Parties at COP16 (held in Cancun, 2010), adopted Decision 1/CP.16, section C, defined guidance and safeguards, the need of a phase approach and the five activities under REDD+ in its paragraph 70 by saying: 'Encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances: Reducing emissions from deforestation; Reducing emissions from forest degradation; Conservation of forest carbon stocks; Sustainable management of forests; Enhancement of forest carbon stocks.'

Since the Bali Action Plan (2007) put forest in the UNFCCC agenda, there is not one single understanding of REDD+ and even greater diversity of views on how best to slow or halt deforestation, but there is a wide recognition of the complexity and that progress is being made in understanding diversity and the importance of national circumstances and drivers of the deforestation and forest degradation. For example, some view REDD+ strictly as a mechanism that provides financial payments for verified emission reductions while for others it is a broader suite of actions and incentives that, when combined, reduce emissions from deforestation and forest degradation.

In light of the new challenges, the lessons learnt during the past three years and the recent discussion at COP18 in Doha, it seems several pathways may be considered for the financing of REDD+ activities and allow countries to adopt alternative development pathways in which deforestation is reduced by tailoring the measures to their needs and national circumstances. However, when creating a forest protection climate agreement, which includes international incentives, it is important to note that if markets have to be considered, deeper commitments from major emitters, with their large mitigation potential, would be required if they need to be environmentally acceptable or politically palatable.

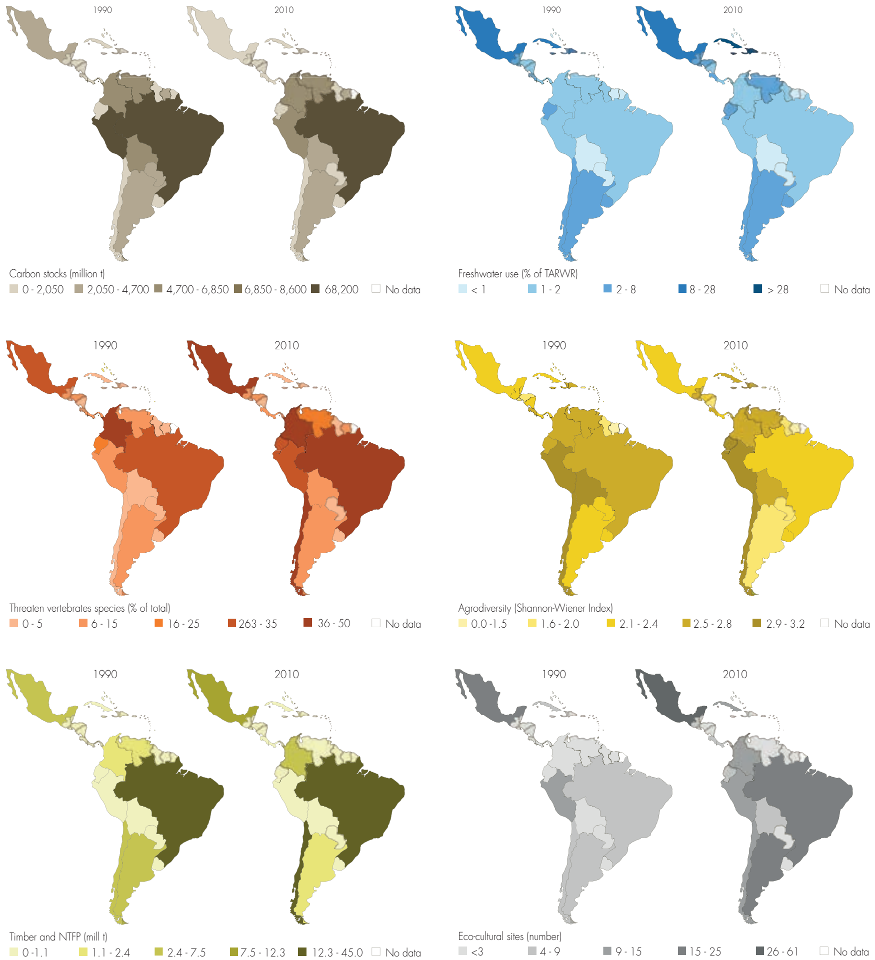

Figure 3.5 Trends in Ecosystem Service provision in Latin America and the Caribbean between 1990 and 2010. *Data and indicators to measure the ES performance are as follows. Carbon sequestration was measured using data on aerial carbon pools obtained from the Global Forest Resource Assessment (FRA) performed by FAO (2010) and the indicator used accounts for the total amount of carbon stored aboveground. Soil carbon stocks are not considered here. Freshwater use data was obtained from FAO (2013) and refers to the % of total actual renewable water resources (TARWR) withdrawals for human uses. Biodiversity data was obtained from the Red-list database of the International Union for Nature Conservation (IUCN, 2013). In order to account for the LAC's agro-diversity, we used the Shannon-Wiener index to measure the variety of crops grown in each country and the relative importance of each one (in terms of area dedicated to its cultivation) during two time periods (1990–2000 and 2000–2010). Timber and non-timber forest products (NTFP) data was obtained from FAO (2010) and the number of ecosites represents the sum of World Heritage Sites (WHS) and Biosphere Reserves (BR) by country and was obtained from UNESCO (2013).*

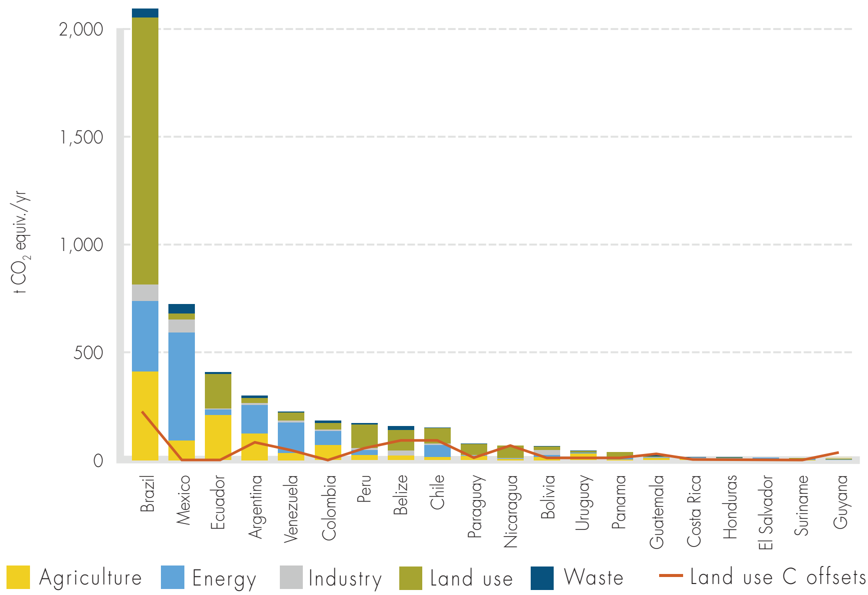

Figure 3.6 Greenhouse Gas Emissions (GHG) by sector in LAC countries. *Source: own elaboration UNFCCC (2013)*

3.4.2 Freshwater use

LAC is an extremely well-endowed region in terms of blue water availability. As described in Chapters 2 and 6, this region holds one-third of the global renewable blue water resources and the average blue water availability per capita for the whole region exceeds the 30,000m^3/cap/yr (FAO, 2013). Over the last few decades water withdrawals have increased, both as a result of endogenous factors such as irrigation development, population growth and urbanization and as a result of exogenous factors such as the globalization of LAC's economies and the increase in exports of agricultural virtual water trade (see Chapter 7).

Freshwater abstractions in LAC have increased nearly 5% between 1990 and 2010, from 277 million cubic metres in 1990 up to 290 in 2010 (FAO, 2013). Such increase implies that 5% of the total actual renewable water resources (TARWR)[3] of LAC is extracted for human uses (Figure 3.5). Only in Mexico, Cuba or Dominican Republic water extractions surpass 15% of the national TARWR. Despite these positive figures, regional water scarcity problems exist in countries like Mexico, Chile, Argentina or Brazil where at least 13% of the population lives in water-scarce basins (see Table 6.3, Chapter 6). Also, as Chapter 6 also outlines, in the majority of countries, pollution rather than over-abstractions represents a greater threat for maintaining this provisioning ES in the medium and long run.

3 TARWR stands for total annual renewable water resources

3.4.3 Biodiversity conservation

LAC is home to seven out of twenty-five world biodiversity hotspots for Conservation Priority (IUCN, 2013). Mega-diverse countries such as Brazil, Colombia, Ecuador, Mexico, Venezuela and Peru alone cover less than 10% of the world's terrestrial surface but contain approximately 70% of the world's mammals, birds, reptiles, amphibians, plants and insects (*ibid.*). Yet 11% of the total number of vertebrate species identified in LAC are threatened (IUCN, 2013) as shown in Figure 3.5. Yet the countries with the largest ratio of threatened species are: Chile (50%), Brazil (43%), Colombia (42%) and Mexico (41%). Countries with ranges of threatened species varying between 20 and 40% are: Ecuador (32%), Peru (28%), Argentina (25%) and Venezuela (20%). The underlying drivers of this decline in order of importance are (IUCN, 2013): agricultural expansion and habitat change (in 25% of the cases); tree felling and wood harvest (22%); urbanization (13%); agricultural and forestry pollution (12%); and alien and invasive species (10%). In less than 10% of the cases climate change was the underlying driver of species pressure, which highlights a key fact: among global drivers, land use changes by far exert the largest pressure on biodiversity, even above climate change.

3.4.4 Agro-diversity

LAC is the home to some key food components of our diets. The highest agro-diversity within LAC is found in the Andean region and Brazil, although in the last two decades, this agro-diversity has decreased sharply (see Figure 3.5). This loss of agricultural diversity is very much related to the progressive trend of agricultural specialization into oilseed and cereal grain production (mostly soybeans, maize, wheat, barley) and also into bio-fuels such as sugar cane. Among all the crops grown in LAC, over sixteen were originally domesticated in this part of the world (see Table 3.2). Cotton, beans and sunflower are the native crops that have experienced the greatest reduction in area cultivated since the 1990s. Maize on the other hand has experienced a sharp increase, particularly in Argentina, Paraguay, Brazil and also Nicaragua and Venezuela. Much of the loss in agricultural area of native species has been due to the expansion of non-native crops like soybean, which has increased its area 2.5 times since 1990. Sugar cane area has also increased substantially. Soybean expansion in Brazil is mostly related with the increasing demand of animal feed by the EU27 and more recently China, whereas sugar cane production has mostly increased as a result of internal biofuel demand.

3.4.5 Forest products

Commercial forestry in LAC is mostly oriented towards the production of non-timber forest products (NTFP) such as pulp. This pulp comes predominantly from softwood tree plantations of Eucalyptus spp. and *Pinus radiata* and it is used to produce paper. The development of the paper industry in LAC is relatively new compared to other parts of the world. To a large extent this has been driven by government policies that have boosted forestation based on high-yielding species to promote the paper industry. Brazil, Chile and Uruguay are currently the three leading countries in the paper industry within

Table 3.2 Trends of native and non-native agricultural crops cultivated in Latin America

	COMMON NAME / SCIENTIFIC NAME	ORIGINALLY FROM	DOMESTICATION DATE	AREA 1990 (ha)	AREA 2010 (ha)
NATIVE	Beans *Pachyrhizus ahipa* *Pachyrhizus tuberosus* *Phaseolus vulgaris*	Andean Region	<1000 BC	8,178,705	6,788,716
NATIVE	Squash and pumkins *Cucurbita pepo*	Mesoamerica	7000 BC	152,556	6,788,716
NATIVE	Maize *Zea mays*	Mesoamerica	6000 BC	24,893,987	28,735,226
NATIVE	Manioc/cassava *Manihot esculenta*	Lowland South America	6000 BC	2,744,838	2,697,564
NATIVE	Avocado *Persea americana*	Mesoamerica	2000 BC	160,276	272,564
NATIVE	Chilli peppers *Capsicum annuum*	Mesoamerica	5000 BC	139,843	237,227
NATIVE	Chilli peppers *Capsicum baccatum*	Andean Region	4000 BC		
NATIVE	Cotton *Gossypium hirsutum*	Mesoamerica	5000 BC	3,723,923	1,617,139
NATIVE	Sunflower *Helianthus annuus*	Eastern North America	2000 BC	2,948,417	2,054,437
NATIVE	Sweet potato *Ipomoea batatas*	Andean Region	4000 BC	252,571	273,136
NATIVE	Tobacco *Nicotiana tabacum*	Andean Region	1000 BC	473,209	609,169
NATIVE	Pinaple *Ananas comosus*	Lowland South America	<1000 BC	96,227	222,481
NATIVE	Cocoa *Theobroma sp*	Mesoamerica	2000 BC	1,490,618	1,529,507
NATIVE	Quinoa *Chenopodium quinoa*	Andean Region	4000 BC	47,585	99,499
NON-NATIVE	Soybean *Glycine max*	East Asia		18,035,280	46,181,492
NON-NATIVE	Sugar cane *Saccharum ssp*	South Asia		7,932,457	12,014,797
NON-NATIVE	Wheat *Triticum spp*	Near East		10,673,991	8,819,368

Source: own elaboration based on Pickersgill (2007) and FAO (2013)

LAC. The availability of space for cultivation together with the advantageous climatic conditions are two important factors explaining its comparative advantage and much of the growth of this sector, particularly since the mid-20th century (Lima-Toivanen, 2012). In fact Brazilian and Chilean pulp and paper producers are among the most profitable companies producing fast-growing eucalyptus trees and have become cost leaders in the production of market pulp (Gurlit et al., 2007).

Brazil, Chile and Mexico are the largest producers of pulp and accrue over 80% of the continental production. Argentina used to be an important producer in the 1990s, but lately it has lost its market share within LAC (from 11% of total LAC pulp production to less than 2%). According to FAO (2010), since 1990, pulp production has increased sharply among the largest producers and also amongst medium producers such as Colombia and Uruguay (see Figure 3.5).

3.4.6 Eco-tourism

The rich diversity of species and ecosystems found in LAC together with its diverse indigenous cultures, provide a wealth of opportunities for recreation and tourism. On the continental scale it is difficult to measure the performance of this cultural ES, as it is determined by a large set of natural, cultural and economic factors. As a proxy indicator to account for the eco-cultural importance of LAC we used the number of World Heritage Sites (WHS) and Biosphere Reserves (BR) as defined by UNESCO (2013).

Mexico, Brazil and Peru are the countries holding the largest number of WHS and BR, here grouped under the name of 'eco-cultural' sites (see Figure 3.4). These three countries also account for the majority of the new WHS and BR declared since 1990. The Caribbean region, except Cuba, has a very small number of 'eco-cultural' sites. In South America, countries like Argentina and Bolivia have experienced a significant increase. The number and progress of WHS and BR in a way represents the effort that regional and national governments are performing to preserve important natural and cultural features and promote them amongst national and international tourists.

Table 3.3 summarizes the trends in ES performance across LAC regions between 1990 and 2010. The general trend points towards a reduction in performance of regulating and some cultural services, whereas production and other cultural services such as eco-tourism opportunities are increasing. The Caribbean region, however, follows an

Table 3.3 Changes in ecosystem service supply (expressed in percentage) across Latin America and the Caribbean between 1990 and 2010. Green values refer to an increase in service supply, whereas orange values stand for service's reduction. Note: ES classification is based on MA (2005)

	REGULATING		CULTURAL		PROVISIONING	
REGION	Carbon Stocks	Biodiversity	Ecosites	Agro Diversity	Forest Products	Water Extraction
AMAZONIAN	-8	-15	200	-5	71	0.1
ANDEAN	-7	-8	88	-2	8	0.1
CARIBEAN	33	-2	213	11	-14	-1.2
SOUTH CONE	-8	-14	128	-13	24	0.2
MESOAMERICA	-15	-7	166	3	39	0.4

Source: own elaboration based on data from FAO (2010), FAO (2013), IUCN (2013) UNESCO (2013) inverse trend, with a general increase in the provision of regulating and cultural services and a general decrease in the demand of provisioning services.

As Chapter 4 outlines, human well-being indicators have improved for the most part, which raises the question about to what extent the observed loss of ES diversity is a consequence of having improved the living conditions of LAC inhabitants. For instance, Rodrigues et al. (2009) found a boom-and-bust pattern in levels of human development (life expectancy, literacy and standard of living) across the deforestation frontier in the Brazilian Amazon, where human development increased rapidly in the early stages of deforestation and then declined as the frontier advanced. Per capita timber, cattle and crop production also reveal a boom-and-bust pattern across the deforestation frontier.

3.5 What options are available in order to spare land and halt deforestation?

Taking into consideration the different drivers of deforestation across LAC, it is clear that a pool of different measures is needed in order to overcome the existing competition for land and develop regional land use strategies to balance food production, rural development and the maintenance of LAC's ES in the long run.

One possible solution is to unwind land competition in LAC as a further intensification of agriculture. Strategic and sustainable agricultural intensification, in terms of elevating yields of existing croplands of under-yielding nations, might be the solution to meet the global crop demand without causing irreversible ecosystem damage (Tilman et al., 2011). In countries like Honduras, Guatemala and Nicaragua, staple crops such as maize have yields below 2.1t/ha/yr, two and three time smaller than those obtained in Brazil or Argentina at present (FAO, 2012). In order to bridge this yield gap, rural development programmes need to be fostered, together with further investments to modernize agriculture, and ensure greater legal certainty to secure such investments, e.g. a better definition of tenure rights (IICA, 2013).

Despite the existing yield gaps across some countries, LAC's agricultural productivity as a whole has increased substantially during the last few decades (Ludena et al., 2010; Maletta and Maletta, 2011). Soybean yields in major producer centres such as Brazil increased at twice the US rate, from a much lower base since 1990 (FAO, 2012), and the yield of tree plantations for wood and pulp in Chile, Brazil and Uruguay is three to four times the level that can be achieved in Europe (FAO, 2010). Soybean, maize and wood-based fuels are the key actors in the agricultural and livestock sector and industries in LAC, and improvements in their productivity may help to spare land. In fact when assessing the evolution of the agricultural sector, it is clear that in the last decade, agriculture growth is mostly being attributed to increasing efficiency and becoming more and more decoupled from land inputs (Figure 3.7).

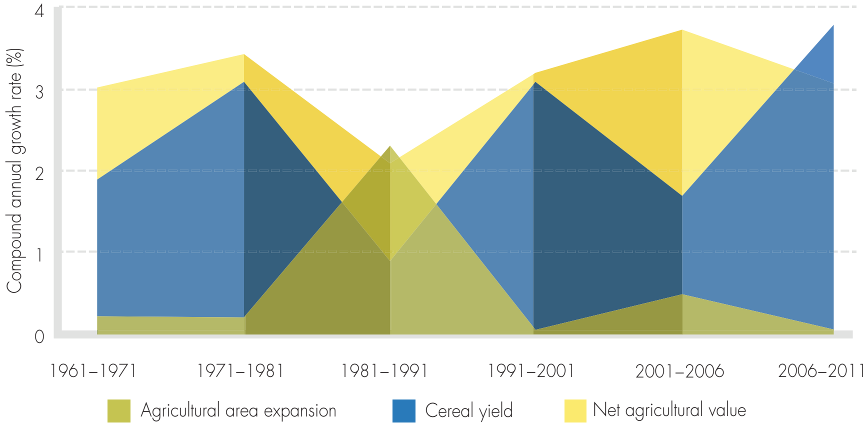

Figure 3.7 Annual growth rates of agricultural land, yields and net production value. *Source: own elaboration, based on FAO (2012)*

Nevertheless, the land-sparing argument, based on modern agriculture, has been criticized for neglecting some important environmental side-effects. It is well known that modern intensive and unsustainable agriculture frequently leads to soil degradation and watershed contamination (Matson et al., 1997; Tilman et al., 2002). Also, natural ecosystems interspersed between highly intensified and productive areas are often forest patches with a low conservation value (Tscharntke et al., 2005; Vandermeer and Perfecto, 2007).

Land sparing through agricultural adjustment has been the predominant land use model followed in Europe and the US. As Tilman et al. (2011) argues, probably the only path to sustain future food demand without causing further ecosystem services losses is through a sustainable intensification of current land use policies, including land use efficiency, together with agricultural practices that avoid depleting soil and biological properties, e.g. agro-forestry practices. Also, a deeper understanding of the environmental implications linked to this land use intensification path is needed (*ibid.*). This will require: determining how land sharing can deliver sufficiently high yields and ecosystem services, assessing trade-offs between increasing yields and environmental benefits across different circumstances and spatial scales, and exploring policy and market mechanisms that enhance sharing initiatives (Garnett et al., 2013).

Nevertheless, Tittonell (2013) recalls on the importance of not falling in to the 'intensification trap', that is the risk of oversimplifying the challenges of feeding a growing population just by intensifying existing agricultural land and balancing environmental trade-offs. He warns against this primarily because intensifying existing agriculture goes hand in hand with larger energy and fertilizer demand, which creates and exacerbates other related societal and environmental problems.

A different argument brought up in support of a less intensive landscape matrix is related to the promotion of organic and wildlife farming agriculture. However, critics argue that organic agriculture may have lower yields and would therefore need more land to produce the same amount of food as conventional farms, resulting in more widespread deforestation and biodiversity loss, and thus undermining the environmental benefits of organic practices. Differences in yields differ greatly depending on the crop type and the region where it is cultivated. According to Seufert et al. (2012), organic to conventional yield ratios of common key LAC products such as soybeans are on average high (0.9). Lower ratios, however, are found for cereals: maize (0.85), barley (0.7) and wheat (0.6).

Overall, and in addition to the pool of measures that can be adopted to overcome land use conflicts between agriculture and nature in LAC, it is important to promote also measures directly aimed at preserving existing nature, e.g. through payment for ecosystem services (see Chapter 14), incentives to reduce deforestation and forest degradation (Box 3.2) and sustainable management of forests and landscape restoration including reforestation. Besides the collection of measures directly targeting at increasing efficient production in the field, off-site efficiency improvements (e.g. along the supply chain) would help to reduce food waste and increase production per unit of land. As IMECHE (2013) highlights we produce about four billion metric tons of food per annum, but it is estimated that 30–50% (or 1.2–2 billion tons) of all food produced never reaches a human stomach due to poor practices in harvesting, storage and transportation, as well as market and consumer wastage. Any such measures should be accompanied by a more transparent food chain with information that will allow consumers to make informed choices.

References

Aide, T.M., Clark, M.L., Grau, H.R., López-Carr, D., Levy, M.A., Redo, D., Bonilla-Moheno, M., Riner, G., Andrade-Nuñez, M.J. & Muñiz, M. (2012). Deforestation and reforestation of Latin America and the Caribbean (2001–2010). *Biotropica*, 0: 1–10.

Armenteras, D., Rodríguez, N., Retana, J. & Morales, M. (2010). Understanding deforestation in montane and lowland forests of the Colombian Andes. *Regional Environmental Change*, 11: 693–705.

Balvanera, P., Uriarte, M., Almeida-Leñero, L., Altesor, L., DeClerck, F., Gardner, T., Hall, J., Lara, A., Laterra, P., Peña-Claros, M., Silva Matos, D.M., Vogl, A.L., Romero-Duque, L.P., Arreola, L.F., Caro-Borrero, A.P., Gallego, F., Jain, M., Little, C., de Oliveira, X.R., Paruelo, J.M., Peinador, J.E., Poorter, L., Ascarrunz, N., Correa, F., Cunha-Santino, M.B., Hernández-Sánchez, A.P. & Vallejos, M. (2012). Ecosystem services research in Latin America: The state of the art. *Ecosystem Services*, 2: 56–70.

Baptista, S.R.(2008). Metropolitanization and forest recovery in Southern Brazil: a multiscale analysis of the Florianópolis city-region, Santa Catarina State, 1970 to 2005. *Ecology and Society*, 13(2): 5.

Bonilla-Moheno, M., Redo, D.J., Aide, T.M., Clark, M.L. & Grau, H.R. (2013). Vegetation change and land tenure in Mexico: A country-wide analysis. *Land Use Policy,* 30: 355–364.

Bray, D.B. & Klepeis, P. (2005). Deforestation, forest transitions, and institutions for sustainability in Southeastern Mexico, 1900–2000. *Environment and History*, 11: 195–223.

Butler, R.A. & Laurance, W.F. (2008). New strategies for conserving tropical forests. *Trends in Ecology & Evolution*, 23: 469–72.

CEPEA (2013). Centro de Estudios Avançados en Economía Aplicada. *Datos PIB do Agronegócio de 1994 a 2011*. ESALQ/USP. [Online] Available from: cepea.esalq.usp.br/pib/. [Accessed June, 2013].

Defries, R.S., Rudel, T., Uriarte, M. & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, 3: 178–181.

ESA (2010). European Space Agency. Globcover 2009. *Global Land Cover Map*. [Online] Available from: due.esrin.esa.int/globcover/. [Accessed March, 2013].

Farinaci, J.S. (2012). *The new forests of São Paulo State: a multiscale study using the forest transition theory perspective*. PhD dissertation. Instituto de Filosofia e Ciências Humanas, Universidade Estadual de Campinas. Campinas, Brazil.

Farinaci, J.S. & Batistella, M. (2012). Variation on native vegetation cover in São Paulo: an overview of current knowledge. *Revista Árvore* ,36(4): 695–705.

FAO (2009). Food and Agriculture Organisation. *How to Feed the World in 2050*. Rome, FAO.

FAO (2010). Food and Agriculture Organisation. *Global Forest Resource Assessment*. Main Report. Rome, FAO [Online] Available from: www.fao.org/docrep/013/i1757e/i1757e.pdf. [Accessed March, 2013].

FAO (2012). Food and Agriculture Organisation. FAOSTAT. [Online] Available from: faostat3.fao.org/home/index.html. [Accessed May, 2013].

FAO (2013). Food and Agriculture Organisation. AQUASTAT. [Online] Available from: www.fao.org/nr/water/aquastat/main/indexesp.stm. [Accessed March, 2013].

Fischer, G., Hizsnyik, E., Prieler, S., Shah, M. & Velthuizen, H. (2009). *Biofuels and food security. Implications of an accelerated biofuels production*. Summary of the OFID study prepared by IIASA. [Online] Available from: www.ofid.org/LinkClick.aspx?fileticket=O3FeeiHvu7U%3D&tabid=109 [Accessed May, 2013].

Fundação SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais (INPE). (2008). *Atlas dos Remanescentes Florestais da Mata Atlântica: Período 2000–2005*. [Online] Available at: mapas.sosma.org.br/. [Accessed June, 2009].

Fundação SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais (INPE). (2009). *Atlas dos Remanescentes Florestais da Mata Atlântica: Período 2005–2008*. [Online] Available at: mapas.sosma.org.br/dados/. [Accessed February, 2010].

Fundação SOS Mata Atlântica & Instituto Nacional de Pesquisas Espaciais (INPE). (2010). *Atlas dos Remanescentes Florestais da Mata Atlântica: Período 2008–2010*. [Online] Available at: mapas.sosma.org.br/dados/. [Accessed February, 2011].

Garnett,T., Appleby, M.C., Balmford, A., Bateman, I.J., Benton, T.G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffman, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J. & Godfray, H.C.J. (2013). Sustainable intensification in agriculture: premises and policies. *Science*, 341: 33-34.

Gloor M., Gatti, L., Brienen, R., Feldpausch, T., Phillips, O., Miller, J., Ometto, J.P., Ribeiro da Rocha, H., Baker, T., Houghton, R., Malhi, Y., Aragão, L., Guyot, J.L.,Zhao, K., Jackson, R., Peylin, P., Sitch, S., Poulter, B., Lomas, M., Zaehle, S., Huntingford, C. & Lloyd, J. (2012). The carbon balance of South America: a review of the status, decadal trends and main determinants. *Biogeosciences*, 9: 5407–5430.

Grau, H.R., & Aide, M. (2008). Globalization and land-use transitions in Latin America. *Ecology and Society*,13 (2): 16.

Gurlit, W., Mencarini, E. & Montealto, R. (2007). *Weighing the risks in South American basic materials*. The McKinsey Quarterly 2007 Special Edition [Online] Available from: commdev.org/files/1730_file_McKinsey_1_.Mining_South_America.pdf. [Accessed October, 2013]

Hecht, S.B., Kandel, S., Gomes, I., Cuellar, N. & Rosa, H. (2006). Globalization, forest resurgence, and environmental politics in El Salvador. *World Development*, 34(2): 308–323.

IBGE (2009). Instituto brasilero de geografia e estatística. Censo Agropecuário 2006. *Brasil, Grandes Regiões e Unidades da Federação*. Rio de Janeiro, IBGE. 777 p.

IICA (2013). Instituto Interamericano de Cooperación para la Agricultura. *Perspectivas de la agricultura y del desarrollo rural en las América: una mirada hacia América Latina y el Caribe*. Santiago, Chile, CEPAL, FAO & IICA.

IMECHE (2013). Institution of Mechanical Engineers. *Global food waste not, want not.* Report No. 31.

INPE (2012). Instituto Nacional de Pesquisas Espaciales. *Projeto PRODES. Monitoramento da floresta amazônica brasileira por satélite*. [Online] Available from: www.obt.inpe.br/prodes/index.php. [Accessed March, 2013].

IUCN (2013). International Union for Conservation of the Nature. *The IUCN Red List of Threatened Species*. Version 2013.1 [Online] www.iucnredlist.org. [Accessed March, 2013].

Klooster, D. (2003). Forest transitions in Mexico: institutions and forests in a globalized countryside. *Professional Geographer,* 55: 227–237.

Kronka, F.J.N, Matsukuma, C.K., Nalon, M.A., Cali, I.H.D., Rossi, M., Mattos, J.F.A., Shin-Ike, M.S. & Pontinha, A.A.S. (1993). *Inventário florestal do Estado de São Paulo*. São Paulo, Brazil, Instituto Florestal-Secretaria do Meio Ambiente. 199 p.

Kronka, F.J.N., Nalon, M.A., Matsukuma, C.K., Kanashiro, M.M., Ywane, M.S.S., Pavão, M., Durigan, G., Lima, L.M.P.R., Guillaumon, J.R., Baitello, J.B., Borgo, S.C., Manetti, L.A., Barradas, A.M.F., Fukuda, J.C., Shida, C.N., Monteiro, C.H.B., Pontinha, A.A.S., Andrade, G.G., Barbosa, O. & Soares, A.P. (2005). *Inventário florestal da vegetação natural do Estado de São Paulo*. São Paulo, Brazil, Instituto Florestal-Secretaria do Meio Ambiente. 200 p.

Lambin, E.F. & Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, 27(2): 108–118.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences*,108(9): 3465–3472.

Lima-Toivanen, M.B. (2012). The South American Pulp and Paper Industry: The Cases Brazil, Chile, and Uruguay. In: Lamberg, J.A., Ojola, J., Peltoniemi,M. & Särkkä, T. (eds). *The Evolution of Global Paper Industry 1800–2050. A comparative analysis.* Dordrecht, The Netherlands, Springer. pp 243–283.

Ludena, C.E. (2010). *Agricultural Productivity Growth, Efficiency Change and Technical Progress in Latin America and the Caribbean*. IDB Working Paper Series No. IDB-WP-186.

MA (2005). Millennium Ecosystem Assessment. *Ecosystems and Human Well-being: Synthesis.* Washington, DC, Island Press.

Maletta, H. & Maletta, E. (2011). Climate Change, Agriculture and Food Security in Latin America and the Caribbean. Essex, UK, Multi Science Publishing Co Ltd. pp.97–103

Mather, A.S. (1992). The forest transition. *Area,* 24 (4): 367–379.

Matson, P.A., Parton, W.J, Power, A.G. & Swift, M.J. (1997). Agricultural intensification and ecosystem properties. *Science,* 277: 504–509.

Martinelli, L.A. (2012). *Ecosystem Services and Agricultural Production in Latin America and Caribbean.* IDB Environmental Safeguards Unit (VPS/ESG). Technical notes. IDB-TN-382.

Perz, S.G. (2007a). Grand theory and context-specificity in the study of forest dynamics: forest transition theory and other directions. *The Professional Geographer,* 59 (1): 105–114.

Perz, S.G.(2007b). Reformulating modernization-based environmental social theories: challenges on the road to an interdisciplinary environmental science. *Society and Natural Resources*, 20: 415–430.

Perz, S.G. & Skole, D.L. (2003). Secondary Forest Expansion in the Brazilian Amazon and the Refinement of Forest Transition Theory. *Society and Natural Resources,*16: 277–294.

Pfister, S., Bayer, P., Koehler, A. & Hellweg, S. (2011). Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. *Environment, Science and Technology,* 45(13): 5761–5768.

Pickersgill, B. (2007). Domestication of plants in the Americas: insights from Mendelian and molecular genetics. *Annals of Botany*, 100: 925–940.

Rademaekers, K., Eichler, L., Berg, J., Obersteiner, M. & Havlik, P. (2010). *Study on the evolution of some deforestation drivers and their potential impacts on the costs of an avoiding deforestation scheme*. European Commission Directorate-General for Environment. Final Report Framework Contract No. DG ENV/G.1/FRA/2006/0073.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., Wit, C. A. de, Hughes, T., Leeuw, S. van der, Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R. W., Fabry, V. J., Hansen, J., Walker, B. & Liverman, D. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society,* 14 (2).

Rodrigues, A.S.L., Ewers, R.M., Parry, L., Souza, Jr.C. & Verissimo, A. (2009). Boom-and-bust development patterns across the Amazon deforestation frontier. *Science,* 324: 1435–1437.

Rudel, T., Coomes O.T., Moran, E., Achard, F., Angelsen, F., Xu,J. & Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. *Global Environmental Change,* 15: 23–31.

Rudel, T. (2007). Changing agents of deforestation: From state-initiated to enterprise driven processes, 1970–2000. *Land Use Policy,* 24: 35–41.

Rudel, T.K., Defries, R.S., Asner, G.P & Laurance, W.F. (2009). Changing drivers of deforestation and new opportunities for conservation. *Conservation Biology,* 23: 1396-405.

SAA, CATI & IEA (2009). (Secretaria de Agricultura e Abastecimento/ Coordenadoria de Assistência Técnica Integral/ Instituto de Economia Agrícola). *Levantamento censitário de unidades de produção agrícola do Estado de São Paulo - LUPA*. Available at: www.cati.sp.gov.br/projetolupa. [Accessed May, 2010].

Sánchez-Cuervo, A.M., Aide, T.M., Clark, M.L. & Etter, A. (2012). Land cover change in Colombia: surprising forest recovery trends between 2001 and 2010. PLoS ONE,7: 1–14.

Seufert, V., Ramankutty, N. & Foley, J.A. (2012). Comparing the yields of organic and conventional agriculture. *Nature* 485 (7397): 229–232.

SIFESP (2010). *Sistema de Informações Florestais do Estado de São Paulo*. Available at: www.iflorestal.sp.gov.br/sifesp/. [Accessed July, 2010].

Smith,P., Gregory, P.J., van Vuuren, D., Obersteiner, M., Havlík, P. & Rounsevell, M. (2010). *Competition for land.* Philosophical Transactions of the Royal Society B, 365: 2941–2957.

Tilman, D., Gassman, K.G., Matson, P.A., Naylor, R. & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418: 671–677.

Tilman, D., Balzer, C., Hill, J. & Befort, B.L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 108: 20260–20264.

Tittonell, P.A. (2013). Farming Systems Ecology. *Towards ecological intensification of world agriculture*. Inaugural lecture upon taking up the position of Chair in Farming Systems Ecology. Wageningen University, The Netherlands [Online]. Available from: www.wageningenur.nl/upload_mm/8/3/e/8b4f46f7-4656-4f68-bb11-905534c6946c_Inaugural%20lecture%20Pablo%20Tittonell.pdf. [Accessed June, 2013].

Tscharntke, T., Klein, A.M., Kruess, A., Steffan-Dewenter, I. & Thies, C. (2005). Landscape perspectives on agriculturall intensification and biodiversity and ecosystem service management. *Ecology Letters,* 8: 857-874.

UNESCO (2013). United Nations Educational, Scientific and Cultural Organization. *World Heritage Sites and Biosphere Reserve Database* [Online] Available from: www.en.unesco.org/. [Accessed June, 2013].

UNFCCC (2013). United Nations Framework Convention on Climate Change. *Non-Annex I National Communications submitted in compliance with the United Nations Framework Convention on Climate Change*. [Online] Available from: unfccc.int/national_reports/non-annex_i_natcom/items/2979.php. [Accessed May, 2013].

USGS (2008). United States Geological Survey. *Global Land Cover Chracterization Database Version 2*. Reference year 1993 [Online] Available from: edc2.usgs.gov/glcc/glcc.php. [Accessed March, 2013].

Vandermeer, J. & Perfecto, I. (2007). The agricultural matrix and the future paradigm for conservation. *Conservation Biology*, 21: 274–277.

Walker, R. (2012). The scale of forest transition: Amazonia and the Atlantic forests of Brazil. *Applied Geography*, 32: 12–20.

World Bank (2013). *World Development Indicators Database*. [Online] Available from: databank.worldbank.org/data/views/variableSelection/selectvariables.aspx?source=world-development-indicators. [Accessed March, 2013].

4

SOCIO-ECONOMIC MEGATRENDS FOR WATER AND FOOD SECURITY IN LATIN AMERICA

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Highlights

- The chapter provides an overview of the main socio-economic megatrends for Latin American and Caribbean (LAC) countries and how these link to water and food security. Main trends include the demographic transition (population growth, urbanization and migration), development model (income growth, income inequality, poverty and the informal economy), and the impact of globalization (trade liberalization, consumption patterns, food security and health). Other trends are the role of technology and climate change.

- Population will continue to increase, although at a slower pace due to the low fertility rate. LAC is the second most urbanized region in the world. It is a region where the urbanization pattern has been rapid, poorly planned and is causing a growing number of social problems. LAC shows all the signs of international migration processes. Nearly 20 million people live outside the country in which they were born and migrants are especially vulnerable since they are more exposed to risks. Urbanization and migration have changed societies in LAC, their needs and the way the population use their natural resources.

- During the last twenty years LAC's per capita growth rate was 1.6%. High commodity prices are leading to some countries to intensify exports of primary commodities making the region more vulnerable to the global economy. LAC displays poor evidence in terms of reducing poverty given its economic growth. Distribution of wealth is the most important issue for a region which globally is one of the most unequal. The informal economy is growing and informal jobs can reach very high levels.

- Market-oriented reforms adopted during the 1990s have not helped to achieve structural challenges. In many LAC countries the correlation between economic growth and trade openness is weak and trade liberalization has not improved income distribution, neither has it reduced poverty. Trade has changed the dietary patterns of LAC societies thus affecting the use of water. Even though undernourished population has declined, 49 million people are still suffering from hunger.

- LAC is undergoing demographic, epidemiological and nutritional transitions. The latter is characterized by a decrease in malnutrition and an increase in obesity due to dietary changes. The health sector faces two challenges: solving traditional problems of infectious diseases and maternal-child mortality, and combating diseases arising from development: chronic-degenerative, senile and mental illnesses, HIV/AIDS and obesity.

- Information and Communication Technology (ICT) may help to guarantee food and water security in LAC. Agriculture can profit from the use of these technologies, improving water-meters and many areas of the food production chain. The participatory approach of water users connected via ICT may create new pathways for water security. LAC countries must increase investment in Research and Development (R&D) which is on average around 0.6% versus 2.3% for OECD.

- Climate change is another phenomenon to consider for socio-economic trends in LAC, due to the high vulnerability of many regions. Increase of some diseases, food insecurity and a growing perception that access to drinking water might be at stake, are some of the potential impacts from climate change. Floods and droughts are and will continue affecting agriculture in particular countries.

- Latin American trends have to be modified. Measures orientated towards achieving a fair income distribution, public policies oriented towards more vulnerable groups of the population, a model of growth supported by domestic markets, formalization of the informal economy, investment in science and technology and policies for improvement and conservation of natural resources, would be key goals to target and report on future socio-economic megatrends to guarantee water and food security.

4.1 Introduction

Latin America is a continent that has experienced dramatic and largely positive changes over the last twenty to thirty years. Development, political stability and an increased global political role bear witness to these changes. This chapter will review these deep dramatic socio-economic changes, identifying, however, some important pending issues and trends for the future. It therefore provides an overview of the main socio-economic and demographic transformations megatrends of Latin American and Caribbean countries (LAC) and as far as possible how these link to water and food security. It will look at the rapid evolution over the last decades regarding what we consider the main 'megatrends'. First, the demographic transition: population growth, urbanization and migration; second, income growth, inequity, poverty and the informal economy; third, changing lifestyles, trade liberalization, consumption patterns, and health; fourth, scenarios on the role of technology and the emergence of vulnerability due to climate change. Finally, we identify some main challenges in terms of socio-economic megatrends for water and food security.

Population growth, although slowing down, could place increasing pressure on resource use in general and especially through a change in consumption patterns and an increase in food production, an activity that competes with other economic activities for land and water use. Demographic trends and economic growth patterns have produced large differences in economic and social equity, as well as the sustainability of resource use. In recent years, due to a reduction in external demand, growth in the region has been driven mainly by the expansion of the domestic market, stimulated by subsidy policies in most countries.

Economic growth in LAC was 3.9% in 2013 and is projected to be 4.4% in 2014 (UN projections); in 2012 a significant slowdown ended with a Gross Domestic Product (GDP) increase of 3.1% due to the fall in the export sector of non-food and feed sectors, showing the fragility of the current development model that depends on the demand from uncertain and volatile foreign markets for raw commodities.

The global economic crisis of 2008 affected the terms of trade of the region; with the exception of hydrocarbons (oil), whose prices remained stable, and oilseeds, whose prices increased (CEPAL, 2012a). Most industrialized countries in the region face strong competition from Asian economies, which generates a perverse dependence on the demand for low-value added commodities that affects the development of the manufacturing industry. Additionally, LAC faces environmental problems derived from an extraction of natural resources focused on intensive agriculture (biofuels, food and feed production for export), a model based on the use of high quantities of water and agro-chemicals which has impaired water quality and poses a risk to human health. In addition to soil and water pollution, the loss of biodiversity has also been accelerated due to the pressure from mining, forestry, heavy fishing, urbanization and infrastructure development.

The moderate demographic growth, the relatively steady economic progress mirrored through some indicators of human well-being, can present noticeable differences between countries, regions within the same country or between different levels of income. Some emergent health problems such as obesity affect the population at all different levels of income in most countries of the region. LAC is becoming an exporter of primary materials, principally food (and thus virtual water) that contributes to global food and water security but does not necessarily represent the best development model for the region and for its own food and water security.

4.2 Main drivers

4.2.1 Demographic trends and transitions

This section aims to highlight the trends of the demographic transition in LAC. The tendencies of three main topics are analysed: population growth (fertility and ageing), urbanization and migration. The evolution and tendency of these factors has and will have a crucial influence in the growth rate of the demand for food and therefore, in the scale and intensity of natural resources use. Water, as well as other natural resources, is under the stress from the requirements of an increasingly younger population whose consumption habits are radically changed by urbanization processes and migration.

4.2.1.1 Population growth

In the 20th century, countries of LAC, which currently represent almost 9% of the world population, saw their populations grow at a very high pace. For example, by mid-century most of the countries grew by as much as 3% (Miró, 2006). Later in the 20th century this trend had reversed, and population growth in LAC is slowing significantly.

According to the Economic Commission for Latin America and the Caribbean, ECLAC (CEPAL, 2012b), in 2012 there were 603.1 million inhabitants in LAC and the population is predicted to continue growing despite the sustained low fertility rate. This is due to a relatively high concentration of people of reproductive age, coming from periods when fertility was higher, meaning births exceed the number of deaths.

The regional average of the total fertility rate (TFR) was 5.9 children per woman in the period between 1950 and 1955, but has steadily decreased since the second half of the 1960s to the present. From1965–1970, the TFR in the region fell by 59% with huge variations among countries, ranging from 20% to 70%. Fertility in LAC in the 1950s and 60s was only surpassed by Africa (6.8 children per woman) and was above the world average of 5.0 children per woman. Currently, the regional value is below the global 2.5 children per woman and resembles the figures seen in Europe forty years ago.

The decline in regional fertility has been sustained, but there are still differences in the current level of fertility between countries. The total fertility rate of Guatemala for the 2005–2010 period is the highest in LAC with an average of 4.15 children per woman and nearly threefold that of Cuba, which is the lowest with an average of 1.49 children per woman

Given the impact of fertility on population projections, the Population Division of the United Nations recommends developing three evolution scenarios for this variable. In the case of mortality and international migration there is only one hypothesis for future changes. In the case of fertility, the most plausible hypothesis is designated as *recommended or media,* while the other two hypotheses for the top and bottom strips of the recommended are also estimated. With the *media or recommended* hypothesis, in 2050 fertility would be 1.85, a figure below the replacement level of 2.2 that is likely be achieved in the period 2015–2020. However, the population would continue growing to 760 million inhabitants in 2050; with the high scenario it would reach 900 million people.

Nowadays the population pyramid of LAC has a rectangular base representing the age group of 40 years (70% of the population of the region). People over 65 (7% of the population) gain relative importance, but the top is still narrow compared with 28% of people under the age of 15. Projections show a decline in varying degrees of the population under 15 years, an increase in the population over 65 years and a thickening of the pyramid between these ages. The region's population will grow older, but despite the decline in the population under 15 years, it will continue presenting a young age structure, allowing for the population to grow as forecasted.

4.2.1.2 Urbanization

LAC is the second most urbanized region in the world, with 79.1% of its population living in cities (UN, 2011); when in 1950 the urban population was less than 42% (CEPAL, 2002). LAC is more urbanized than an average high-income country.

Both megatrends of population growth and urbanization have caused many social changes in recent years. Cities have witnessed and partly helped generate a middle class whose importance has caused substantial changes in transport patterns, habitats and consumption. This urbanization trend is rooted in the early 20th century and is deepening. In Argentina, Chile, Venezuela, Uruguay and Puerto Rico at least nine out of ten people live in urban settings (Table 4.1).

Table 4.1 Evolution of urban population, percentage living in urban areas by region (1925–2000)

REGIONS	1925	1950	1975	2000
World	20.5	29.7	37.9	47.0
Most development regions	40.1	54.9	70.0	76.0
Less development regions	9.3	17.8	26.8	39.9
Africa	8.0	14.7	25.2	37.9
Latin America & Caribbean	25.0	41.4	61.2	75.3
North America	53.8	63.9	73.8	77.2
Asia	9.5	17.4	24.7	36.7
Europe	37.9	52.4	67.3	74.8
Oceania	48.5	61.6	71.8	70.2

Source: year 1925: Hauser and Gardner (1982); years 1950–2000: UN (2011)

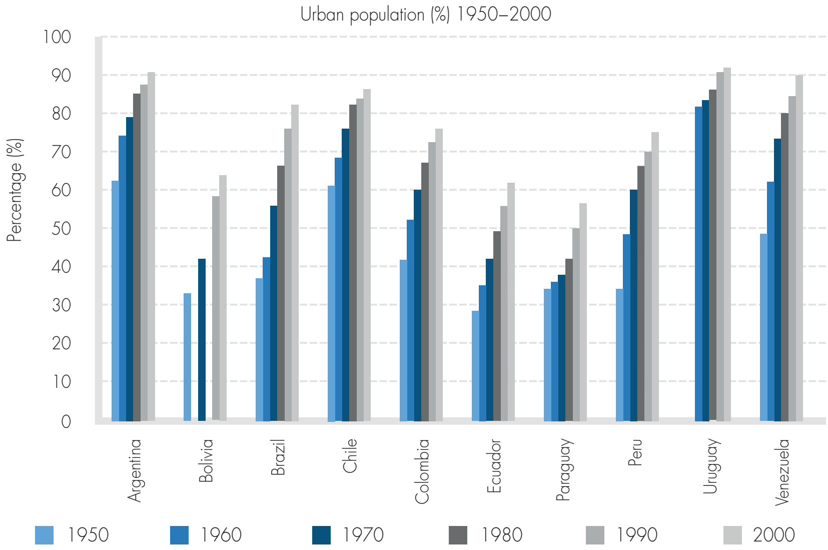

Figure 4.1 Trends in urban population between 1950 and 2000. *Source: CEPAL (2006).*

This pattern of urbanization that has prevailed in LAC has been rapid and poorly planned, not creating an ideal spatial distribution of the population, which is concentrated in large cities. In 2005, there were sixty-seven cities with more than one million inhabitants and four 'megacities' with more than 10 million (Mexico City, São Paulo, Buenos Aires and Rio de Janeiro). These 'megacities' are characterized by inequality, and social problems with a segregated profile in spatial and social terms.

However, the current trend is somehow different. Since 2000, the average annual growth of the urban population is less than 2%, which is a fairly normal population growth (UN-Habitat, 2012). Moreover, the growth of medium-sized cities is an opportunity to overcome the urban problems of the larger cities on the continent.

Often, population growth in urban centres outpaces the ability of utilities to provide adequate services such as water and sanitation. In the absence of piped water systems, communities in these areas meet their water needs through a combination of different sources and means. According to the Global Water Partnership (GWP, 2012) the challenge in LAC is to accelerate the incorporation of the mobile population into informal settlements in order to ensure the formal structure of housing and water and sanitation services. Thus the phenomena of urban transition, the formalization of the economy and water security are all linked. Meanwhile the opposite also holds: rapid urban growth exacerbates the problem (see Box 4.1).

Box 4.1 Slums and access to piped water

Considering that LAC is the second most urbanized region in the world (after North America), the case of slums is extremely pertinent. As can be seen in Figure 4.2 there seems to be a strong correlation between having a high number of people living in slums and overall lack of access to piped water.

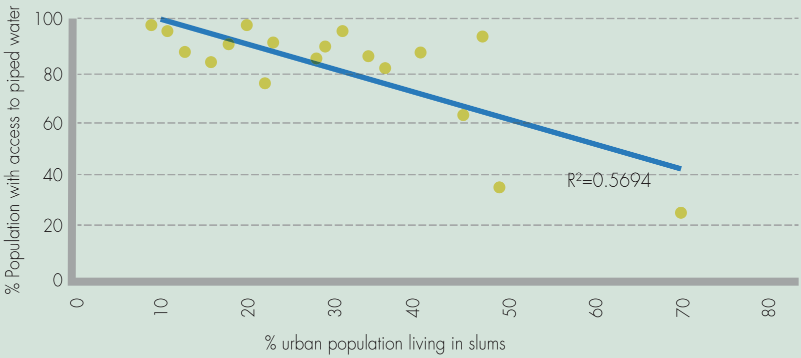

Figure 4.2 Population living in slums and population with access to piped water. *Source: own elaboration based on data from: UN-Habitat, (2012), UN-DESA data (2011) and WHO-UNICEF (2013).*

4.2.1.3 Migration

International migratory processes are motivated by economic, social, cultural and political factors. Recently, studies have also included environmental factors. The total migrant population has been calculated as 3% of the total inhabitants of the planet and 13% of them (about 25 million) were born in LAC. It could be seen as a minor phenomenon but it has a true significance not only in quantitative terms, but also in its impact on social and economic life for both the migrant's country and the host country (CEPAL, 2003).

The Report on Migrations in the World 2010, published by the International Organization for Migration (IOM, 2011), reveals that the number of international migrants increased 11%, from 191 million in 2005, to 214 million in 2010. The Report also indicates that the number of domestic migrants was 740 million in 2009; implying that globally the number of domestic and international migrants is close to 1,000 million, a figure likely to keep increasing (Domínguez-Guadarrama, 2011).

LAC is the scene of intense migration processes that have changed societies in many ways. In this region, all the different types of modern international migration have taken place, from the migration of LAC people (the most visible feature), to immigration, return, irregular migration, forced displacement and the search for shelter, plus the flow of remittances, skilled migration and the presence of dense communities abroad (*ibid.*).

According to the Department of Economic and Social Affairs of the United Nations, in 2010 six out of ten migrants live in developing regions, three-quarters of migrants are concentrated in only twenty-eight countries, and one in every five lives in the United States (UN, 2011). But it is important to point out that only 37% of global migration is from developing countries to developed countries. Most of the displacement takes place between countries in the same category of development.

Furthermore, in LAC nearly 20 million people live outside the country in which they were born and three-quarters of them move to the United States, mainly from Mexico and the Caribbean. From 1970 to 1980, this migration grew two and a half fold, and then duplicated between 1980 and 1990. In 2010, the United States hosted around 43 million foreign nationals, representing 13.5% of the total US population (World Bank, 2011). Results of the 2010 Census indicate that Hispanics made up 16.3% of the total population and that the population increased from 35.3 million in 2000 to 50.5 million in 2010 (Pew Hispanic Center, 2011).

Canada, Spain, United Kingdom, Japan and Australia are other countries where Latin American migrants often go. Spain has recently turned into the second destiny for regional migration; in 2001 there were 840,000 people from South America (mainly from Ecuador) living in Spain and in 2009, one in three foreigners resident in Spain were from LAC (2,479,035 registered) (CEPAL, 2011).

LAC migration has been also intraregional, due to geographic and cultural proximity. In the 1970s, the number of intraregional migrants was near 2 million; in the 1980s and 1990s it grew slowly but by 2000, migrants numbers reached 3 million and by 2005 almost 4 million (3,800,000). At the beginning of the 1990s, most of the immigrants were from outside the region but in 2010, the majority came from the same region, most of them living in Argentina and Venezuela. Costa Rica was the main destination for Central American migrants (CEPAL, 2012b; IOM, 2012).

Throughout its history, Argentina has received immigrants from all its neighbouring countries: Paraguay, Chile, Bolivia, Uruguay and Brazil. This is the case of Venezuela too, where migration was stimulated by the internal conditions such an economic growth and political stability. Immigration in these two countries is higher than emigration. Recent data shows Argentina, Brazil and Chile as the three South American consolidated regional migration receptors. In Brazil, the number of foreigners has experienced strong growth in the past decade: 961,867 in 2010 and 1,510,561 in 2012.

Bolivia, Colombia, Ecuador, Paraguay and Peru maintain a profile mainly for emigration. Within the region, the Bolivians have a strong presence in Argentina and Brazil, Colombians in Ecuador and Venezuela, Paraguayans in Argentina (325,046 in 2001 and 550,713 in 2010), the Peruvian in Argentina (88,260 in 2000 and 157,514 in 2010) and Chile (39,084 in 2002 and 130,859 in 2010) (IOM, 2012).

Inter-urban flows, moving from one city to another, account for the largest volume of population movement within countries of the region. In Mexico, for example, between 1995 and 2000, 70% of the transfers between municipalities were urban–urban type, while rural–urban migration reached 14%. Internal migration is closely related to regional inequalities. In establishing territorial disparities relevant to migration, labour markets play a major role, especially in regard to wages and unemployment in the different zones. There is no evidence, however, that migration reduces the severity of regional inequalities (CEPAL, 2006).

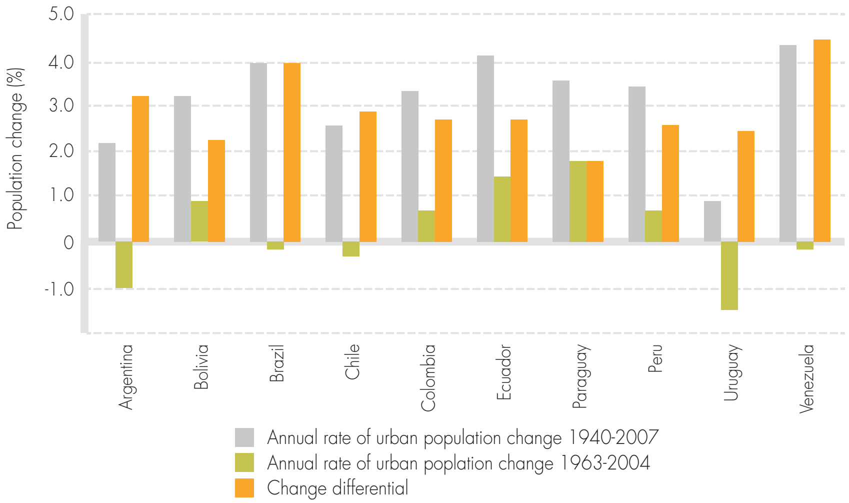

Figure 4.3 Annual rate of urban–rural population change (%). *Source: own elaboration based on data from CEPAL (2006)*

Trade and economic cooperation agreements in LAC (see Chapter 5) such as MERCOSUR (Common Market of the South), CAN (Andean Community of the Nations) and UNASUR (South American Nations Union) have also favoured migration due to its recognition of the importance of the free movement of people (CEPAL, 2012b). Recently, there has been interest in researching the effects of natural disasters; the environment and climate change on migration (see Box 4.4). For example, over 1 million people were estimated to have been displaced due to Haiti's earthquake in 2010 (IOM, 2009).

Even though during the last few years a human rights approach has been progressively introduced into the national and international debate, migrants are very exposed to situations which prevent the exercise of these rights, both during the journey and upon arrival at their destination. These situations include slavery, prostitution, abuse, gender violence, discrimination, expulsion, lack of social support networks and barriers in access to basic health services. In general, this vulnerability is worse in the case of border migrants (CEPAL, 2012b).

4.2.2 Development, income growth, income disparity and poverty

In terms of economic development, LAC was a relatively wealthy region at the start of the 19th century (Millennium Project, 2012). In fact, some countries of LAC were richer than the nascent USA. The Dominican Republic, Mexico and Peru had universities almost one century before Harvard was founded. Haiti was a very wealthy colony in 1800, richer than many parts of the USA. LAC was on a par with most of Europe, and it was richer than Africa, China, India and Japan. At the beginning of the 20th century, Argentina was still one the ten wealthiest countries in the world, and many poor Chinese and Japanese migrated to richer LAC countries like Brazil, Mexico and Peru. However, by the beginning of the 21st century, LAC fell behind, and many countries in East Asia had overtaken it in terms of economic growth. If current trends continue, China will overtake LAC in terms of GDP per capita by the 2020s (Figure 4.4).

Economic growth in LAC in the last thirty years has been modest (in per capita terms) and the varying growth regimes are due to the shocks the region has faced during that period. During the 1970s, shocks were associated with the collapse of the Bretton Woods exchange rate parities and oil-price increases. Throughout the 1980s the region confronted the debt crises and high inflation which was followed by a period of slow and unstable growth and macro-economic instability. Market-oriented reforms were adopted by several LAC countries during the 1990s; however, the slow growth cycle has lasted more than two decades. The different per capita growth rates of seven LAC countries during these periods are presented in Table 4.2.

During the last twenty years (1990–2010) LAC's per capita growth rate has been 1.6% and, of the seven economies studied, only Chile, Costa Rica and Peru exhibit more vigorous growth rates (Figure 4.5). The per capita growth rates observed in LAC throughout the 1980–2010 period also coincide with slower per capita growth in the world economy during the same period.

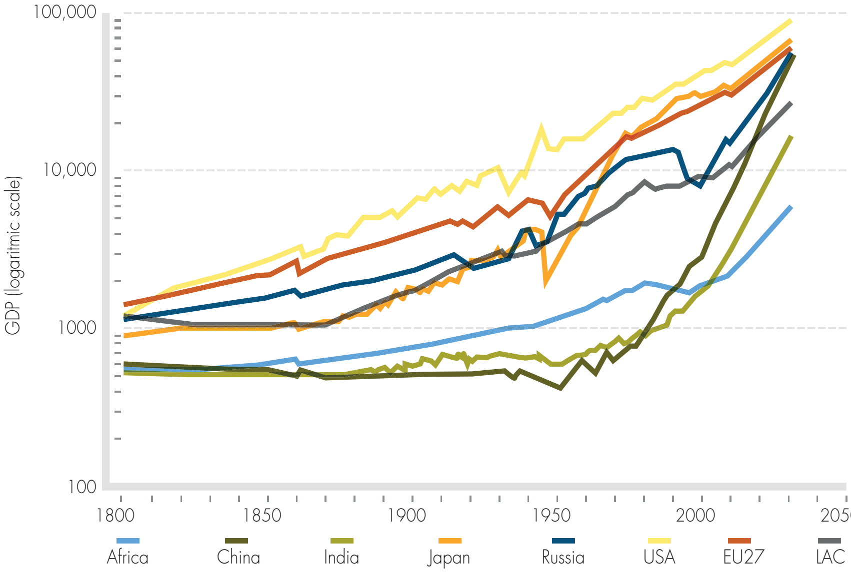

Figure 4.4 Comparative Evolution of GDP per Capita (GDP, logarithmic scale). (Historic and Projections: 1800–2030). Note: The GDP per capita projections are an extrapolation to 2030 using the same growth forecast 2011–2015 by the IMF. *Source: Millennium Project (2012).*

Table 4.2 **Real per capita income growth 1960-2010**

PERIOD	LESS THAN ZERO	0%–1%	1%–2%	2%–3%	ABOVE 3%
1960–1980			Chile, Peru	Argentina	Brazil, Costa Rica, Colombia, Mexico
1980–2010	Argentina, Peru	Brazil, Costa Rica, Colombia, Mexico			Chile

Source: own elaboration on basis of CEPAL (2005).

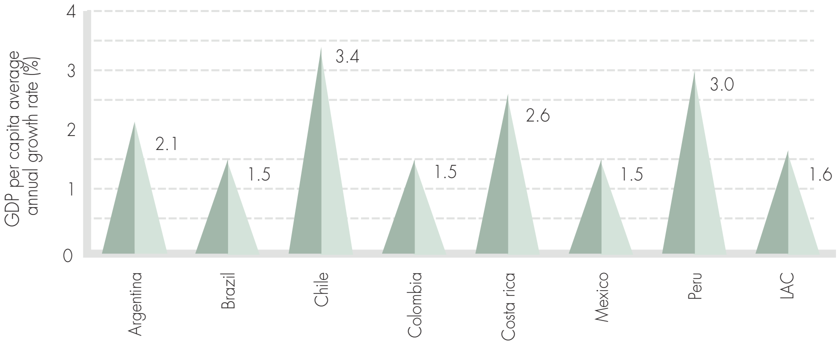

Figure 4.5 GDP mean annual growth rate, period1980–2010. *Source: own elaboration based on UN data.*

LAC's GDP growth for 2013 was projected to be 3.9% and 4.4% in 2014, but growth volatility is a real possibility. In Brazil, for instance, consensus forecasts for 2012 moved from 3.3% in January to 1.6% in October and drastic corrections are being registered for Argentina (Gurría, 2012). The region still has to tackle many structural challenges in order to turn stability into long-term growth. For example, high commodity prices are leading some countries to favour an economic model based almost exclusively on primary commodities, and this is making the region vulnerable; Chile is an example of this tendency.

Solimano and Soto (2006) found a direct relationship between each country's real GDP per working-age person and 'total factor productivity' (TFP) and the efficiency and rate of the use of capital and labour. Figures 4.6 and 4.7 analyse what appears to be a decoupling in some countries between GDP growth, water consumption and population growth. At LAC scale, this decoupling between population growth and GDP per capita increase and annual freshwater withdrawals seems clear (Figure 4.6). However, a detailed country analysis shows different trajectories (Figure 4.7). While in some countries (Argentina, Peru, Colombia, Costa Rica and Chile) decoupling is a clear, i.e. higher GDP per capita and less water consumption, in other countries (Brazil, Colombia and Mexico) there is no clear trend.

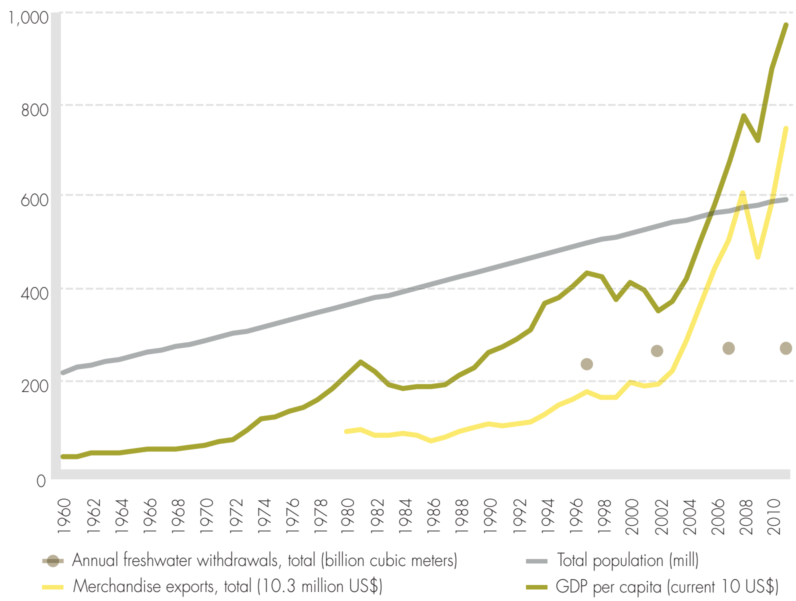

Figure 4.6 Population growth in LAC (1990–2000), Water consumption in LAC (1990–2000) and Evolution of GDP (1990–2000). *Source: own elaboration based on data from World Bank-World Development Indicators database (Population and GDP per capita), FAO-AQUASTAT (Annual freshwater withdrawals) and IMF-World Economic Outlook Database (Total merchandise exports).*

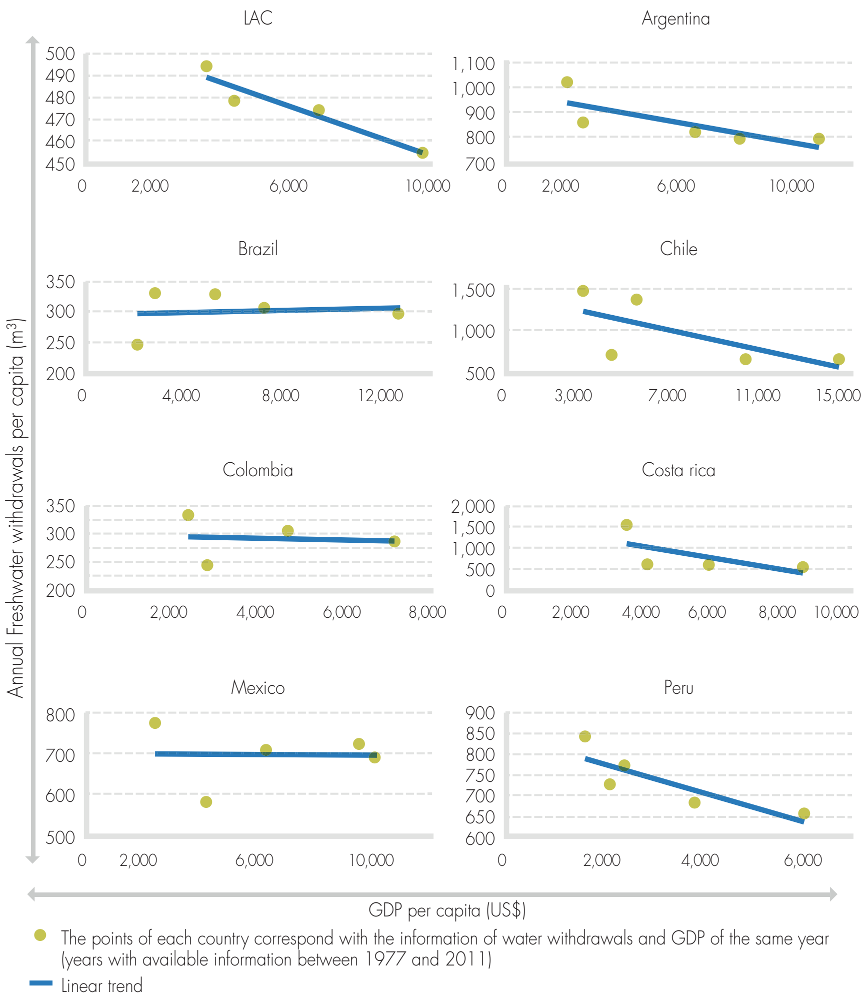

Figure 4.7 Annual freshwater withdrawals per capita vs GDP per capita (1977–2011). *Source: own elaboration on data from FAO-AQUASTAT and World Bank-World Development Indicators database.*

4.2.2.1 Beyond GDP: human well-being progress

GDP is an important variable but certainly not the only relevant indicator to measure progress. An analysis based exclusively on GDP would be too simplistic. Thinking beyond GDP we can use a Society–Technology–Economics–Ecology–Politics (STEEP) approach, the Human Development Index (HDI) developed by the United Nations Development Program and other variables. Table 4.3 shows some of the variables included during the Latin America 2030 study on Scenarios (Millennium Project, 2012). It is useful to analyse the, best and worst values for each variable, both in LAC and for the rest of the world.

Table 4.3 **Comparative Best and Worst Cases for International Indexes for the year 2010 using the STEEP (Society—Technology—Economics—Ecology—Politics) approach**

VARIABLE / INDICATOR/INDEX	WORLD WORST	LATIN AMERICAN WORST	WORLD AVERAGE	LATIN AMERICAN AVERAGE	LATIN AMERICAN BEST	WORLD BEST
Society: HDI (from 0 worst to 1000 best)	0.140 (Zimbabwe)	0.404 (Haiti)	0.624	0.704	0.783 (Chile)	0.938 (Norway)
Technology: E-Readiness index (from 0 worst to 10 best)	2.97 (Azerbaijan)	3.97 (Ecuador)	4.30	5.40	6.49 (Chile)	8.87 (Denmark)
Economics: GDPc (PPP, Thousand US$ 2010)	340 (Congo)	1,121 (Haiti)	10,711	11,188	19,600 (Puerto Rico)	88,232 (Qatar)
Environment: CO_2 emissions per capita (Tons/person)	55.5 (Qatar)	6.0 (Venezuela)	4.6	3.7	0.2 (Haiti)	0.0 (Mali)
Politics: Corruption index (from 0 worst to 10 best)	1.1 (Somalia)	2.0 (Venezuela)	3.3	3.6	7.2 (Chile)	9.3 (Denmark)

Source: Millennium Project (2012).

Notes: (1) The best and worst values correspond to the latest information of the countries with available data in 2010. (2) The Latin American and world averages and based on population-weighted values

The analysis of educational, health or employment indicators also offers relevant information to measure progress in contrast to pure GDP metrics. As Table 4.4 shows, LAC citizens today have greater educational, health and employment opportunities compared to twenty years ago but key issues like wealth distribution and gender equality are pending targets. Regarding health, important progress has been achieved. Life expectancy has increased in all regions, particularly in the Amazonian, Mesoamerican and Caribbean countries. The current rate of life expectancy surpasses 73 years on average. Sanitation facilities and access to safe water source have also increased in most regions but challenges remain in improving access to water and sanitation in rural and peri-urban areas. Schooling rates are also progressing; between 95 to 97% of LAC population complete primary school. Important progress has been reached concerning employment. Nevertheless, the female employment rate (50%) is still far below the men's average (over 70%) and employment vulnerability (unpaid family work or self-employment) has increased for both men and women. Despite this socio-economic progress, income distribution has not improved across all regions. The GINI index has only decreased in the Amazon region and in Mesoamerica. In the other regions it has either increased or remained stable in time. Likewise, the share of the wealth among the richest has increased while it has decreased among the poorest, widening the distance between those that have accrued most of the money and those who have less.

Table 4.4 Trends of human well-being across different regions of Latin America and the Caribbean (LAC) in the last two decades

DIMENSION		AMAZON		ANDEAN		CARIBBEAN		MESOAMERICA		SOUTH CONE	
	INDICATOR	1988/ 1992	2008/ 2012	1988/ 1992	2008/ 2012	1988/ 1992	2008/ 2012	1988/ 1992	2008/ 2012	1988/ 1992	2008/ 2012
EDUCATION	Rate of males completing primary education (% of relevant age group)	95	91	78	96	95	95	73	95	81	100
EDUCATION	Rate of females completing primary education (% of relevant age group)	88	84	81	97	95	95	71	95	79	100
HEALTH	Life expectancy at birth (years)	63.	71	71	73	70	74	68	75	73	76
HEALTH	Population with access to improved sanitation facilities (%)	68	81	59	66	84	83	66	79	77	89
HEALTH	Rural population with access to improved sanitation facilities (%)	33	64	32	48	81	81	53	71	56	74
HEALTH	Population with access to improved water source (%)	89	94	80	89	91	93	81	92	84	94
JOBS AND EQUITY	Female population employed 15+ (%)	35.8	39.9	35.7	50.6	40.7	48	33.6	43.5	39.4	46.3
JOBS AND EQUITY	Male population employed 15+ (%))	72.1	70.3	75.9	76.5	65.9	67.3	77.9	77.8	75.7	73.3
JOBS AND EQUITY	Vulnerable female employment (% of female employment)	34.1	22.5	37.4	42.1	18.4	31.1	28.6	31.3	27.6	28.4
JOBS AND EQUITY	Vulnerable male employment (% of male employment)	31.4	27.1	31.3	34.5	22.5	40.7	39.9	27.2	22.4	27.8
WEALTH	GDP per capita (constant 2,000 US$)	2,032	2,812	2,258	3,003	6,631	8,498	2,312	3,503	4,020	6,910
WEALTH	GINI index (1–100)	60	55	46	53	45	48	54	51	46	49
WEALTH	Income share held by highest 10%	47	43	35	41	35	38	39	40	36	38
WEALTH	Income share held by lowest 10%	1	1	2	1	2	1	1	1	2	1

Source: own elaboration based on data from World Bank-World Development Indicators database

4.2.2.2 Income growth and poverty reduction

The link between national economic growth and poverty reduction is well known, although it is different for specific countries, each with its own cultural and political history. Due to the negative association between growth and the incidence of poverty,[1] some analysts and international agencies support the recommendation that governments focus on growth in order to alleviate poverty (e.g., Dollar and Kraay, 2001, Ravallion, 2004).

1 Statistical analysis has shown that the poverty-reduction elasticity with respect to national income growth has been in the range of 2 to 3.5 percent (Ravallion, 2004)

The debate about growth and poverty is particularly relevant in LAC where countries show poor evidence in terms of poverty reduction over the last fifteen years given their economic growth. Argentina experienced an important increase in poverty during the 1990s, despite having a growing economy during the same period. Poverty significantly decreased in Brazil during the first half of the 1990s, driven by economic growth and improvements in income distribution; however, since 1995, poverty reduction has slowed. There is a positive trend in the reduction of the population below the poverty and indigence line, for the cases of Chile, Brazil, Peru and Colombia, and less constant reduction trends for Mexico, whereas Costa Rica seems fairly stable (Figures 4.8 and 4.9).

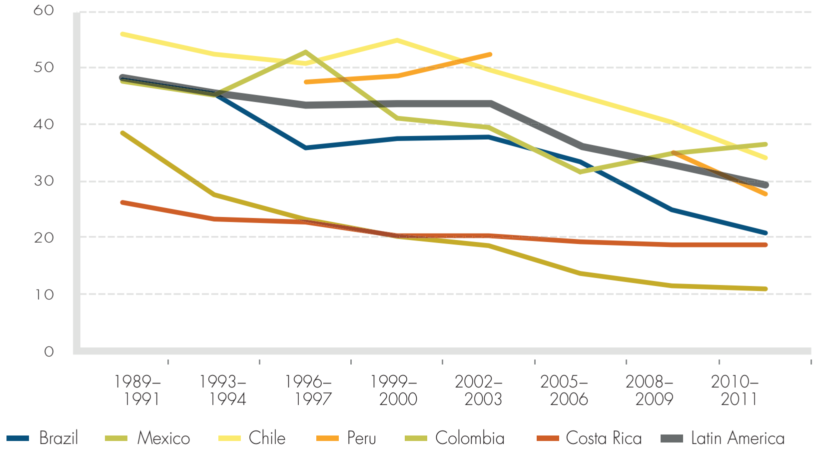

Figure 4.8 Percentage of population below poverty line. *Source: own elaboration based on ECLAC (2012).*

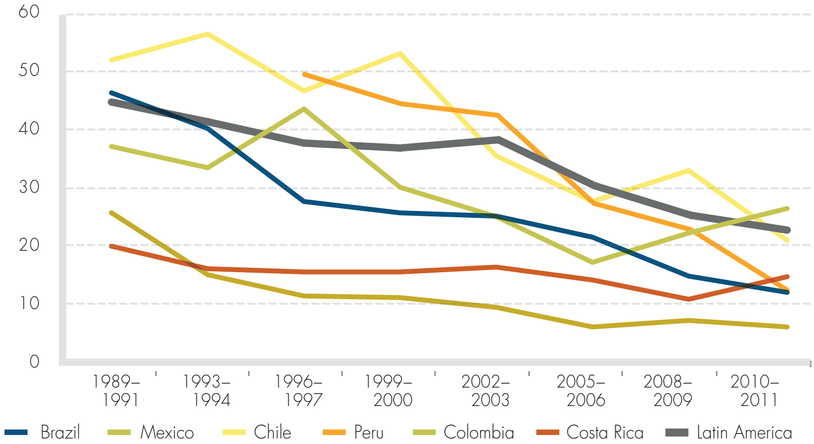

Figure 4.9 Percentage of population below indigence line. *Source: ECLAC (2012).*

Chile is a successful story of consistent poverty reduction, from 5 million people below the poverty line in 1990 – approximately 40% of the population – to 2.5 million in 2009 – i.e. about 15%. The rate of extreme poverty also decreased fast, from 13% of the population in 1990 to 3.7% in 2009. The performance of the Andean community economies in terms of poverty reduction has not been so consistent. Poverty has decreased in Peru, whereas in Colombia current poverty levels are equivalent to those of two decades ago. Costa Rica has the lowest poverty rate among Central American countries, and the poverty line is close to 20% while extreme poverty has fallen to almost 7%. Mexico does not have a good track record for poverty reduction; poverty rates recorded during the 2000s are not significantly different from those of the 1990s. Box 4.2 shows how water poverty plays out in LAC, calculated on the basis of research conducted by Lawrence et al. (2003).

For the particular case of Latin America, the most important aspects are not GDP per capita and the reduction or increase in poverty, but the distribution of wealth. GDP per capita has increased in most cases (Figure 4.11) yet things look very different when considering income distribution (Figure 4.12). The income share held by the highest 20% sub-group of population has reduced for the cases of Argentina, Brazil and Colombia, but it is less clear for the cases of Mexico or Chile (Figure 4.12a). In contrast, the income share held by the lowest 20% sub-group of the population has increased in Colombia, Argentina, Brazil and Peru, but it is less marked in countries like Mexico or Chile (Figure 4.12b).

Box 4.2 Water poverty index in LAC

The water poverty index (WPI) is calculated based on a series of parameters related to resources, access, capacity, use and environment. 'Resource availability' is measured taking into account availability but also quality. 'Access' refers to the human access to water, including distance to a safe source, time needed for collection, access for irrigation, etc. 'Capacity' refers to the effectiveness of people's ability to manage water, whereas 'use' refers to the amount of water used for productive uses like agriculture, industry or urban water supply. Lastly, 'environment' accounts for the integrity and flow of ecosystem services provided by freshwater ecosystems. Globally, Finland has the highest WPI score (79) and Haiti the lowest (35). As Figure 4.10 shows, WPI varies across LAC countries, with scores ranging from 55 to 69. Countries with the lowest WPI values are Paraguay, El Salvador, Mexico, Nicaragua and Guatemala. Meanwhile Chile, Ecuador, Uruguay, Costa Rica and Panama have the highest scores. It is striking that countries that do not have the highest rain indexes do not have the lowest WPI. That means that good management is crucial for achieving the best water use given a particularly water resource endowment. For instance, Peru's water resources are slightly more abundant than those of Chile, but Chile has higher levels of the population with access to clean water and sanitation coverage. On the other hand, there are regional differences in each country, especially in the bigger ones: Mexico, Brazil, Argentina or Peru, which have very humid regions and also very dry ones. In these countries water management has to be tailored for each hydrological region to reduce water poverty.

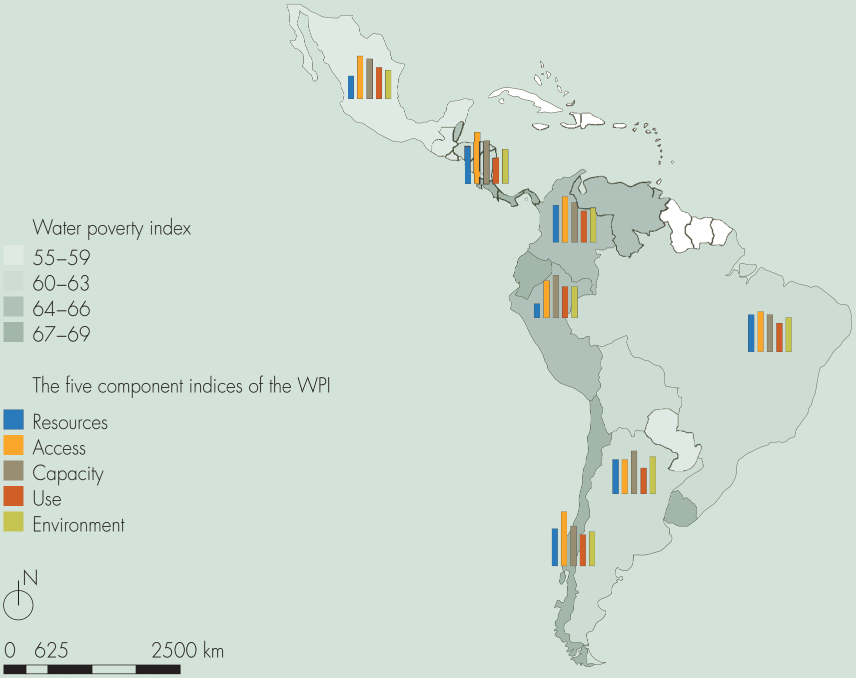

Figure 4.10 Water Poverty Index in LAC countries. *Source: own elaboration based on data from Lawrence et al. (2003).*

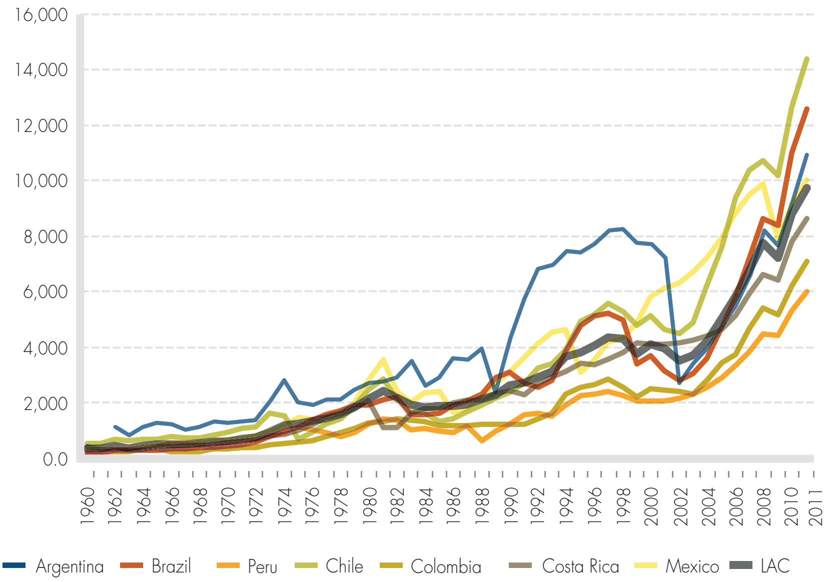

Figure 4.11 Annual GDP per capita growth (expressed in current US$) for the time period 1980–2010. *Source: own elaboration based on data from World Bank-World Development Indicators Database.*

a)

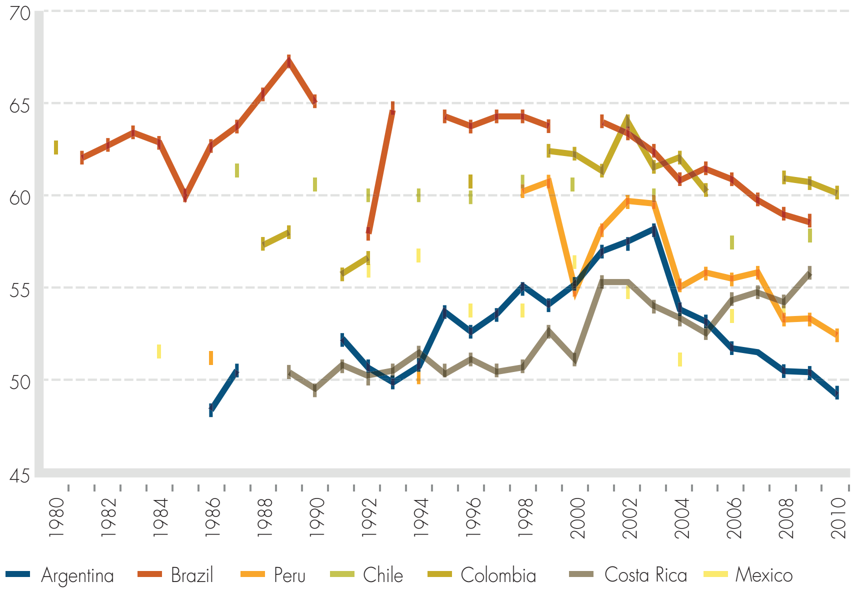

Figure 4.12a Inequality in income distribution. Percentage of the income share held by highest 20% subgroup of population. *Source: own elaboration based on data from World Bank-World Development Indicators Database.*

b)

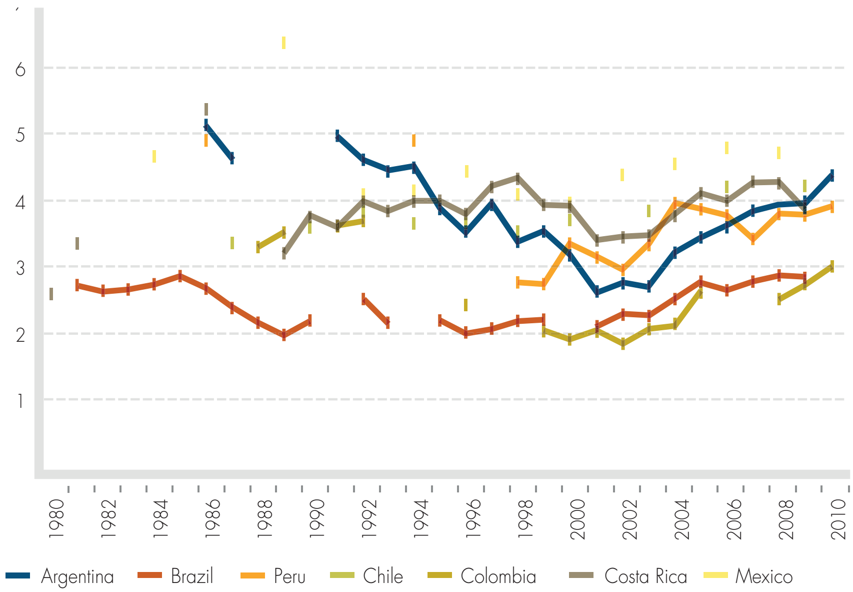

Figure 4.12b Inequality in income distribution. Percentage of the income share held by lowest 20% subgroup of population. *Source: own elaboration based on data World Bank-World Development Indicators Database.*

4.2.2.3 The informal economy in water and food security

The informal economy and its activities are the 'unregistered economic activities that contribute to the officially calculated GDP' (Schneider, 2002). The informal economy contributes to the country's economy but these activities are informal in terms of registration, tax payments, operating licenses, employment conditions and regulations (Becker, 2004). The informal economy represents a transition period that would under normal development paths disappear once countries achieved sufficient levels of economic growth and modern industrial development (Becker, 2004). There is now, however, increased evidence that the informal economy can no longer be considered as a temporary phenomenon. The informal economy has a more fixed character in LAC and this is particularly the case for those countries where incomes and assets are not equitably distributed[2] (Figures 4.12a and 4.12b).

In terms of employment, estimates show that non-agricultural employment as a share of the informal workforce is 57% in LAC. Meanwhile GDP estimates of the contribution of the informal sector (i.e. not the informal economy as a whole, but only informal enterprises) indicate that the contribution of informal enterprises to non-agricultural GDP is significant, representing 29% for LAC (Flodman, 2004). As can be seen in Figure 4.13, the share of informal jobs in total employment can be high, reaching in some cases very high levels like Bolivia, Honduras, Paraguay or Peru, but also pronounced in countries like Colombia, Mexico or Argentina.

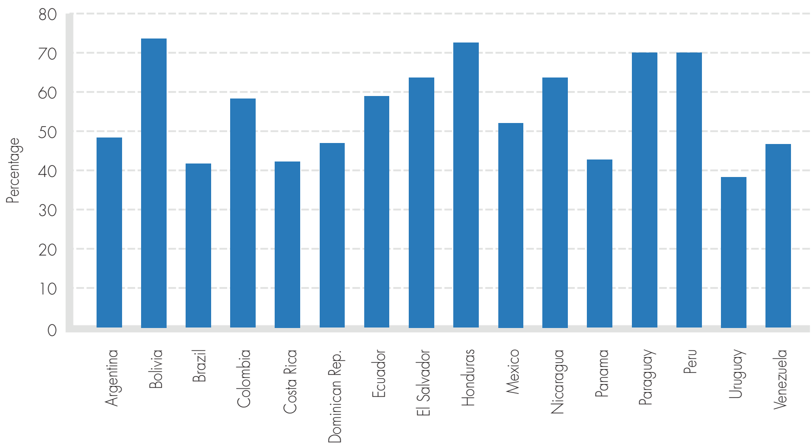

Figure 4.13 Informal employment and the informal economy as part of GDP. *Source: own elaboration based on data from Herrera et al (2004).*

A modern approach to informality does not see informality as an all-or-nothing, but as degrees of informality and formality, along a spectrum where a number of factors can impact its evolution. Informality can become a potential nascent entrepreneurial sector for

2 As Becker (2004) states 'if economic growth is not accompanied by improvements in employment levels and income distribution, the informal economy does not shrink'.

growth and innovation or instead a structural problem of under-development and poverty. The majority of informal economy activities provides goods and services, whose production and distribution are legal. LAC has abundant metals, foods and energy resources, and without strong institutions (Millennium Project, 2012), there are risks of criminalization of the economy, and lack of personal safety due to deep social inequalities. Hence the importance of realizing the potential the informal economy has for water and food security in LAC.

4.2.3 Trade liberalization, consumption patterns, food security and health transition

4.2.3.1 Trade liberalization

Over more than four decades, LAC countries have signed agreements and regional integration treaties of different types. The integration aims to remove barriers to free interconnection of the economies in order to increase their production capacity, trade, and investment; that is, to drive economic growth (Guerra-Borges, 2012). There are significant integration structures in the region, including the General Treaty of Central American Integration, the Latin American Integration Association (ALADI), the Southern Common Market (MERCOSUR), the Andean Community and the newly created Union of South American Nations. There are also treaties and other trade agreements of different levels such as the North America Free Trade Agreement signed between Canada, the US and Mexico, or the fifty-eight free trade agreements signed between Chile and other nations. During the 1980s and 1990s, the region undertook deep processes of structural reform: the reduction of state functions, deregulation, and privatization of state enterprises, among others. Trade liberalization (TL), a central component of the reforms, began with a unilateral reduction of tariffs but nowadays includes complex provisions including labour and environmental issues (IICA, 2009).

One question that it is important to discuss is whether trade and trade liberalization benefit the poor in LAC. Trade–poverty linkages are complex and diverse, but according to orthodox mainstream economic theory and empirical findings, they can be divided into a few important pathways: (a) trade-induced growth; (b) effects of trade on prices, income and consumption patterns; (c) effects of trade on wages and employment. Chapter 5 discusses all these pathways in detail. Buitagro (2009) points out that even though trade liberalization has been considered a key element in economic growth and development, indiscriminate trade liberalization strategies have not been beneficial for low- and middle-income countries. Empirical studies conducted in LAC have shown little correlation between trade liberalization, economic growth and poverty reduction (Buitagro, 2009).

Between 1985 and 2000 all economies in the region experienced important TL. Exports increased fivefold in Mexico, tripled in Argentina and doubled in Brazil. A low growth, the unequal distribution of income, and in recent years the high volatility of agricultural prices, has increased society's vulnerability and prevent poverty reduction, especially in the agricultural sector, the most opened in the economy (Table 4.5).

Table 4.5 **Merchandise trade in selected countries of LAC (% of GDP)**

	1990–2000	2010
ARGENTINA	18	35
BRAZIL	17	19
CHILE	46	61
COLOMBIA	25	31
COSTA RICA	79	64
MEXICO	59	60
PERU	36	45

Source: World Bank-World Development Indicators.

4.2.3.2 Changes in consumption and dietary shifts

Evidence of a change in the dietary patterns of LAC societies have been found since the 1980s. The consumption of fats, animal products, processed foods, fast food and non-alcoholic beverages has increased while cereals, fruits and some vegetables and tuber consumption has diminished. For Regmi (2001), a change in diet occurs gradually and is the result of income growth, urbanization, changing prices, the rise of the processed food sector, changes in the age structure of the population and awareness of food security, among other factors. Morón and Schejtman (1997) and Rastoin (2009) add the 'terciarization' of the agro-food sector and the impact of advertisement.

Regmi et al. (2008) recognize that the global expansion of industries, agribusiness services and supermarket chains, modifies food prices and shapes tastes and diets, tending to standardize how food is produced, distributed and consumed worldwide. For Bermudez and Tucker (2003) food supply is the mechanism by which modernization affects the Latin American diet and the transition or 'convergence' occurs in different social and economic conditions. This has caused a double problem of public health: malnutrition, due to the prevalence of poverty and unequal income distribution, along with obesity and chronic degenerative diseases, result of more 'refined' diets. More use of water and its pollution are collateral problems of dietary changes.

According to the Pan-American Health Organization (PAHO, 2012) at the regional level a detrimental change in nourishing patterns rapidly unfolded. Between 1984 and 1998, the purchasing of refined carbohydrates and sodas increased by 6% and 37% respectively (Rivera et al., 2004).

Box 4.3 The Mexican case

The study by Santos-Baca (2012) corroborates the results of Bermudez and Tucker (2003). She found that the reduction in animal food consumption was created by a reduction in milk intake, a phenomenon that some researchers associate with the increase in soft drink consumption (Rivera et al., 2008: 175). Cereals and legumes particularly beans, which was the basis of the Mexican diet, have reduced their importance. Maize remains the most consumed cereal but the consumption declined 18% from 1992 to 2010, when its price increased 53%. Wheat is the second most important cereal consumed but in much smaller quantities than corn; however, wheat spending is similar to that of corn. The average amounts of consumed fruits and vegetables (sources of essential vitamins and minerals), fell from 0.74kg in 1992 to 0.61kg in 2010; those amounts represent 70% and 66% respectively of the quantity recommended by FAO: 400g per person/day. Beverage consumption, except bottled water, increased 37% between 1992 and 2010, due to the significant increase in the consumption of soft drinks. Consumption of sodas increased 40%, and processed juices and nectars increased 141%. Mexico has the second highest per capita consumption of soft drinks in the world. Unlike in developed countries where changes occurred because of modernization, food transition in Mexico from 1992 to 2010 is characterized by the deterioration in food intake (Figure 4.14).

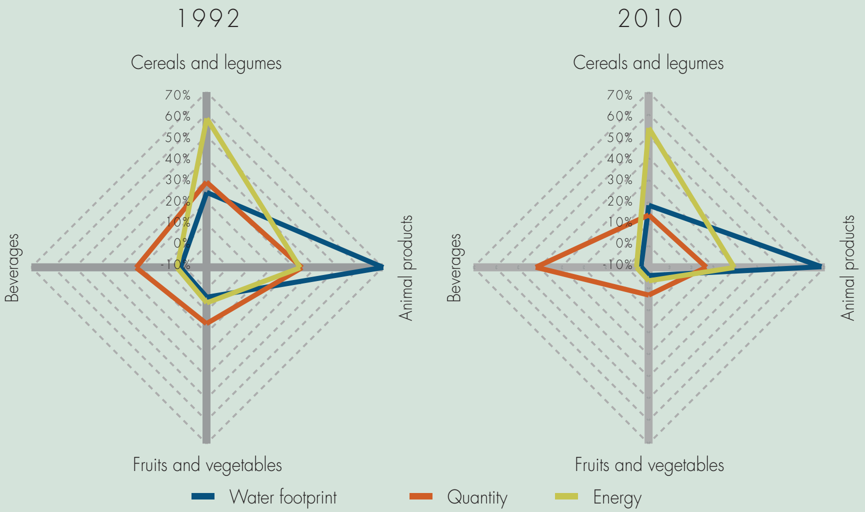

Figure 4.14 Mexican food consumption pattern. Quantity, energy, water footprint of main food products. 1992 and 2010. *Source: own elaboration with data from INEG (1992, 2010), Mekonnen and Hoekstra (2010a, 2010b) and Ercin et al. (2011).*

4.2.3.3 Food security

Hunger currently affects 49 million people living in LAC. This means that 8.3% of the population of the region does not consume the necessary daily calories. Between 1990–1992 and 2010–2012, the undernourished population declined by 16 million people (24.9% over the period), but still an unacceptable number of people are suffering from hunger (FAO, 2012).

The trend in hunger reduction has slowed from 8% between 1990–1992 and 2007–2009, to 2% in 2010–2012. This is the result of the world economic crisis and the slower economic growth in the region but also due to structural problems. The number of hungry people in LAC declined from 57 million in 1990–1992 to 49 million in 2010–2012. The increase in commodity prices and the drought of the last three years have added 3 million people to the category of the poor. Countries like Bolivia and Paraguay, but also Peru, Ecuador and Colombia display hunger problems according to the indicator of chronic malnutrition in children under five years old (FAO, 2012).

On the other hand, adequate calorie consumption does not mean adequate nutritional conditions. Nutrition problems arise from insufficient vitamins and intake of other essential micronutrients. The nutritional problems of the region are not only about hunger in the sense of insufficient energy consumption. Malnutrition caused from inadequate diets which provoke health problems related to nutrients deficiency can also lead to obesity problems (FAO, 2012). According to FAO (2012) Cuba, Argentina, Chile, Mexico, Uruguay and Venezuela have managed to eradicate the scourge of hunger. The case of Brazil is outstanding with the reduction of hunger in absolute and relative terms. The prevalence rate of malnutrition in the total population, and in children under five, diminished from 1999–2000 to 2010–2011. In Peru and Brazil this decrease is very strong but their levels remain high, particularly in children under five years.

4.2.3.4 Health transition

LAC is currently undergoing important demographic, epidemiological (PAHO, 2012) and nutritional transitions (Rivera et al., 2004). The demographic transition is characterized by a reduction in fertility and mortality rates, the increase in life expectancy and by population ageing (PAHO, 2007a and b). The nutritional transition is characterized by a decrease in the prevalence of malnutrition and an increase in obesity, which is a risk factor for chronic diseases such as cardiovascular disease, diabetes and cancer (Pi-Sunyer, 2002). The epidemiological transition is characterized by a triple burden of disease comprising: *infectious diseases*, whose prevalence is declining; *chronic diseases,* registering a rapid increase, and *external causes*, related to accidents and violence.

The drivers of the nutritional transition are complex and multi-causal. Important determinants are the process of urbanization and economic growth, technological changes and innovations that lead to reduced physical activity at work, in leisure and in transportation, and changes in nourishing patterns and dietary intake, with particular emphasis on the increased consumption of processed foods with high-energy content.

The nutritional transition has evolved at different rates in LAC (Barría and Amigo, 2006). Nevertheless, they all display a twofold pattern. On the one hand, there is a diminishing tendency in the prevalence of low weight and height. On the other hand, there is a tendency in the increase in caloric intake, information which has been captured by all surveys of food availability per country (Rivera et al., 2004). Coupled with an increasingly sedentary lifestyle, the result has been a dramatic increase of obesity in many

LAC countries. These are risk factors for morbidity and mortality from diabetes mellitus, hypertension and myocardial infarction, among others.

The health sector in LAC faces a number of challenges: solving problems of infectious diseases and maternal-child mortality, and combating the changes in the disease profiles arising from development and changes in diet; the increase of chronic-degenerative, senile and mental diseases, HIV/AIDS and obesity. Mortality from transmissible diseases and perinatal period decreased while chronic and degenerative diseases linked to external causes (violence, accidents and injuries) have increased. Infant mortality has fallen and the change in age structure has led to an increase of deaths among older adults (Arriagada et al., 2005; CEPAL, 2005).

Obesity is now a widespread growing health problem. Changes in dietary patterns (excessive caloric consumption), sedentary lifestyles, and heavily advertised products with excess fats, salts and sugars, have triggered a rise in obesity (Olaiz-Fernández et al., 2006). Prevalence of hypercholesterolemia found in two cross-sectional samples of adult men and women living in Santiago de Chile increased dramatically in just five years, from 34% in 1987 to 42.5% in men and 46.1% in women in 1992. In Mexico, the mortality rate from diabetes mellitus is 12%. An analysis from 1980 to 1998 of age-adjusted standardized mortality rates for acute myocardial infarction (AMI), diabetes mellitus and hypertension showed a rapid increase of 53% for AMI, 62% for diabetes and 55% for hypertension (Olaiz-Fernández et al., 2006).

In LAC obesity prevalence in adults is high and accounts for over 20% of the population: in Mexico, 33%, Venezuela 31%, Argentina 29% and Chile 29%. The prevalence in children is also concerning. In 2010, more than 2 million under five years old in South America were classified as overweight or obese, more than a million in Central America and approximately 300,000 in the Caribbean. Barría and Amigo (2006) found there is a prevalence of more than 6% of the child population in five countries. Surveys showed that child obesity exceeds 6% in Argentina, Chile, and Peru (Olaiz-Fernández et al., 2006).

The three causes of death (myocardial infarction (AMI), diabetes mellitus and hypertension) have different causes and risk factors. Undeniably, genetics has its influence, but the relationship between these diseases and obesity, poor diet and lack of physical activity is strong and well established in the literature. An important observation about the epidemiological trends in LAC is that obesity and communicable diseases are affecting the populations of all socio-economic levels. Moreover, several studies have found a negative relationship between socio-economic status and prevalence of obesity (PAHO, 2011). Also socio-economic status appears to be positively related to physical activity (Monteiro et al., 2002). These results confront the misconception that obesity is a feature of wealthy populations.

4.3 Other drivers

4.3.1 Scenarios of technological change 2030

A study on potential scenarios for LAC for 2030 was undertaken in 2012. According to the Scenario 1 'Mañana is Today: Latin American Success' of the Latin America 2030 study by the Millennium Project[3] (see Figure 4.15) breakthroughs in science and technology around the world will play a key role. No matter where these advances originated, they will spread quickly throughout the planet. Imagine a scenario in LAC for 2030 where the WTO and Internet 7.0 will help ensure that knowledge moves fast from country to country. Technology will continue improving and synergies among nanotechnology, biotechnology, information technology, and cognitive science (commonly known as NBIC technologies) shall boost technology value and efficiency whilst lowering costs. However, some people could complain about too much technology and unintended consequences like over reliance on technological solutions and furthermore feasible scenarios where socio-political instability and economic constraints become barriers for technology deployment. However, this is one of four possible scenarios for LAC in 2030. These scenarios highlight the role of ICT and technology as game changers, compared to megatrends (NIC, 2008). However, these game changers will probably not materialize without political leadership and vision to address the issues raised earlier in terms of development challenges and opportunities.

4.3.2 Socio-economic impacts of technological change

Information and Communication Technology (ICT) may be the most developed aspect within the NBIC technologies and the best example to analyse their expected impact. ICT has become a key feature in modern life and has proliferated across many sectors, providing new challenges and opportunities. Cell phones that used to be a luxury product can now be bought at an affordable price which has fuelled a rising global ICT market (Figure 4.16).

In 2012, the 2G connection technology (GSM/EDGE) was used by 80% of mobile phones in LAC, although a fast deployment of 3G technologies is foreseen, and the latter should be dominant by 2018 (ERICSSON, 2012). If economic development and consumer demand allow this forecast to be fulfilled, the percentage of individuals using the Internet could skyrocket from 35% in 2011 (16.5% in 2005) to an interval between 70 and 80% in 2018, not far away from the current figures of America's most developed countries, the US and Canada, with approximately 85% (ITU, 2013).[4]

3 www.proyectomilenio.org

4 ITU (International Telecommunication Union) is the United Nations specialized agency for information and communication technologies – ICTs.

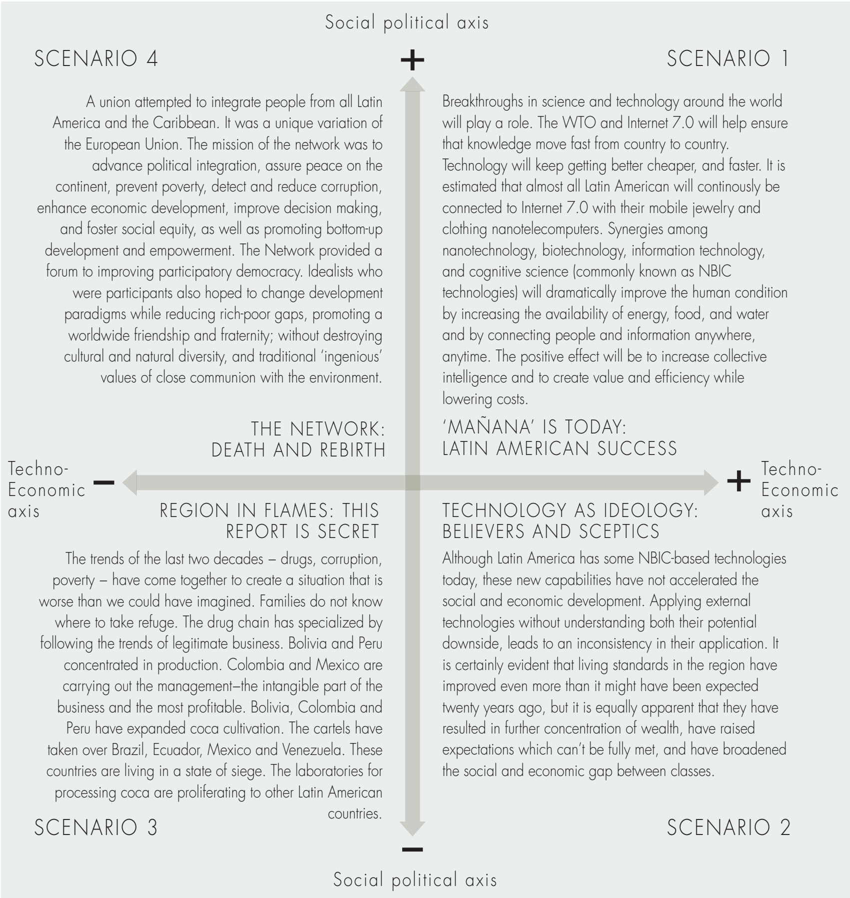

Figure 4.15 Development scenrios for Latin America 2030. *Source: own elaboration based on data from the Millenium Project (2012).*

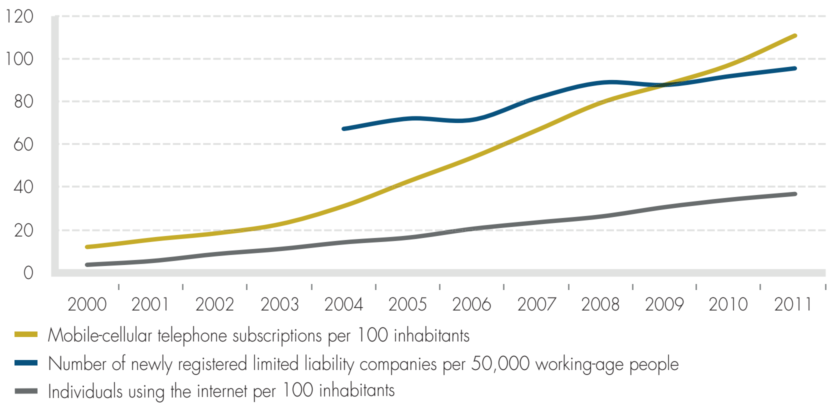

Figure 4.16 Trends in entrepreneurship and access to information and ICT worldwide. *Source: own elaboration based on data from ITU (2013).*

Thus, in many rural areas of some LAC countries, the breach is greater in basic matters such as access to safe water or water disposal systems than in access to up-to-date ICT. Concerning food security, both public and private sectors are embracing the potential of ICT (World Bank, 2011; Vodafone & Accenture, 2012), concluding that a significant increase in agricultural income can be achieved through their use. The so-called e-agriculture is gaining relevance, taking advantage of ICT to promote new possibilities and alternatives and improve many of the areas related to the food production chain, covering issues as varied as financial services, transportation, commerce and marketing, traceability and quality assurance, storage or training, as well as all activities related to crop management, including the optimization of water management. Farmers can benefit from initial/wider access to credit, logistic and commercial support, building visibility, improving the quality of their products and gaining in capacity and education. Also, farmers can obtain expert agronomic advice, key information on weather forecasts, diseases control or best cultivation practices according to the phenological status of plants.

Concerning water security in LAC, the percentage of people with no access to safe water has successfully decreased from 22.6% in 1980 to 5.8% in 2010. A projection made for 2030 (Millennium Project, 2012) estimates this figure will only reach 3.9%, since most of these people live in rural areas where water plans are difficult to implement. An extended use of ICT could help change this trend. Modern water-meters as well as the fostering of a participatory approach by water users connected via ICT are creating new pathways for water security. As an example, the use of innovative crowd-sourcing approaches via text messages and/or the installation of low-cost performance sensors (Hope, 2012) are allowing the appliance of scale economies to hand-pump construction and maintenance, while increasing transparency of the efficiency and effectiveness of investments.

Technology brings new opportunities and challenges for farmers' capacity building: firstly, promoting online education and training for farmers; secondly, strengthening cooperativism and finally, opening new employment niches, markets and commercialization channels.

However, it would be over simplistic to exalt the role of technology while losing sight of the underpinning structural changes that are needed. For example, the priority of education is fundamental to be able to make the most of these technological opportunities. As can be seen in Figures 4.17, 4.18 and 4.19, the trends in this respect are mixed in relation to primary, secondary and tertiary education, which cautions against the ability to realize the full potential of ICT if no parallel investment is made in education and training.

A further challenge for LAC countries is the need to increase investment in Research and Development (R&D), which is on average around 0.6% of GDP while the same ratio for OECD countries is approximately 2.3%. In order to increase and sustain growth, the region must raise productivity levels to improve competitiveness, which in turn depends on increased innovation and R&D.

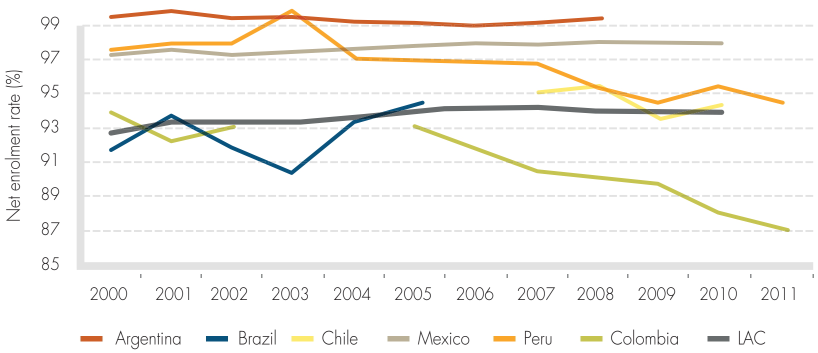

Figure 4.17 Net enrolment rate in first-level education (%). *Source: own elaboration based on data from UNESCO Statistics.*

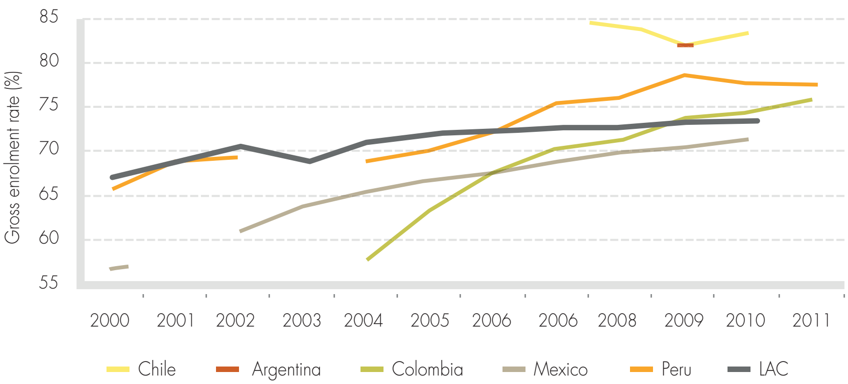

Figure 4.18 Net enrolment rate in second-level education (%). *Source: own elaboration based on data from UNESCO Statistics.*

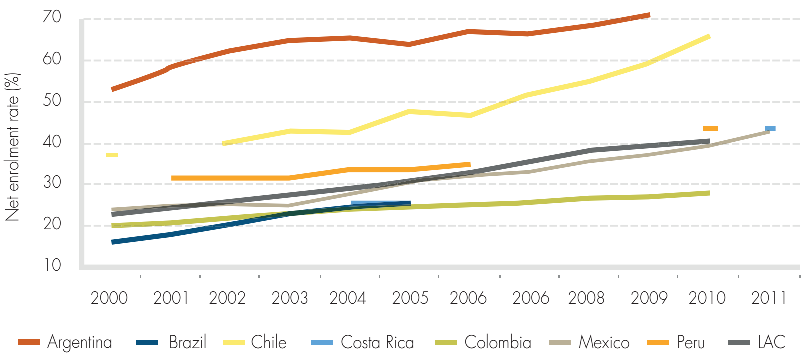

Figure 4.19 Gross enrolment rate in third-level education (%). *Source: own elaboration based on data from UNESCO Statistics.*

4.3.3 Vulnerability to climate change in LAC

Another trend to consider in the future is the potential impact of climate change. Assessing the vulnerability to climate change implies determining the magnitude of adverse effects on the social, economic and ecological systems, its sensitivity to stress factors and its capacity to cope or adapt to the stressor. The Fourth Climate Change Assessment Report of the IPCC (Parry et al., 2007), defines vulnerability as '*The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extreme events*'.

The need for improved decision making has motivated an expansion in the number of climate-change impacts, adaptation and vulnerability (CCIAV) assessments and methods in use over the last decades. CCIAVs are undertaken to inform decision making about the degree of risk associated with climate change impacts, so that the most appropriate and cost-effective policy responses can be adopted. The National Communications (NCs) developed by the LAC parties supporting the implementation of the UNFCCC can be classified as a mixed vulnerability and adaptive-based CCIAV. NCs follow mainly a bottom-up approach, where vulnerability to climate is addressed largely as a problem of climate variability within the countries. As Carter and Mäkinen (2011) argue the great majority of assessments that follow this bottom-up approach are found in developing countries, where vulnerability to present-day climatic variability is commonly perceived to be more of a threat than long-term climate change. Table 4.6 summarizes the outcomes of the vulnerability assessments of twenty NCs in LAC countries. The social, economic and environmental risks differ greatly across countries. Nevertheless, social and environmental vulnerability is currently perceived as high in all LAC regions.

In relation to social vulnerability in LAC, the most frequent impacts are related to the increase of diseases, food insecurity and a growing perception that access to drinking water might be at stake. Also, migration linked to worsening climate conditions has been reported, although it is yet unclear whether climate is a driver of such migration flows (see Box 4.4). An increase in the frequency of malaria and dengue fever has also been reported. Food insecurity risks are related to the increased occurrence of the El Niño Southern Oscillation (ENSO) phenomenon and associated with extreme events (e.g. droughts, floods). In 2009/2010 a severe drought affected agricultural areas of Guatemala causing the loss of 100% of the harvest. National production of maize, bean and rice only dropped on average 1.5%; yet over 145,000 people needed emergency food assistance. In 2007/2008, Bolivia was affected by La Niña, which caused floods, droughts, frost and hail-storms, across the whole country. Rice crops losses reached up to 25% and prices of the main basic products rose sharply with a strong negative impact on the price and access to food especially in urban areas. Changing climatic conditions are also affecting water access, like, for example, the case of Chile's glacier Echaurren Norte, one of the most important sources of drinking water for the metropolitan area of Santiago.

Table 4.6 Social vulnerability assessment to climate change in Latin America. Note: Values refer to the percentage of countries reporting vulnerability to the different impacts. Grey cells represent impacts affecting less than 50% of the countries; yellow between 50–75%; and brown cells account for impacts affecting more than 75% of the countries.

	IMPACTS		VULNERABLE COUNTRIES (%)				
			MESOAMERICA	SOUTH	AMAZONIAN	ANDEAN	FREQUENCY AVERAGE
SOCIAL	Higher risk of diseases		75	75	100	100	88
SOCIAL	Unsafe access to drinking water		88	50	33	60	58
SOCIAL	Damages to infrastructures (dwellings, protection areas)		50	25	67	40	46
SOCIAL	Impact on food security		75		67	40	61
SOCIAL	Migrations		50	50	67		56
SOCIAL	Increase in poverty		38				38
SOCIAL	Human losses caused by natural disasters				33		33
ENVIRONMENTAL	Changes in the hydrological cycle and water quality		63	75	33	20	48
ENVIRONMENTAL	Coastal erosion and coastline retreat		25	60	100	20	49
ENVIRONMENTAL	Changes in ecosystem productivity and biodiversity loss		75	50	67	60	63
ENVIRONMENTAL	Higher risk of fires		25	25	67		63
ENVIRONMENTAL	Salinization		38	25	100		39
ENVIRONMENTAL	Increase in pests		25		33		29
ECONOMIC	Agriculture	Reduction in water availability	75	25	33	20	38
ECONOMIC	Agriculture	Reduction in crop yields	88	25	67	80	65
ECONOMIC	Agriculture	Damage to agricultural infrastructures	13			20	17
ECONOMIC	Agriculture	Soil erosion and desertification	25			20	23
ECONOMIC	Agriculture	Loss of agrodiversity		25		20	23
ECONOMIC	Agriculture	Loss of harvests	13			20	17
ECONOMIC	Agriculture	Decrease in aquaculture production	38		33	40	37
ECONOMIC	Agriculture	Losses in livestock production	38		67		53
ECONOMIC	Energy	Lower hydropower generation	38	75	100	20	58
ECONOMIC	Energy	Damages to energy infrastructures	50	25			8
ECONOMIC	Energy	Excessive reliance in fossil fuels	13	50			32
ECONOMIC	Energy	Risk to invest in biofuels		25	33		29
ECONOMIC	Energy	Increase in energy demand		25			25
ECONOMIC	Minery	Reduction in water availability		25			25
ECONOMIC	Tourism	Damages to tourism infrastructures	50	25		20	32

Source: own elaboration based on the (NCs) National Communication Strategies of twenty LAC countries (UNFCC, 2013).

Box 4.4 The nexus between climate change and migration

The climate change-migration relationship is as yet unclear. Extreme weather shocks have been associated with migration processes at the micro-level, although no clear macro-trend has been observed. So far no projection exists regarding expected 'environmental migrants' (Wilbanks et al. 2007) and some authors argue that environmental migration might be a 'myth'. Global estimates of environmental migrants –25 million according to Myers and Kent (1995) – are outdated and have been the subject of debate. In LAC no concrete figures exist despite the high frequency of meteorological events that occurred over the last century (see Figure 4.20). In Mesoamerica, storms and floods are the most frequent hazards, whereas in South America, floods prevail. Nevertheless, droughts have caused the largest impacts on the South American population.

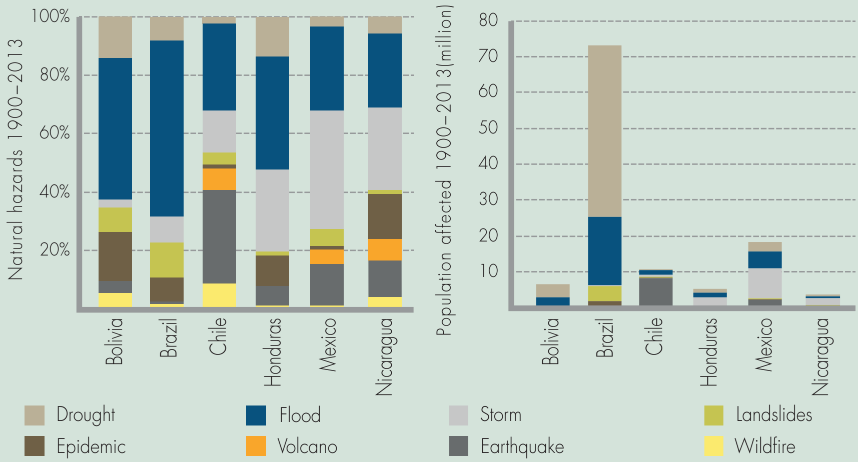

Figure 4.20 Type of natural hazards and population affected in selected countries in Latin America. *Source: own elaboration based on data from the EM-DAT database (2013)*

People often speak of the rural poor as the main victims of migration associated with climate change. In the case of LAC the impact should be observed at a much slower pace given its high degree or urbanization. The highest rural population in LAC is concentrated in the less developed countries, which thus increases the social vulnerability and the risk of migration. The most likely impacts of climate change in LAC may include damage to coastal areas consequently impacting tourism infrastructure and generating migration of local populations to safer areas and the reduction of glaciers, which could affect the Pacific cities and their water reserves. The effects of climate change on migration will be very different in countries like Bolivia or Paraguay, without coasts, than in the Turks and Caicos, the Cayman Islands and the Bahamas, which have a 100% of its population below the10 metres elevation mark.

4.4 Conclusions

This chapter has identified the main socio-economic trends in LAC and Caribbean (LAC) and their direct and indirect consequences for water and food security. In relation to water security, the LAC population will continue to grow, despite the decrease in the fertility rate, with changes in lifestyles and the growth of the middle class which will increase the demand for water services and food, as well as external demand for producing agricultural commodities for export. As was shown, LAC has experienced a modest level of development in terms of per capita gross domestic product; centred around a fairly intensive use of water resources due to its economic model based on primary goods, recently triggered by the high prices in the international markets.

One of the main issues is whether this economic growth has been decoupled from increased water use. Since the model has been based on a re-primarization of the economy and exports, issues arise regarding the potentially large (green) virtual water of food exports. The other issue relates to poverty and water; water and sanitation in LAC in general has progressed well, in relation to the Millennium Development Goals, particularly in urban areas. LAC is the second most urbanized region in the world, including sixty-seven cities with more than 1 million inhabitants and four 'megacities' with more than 10 million (Mexico City, São Paulo, Buenos Aires and Rio de Janeiro). Sometimes it is hard to provide sufficient water services, with problems emerging from the relatively large informal economy and informal settlements, as well as from dispersed rural areas which could be left behind.

With regard to trade and food sovereignty, related to water security, linkages with price volatility in the case of LAC deserve a more detailed study in order to better understand the inter-linkages due to the economic models adopted in some of the emergent LAC economies. In LAC, the inequitable distribution of income could make it much more difficult to establish potential cross subsidy schemes, e.g. for the urban poor or even in rural areas. Thus equity remains a central pivotal issue for water and food security.

Water and food security confront important challenges imposed by globalization. Trade liberalization, increasing demand from countries such as China for primary goods, compounded with changes in consumption patterns also prompted by urbanization, the increase in per capita income and advertising have changed societal priorities and the way natural resources are used. New dietary patterns based on animal and agriculturally industrialized products require more water and raise issues of food security in terms of the nutritional quality of the 'modern diet'. As a result, health trends reflect the emergence of diseases like obesity and diabetes.

The democratization and adoption of ICTs could present a window of opportunity for water and food security, because of their cost, popularity and access are likely to increase exponentially. Water management in rural areas could be revolutionized through new instruments that can generate more accurate and visible data and information, essential to pinpoint better planning and use of water (and food) resources. The use of ICT can also help to support environmental and biodiversity conservation and further to avoid environmental, social and human harm for future generations.

Rural development could be supported by new technologies in the agriculture and food value chain, access to markets and financial services. There are barriers for ICT uptake in agriculture such as farmers' education and training (illiteracy or lack of technical skills), the lack of awareness and understanding of ICT and also the cost of deployment of some new technologies.

In order to guarantee water and food security faced with the potential impacts of climate change in socio-economic terms, it is important to define long-term targets for CC mitigation, to identify vulnerable regions and groups, prioritize research and adaptation, and to invest in adaptation and mitigation measures. Social and environmental vulnerability is high in all LAC regions where the most frequent impacts are related to increasing diseases such as malaria and dengue fever, food insecurity and a growing perception that access to drinking water may be at risk. Extreme events such as droughts and floods are affecting agricultural areas in many countries and in some cases access to water.

Latin American trends can, however, be modified. Measures orientated towards achieving fair income distribution, public policies orientated towards more vulnerable groups of population, a model of growth sustained on domestic markets, formalization of the informal economy, investment in science and technology and policies for improvement and conservation of natural resources would be key goals to prioritize and thus allow progress to be made on future socio-economic megatrends in order to guarantee water and food security into the future.

References

Arriagada, I., Aranda, V. & Miranda, F. (2005). *Políticas y programas de salud en América Latina. Problemas y propuestas. División de Desarrollo Social.* Santiago, Chile, Comisión Económica para América Latina y el Caribe (CEPAL). Serie Políticas Sociales No. 114.

Barria, R.M.P & Amigo, H. (2006). Transición Nutricional: una revisión del perfil latinoamericano. *ALAN*, 56 (1): 3–11.

Becker, K.F. (2004). *The Informal Economy: a fact finding study prepared for the Swedish International Development Agency.* Stockholm, Sweden, SIDA.

Bermudez, O. & Tucker, K. (2003). Trends in dietary patterns of Latin American populations. *Saude Publica* 19(1): 87–99.

Buitagro, R.E. (2009). Reformas comerciales (apertura) en América Latina. Revisando sus impactos en el crecimiento y el desarrollo. *Revista de la Facultad de Ciencias Económicas: Investigación y reflexión*, 17 (2): 119–132.

Carter, T.R. & Mäkinen, K. (2011). *Approaches to Climate Change Impact, Adaptation And Vulnerability Assessment: towards a classification framework to serve decision-making*. Helsinki, Finland, Finnish Environment Institute (SYKE). MEDIATION Technical Report No. 2.1.

CEPAL (2002). Comisión Económica para América Latina y el Caribe. *Urbanización, redistribución espacial de la población y transformaciones socioeconómicas en América Latina*. Santiago, Chile, CEPAL [Online] Available from: www.CEPAL.org/cgi-bin/getProd.asp?xml=/publicaciones/xml/2/11482/P11482.xml&xsl=/publicaciones/ficha.xsl&base=/publicaciones/top_publicaciones.xsl#. [Accessed June, 2013].

CEPAL (2003). Comisión Económica para América Latina y el Caribe. *La migración internacional en América Latina y el Caribe: tendencias y perfiles de los migrantes*. Serie Población y desarrollo. Santiago, Chile, CEPAL Report No. 35.

CEPAL (2005). Comisión Económica para América Latina y el Caribe. *Panorama social de América Latina 2005*. Documento Informativo. Santiago, Chile, CEPAL.

CEPAL (2006). Comisión Económica para América Latina y el Caribe. *Migración interna y distribución espacial*. CELADE, División de Población de la CEPAL. Brief No. 6.

CEPAL (2011). Comisión Económica para América Latina y el Caribe. *Migración internacional en América Latina y el Caribe. Nuevas tendencias, nuevos enfoques*. Santiago, Chile, CEPAL Report No. LC/R.2170.

CEPAL (2012a). Comisión Económica para América Latina y el Caribe. *Balance Preliminar Economías de América Latina y Caribe 2012*. Santiago, Chile, CEPAL Report No. LC/G.2555-P.

CEPAL (2012b). Comisión Económica para América Latina y el Caribe. *La migración internacional desde una perspectiva regional e interregional*. Santiago, Chile, CEPAL Report No. LC/W.475.

Dollar, D. & Kraay, A. (2001). *Growth Is Good for the Poor*. World Bank Policy Research Working Paper No. 2587.

Domínguez-Guadarrama, R.(2011). El fenómeno migratorio desde una perspectiva global; entendimiento y apuestas teóricas. *Escenarios XXI*, 11(II).

ECLAC (2012). Economic Commission for Latin America and the Caribbean. *Statistical Annex Social Panorama of Latin America 2012*. Santiago, Chile, ECLAC report.

EM-DAT (2013). International Disaster Database. *The OFDA/CRED International Disaster Database*. [Online] www.emdat.be. [Accessed May, 2013].

Ercin, E., Martinez, M. & Hoekstra, A. (2011). Corporate Water Footprint Accounting and Impact Assessment: The case of the Water Footprint of a Sugar-Containing Carbonated Beverage. *Water Resources Management*, 25: 721-741.

ERICSSON (2012). *On the pulse of the networked society*. Ericsson mobility report. [Online] Available from: www.ericsson.com/res/docs/2012/ericsson-mobility-report-november-2012.pdf. [Accessed March, 2013].

FAO (2012). Food and Agriculture Organisation. *Panorama de la Seguridad Alimentaria y Nutricional en América Latina y el Caribe 2012*. Rome, FAO.

Flodman, B.K. (2004). *The Informal Economy. A Fact Finding Study*. SIDA.

Guerra-Borges, A. (2012). *Panorama actual de la integración Latinoamericana y Caribeña*. Mexico, UNAM-Instituto de Investigaciones Económicas.

Gurría, A. (2012). *Perspectives economiques*. Conférence de presse. Paris, 22 May, 2012. OCDE. Report No. 91.

GWP (2012). Global Water Partnership. *Regional Process of the Americas: Access to water and sanitation for all and the Human Right to water and sanitation in the Americas*. Target 1.1. Marseille, France, 6th World Water Forum.

Hauser, P. & Gardner R. (1982). Urban future: Trends and prospects, Honolulu, East-West Population Institute, Reprint. No. 146.

Herrera, J., Roubaud, F. & Suárez Rivera, A. (2004). *El sector informal en Colombia y demás países de la Comunidad Andina.* Instituto de Estadística. Bogotá, Colombia, IRD.

Hope, R. (2012). *Water Security and Mobile Technologies*. University of Oxford, UK. Water Security, Risk & Society brief No. 4.

IICA (2009). Instituto Inter-americano de Cooperación para la Agricultura. *Los Tratados de Libre Comercio negociados por América Latina con La República Popular de China, India, Singapur y Taiwán. Estudio comparativo*. San José, Costa Rica, IICA.

INEGI (1992). Instituto Nacional de Estadística y Geografía. *Encuesta nacional de ingresos y gastos de los hogares* (ENIGH).[Online] Available from: www.inegi.org.mx/est/contenidos/Proyectos/Encuestas/Hogares/regulares/Enigh/default.aspx. [Accessed May, 2013].

INEGI (2010). Instituto Nacional de Estadística y Geografía. *Encuesta nacional de ingresos y gasto de los hogares* (ENIGH).[Online] Available from: www.inegi.org.mx/est/contenidos/Proyectos/Encuestas/Hogares/regulares/Enigh/default.aspx. [Accessed May, 2013].

IOM (2009). International Organization of Migration. *Climate, migration, climate change and the environment.* [Online] Available from: publications.iom.int/bookstore/free/migration_and_environment.pdf [Accessed March, 2013].

IOM (2011). International Organization of Migration. *The State of Environmental Migration* 2011. [Online] Available from: publications.iom.int/bookstore/free/State_Environmental_Migration_2011.pdf [Accessed March, 2013].

IOM (2012). International Organization of Migration. *Panorama Migratorio de América del Sur, 2012*. [Online] Available from: www.iom.int/…/Panorama_Migratorio_de_America_del_Sur_2012.pdf [Accessed March, 2013].

ITU (2013). International Telecommunication Union. *Statistics*. [Online] Available from: www.itu.int/en/ITU-D/Statistics/Pages/default.aspx. [Accessed March, 2013].

Lattes, A. (2000). *Población urbana y urbanización en América Latina*. II Jornadas Iberoamericanas de Urbanismo sobre las Nuevas Tendencias de la Urbanización en América Latina. Quito, Ecuador. Conference proceeding. [Online] Available from: www.flacso.org.ec/docs/sfcclates.pdf [Accessed March, 2013].

Lawrence, P., Meigh, J. & Sullivan, C. (2003). *The Water Poverty Index: an International Comparison*. Keele University. Staffordshire, UK, Keele Economics Research Papers.

Mekonnen, M. & Hoekstra, A. (2010a). *The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products.* UNESCO-IHE. Value of Water Research Report Series No. 47.

Mekonnen, M. & Hoekstra, A. (2010b). *The Green, Blue and Grey Water Footprint of Farm Animals and Animal Products*. UNESCO-IHE. Value of Water Research Report Series No. 48.

Millennium Project (2012). Estudio Delphi sobre escenarios para Latinoamérica al año 2030. In: Cordeiro, J.L. (ed). *Latinoamerica 2030*. Caracas, Venezuela, Global Futures Studies and Research.

Miró, C. (2006). La demografía en el siglo XXI en América Latina. *Papeles de Población*, 50 (12): 13–22.

Monteiro, C.A., Wolney, L. & Popkin, B. (2002). Is obesity replacing or adding to under-nutrition? Evidence from different social classes in Brazil. *Public Health Nutrition*, 5.

Morón, C. & Schejtman, A. (1997). *Evolución del consumo de alimentos en América Latina, en Producción y manejo de datos de composición química de alimentos en nutrición*. Rome, FAO.

Myers, N. & Kent, J. (1995). *Environmental Exodus: an Emergent Crisis in the Global Arena*. Washington DC, Climate Institute.

NIC (2008). Network Information Centre. *Global Trends 2025: A transformed world*. November, 2008. [Online] Available from: www.dni.gov/nic/NIC_2025_project.html. [Accessed March, 2013].

Olaiz-Fernández, G., Rivera-Dommarco, J., Shamah-Levy, T., Rojas, R., Villalpando-Hernández, S., Hernández-Avila, M. & Sepúlveda-Amor, J. (2006). *Encuesta Nacional de Salud y Nutrición 2006*. Cuernavaca, Mexico, Instituto Nacional de Salud Pública.

PAHO (2007a). Pan-American Health Organization. *Health in the Americas*. Washington DC. PAHO Scientific Publication No. 622.

PAHO (2007b). Pan-American Health Organization. *Non-communicable diseases in the Americas: building a healthier future*. Washington DC, PAHO.

PAHO (2011). Pan-American Health Organization. *Situación de la salud en las Américas. Indicadores Básicos*. Washington DC, PAHO.

PAHO (2012). Pan-American Health Organization. *Health in the Americas*. Volume II. Washington DC, PAHO.

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E. (2007). Climate Change 2007: *Impacts, Adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York, Cambridge University Press.

Pew Hispanic Center (2011). *Census 2010: 50 Million Latinos Hispanics Account for More Than Half of Nation's Growth in Past Decad*e, March 24, 2011. Available at: www.pewhispanic.org/ [Accessed July, 0213].

Pi-Sunyer, F. (2002). The Medical Risks of Obesity. *Obesity Surgery*, 12(1): 6–11.

Rastoin, J.L. (2009). Prospective alimentaire. Serie Systemes Agroalimentariares. 31/2009. *Economies et Sociétés*. p.1725.

Ravallion, M. (2004). Competing Concepts of Inequality in the Globalization Debate. In: Collins, S. and Graham, C. (eds). *Brookings Trade Forum 2004*. Washington DC, US, Brookings Institution. pp.1-38.

Regmi, A. (2001). *Changing Structure of Global Food Consumption and Trade*. Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture and Trade Report. WRS-01-1.

Regmi, A., Takeshima, H., & Unnevehr, L. (2008). *Convergence in Global Food Demand and Delivery*. Washington DC, USDA Economic Research Report No. 56.

Rivera, J., Muñoz-Hernández, R., Rosas-Peralta, A. & Popkin, W. (2008). Consumo de bebidas para una vida saludable: recomendaciones para la población mexicana. *Salud Pública de México*, 50 (2).

Rivera, J.A, Barquera, S., González-Cossío, T., Olaiz, G. & Sepúlveda, J. (2004). Nutrition transition in Mexico and in other Latin American countries. *Nutrition Reviews*, 62 (7): 149–157.

Santos-Baca, A. (2012). *Efectos de la apertura comercial en el consumo de alimentos de los hogares urbano-populares, 1992-2010*. MSc Thesis in Social Sciences. Facultad Latinoamericana de Ciencias Sociales. Sede México.

Schneider, F.G. (2002). T*he Size and Development of the Shadow Economies of 22 Transition and 21 OECD Countries*. IZA, Institute for the Study of Labour. Discussion Paper No. 514.

Solimano, A. & Soto, R. (2006). Economic growth in Latin America in the late XX century: evidence and interpretation. In: Solimano, A. (ed). *Vanishing Growth in Latin America: The Experience of the Late XX Century*. Massachusetts, US, Edward Elgar Publishers. pp.11–45.

UN (2001). United Nations. *Urban and Rural Population by Age and Sex 1980-2015*. [Online] Available from: www.un.org/en/development/desa/population/publications/dataset/urban/urbanAndRuralPopulationByAgeAndSex.shtml [Accessed June, 2013].

UN (2011). United Nations. *World Urbanization Prospects*. The 2011 Revision, Economic & Social Affairs, New York, UN report.

UN-DESA (2011). United Nations Department of Economics Social Affairs. *World Population Prospects, The 2010 Revision*. Volume I: Comprehensive Tables. UN Report ST/ESA/SER.A/313.

UN-Habitat (2012). United Nations Human Settlements Programme. *Estado de las ciudades de América latina y Caribe 2012. Rumbo a una nueva transición urbana,* Nairobi, Kenia, UN.

UNFCCC (2013). United Nations Framework Convention on Climate Change. *Non-Annex I National Communications submitted in compliance with the United Nations Framework Convention on Climate Change*. [Online] Available from: unfccc.int/national_reports/non-annex_i_natcom/items/2979.php. [Accessed May, 2013].

Vodafone & Accenture (2012). *Connected agriculture. The role of mobile in driving efficiency and sustainability in the food and agriculture value chain*. [Online] Available from: www.vodafone.com/content/dam/vodafone/about/sustainability/2011/pdf/connected_agriculture.pdf. [Accessed March, 2013]. Corporative Report.

WHO-UNICEF (2013). *Joint Monitoring Programme (JMP) for Water Supply and Sanitation data*. [Online] Available from: www.wssinfo.org/data-estimates/table/ [Accessed July, 2013].

Wilbanks, T.J., Romero, P., Lankao, M., Berkhout, F., Cairncross, S., Ceron, J.P., Kapshe, M., Muir-Wood, R. & Zapata Marti, R. (2007). Industry, settlement and society. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (eds). *Climate Change 2007: Impacts, Adaptation and vulnerability.* Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge, Cambridge University Press. pp. 357–390.

World Bank (2011). *ICT in Agriculture Sourcebook. Connecting Smallholders to Knowledge, Networks, and Institutions* [Online] Available from: www.ictinagriculture.org/content/ict-agriculture-sourcebook. [Accessed March, 2013].

5

GLOBALIZATION AND TRADE

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Highlights

- The world's economy and agriculture have become ever more intertwined, reinforcing interdependencies, and multiplying network connections. The Latin America and Caribbean (LAC) region has experienced an accelerated growth of imports, exports and inward foreign investment.
- The expansion of the middle class in LAC and Asia and the associated changes in eating habits are adding pressure on agricultural commodities markets, with LAC itself becoming a leading exporter of calories and vegetal proteins required to sustain the expanding livestock sector in the world.
- LAC is still relatively isolated from the rest of the world, in terms of personal air traffic and major port activity, yet well connected through raw materials markets.
- Significant production increases can be obtained in many LAC regions with both rain-fed agricultural practices and farming systems under irrigation.
- LAC's main trading partners are now in Asia, especially China and India, but Central America and the Caribbean still export primarily to North America.
- LAC's increasing exports and imports may have rendered certain social advances in terms of poverty reduction in Argentina, Brazil, Chile, Mexico and Peru. And yet, 174 million people in LAC are considered poor, and 73 million of these are extremely poor (FAO, 2013b). However, causality between trade and poverty cannot be clearly established.
- International trade can make an important contribution to global decoupling (economic growth independent of resource use and impacts) when guided by appropriate environmental and trade policies. These have hitherto been managed separately at country and global levels.

5.1 Introduction

By all accounts, the world has never been more globalized since World War II. Improvements in transportation, logistics, telecommunications and global production systems attest to increasing worldwide economic integration. Furthermore, world food systems have never been as integrated and developed as they are at present (Prakash, 2011) with production specialization, technological advances and the wide dissemination of knowledge. However, doubts exist as to whether agriculture has the potential to feed the world when the population goes beyond 9 billion unless significant improvements are made in production efficiency and food habits change. In 2012, the FAO estimated that 852 million people were undernourished, which is equivalent to 14.9% of the world's population (FAO, 2013b). To this end, the National Intelligence Council of the US has identified the nexus of food, water and energy as one of its four 'megatrends', which are likely to transcend all future scenarios, demonstrating that a growing global population will place more demand on these inextricably linked resources (NIC, 2012).

Globalization is an ambiguous concept without a widely accepted scientific definition. It involves trade relationships and the movement of capital, ideas and even people. It also encompasses the sharing and expansion of risks (such as epidemics or terrorist attacks) and global environmental threats. Agricultural trade has been accelerated by the rapid decline in the costs of cross-border trade of farm produce and other products, driven also by reduction in transportation costs, the information and communication technology (ICT) revolution and major reductions in governmental distortions. As a result, it has altered global agricultural production, consumption and hence trade patterns (Anderson, 2010), not least in the Latin America and Caribbean (LAC) region.

This chapter will review some facts and data that describe what globalization is and what shape it may take in the future. We focus primarily on the LAC region but also provide a global perspective and, in coordination with other chapters of this book (Chapters 4 and 7), we will focus on trade looking in more detail at agricultural commodities. We begin by providing the context of international trade and identify the resulting major trends. In the second section we present the most significant trade data reported at a regional level, again, specifically concentrating on the agricultural context. The third section discusses the main drivers behind the observed trade data and trends in the LAC. The chapter closes with an overview of issues more closely related to social and environmental sustainability.

5.2 Global context and major trends

Recent popular press media has disseminated the trajectory of the world's economic centre of gravity.[1] Two significant points can be identified in the last two millennia. Firstly, the world's economic centre of gravity in 2012 is in almost the same longitude than it was in the year AD 1. Secondly, during almost 2000 years it moved westwards to where, in 1950, it reached the North of Iceland and since then it has moved extremely rapidly to a position in Russia and is projected to continue to a point north of Kazakhstan in 2025. This shift attests to the growth of East Asia and the Pacific area.

Table 5.1 shows the changing percentage of the world's economy and population among the world's regions. LAC's economic importance grew from 5.3% in 1990 to

1 Published in *The Economist* (The world's shifting centre of gravity 28 June 2012, 14:34 by The Economist online). Calculated weighting national GDP by each nation's geographic centre of gravity; a line drawn from the centre of the earth through the economic centre of gravity locates it on the earth's surface. (see McKinsey Global Institute, 2013)

8.3% in 2011, whereas its share of the population remained stable at 8.5%. The most significant changes are the increasing share of the world's GDP in South and East Asia, the population decline in North America and the slight decline of Europe and Central Asia.

Table 5.1 Percentage of GDP and population of each region with respect to the world

		1990	2000	2011
SOUTH EAST ASIA	% of GDP/world's GDP	23.2%	26.9%	30.1%
	% of Pop/world's Pop	56.0%	56.3%	55.5%
EUROPE & CENTRAL ASIA	% of GDP/world's GDP	39.0%	29.7%	31.6%
	% of Pop/world's Pop	15.9%	14.1%	12.8%
LATIN AMERICA & CARIBBEAN	% of GDP/world's GDP	5.4%	6.6%	8.3%
	% of Pop/world's Pop	8.3%	8.5%	8.5%
NORTH AMERICA	% of GDP/world's GDP	28.8%	32.9%	23.9%
	% of Pop/world's Pop	5.2%	5.1%	5.0%

Source: World Bank (2012)

A major driving force of the world's economy is the level and instability of commodity markets. Figure 5.1 plots the commodities price indices, showing composite indices of energy, food and metals and minerals, between 1960 and 2011. All three exhibit a long and stable trend between 1978 and 2007, and a rapid escalation after this year. This has been accompanied by increased volatility for all specific products and markets, and the extreme financialization[2] of the commodity markets around the world.

The increasing importance of trade in the world's economy is also a major driver of globalization. Figure 5.2 shows the percentage of trade as a share of the world's GDP. Since 1960, trade value has almost tripled in relative terms in the world and the expansion of trade has been greater in East Asia and the Pacific than in LAC, whose relative trade volume grew less than the world's average.

The growth of trade goes hand in hand with the expansion of transportation. The world's container traffic grew between 2000 and 2010 by a factor of 2.3, and LAC's participation in this traffic augmented from 6.8% in 2000 to 7.4% in 2010. Despite this, the LAC region still lags behind other regions in the world as shown in Table 5.2, which reports the LAC's main port's activity relative to the fifty busiest ports in the world in 2011.

2 'Financialisation refers to the increasing amount of liquid funds which have become engaged in agricultural commodity markets over the past years. Often, the role of hedge and index funds is emphasised in particular for price formation on futures markets. Speculation is an even less clearly defined term. Major notions in the literature are speculative bubbles, when asset prices deviate systematically from their fundamental values, speculative hoarding, when stocks are built in the expectation of ever higher prices, and market manipulation, where price movements on less liquid markets are deliberately triggered by some market participants. The economic concept of speculation is yet defined differently; speculators in this meaning are market participants who are willing to take over price risks from hedgers at a premium (and thus fulfil an economically desirable function).' Brummer et al. 2013, p. 3.

Note that Colon and Balboa ports are related to the operation of the Panama Canal and are thus not so involved in operations of loadings and shipments.

The fact that LAC is still weakly connected within world trade circuits is also shown by the statistics of air travel and air passengers. In 2011, only São Paulo-Guarulhos International Airport, ranking 45th, appeared amongst the fifty busiest world airports. In 2010 no LAC airport appears in the list and in 2009 Mexico International Airport is the only LAC present on the list, in 50th position (Airports Council International, 2012).

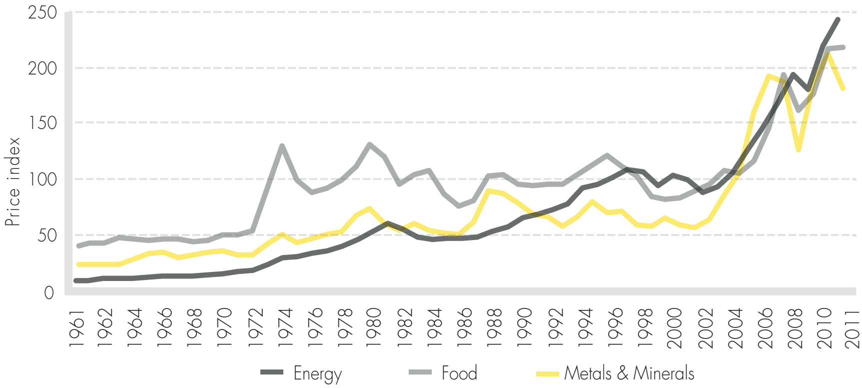

Figure 5.1 Commodities Price Indices (1960–2011) (Average =100). *Source: World Bank (2012)*

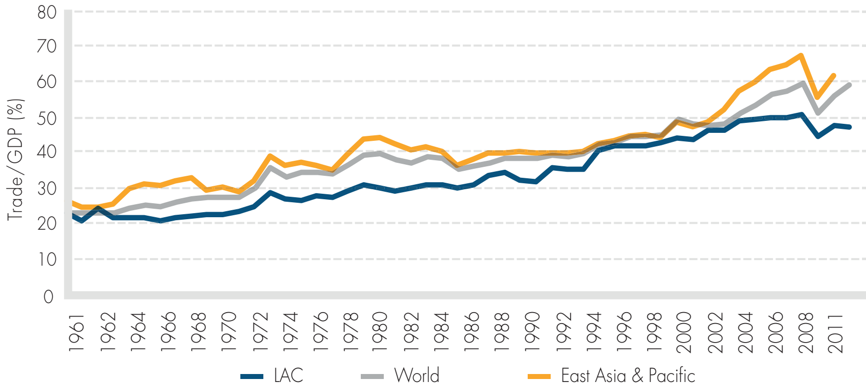

Figure 5.2 Trade as a share of gross domestic product (GDP) (1961–2011). *Source: World Bank (2012)*

Table 5.2 LAC's busiest ports in thousands of TEUs (twenty-foot equivalent units) in 2011

Busiest LACS ports	Rank In world	1000 TEUs	Activity with respect to busiest port (Shanghai) In %
Colon (Panama)	37	3,370	10.6%
Balboa (Panama)	39	3,230	10.2%
Santos (Brazil)	43	2,990	9.4%

Source: Journal of Commerce: The JoC top 50 world container ports (2012)

These data seem to suggest that LAC's growth expansion is primarily based on commodities and industrial products as opposed to the service sector, which could also account for the fact that LAC is relatively less densely populated and the few large populous areas are widely spread across the continent compared to Asia and Europe.

Figure 5.3 shows data for inward foreign direct investment in the region between 1970 and 2011. Foreign direct investment has seen unprecedented growth in the last ten years, but has been very volatile.

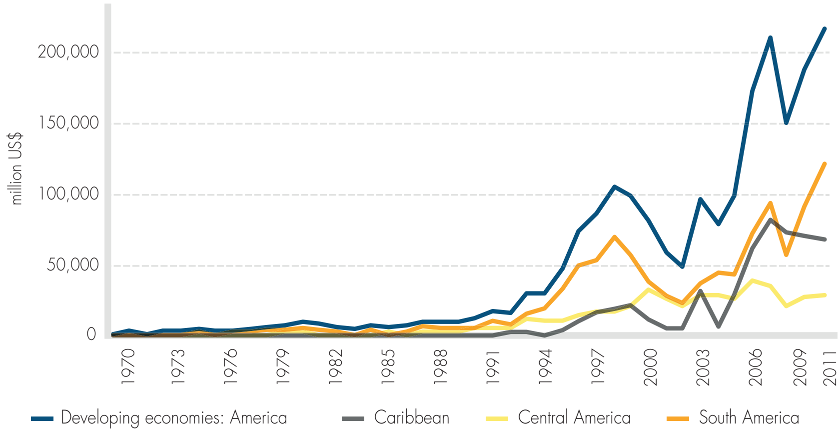

Figure 5.3 Inward foreign direct investment flows, annual, 1970–2011 in million US$. *Source: UNCTAD (2012)*

Figure 5.4 shows that LAC has not been a principal beneficiary of official development assistance in agriculture and infrastructure whereas since 1995 East Asia and Pacific, South Asia and sub-Saharan Africa have received significant aid. However, the region's increasing political stability and economic potential have certainly given an extraordinary push to private investment in infrastructure, making LAC the world's primary recipient in 2002 and 2009 (Figure 5.5).

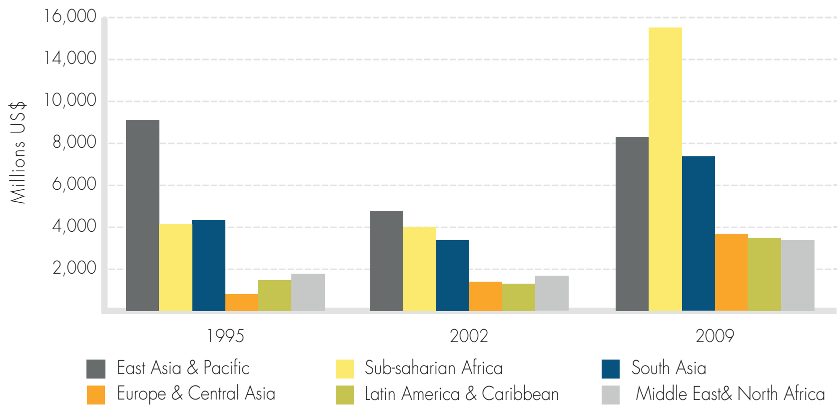

Figure 5.4 Official Development Assistance in agriculture & infrastructure by area, in 1995, 2002 and 2009. *Source: OECD (2012)*

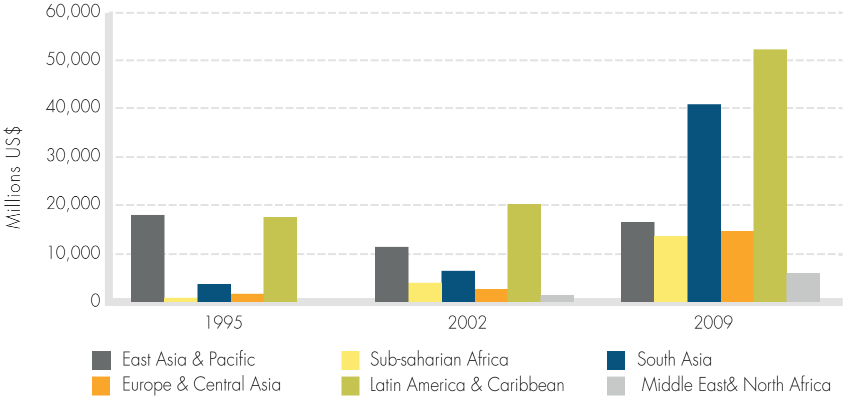

Figure 5.5 Private participation in infrastructure by area in 1995, 2002 and 2009. *Source: PPIAF (2013), World Bank (2012)*

5.3 Trends of trade in the LAC region

LAC has historically established a trade model characterized by intensive goods exports, particularly associated with the region's natural resources (land, minerals, oil and water) and the import of capital-intensive goods and knowledge. While it plays a modest role in world market (10–12%) in recent years some growth has been reported although this is largely due to the increased value of commodities (UNEP, 2010) (Table 5.3).

Table 5.3 Participation of LAC in world agricultural trade in dollar terms

	1980	1985	1990	1995	2000	2005	2010
Agricultural commodities	9.50%	13.58%	11.43%	13.90%	16.29%	16.51%	18.10%
Food commodities	8.40%	9.44%	7.04%	7.98%	9.22%	10.37%	11.55%

Source: WTO (2012)

LAC's trade model has been strengthened by the trend towards an increased integration of the countries with the rest of the world. Indeed, the international integration of the region, especially in South America, is determined by a pattern where natural resources are seen to account for over half of total exports. These are minerals, hydrocarbons (notably natural gas and oil), agricultural, livestock, forestry and fishery products with little or no processing (UNEP, 2010).

Approximately 54% of the region's exports are raw materials. However, there are important sub-regional differences such as Mexico which shows a pattern of exports strongly linked to manufacturing (about 74%). Thus, excluding Mexico, of the remaining

Latin American exports, almost 73% are commodities based on natural resources. In some countries, exports of primary goods exceed 95% of total exports (UNEP, 2010).

A dependence on a few products is also observed. In effect, the ten principal export products of most countries are mining and agricultural goods. At the regional level, the main products exported are crude oil and its derivates (UNEP, 2010).

In the last twenty years (1992–2012), international trade has been conditioned by economic opening based on minimizing the presence of the government through the liberalization of trade forces (Washington Consensus, Williamson, 1990). These policies are considered key tools for development and opening national trade to international competition and elimination of regulations associated with international trade. This has resulted in trade agreements between the countries of the region and has allowed for an open regional market under competitive conditions that promotes trade growth. This situation is clearly shown in the graphs in Figure 5.6.

The composition of exports and imports amongst agricultural and mining products and other merchandises has been quite stable between 1992 and 2011. Agricultural and mining products represented a maximum share of exports of 38% in 1992 and a minimum of 31% in 2001. In terms of imports, 10% were agricultural and mining products in 2011 and 5.8% in 1991 (Inter-America Development Bank, 2012).

Figure 5.7 provides the breakup of agricultural and mining goods exports in 2000, 2005 and 2011 to different world regions. In 2000, North America was the main importer of goods from the three regions of LAC (South America, Central America and the Caribbean). In 2011, Central American and Caribbean exports were still concentrated on North America, but exports from South America were destined primarily to East Asia and the Pacific, followed by the EU and LAC, with North America being the fourth largest importing region.

China and other countries in Southeast Asia are the main importers of Latin American commodities such as copper or soybean. The increasing demand for inputs from emerging economies like India and China has had a noticeable impact on the region's exports. Consumption in Asia, and particularly in China, explains the continued commercial importance of extracting natural resources. In 2007 goods imported from Latin America and the Caribbean were mainly soybean (grain and oil), followed by copper ore (gross and concentrate), copper alloys, fish meal, leather and paper pulp (UNEP, 2010). South American major exports were to East Asia and the Pacific in 2011, whereas Caribbean and Central American major trading partners were in North America. Internal regional trade in LAC's reduced in percentage terms from 2000 to 2011.

The agro-industry has also witnessed strong growth in the region due to increased global demand and international prices for both agro-foods and raw materials to produce biofuels. Agricultural production is being reshaped by an expansion of oilseeds, especially soybean, while there is stagnation in some grains and a reduction in other more traditional products such as coffee and cocoa. There is also an increase in sales of meat, i.e. beef, pork, and poultry, that creates additional demand for grain for animal feed (UNEP, 2010).

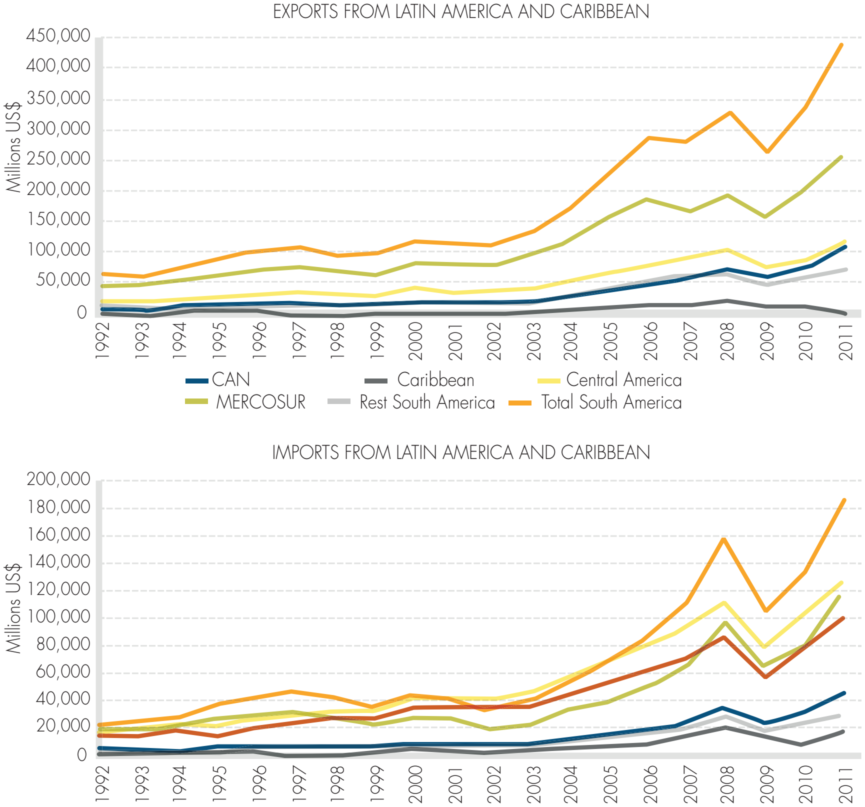

Figure 5.6 Value of imports and exports of agricultural and mining commodities of LAC between 1992 and 2011 expressed in nominal US dollars. *Source: Inter-America Development Bank (2012) Note: CAN (Andean Community of Nations): Bolivia, Colombia, Ecuador and Peru. Caribbean: Antigua and Barbuda, Bahamas, Barbados, Dominica, Dominican Republic, Grenada, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Trinidad and Tobago. Central America: Belize, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador. MERCOSUR (Southern Common Market): Argentina, Brazil, Paraguay, Uruguay, Venezuela. Rest of South America: Chile, Guyana, Suriname.Total South American (CAN, MERCOSUR, Rest South America): Argentina, Bolivia, Brazil, Colombia, Chile, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.*

At least ten countries – Argentina, Bolivia, Brazil, Colombia, Ecuador, Guatemala, Honduras, Mexico, Paraguay and Peru – produce biofuels, and four countries export biofuels produced from their own crops with Brazil being the largest exporter. There are smaller sales from Bolivia and Guatemala and, recently, from Argentina. However, programmes are underway in almost all countries and so the list of producers is constantly increasing (*ibid.*).

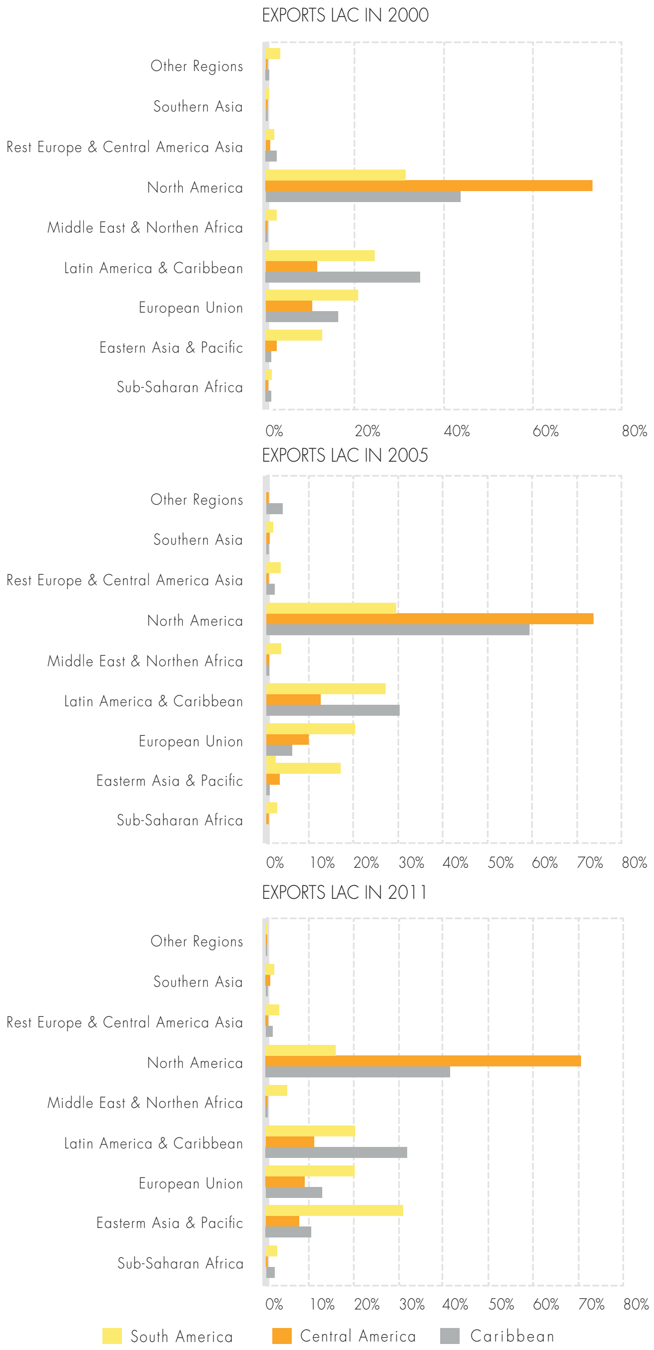

Figure 5.7 Breakup of exports from Latin America and the Caribbean to different world regions in 2000, 2005 and 2011 (%). *Source: Inter-America Development Bank (2012)*

5.4 Main drivers of LAC's increasing globalization and trade

5.4.1 Abundant water and land resources

LAC has the greatest agricultural land and water availability per capita in the world. With 15% of the world's land, it receives 29% of precipitation and has 33% of available renewable resources (Mejía, 2010). In 2007, LAC had about 10.8% of the world's cultivated land, but its growth has lagged behind other regions and the world in general since 1961. Annual growth of LAC's cultivated land between 1961 and 1997 was 1.62% against 4.49% globally, and between 1997 and 2007 annual growth was 0.71% in LAC and 3.04% in the world (Deininger, 2011). This suggests that the expansion of the agricultural frontier has grown at a slower pace in LAC than in other continents. As Chapter 3 explains, the proportion of primary sector activity devoted to agricultural production in LAC remains below the global average despite the net positive deforestation trend.

However, agricultural export growth in LAC has been the result of the expansion of land rather than yields (Deininger, 2011), since most exports come from areas in which yields are at their maximum with little or no yield gaps (Deininger, 2011; Foley et al., 2011). Chapter 10 shows that there are countries in LAC where yield gaps are still significant, and output from cultivated land can still be improved.

5.4.2 Consequences of liberalization and dismantling of tariffs, other trade barriers and the role of Free Trade Agreements

LAC exports represent 6% of world trade (18% of agricultural products), but are affected by 30% of measures of border protection (Giordano, 2012). However, tariffs have been reduced in the region, and freights costs have become more relevant. Tariffs range from 7% in Nicaragua and almost 0% in the Caribbean states, whereas freight costs range from 18% in Ecuador to 7% in Antigua and Barbuda, and between 10% and 15% in most South American countries. Upon the collapse of the third WTO Ministerial Conference of Seattle in 1999 and the standstill of the Doha Round, most LAC countries have adopted free trade agreements (bilateral/plurilateral) in order to pursue export growth and diversification (Dingemans and Ross, 2012).

According to the Information System on Foreign Trade of the Organization of American States (OAS, 2012), there are 111 trade agreements active that involve one or more of the eleven countries with the largest trade volume and population in the region[3] (sixty-three Free-Trade Agreements (FTA) and forty-eight Preferential Trade Agreements (PTA)) with 241 worldwide trade partners (countries).

3 Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay, Venezuela.

FTAs are presented as a key policy and economic tool to achieve economic growth and integration. However, the long-term results of these agreements are not wholly positive. Indeed, according to an analysis of the intensive and extensive economics margins,[4] the FTAs have focused on the formalization of existing trade links within natural existing markets, without seeing any real incentive in order to achieve the diversification of production, markets and trade for the region. This situation is clearly shown in Figures 5.8 to 5.10. For instance, Figure 5.10 shows that the large majority of exports have been in the form of increased exports to an already existing market (Intensive Trade Margin). As Dingemans and Ross (2012) conclude, FTAs have not accomplished significant diversification in LAC's exports, despite the significant growth exports shown in Figure 5.8.

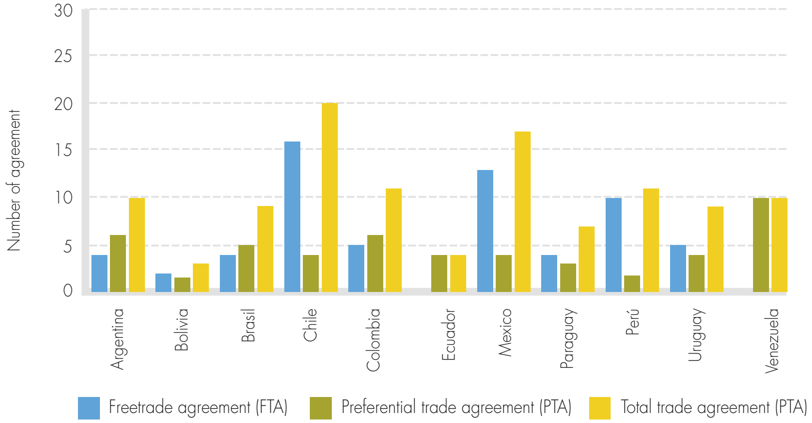

Figure 5.8 Trade agreements in the LA region. *Source: Dingemans and Ross (2012)*

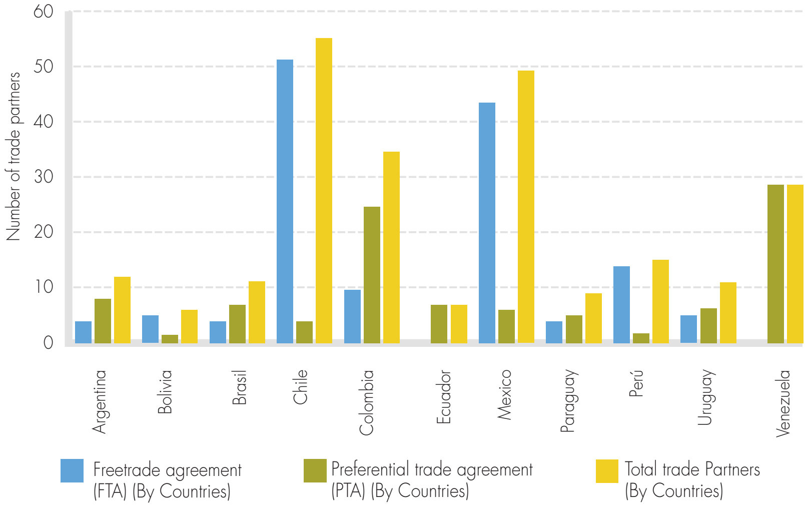

Figure 5.9 Trade partners in the LA region. *Source: Dingemans and Ross (2012)*

4 Intensive margin is the increase of trade with the same products and with the same partners, and extensive margin is the increase of trade of new products with new partners (Brenton et al., 2009).

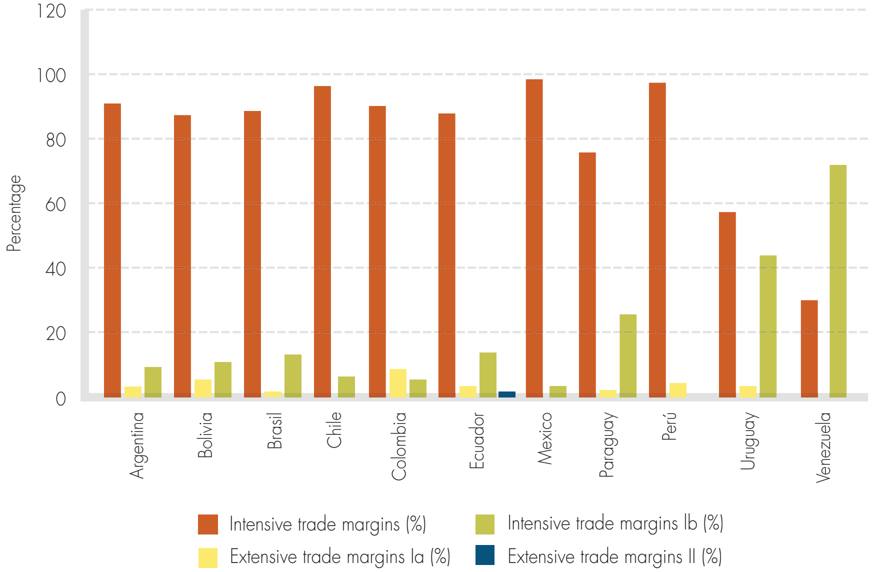

Figure 5.10 Changes in extensive and intensive trade margins in the LA region. *Source: Dingemans and Ross (2012).* Note: Intensive trade margin: expansion of export of a product to an existing market; Intensive Trade Margin Ib, increase of exports to a new market; Intensive Trade Margin Ia, export of a new product to an existing market; Extensive Trade Margin II, increased export of a new product to a new market.

5.4.3 Increasing competitiveness

For many products, LAC exports have been fostered by increasing competitiveness against many other trading partners. In terms of commodity prices and competitiveness, for instance, soybean in Brazil is more efficient than in the US. Annual yield growth in LAC has surpassed others: 2.9% in 1987–2007 and 3.6% 1997–2007, versus 2.1% and 2.2% relative to the world (Bruinsma, 2009). Chapter 10 provides a more detailed overview of trends of agricultural yields for the main products and most of LAC's countries.

5.4.4 Meat demand in emerging countries

More affluent populations have tended to diversify diets towards animal food items which require several multiples of water per calorie of dietary energy. The consumption of calories has also increased significantly in the last four decades in many developing countries. For example, meat demand (including demand for beef, meat, eggs and dairy products) or calorie consumption has grown in the Chinese diet from less than 100kcal/capita/day to more than 600kcal/capita/day between 1961 and early 2003. All of this increase in calorie consumption requires large amounts of grain and fodder (as extensive pastures are relevant for changes in land use) to feed livestock. In addition to calories, meeting growing meat demand requires supplementary production of protein crops for feed. The main growth of protein crop production has been obtained from soybean cultivation, and a significant part of it from soybean produced in Argentina and Brazil.

China alone may account for 43% of additional meat demand worldwide in 2020 compared to 1997, placing higher demand on world water resources and upward pressure on commodity prices in the longer term. But meat demand has also grown in the EU and many other countries. The population of EU27 grew by 20% between 1961 and 2007, whereas consumption of animal protein increased by 80% (Westhoek et al., 2011). It is worth noting that these are the main trading partners of LAC and hence any proposed change in trade patterns should bear this in mind.

Since 2000 there has been a massive change in the composition of the middle class in many world regions. There are various sources to define middle class. With the International Futures model middle-class membership is defined as per capita household expenditures of US$10–50 per day at PPP (power purchasing parity). Goldman Sachs used a comparable GDP per capita of US$6,000–30,000 per year, which yields a similar estimate of 1.2 billion middle-class people in the world in 2010 (NIC, 2012). While in this year, the US, EU and Japan made up 70% of the world's middle class, in 2030 this percentage will shrink to 30%. Except for India, which will make up 25% of the middle class in 2030, in the other growing regions, increased meat consumption is associated with increased affluence. LAC is one of the world's main producers of vegetable protein required to feed the animals, particularly in Argentina and Brazil.

5.4.5 Biofuel use in the EU and US

The expansion of biofuel production and consumption in the EU and US has resulted in significant and sustained pressure on agricultural markets worldwide. World biofuel production increased by a factor of five between 2001 and 2011, reaching 100hm^3 /year. About one-third of corn production in the US is used to produce bioethanol. The literature disagrees on the impact of biofuels during the surge of prices between 2007 and 2008. In quantifying the impact of biofuel production on price variability, Mueller et al. (2012) quote sources varying between 3% and 30% (Von Braun, 2008), reaching up to 70% (Mitchell, 2008, who included the indirect consequences on stocks, large use shifts, and speculative activity).

Other evaluations found impacts of 60–70% price increase in corn and 40% in soybeans (Headey and Fan, 2008). About 2% of the world production of grains is used for ethanol production, representing about 14 million hectares in the US, EU, Brazil and China. Rosegrant et al., (2008) found that biofuels were responsible of 30% of the food price increases. Perhaps the most significant effect of the use of biofuels comes from the impact of prices rather than needs of agricultural land, which is expected to grow from 30 to 60 million hectares (Ajanovic, 2011). Pressures to keep on producing more biofuels will grow in the future, to such an extent that oil prices will also grow, in turn further pushing up commodity prices.

However, this prognosis may change if the shale gas expansion in the US were to generate an excess capacity of up to 8 billion barrels, making the OPEC (Organization of the Petroleum Exporting Countries) lose control of oil prices (NIC, 2012). With a breakeven price as low as US$44–68 per barrel, world energy markets may see profound transformations in the upcoming decades, including a reduction of first-generation biofuels.

5.5 Issues of concern

In view of the previously presented data and facts, we have identified five issues of concern for LAC, concerning; (1) implications of trade on water use and access; (2) unregulated access to agricultural land from foreign countries (land-grab); (3) the role of trade on the world's food system); (4) the potential impact of trade on the poor in LAC; and (5) whether trade may hamper the equitable access to land and water resources.

5.5.1 Implications of trade on water use and access

World trade patterns are extremely dynamic and unstable. Specialization, technology adoption and market prices volatility and growth have given rise to fundamental changes in agricultural production and trade worldwide and in LAC. Building on the pioneering analyses of virtual water trade (VWT) (Hoekstra and Chapagain, 2008), a recent literature strand has been analysing trend connections, with a view to observe patterns and draw relevant conclusions for the world's food system today and in the coming decades. Trade connections have been evaluated in physical units (tonnes, monetary units and virtual water), but recently the focus has been placed on the analysis of the networks' formation, stability and configuration. The role of LAC in the world's trade has been presented in Part 3, but Chapter 7 reviews the most recent literature, which offers conflicting views of the role of virtual water trade.

5.5.2 Is land-grab a source of concern for LAC?

Based on the assessment of Rulli et al. (2013), land grabbing is a global phenomenon, which involves at least sixty-two grabbed countries and forty-one grabbers. Africa and Asia account for 47% and 33% of the global grabbed area, respectively. About 90% of the grabbed area is located in twenty-four countries, which includes Argentina, Australia, Brazil and Uruguay, among non-African and non-Asian countries. The grabbed area is often a non-negligible fraction of the country area (up to 19.6% in Uruguay, 17.2% in the Philippines, or 6.9% in Sierra Leone). The countries that are most active in land grabbing are located in the Middle East, Southeast Asia, Europe, and North America.

A key feature of the Latin American case is its intra-regional land grabbing driven by (trans) Latina companies (TLCs). These are companies that involve mainly national capital, as in the case of many Chilean companies, or alliance with companies from different countries in the region, or, finally, alliances of Latino firms with capital from outside the region (Borras et al., 2011). Another particular feature of Latin America is that land grabbing occurs in settings marked by more or less liberal-democratic political conditions, such as those of Brazil, Uruguay and Argentina; not necessarily in fragile states marked by weak governance as is generally believed (*ibid.*).

However, land-grabbing is a concept that requires finer analyses and conceptualization. The cases of grabbed Latin American countries seem to be closer to foreign direct investments than to actually grabbed land (see Zetland and Möller-Gulland, 2013, for a systematic analysis of land taken as grab or as foreign direct investment). Argentina, Brazil, and other countries are passing legislation in place to control foreign investments to control land grab. Much of the ongoing problem is also related with the land tenure.

5.5.3 Does increased world food demand pose risks for sustainable land and water use in Latin America?

In comparison with other regions, LAC is the region with the greatest land and water resources per capita. As mentioned earlier, the increase of agricultural production has been primarily in terms of land expansion, and less in terms of increased yields. The region's low penetration of irrigation and relatively low utilization rates of fertilizers suggest that agricultural sustainable intensification must be developed in the region, before it can close the gap with North America, Western Europe and South and Southeast Asia (Mueller et al., 2012).

Foley et al. (2011) claim that there are significant opportunities to increase yields across many parts of Africa, Latin America and Eastern Europe, where nutrient and water limitations seem to be strongest. Better deployment of existing crop varieties with improved management should be able to close many yield gaps, while continued improvements in crop genetics will probably increase potential yields into the future. Pfister et al. (2011) show that in LAC the ratio of water and land stress (Relevant for Environmental Deficiency) are clearly less than 1 (being land stress greater than water) in most production regions, except in Chile, Mexico, Peru and northeast Brazil. And yet, the main exporter areas in Argentina, Brazil, Chile and Mexico have yields close to their potential ceiling. This means that agricultural expansion will have to occur in Central America and the Andean region, where intensification still has a lot of potential.

Most serious concerns about continuing agricultural expansion in LAC are related to the reduction of regional and global ecosystem services, chief among these are CO_2 emissions, regulation of the water cycle and biodiversity losses. This is elaborated to a much greater extent in Chapter 3.

5.5.4 Do trade and globalization benefit the poor in LAC?

Trade-poverty linkages are complex and diverse, but according to economic theory and empirical findings, they can be divided into a few important pathways: (a) trade-induced growth; (b) effects of trade on prices, income and consumption patterns; (c) effects of trade on wages and employment.

Trade generally stimulates growth since more open markets lead to access to new technologies and appropriate intermediate and capital goods, which in turn cause increases in production, scale economies and competitiveness. The economy specializes in industries in which it has comparative advantages, meaning that resources are allocated most efficiently (Edwards, 1993; Duncan and Quang, 2002). This is especially important in the agricultural sector, as in LAC a large portion of the poor live in rural areas. If more open agricultural trade generates growth in this sector, it is likely that the rural poor will benefit (Bakhshoodeh and Zibaei, 2007; Cain et al.,2010; Cervantes-Godoy and Dewbre, 2010). Some empirical studies underpin the trade-growth nexus in LAC; for example, Castilho et al., (2012) studied the impact of globalization on household income inequality and poverty using detailed microdata across Brazilian states from 1987 to 2005. Results suggest that trade liberalization contributes to growth in poverty and inequality in urban areas and may be linked to reductions in inequality (possibly poverty) in rural areas. Edwards (1998) analyses comparative data for ninety-three countries, among them ten LAC, and finds that trade openness favours growth and that capital accumulation plays an important role in reducing poverty. Dollar (2005), however, counters that those countries being increasingly integrated into world markets are those where poverty has increased most since the 1980s.

We investigated this relationship in five LAC countries between the mid 1990s of the past century and 2010. Figure 5.11 shows that there is a correlation between the degree of trade openness and GDP growth in the agricultural sector. However, results seem to be very side-specific, depending on each country's development level and on whether it has a net importing or exporting position in agriculture. It seems that in Mexico the correlation between economic growth and trade openness is weak, while Chile even shows a negative correlation. Mexico is a large net importer with comparative advantages in other sectors due to its scarce natural resource endowments. Therefore, open trade in agriculture might not enforce growth in this sector. Chile's is rather shifting away from agriculture, because it is already a developed country in comparison with the other four. Especially in Peru, agricultural trade openness seems to favour GDP growth in agriculture.

Secondly, trade affects agricultural prices and relative prices in an economy, and in turn the real income of poor households, since agriculture represents their main livelihood source and their main consumption expenditure. To what degree price changes transmit to poor household's income depends on market access and their ability to benefit from the trade environment. Hassine et al. (2010) and Taylor et al. (2010) find that lower tariffs reduce nominal incomes for nearly all rural household groups in El Salvador, Guatemala, Honduras and Nicaragua, but they also lower consumption costs substantially leading to a positive net effect on rural households' welfare. Field and Field (2010) and Finot et al. (2011) came to the conclusion that tariff reductions in Chile and Peru between 1994 and 2006 increased total household incomes.

We investigate the relationship between trade openness and income of the 10% poorest population group in five LAC countries. Figure 5.12 shows that the direct effect of liberalizing agricultural markets on the development of the income of the poor is rather small, with the strongest correlation within a 95% confidence interval in Chile and Peru. Both countries have been increasingly exporting high value products and importing lower value staple food. The results show that the poor have probably benefited from these market-driven changes in the sector of agriculture.

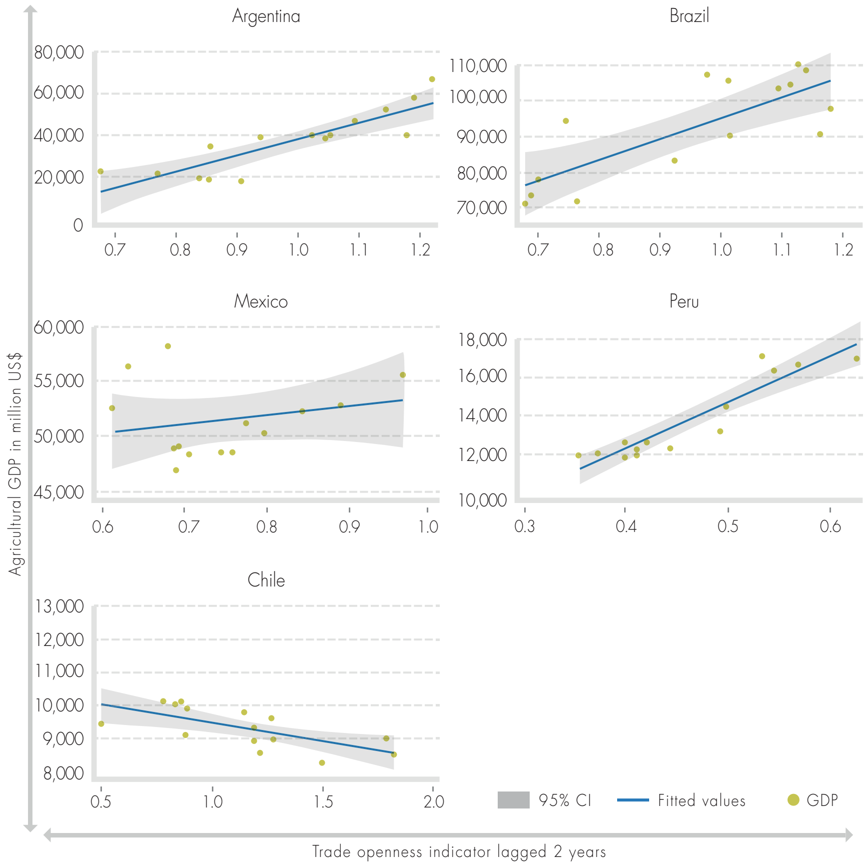

Figure 5.11 Trade and agricultural growth nexus in five LAC countries (1995–2010). *Source: own elaboration, data from WBDI (2012) and FAO (2013a)*

Thirdly, the impact of trade on wages and employment is grounded in the Heckscher-Ohlin model. With labour as an input factor, developing countries will specialize in the production of labour-intensive products which boosts demand for labour and in turn leads to higher wages in these sectors and thus poverty reduction. One of the reasons why agricultural trade liberalization is so important for poverty alleviation is that low-skilled workers in rural areas will benefit through production responses. For example Bussolo et al. (2011) found that the losses and gains in agricultural wages exhibit strong regional patterns: real wages of unskilled farmers rose in Latin America, the Middle East, and East Asia and Pacific, while declining in other developing regions.

Due to missing data, a direct analysis between agricultural trade and wages would not deliver reliable results. Thus we directly view a possible connection between agricultural trade liberalization and poverty rates in five LAC countries (Peru, Mexico, Chile, Argentina and Brazil). Figure 5.13 shows a clear trend between more liberalized trade and declining poverty rates.

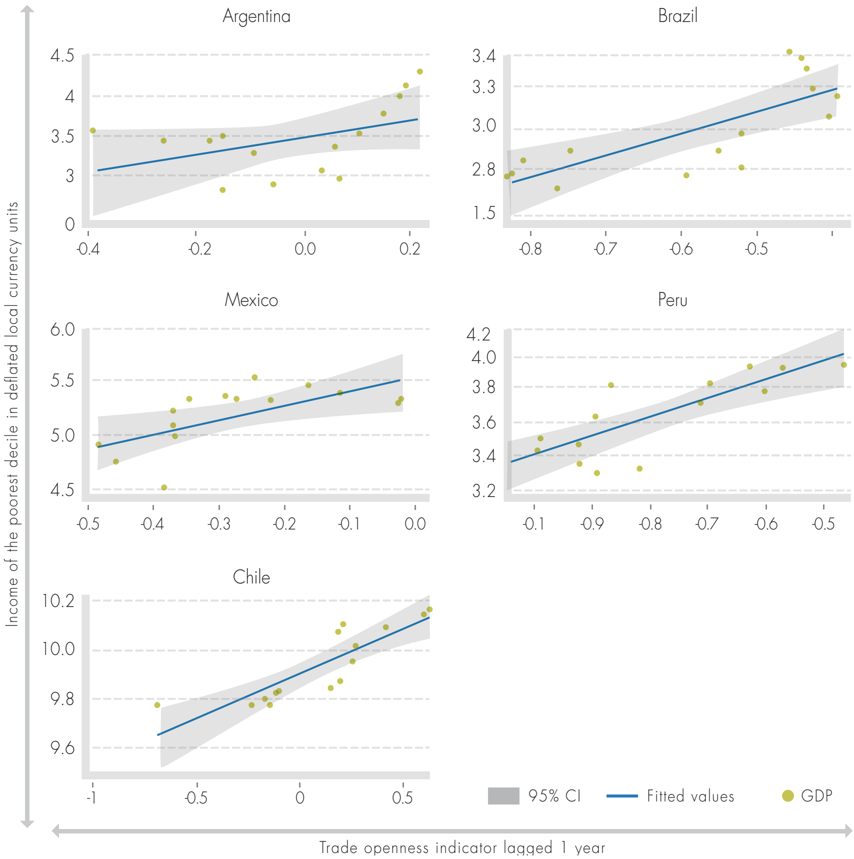

Figure 5.12 Trade and income of the poorest decile in five LAC countries (1996–2010). *Source: own elaboration, data from WBDI (2012) and SEDLAC (2012)*

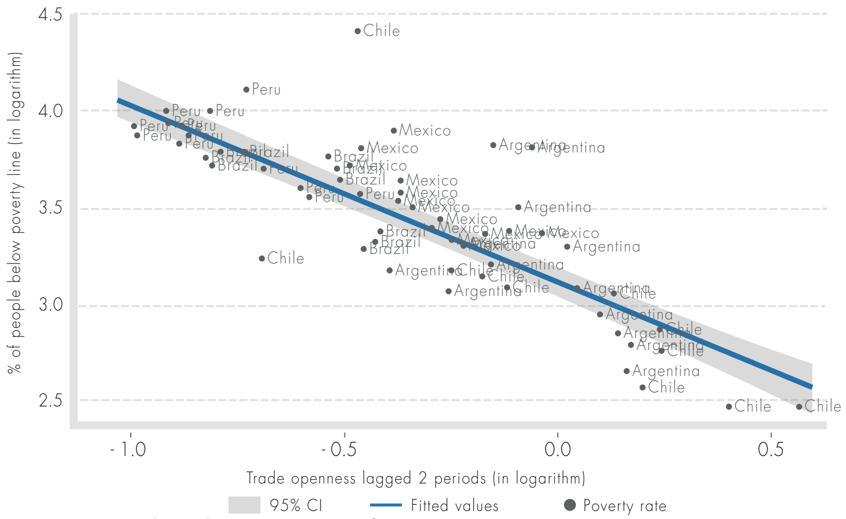

Figure 5.13 Trade and poverty rates in five LAC countries (1996–2010). *Source: own elaboration, data from WBDI (2012) and SEDLAC (2012).*

5.5.5 Do increasing trade and globalization impair or hamper the equitable access to resources (land and water)?

There are conflicting views about the role of trade regulations over water use. Gawel and Bernsen (2011) advise not to look at water footprint differences to support international trade regulations. The need for water governance at the global scale results from growing concerns over, firstly, water security in many parts of the world, and secondly, whether the existing commodity market system can deliver security as well as the necessary stewardship of water resources (Allan, 2011; Sojamo et al., 2012). Even if international trade presently involves products for which a significant part of the production is water-intensive, and virtual water flows are mainly subordinated to world trade rules, the policy linkages between international trade and impacts on freshwater have rarely been analysed. Chico et al. (2014) discuss options to improve global water governance through trade.

It is well known that water is seldom the dominant factor determining trade in water-intensive commodities. Many factors influence virtual water trade, such as direct or indirect subsidies, availability of land, labour, technology, level of socio-economic development, national food policies and international trade agreements (Aldaya et al., 2010; Rogers and Ramirez-Vallejo, 2011). Currently, virtual water flows are mainly subordinated to world trade rules (Hoekstra et al., 2011). The European Single Market and WTO frameworks are potentially suited to address the link between international trade and sustainable water use. Hoekstra et al. (2011) identifies several mechanisms to better ensure that trade and sustainable water use go hand in hand, such as product transparency or an international water pricing protocol. Trade will never contribute to optimal production and trade outcomes, from a water perspective, as long as water remains so underpriced (*ibid.*). There is a need to arrive at a global agreement on water pricing structures that cover the full cost of water use, including investment costs, operational and maintenance costs, a water scarcity rent and the cost of negative externalities of water use. Without an international treaty on proper water pricing it is unlikely that a globally efficient pattern of water use will ever be achieved. However, finding a harmonized water pricing mechanism may be so elusive that second-best solutions may be more feasible.

More recently, the WTO has started looking at the trade interventions that can influence water-related policies on either the production side (irrigation subsidies) or the consumption side (water footprint labelling) (Jackson et al., 2014). More work is needed to clarify key concepts and to enhance transparency in order to have a more comprehensive understanding of the ways in which these rules alter water resource outcomes.

Even if it is not yet widely recognized, the private sector has also a vital role to play in ensuring food-water security. Food supply chains operate beneath a complex pact between the state and the market. The agents in these food supply chains – mainly farmers – determine whether food-water is managed sustainably and securely (Allan, 2011; Sojamo et al., 2012).

Water and food security is today much more related to economic capacity and trade, than to physical water scarcity. Knowledge about the virtual water flows entering and leaving a country can cast a completely new light on the actual water scarcity of a country. This shift in perception forces a reconsideration of what are the main problems of food security, away from pure physical scarcity and technological fixes. The main issues that have to be addressed globally in relation to food security are: the hidden monopolies that currently exist in the WTO, the potential threat of political embargoes and the need for domestic social changes to be fulfilled.

References

Airports Council International (2012). *Passengers data*. Several years. [Online] Available from: www.aci.aero/Data-Centre/Annual-Traffic-Data/Passengers/2010-final. [Accessed January, 2013].

Ajanovic, A. (2011). Biofuels versus food production: Does biofuels production increase food prices? *Energy,* 36 (4): 2070–2076.

Aldaya, M.M., Allan, J.A. & Hoekstra, A.Y. (2010). Strategic importance of green water in international crop trade. *Ecological Economics,* 69 (4): 887–894.

Allan, T. (2011). *Virtual Water: Tackling the Threat to Our Planet's Most Precious Resource.* London, IB Tauris Publishers.

Anderson, K. (2010). Globalization's effects on world agricultural trade, 1960–2050. *Philosophical Transactions of the Royal Society of London – Series B: Biological Sciences,* 365 (1554): 3007–3021.

Bakhshoodeh, M. & Zibaei, M. (2007). No agriculture trade openness and poverty reduction: cross-country analysis. *Iran Agricultural Research*, 25(2).

Borras, S.J., Franco, J., Kay, C., Gómez, S. & Wilkinson, J. (2011). Land grabbing in Latin America and the Caribbean. *The Journal of Peasant Studies*, 39: 1–54.

Brenton, P., Newfarmer, R. & Walkenhorst, P. (2009). Avenues for export diversification: issues for low-income countries. Germany, University Library of Munich. MPRA Paper No. 22758.

Bruinsma, J. (2009). The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050?. In: *Conference on Expert Meeting on How to Feed the World in 2050*. Rome, FAO.

Brummer, B., Korn, O., Jaghdani, T.J., Saucedo, A. & Schlüßler, K. (2013). Food price volatility drivers in retrospect. Policy Brief 1. EU ULYSSES Project. [Online] Available from: www.fp7-ulysses.eu/publications/ULYSSES%20Policy%20Brief%201_Food%20price%20volatility%20drivers%20in%20retrospect.pdf. [Accessed August, 2013].

Bussolo, M., De Hoyos, R. & Medvedev, D. (2011). Free trade in agriculture and global poverty. *The World Economy*, 34: 2019–2043.

Cain, J., Hasan, R. & Mitra, D. (2010). Trade liberalization and poverty reduction: new evidence from Indian states. In: Bhagwati, J., & Panagariya, A. (eds). *'India's Reforms: How They Produced Inclusive Growth'*. New York, Oxford University Press. pp. 91–169.

Castilho, M., Menéndez, M. & Sztulman, A. (2012). Trade liberalization, inequality, and poverty in Brazilian states. *World Development,* 40 (4): 821–835.

Cervantes-Godoy, D., & Dewbre, J. (2010). *Economic importance of agriculture for poverty reduction*. OECD Publishing. Report No. 23.

Chico, D., Aldaya, M.M., Flachsbarth, I. & Garrido, A. (2014). Virtual water trade, food security and sustainability: lessons from Latin America and Spain. In: Martínez-Santos, P., Aldaya, M.M. & Llamas, R. (eds). *Integrated water resources management in the 21st Century: Revisting the paradigm*. London, CRC Press. Forthcoming.

Deininger, K. (2011). Challenges posed by the new wave of farmland investmente. *The Journal of Peasant Studies,* 38 (2): 217–247.

Dingemans, A. & Ross, C. (2012). Free trade agreements in Latin America since 1990: an evaluation of export diversification. CEPAL *Review,* 108W: 27–48.

Dollar, D. (2005). Globalization, poverty, and inequality since 1980. T*he World Bank Research Observer,* 20 (2): 145–175.

Duncan, R. & Quang, D. (2002). *Trade Liberalisation, Economic Growth and Poverty Reduction Strategies*. Canberra, Australia, AusAID. Technical report.

Edwards, S. (1993). Openness, trade liberalization, and growth in developing countries. *Journal of Economic Literature,* 31: 1358–1393.

Edwards, S. (1998). Openness, productivity and growth: what do we all know? *The Economic Journal*, 108: 383–398.

FAO (2013a). Food and Agriculture Organization of the United Nations. FAOSTAT. Available from: faostat.fao.org/. [Accessed January, 2013].

FAO (2013b). Food and Agriculture Organization of the United Nations. FAO Statistical Yearbook 2013. Rome, Italy, FAO.

Field, A.J. & Field, E.M. (2010). Globalization, crop choice, and property rights in rural Peru, 1994–2004. In: *The Poor Under Globalization in Asia, Latin America, and Africa*. Oxford, Oxford Univ. Press. pp. 284–323.

Finot, A., LaFleur, M., & Lima, J. D. (2011). *Analysis of the effects of trade opening on household welfare: an application to Chile,* 1999–2006. CEPAL Working Paper No. 405.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.M., Gerber, J.S, Johnston, M., Mueller, N.D., O'Connell, C., Ray, D.K., West, P.C., Balzer, C., Bennett, E.M., Carpenter, S.R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., Tilman, D. & Zaks, D.P.M. (2011). Solutions for a cultivated planet. *Nature,* 478 (7369): 337–42.

Gawel, E. & Bernsen, K. (2011). Global trade, water scarcity and the limited role of virtual water. *Gaia,* 3: 162–167.

Giordano. P. (2012). Food Security and Trade in LAC. Necessarily unstructured and unrelated comments to David Laborde. *Workshop Drivers of Food Security in Latin America and the Caribbean* CIAT/IDB, Cali, Nov. 8–9, 2012.

Hassine, N. B., Robichaud, V. & Decaluwe, B. (2010). *Agricultural Trade Liberalization, Productivity Gain, and Poverty Alleviation: A General Equilibrium Analysis*. Cairo, Egypt, Economic Research Forum Working Paper No. 519.

Headey, D. & Fan, S. (2008). Anatomy of a crisis: the causes and consequences of surging food prices. *Agricultural Economics,* 39: 375–391.

Hoekstra, A.Y. & Chapagain, A.K. (2008). *Globalization of Water: Sharing the planet's freshwater resources.* Oxford, Blackwell Publishing.

Hoekstra, A.Y., Aldaya, M.M. & Avril, B. (2011). *Proceedings of the ESF Strategic Workshop on Accounting for Water Scarcity and Pollution in the Rules of International Trade,* Amsterdam, 25–26 November 2010. UNESCO-IHE. Value of Water Research Report Series No. 54.

IDB (2013). Inter-America Development Bank. Statistics and databases. [Online] Available from: www.iadb.org/en/research-and-data/statistics-and-databases,3161.html#.UkK8JsY0xZo [Accessed February, 2013].

Jackson, L.A., Pene, C., Martinez-Hommel, M.B., Hofmann, C. & Tamiotti, L. (2014). Water policy, agricultural trade and WTO rules. In: Martinez-Santos, P., Aldaya, M.M. and Llamas, M.R. (eds). *Integrated water resources management in the 21st century: Revisting the paradigm*. London, UK, CRC Press. Forthcoming.

Journal of Commerce (2012). *The Joc Top 50 World Container Ports*. [Online] Available from: www.joc.com/sites/default/files/u48783/pdf/Top50-container-2012.pdf.[Accessed February 2013].

Mejía, A. (2010). *Water For The Americas: Challenges & Opportunities*. Rosenberg International Forum on Water Policy. Buenos Aires, Argentina.

Mitchell, D. (2008). *A note on rising food prices*. World Bank Policy Research Working Paper Series No. 4682. [Online] Available from: www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/07/28/000020439_20080728103002/Rendered/PDF/WP4682.pdf [Accessed February 2013].

Mueller, N.D., Gerber, J.S., Johnston, M., Ray, D.K., Ramankutty, N. & Foley, J. A. (2012). Closing yield gaps through nutrient and water management. *Nature,* 490 (7419): 254–257.

NIC (2012). *National Intelligence Council. Global Trends 2030: Alternative Worlds*. Washington DC. [Online] Available from: globaltrends2030.files.wordpress.com/2012/12/global-trends-2030-november2012.pdf. [Accessed March, 2013].

OAS (2012). Organization of American States. *Foreign Trade Information System of the Organization of American States*. [Online] Available from: www.sice.oas.org. [Accessed February, 2013].

Pfister, S., Bayer, P., Koehler, A. & Hellweg, S. (2011). Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. *Environmental Science Technology,* 45 (13): 5761–5768.

PPIAF (2013). Public-Private Infrastructure Advisory Facility. Data sources. [Online] Available from: www.ppiaf.org. [Accessed March, 2013].

Prakash, A. (2011) *Safeguarding food security in volatile global markets*. Rome, FAO.

Rogers, P. & Ramirez-Vallejo, J. (2011). Failure of the virtual water argument, in: Hoekstra, A.Y., Aldaya, M.M. and Avril, B. (eds). (2011) *Proceedings of the ESF Strategic Workshop on Accounting for Water Scarcity and Pollution in the Rules of International Trade,* Amsterdam, 25–26 November 2010: UNESCO-IHE. Value of Water Research Report Series No. 54.

Rosegrant, M.W., Zhu, T., Msangi, S., Palazzo, A., Miroslkav, B., Magalhaes, M., Valmonte-Santos, R., Ewing, M., Nelson, G.C., Koo, J., Robertson, R., Sulser, T., Ringler, C. & Lee, D. (2008). Global scenarios for biofuels: impacts and implications. *Review of Agricultural Economics,* 30 (3): 495–505.

Rulli, M.C., Saviori, A. & D'Odorico, P. (2013). Global land and water grabbing. *Proceedings of the National Academy of Sciences* 110 (3): 892–897.

SEDLAC. (2012). Socio-Economic Database for Latin America and the Caribbean. SEDLAC and The World Bank. [Online] Available from: data.worldbank.org/data-catalog/sedlac [Accessed March, 2013].

Sojamo, S., Keulertz, M., Warner, J. & Allan, J.A. (2012). Virtual water hegemony: the role of agribusiness in global water governance. *Water International,* 37(2):169–182.

Taylor, J. E., Naude, A.Y. & Jesurun-Clements, N. (2010). Does agricultural trade liberalization reduce rural welfare in less developed countries? The case of CAFTA. *Applied Economic Perspectives and Policy,* 32: 95–116.

The Economist (2012). *The world's shifting centre of gravity*. June 28, 2012. [Online] Available from: www.economist.com/blogs/graphicdetail/2012/06/daily-chart-19. [Accessed march, 2013].

UNCTAD (2012). United Nations Conference on Trade and Development. UNCTADSTAT. [Online] Available from: unctadstat.unctad.org/ReportFolders/reportFolders.aspx?sRF_ActivePath=P,5,27&sRF_Expanded=,P,5,27 [Accessed May 2013].

UNEP (2010). United Nations Environment Programme. *Environment Outlook for Latin America and the Caribbean:* GEO LAC 3. Panama City, Panama, UNEP.

Von Braun, J. (2008). *Responding to the World Food Crisis Getting on the Right Track: IFPRI 2007–2008:* International Food Policy Research Institute (IFPRI). Annual Report Essay 2007–2008. Essay No. 1.

Westhoek, H.J., Rood, G.A., Berg, M, Van Den, Jansen, J., Nijdam, D., Reudink, M. & Stehfest, E. (2011). The protein puzzle: the consumption and production of meat, dairy and fish in the European Union. *European Journal of Food Research Review,* 1 (3):123–144.

Williamson, J. (1990). *Latin American Adjustment: How Much Has Happened?*. Washington DC, Instituto de Economía Internacional.

WBDI (2012). World Bank Development Indicators (WBDI). [Online] Available from: data.worldbank.org/data-catalog/world-development-indicators. [Accessed February, 2013].

WorldBank (2012). World Bank Statistics. Available from: data.worldbank.org/ [Accessed February, 2013].

WTO (2012). World Trade Organization. Statistics database. Available from: stat.wto.org/Home/WSDBHome.aspx?Language=. [Accessed February, 2013].

Zetland, D., & Möller-Gulland, J. (2013). The political economy of land and water grabs. In: Allan, T.,Keulertz, M., Sojamo, S., and Warner, J. (eds). *Handbook of Land and Water Grabs in Africa. Foreign direct investment and food and water security.* Abingdon, Routledge. pp.257–272.

6

TRACKING PROGRESS AND LINKS BETWEEN WATER AND FOOD SECURITY IN LATIN AMERICA AND THE CARIBBEAN

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Highlights

- The concepts of water security (WS) and Food Nutritional Security (FNS) have evolved from narrow and well-defined goals of guaranteeing citizens' access to sufficient water and food resources into much broader concepts, embracing health, sustainability, efficiency and social equity aspects. Such wide visions go beyond the physical availability or productive value of water and food, and testify to its importance as key elements to human well-being.
- During the last decade, significant progress has been achieved across many Latin American and Caribbean (LAC) countries on essential WS fronts, such as improving access to drinking water and sanitation, reducing social vulnerability to water hazards and water use efficiency. These achievements have contributed to improving health, physical protection and material needs, but important challenges remain. Water pollution is now one of the most important water security threats to LAC and requires greater attention at all levels.
- Efforts to improve basic WS goals are still needed in most countries, particularly in the low income countries of the Caribbean, Mesoamerica and Andean regions. Wealthier countries such as Mexico, Chile, Argentina, Brazil or Uruguay have higher WS standards, although physical water scarcity is becoming a growing problem, particularly in som of these countries.
- As with WS, most countries in LAC have improved basic food security indicators, predominantly in terms of food availability and access. However, the food crisis of 2007–2009 slowed down progress or even worsened some indicators for a few countries like Haiti, Paraguay and Guyana. Others like Bolivia, Ecuador, Peru, Honduras, Guatemala, Nicaragua and El Salvador have made significant progress, but still have a considerable gap to bridge.
- The most important challenge in LAC regarding food and nutritional security (FNS) is to overcome malnutrition rather than a physical lack of food. Currently, there are still 49 million people undernourished (8% of LAC population), but obesity now affects 20% of the LAC population (> 110 million people) and overweight up to 35% (> 200 million people).
- Between 2000 and 2010 WS and FNS indicators have progressed more rapidly and consistently in the wealthiest half of LAC countries. Progress among the poorest countries has been more erratic, inconsistent and inadequate. Per capita income is a good predictor of the levels of WS and FNS standards but there is considerable variation of performance amongst countries with similar incomes. This suggests that setting the right priorities and implementing the right policies can make a difference.

6.1 Introduction

The concept of security has long been understood as a country's safety faced with external aggression (e.g. wars or conflicts) and the defence of national interests in foreign policies (UNDP, 1994). Yet, human security has a much wider interpretation as it is focused on improving human well-being within countries, beyond defending strategic interests between nations. As the 1994 Human Development Report states 'Human security is concerned with how people live in societies, how freely they exercise their many choices, what access do they have to material well-being, and whether they live in a climate of political stability and peace' (*ibid.*). Because of the many dimensions included in the notion of human well-being, different security branches have emerged since the early 1990s, including food and nutritional security (FNS), water security (WS) and/or environmental security (ES).

WS and FNS are particularly concerned with those issues surrounding water and food, e.g. access, availability, quality and stability, which are critical to human well-being. Both *securities* imply that people have sufficient and stable access to food, enjoy a healthy diet, have access to drinking water and improved sanitation facilities and are physically protected from water hazards, among many other aspects. Not being deprived of these conditions is also a necessary condition for living a dignified life and being morally resilient. The future prospects of a foetus, a new-born or a child are to a great extent conditioned on the mother's and the household's material well-being. A child with adequate access to drinking water, sanitation and food security will have a better chance of surviving and progressing to a mature age. Further, being physically protected against natural disasters and diseases are fundamental conditions for human security and societal resilience.

The extent to which a country is water and food secure depends on the physical environment but predominantly it is the level of poverty and the constrained socio-economic context that really dictates their degree (Grey and Sadoff, 2007). As Allan (2013) states '(…) poverty determines water poverty: water poverty does not determine poverty' (p. 2) When both these circumstances are aligned, harsh natural conditions and widespread poverty, options to improve water and food gaps are rather complex. In Latin America and the Caribbean (LAC), water and land resources are for the most part abundant, and what lies behind existing water and food insecurities is the prevailing poverty (OECD, 2013a). While LAC is on good track to meet many of the Millennium Development Goals (MDGs) ahead of 2015, poverty and inequality are still widespread in the region, and basic indicators of human material well-being remain below minimum standards. Currently, LAC still has 49 million undernourished people, 33 million lacking access to an improved clean water source and 20 million still practice open defecation (FAO, 2012a; WHO-UNICEF, 2013). In addition to this, the region also faces serious nutritional problems, with 20% of the population being obese (equivalent to over 110 million people) and 13.5% of pre-school children with stunted growth (FAO, 2012b; Finucane et al., 2011; Onis et al., 2011).

Improving WS and FNS within countries requires a wide range of different policies, as well as a clear definition of priorities based on their socio-political and economic statuses. However, in spite of these differences, there are also numerous interrelated aspects of water and food within countries that call for a joint analysis, since both securities are inextricably linked. Currently, 95% of the water consumed in LAC is used for producing food (Mekonnen and Hoekstra, 2011); therefore improving FNS inevitably requires having secure access to sufficient and stable water resources. Also, other important components of FNS in LAC like food safety, acceptable cooking conditions and personal hygiene require a minimum set of water quality standards to be in place. The importance of water for food production is what led Allan (2013) to distinguish between 'food-water', i.e. 90% to 95% of total water consumption which is invested in agricultural production, and 'non-food water', i.e. the remaining 5% to 10% of water resources needed to sustain all the other economic activities beyond agriculture.

The aim of this chapter is to explore the progress achieved in WS and FNS in LAC countries during the last decade, outline the main challenges ahead and assess the relevance of the food-water security link in this region. Accordingly, this chapter is organized as follows: Section 6.2 provides a conceptual discussion of the concepts of WS and FNS, reviewing how these two concepts have been defined and refined over time by different authors and institutions; Section 6.3 quantitatively synthesizes the trends and progress of both securities over the last decade; Section 6.4 assesses the links between both securities outlining the different synergies found in the LAC context; and lastly, Section 6.5 includes some final remarks.

6.2 Evolving concepts of water and food security

6.2.1 Water security: concept and metrics

The concept of WS was introduced in the early 1990s and it has evolved significantly ever since (Cook and Bakker, 2012; López-Gunn et al., 2012). Originally WS was approached from a physical perspective, linked to the idea of national security, and the threat that physical water scarcity and conflicts-over-water could represent for neighbouring countries (Starr, 1992). Under this framework, WS was closely linked to the goal of ensuring sufficient water resources and guaranteeing access in order to maintain political stability within and outside national borders.

Over time, the concept has further evolved to include other economic, social and environmental aspects of water important to human well-being beyond its physical availability. These include protection against water hazards, safeguarding human health, maintenance of healthy aquatic ecosystems as well as cultural and spiritual values linked to water (see Table 6.1). One of the most recent definitions proposed by UN-Water (2013) defines WS as *'the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-*

being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' (p.2).

The increasing use of this concept raises fundamental questions for water policy, including whether or not it overlaps or aligns with IWRM (see Chapter 15). As Cook and Bakker (2012) argue, both approaches are complementary since water security is focused on the end goal (being water secure) whereas IWRM is process-orientated (the path and steps required to become water secure).

Table 6.1 Human well-being dimensions considered under different approaches to water security

DIMENSIONS	Starr (1992)	GLOBAL WATER PARTNERSHIP (2000)	Grey and Sadoff (2007)	UNESCO IHE (2010)	UN WATER (2013)
Access to drinking water and sanitation	■	■	■	■	■
Protection from water hazards		■	■	■	■
Ecosystem protection (water quality and quantity)		■	■	■	■
Adequate livelihoods (e.g. health, material goods, education)		■	■		■
Preserve non-material aspects of water (e.g. cultural and ethical values)		■			■
Maintain peace and political stability (e.g. transboundary water cooperation, public participation, etc.)	■				■

Source: own elaboration

Improving WS of LAC citizens will require a pool of measures, including hard-path solutions, i.e. technological responses based on infrastructure development, as well as soft-path solutions, i.e. an institutional response including legal framework development and enforcement, greater transparency or economic instruments to improve water management. The type of measures as well as the implementation sequence will largely depend on the socio-economic context and the degree of development within countries, above any favourable hydrological condition. Foremost because improving WS and reducing people's vulnerability to water risks largely relies on the capacity of nations to make investments and develop infrastructures and policy tools (Grey and Sadoff, 2007; Allan, 2013).

Nevertheless, having a favourable hydrological situation is an advantageous factor to become more water secure. As described in Chapter 2, LAC is extremely well endowed in terms of water resources; however, it also has a high hydro-climatic variability (e.g. floods and droughts linked to the El Niño and La Niña phenomena). Such inherent variability often affects the most vulnerable and poorest, but also LAC's richest countries, such as Chile or Mexico. In fact, droughts in Chile represent a major water risk since they are highly frequent in the centre-north part of the country, where the majority of the population lives and most agriculture takes place (UNESCO, 2010).

An inherent characteristic of countries' WS is that it is a scale-dependent goal (Cook and Bakker, 2012). In fact, national WS assessments can mask significant variations compared to those performed at the more regional or local scale (Vörösmarty et al., 2010). Moreover, WS goals are likely to change over time, depending on the priorities countries have at a given time or stage of development. For instance, in Europe conventional approaches to water management have for a long time prioritized the need for building infrastructures and attending to the increasing demands of competing users. However, the goal of the current European water policy i.e. the Water Framework Directive (WFD 2000/60/EC) represents a radical shift with respect to this previous approach since it considers environmental sustainability of aquatic ecosystems as a priority to ensure WS in Europe.

The benefits gained by LAC countries when improving their WS and reducing their water risk to tolerable levels entail inevitable *trade-offs*, e.g. guaranteeing water access to big urban areas requires the constructions of dams, and even large inter-transfer schemes, which often have large social and environmental implications. However, some of these *trade-offs* are avoidable, such as reducing water pollution, and these will depend to a larger extent on the priorities defined by governments. The path followed by developed regions such as Europe to achieve WS has brought about serious environmental degradation, and yet there is no full understanding of the costs and the actions needed to reverse this problem despite ongoing efforts. Hence, developing countries striving for WS would need to make large investments in water management and infrastructure at all levels, but they can benefit from the experience gained in regions like Europe of the need to pay greater attention to institutional development, environment sustainability and social inclusion to avoid unintended and avoidable costs.

In order to keep track of regional progress in WS, a number of operational frameworks have been developed over the last few years (see Figure 6.1). The overall purpose of these frameworks is to determine whether countries or regions are on the right path to increase resilience to water risks and what are the main challenges. As Figure 6.1 shows, the majority of existing operational frameworks propose a different set of indicators to measure the hydrological status within countries (resource physical availability and environmental status), as well as the use and access of water from a socio-economic perspective (access, sanitation and economic water efficiency). The existence of water institutions to ensure WS stability is barely considered under these frameworks, partly because of the lack of robust metrics to measure institutional progress, and also because of the difficulty of quantifying what is good governance. Neither the risks related to water hazards, nor those associated with natural disasters, are explicitly considered in most of the cases despite the importance they have in regions like LAC.

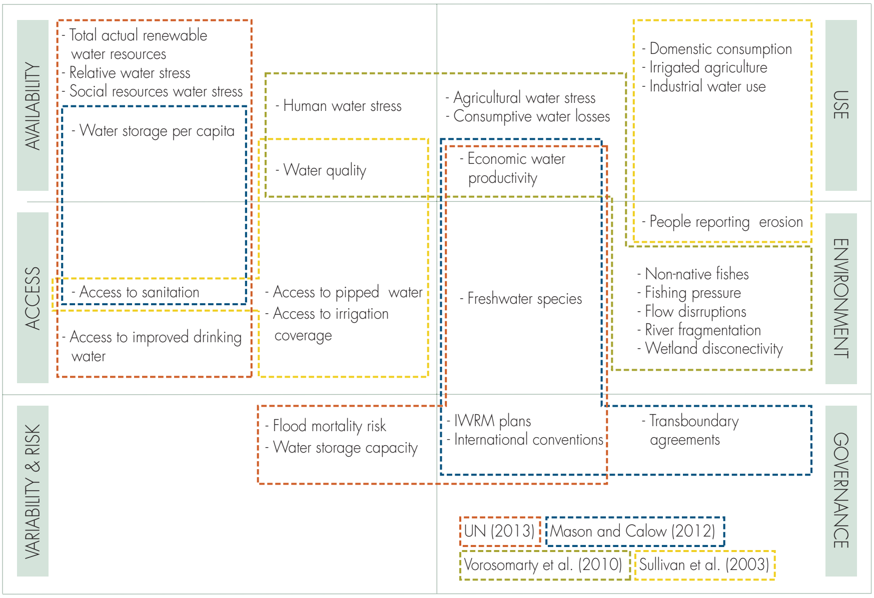

Figure 6.1 Indicators and operational frameworks for measuring water security. *Source: Own elaboration based on UN (2013), Mason and Calow (2012), Sullivan et al. (2003) and Vörösmarty et al. (2010)*

6.2.2 Food and nutritional security: concepts and dimensions

Similarly to the WS concept, the notions of FNS have evolved significantly in the last sixty years. Table 6.2 synthesizes the major milestones of the concept since the 1940s.

The notion of food security has generated tremendous attention in the last years, and it is now a well-established concept. According to FAO (1998) food security (FS) exists when (a) all people at (b) all times have (c) both physical and (d) economic access to sufficient food to (e) meet their dietary needs for (f) a productive and healthy life. Often, FS is framed in four dimensions: availability, access, stability and utilization.

According to FAO (1998):

> Food insecurity exists when people are undernourished due to the physical unavailability of food, their lack of social or economic access, and/or inadequate food utilization. Food insecure people are those individuals whose food intake falls below their minimum calorie (energy) requirements, as well as those who exhibit physical symptoms caused by energy and nutrient deficiencies resulting from an inadequate or unbalanced diet, or from the inability of the body to use food effectively because of infection or disease. An alternative view would define the concept of food insecurity as referring only to the consequence of inadequate consumption of nutritional food, considering the physiological utilization of food by the body as being within the domain of nutrition and health. Vulnerability refers to the full range of factors that place

Table 6.2 **Evolving definition and scope of the food security concept**

FOOD AND NUTRITIONAL SECURITY	
1940–1980	Food security and nutrition security (WW II), 43 countries met in Hot Springs, Virginia, 1943 'Freedom from want' meaning a secure, adequate and suitable supply of food for ever y man, woman and child, where 'secure' referred to the accessibility, 'adequate' referred to the quantitative sufficiently of the food supply and 'suitable' referred to nutrient content.
1980–1990	'Concept of entitlement' Sen (1982). Food problems associated to agricultural production and food supply, but also with the governing economies and societies.
1940–1980	1996 World Food Summit 'All people at all times have physical and economic access to sufficient, safe and nutritional food to meet …' 'A person is considered nutritionally secure when he/she has a nutritional diet and the food consumed is biologically utilized… resisting or recovering from disease, pregnancy, lactation and physical work' Frankenberger et al. (1997) Joint use of FS and NS concepts IFPRI, UNICEF and FAO (mid-1990s)
2000–PRESENT	Road Map for Scaling-Up Nutrition 'NS is achieved when secure access to an appropriately nutritious diet is coupled with a sanitary environment, adequate health services and care, to ensure a healthy and active life for all household members' 2010 Weingärter (2010), Food and Nutritional Security is a condition under which adequate food (quantity, quality, safety, socio-cultural acceptability) is available and accessible for and satisfactorily utilized by all individuals at all times to live a healthy and happy life. FAOs 'FNS is a condition when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment adequate health and care' (CFS, 2009)

Source and quotes from: Pangaribowo et al. (2013)

people at risk of becoming food insecure. The degree of vulnerability for an individual, household or group of persons is determined by their exposure to the risk factors and their ability to cope with or withstand stressful situations.

Hoddinott (1999) claims that there are 200 definitions and 450 indicators of food security. As we will review in section 6.3.2 below, dozens of indicators are identified as having a direct and indirect influence on food security assessments. Less straightforward and evident are the drivers of food insecurity. Consider one of the factors that have been mentioned as having a crucial impact on the number of people suffering from hunger or being vulnerable to food insecurity: agricultural prices levels and volatility. Swinnen and Squicciarini (2012) found contradictory statements from two leading institutions, FAO and OXFAM, in relation to the role of agricultural prices in explaining rural poverty and food insecurity. The difficulty of ascertaining the impact of food prices on food security is due to the fact that people in poor rural areas are often producers and consumers, a factor whose complexity escalates as some households could be net buyers under some price situations and net sellers under others.

Recently, the notion of FS has also been expanded to include nutritional security, the two now being commonly addressed as 'Food and Nutritional Security' (FNS). The G8 supported the New Alliance for Food Security and Nutrition, which included the endorsement of the 'Scaling Up Nutrition movement' and 'welcome the commitment of African partners to improve the nutritional well-being of their populations, especially during the critical 1,000 days window from pregnancy to a child's second birthday'. This attests to the fact that, while calorie intake may be sufficient to cover body-energy demands, many other dietary elements are also required, especially for pregnant women and children, to ensure a healthy life and growth.

And yet, well-known experts still puzzle at the low adoption rates of a number of crucial habits for health improvement and income generation among the world's poorest, e.g. application of fertilizers, use of anti-malaria nets, application of chlorine to drinking water, vaccinations and routine medical checks to name but a few (Banerjee and Duflo, 2011). Another unresolved query is the increasing prevalence of obesity among the poorest households in some developed and developing countries alike. Ultimately, having a healthy diet requires not only sufficient access to food under all FNS dimensions, but also the willingness to adhere to it and minimum knowledge of its components and sources.

What the above comments may suggest is the following. First, whilst an increase in agricultural production is fundamental in order to increase FNS, it may not guarantee it. This is one of the blurring elements of the linkages between water and food security, in the sense that more water (or land) available for agriculture does not necessarily improve FNS indices, although increasing agricultural production among the poorest rural households improves their nutritional outlook. Second, the new approach of FNS places more emphasis on nutritional aspects than FS, but in order to monitor them there is a need for data which is much harder to obtain and of which we do not have historical records. Furthermore, the consequences of reduced FNS could have delayed effects which may only become evident as children become adolescents and young adults. Third, as this book shows, virtually all the variables directly related to FNS in the LAC region have been changing rapidly in the last decade, in the course of which commodities prices have become very volatile and followed an upward trend (see Chapters 4 and 5). Thus, FNS performance indicators co-vary with other major drivers; with which it has only an indirect relationship, meaning causality is almost impossible to establish (see Table 6.5).

As Barrett (2010) mentions, the FNS concept is elusive because a single indicator cannot summarize its complexity. It is thus necessary to analyse a set of indicators in order to capture all its relevant dimensions. Some of the existing composite food security indicators that focus on macro levels are: the FAO Indicator of Undernourishment (FAOIU); the Global Hunger Index (GHI); the Global Food Security Index (GFSI); the Poverty and Hunger Index (PHI); the Hunger Reduction Commitment Index (HRCI)). Some indicators that focus on micro level are the anthropometric indicators (measure nutritional outcomes) and the medical and biomarkers indicators (measure micronutrient deficiencies) (Pangaribowo et al., 2013). Many of the different FNS frameworks or compound indicators developed complement each other because they refer to different critical dimensions of food security (see Figure 6.2). Dimensions such as access, use and utilization are well represented by most composite indicators, only stability is clearly under-represented. Pangaribowo et al. (2013) recommend including two outcome indicators to capture the short-term FNS stability: per capita food supply variability and food price variability.

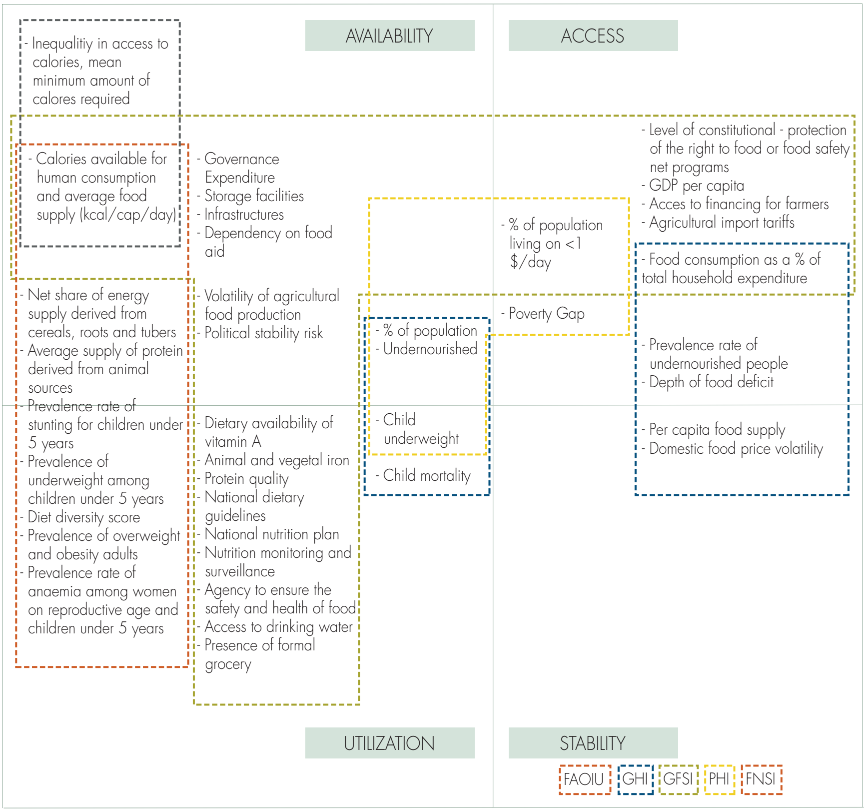

Figure 6.2 Existing food and nutrition indicators. *Source: own elaboration based on Pangaribowo et al. (2013).* Note: the FAO Indicator of Undernourishment (FAOIU); the Global Hunger Index (GHI); the Global Food Security Index (GFSI); the Poverty and Hunger Index (PHI); Food and Nutrition Security Indicators proposed by EU project 'Food Secure' (FNSI).[1]

6.3 Water and food security status and trends in LAC

6.3.1 Water security performance

Table 6.3 summarizes the WS status of LAC countries in 2010 and the progress achieved since 2000. The framework used in this assessment to measure WS is a mixture of the ones presented in Figure 6.1. An imposed pre-requisite was to choose only those indicators for which it was possible to track changes over time, as well as selecting a pool of indicators capable of reflecting the different dimensions involving WS.

In terms of blue water availability (runoff), LAC countries have a privileged status, only the Caribbean islands of Dominican Republic and Haiti show a total actual renewable water resources (TARWR) below 3000 m^3/cap/yr (Table 6.1). Despite this overall water

1 www.foodsecure.eu/

richness, physical blue water scarcity exists due to the spatial mismatch between where water is naturally available and where it is demanded. For instance, more than 75% of Mexicans live in basins where water consumption is at least twice the volume of water renewed naturally every year (blue water scarcity index ≥ 2) (see Figure 6.3 and Table 6.3). The northern part of Chile also faces serious blue water stress, with current demand being three times more than the natural available flow. In the northern part of Argentina and northeast Brazil, blue water scarcity problems are currently affecting 14% and 13% of their national populations respectively, and this trend has grown since the year 2000. Along the Peruvian coast, blue water scarcity is approaching a critical threshold, which poses an important risk for Peru's development since the majority of the population and agricultural activity is concentrated along the coastal basin.

Green water (soil moisture) plays a fundamental role in LAC's agriculture (see Chapter 7) and it is a key asset for achieving regional and global food-water security. Green water availability (measured in terms of arable land per capita) in LAC is high (0.26 ha per capita per year in 2010), and only the Caribbean islands, Costa Rica and Colombia have lower ratios. These punctual green water shortages are mostly compensated through regional agricultural trade and do not represent a major water risk for the above mentioned countries. The most important risk from a food-water security perspective in LAC is related

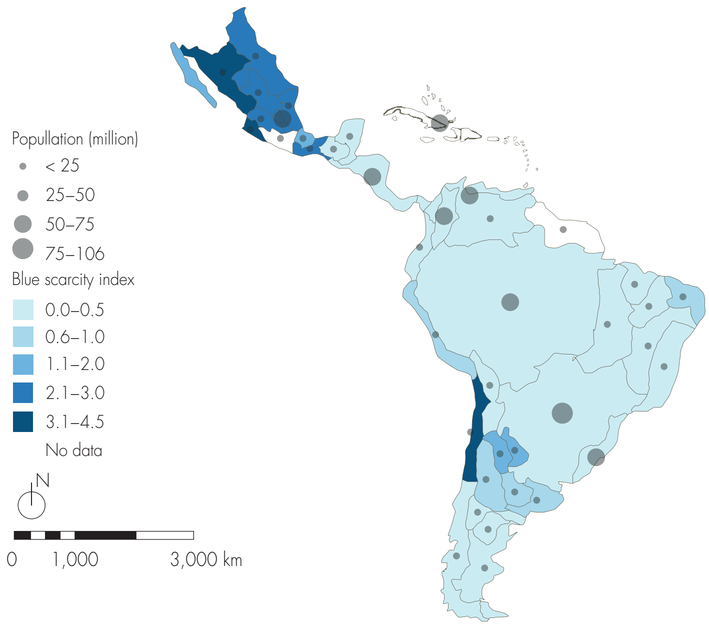

Figure 6.3 Blue water scarcity and population distribution estimates for 2010 in Latin America. *Source: own elaboration with data from Hoekstra and Mekonnen (2011) and CIESIN-FAO-CIAT (2005).* Note: The blue water scarcity index as defined by Hoekstra and Mekonnen (2011) is the ratio between the annual blue water consumption and the naturally available runoff minus the environmental flow requirements.

to the intra- and inter-annual variability of green water, i.e. the high frequency of droughts and floods linked to El Niño and La Niña, and the impacts these phenomenon have on rain-fed agriculture and food security. Alongside this, the high reliance on green water for food production has associated large environmental trade-offs, since the expansion of arable land calls for the extension of the agricultural frontier over natural ecosystems (see Chapter 3).

With regard to access to water, significant improvements have been achieved across most LAC countries. Approximately 90% of the households in LAC have access to an improved water source and 76% to sanitation facilities (see Table 6.3). Only Bolivia and Haiti remain below these rates, particularly regarding sanitation facilities. This positive trend nevertheless masks an important gap between urban and rural access, particularly in the Andean region, Brazil and some Mesoamerican countries such as Nicaragua (see Figure 6.4). According to the latest figures of the Joint Monitoring Program on water (WHO-UNICEF, 2013) in 2011, 32.7 million people in LAC still have no access to an improved drinking water source and 21 million still practice open defecation, the majority of these in rural areas.

Assessing the productive use of water determines nations' dependency on water resources for its economic development. Table 6.3 summarizes the trends in green water productivity. Overall, the majority of countries show a positive increase in the efficiency of green water use (measured in terms of improvements in rain-fed agricultural yields), particularly the most important agricultural producers like Chile, Argentina, Brazil and Paraguay. In Mesoamerica, green water productivity has increased, but to a lesser extent. Only the countries Dominican Republic and Cuba, together with Belize, have experienced a reduction in their agricultural yields. These results evidence a progressive decoupling of agricultural growth from agricultural area expansion, which is a positive sign to increase food-water security. Regarding blue water efficiency use in agriculture, no data exists to track progress over time, which prevents a detailed analysis. However, as discussed in Chapter 10 and detailed in Figure 6.5, irrigation efficiency in LAC remains low compared to the global average (39% of LAC average compared to a global efficiency of 56%). Mesoamerican countries and the Caribbean islands show the lowest rates of irrigation efficiency.

Concerning the environmental status of aquatic ecosystems, the indicator on freshwater diversity status shows a clear trend of environmental degradation across the entire region (see Table 6.3). Countries whose rivers are most degraded include Brazil, Colombia, Peru and Mexico. Overall, and despite the lack of robustness of this indicator, it seems clear that averting environmental degradation and reduced water quality is probably the next most important challenge LAC needs to face in order to avoid unintended environmental but also social and economic side effects. Figure 6.6 shows the trends in public investments in LAC countries on water resources management. Since 2000 a large fraction of the public investments in LAC (either as Official Development Aid (ODA) or as Other Official Flows (OOF)) have been directed to mixed projects of water supply and sanitation. Wastewater treatment investments still represent less than 1% of total public investments.

Table 6.3 Water security progress between 2000 and 2010 in LAC

		AVAILABILITY						ACCESS				UTILIZATION		STATUS		RISK		GOVERNANCE			
		Total Actual Renewable water resources (TARWR, m³/cap./yr) [1]		% Pop. living in water scarce basin		Green water availability (ha of arable land /cap/yr) [1]		% Pop with access to an improved water source		% Pop with access to sanitation		(Green water) Arable productivity (ton/ha/yr) [1]		Freshwater biodiversity (number of threaten species) [2]		Flood risk Index (% population affected by water floods, storms and landslides)		State recognition on the human right to water and sanitation [3]		Water Laws (national laws) [4]	
	COUNTRY	2000	2010	2000	2010	2000	2010	2000	2011	2000	2011	2000	2010	2000	2008	2000	2010	2000	2010	2000	2010
AMAZONIAN	Brazil	45,920	41.886	12	12	0.33	0.31	93	98	75	79	2.6	3.6	70	737	< 1	<1	no	yes	1	3
	Guyana	326,558	318.783	<1	<1	0.61	0.56	89	94	79	84	2.6	2.8	3	23	2	14	yes	yes	no data	no data
	Suriname	254,167	230.624	<1	<1	0.12	0.11	89	92	81	83	2.5	2.8	2	16	<1	3	no data	no data	no data	no data
ANDEAN	Bolivia	71,990	61.707	<1	<1	0.36	0.38	79	88	37	27	1.5	2.0	23	57	<1	<1	no	yes	1	1
	Ecuador	33,242	28.938	<1	<1	0.11	0.11	84	94	81	92	1.6	2.4	no data	no data	<1	<1	yes	yes	1	2
	Peru	71,974	65.068	<1	<1	0.14	0.13	80	85	63	71	2.6	3.1	45	118	<1	<1	yes	yes	1	1
	Colombia	51,901	45.432	<1	<1	0.07	0.04	91	92	73	78	2.7	3.3	148	229	<1	<1	no	yes	1	2
	Venezuela	48,787	41.886	<1	<1	0.11	0.10	92	no data	89	no data	3.0	3.1	43	101	<1	<1	no	yes	0	2
MESOAMERICA	Belize	70,532	58.333	<1	<1	0.26	0.20	85	98	83	90	2.6	2.5	9	25	14	6	no data	no data	no data	no data
	Costa Rica	27,529	45.432	<1	<1	0.05	0.04	95	97	91	95	2.5	2.6	31	69	3	<1	no	yes	no data	no data
	El Salvador	4,213	4.052	<1	<1	0.11	0.11	83	88	61	87	2.1	2.7	4	19	<1	<1	yes	yes	1	1
	Guatemala	9,432	7.542	<1	<1	0.12	0.10	87	92	71	78	1.8	2.1	34	73	<1	<1	no	yes	0	1
	Honduras	14,809	12.370	<1	<1	0.17	0.13	81	87	65	77	1.3	1.5	27	56	4	<1	no	yes	0	2
	Mexico	4,455	3.983	77	78	0.25	0.22	89	96	75	85	2.8	3.5	205	335	<1	<1	yes	yes	1	2
	Nicaragua	37,663	33.492	<1	<1	0,38	0.33	80	85	48	52	1.5	1.7	6	26	3	<1	yes	yes	2	3
	Panama	48,224	41.445	<1	<1	0.19	0.16	90	94	65	69	1.5	1.7	no data	no data	<1	<1	yes	yes	1	2
SOUTH CONE	Argentina	21,616	19.968	13	14	0.76	0.77	96	99	92	90	3.3	4.2	40	86	<1	<1	yes	yes	1	1
	Chile	58,414	84.483	62	63	0.11	0.07	95	96	92	96	4.4	6.0	7	57	<1	<1	yes	yes	6	6
	Paraguay	60,337	51.157	<1	<1	0.57	0.59	74	86	58	71	2.0	2.8	9	27	1	<1	no	yes	1	2
	Uruguay	41,805	41.124	<1	<1	0.42	0.56	98	100	97	100	2.9	3.6	10	27	<1	<1	yes	yes	no data	no data
CARIBBEAN	Cuba	3,411	3.387	no data	no data	0.32	0.32	91	94	87	91	2.1	1.8	16	35	<1	4	no	no	no data	no data
	Dom. Republic	2,370	2.088	no data	no data	0.07	0.09	86	82	78	83	2.8	2.3	no data	no data	2	<1	no	no	1	1
	Haiti	1,580	1.386	no data	no data	0.10	0.11	62	69	23	17	0.8	0.9	no data	no data	2	<1	no	yes	1	1
LAC	weighted average	34,917	32.465	22	23	0.28	0.26	90	90	75	76	2.6	3.3	34	65	3	3	no	yes	1	2

Improvement above the regional average growth — Improvement below the regional average growth — Deterioration or no improvement — No risky change

Source: own elaboration using data from EM-DAT (2013), FAO (2013b; 2013c; 2013d), Hoekstra and Mekonnen (2011), IUCN (2013), World Bank (2013) and WHO-UNICEF (2013)

1 Data for 2000 represent an average for the values of 1999-2001, whereas data for 2010 represent also an average for values of 2008–2010.
2 The inventory of freshwater threatened species was for the first time conducted in 2004 and updated in 2008.
3 State recognition of the human right to water and sanitation acknowledged in national constitutions, laws or policies.
4 Includes national or regional water legislation, laws on natural resources with a specific section on water, domestic supply legislation and specific groundwater law in selected LAC countries.

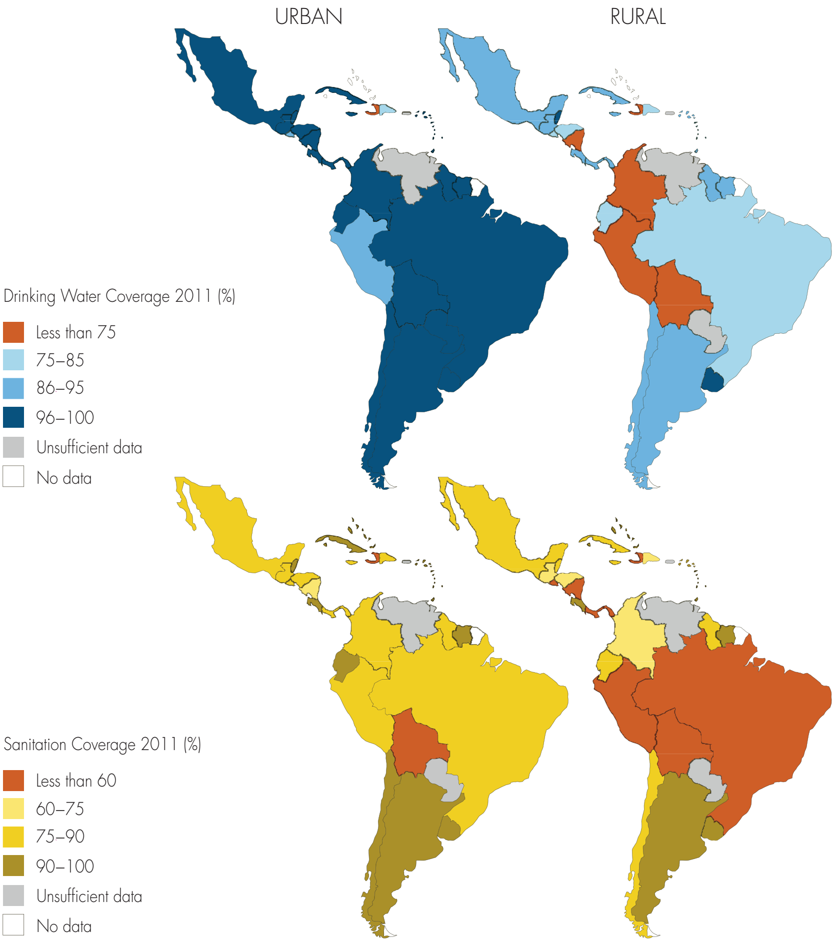

Figure 6.4. Percentage of population with access to drinking water and sanitation coverage in urnban (left) and rural (right) areas in LAC. *Source: own elaboration based on data from WHO-UNICEF (2013).*

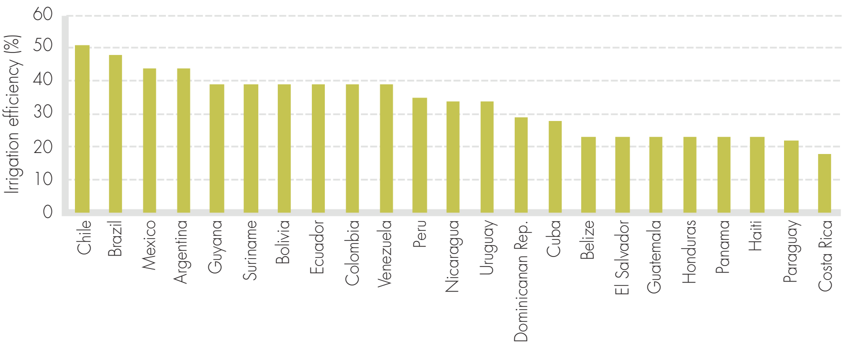

Figure 6.5 Irrigation efficiency (measured in terms of water requirement ratios) for Latin American countries, average for the period 1990–2012. *Source: FAO (2013a)*

The high hydro-climatic variability across many LAC countries represents an important water risk. Floods and droughts have large impacts on WS and FNS as they have large social and economic implications. As Table 6.3 shows, the social impacts of floods (measured in terms of the percentage of the population affected) are relatively low (<3%) for the entire LAC, but in countries like Belize, Guyana or Cuba they have larger impacts. Figure 6.7 summarizes the economic impacts attributed to natural hazards in LAC since 1980. Even though variability is a constant over time, economic impacts related to water hazards are still high, for instance in 2010 they peaked to almost 2 % of LAC's GDP. These trends shows that the region's vulnerability to water hazards is still high, and may not subside, in relative terms, as more growth is seen in terms of infrastructures, the economy, population density and the concentration of said population, thus increasing exposure to these risks (Berz, 1999; Mills, 2009).

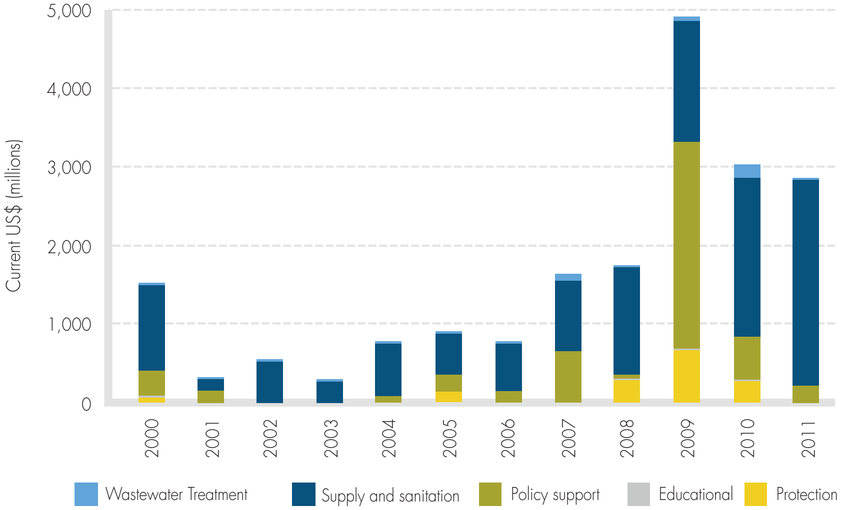

Figure 6.6 Allocation of public investments in water supply and sanitation in LAC, 2000–2010. *Source: based on data from OECD (2013b).*

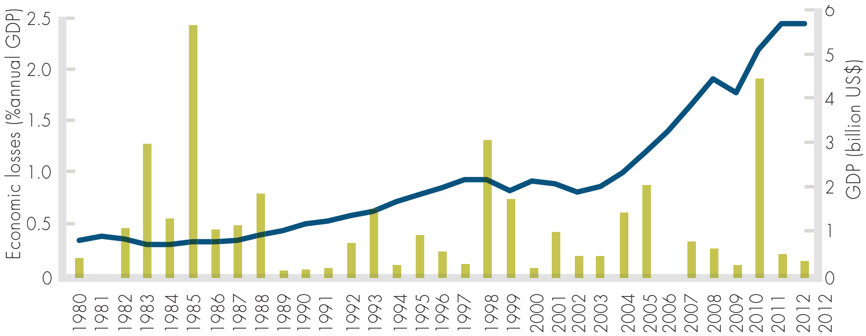

Figure 6.7 Economic losses (expressed in % of annual GDP, bars) attributed to water-related hazards (storms, floods and droughts) and GDP evolution (in USD, line) in Latin America and the Caribbean, 1980–2012. *Source: EM-DAT (2013) and World Bank (2013)*

Good governance and the development of a basic legal framework is a pre-requisite for ensuring countries' WS in the long run (Cook and Bakker, 2012). Several countries such as Costa Rica have made significant progress towards WS despite lacking a national water act. Nevertheless, the existence of a basic legal framework should facilitate the road to improve WS within countries. The recognition of water as a human right, either in their constitutions or under different legislations, and the number of existing water laws (national or regional water acts, groundwater, urban water supply) were used here as a proxy-indicator to ascertain the extent to which legal baseline conditions are in place in LAC countries to reach WS goals and minimize water risks (see Chapter 11). As Table 6.3 shows, water governance overall seems to have progressed substantially more than some WS goals. There is a close correlation between progress achieved in water access and sanitation and the development of legal frameworks. However, these legal frameworks have not been effective at reducing other important water risks associated with increased water pollution and vulnerability to hydro-meteorological events, probably because policy goals were mostly oriented towards securing access to citizens.

The above results can be summarized into two major trends. First, government priorities to improve WS (mostly those concerned with securing access and sanitation) have been effective and remarkable progress has been accomplished. Still, greater efforts are required among the low- and middle-income countries of Mesoamerica and Andean region (see Figure 6.8). The second trend is that upcoming water challenges will most likely require addressing the growing water pollution problem, particularly in megacities, because of the high threat such a trend could represent for LAC's development.

Figure 6.8 Water security performance in LAC countries. *Source: own elaboration based on the data from Table 6.3.*

6.3.2 Food security indicators in LAC

In this section we review a selection of food and nutritional indicators across LAC countries in order to track progress in FNS during the period 2000–2010. As with WS indicators, only those available for the majority of LAC countries and for which it was possible to track temporal changes were considered in this analysis. The selected indicators are shown in Table 6.4.

Table 6.4 Food and nutritional security indicators selected to assess Food and Nutritional Security (FNS) performance in Latin America and the Caribbean (LAC)

DIMENSION	INDICATOR	UNITS
AVAILABILITY	Per capita total amount of net calories available in a given country	kcal/person/day
	Average supply of protein derived from animal resources	g/cap/day
ACCESSIBILITY	Prevalence rate of undernourished people	% of population
	Depth of food deficit (how many calories would be needed to lift the undernourished from their status)	kcal/person/day
UTILIZATION	Prevalence rate of stunting for children under five years old (height-for-age < two standard deviations of the WHO Child Growth Standards Median)	%
	Body Mass Index [BMI < 18.5 Low BMI (chronic energy deficiency)/ BMI > 25 Overweight]	kg/m^2
STABILITY	Per capita food supply variability (Variability of the net food production value between 2004 and 2006 in constant $ divided by the population from UN 2010 estimates.)	%
	Cereal import dependency (Cereal imports/(cereal production+cereal import-cereal export)	%

Source: FAO (2012c)

Table 6.5 reports the progress of the indicators between 2000 and 2010. The indicators that show the best performance in LAC are those related to availability and access. 'Energy supply' improved in most countries and in those where it worsened, only slight reductions were experienced. Among these, Paraguay has the lowest levels and worsened over the specified time period. Ecuador, Guatemala and Haiti stood at fewer than 2,500 kcal/cap in 2010. Also, availability of 'energy from animal protein' improved in most countries. It ranges from 63 grams of protein per capita per day in Argentina to 9 in Haiti. It is below 30 in Belize, Bolivia, Cuba, Guatemala, Haiti, Honduras, Nicaragua, Paraguay, Peru, El Salvador and Suriname. In addition to Haiti's low score, the availability of animal protein is also particularly low in Nicaragua and Guatemala (19), although 35% higher than in 2000. It decreased in Paraguay (reaching 29), Uruguay and Argentina, but in these last two it is still above the regional average.

Overall it is interesting to note that food availability has improved the most among the Andean and Mesoamerican countries and the Caribbean. All Andean countries have improved their availability and access indicators (cells in green). Some countries have recorded increases higher than the average regional growth in these indicators. Some examples of this remarkable positive performance are: Peru and Venezuela in the Andean Region, Dominican Republic in the Caribbean and Nicaragua, Panama and

Honduras in the Mesoamerican region. Although this last region has exhibited significant growth, the case of Guatemala ought to be highlighted. In this country the prevalence of undernourishment ratio is still above 20%. Nicaragua has reduced this indicator from 37.5% to 22.7%, but still this percentage is notably high. Paraguay has seen all of its availability and access indicators go down between 2000 and 2010.

Food access indicators such as 'prevalence rate of undernourished people' and 'depth of food deficit' behaved well in the region. However, a few countries (Argentina, Costa Rica, Guatemala, Paraguay, El Salvador, and Uruguay) worsened in one or the other. Guatemala and Paraguay experienced significant worsening indicators. But Peru, Honduras, Nicaragua, Panama and Venezuela improved significantly. The depth of food deficit was still above 150 kcal in Guatemala, Haiti and Nicaragua in 2010.

Trends for food utilization vary across the LAC region. The prevalence of stunting for children under five has improved in most of the cases, except in Guyana, Dominican Republic and Haiti. Although the largest improvements were concentrated among Andean countries, these countries still have a high percentage of children likely to have stunted growth (more than 20% of children under five years old). For the year 2010, Bolivia, Ecuador and Peru also displayed this ratio above 20%. Considering the relative number of stunted children under five, in 2010 the prevalence rate was 8.2% in Argentina, 7.1% in Brazil, 12.7% in Colombia, 15.5% in Mexico, and 28.2% in Peru, to mention only the most populous countries.

Regarding food, stability indicators vary across the region. In terms of stability, the indicator 'variability of food supply' exhibits a mixed performance in the region. Some countries reduced it significantly, mainly in the Mesoamerican region (Belize, Costa Rica, Nicaragua and Panama) and in the Andes (Bolivia, Ecuador and Peru). Others saw it worsened, including Chile, Paraguay, and Brazil. Most of the countries show a greater cereal imports dependency ratio in 2010 than in 2000, predominantly among Mesoamerican and Caribbean countries where it ranges from 12% in Paraguay to more than 100% in Haiti.

The role of international trade as a means of achieving improved food security has been at the centre of numerous discussions, both in the academic world and at the top international political arena because of the 2007–2009 food price crises. The G20[2] wrote:

> (1). Under the Food Security pillar of the Seoul Multi-year Action Plan on Development, the G20 request that FAO, IFAD, IMF, OECD, UNCTAD, WFP, the World Bank and the WTO work with key stakeholders to develop options for G20 consideration on how to better mitigate and manage the risks associated with the price volatility of food and other agriculture commodities, without distorting market behaviour, ultimately to protect the most vulnerable. … [This report] has been prepared

2 G20 Agricultural Ministers agreed in June 2011 on an 'Action Plan on food price volatility and agriculture', www.g20-g8.com/g8-g20/g20/english/news/news/declaration-of-the-ministers-of-agriculture.1401.html.

Table 6.5 Food security progress between 2000 and 2010 in LAC countries

		AVAILABILITY				ACCESS				UTILIZATION				STABILITY			
	COUNTRY	ENERGY SUPPLY (kcal/cap/day)		ENERGY FROM ANIMAL PROTEIN (gr/cap/day)		PREV. UNDER-NOURISMENT (%population)		DEPTH OF FOOD DEFICIT (kcal/cap/day)		PREV. STUNTING CHILDREN UNDER FIVE YEARS (%)		BODY MASS INDEX (kg/m²)		VARIABILITY FOOD SUPPLY (kcal/cap/day)		CEREAL IMPORTS DEPENDENCY RATIO (%)	
		2000	2009	2000	2009	2000	2010	2000	2010	2000[1]	2010[1]	2000	2008	2000	2010	2000	2010
AMAZONIAN	Brazil	2,882	3,173	40	45	13	8	83	60	14	7	25	26	18	18	19	14
	Guyana	2,814	2,718	38	31	8	6	52	37	14	18	24	26	46	29	36	34
	Suriname	2,457	2,548	24	23	18	13	121	89	15	11	25	27	30	28	34	30
ANDEAN	Bolivia	2,121	2,172	23	26	30	26	200	175	33	27	24	27	64	13	29	24
	Colombia	2,662	2,717	29	34	13	12	86	82	18	13	24	26	24	21	54	59
	Ecuador	2,221	2,267	26	32	20	19	126	124	33	29	25	27	46	19	37	37
	Peru	2,379	2,563	21	25	23	14	151	92	31	28	25	26	36	14	46	49
	Venezuela	2,484	3,014	34	44	15	5	102	20	17	16	27	27	47	41	54	48
MESOAMERICA	Belize	2,560	2,680	26	26	9	7	52	45		22	26	30	36	30	30	30
	Costa Rica	2,825	2,886	36	39	5	5	27	35	9	6	26	26	60	33	87	95
	Guatemala	2,096	2,244	14	19	27	30	167	192	50	48	24	27	48	16	45	49
	Honduras	2,435	2,694	22	27	17	11	100	60	43	30	25	26	8	16	46	52
	Mexico	3,158	3,146	37	42	<5	<5	21	6	22	16	27	29	23	16	35	34
	Nicaragua	2,148	2,517	14	19	38	23	265	151	31	23	25	27	43	16	31	39
	Panama	2,195	2,606	36	40	25	12	175	79	22		26	27	86	41	64	70
	El Salvador	2,561	2,574	18	25	11	12	64	74	29	21	25	28	30	20	47	54
SOUTH CONE	Argentina	3,268	2,918	67	63	<5	<5	7	25	17	8	27	28	54	35	1	0
	Chile	2,808	2,908	38	47	<5	<5	31	26	3	2	26	28	20	39	45	52
	Paraguay	2,596	2,518	42	29	13	19	85	132	18	18	25	25	12	25	15	12
	Uruguay	2,844	2,808	56	39	<5	<5	27	33		14	25	27	43	35	27	16
CARIBBEAN	Antigua & Barbuda	2,155	2,373	49	60	39	21	293	156					48	60	99	99
	Bahamas	2,785	2,750	56	57	6	7	42	50			26	29	41	64	99	99
	Barbados	2,832	3,021	48	54	<5	<5	32	24			26	28	68	16	109	112
	Cuba	3,046	3,258	23	26	<5	<5	21	6	7		25	26	88	111	72	76
	Dominica	3,081	3,147	50	54	<5	<5	24	18					35	36	97	98
	Dom. Republic	2,322	2,491	23	29	23	16	156	107	8	10	25	26	37	31	76	75
	Grenada	2,220	2,456	37	48	31	21	228	156			25	27	45	26	178	129
	Haiti	1,931	1,979	8	9	52	45	429	375	28	30	23	23	55	35	58	59
	Jamaica	2,729	2,807	36	40	7	9	49	58	7	6	23	27	14	7	101	102
	Saint Kitts&Nevis	2,513	2,546	43	43	20	17	143	121					34	54	101	100
	Saint Lucia	2,720	2,710	55	54	11	14	74	97			24	27	30	39	100	101
	S.Vincent	2,528	2,914	35	48	14	6	99	39			25	27	32	14	178	188
	Trinidad & Tobago	2,696	2,751	25	31	13	10	94	73	5		25	29	16	26	111	116

Improvement above the regional average growth | Improvement below the regional average growth | Deterioration

Source: FAO (2012c)

by the listed organisations, with the addition of IFPRI and the UN HLTF, in response to the G20 request. (2). The approach taken in this report reflects the view of the collaborating international organisations that price volatility and its effects on food security is a complex issue with many dimensions, agricultural and non-agricultural, short and long-term, with highly differentiated impacts on consumers and producers in developed and developing countries.

Timmer (2013) indicated that:

> Macro food security refers to a society-wide sense that food is reliably available in urban markets and that adequate purchasing power is a sufficient condition for accessing this food. 'Micro' food security requires that all households (urban and rural) have access to sufficient food, but that is only possible when poverty has been eliminated. 'Macro' food security is often confused (especially politically) with food self-sufficiency, but imported food often plays a key role in providing macro food security. (p.12)

Openness and increasing reliance on trade to import food staples is both a necessity and source of serious concern. Primarily, while 16% of the world's population today relies on food imports, Fader et al. (2013) conclude that 50% of the population will be dependent on imports in 2050 because of land and water constraints, even if food productivity in these countries reached its maximum potential. The OECD (2013b) reports that the net agricultural trade of all the developing countries, excluding Brazil, worsened significantly after the food crisis of 2007–2009.

It has been concluded by numerous authors that the food crisis in 2007–2009 worsened food security indicators in many countries (de Schutter, 2012; and OECD, 2013b). In Table 6.6 it is clear that the rate of improvement of food security indicators was much slower between 2007–2009 and 2010–2011 than it had been between 1990–1992 and 2007–2009. In some countries, including Colombia, Costa Rica, El Salvador, Guatemala, and Paraguay the proportion of people that suffered from hunger increased during the last comparison periods.

Table 6.6 Percentage of people suffering from hunger

	1991–92	2007–09	2010–12	CHANGE BETWEEN 1990–92 AND 2007–09	CHANGE BETWEEN 2007–09 AND 2010–12
LAC	14.6	8.7	8.3	-5.9	-0.4
Caribbean	28.5	18.6	17.8	-9.9	-0.8
Cuba	11.5	<5	<5		
Dominican Rep.	30.4	15.9	15.4	-14.5	-0.5
Haiti	63.5	46.8	44.5	-16.7	-2.3
Latin America	13.6	8.1	7.7	-5.5	-0.4
Argentina	<5	<5	<5		
Bolivia	34.6	27.5	24.1	-7.1	-3.4
Brasil	14.6	7.8	6.9	-6.8	-0.9
Chile	8.1	<5	<5		
Colombia	19.1	12.5	12.6	-6.6	0.1
Costa Rica	<5	5.0	6.5		1.5
Ecuador	24.5	19.6	18.3	-4.9	-1.3
El Salvador	15.6	11.3	12.3	-4.3	1.0
Guatemala	16.2	30.2	30.4	14.0	0.2
Honduras	21.4	11.6	9.6	-9.8	-2.0
Mexico	<5	<5	<5		
Nicaragua	55.1	23.9	20.1	-31.2	-3.8
Panama	22.8	13.1	10.2	-9.7	-2.9
Paraguay	19.7	16.8	25.5	-2.9	8.7
Peru	32.6	15.9	11.2	-16.7	-4.7
Uruguay	7.3	<5	<5		
Venezuela	13.5	<5	<5		

Improvement above the regional average growth   Deterioration

Source: FAO (2012b)

The case of Paraguay has special relevance for our study. In 2011, it exported 48% of the soybean production (FAO, 2012b), reaching US$2.23 billion in exports revenues, 44% more than in the period 2009–2010. And yet, food security indicators worsened significantly in the period of measurement.

In Table 6.7 we report the ratio of imports over national utilization of wheat and maize in several LAC countries. Note that among the worst performing countries in terms of food security indicators, all except Paraguay had dependency rates of 99% or 100%.

De Schutter (2012) highlights some of the improvements being achieved in LAC on implementing the right to food, including: (1) the increased recognition of the right to food in the constitutions of many countries – rich and poor alike – with the development of an expansive legal framework on FNS (e.g. Ley Sistema de Seguridad Alimentaria y Nutricional in Guatemala (2005), Ley de Soberanía y Seguridad Alimentaria in Ecuador (2006), Ley Orgánica de Seguridad Alimentaria y Nutricional in Brazil (2006), Ley Orgánica de Seguridad y Soberanía Agroalimentaria in Venezuela (2008), Ley de Soberanía y Seguridad Alimentaria y Nutricional in Nicaragua (2009), or Ley de Seguridad Alimentaria y Nutricional in Honduras (2011)); and (2) the development of FNS strategies and plans of action (e.g. the Plan Nacional de Seguridad Alimentaria 2009–2015 of Paraguay, the Política Nacional de Seguridad Alimentaria y Nutricional of Nicaragua, the Política de Seguridad Alimentaria y Nutricional 2006–2015 of

Table 6.7 External dependencies of wheat and maize in LAC, (average 2007–2008 and 2011/2012)

	WHEAT		MAIZE	
	Ratio Imports/ Utilization	Consumption (kg/cap/yr)	Ratio Imp/ Utilization	Consumption (kg/cap/yr)
Mesoamerica & Caribbean				
Costa Rica	100	50	-	-
Dominican Rep	99	29	-	-
El Salvador	100	31	38	116
Guatemala	99	34	28	85
Haiti	100	25	-	-
Honduras	98	32	40	79
Mexico	54	50	28	144
Nicaragua	100	21	19	57
Panama	100	43	83	24
South America				
Bolivia	70	55	-	-
Brazil	61	52	-	-
Chile	35	114	52	17
Colombia	100	27	38	41
Ecuador	99	35	37	17
Peru	91	57	54	19
Venezuela	96	56	39	49
Uruguay	-	-	26	32

Source: FAO (2012b)

Honduras, the Política Nacional de Seguridad Alimentaria y Nutricional 2008 in Colombia, the Estrategia Nacional de Reduccion de la Desnutrición Crónica 2006–2016 of Guatemala, the Política Nacional de Seguridad Alimentaria y Nutricional (2003 and 2011) of El Salvador or the Plan Nacional de Seguridad Alimentaria y Nutricional 2009–2015 of Panama). Furthermore, a series of national social programmes also aim explicitly at combating hunger and food and nutrition insecurity, such as the 'Fome Zero' in Brazil, the 'Vivir mejor' in Mexico, 'Bogotá sin Hambre' in Colombia, 'Desnutrición Cero' in Bolivia, or 'Hambre más urgente' in Argentina.

Underlying the general improvement of the LAC region in most FNS indicators, the other side of the coin of food insecurity and probably the greatest challenge this region needs to face in relation to malnutrition is obesity. As shown in Table 6.5, most countries' body mass index indicates worrying levels of overweight (i.e. are above 25 kg/m^2). LAC is the second region in the world, after the US, with the highest percentage of its population obese or overweight (Finucane et al., 2011). Obesity today affects 20% of the Latin American population (> 110 million people) and overweight up to 35% (> 200 million people) (FAO, 2012b). In countries such as Belize, Mexico, Venezuela, Argentina and Chile obesity affects almost 30% of the countries' population, whereas in Brazil and most Andean countries it affects closer to 20% of the population (*ibid.*). Yet, the highest rates of overweight and obesity are found in those countries which are at a stage of nutritional post-transition (FAO, 2010, see also Box 6.1). The underlying reasons behind this type of food insecurity are diverse and include economic, as well as cultural factors. As claimed by Cuevas et al. (2009), 'the increase of overweight and obesity [has] been

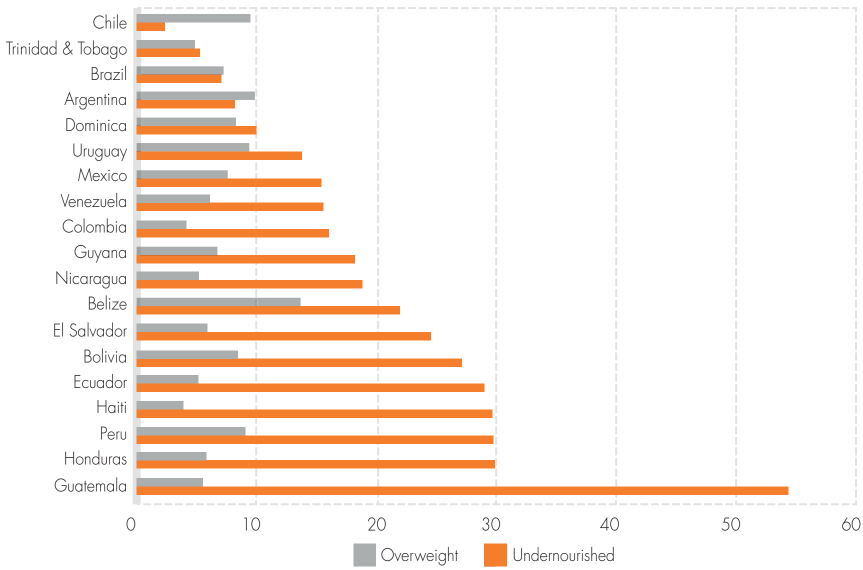

Figure 6.9 Percentage of undernourished and overweight children under five years old (2000–2009). *Source: FAO (2010) using data from Global Health Observatory-WHO 2010*

attributed to lifestyle changes occurring in recent decades related to rapid socioeconomic development, including a more Westernized diet, physical inactivity, urbanization, rural-urban migration and some maternal-fetal factors' (see Box 6.1). Obesity is a serious sign of malnourishment, stands in contrast to the hunger pandemic and has consequences for future generations. Countries that have eradicated hunger are those in a stage of nutritional post-transition and have the highest rates of child obesity. Among them, Argentina, Uruguay and Chile show obesity rates above 9 % (see Figure 6.9).

Box 6.1 The nutritional transition of emerging economies: the case of Brazil

Population growth, economic globalization, improving living standards and urbanization are causing important changes in the global food system in addition to modifying the dietary habits in many parts of the world (CAWMA, 2007; Godfray et al., 2010). As countries develop and populations become wealthier, the nutritional transition occurs. This transition implies a shift away from traditional staple foods such as roots and tuber vegetables and a rise in the consumption of meat and milk products, refined and processed foods as well as sugars, oils and fats (Ambler-Edwards et al., 2009).

In Brazil important changes have occurred to the food consumption patterns since 1987 (see Figure 6.10). In absolute terms, food consumption per capita has decreased over time from 360kg per capita in 1987 to 315kg per capita in 2009. However, most importantly the composition of the diet has experienced significant changes. In 1987 Brazilians had a balanced diet with an intake of predominantly vegetables, fruits, cereals and legumes (around 90 per capita per year of each). Rice, native tubers such as cará, potatoes, beans and tropical fruits like bananas and citruses were fundamental components of the diet prior to 1990. Animal protein consumption in the late 1980s was relatively high (> 50kg per person per year), equivalent to the average intake of richer regions like Europe (≈ 60kg per person per year in 1990) (Westhoek et al., 2011). However, since 1987 noteworthy changes have taken place in the composition of the food pyramid. Overall, the intake of vegetables, fruits and dairy products has decreased significantly (between 36 and 38%), whereas the consumption of processed food, stimulants and sugary products has experienced a dramatic increase (80%). Brazilians eat twice as much sugar as they did in 1987, 30% more processed food and almost 50% more non-alcoholic drinks and mineral water. The largest reduction in fruit and vegetable consumption is due to the lower intake of citruses and local tubers. Among the dairy products, the largest reduction is due to the lower intake of milk (from 68 litres per capita in 1987 to 40 litres in 2009). Overall, a nutritional transition in Brazil occurred in the late 1990s and early 2000s, overlapping with the economic takeoff of the country. Nevertheless, and compared to the prevailing trend in other developed regions, diet changes in Brazil have not translated into a greater consumption of animal protein, simply of food items linked to urban lifestyles.

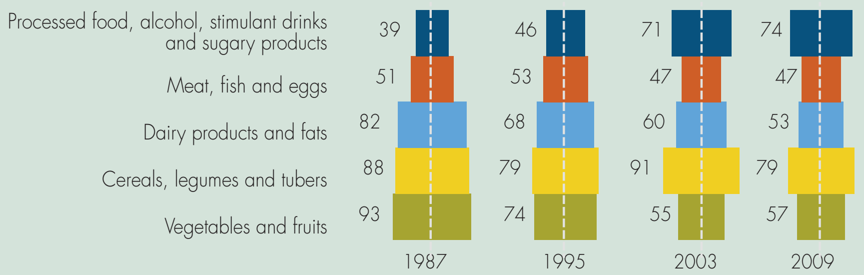

Figure 6.10 Food consumption pyramids (in consumed kg per capita per year) for Brazilians during the last two decades. *Source: own elaboration based on household survey – Pesquisa de Ornamentos Familiares: POF – for the years 1987/1988, 1995/1996, 2002/2003 and 2008/2009 (IBGE, 2013).*

6.4 Linking water and food security in Latin America

The purpose of this final section is to assess whether improvements and progress in water and food security indicators correlate across countries and to what extent they are interrelated. As shown in previous sections, economic development to a large extent explains part of the trends and current status. Therefore, in order to carry out the joint analysis of water and food security indicators we grouped the countries according to per capita income (as measured in 2010). The four figures (6.11 to 6.14) all have three panels, each with the set of countries belonging to the corresponding quartile of per capita income. Lastly, for each country and panel we present two points, corresponding to the pairs of selected WS and FS indicators measured in 2000 and 2010. Note that the scale differs across the three panels of each graph. This way data in this section shows five dimensions: time, country, per capita income, one WS indicator and one FS indicator.

The following pairs of indicators are plotted in Figures 6.11, 6.12, 6.13 and 6.14: prevalence of undernourishment (%) against access to improved sanitation (%); prevalence of stunting in children under five (%) against access to improved sanitation in rural areas (%); and finally prevalence of stunting in children under five (%) against access to drinking water (%).

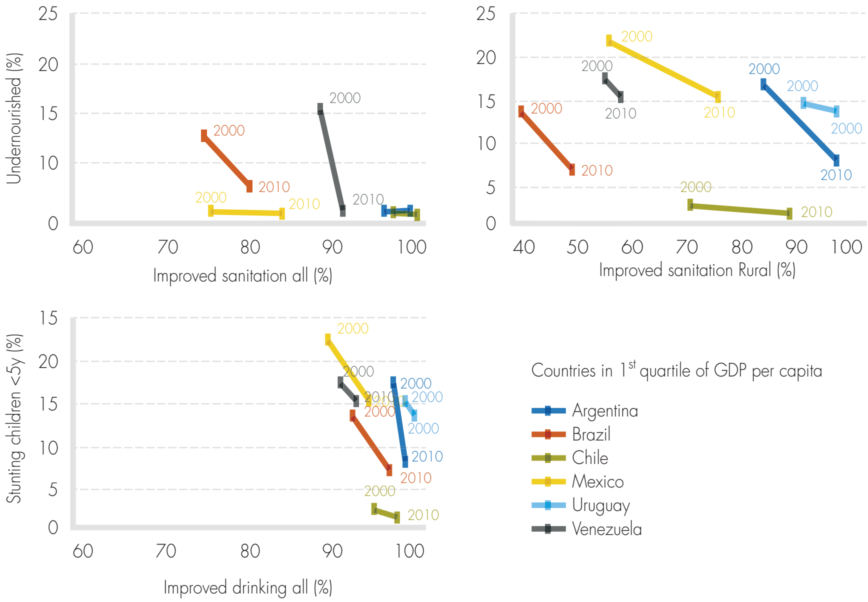

Figure 6.11 Three pairs of water and food security indicators measured in 2000 and 2010 (countries of the first quartile of per capita income in 2010). *Source: FAO (2010) using data from Global Health Observatory.*

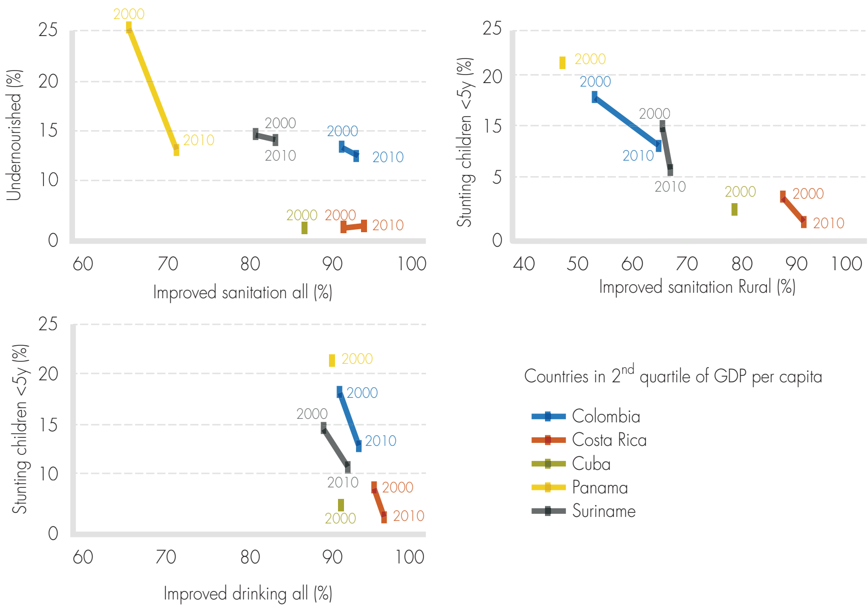

Figure 6.12 Three pairs of water and food security indicators measured in 2000 and 2010 (countries of the second quartile of per capita income in 2010). *Source: FAO (2010) using data from Global Health Observatory.*

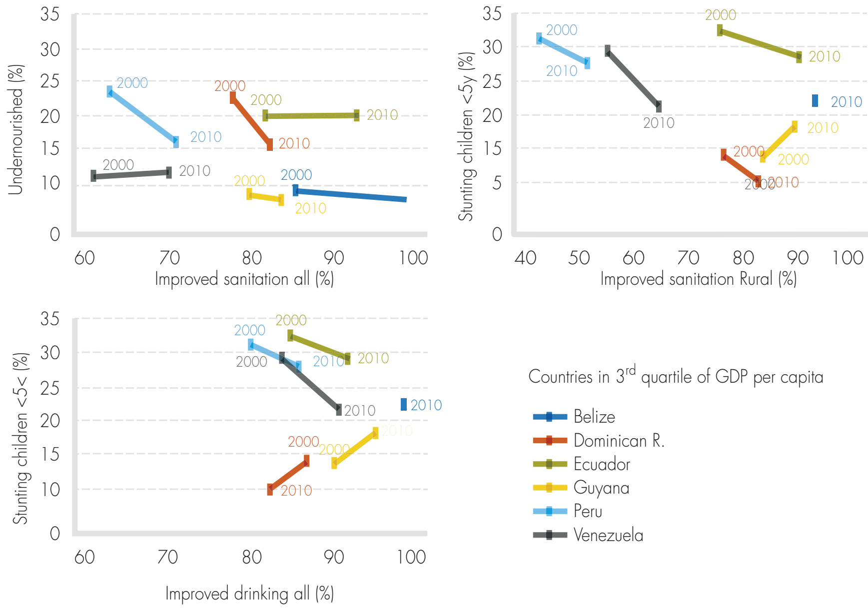

Figure 6.13 Three pairs of water and food security indicators measured in 2000 and 2010 (countries of the third quartile of per capita income in 2010). *Source: FAO (2010) using data from Global Health Observatory.*

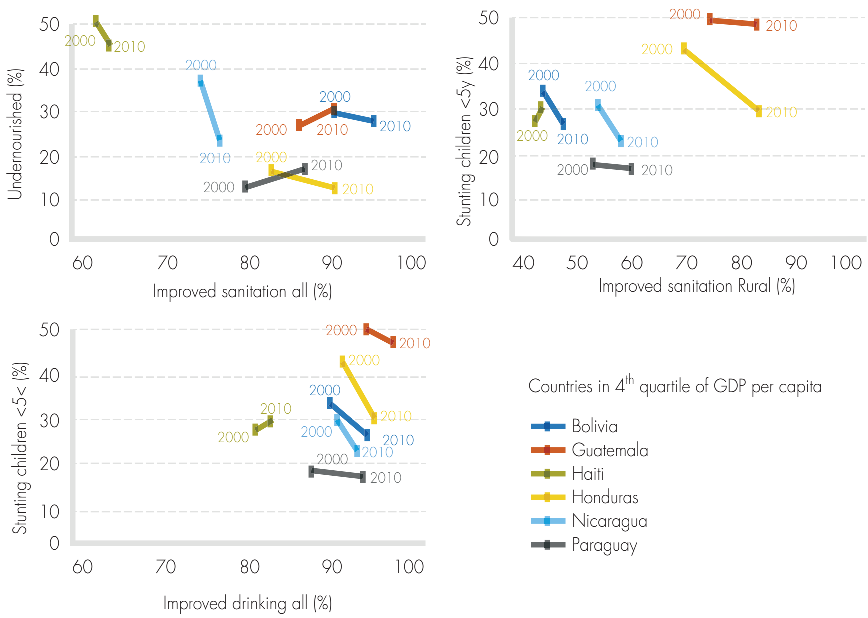

Figure 6.14 Three pairs of water and food security indicators measured in 2000 and 2010 (countries of the fourth quartile of per capita income in 2010). *Source: FAO (2010) using data from Global Health Observatory.*

By examining the Figures 6.11 to 6.14, we can draw the following conclusions. First, per capita income largely explains the pattern of improvements of the five indicators represented in these figures. From countries with the highest (Figure 6.11) to the lowest per capita income (Figure 6.14), the direction and slope of the segments overall become less homogeneous and more chaotic. In the groups of countries of the two lowest quartiles, some segments are upwardly sloped, and some hardly show any improvement between 2000 and 2010. Therefore, income growth and per capita income is fundamental for improving both WS and FS indicators.

Second, the reduction of the prevalence of stunting in children under five is closely correlated to the improvement of access to sanitation in rural areas. Except for Guyana, the remaining twenty-two countries exhibit downward sloping segments whose slopes tend to be similar within groups of countries. This would indicate that improved sanitation and the reduction of stunting in children evolve in parallel, although causation cannot be established.

Third, based on the different improvements and base levels of the percentage of undernourished people and stunted children across groups of countries, it seems clear that the reduction of undernourishment precedes the reduction of stunting in children. This would suggest that countries find it easier to reduce undernourishment rates than reducing the proportion of stunted children. We would thus conclude that ensuring nutritional security is more complex than simply reducing undernourishment, such as these concepts are defined by FAO. NS requires more specific programmes, population targets and a strong focus on pregnant women and children, especially amongst the most vulnerable.

Fourth, improving sanitation is for the most part preceded by improvements in access to drinking water, especially in rural areas. The consequences of not improving sanitation infrastructure and delaying its deployment to further stages of economic development are found in impaired water quality and ecosystems, reduced biodiversity and a greater prevalence of water-borne diseases.

Last, there is still a huge gap in terms of improving sanitation in the region, especially in rural areas. The investments required to bridge this gap are reviewed in Chapter 13, and the institutional challenge is the focus of Chapter 1.

6.5 Final remarks

The overview of a wide range of variables for most LAC countries within a span of a decade tells three overall stories. First, that the consequences in coping with the problems of insufficient sanitation have eventually materialized in increasing costs to reverse its impacts and in moving towards more sustainable economic development. It is true that the investment needs are, for some countries, overwhelming. For others with growing economies and rapid poverty alleviation, ensuring proper sanitation in rural areas and water treatment in both large cities and rural areas should be an affordable priority.

Second, it seems that common patterns of nutritional transition in the prosperous LAC countries show growing rates of overweight and obesity. This has worrying negative effects, in both impaired human health and pathologies, but also in the larger footprints of the diets that are behind this emerging pandemic. In the case of LAC, the 49 million people suffering from undernourishment coexist with 110 million obese people, and with 200 million overweight. Only by educating people at the basic level can this trend be curbed and a worse disaster averted. It is important that the nutritional transition does not follow this path, but solutions are far from clear.

Last, while the performance in LAC countries of most WS and FNS indicators can be explained by the relative level of per capita income, there are significant differences amongst countries even within the same income quartile. National policies are thus crucial to rapidly improve the situation and reach the poorest and more vulnerable members of society.

References

Allan, J.A. (2013). *Food-water security: beyond hydrology and the water sector*. Working paper. [Online] Available from: www.ditchley.co.uk/assets/media/Allan%20-%20water%20security%20chapter%20v3.pdf [Accessed May, 2013].

Ambler-Edwards, S., Bailey, K., Kiff, A., Lang, T., Lee, R., Marsden, T., Simons, D., & Tibbs H. (2009). *Food Futures: Rethinking UK Strategy*. The Royal Institute of International Affairs. London, Chatham House Report.

Banerjee, A.V., & Duflo, E. (2011). *Poor economics: a radical rethinking of the way to fight global poverty*. New York, Public Affairs.

Barrett, C.B. (2010). Measuring food insecurity. *Science,* 327: 825–828.

Berz, G.A. (1999). Catastrophes and climate change: concerns and possible countermeasures of the insurance industry. *Mitigation and Adaptation Strategies for Global Change*, 4: 283–293.

CAWMA (2007). Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, Earthscan, and Colombo, International Water Management Institute.

CIESIN-FAO-CIAT (2005). Center for International Earth Science Information Network-Columbia, University United Nations Food and Agriculture Programme, Centro Internacional de Agricultura Tropical. *Gridded Population of the World, Version 3 (GPWv3): Population Count Grid, Future Estimates*. Palisades, NY, NASA Socioeconomic Data and (SEDAC). [Online] Available from: sedac.ciesin.columbia.edu/data/set/gpw-v3-population-count-future-estimates [Accessed May 2013].

CFS (2009). Committee on World Food Security. *Reform of the Committee on World of Food Security: Final Version*. [Online] Available from: ftp://ftp.fao.org/docrep/fao/meeting/017/k3023e3.pdf [Accessed September, 2012].

Cook, C., & Bakker, K. (2012). Water security: Debating an emerging paradigm. *Global Environmental Change*, 22(1): 94–102.

Cuevas, A., Alvarez, V., & Olivos, C. (2009). The emerging obesity problem in Latin America. *Expert Review Cardiovascular Therapy, 7*(3): 281–288.

De Schutter, O. (2012). *United Nations Special Rapporteur on the Right to Food*. September, 2012. Briefing Note. [Online] Available from: www.srfood.org/images/stories/pdf/otherdocuments/note06-septembre2012-en-v2.pdf [Accessed May, 2013].

EM-DAT (2013). Emergency Events Database on Disasters. World Health Organization and Centre for Research on the Epidemiology of Disasters Database. [Online] Available from: www.emdat.be/ [Accessed May, 2013].

Fader, M., Gerten, D., Krause, M., Lucht, W., & Cramer, W. (2013). Spatial decoupling of agricultural production and consumption: quantifying dependences of countries on food imports due to domestic land and water constraints. *Environmental Research Letters*, 8(1): 014046.

FAO (1998). Food and Agriculture Organization. *Guidelines for national food insecurity and vulnerability information and mapping systems (FIVIMS): background and principles*. Rome, FAO. [Online] Available from: www.fao.org/docrep/meeting/W8500e.htm [Accessed May, 2013].

FAO (2010). Food and Agriculture Organization. *Panorama de la Seguridad Alimentaria y Nutricional en América Latina y el Caribe 2010*. Rome, FAO.

FAO (2012a). Food and Agriculture Organization. *Coping with water scarcity. An action framework for agriculture and food security*. Rome, FAO.

FAO (2012b). Food and Agriculture Organization. *Panorama de la Seguridad Alimentaria y Nutricional en América Latina y el Caribe 2012*. Rome, FAO. [Online] Available from: www.rlc.fao.org/es/publicaciones/panorama-2012/.[Accessed May, 2013].

FAO (2012c). Food and Agriculture Organization. *Food security indicators*. Rome, FAO. [Online] Available from: www.fao.org/fileadmin/…/foodsecurity/Food_Security_Indicators.xlsx. [Accessed May, 2013].

FAO (2013a). Food and Agriculture Organization. *Irrigation water requirement and water withdrawal by country*. Rome, FAO. [Online] Available from: www.fao.org/nr/water/aquastat/water_use_agr/index7.stm [Accessed May, 2013].

FAO (2013b). Food and Agriculture Organization. FAOSTAT. [Online] www.faostat.fao.org/ [Accessed May, 2013].

FAO (2013c). Food and Agriculture Organization. AQUASTAT. [Online] Available from: www.fao.org/nr/water/aquastat/main/index.stm [Accessed May, 2013].

FAO (2013d). Food and Agriculture Organization. WATERLEX Statistics. Rome, FAO. [Online] Available from: faolex.fao.org/waterlex/ [Accessed May, 2013].

Finucane, M.M., Stevens, G.A., Cowan, M.J., Danaei, G., Lin, J.K., Paciorek, C.J. & Ezzati, M. (2011). National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. *The Lancet,* 377 (9765): 557–567.

Frankenberger, T.R., Oshaug, A. & Smith, L.C. (1997). *A definition of nutrition security*. Atlanta, CARE.

GWP (2000). Global Water Partnership. *Towards Water Security: A Framework for Action*. [Online] Available from: www.gwp.org/ [Accessed July, 2013].

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F. & Toulmin, C. (2010). Food security: the challenge of feeding 9 billion people. *Science,* 327 (5967): 812–818.

Grey, D. & Sadoff, C.W. (2007). Sink or swim? Water security for growth and development. *Water Policy,* 9(6): 545.

Hoddinott, J. (1999). *Choosing outcome indicators of household food security. Technical Guide No. 7*. Washington DC, IFPRI. [Online] Available from: afghanlivelihoods.com/virtual-library/Livelihoods/householdfoodsecurity-ifpr.pdf [Accessed July, 2013].

Hoekstra, A.Y. & Mekonnen, M.M. (2011). Global water scarcity: the monthly blue water footprint compared to blue water availability for the world's major river basins. Delft, The Netherlands, UNESCO-IHE. Value of Water Research Report Series No. 53.

IBGE (2013). Instituto Brasileiro de Geografia e Estatística. *Pesquisa de Ornamentos Familiares (POF) 1987/1988, 1995/1996, 2002/2003 & 2008/2009*. [Online] Available from: www.sidra.ibge.gov.br. [Accessed July, 2013].

IUCN (2013). International Union for Conservation of the Nature. *The Red List Database of Threatened Species*. Version 2013.1. [Online] Available from: www.iucnredlist.org. [Accessed July, 2013].

Lopez-Gunn, E., Willaarts, B.A., Dumont, A., Niemeyer, I. & Martinez-Santos, P. (2012). The concept of water and food security in Spain. In: De Stefano and Llamas. *Water, agriculture and the environment in spain: can we square the circle?* CRC – Press and Botín Foundation.

Mason, N. & Calow, R. (2012). *Water Security: from abstract concept to meaningful metrics. A initial overview of options*. London, Overseas Development Institute.

Mekonnen, M.M. & Hoekstra, A.Y. (2011). *National water footprint accounts: The green, blue and grey water footprint of production and consumption:* UNESCO-IHE. Value of Water Research Report Series No. 50. [Online] Available from: www.waterfootprint.org/Reports/Report50-NationalWaterFootprints-Vol1.pdf [Accessed May, 2013].

Mills, E. (2009). A Global Review of Insurance Industry Responses to Climate Change. *The Geneva Papers*, 34: 323–359.

OECD (2013a). Organization for Economic Development and Cooperation. *Global food security. challenges for the food and agricultural system*. Paris, OECD publishing.

OECD (2013b). Organization for Economic Development and Cooperation. *OECD StatExtracts*. [Online] Available from: stats.oecd.org/Index.aspx?DatasetCode=CRSNEW [Accessed July, 2013].

Onis, M.D., Blössner, M. & Borghi, E. (2011). Prevalence and trends of stunting among pre-school children, 1990–2020. *Public Health Nutrition*, 14 (7): 1–7.

Pangaribowo, E.H., Gerber, N. & Torero, M. (2013). *Food and Nutrition Security Indicators: A Review* (No. 147911). FOODSECURE working paper No. 5. [Online] Available from: www.foodsecure.eu. [Accessed March, 2013].

Sen, A. (1982). *Poverty and famines: an essay on entitlement and deprivation*. London, Oxford University Press.

Starr, J. (1992). Water security: The missing link in our Mideast strategy. *Canadian Journal of Development Studies/Revue canadienne d'études du développement*, 13(4): 35–48.

Sullivan, C.A., Meigh, J.R., & Giacomello, A.M. (2003). The Water Poverty Index: Development and application at the community scale. *Natural Resources Forum*, 27 (3): 189–199.

Suweis, S., Rinaldo, A., Maritan, A. & D'Odorico, P. (2013). Water-controlled wealth of nations. *Proceedings of the National Academy of Sciences,* 110 (11): 4230–4233.

Swinnen, J. F. & Squicciarini, P. (2012). Mixed messages on prices and food security. *Science,* 335(6067): 405–406.

Timmer, P. (2013). Preface. In: Gaultier, F. (ed). *Managing food price instability in developing countries: A critical analysis of strategies and instruments*. Paris, CIRAD.

United Nations (2012). *Food and nutrition security for all through sustainable agriculture and food systems.* Note from the United Nations System High Level Task Force on Global Food Security. [Online] Available from: www.un-foodsecurity.org. [Accessed July, 2013].

UNDP (1994). United Nations Development Programme. *New dimensions of human security. human development Report 1994.* New York, Oxford, Oxford University Press.

UNESCO (2010). *Guía metodológica para la aplicación del Análisis Regional de Frecuencia de Sequías basado en L-momentos y resultados de aplicación en América Latina.* Montevideo, Uruguay, CAZALAC. Documentos Técnicos del PHI-LAC No. 27.

UN-Water (2013). United Nations Water Programme.*Water security & the global water agenda: a un-water analytical brief.* [Online] Available from: www.unwater.org/downloads/watersecurity_analyticalbrief.pdf [Accessed July, 2013].

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P. & Davies, P.M. (2010). Global threats to human water security and river biodiversity. *Nature,467* (7315): 555–561.

Westhoek, H., Rood, T., Van den Berg, M., Janse, J., Nijdam, D., Reudink, M. & Stehfest, E. (2011). *The protein puzzle.* The Hague, PBL Netherlands Environmental Assessment Agency.

WHO-UNICEF (2013). *Joint Monitoring Programme (JMP) for water supply and sanitation data.* [Online] Available from: www.wssinfo.org/data-estimates/table/ [Accessed July, 2013].

World Bank (2013). *World Bank Development Indicators Database.* [Online] Available from: data.worldbank.org/data-catalog/world-development-indicators [Accessed July, 2013].

Part 3

Water for food and non-food

7

WATER AND AGRICULTURE

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Highlights

- This chapter shows the strong links between water, agriculture and the economy in Latin America and Caribbean (LAC). Both green and blue water are vital for LAC's economies and for its food security. Awareness of LAC's virtual water trade volumes and water footprints alone will not solve the local or global water problems. However, the awareness gained increases the likelihood that optimized water allocation decisions, which consider the hydrological and economical aspects of water resources, are made.
- Agriculture is a significant economic sector for many LAC countries with some being major world players in the agricultural commodities world markets, such is the case for Brazil and Argentina who contribute to 13% of the global green water export. At the micro level, agriculture still plays a significant role for the food security of the population.
- The consumptive water use of agricultural production was on average 1,057Gm^3/yr for the period 1996–2005; of which, 95% corresponds to the green water footprint, whereas 5% refers to the blue component. This indicates that LAC relies heavily on green water for agricultural production, i.e. rain-fed agriculture.
- Maize is a fundamental crop in Argentina, Brazil, Chile, Mexico and Peru, representing 15% of the total agricultural blue and green water footprint (773,408hm^3/yr) and contributing to 35% of the agricultural nitrogen pollution, estimated as grey water footprint, in Argentina, Brazil, Chile, Colombia, Mexico and Peru. Only in Mexico, maize contributes 60% of the agricultural grey water footprint.
- Grazing represents 24% of the total green water footprint of agriculture in these countries. The blue water consumption by the animal water supply is very significant in Argentina, Brazil, Chile, Mexico and Peru, which amounts to 13% (38,825hm^3/yr) of the total consumption.
- Concerning agricultural products, the LAC region was a net exporter of green virtual water (14Gm^3/yr) and a net importer of blue virtual water (16Gm^3/yr) during the period 1996–2005.
- Export-oriented industrial agriculture has become the main driver of South American deforestation.
- Sustainable water management should not be seen as a barrier for the development of the region, but rather as the way to develop and grow as a region.

- Understanding the magnitude of overlap and interactions between poverty, conservation and macro-economic processes is crucial in order to identify possible win–win solutions for the LAC region. Access to agricultural water has secondary effects on poverty through output, employment and prices.

7.1 Introduction

The Latin American and Caribbean region (LAC) as a whole is increasingly becoming a major source of agricultural commodities for the world market and thus influencing food security. As such, improving resource management in the region promises to have important benefits for both the inhabitants of LAC and the world.

Agriculture is essential to food security. However, food production requires substantial amounts of water, both stored in the soil as soil moisture from rain (green water) and as water for irrigation (blue water). FAO (2012b) estimated an annual blue water use in LAC of 262,800hm^3/yr. Globally, agriculture is the sector with the largest water withdrawal by far, with about 70%. This percentage compares to 73%, (192,700hm^3/yr) in LAC, whereas 19% and 9% correspond to the domestic and industrial sectors respectively (*ibid.*). The Guyana sub-region (Guyana and Suriname) and Southern Cone (Argentina, Chile, Paraguay and Uruguay) have the highest level of agricultural water use, with values of 96% and 91% respectively (*ibid.*). Agriculture is also central to economic growth in LAC. For the period 2000–2007, it contributed an average of 9.6% to its GDP and exports of agricultural commodities accounted for 44% of total export value in 2007 (Bovarnick et al., 2010). Notably the agricultural sector provides employment for about 9% of LAC's population (UNEP, 2013).

Globally, a substantial part of the most fertile land is already being used for agriculture. According to FAO (2012a), much of the remaining arable land is located in LAC and sub-Saharan Africa, however, it is in remote locations, far from population centres and agricultural infrastructure, and cannot be converted into productive land without investments in infrastructure development. In LAC, agricultural production increased by more than 50 % from 2000 to 2012, with Brazil expanding production by more than 70 %. Most food is produced by rain-fed agriculture in LAC, with 87% of the cropland being rain-fed (Rockström et al., 2007). The irrigation potential for the region is estimated at 77.8 million hectares (FAO, 2013), whereas in 2009 the LAC region had 13.5 million hectares of irrigated agriculture. The gap between the irrigation potential and actually irrigated agriculture is due to increasing costs of construction, limited government support for large-scale irrigation investments and concerns about the negative social and environmental impacts of irrigation (UNCTAD, 2011). Most of the regional irrigation potential (66%) is located in four countries: Argentina, Brazil, Mexico and Peru (*ibid.*). Figures on irrigation potential usually only take into account climatic conditions and land irrigation sustainability, while studies including surface- and groundwater availability are considered scarce (FAO, 2013).

Water quality deserves as much attention as water quantity. Local and regional physical water scarcity problems are exacerbated by severe water quality problems in LAC; leading to the frequent usage of wastewater for irrigation. Many countries in LAC have been facing increasing challenges in water quality management. The world's major water quality issues as identified by United Nations (UN, 2003) are organic pollution, pathogens, salinity, nitrate, heavy metals, acidification, eutrophication and sediment load either in surface water bodies or in groundwater.

LAC is relatively well endowed with water resources. However, the spatial and temporal variability of water, coupled with rapid urbanization and inadequate water governance is putting considerable pressure on the available water resources (see Chapter 2 and 6 for an analysis of water scarcity in LAC). Ironically, in the water abundant LAC, almost 20% of its nearly 600 million inhabitants do not have access to drinking water, 20% do not have any kind of access to a sewage system, and less than 30% of the wastewater receives treatment (Proceso Regional de las Américas, 2012). In addition almost 18 million of children under five suffer from chronic malnutrition (FAO, 2012b). This elevated distributive inequity is a notable element in the reality of LAC.

This chapter analyses the challenges and opportunities of water management in the region from the perspective of the agricultural sector. First, water is accounted in terms of quantity and quality. Virtual water trade in the LAC region is also analysed and, finally, a productivity analysis is presented taking into account social and economic aspects.

7.2 Methodology and data

In this chapter we use the water footprint (WF) (Hoekstra et al., 2011) to calculate water consumption. The 'water footprint' is a measure of humans' appropriation of freshwater resources. Freshwater appropriation is measured in terms of water volume consumed (evaporated or incorporated into a product) or polluted per unit of time. A water footprint has three components: green, blue and grey. The blue water footprint refers to consumption of blue water resources (surface and ground water). The green water footprint is the volume of green water (rainwater stored in the soil as soil moisture) consumed, which is particularly relevant in crop production. The grey water footprint is an indicator of the degree of freshwater pollution and is defined as the volume of freshwater that is required to assimilate the load of pollutants based on existing ambient water quality standards.

In the context of the countries considered, the water footprint accounting is applied from two perspectives: the water footprint of agricultural production and the water footprint of agricultural consumption. The water footprint of agricultural production for a given country refers to the blue, green and grey water footprints of all the agricultural processes, that is, crop and livestock production, taking place within the political borders of the country. The water footprint of agricultural production is equivalent to the agricultural 'water footprint within the area of the nation' (Hoekstra et al., 2011), and is defined as the total freshwater volume consumed or polluted within the territory of the nation as a result of activities within the different sectors of the economy, in this case agriculture.

The water footprint of agricultural consumption refers to the quantification of the water consumed and polluted to produce the agricultural products consumed by the population of a country. It consists of two components: the internal and external water footprint of national consumption. The internal water footprint is defined as the use of domestic water resources to produce goods and services consumed by the population of the country. It is the sum of the water footprint within the nation minus the volume of virtual-water exported to other nations through the export of products produced with domestic water resources. The external water footprint is defined as the volume of water resources used in other nations to produce goods and services consumed by the population in the nation under consideration. It is equal to the virtual water import into the nation minus the volume of virtual water export to other nations as a result of re-export of imported products. The virtual water export from a nation consists of exported water of domestic origin and re-exported water of foreign origin. The virtual-water import into a nation will partly be consumed, thus constituting the external water footprint of national consumption, and may in part be re-exported (Mekonnen and Hoekstra, 2011).

The grey water footprint data used refer to the nitrogen pollution alone and are based on Mekonnen and Hoekstra (2011), who estimated the grey water footprint based on nitrogen leaching-runoff from fertilizer use. The fraction of nitrogen that leaches or runs off multiplied by the nitrogen application rate represents the load of nitrogen reaching the surface and subsurface water bodies. Some 10% of the applied nitrogen fertilizer is assumed to be lost through leaching-runoff. In order to estimate the grey water footprint, an ambient water quality standard of 10mg/l measured as Nitrate-nitrogen (NO_3-N) was used, following the guidelines of the US Environmental Protection Agency (US-EPA).

The countries analysed in this chapter as LAC correspond to the thirty-three countries of the Economic Commission for Latin America and the Caribbean (ECLAC) plus Puerto Rico. Data from other non-sovereign Caribbean islands are included in tables whenever available.

7.3 Water accounting

7.3.1 Water quantity

7.3.1.1 Water withdrawal in agriculture

In the majority of the countries of the region, irrigation is seen as an important means to increase productivity, and enable and intensify crop diversification, an objective of most agricultural policies of governments in the region (FAO, 2013). Irrigated areas increased steadily during the 20th century and particularly from the 1950s onwards (*ibid.*). These increases are, however, modest in comparison to Asia and sub-Saharan Africa. Mexico has by far the largest irrigated area with over 6.5 million hectares; and Brazil is next with 3.2 million hectares, followed by Chile, Argentina, and Bolivia (UNCTAD, 2011). About

0.5 million hectares in Brazil are located in the semi-arid northeast region – an area with the lowest social and economic indicators (Oliviera et al., 2009).

Figures on irrigation water use (non-consumptive) are expressed in cubic metres per hectare per year, and show certain homogeneity for the whole of South America and the Greater Antilles, varying between 9,000m^3/ha/yr and 12,000m^3/ha/yr. Figures for Mexico are slightly higher, 13,500m^3/ha/yr, and for Central America even higher. In the case of Mexico, the higher value is probably due to its climatic characteristics (higher potential evapotranspiration), while Central America is dominated by its permanent crops (banana, sugar cane, etc.) and its high cultivation intensity in temporary crops such as rice (FAO, 2013).

Concerning the irrigation techniques, surface irrigation is by far the most widespread irrigation technique in LAC. Table 7.1 presents information on irrigation techniques by sub-region for the countries in which information was available. It is worth noting the importance of localized irrigation in the Lesser Antilles (32.1%), where water scarcity and farm characteristics have induced an extensive utilization of localized irrigation, and in Brazil (6.1%). Sprinkler irrigation covers significant areas in Cuba (51%), Brazil (35%), Panama (24%), Jamaica (17%) and Venezuela (16%).

According to FAO (2013), the major source of irrigation water in the region is surface water, with the exception of Nicaragua and Cuba where groundwater is the source for respectively 77% and 50% of the area under irrigation.

Mexico, Brazil, Argentina, Chile, Venezuela and Peru have the highest irrigation water withdrawal (FAO, 2013) and account for 81% of the total irrigation water withdrawal in the region. It is worth noting that from these six countries, Mexico, Chile and Peru have the highest levels of water scarcity in the region.

7.3.1.2 Blue and green water consumption of agricultural production

Quantifying actual crop water consumption is crucial to understanding real water needs for agriculture. The consumptive water use of agricultural production (crops and livestock) for the LAC region, i.e. the green and blue water footprints of agricultural production, was on average 1,057Gm^3/yr for the period 1996–2005, corresponding to 13.9% of the global water footprint of agricultural production (Mekonnen and Hoekstra, 2011). Of these 1,057Gm^3, 95% corresponds to the green component of the water footprint, whereas only 5% corresponds to the blue component. Brazil alone accounts for 42.4% of the total (green and blue) water footprint in the region, followed by Argentina (17.1%), Mexico (11.7%), Colombia (4.9%) and Paraguay (3.1%) (Figure 7.1). These five countries account for 79.2% of the total water footprint of the region. This data points towards two fundamental issues: (i) LAC relies heavily on green water (95%) for agricultural production, i.e. rain-fed agriculture; (ii) Brazil and Argentina alone account for 60% of agricultural water consumption in LAC. This provides an indication of the global significance of these two countries in terms of agricultural water consumption and virtual water trade.

The total blue water footprint of agricultural production in the region was 50.9Gm^3/yr. In this case, the country with the biggest contribution is Mexico (29.2%), followed by

Table 7.1 **Irrigation techniques in the LAC region**

SUB-REGION	IRRIGATION TECHNIQUES						
	SURFACE		SPRINKLER		LOCALIZED		TOTAL
	ha	%	ha	%	ha	%	ha
MEXICO	5,802,182	92.7	310,800	5.0	143,050	2.3	6,256,032
CENTRAL AMERICA	418,638	93.0	17,171	3.8	14,272	3.2	450,081
GREATER ANTILLES	746,894	63.6	407,075	34.6	21,256	1.8	1,175,225
LESSER ANTILLES	2,890	53.8	761	14.2	1,725	32.1	5,376
GUYANA SUB-REGION	201,314	100	0.0	0.0	0.0	0.0	201,314
ANDEAN SUB-REGION	3,379,637	95.6	122,364	3.5	34,536	1.0	3,536,537
BRAZIL	1,688,485	58.8	1,005,606	35.0	176,113	6.1	2,870,204
SOUTH SUB-REGION	3,445,068	95.6	95,730	2.7	62,153	1.7	3,602,951
LAC REGION	**15,672,050**	**86.7**	**1,960,365**	**10.8**	**453,105**	**2.5**	**18,097,720**(1)

Source: FAO (2013).

1 This is an approximate figure of land under irrigation, which represents the physical area with irrigation infrastructure. It is not the area that is actually irrigated in a given year. As a global figure provided by FAO, 80% of the area under irrigation is actually irrigated. Given the problems in operation, maintenance and rehabilitation of the irrigation districts, it is estimated that the real figure must be lower (see section 7.1 for estimated numbers of area under irrigation in LAC).

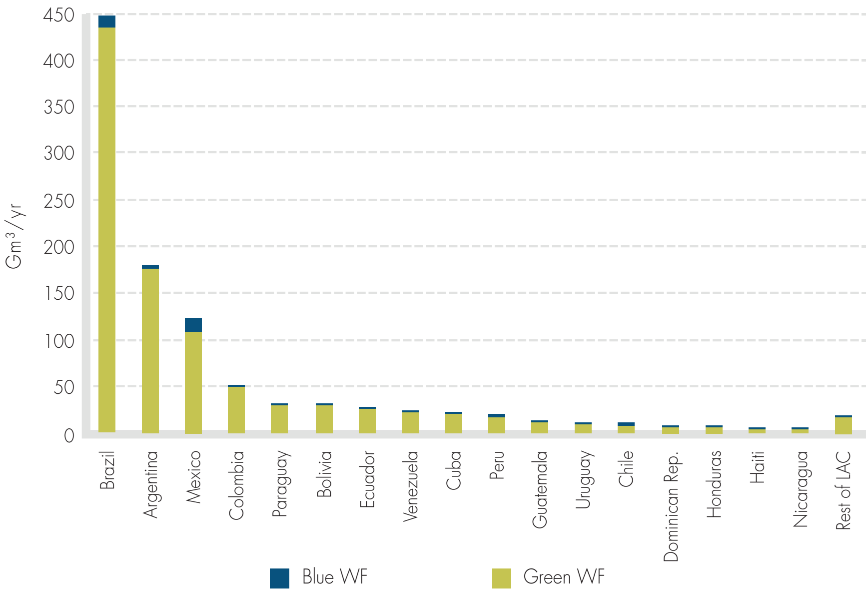
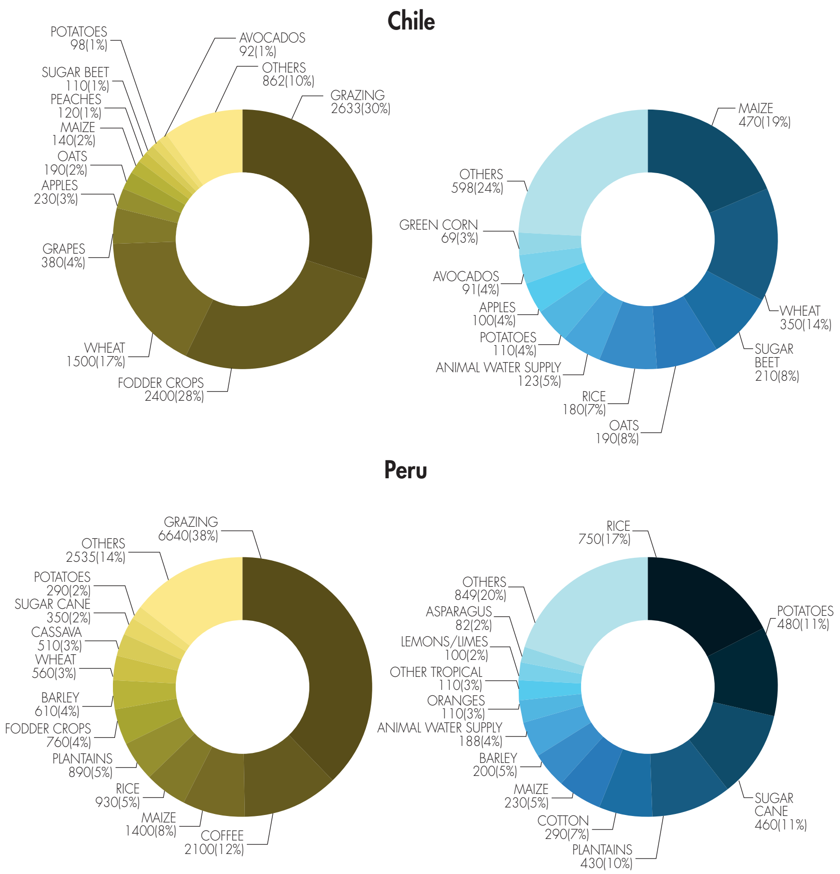


Figure 7.1 **Green and blue water footprint (in cubic Gigametres per year) of agricultural production for the LAC region (average 1996–2005).** *Source: own elaboration based on data from Mekonnen and Hoekstra (2011).*

Brazil (23.7%), Argentina (10.0%), Peru (8.4%) and Chile (4.9%). These five countries are responsible for 76.2% of the total blue water footprint in the LAC region and for 75% of the total (green and blue) water footprint of the region.

Not surprisingly, countries with fewer available water resources in the areas of important economic activity, like Mexico, Peru and Chile, rely more on blue water resources compared to the other countries. Brazil and Argentina occupy together 55% of the LAC area and therefore contribute with a significant blue water footprint. These five countries with the greatest blue water footprint of agricultural production, namely Mexico, Brazil, Argentina, Peru and Chile, together cover 75% of the LAC area.

Figure 7.2 shows the distribution of agricultural green and blue water footprints for Mexico, Brazil, Argentina, Peru and Chile, according to their main agricultural uses.



(Figure 7.2 continues in the next page)

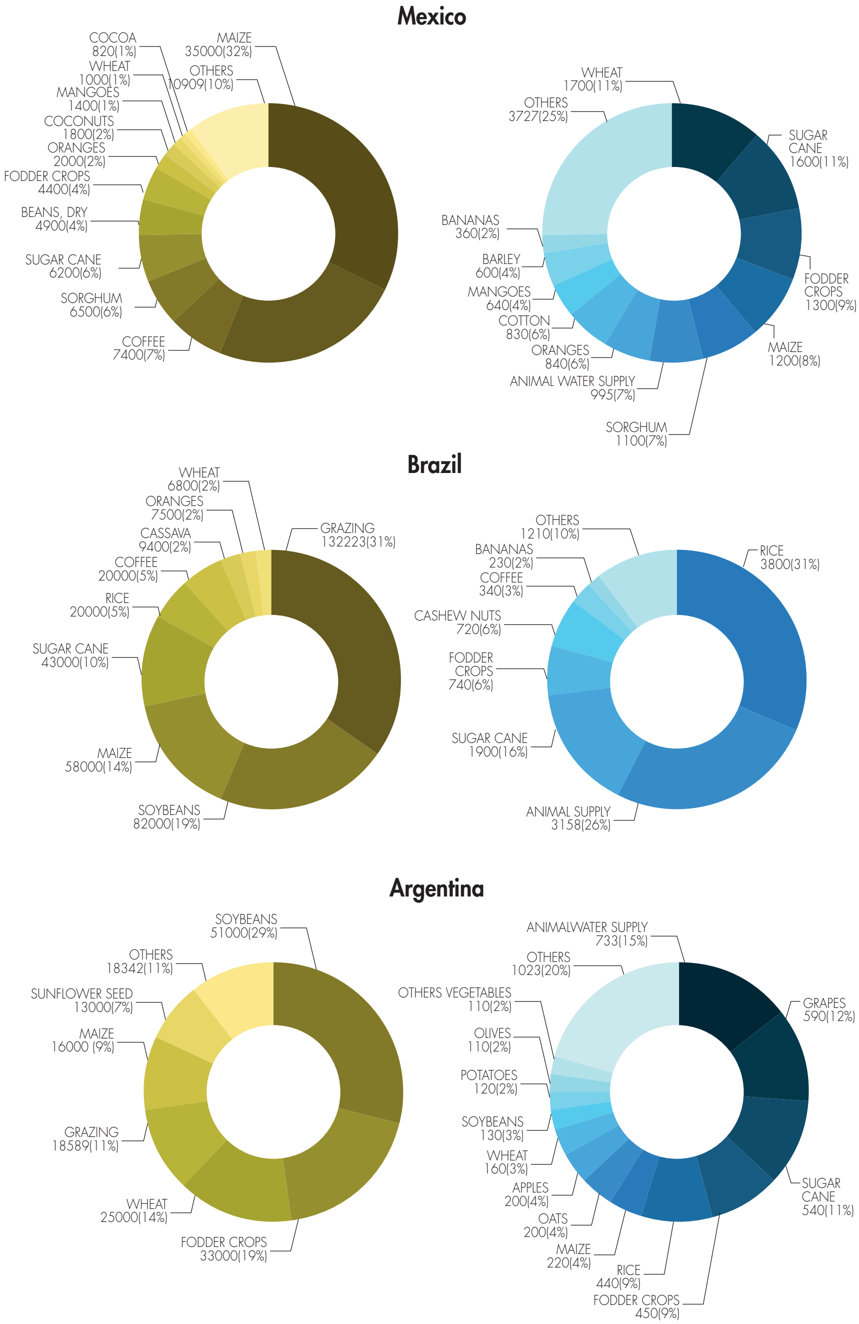


Figure 7.2 **Distribution of the agricultural green and blue water footprint (in cubic hectometres per year) of Mexico, Brazil, Argentina, Peru and Chile (average for the years 1996–2005).** *Source: own elaboration based on Mekonnen and Hoekstra (2011) and the Water Footprint Assessment Tool (WFN, 2013b).*

Maize is a fundamental crop in all five countries as shown in Figure 7.2. It represents 15% of the total agricultural (blue and green) water footprint (WF) of these five countries equivalent to 773,408hm^3/yr. Soybean is especially important in Brazil and Argentina, and accounts for 17% of the total agricultural blue and green WF of these five countries. Grazing contributes significantly with 24% of the total green WF of agriculture in these countries. The blue water consumption for the animal water supply in the five countries, which amounts to 13%, or 8,825hm^3/yr, is also noteworthy. In the context of water policy, being aware of water allocation for livestock is essential when considering food security for LAC (Box 7.1). Sugar cane is also an important crop for all the above-mentioned countries except Chile (for climatic reasons), which shows a stronger production of cash crops such as grapes, apples and avocados. Rice makes up a significant part of the blue WF for all the countries except Mexico (14% of the total blue WF of the five countries). Potatoes constitute a very important crop in Peru (Box 7.2).

7.3.1.3 Water footprint agricultural products' consumption: externalization of the water footprint

The average global water consumption of agricultural products was 1,156m^3/capita/yr (88% green, 12% blue) for the period 1996–2005 (Mekonnen and Hoekstra, 2011). The equivalent value for the LAC region was 1,473m^3/capita/yr (94% green, 6% blue). Figure 7.3 shows that water footprints range between 3,420m^3/capita/yr (98% green, 2% blue) for Bolivia and 833m^3/capita/yr (95% green, 5% blue) for Nicaragua. Chile, Peru, Mexico and Dominican Republic have the highest percentage of blue water in their water footprints of consumption, with values of 16, 15, 10 and 10% respectively. Countries with the lowest blue water proportion are Bolivia (2%), and Brazil, Uruguay, Paraguay and Dominica (3%).

The virtual water import dependency of a nation is defined as the ratio of the external to the total water footprint of national consumption, whereas the national water self-sufficiency is defined as the ratio of the internal to the total water footprint of national consumption. The Lesser Antilles and Mexico have the highest virtual water dependency in the LAC region. Saint Lucia, Trinidad and Tobago and Bahamas show virtual water dependencies above 90%, whereas Mexico's corresponding value is approximately 45%. This means that these countries import most of the virtual water required to cover the agricultural needs of its population, meaning they have a notable dependency on external water resources. Chile and Peru, both countries characterized by significant levels of water scarcity (see Chapter 2), show virtual water import dependencies of 37 and 34% respectively. Conversely, Paraguay, Argentina, Bolivia and Brazil have very low virtual water import dependency values (2, 3, 9 and 9 % respectively) indicating high self-sufficiency. This means that these countries use their own available resources to supply most of the agricultural products consumed by their inhabitants.

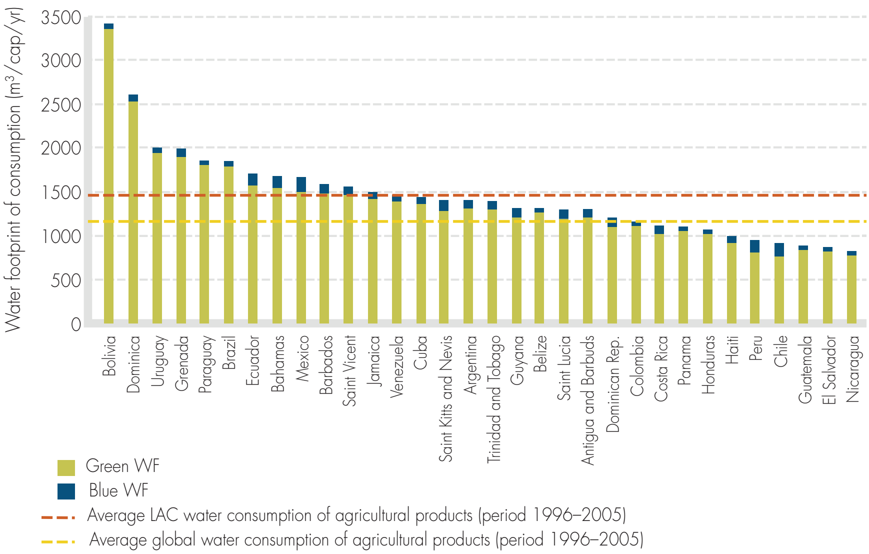


Figure 7.3 Water footprint (in cubic metres per inhabitant per year) of the consumption of agricultural products (green and blue) in the LAC region (average 1996–2005). *Source: own elaboration based on data from Mekonnen and Hoekstra (2011).*

Box 7.1 Water footprint of poultry and swine production per Brazilian state

Brazil is one of the major producers of animal products in the world and also a large exporter. The country is rich in water sources, which are mostly located in the Amazon Basin. Swine and poultry production are concentrated in different regions, mainly in the south, one of the most urbanized and industrialized parts of the country. Therefore, studies that aim to calculate the water footprint are extremely important to the society to inform upon water security, elaborate discussions on the topic and ensure the future of the production.

We calculated the water footprint of pigs slaughtered in 2008 in south-central states of Brazil. Calculations considered indirect water consumed in grain production (corn and soybean), and direct water, drinking and washing water consumed on the farm. Rio Grande do Sul was the state with the largest water footprint (2,702,000hm^3, 99.9% green and 0.09% blue), followed by Santa Catarina (2,401,000hm^3, 99.88% green and 0.12% blue), and Parana (1,089,000hm^3, 99.85% green and 0.15% blue). These are the states where slaughter is practised most. Although, Rio Grande do Sul is the second in terms of animals slaughtered, its water footprint was the largest due to dry climatic conditions, which require more water to produce the same amount of corn and soybean. States with high corn and soybean productivity had a lower ratio of water volume consumed per kg of meat, namely Distrito Federal (2.49m^3/kg), Parana (2.53m^3/kg), and Goias (2.77m^3/kg).

The water footprint of broiler chicken slaughtered in the decade 2000–2010 in each of Brazil's south-central states was also calculated. Similarly the calculation considered indirect water, consumed in grain production, and direct water, consumed on the farm. South states had the largest water footprints and the largest number of animals slaughtered during the period. The average footprint for Parana in the decade in question (2000–2010) was 4,334hm^3 (99.7% green and 0.3% blue) and Rio Grande do Sul 4,216hm^3 (99.8% green and 0.2% blue). Slaughters increased and/or remained constant in all states. Annual variation was determined by productivity of corn and soybeans.

Results show that water management in animal production should not only address the farm; but also include related agricultural supply chains, where most of the water consumed is green. Blue and grey water footprints, most notable in the direct water use of the farm, are also important as they are consumed in watersheds with an increased potential for water use conflicts (Palhares, 2012).

Box 7.2 Importance of potatoes in the Peruvian diet

Potato (*Solanum Toberusum*) is a South American tuber that grows in a wide variety of environments, ranging from cold to temperate climates, and in altitudes ranging from sea level to 4,700m. It is the fourth most important crop in the world behind rice, wheat and maize and the third most important in human consumption, feeding more than one billion people worldwide (CIP, 2010).

FAO (2008) indicates that potatoes are very productive from the nutritional viewpoint. For each m^3 of water applied to potato crops, 5,600 calories are produced. By comparison, 1m^3 of water applied to corn produces 3,800 calories and only 2,000 calories if it is applied to rice. In addition, 1m^3 of water applied to potatoes produces 150g of proteins and 540mg of calcium. Therefore, potatoes' protein content per cubic metre is more than double that of maize and wheat and offers twice the calcium provided by wheat and four times that of rice.

The average European consumption is 87.8kg potatoes/year/person. By comparison, per capita consumption of potatoes per year is 60kg in North America, 13.9kg in Africa, 23.9kg in Oceania and 20.7kg in Latin America, although its consumption is steadily growing in the latter region (FAO, 2008).

In Latin America, the highest yields are obtained in Argentina (28.7t/ha) and the lowest yields are obtained in Bolivia (5.6t/ha). In the Andean countries potato cultivation is mostly in hands of small farmers. Higher yields are related to improved technology, sufficient water supply and better management.

The Andean population uses productive domesticated species to overcome the limitations of poor productivity of wild plants, although these do not grow at altitudes greater than 4,500m. *Solanum jozepozukii* and *Solanum curtilobum* are frost-resistant potatoes that grow at high elevations where agriculture is practised (Moran, 1982).

An ongoing study (LA-Peru, 2012) indicates that, on average, production of 1kg of potatoes requires only 469 litres of water. Mekonnen and Hoekstra (2011) provide a lower global average WF figure of 290litre/kg: 66% related to green, 11% to blue and 22 % to grey WF. Potato cultivation is concentrated in the mountainous area of the Andean region and the Pacific Basin. Crops are rain-fed during the wet season (January–March) and during the rest of the year in which precipitation is negligible, flood or furrow irrigation is used. In some cases, water is not applied in the last months of the vegetative period, and the yield is very low (Egúsquiza, 2000). Initial watering appears to be sufficient to achieve an acceptable growth and even with a low yield potatoes help to cover part of the basic nutritional needs of poor communities in the Andean Highlands.

Further population growth and shortage of water resources in some areas in the near future may force a substantial change in crop cultivation patterns. For instance, rice is grown in a number of valleys where water is scarce. It might be more advantageous from the water conservational, nutritional and even economic point of view to grow potatoes instead. In addition, potato productivity ought to be increased, particularly in the Andean countries.

7.3.2 Water quality

The most well-known effects of agriculture on water quality are due to chemical contamination by fertilizers and pesticides that accumulate in water sources. Additionally the reuse of sewage effluent for irrigation, known to transmit a number of pathogens even after secondary water treatments, can seriously affect the quality of the water used in agriculture. Significant water pollution due to irrigation has been reported in Barbados, Mexico, Nicaragua, Panama, Peru, Dominican Republic and Venezuela (Biswas et al., 2006). In addition, the problem of salinity caused by irrigation is a serious constraint in Argentina, Cuba, Mexico, and Peru and, to a lesser extent, in the arid regions of northeastern Brazil, north and central Chile and some small areas of Central America (*ibid.*).

This section focuses mainly on the agricultural grey water footprint caused by nitrogen pollution in LAC due to the use of fertilizers. The total of which amounted to 44,412hm^3/yr for the period 1996 to 2005. This value corresponds to 46% of the total grey water footprint in the region; 96,649hm^3/yr including the industrial and domestic sectors (17% and 37%, respectively). The countries contributing the most to the total agricultural grey WF of the region are Brazil, Mexico, Argentina, Chile, Colombia and Peru. The total agricultural grey WF of these six countries was 39,017hm^3/yr, corresponding to 88% of the agricultural grey WF in the LAC region. Brazil and Mexico alone already constitute 61% of the agricultural grey water footprint in the region (and 51% of the LAC area).

7.3.2.1 Most important corps contributing to the grey water footprint in the LAC region

Figure 7.4 shows the crops contributing the most to the grey WF for Brazil, Mexico, Argentina, Chile, Colombia and Peru.

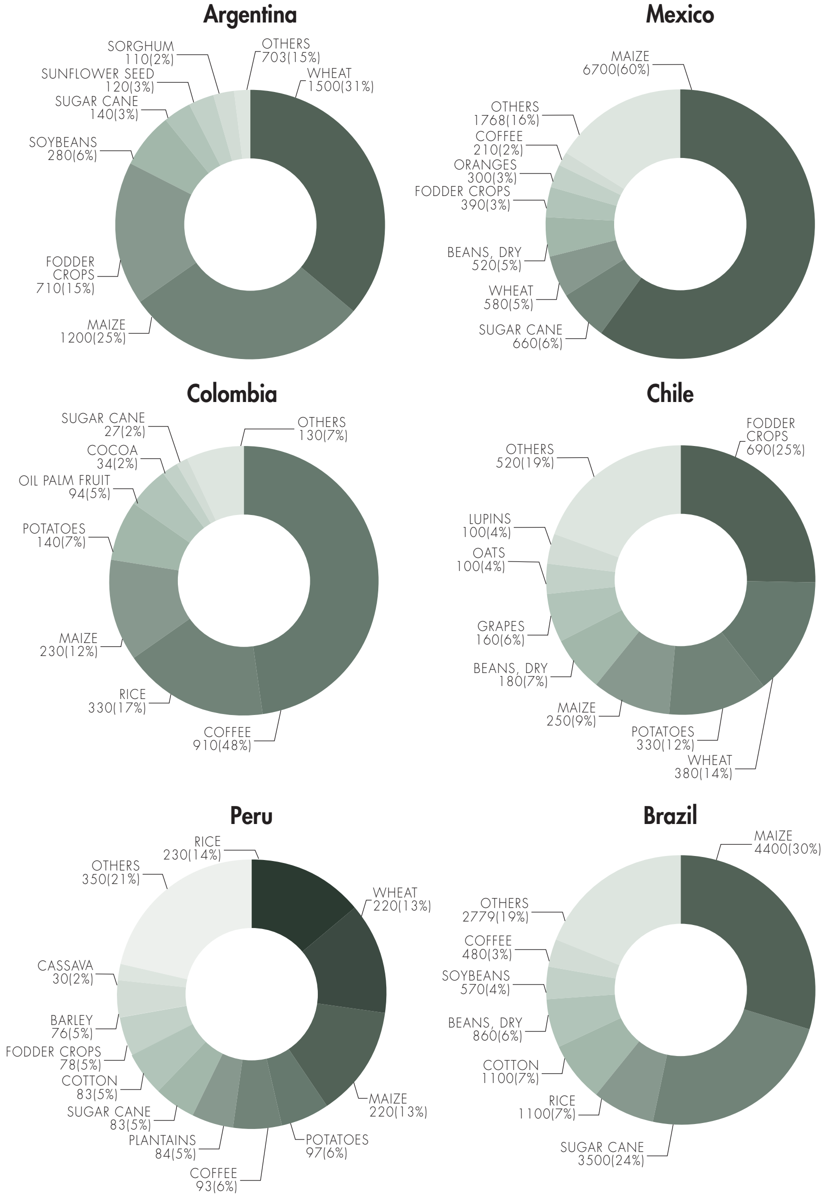


Figure 7.4 Composition of the agricultural grey water footprint (in cubic hectometres per year) by crops in Brazil, Mexico, Argentina, Chile, Colombia and Peru. *Source: own elaboration based on Mekonnen and Hoekstra (2011) and the Water Footprint Assessment Tool (WFN, 2013b).*

These figures show that maize is a heavily fertilized crop and contributes significantly to the grey WF in all six countries: 35% of the agricultural grey WF of these six countries corresponds to this crop. In Mexico alone it contributes to 60% of the agricultural grey WF. Sugar cane contributes 12% of the total agricultural grey water footprint of these six countries, whereas coffee, rice and fodder crops contribute 5%. Notably coffee contributes 48% of the agricultural grey WF of Colombia.

These above-mentioned grey water footprint results are only with respect to nitrogen, for which the grey water footprint for all the countries and products is publicly available (Mekonnen and Hoekstra, 2011). This allows for straightforward comparisons, however, a large number of agrochemicals are used in the LAC region. For example, Costa Rica tops the list of Latin American countries using multiple agrochemicals, which counter-balances many of their environmental policies seeking to improve environmental quality in the country (LA-Costa Rica, 2012). Costa Rica annually imports about 13,000t of some 300 active ingredients, many of which are restricted and/or prohibited in other countries and are even included in international disposal agreements (*ibid.*). A portion of the active ingredients is repackaged and re-exported. Although there are no precise data on the exported quantities, it is estimated that around 20–25% of total imports are re-exported (Ramirez et al., 2009). The import data therefore does not accurately reflect the quantities used in the fields, but they serve to check usage trends (LA-Costa Rica, 2012).

7.3.2.2 Grey water footprint of consumption of agricultural products in LAC

The average world WF of consumption of agricultural products was 1,268m^3/capita/yr during the period 1996–2005, with 1,156m^3/capita/yr corresponding to the blue and green WF and 112m^3/capita/yr to the grey WF, equivalent to 91 and 9% of the total respectively (Mekonnen and Hoekstra, 2011). For the LAC region, the average was 1,560m^3/capita/yr, with 1,473m^3/capita/yr corresponding to the blue and green WF and 87m^3/capita/yr to the grey WF, equivalent to 94 and 6 % respectively. Grey WF values range from 272.4m^3/capita/yr for Belize and 19.5m^3/capita/yr for Bolivia.

The externalization of the grey WF is equivalent to the externalization of pollution due to importing of agricultural products. Argentina has the lowest external grey water footprint as a proportion of their total grey WF (6%), together with Paraguay and Belize (9%). On the other hand, countries like Bahamas, Saint Lucia, Grenada, Trinidad and Tobago, Saint Vincent and the Grenadines, Antigua and Barbuda and Dominican Republic have a 100% external grey water footprint. This indicates that while for Argentina, Paraguay and Belize the pollution caused by consumption of agricultural products (in this case due to nitrogen) is mostly internal, i.e. caused within the borders of the countries, pollution caused due to consumption of agricultural products in the Antilles is borne by other countries.

7.3.3 Virtual water flows related to trade of agricultural products

The net virtual water import of a country or region during a given period of time is defined as the gross import of virtual water minus the gross export. A positive net import of virtual water implies net inflow of virtual water to the country or region. A negative net import of virtual water implies net outflow of virtual water, which means that the country is a net exporter of virtual water (Hoekstra et al., 2011). LAC was a net exporter of virtual water in terms of agricultural products during the period 1996–2005 (Mekonnen and Hoekstra, 2011). The net virtual water import for LAC was 125.4Gm^3/yr. This means that for agricultural products, LAC was a net exporter of green virtual water (141.5Gm^3/yr) and a net importer of blue virtual water (16.1Gm^3/yr).

Figure 7.5 shows the countries with the largest virtual water flows of agricultural products in the region. Mexico is the largest virtual water importer, followed by Trinidad and Tobago, Venezuela, Peru and Chile. The countries with the largest virtual water exports related to agricultural products are Argentina, Brazil, Paraguay, Uruguay and Honduras.

Argentina and Brazil primarily produce for world markets under rain-fed conditions, which indicates an increased use of green water instead of blue water. This is reflected in the scale differences used for blue and green virtual water exports in Figure 7.6. According to Mekonnen and Hoekstra (2011), these two countries contribute with 13% of the total green water exported in the world (whereas LAC contributes with 19%), which constitutes an indication of the global importance of green water provided to the world food market by Argentina and Brazil, notably as green water is generally associated with lower opportunity costs than blue water (Albersen et al., 2003). Following the notion of opportunity costs, it has been argued that the use of green water in crop production

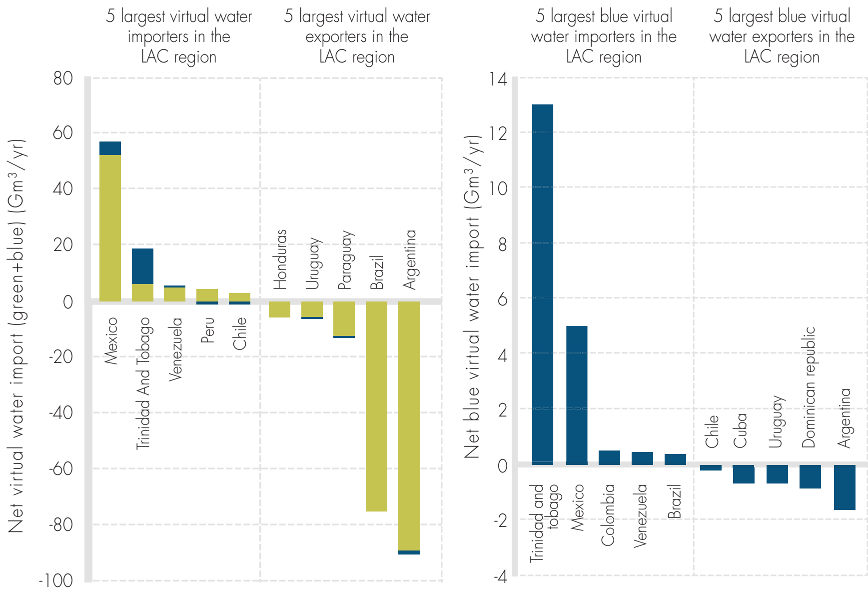
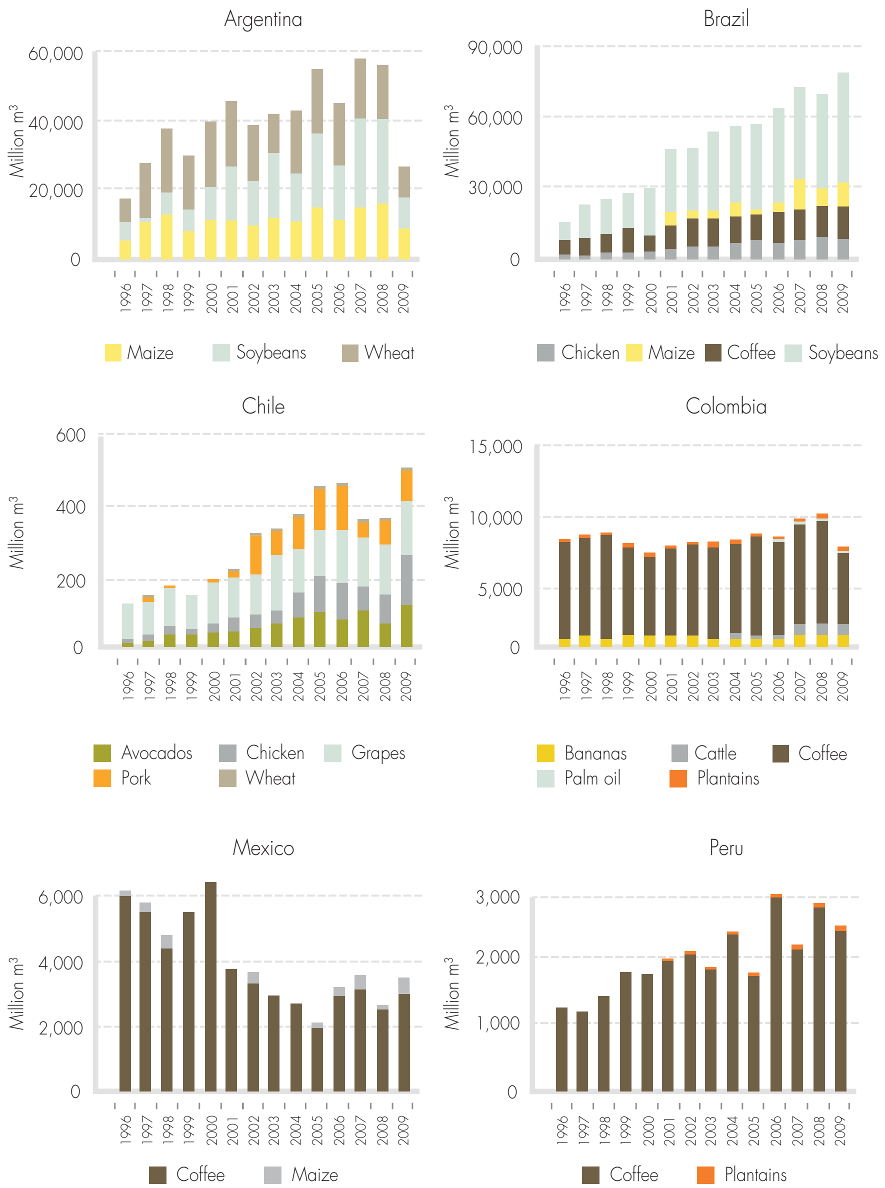


Figure 7.5 Largest total (green and blue) net virtual water importers and blue net virtual water importers (in cubic Gigametres per year) of agricultural products in the LAC region (average 1996–2005). *Source: own elaboration based on data from Mekonnen and Hoekstra (2011).*

is considered more sustainable than blue water use, except when replacing high-value ecosystems (Yang et al., 2006; Aldaya et al., 2010; Niemeyer and Garrido, 2011). On the other hand, expanding rain-fed agriculture is often associated with massive land use changes. Especially in Brazil where increasing virtual water exports contained in soybeans has led to a threefold land footprint increase.

Green virtual water exports



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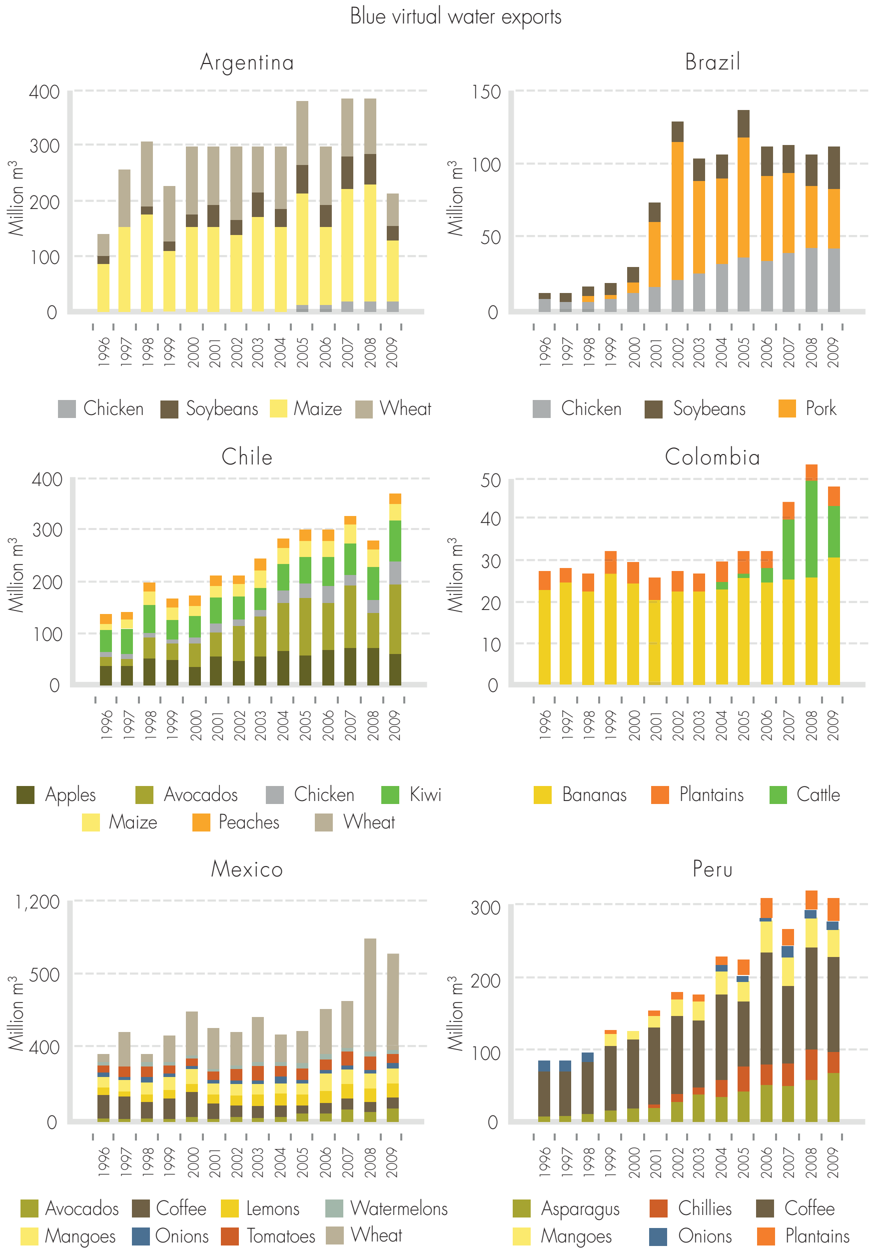
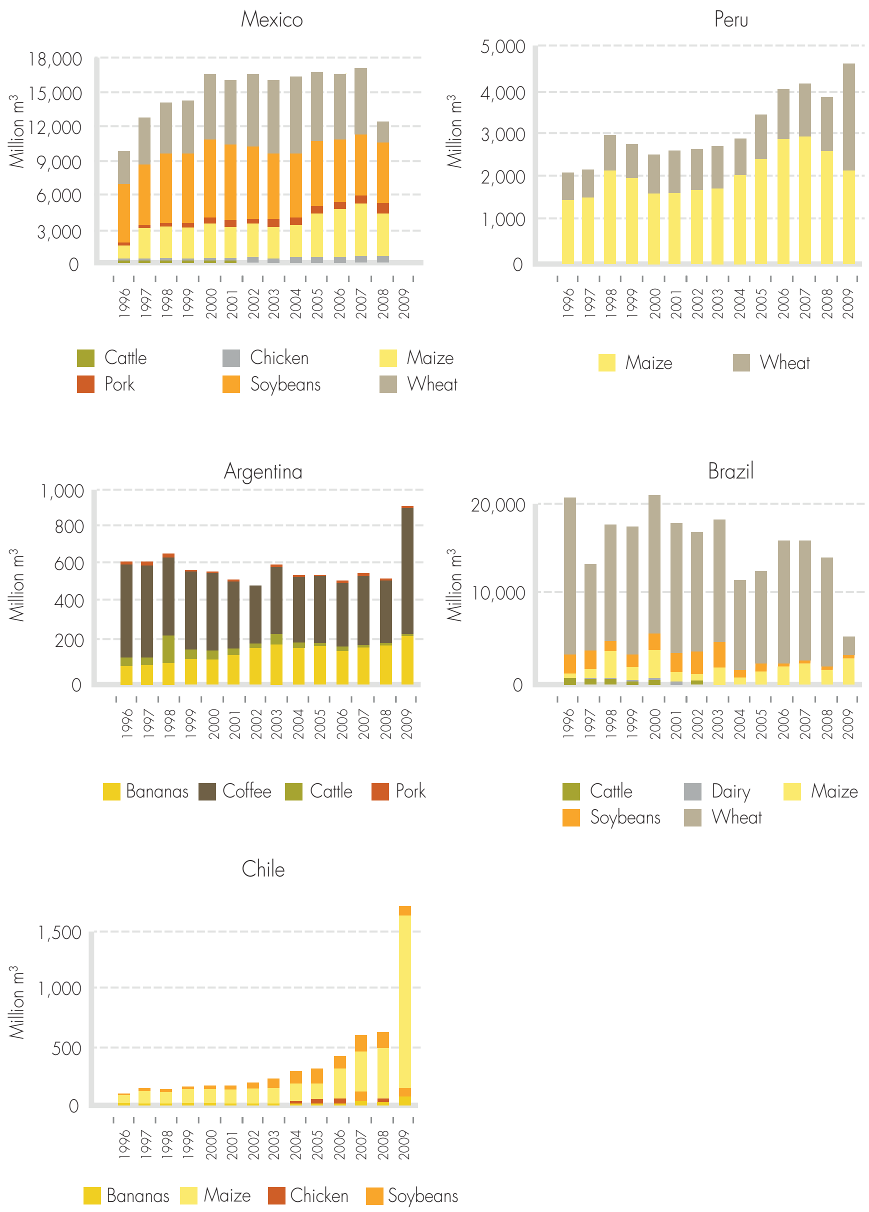


Figure 7.6 Green (above) and blue (below) virtual water exports (in million cubic metres) per country and main products (1996–2009). *Source: own elaboration based on data from Mekonnen and Hoekstra (2011) and FAO (2012d).*

Green virtual water imports



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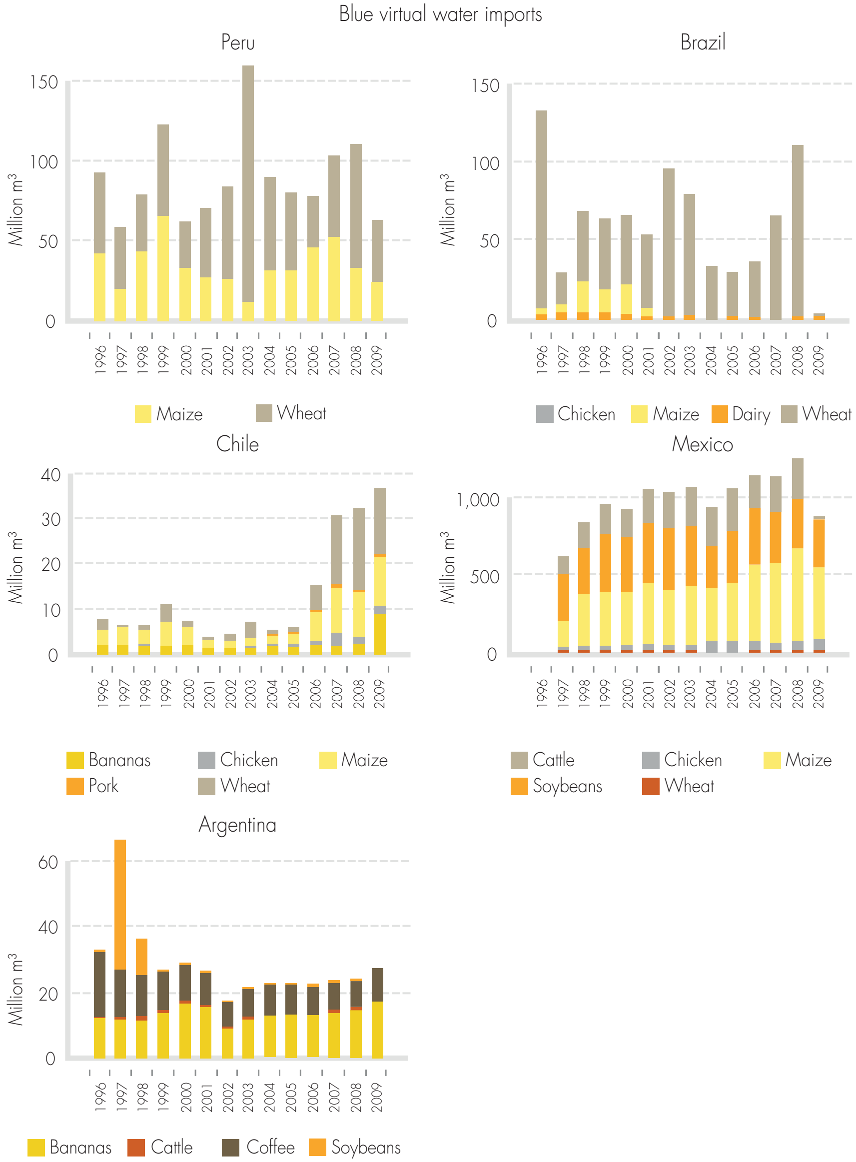
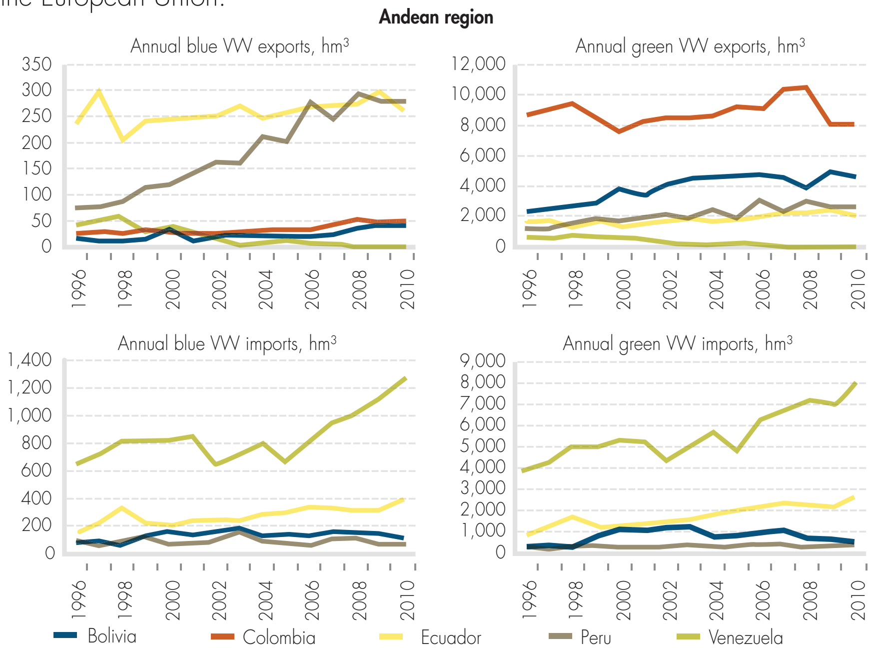


Figure 7.7 Green (above) and blue (below) virtual water imports (in million cubic metres) per country and main products (1996–2009). *Source: own elaboration based on data from Mekonnen and Hoekstra (2011) and FAO (2012d).*

Mexico is a large agricultural net importer. This country must cope with green water constraints and thus highly depends on irrigated agriculture. The substitution of domestic staple food production by imports has led to a shift in agricultural production towards higher value fruits and vegetables as well as livestock production (Figure 7.7). Fruits and vegetables are mostly produced under irrigated conditions leading to higher blue water use. Furthermore, agricultural production has increased substantially due to global market forces. This has resulted in accelerating blue water depletion rates. For example, the Rio Grande river basin has already reached or surpassed sustainable extraction rates during some months of the year (Chapter 6). A similar trend can be observed in Chile and Peru. In Argentina and Brazil blue water exports play a rather minor role.

Trade patterns are extremely dynamic and unstable. Specialization, technology adoption and market prices volatility and economic growth have given rise to fundamental changes in agricultural production and trade worldwide and in LAC (Figure 7.8). From Figure 7.8, one can see that the Caribbean economies are increasingly dependent on virtual water imports while the South Cone and Amazonian region are increasing their virtual water exports the majority of which are green virtual water exports.

Deforestation continues to be the dominant land-use trend in LAC, and subsistence agriculture, an important part of many local economies, is one of the major contributors (Grau and Aide, 2008). But, socio-economic changes related to globalization are promoting a rapid change towards agricultural systems oriented to local, regional, and global markets. The Amazon basin is the region that has lost the largest area to deforestation, with the greatest impacts on biodiversity and biomass loss, but other biomes have also been and continue to be severely affected by conversion to agriculture and pastures (see Chapter 3). Export-oriented industrial agriculture has become the main driver of South American deforestation. In Brazil, Bolivia, Paraguay, and Argentina, extensive areas of seasonally dry forest with flat terrain and enough rainfall for rain-fed agriculture are now being deforested for soybean production, which is mainly exported to China and the European Union.



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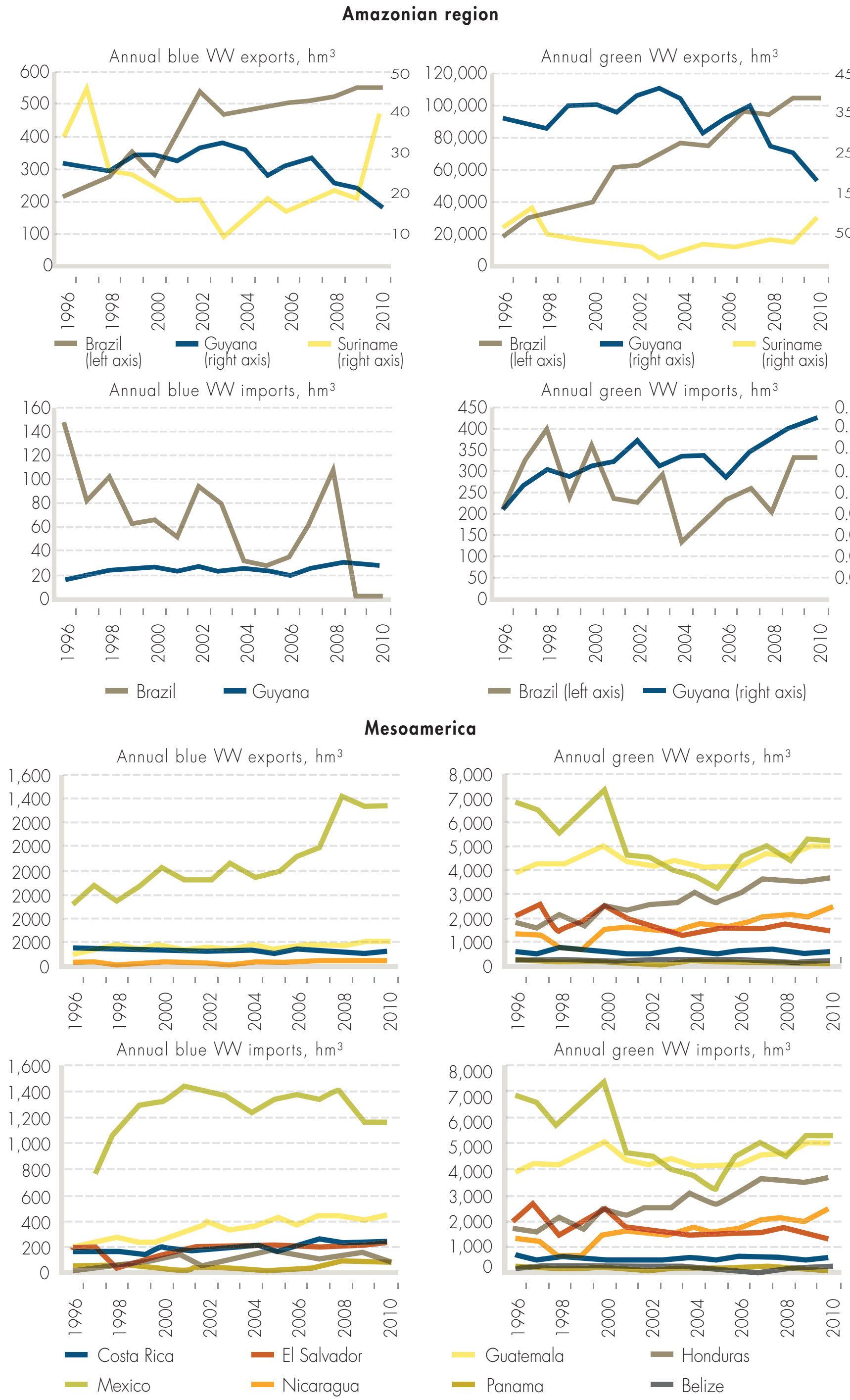

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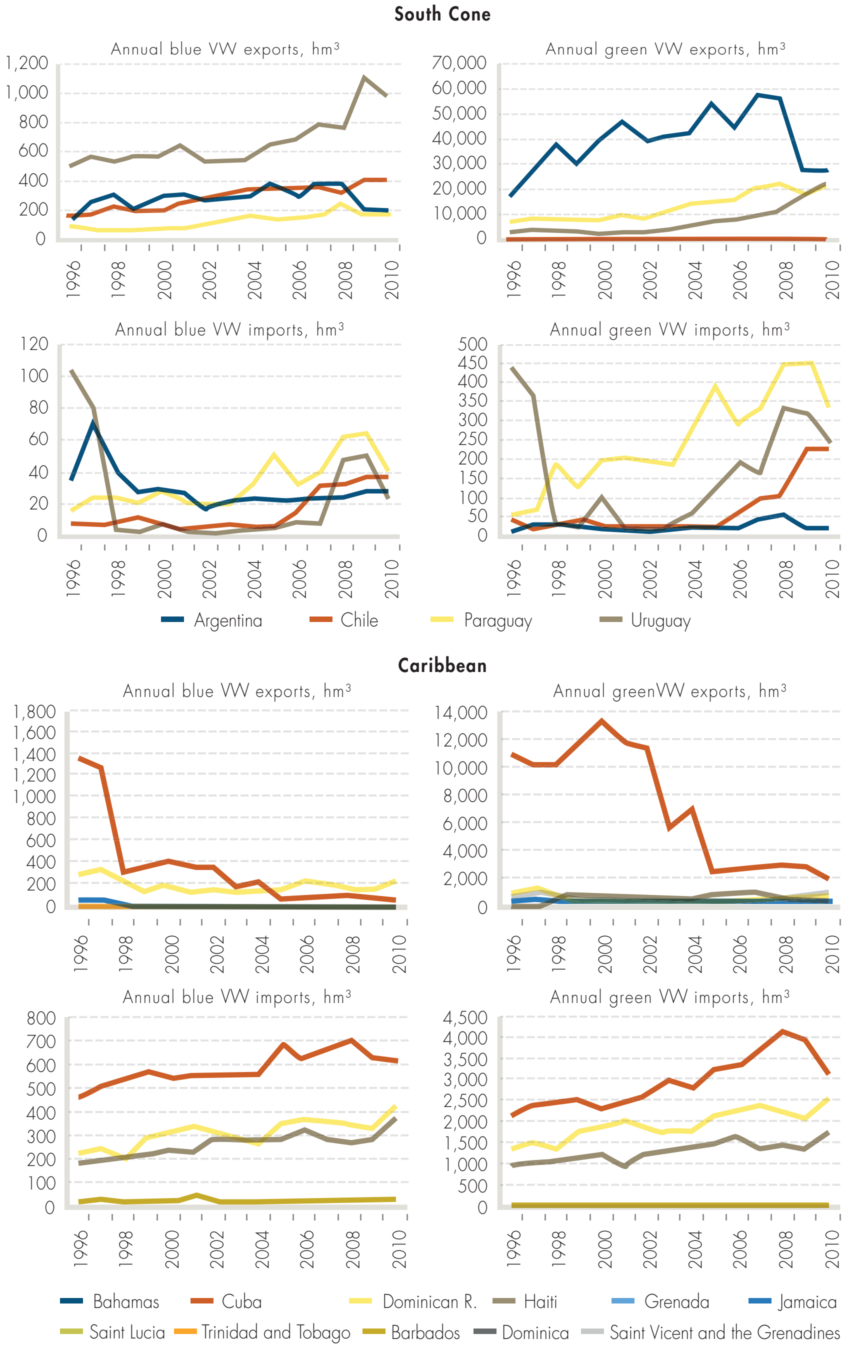


Figure 7.8 Blue and green virtual water exports and imports (in million cubic metres) between 1996 and 2010 in LAC. Note the difference in scales for the vertical axes in the plots. *Source: own elaboration based on data from the Water Footprint Network WaterStat Database (WFN, 2013a).*

7.4 Trends in agriculture: physical, economic and social aspects

7.4.1 Land accounting

The evolution of arable lands in LAC since 1995 (Table 7.2) shows that arable land use has particularly increased for the countries in the Amazonian region, in the South Cone and in Mesoamerica. It has remained constant in the Andean region, and decreased in the Caribbean region. In 2011, average arable land values ranged between 3.2% for the Andean region and 14.9% for the Caribbean. However, the arable land per capita shows a decrease for all the LAC regions between 1995 and 2011, except for the South Cone region, which increased from 0.47ha/person in 1995 to 0.53ha/person in 2011. The lowest regional average of arable land per capita is registered for the Caribbean region (0.08ha/person), and the highest for the South Cone (0.49ha/person).

7.4.2 Productivity analysis

7.4.2.1 Yield

According to the CAWMA (2007), part of the increase in food production can be achieved by improving crop yields and increasing crop water productivity through appropriate investments in both irrigated and rain-fed agriculture. There is good scope for improved productivity in LAC rain-fed areas but less so in irrigated areas. Rain-fed agriculture holds great under-exploited potential for increasing water productivity through better water management practices – gaining more yield and greater value from water. This is an effective means of intensifying agricultural production and reducing environmental degradation (*ibid.*).

LAC is globally important in a number of crops and often achieves yields significantly above the developing world average (Hall, 2001). As shown in Table 7.3, the major cereal yields (e.g. maize, wheat, rice) have increased in line with their production, during the period 1995–2005. The average regional yield per unit of land for wheat in LAC is similar to the average yield output of 2.5–2.7t/ha in North America, while wheat yield in Western Europe is approximately twice as large (5t/ha) and in sub-Saharan Africa it remains below 2t/ha. Yield increases have also happened in tuberous crops (principally potato).

However, yield gaps are still significant in the region, though not so pronounced for the main exporters, such as Argentina or Brazil. Closing the yield gap on a large scale requires investments in rural infrastructure and institutions as well as technology transfer. In LAC, public sector agencies together with the private sector have made some headway in closing the yield gap.

Table 7.2 Evolution of the arable land (in % of countries' land area) in Latin American and Caribbean countries, for the years 1995, 2002 and 2011

	1995	2002	2011
AMAZONIAN REGION			
BRAZIL	6.86	7.27	8.50
GUYANA	2.44	2.29	2.13
SURINAME	0.37	0.29	0.38
ANDEAN REGION			
BOLIVIA	2.31	2.86	3.54
COLOMBIA	2.16	1.99	1.89
ECUADOR	5.69	5.48	4.65
PERU	2.81	2.85	2.85
VENEZUELA, RB	2.93	2.83	2.95
CARIBBEAN			
ANTIGUA AND BARBUDA	9.09	9.09	9.09
BAHAMAS, THE	0.60	0.70	0.90
BARBADOS	37.21	32.56	27.91
CUBA	34.30	35.70	33.35
DOMINICA	4.00	6.67	8.00
DOMINICAN REPUBLIC	18.63	17.96	16.56
GRENADA	5.88	5.88	8.82
HAITI	29.03	32.66	36.28
JAMAICA	14.59	12.47	11.08
PUERTO RICO	3.72	7.67	6.76
ST KITTS AND NEVIS	26.92	26.92	19.23
ST LUCIA	8.20	3.28	4.92
ST VINCENT AND THE GRENADINES	12.82	12.82	12.82
TRINIDAD AND TOBAGO	7.80	5.85	4.87
MESOAMERICA			
BELIZE	2.72	3.07	3.29
COSTA RICA	4.31	3.92	4.90
EL SALVADOR	28.09	33.30	32.09
GUATEMALA	12.64	13.30	14.00
HONDURAS	14.30	9.55	9.12
MEXICO	12.91	12.91	13.11
NICARAGUA	13.71	16.62	15.79
PANAMA	6.73	7.37	7.26
SOUTH CONE			
ARGENTINA	9.90	10.18	13.90
CHILE	2.85	2.22	1.77
PARAGUAY	6.54	8.08	9.82
URUGUAY	7.37	7.43	10.32

Source: World Bank (2013).

Table 7.3 Yield compound annual growth rate by crop and country, period 1995–2001[1]

	CASSAVA	COFFEE	DRY BEANS	MAIZE	ORANGES	POTATOES	RICE	SOYBEANS	SUGAR CANE	WHEAT
MESOAMERICA										
BELIZE	>2%	<0%	<0%	>2%	0–1%	>2%	>2%	>2%	<0%	
COSTA RICA	<0%	<0%	0–1%	0–1%	1–2%	1–2%	<0%		<0%	
EL SALVADOR	<0%	<0%	<0%	0–1%	<0%	>2%	1–2%	<0%	0–1%	
GUATEMALA	1–2%	0–1%	1–2%	1–2%	1–2%	0–1%	1–2%	<0%	<0%	<0%
HONDURAS	<0%	>2%	0–1%	<0%	>2%	>2%	>2%	0–1%	>2%	<0%
MEXICO	1–2%	<0%	1–2%	0–1%	<0%	0–1%	1–2%	<0%	<0%	>2%
NICARAGUA	<0%	0–1%	1–2%	1–2%	<0%	1–2%	1–2%	<0%	0–1%	
PANAMA	>2%	<0%	<0%	1–2%	0–1%	0–1%	1–2%	<0%	0–1%	
AMAZONIAN										
BRAZIL	1–2%	>2%	>2%	>2%	1–2%	>2%	>2%	>2%	1–2%	>2%
GUYANA	<0%	<0%		0–1%	<0%		0–1%		<0%	
SURINAME	>2%	<0%		0–1%	>2%		1–2%	0–1%	1–2%	
ANDEAN										
BOLIVIA	<0%	0–1%	1–2%	>2%	<0%	1–2%	0–1%	1–2%	<0%	0–1%
COLOMBIA	1–2%	<0%	1–2%	>2%	<0%	1–2%	0–1%	1–2%	>2%	<0%
ECUADOR	<0%	<0%	<0%	>2%	<0%	1–2%	0–1%	>2%	>2%	0–1%
PERU	1–2%	>2%	1–2%	>2%	0–1%	>2%	0–1%	0–1%	1–2%	1–2%
VENEZUELA	>2%	1–2%	1–2%	0–1%	1–2%	0–1%	0–1%	1–2%	0–1%	<0%
SOUTH CONE										
ARGENTINA	0–1%		1–2%	>2%	1–2%	1–2%	0–1%	0–1%	0–1%	>2%
CHILE			>2%	0–1%	1–2%	>2%	0–1%	1–2%	1–2%	>2%
PARAGUAY	<0%	>2%	<0%	>2%	0–1%	>2%	>2%	<0%	1–2%	1–2%
URUGUAY			1–2%	>2%	>2%	>2%	>2%	<0%	<0%	>2%
CARIBBEAN										
ANTIGUA & BARBUDA	0–1%			0–1%						
BAHAMAS	0–1%			>2%					0–1%	
BARBADOS [2]	0–1%		<0%	0–1%					1–2%	
CUBA	>2%	>2%	>2%	>2%	>2%	1–2%	1–2%		1–2%	
DOMINICA	<0%	<0%		>2%	0–1%	0–1%			<0%	
DOMINICAN R.	0–1%	<0%	0–1%	0–1%	1–2%	>2%	<0%		>2%	
GRENADA	0–1%		1–2%	1–2%	1–2%	1–2%	1–2%		<0%	
HAITI	1–2%	<0%	1–2%	1–2%	1–2%	<0%	1–2%		>2%	
JAMAICA	<0%	>2%	>2%	<0%	1–2%	0–1%	<0%		<0%	
MONTSERRAT				>2%		>2%				
PUERTO RICO	<0%	<0%	>2%	0–1%	<0%					
S.KITTS AND NEVIS [3]						>2%			1–2%	
S. VICENT G.	1–2%	<0%		>2%	<0%				1–2%	
SAINT LUCIA	<0%				0–1%					
TRINIDAD & TOBAGO [4]	0–1%	>2%		1–2%	1–2%		<0%		1–2%	

(1) It refers to the compound growth rate of selected crops' yield. For comparison reasons, data from the global FAOSTAT database were used. Newest individual country information may differ.
(2) Period 1995–2005
(3) Dry Beans: Period 1998–2010
(4) Sugar: Period 1995–2007

Compound Annual Growth Rate<0%
0=<Compound Annual Growth Rate<=1%
1%<Compound Annual Growth Rate<=2%
Compound Annual Growth Rate>2%
No data

Source: FAO(2012d)

7.4.2.2 Economic

Agricultural economic productivity (US$/ha)

Agriculture is a significant economic sector for many of the LAC countries. It is so at the macro level, with some of the countries being major world players in the agricultural commodities markets, or at the micro level, with agriculture playing a significant role in terms of food security.

In the last decade, the largest producers in the Southern hemisphere have responded to demand by increasing their cultivated areas, especially that of cereals, oil crops and sugarcane, and most significantly the share of those products that are irrigated. However, the countries production differs greatly. Some countries have highly specialized production (Argentina, Brazil), while others rely on a wider array of products (Mexico, Colombia, Peru, Chile). Consequently the economic effects of world markets on each country's agricultural sector will differ substantially.

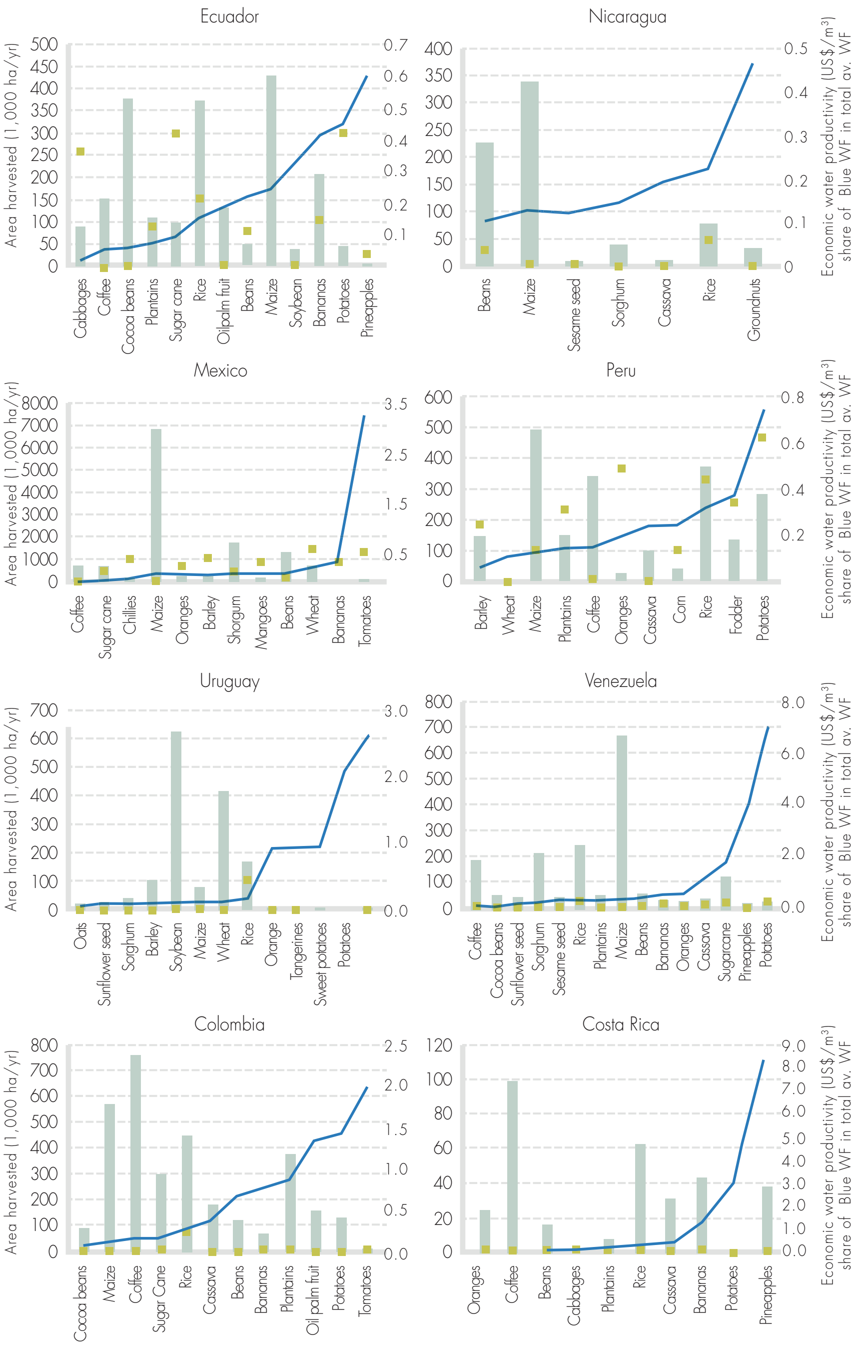
On average, yields in the region have improved in the period 2000–2010 by 9% whereas economic productivity of land grew a 19% (constant US$/ha, own calculations based on FAO, 2012d). As reported by FAO (2012a), the increase in production, productivity and income vary between the countries. Figure 7.9 shows the compound growth rate in agricultural land productivity in physical productivity, that is, yield (t/ha), and in economic productivity (US$/ha) between the average of the years 1991–1993 and 2008–2010 for the countries in Central and South America, for some specific products. Economic productivity growth rates are consistently higher than physical productivity growth rates. Particularly potatoes, coffee, wheat and maize have shown in average higher growth rates. Nevertheless, the behaviour of each product shows great variations among countries, as in the case of sugarcane or cassava.

Economic blue water productivity: surface and groundwater

For selected countries Figure 7.10 shows the area harvested and the economic water productivity per crop alongside the share of blue WF related to the total (green and blue) WF. These data are averages for the period 1996–2005. The cultivated surface data was obtained from FAO (2012d). Economic water productivity was calculated using the average producer's price per crop (US$, constant prices) from FAO (2012d) divided by the green and blue water footprint. Data on green and blue water footprints was obtained from the respective countries report or, in the absence of a specific national figure, from Mekonnen and Hoekstra (2011).

Some countries show low economic water productivity, such as Argentina, Brazil, Nicaragua, Bolivia, Uruguay and Mexico. In very general terms, these countries dedicate significant areas for the cultivation of cereals, coffee, cocoa and sugarcane, which have lower economic productivity. Peru, Ecuador and Chile, and to a lesser extent Colombia and Costa Rica, do have a notable amount of area dedicated to crops with medium-high economic productivity, like grapes, onions, pineapples and potatoes. On average, Chile, Venezuela and Costa Rica show higher average productivities (0.57, 0.54 and 1.21US$/m^3 respectively), whereas Bolivia, Argentina and Brazil show lower ones (0.13, 0.12 and 0.11US$/ m^3).

Figure 7.9 Compound growth rate (%) of yield (t/ha) and economic productivity (US$/ha) between av. 1991–1993 and av. 2008–2010 for selected countries and crops. *Source: own elaboration based on FAO (2012d).*



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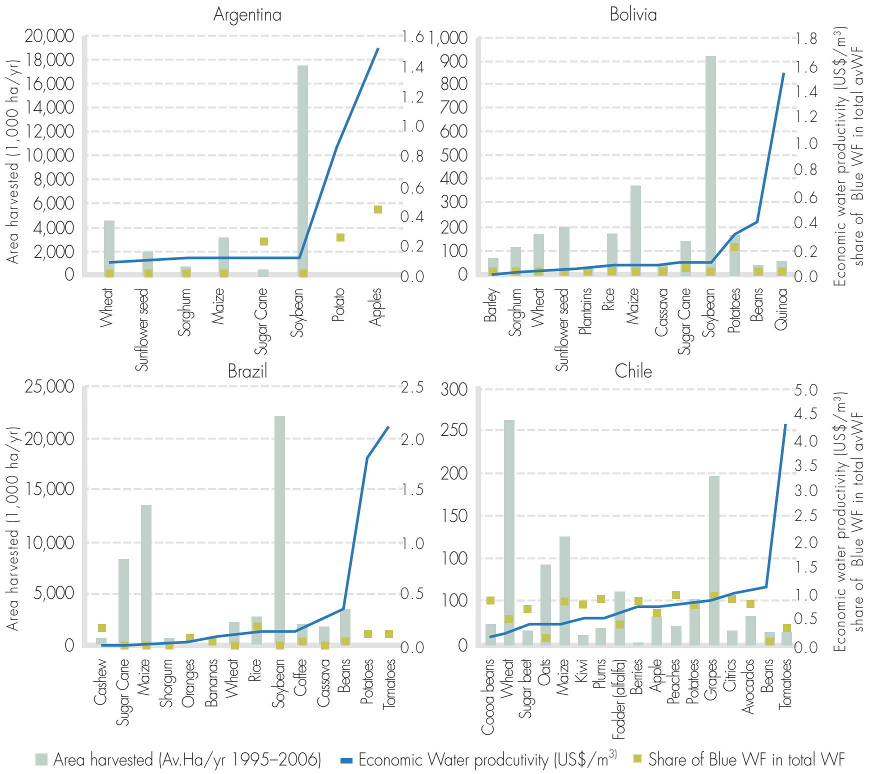

Figure 7.10 Average cultivated area (1,000ha/yr), economic water productivity (US$/m³) and share of blue WF in crop WF for selected countries and crops. The data shown corresponds to an average of the years 2007-2010. Note the difference in scale for each country. *Source: Own elaboration based on FAO (2012d) and Mekonnen and Hoekstra (2011).*

7.4.2.3 Social

Insecure access to reliable, safe, and affordable water keeps hundreds of millions of people from escaping poverty. Most of them rely directly on agriculture for their food and income. According to the CAWMA (2007), poverty could be reduced by improving access to agricultural water and its use. Livelihood gains of smallholder farmer could be obtained by securing water access (through water rights and investments in water storage and delivery infrastructure), improving value obtained by water use through pro-poor technologies, and investing in roads and markets.

Increased productivity by improving irrigation has a multiplier effect on the economy (Table 7.4). Improved agricultural water management boosts total farm output. Increased output may arise from improved yields, reduced crop loss, improved cropping intensity, and increased cultivated area. Reliable access to water enhances the use of complementary inputs such as high-yielding varieties and agrochemicals, which also increases output levels (Hasnip et al., 2001; Bhattarai and Narayanamoorthy, 2003; Hussain and Hanjra, 2003; Smith, 2004; Huang et al., 2006). FAO (2003) data show that the major sources of growth in crop production for all developing countries during 1961–1999 were yield increase (71%), area expansion (23%), and cropping intensity (6%). Empirical evidence for a sample of forty countries shows that for a 1% improvement in crop productivity poverty – in terms of those living on less than US$1 a day – fell by about 1% and the human development index rose by 0.1% (Irzet al., 2001). There seems to be a solid link between yield growth, poverty reduction, and human development. Access to agricultural water has secondary effects on poverty through output, employment and prices. Two factors contribute to output fluctuations: rainfall variability and the relative prices of outputs. Food grain output is sensitive to variations in rainfall (Lipton et al., 2003; Smith, 2004) and as such reliable access to agricultural water not only raises crop output levels, but also usually reduces variance in output across seasons and years.

Finally, stabilization of farm output cannot be achieved merely through a reliable system of agricultural water management. Reducing risk and uncertainty for farmers requires the general improvement of the farming environment (Smith, 2004).

Table 7.4 **Impact of irrigation by type of system**

	IMPACT	LARGE-SCALE PUBLIC, DRY ZONE	LARGE-SCALE PUBLIC, PADDY-BASED	SMALL- OR MEDIUM- SIZE COMMUNITY-MANAGED	PRIVATE, COMMERCIAL	SMALLHOLDER, INDIVIDUAL
ECONOMIC	Production	Low positive	Low positive	Low positive	High positive	High positive
	Food security	High positive	High positive	High positive	Low positive	High positive
	Rural employment	High positive	High positive	High positive	Low positive	High positive
SOCIAL	Settlement strategies	Mixed	Mixed	High positive	None	None
	Social capital	None	Low positive	High positive	None	None
	Health	Mixed	Mixed	Mixed	Low negative	Mixed
ENVIRONMENTAL	Biological diversity	Mixed	Mixed	Mixed	Mixed	None
	Social and water conservation	Mixed	Mixed	Mixed	Mixed	None
	Water quality	High negative	Mixed	Mixed	High negative	Low negative
CULTURAL	Religious ceremonies	Low negative	None	Low positive	None	None
	Landscape, aesthetics	Mixed	High positive	High positive	Low negative	None
	Cultural heritage	Mixed	Mixed	High positive	None	None

Source: CAWMA (2007)

7.5 Conclusions and recommendations

The LAC region's economy is on average growing rapidly. With its green water and land availability, LAC could potentially represent a good opportunity to produce and supply more food for itself and for other parts of the world. This option also denotes the chance to boost economies in some of these emerging countries. This is the general case for the whole continent; however, particular areas, such as the Antilles, show severe water scarcity levels at the country level, with high levels of dependency on external water resources for food supply.

In spite of the positive agricultural development perspectives and the satisfactory water availability in most areas of the LAC region, if not carefully planned, using local water resources to satisfy this food demand may exert more pressure on water and land resources and increase the already severe water quality problem in the region. The combination of rapid urbanization over the past fifty years and more importantly weak governance are crucial factors affecting water scarcity in a water-rich region.

As economies emerge and there is more investment for natural resources exploitation and use, competition among sectors increases, such as in the case of biofuels and mining versus agriculture for food in the LAC region. The domestic, industrial and hydropower sectors also compete with agriculture. The complex trade-offs across sectors and across water users can best be managed through integrated water management at the river basin level, developed in agreement with the national policies and planning – but establishing appropriate institutions for inter- and intra-sectorial water allocation remains an important challenge under the fragmented management structure in most of LAC. Appropriate water accounting systems, including the green, blue and grey water footprint and the related socio-economic and environmental impacts can inform decision-makers, planners and developers at different levels (river basin, departmental, national) on the sustainability of different water management options. These water accounting systems can also inform about crop water consumption and its economical and social benefits to optimize the allocation of water resources when planning irrigation development (Box 7.3). Sustainable water management should not be seen as a barrier for the development of the region, but rather as the way to develop and grow as a region.

Overall, this chapter shows the strong links between water, agriculture and economy in LAC. Both green and blue water are a vital fuel for LAC's economies and for its food security. Awareness of LAC's virtual water trade volumes and water footprints will not alone solve the local or global water problems. However, the awareness gained increases the odds that optimized water allocation decisions, which consider the hydrological and economical aspects of water resources, are made (Allan, 2011).

Box 7.3 Water footprint assessment of Porce River Basin, Colombia

The Water Footprint Assessment (WFA) of Porce River Basin (2012) included the five main productive sectors in the basin (crop and livestock, industry, domestic, hydropower and mining) and the four phases of the WFA were analysed.

The total WF of crop production was 250hm^3/yr, (93% green – 5% blue – 2% grey). Coffee is the crop that contributes the most to the WF (green and blue, 31%), followed by sugar cane with 19%, potatoes 15% and plantain 8%. In terms of the grey WF, coffee is the crop with the highest impact in the watershed followed by potatoes (based on nitrogen). The water footprint of livestock is 700hm^3/yr, (66% green – 32% blue – 2% grey). Cattle contribute with more than 80% to the total WF of livestock, followed by horses, poultry and pigs respectively. Cattle equally occupy the first place (76% blue and 65% grey), followed by poultry (11% blue and 21% grey), pigs (10% blue and 9% grey) and horses (3% blue and 5% grey).

Table 7.5 The green, blue and grey water footprint in the Porce River Basin

SECTOR	GREEN WF m^3/yr	BLUE WF m^3/yr	GREY WF m^3/yr	CRITICAL POLLUTANT
CROP PRODUCTION	231.0	13.5	4.8	N
LIVESTOCK	463.0	12.4	215.8	N
HOUSEHOLD	-	27.8	11,788.2	BOD
INDUSTRIAL	-	8.0	4,078.5	BOD
HYDROPOWER	-	24.4	-	-
MINING	-	3.7	3,059.1	TSS

Source: CTA (2013)

The environmental, economic and social components of the WF sustainability assessment were included. The biggest environmental problem identified is the lack of pollution assimilation capacity, especially in the upper basin (city of Medellin). This region presents critical pollution indexes, according to the maximum allowed concentration criteria used. For the economic analysis, apparent water productivities were analysed for each of the productive sectors. For the social analysis indicators on public health, coverage in water supply and sanitation were taken into account.

The complex WF sustainability assessment (environmental, economic and social) identifies the basin's hotspots, enabling the formulation of responses in terms of public policy and public–private partnerships.

References

Allan, T. (2011). *Virtual Water: Tackling the Threat to Our Planet's Most Precious Resource*. London, IB Tauris Publishers.

Albersen, P.J., Houba, H.E.D. & Keyzer, M.A. (2003). Pricing a raindrop in a process-based model: General methodology and a case study of the upper-zambezi, *Physics and Chemistry of the Earth*, 28: 183–192.

Aldaya, M.M., Allan, J.A. & Hoekstra, A.Y. (2010). Strategic importance of green water in international crop trade, *Ecological Economics*, 69 (4): 887–894.

Bhattarai, M., & Narayanamoorthy, A. (2003). Impact of Irrigation on Rural Poverty in India: An Aggregate Panel-Data Analysis. *Water Policy, 5* (5–6): 443–458.

Biswas, A.K., Tortajada, C., Braga, B., & Rodriguez, D.J. (eds) (2006). *Water Quality Management in the Americas. Water Resources Development and Management.* The Netherlands, Springer.

Bovarnick, A., Alpizar, F. & Schnell, C. (eds) (2010). United Nations Development Programme. *The Importance of Biodiversity and Ecosystems in Economic Growth and Equity in Latin America and the Caribbean: An economic valuation of ecosystems*. UNDP.

CAWMA (2007). Comprehensive Assessment of Water Management in Agriculture. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, Earthscan.

CIP (2010). Centro Internacional de la Papa. *Facts and Figures about Potato*. Lima, Peru, CIP. [Online] Available from: www.cipotato.org. [Accessed February, 2013].

CTA (2013). Centro de Ciencia y Tecnología de Antioquía. Evaluación de la huella hídrica de la cuenca del río Porce. Resumen de resultados. Mayo 2013. pp.102.

Egúsquiza, B.R. (2000). *La Papa, Producción, Transformación y Comercialización.* Convenio MSP ADEX-USAID. Lima, Perú, Universidad Nacional Agraria La Molina.

FAO (2003). Food and Agriculture Organization. *World Agriculture: Towards 2015/2030. An FAO Perspective.* FAO and Earthscan.

FAO (2008). Food and Agriculture Organization. *Potato International Year.* [Online] Available from: www.potato2008.org/es/mundo/america_latina.html. [Accessed February, 2013].

FAO (2012a). Food and Agriculture Organization. *The State of Food and Agriculture*. Rome. [Online] Available from: www.fao.org/docrep/017/i3028e/i3028e.pdf [Accessed February, 2013].

FAO (2012b). Food and Agriculture Organization. *Panorama de la Seguridad Alimentaria y Nutricional en América Latina y el Caribe 2012*. Rome, FAO. [Online] Available from: www.rlc.fao.org/es/publicaciones/panorama-2012/. [Accessed May, 2013].

FAO (2012c). Food and Agriculture Organization. *The Outlook for Agriculture and Rural Development in the Americas: A Perspective on Latin America and the Caribbean*. Santiago, Chile, CEPAL, FAO & IICA. [Online] Available from: www.rlc.fao.org/en/publications/outlook-2013 [Accessed February, 2013].

FAO (2012d). Food and Agriculture Organization. FAOSTAT. *Production and Trade Statistics*. [Online] Available from: faostat.fao.org/site/291/default.aspx. [Accessed December, 2012].

FAO (2013). Food and Agriculture Organization. AQUASTAT. [Online] Available from: www.fao.org/nr/water/aquastat/main/index.stm [Accessed February, 2013].

Grau, H.R., & Aide, M. (2008). Globalization and land-use transitions in Latin America. *Ecology and Society*,13 (2): 16.

Hall, M. (ed.) (2001). Food and Agriculture Organization. *Farming Systems and Poverty. Improving farmers' livelihoods in a changing world*. FAO-World Bank.

Hasnip, N., Mandal, S., Morrison, J., Pradhan, P. & Smith, L.E.D. (2001). *Contribution of Irrigation to Sustaining Rural Livelihoods*. Wallingford, UK, HR Wallingford.

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M. & Mekonnen, M.M. (2011). *The Water Footprint Assessment Manual: Setting the global standard*. London, Earthscan.

Huang, Q., Rozelle, S., Lohmar, B., Huang, J. & Wang, J. (2006). Irrigation, agricultural performance and poverty reduction in China. *Food Policy,* 31 (1): 30–52.

Hussain, I. & Hanjra, M.A. (2003). Does irrigation water matter for rural poverty alleviation? Evidence from South and South-East Asia. *Water Policy,* 5 (5–6): 429–42.

Irzet, X., Lin, L., Thirtle, C. & Wiggins, S. (2001). Agricultural productivity growth and poverty alleviation. *Development Policy Review,* 19 (4): 449–66.

LA–Costa Rica (2012). *Report of Costa Rica*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain: Fundacion Botín.

LA–Peru (2012). *Report of Peru*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain: Fundacion Botín.

Lipton, M., Litchfield, J. & Faurès, J.M. (2003). The effects of irrigation on poverty: a framework for analysis. *Water Policy*, 5 (5–6): 413–27.

Mekonnen, M.M. & Hoekstra, A.Y. (2011). *National Water Footprint Accounts: The Green, Blue and Grey Water Footprint of Production and Consumption. Volume 2: Appendices*. Delft, The Netherlands, UNESCO-IHE. Value of water, Research Report Series No. 50.

Moran, E.F. (1982). *Human Adaptability. An Introduction to Ecological Anthropology.* Colorado, Westview Press.

Niemeyer, I. & Garrido, A. (2011). International farm trade in Latin America: does it favour sustainable water use globally? In: Hoekstra, A.Y., Aldaya, M.M. & Avril, B. (eds). *Proceedings of the ESF Strategic Workshop on Accounting for Water Scarcity and Pollution in the Rules of International Trade*. Delft, The Netherlands, UNESCO-IHE. Value of Water Research Report Series No. 54. pp. 63–84.

Oliviera, A.S., Trezza, R., Holzapfel, E., Lorite, I. & Paz, V.P.S. (2009). Irrigation water management in Latin America. *Chilean Journal of Agricultural Research,* 69: 7–16.

Palhares, J.C.P. (2012). Pegada Hídrica das aves abatidas no Brasil na década 2000–2010. In: Macari, M. & Soares, N.M. (Org.). *Água na avicultura*. Campinas, Brazil, Facta. pp. 40–53.

Proceso Regional de las Américas (2012). Agenda del Agua de las Américas. *Agenda del agua de las Américas: Metas, soluciones y rutas para mejorar la gestión de los recursos hídricos*., Marseille, France, 6th World Water Forum.

Ramírez, F., Chaverri, F., de la Cruz, E., Wesseling, C., Castillo, L. & Bravo, V. (2009). *Importación de plaguicidas en Costa Rica*. Periodo 1977–2006. Instituto Regional de Estudios en Sustancias Tóxicas. Facultad de Ciencias de la Tierra y el Mar. Heredia, Costa Rica, Universidad Nacional,. Serie Informes Técnicos IRET No. 6.

Rockström, J., Hatibu, N., Oweis, T. Y., Wani, S., Barron, J., Bruggeman, A., Farahani, J., Karlberg, L. & Qiang, Z. (2007). Managing water in rainfed agriculture. In: Molden, D. (ed.). Water for Food, Water for Life: *A Comprehensive Assessment of Water Management in Agriculture*. London, Earthscan. pp. 315–352

Smith, L.E.D. (2004). Assessment of the contribution of irrigation to poverty reduction and sustainable livelihoods. *Water Resources Development,* 20 (2): 243–257.

UN (2003). United Nations. *Water for People, Water for Life*. The first UN edition of the World Water Development Report (WWDR1).

UNCTAD (2011). United Nations Conference on Trade and Development. *Water for Food. Innovative water management technologies for food security and poverty alleviation*. [Online] Available from: http://unctad.org/en/Docs/dtlstict2011d2_en.pdf. [Accessed February, 2013]. Current Studies on Science, Technology and Innovation report no 4.

UNEP (2013). United Nations Environment Programme. *The State of Natural Resource Management in LAC - Opportunities for Sustainable Practices and Prioritization of Resources*. UNEP - Division of Technology, Industry and Economics (UNEP DTIE) and UNEP Regional Office for Latin America and the Caribbean (PNUMA ROLAC).

WFN (2013a). Water Footprint Network. WaterStat Database. [Online] Available from: www.waterfootprint.org/?page=files/WaterStat. [Accessed March, 2013].

WFN (2013b). Water Footprint Network. Water Footprint Assessment Tool. [Online] Available from: www.waterfootprint.org/?page=files/waterfootprintassessmenttool [Accessed February, 2013].

World Bank (2013). *World Bank Development Indicators*. [Online] Available from: data.worldbank.org/indicator. [Accessed May, 2013].

Yang, H., Wang, L., Abbaspour, K.C. & Zehnder, A.J.B. (2006). Virtual water trade: An assessment of water use efficiency in the international food trade, *Hydrology and Earth System Sciences,* 10: 443–454.

8

WATER SECURITY AND CITIES

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Highlights

- Latin America has achieved good progress in urban water supply and sanitation, although gaps have to be bridged and efficiency has to be improved, especially in what refers to sanitation.
- Urban water supply quality presents deficiencies in some urban areas, some due to poor natural water quality and to inadequate functioning of supply networks.
- A lot could be socially gained by investments in better functioning of urban water supply and sanitation networks.
- Water users have to cover the full cost of urban water supply and sanitation, including maintenance and renovation of infrastructure, most probably the main bottleneck in the way to achive sustainable urban water systems.
- The most deprived population has the right to receive drinking water and sanitation at affordable price for them, but the additional cost has to be covered by the other users and the society in general, without compromising the needed investments.
- The dilemma between public and private water services is not the key issue.

8.1 Introduction

A large and growing fraction of humanity currently lives in urban areas, many of which are, so-called, megacities. Table 8.1 shows some of the most relevant cities in Latin America (LA). In this chapter we consider only continental Latin American countries, Mexico being the most northerly country down to Argentina and Chile in the south. The focus is on water security for large urban areas, with particular emphasis on water services. Various case studies are provided by local experts with short comments on water issues in specific LA large cities. These represent some of the best managed cities in the area, so to some extent the sample is biased. However, what is presented helps to understand the current situation even though they do not necessarily correspond to the general picture of the continent as a whole.

The urban water cycle is a relatively new concept (Cabrera and Custodio, 2013). Even if all early civilizations had large waterworks in order to secure good access to water for their citizens, the generalized establishment of urban supply did not start worldwide until the middle of the 19th century. Thus, available data and studies are based on recent history. In particular, the introduction of water chlorination by English physician John Snow to control water-borne diseases was a real turning point. Although it was not until the early

Table 8.1 **Data on some of the largest cities in LA**

TOWNS	POPULATION 2011 (millions)	WORLD RANKING IN URBAN POPULATION	SUPLIED SURFACE AREA (km^2)	% POPULATION OF LA	PER CAPITA DAILY SUPPLY (L/day/cap)	PER CAPITA DAILY SUPPLY (hm^3/cap)
SÃO PAULO	20.6	9	3173	3.43	180	3,702,240
MEXICO D.F.	20.0	10	2046	3.34	360	7,211,520
BUENOS AIRES	13.8	21	2642	2.30	370	5,097,120
RIO DE JANEIRO	12.6	26	4026	1.94	190	2,207,040
LIMA	9.4	30	648	1.57	254	2,387,600
BOGOTÁ	9.0	36	414	1.50	136	1,225,224
SANTIAGO DE CHILE	6.2	53	984	1.03	196	1,209,516
MONTERREY	4.2	88	894	0.70	300	1,266,000
CARACAS	3.3	124	272	0.55	400	1,311,600

Source: own elaboration.

20th century that this technique was widely applied (McGuire, 2013), it is still credited for being the primary cause of last century's increase in life expectancy. In terms of public health, it could be considered the greatest advancement of the millennium.

By the early 20th century most of the world's developed cities had introduced urban water supply networks. However, a few decades later these networks were stressed due to the much higher demand produced by rapid urban growth.

Apart from some pioneering examples of sewage water treatment (the first plant was established in 1890 in Worcester, Massachusetts, USA), they were not at all common in the USA until the end of the Second World War; when in 1948, under the Federal Water Control Act,[1] funds were made available for the construction of treatment plans to ensure water quality. In developed countries, almost 100% of urban and industrial wastewater is currently treated, albeit large improvements can still be made. In Europe the main impetus came from new regulations relating to water quality and pollutants; chief amongst these is the Water Framework Directive (OJEU, 2000). There are still some challenges given that tertiary wastewater treatment to eliminate organic load is still not sufficient to eradicate some worrisome contaminants, which appear in relatively low concentrations.

Latin America has partly followed the path of developed countries, albeit delayed in time and with a long way to go. This is reflected in the America's Water Agenda (Regional Process of the Americas, 2012), a report backed by the Inter-American Development Bank and produced by relevant institutions of the Americas involved in water affairs.

1 www.fws.gov/laws/lawsdigest/FWATRPO.HTML (accessed in June, 2013)

The challenges for America are grouped into fourteen points, of which the first four refer specifically to water supply and sanitation:

- Implementation of the human rights; access to water and sanitation, in response to the July 2010 United Nations resolution A/RES/64/292
- Water, sanitation and service quality deficiencies
- Universal coverage for current urban and marginal areas
- Water and sanitation in rural areas.

A large number of the remaining points also refer to urban water, albeit not so directly, like the 5th point (climatic change), 6th point (governance), 7th point (need for integrated water resources management), 10th point (increasing water contamination, largely due to urban and industrial pollution), and 14th point (creation of a political environment willing to make the necessary investments into urban water planning and infrastructure).

All of these aspects are relevant and important since humans need water to live and yet the way to provide this water is becoming progressively more complex. Towns and the associated water systems expand, while their supporting infrastructures are neither upgraded nor modernized at the same pace, and thus they age and their service quality decreases. This is an issue that must be specifically addressed as often citizens believe that, water being a universal right, the government ought to provide it at no cost to them. This explains their reluctance to pay the true cost of a service that is becoming increasingly costly and complex. As a consequence, politicians responsible for urban water management, who depend largely on citizens votes in many countries, and LA is not an exception, are unlikely to charge the full water service cost. The consequence is that water services often become economically collapsed. The antidote is full, transparent information.

Available documents show that top-down points of view alongside socio-economic and political analysis tend to be prioritized whilst technical aspects are largely disregarded, when they could in fact be the key to better understanding of the problems. To some extent, what follows is an attempt to better understand this discrepancy.

8.2 Water sources for urban supply

Most large cities in LA depend on surface water from river basins (Santiago, Chile, Box 8.1). However groundwater is also important for many of them, occasionally the only source, as is the case of Mar del Plata, Argentina (Box 8.2), or sometimes groundwater is a key complement that cannot easily nor quickly be substituted (São Paulo, Brazil, Box 8.3). At times it is used as a necessary backup as in Lima, Peru, or simply for the supply of fast expanding and poor peri-urban areas (Rio de Janeiro, Brazil, Box 8.4; Lima, Peru, Box 8.5, and Buenos Aires, Argentina, Box 8.6). Mexico City, in terms of urban water management, is one of the most complex ones in the world. It is served by a mixture of imported, local and further afield groundwater resources (Box 8.7 and SACM, 2012). Even though many of the large cities on the continent are near or next to the sea, seawater desalination is seldom employed as an urban water source in LA, with a few exceptions in medium-size towns (e.g. Antofagasta and Iquique, Chile).

Box 8.1 Water supply to Santiago, Chile

[By Joaquim Martí, Aguas Andinas, Santiago, Chile, and Manuel Cermerón, Aqualogy, Barcelona]

Santiago, the capital city of Chile, is located in the Intermediate Chilean Depression, the depression between the Andes and the Chilean coastal range. It receives an annual average precipitation of 320mm mainly concentrated in the May–August period; the summers are long and dry. The population is about 6.5 million inhabitants, of which 95% have their water supply and sanitation needs provided by the Aguas Andinas group, the remaining 5% are served by a municipal company.

Most of the supplied water (86%) is surface water from the Maipo and Mapocho rivers, complemented by some 14% groundwater. To guarantee a continuous drinking water supply, large reservoirs exist, such as El Yeso (220hm^3), Laguna Negra (600hm^3) and Laguna Lo Escañado (50hm^3). Two main plants, Las Vizcachas (15.8m^3/s) and La Florida (4.0m^3/s), produce drinking water alongside twelve smaller plants. The water is then distributed via a 12,094km piping network. Unaccounted water amounts to 29% and includes technical, commercial and measurement components.

The sanitation network covers 100% of the area with 10,501km of sewers. Sewage water is treated in thirteen plants, the two main ones being, La Farfana (8.8m^3/s) and Mapocho–Trabal (6.6m^3/s). All treated waste waters are disposed of downstream from Santiago, in the Mapocho River.

Drinking water price is 0.595US$/m^3, plus 0.465US$/m^3 for sewage service and 0.307US$/m^3 for wastewater treatment. However, low-income citizens may ask for half the price to be covered. All the revenue generated is used to cover the operation, maintenance, replacement and any future works needed to improve the service and ensure water supply security.

Box 8.2 Water security in the supply of Mar del Plata, Argentina

[By Dr Emilia Bocanegra, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina]

The coastal town of Mar del Plata, Argentina, is approximately 450km south of Buenos Aires. It spans an area of 80km^2 and has 620,000 residents, a figure which is doubled during the summer period. The local economy depends on tourism, harbour activities (mostly fisheries), textiles and leather, and fruit trees and orchard agriculture. All water resources are supplied by groundwater coming predominantly from rural areas in the north and northeast of the city but also abstracted inside the urban and peri-urban area. Approximately 129hm^3/yr of good quality groundwater is abstracted from 274 wells. Intensive groundwater abstraction in the urban area has induced seawater intrusion into the aquifer, forcing forty wells to be abandoned. Other wells have also been taken out of service due to high level of nitrates. The limit of 45mg/L of nitrate concentration is exceeded in 117 wells. Water is periodically chlorinated and meets drinking water standards in 96.6% of cases. Some 93% of the population is connected to the distribution network. The network loses 40% and suffers 0.38breaks/km each year. Most residences have tanks to store water since in summer months water pressure may be insufficient to reach some neighbourhoods.

Regarding the sanitation network 92% of population is connected to it, and it suffers 0.17breaks/km each year. Four main servers feed a final pre-treatment plant where solids are separated, dried and aerobically stabilized to produce a soil conditioner that is principally used for ornamental plant cultivation. The effluent is disposed of in the sea.

Drinking water is served at a cost of 0.17US$/m^3, plus 0.12US$/m^3 for sanitation. The joint average yearly charge for connection is 98US$/yr. Commercial and industrial establishments are often metered amounting to approximately 20% of the water provided. The domestic charge is calculated according to the surface area of the dwelling and the area of the city where it is located.

Urban water use rate is high (296L/day/cap). Despite public campaigns to reduce water use, results have not been very effective. In order to encourage water savings there is a surcharge for indoor pools.

The contribution from customers is sufficient for the efficient maintenance and operation of the water and sanitation services. Network expansion and major infrastructure projects are financed by subsidies received from the government. Expansion is planned in the future including the incorporation of a further seventy-four wells into the network in order to supply the western main and the construction of a submarine outfall in order to improve local coastal seawater quality. The municipal company Obras Sanitarias de Mar del Plata (OSMP, Mar del Plata Waterworks) is responsible for supplying water and sanitation services and regulates the different uses under the Water Code of the Province of Buenos Aires thus helping water governance. Currently there is no known conflict between OSMP and rural and industrial users.

Box 8.3 Water security in the metropolitan area of São Paulo, Brazil: the key role of groundwater

[By Ricardo Hirata, CEPAS-Universidade de São Paulo, São Paulo, Brazil]

The megacity of São Paulo, including the surrounding thirty-five municipalities, reunites 20.6 million inhabitants. They are located in the Alto Tietê Watershed (ATW), which has a surface area of 5,720km^2. The public water supply system is operated by SABESP, a state-owned company that provides 2,144hm^3/yr (68m^3/s) of water coming from eight surface water sources, half of them imported from another water basin. More than 95% of the total population is provided for in this way. Additionally, a total of 347hm^3/yr (11m^3/s) of water comes from approximately 9,000 privately owned tube-wells. Even though this supply is only 17% of total demand, if it fails due to water contamination or excess of abstraction, it will seriously compromise water security in the ATW. SABESP currently has no more water resources available to substitute for this groundwater use. Water transfers from further water basins, although planned, will not be available in the near future. Average groundwater abstraction in the area is about 32% of total recharge (400mm/yr), including rainfall infiltration (45%). Losses from the supply and sewage network are 55%. However, abstraction is irregularly distributed in the area and concentrates especially in the central area of Penha-Pinheiros sub-basin where abstraction exceeds 80% of the recharge.

Water supply security in the ATW is also a concern with regard to well conditions as 60–70% of them lack operation permits and, as a consequence, there is no control on them. Well drilling and construction does not follow acceptable standards, so the wells and the aquifer itself are under risk of contamination. More than 50% of declared contamination cases in São Paulo State are located in the ATW. This is the result of intense industrialization and unplanned, dense and rapid urban expansion.

Box 8.4 Water security in the metropolitan area of Rio de Janeiro, Brazil: groundwater, the unknown resource

[By Gerson Cardoso da Silva Jr, IGEO, Universidade Federal do Rio de Janeiro, Brazil]
The Metropolitan Area of Rio de Janeiro (MARJ), Brazil, with a land area of 5,292km^2 plus 400km^2 of the Guanabara Bay, comprises seventeen municipalities with approximately 12.6 million inhabitants. The significant demographic and economic growth in recent decades is the cause of a notable increase in the consumption of water resources. The Hydrographical Region of Guanabara Bay (HRGB) includes the MARJ and other territories, but predominantly, river headwaters. About 50m^3/s are transferred from the Paraíba do Sul River to the Guandu Water Plant, the main source of water for public supply. The price for the final user is approximately 0.65US$/m^3 which includes sewage treatment. This is complemented by water from other minor sources, groundwater being approximately 2% of the total. In general, high-quality water is supplied by the water plants. The gross revenue accounts for financial costs and investments, as well as for operational and maintenance costs. Water losses due to leaks in pipelines and 'social losses' (e.g. unpaid water for shantytowns) represent 30% of the total distributed water.

In many situations a significant use of groundwater resources as a supplementary source of water in the region is made, even though the aquifer characteristics are poorly known. Most wells lack any kind of register or permit. The Rio de Janeiro State has implemented in recent years a programme for well legalization, raising the number of permitted wells from a few hundred to thousands in the last five years alone, although official federal statistics point to approximately 0.5 million shallow wells in the area, which are mainly used by low-income populations as a complementary source and sometimes as the sole water source. Aquifer overexploitation is not reported. Groundwater quality is sometimes poor due to pollution or salinity.

About 44% of sewage water (13.2m^3/s) is treated, and most of the remaining discharge flows to the sea through a pipeline or to the Guanabara Bay. In general the situation is improving.

Box 8.5 Urban water in Metropolitan Lima, Peru

[By Javier Dávara, Aqualogy-CEDAPAL, Lima, Peru, and Manuel Cermerón, Aqualogy, Barcelona]
The metropolitan area of Lima, which comprises Lima (Peru's capital) and Callao (main Peru's harbour) has approximately 9.4 million inhabitants. It is in an arid zone which depends fully on river water from the high Andes Range. Urban water supply is tapped from two of the three local rivers and the local aquifer. In this arid area aquifer recharge is through river and urban water infiltration.

The state-owned Servicio de Agua Potable y Alcantarillado de Lima (SEDAPAL, Lima's Drinking Water and Sanitation Service) fully supplies forty-three out of the forty-eight city districts and partially two others, with 83% of surface water and 17% of groundwater, which is treated in three plants. Some 89% of the inhabitants are supplied through 13,700km of pipes, and 85% of sewage water is collected through 12,000km of sewers, 20.6% of which is treated in seventeen plants.

Water prices are 0.67US$/m^3 plus 0.29US$/m^3 for sanitation. There is fixed base rate plus a charge proportional to the volume of the water supplied, with different rates for domestic, commercial, industrial and state demands.

Box 8.6 Urban water in the city of Buenos Aires, Argentina

[By María Josefa Fioriti, Under-Secretariat of Water Resources, Buenos Aires, Argentina]
The water supply and sanitation of the Autonomous City of Buenos Aires, the capital of Argentina, and its seventeen neighbouring administrative areas ('partidos') is the responsibility of AySA (Agua y Saneamientos Argentinos S.A.). The very flat area covers over 18,11km^2, it has 10.2 million inhabitants, of which 90.6% receive drinking water and have sanitation. 4.53hm^3/day of surface water from the Rio de la Plata and 0.25hm^3/day of groundwater from 238 wells is supplied, about 600m^3/day/cap. The water supply network exceeds 18,000km. Supplied water quality complies with the fifty-eight values of the Regulatory Framework, which is based on the Argentinean Food Code and Word Heath Organization recommendations.

Some 62.6% of population is served by the 10,600km sewage water network and five treatment plants, discharging to an outfall that takes and diffuses the 2.25hm^3/day of effluents to a point near the end of the estuary of La Plata River, 2.5km offshore.

Water is charged to domestic, commercial and industrial establishments, and non-occupied land according to the metered volume for those who have a water meter and according to building or house characteristics for the other ones. Social tariffs are applied to low-income citizens and also they participate in local water management affairs as regulated by national authorities.

The Director Plan Framework for water aims to have 100% coverage by 2018. This will require a new drinking water treatment plant, modernization of the existing networks, five new sewage water treatment plants and the enlargement of four of the existing ones.

Quality of service, the protection of human rights and the delivery of concession conditions to the water company depends on the Water and Sanitation Regulatory Entity (ERAS). Water planning for water service and sanitation works depends on the Planning Agency (APla).

Box 8.7 Urban water in Mexico City

[By Ramón Aguirre Díaz, Director General of Waters Systems, Mexico City, Mexico].
The metropolitan area of Mexico City exceeds 20 million inhabitants and is located in the Valley of Mexico, a closed basin 2,240m above sea level. Current water outflows from the area are artificial. Water availability is 160m^3/yr/cap, while for the whole country is 4,090m^3/yr/cap. The main water source is the aquifer, which has been over-drafted by a factor of two for more than a decade. This is a non-sustainable situation. Some studies indicate that the aquifer could be completely exhausted in two or three decades. Complementary water supply from the Cutzamala water surface dams is not enough in the event of a serious drought. About 10% of the population receives water once or twice per week, another 15% will suffer from low water pressure during five to six hours per day and 5% does not receive good quality drinking water. Current average urban water use is 530L/day/dwelling, which is a very high figure under current circumstances. This is the result of water prices being well below the real cost of water and the almost non-existent water meters in the dwellings.

To deal with this huge and concerning problem and to take care of the future generation, an Integrated Water Resources Management Program (PGIRH) has been prepared and launched, for the coming twenty years. Among the many actions, 225 new wells, the protection of 111 springs, the substitution of 5,700km of pipes to reduce leakages, 1,326km of new pipes, seventy-four improved or new drinking water treatment plants and the use of reclaimed treated sewage water for non-drinking uses are included. Aquifer recharge with reclaimed sewage water treated up to drinking water quality is foreseen to increase storage and to control subsidence problems, especially where thick clay layers exist. The programme aims at raising water prices to cover real cost and to install in-house water metering to reduce water use, but considering social tariffs for the more deprived. Although the programme is very ambitious and involves very high investment of 13 billion US$ investment in twenty years, it is feasible and it is what the City of Mexico requires to achieve a sustainable, quality water service.

Water quantity is not generally a limitation in LA (see per capita consumption in Table 8.1). However, per capita consumption is often high, particularly in Argentina and Mexico. The limitations come mainly from the needed infrastructure associated to water storage and transport. Sometimes water transportation may involve important energy consumption when natural barriers have to overcome, as in Peru for the transport of water resources from the water-rich and relatively low-lying upper Amazonas basin to supply the arid western coastal area, where most of the large urban areas are located. Mexico City and other urban areas at high altitude require costly water pumping from low-lying areas. Furthermore conflicts with local residents arise as they compete for the resources or do not accept wastewaters for agriculture in exchange of handling over the water resources they already have. Here groundwater plays an important role but it is also a source of conflicts with other users. Deeper wells are drilled in order to tap up-to-now little exploited aquifers and offered as a new water resource when it is in fact part of the same system and their exploitation will only worsen current problems of over-draft and also serious land subsidence in some areas.

The water quality of urban supply sources is often an important issue, and will be more in the future. Buenos Aires (Argentina) takes a large part of its water from the urban and industrially polluted Rio de la Plata, which can suffer large quality fluctuations. The urban areas in Colombia and Venezuela cannot use the numerous local rivers, lakes and aquifers due to intense pollution from important urban, industrial and mining areas upstream. Groundwater is commonly of enough good quality, but there are important exceptions. In coastal urban areas seawater intrusion has forced the closure of part of the supply wells (Mar del Plata, Argentina; Recife, Brazil). High natural groundwater salinity due to aridity is found in northern Chile and Peru, and in parts of northeastern Brazil. An excess of nitrates is also a common groundwater quality problem, mostly caused by the activity of the urban area itself, for example when collective sanitation is insufficient (Conurbano Bonaerense, Buenos Aires, Argentina, and Lima, Peru) and in some cases of agricultural origin, although this does not occur as intensely as it does in North America and Europe. This last aspect is important around urban areas in Mesoamerica (Costa Rica, Nicaragua, and Guatemala). Unwanted and noxious solutes, such as relatively high concentrations of fluoride and arsenic, can be found in groundwater. Although this problem rarely affects people in large cities connected to public water supply, it is a serious issue in many rural areas of Argentina, Paraguay, Chile, Peru and Mexico. Some large towns do often have to blend the different water sources in order to dilute waters that do not meet the standards or take out of service some others – an often-used situation when sanitary authorities intervene or use them only as backup in emergencies. Blended water may not always be available to all citizens. Treatment for natural poor water quality is not common in LA, where looking for new water sources is preferred, even if this is more expensive.

8.3 Current situation of urban water services

The initial euphoria at establishing water services throughout the 20th century, their advantages being so obvious, made sure that the funds needed to initiate the projects were provided. However, this euphoria has not been maintained, and in fact many water services are currently in dire need of modernization. This and the great population growth, especially in urban areas, are responsible for the existing problems, which are especially pronounced in LA. The most important of them are presented below.

8.3.1 Insufficient water service cover

Reducing the percentage of people lacking water services is one of the main Millennium Development Goals, which also include halving by 2015 the number of people lacking drinking water. The World Summit for Sustainable Development in Johannesburg in 2002 added sanitation to these goals (GTAS, 2003). These goals have been globally accomplished and exceeded for water supply, but not for sanitation that is likely to fall 85% short of the objective (Regional Process of the Americas, 2012). Prospects are good for LA (ONU, 2011; UNICEF/OMS, 2012), although in rural areas the situation is not as positive since 20% of these populations do not have adequate water supply and 50% of them lack appropriate sanitation (Pearce-Oroz, 2011) (see Chapter 6 for a detailed presentation of these indicators).

8.3.2 Lack of urban and industrial wastewater treatment

This seems to be the main mid-term problem to be addressed by developing countries and by LA in particular. By prioritizing the Millennium Development Goals to increase water supply and sanitation networks, wastewater treatment has been put to one side. The Americas' Water Agenda report (Regional Process of the Americas, 2012) highlights the effect of increasing water contamination but does not deal with the causes; the problem is simply considered a service deficiency. The IV World Water Forum of Mexico (CNA/WWC, 2006) provided the impressive figure that more than 86% of wastewater is disposed of into the environment without any treatment, and irrigating with untreated wastewater is a common practice, highly risky for citizens' health.

Good wastewater treatment before disposal is a key component of sustainable water management, even if it requires costly investments, expensive maintenance and modernization of the existing network. After a global analysis avoiding contaminated water in the urban environment, treatment is much cheaper than importing water resources from elsewhere. However, in the real world short-term goals overcome the mid- and long-term points of view. This problem will never be solved if water prices do not allow a reasonable cost recovery since Governments do not have enough economic resources to subsidize water treatment, especially for a population that is polluting more and more and increasingly using more household polluting chemicals.

8.3.3 Economic unsustainability

Economic sustainability is a necessary although not sufficient condition to solve the above mentioned problems. Efficient management needs not only technological capacity to identify the best cost-benefit actions, but also economic resources to carry them out. Without them the system advances towards economic collapse, as too often happens in LA urban water services.

In practice, the efficient and accurate administration of economic resources is difficult, as dealt with extensively in the OECD (2012) report, although this will be not addressed here. Up to seven key coordination gaps are identified for better water governability: administration, information, policy, capacity, financing, objectives and accounting. Economic resources are needed and they should be wisely managed.

Water service economic unsustainability refers not only to the lack of funds needed to improve the facilities and systems of the fast growing cities – they may come from international organizations in the case of poor countries – but also to the more complex problem of obtaining the funds needed for the correct functioning of the existing, expensive infrastructures. These funds ought to be secured from the water services users themselves. This opens two permanently debated points: 1) tariffs that allow for cost recovery, which is a complex matter in countries with deep social inequalities, and 2) corruption, which is especially concerning in LA. In poorly consolidated democracies corruption is a rather frequent temptation in front of the increasing economic resources being used and attracted, as shown in an OECD website[2] on this topic.

8.3.4 Ageing of existing water infrastructures

The ageing of water infrastructures is a very serious problem that passes almost unnoticed due to the more conspicuous problems commented above. This problem even affects the USA, the richest of all the American countries, as underlined by the EPA (Environmental Protection Agency). In 2007 the EPA estimated that 334,800 million US$ has to be invested during twenty years in order to modernize drinking water supplies (EPA, 2009). In other recent studies it is estimated that about 1,600,000km of drinking water pipes have to be modernized in the USA, which means about 3000 billion US$ over the coming twenty-five years (AWWA, 2012). Figure 8.1 depicts the magnitude of this great problem by showing the evolution of the median age of the infrastructures and the median age of the population in the USA.

In LA this problem is even more serious. This is a direct consequence of the economic unsustainability mentioned previously, worsened by the fact that most new investments are for new infrastructures to progressively extend water services and approach the MDGs, while existing infrastructures are poorly maintained. Some of them are many decades old. All of them have an expiry date. Maintenance, rehabilitation or replacement failures will have serious consequences in the long term. In some way they are the main cause of the deficient quality of supplied services (Regional Process of the Americas, 2012).

2 www.oecd.org/corruption/latinamerica

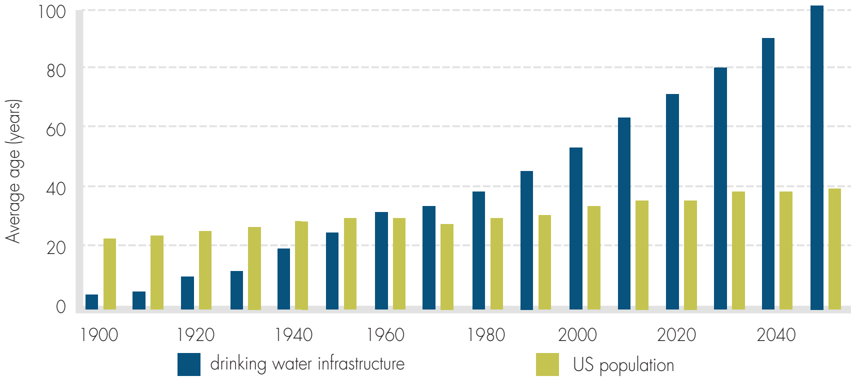

Figure 8.1 Median age of population and of water pipes in the USA. *Source: Buchberger (2011)*

8.3.5 Poor quality of water services

This is the natural consequence of economic unsustainability, caused by poor maintenance and the lack of infrastructures renewal. The Regional Process of the Americas (2012) report explicitly highlights the most relevant deficiencies to be insufficient water disinfection, poor surveillance of water abstractions, discontinuous service, insufficient pressure, high leakage percentage and the low wastewater treatment degree. These are big challenges.

The problems identified by the Regional Process of the Americas (2012) report can be grouped into water quality (treatment and monitoring) and distribution (pressure, leakage, continuity of service). Something similar has been identified by Aqua Rating, a project sponsored by the IDB with the help of the IWA (International Water Association). The project aims at developing a system to qualify water and sanitation suppliers (Krause et al., 2012). For water service quality the project considers drinking water quality, water distribution for use and consumption, wastewater collection, and care of the users (this last point being more commercial than structural).

8.4 The enormous cost of poor water service quality

In any country urban water services should and can be economically, environmentally and socially sustainable. In spite of the big financial resources required, scale economies in cities allow to provide these water services at a reasonable cost, which is more difficult in rural areas (Pearce-Oroz, 2011). This is not discussed here. Sustainability demands governance and long-term vision, which is the bottleneck of implementing these systems. The other aspects are easier to solve. The fact that providing a low-quality service is more costly to citizens than attaining the adequate standards needs to be clearly shown and argued. This can be easily understood from a social point of view by showing the savings that would be obtained if the individual no longer had to support the failings of the poor-quality service. However, the supplier will always look to their own short-term economy if not pushed to do otherwise by well-informed and organized citizens.

Each of the six deficiencies described below is accompanied by the associated costs, which are seldom considered and often transferred as a burden for future generations. However when all these costs are included, good management of the water service is much cheaper. The problem comes down to the need to involve society much more in the water services through appropriate institutions.

8.4.1 Insufficient disinfection and drinkability

According to the World Health Organization (OMS, 2002), inadequate water and sanitation are the main causes of illness, such as malaria, cholera, dysentery, schistosomiasis, infectious hepatitis and diarrhoea, which are related to 3,400 million deaths in the world and LA is not an exception. Inadequate water and sanitation are also a main cause of poverty and of the growing gap between the rich and the poor. Figure 8.2 shows the close link between child mortality and access to improved water and sanitation (Robinson et al., 2006).

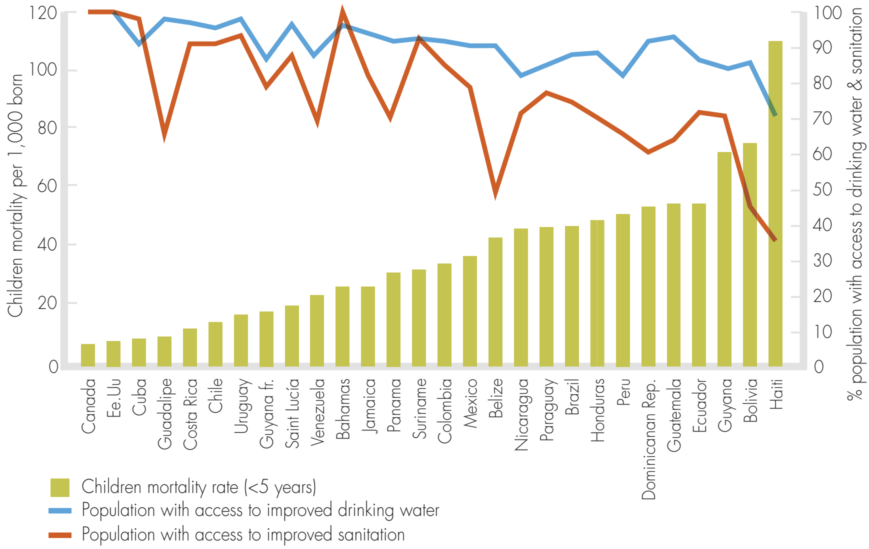

Figure 8.2 Access to water and sanitation (%) and child mortality (deaths per 1,000 born) in different American Countries. *Source: Robinson et al. (2006)*

8.4.2 Lack of quality control

There is a long path through pipes from the drinking water plant to the citizen's tap. The pipes may be sometimes over one hundred years old. Even if at the inflow point to the system water quality is guaranteed, along the distribution path it deteriorates, especially when the residence time in the distribution network can be up to several days. A control of water at the outflow of the drinking water plant is needed but is not sufficient as the water quality will deteriorate, the older the network is.

Much attention has been paid to this aspect in the last two decades in developed countries. One example is the EPANET programme for analysis of water networks, sponsored by the US Environmental Protection Agency (Rossman, 2000). It is a free access programme aimed at facilitating the study of water quality evolution through pipes.

Urban water quality is of great concern in all developed countries (Kastl et al., 2003; MHLS, 2010) due to trihalomethane generation, which is a carcinogenic compound resulting from the progressive interaction of organic matter in water – mostly that from surface resources – and chlorine (Aieta and Berg, 1986). This is the reason why in some countries, like The Netherlands and many areas in Germany, the use of chlorine as a disinfectant has been abandoned and substituted by other disinfection processes, which do not impair the taste, but they are often more expensive. As a result, these countries have drastically reduced the consumption of bottled water (den Blanken, 2009).

8.4.3 High percentage of losses

Unreliable or inadequate pipes for the soils in which they are laid, careless assembly, lack of maintenance and scarce – sometimes, inexistent – network rehabilitation or replacement are the main factors that cause the water distribution system deterioration. Water supply reliability depends on pipe proofing, which decreases progressively over time.

Network water losses in LA are often very high. According to ADERASA (Association of Regulating Entities for Drinking Water and Sanitation of the Americas) the average value is 42% (Figure 8.3), and this value is possibly quite conservative as it refers to a set of the best managed towns in the area (ADERASA, 2012). According to the Cooperativa Andina de Fomento (Andean Cooperative for Enterprenery, CAF, 2011) losses are 40%, which is also quite optimistic as it is estimated from data contributed by the own water distribution utilities. In a later publication (CAF, 2012) the fraction of unaccounted water (real leakage, measurement errors and thefts) had risen to 50%. Consequently, it seems that in LA about half of outflow water from drinking water plants does not get to the users, which is economically, environmentally and socially unsustainable, even if the water resource is not entirely lost for later use.

The consequences of high network losses are well known. The most relevant are:

- Existing infrastructures (pumps, drinking water plants, reservoirs, networks) become insufficient to secure the water supply and they have to be enlarged. This means doubling current capacity in LA.
- High probability of pathogenic intrusion into the water network. If water pressure drops below atmospheric pressure in a network – something that happens often when water service is not continuous – leaked water may get back into the system (Kirmenyer and Mantel, 2001). This poses a more serious problem than quality deterioration during distribution.
- Water supply may be intermittent in dry periods, when less water is available. This has a series of other drawbacks that will be commented upon below. Should the water losses be small, there is no need to interrupt water supply. There are other more reasonable methods to save water without recourse to temporal interruption of the supply (Cabrera, 2007).
- Water users' poor trust in the water utility, thus reducing willingness to pay.

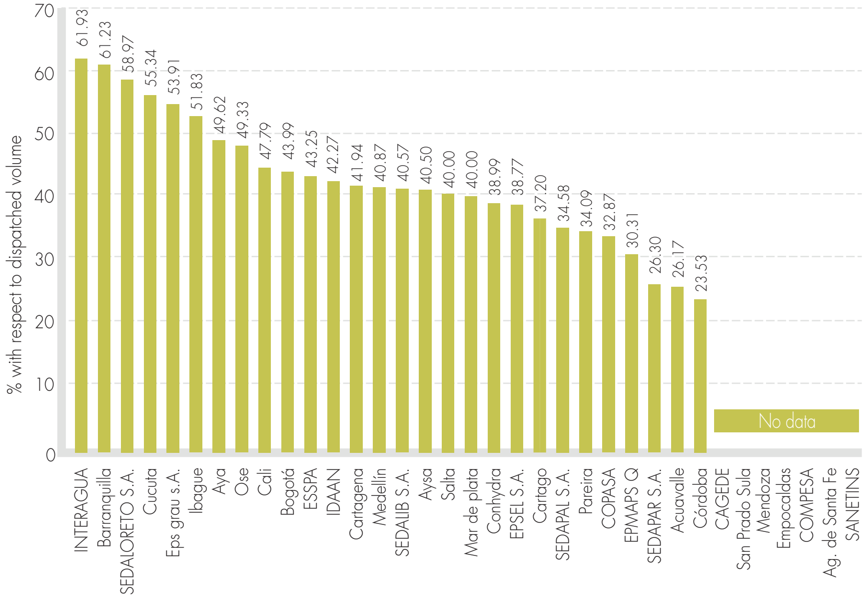

Figure 8.3 Water network losses in representative urban areas in LA. *Source: ADERASA (2012)*

8.4.4 Low water supply pressure and domestic storage tanks

Leakages aside, a network becomes insufficient if it cannot supply the demanded flow at water demand peaks at the established pressure – at least approximately 20m of water head (two atmospheres) – when water demand peaks. Problems appear when the network does not improve its capability at the same rate as population growth. Often pipe diameters are those required by the city before a significant increase of connected people. In order to solve supply problems the manager of an insufficient network forces or recommends the construction of domestic water storage tanks and butts, to decouple water demand from users from actual supplied water. They store water when demand is low (e.g., from 0:00 to 6:00 am) and release it in peak hours. The method has clear disadvantages:

- Water quality can be significantly affected due to storage time, mostly because storage time is unknown, but also to the high possibility of a pathogenic intrusion as pressure – the guarantee against intrusion – is lost. Besides, tanks and cisterns are barely protected and cleaned; this contributes to a worsened water quality guarantee, as shown in the experimental studies carried out in Tiquipaya, Bolivia (Schafer and Mihelcic, 2012).
- Energy is wasted since water is depressurized to later be pressurized again for the users.
- From a more technical point of view, water demand timing is quite distorted and the system loses a great deal of its characteristics, thus making it more difficult to conduct mathematical simulation and leakage surveys.

Temporal water service interruption shows that the network is clearly inadequate to supply a growing population. Looking globally at the problem, this implies a very important economic loss (Cabrera et al., 2013): the money the system manager saves by not investing is much less that the set of expenses transferred to all connected customers.

8.4.5 Intermittent service

Often inefficiency – high leakage – and insufficiency – lack of pressure – go together and then the water supply manager has no other recourse than intermittent service by interrupting water supply periodically. This is frequent in LA, where it has been observed in almost 30% of the systems (CAF, 2012). The most serious drawbacks of water quality loss and the causes of the system becoming no more secure are well documented (Yepes et al., 2001; Totsuka et al., 2004). One of the most serious problems is faster network deterioration as a result of alternatively pressurizing and depressurizing the network, which leads to increasingly more frequent and lasting breakdowns and water losing points. According to Charalambous (2011), the number of pipe breaks each year triples with respect to a continuous water supply.

8.4.6 Lack of wastewater treatment

In LA most urban and industrial water discharges lack treatment, and this has important consequences due to the serious sanitary, environmental and the not always fully recognized economic consequences. If the town pollutes the near-by waters, it has to look for more distant water supply sources and consequently more expensive ones. Looking for water sources further afield is not a new phenomenon: in 1890 in order to supply Paris, it was proposed that water be taken from Lake Leman, 450km away (Barraqué, 2004). What at that time was a fashion, declined by end of the 19th century and beginning of the 20th century after the discoveries of Pasteur and Koch that lead to disinfection thus allowing the use of local water. However, in some of America's large cities, importing water seems a real necessity, as is the case of Mexico City (Perlo and González, 2009), and probably of Lima.

8.4.7 Conclusion on poor water quality supply

From any point of view, making use of economies of scale is the most logical and feasible solution to provide a good quality urban water service to the citizen at the lower possible cost when all involved costs (e.g. the bottled water to substitute for tap water, see Box 8.8) and a mid- and long-term economic balance are considered (Cabrera et al., 2013). However, this needs a good administrative structure and political support, in addition to a large capacity for leadership amongst decision makers. Currently, most or all urban water cycles in LA are unsustainable.

Box 8.8 Bottled water and soft drinks for domestic consumption

In many LA countries the production of bottled water and soft drinks is not only quite developed but has a special economic and social relevance, with the trade mostly in the hands of a few large firms. Mexico is a leading country. One of the main drivers seems to be the once unreliability and poor quality of in-house water supply, without guarantee of being pathogen free, or too saline, or containing an excess of toxic natural solutes for sustained consumption, such as fluorine or arsenic. This is the case in many rural and small urban areas of Mexico, Argentina and Paraguay, most of them using groundwater without adequate hydrogeological studies. Large efforts are devoted to better understand the origin of these natural pollutants and on practical means to reduce economically their content. Interruptions in domestic supply in the past, as explained in the main text, can be considered the main cause of the widespread use of small domestic storage tanks on the roofs of the houses, as can be seen in many of the low-rise residential areas of several towns in LA. Some water-related diseases are not uncommon, often with mild results to locals, not always to travellers; there is a real risk of epidemic spreading. Another important driver of bottled water and beverages consumption is the increasing living standards. Drinking bottled products is often considered a sign of affluence, which becomes a social issue and a display of personal status. This is widely propagated by effective advertising by large companies and good distribution logistics. Even though this represents a large part of income to individuals and to society, it is difficult to be reversed.

Production of bottled water and drinks uses about two to three times the water in the final product and about 25% of its volume as fuel consumption. These amounts include the water used to produce the bottles and the fuel to distribute them which has to be added as well as that needed to produce the additives. Furthermore used plastic bottles is becoming a serious environmental problem.

Bottled water price in the market ranges from 500 to 5,000 times higher than the average tap water price. It is one of the main hidden personal, social and environmental costs of a deficient water supply.

8.5 Causes of the current water services situation

After describing the main problems of urban water services and the associated serious consequences, the present situation is taken into account in order to define measures aimed at improving it. This is a complex task. Economic and social–political causes have been described in detail by some organizations (CAF, 2011; Regional Process of the Americas, 2012; OECD, 2012) as well as by some authors that have a great wealth of knowledge about LA (Jouravlev, 2004; Hantke-Domes and Jouravlev, 2011), and will not be repeated here. As an overview, key phrases from three of these works that explain current situation are given opposite.

In the report 'Water Governability in Latin America and the Caribbean: A multilevel point of view', the OECD (2012) concludes that [translation from Spanish]:

Key challenges are institutional and territorial fragmentation and badly managed multi-level governance, as well as limited capacity at the local level, unclear allocation of roles and responsibilities and questionable resource allocation. Insufficient means for measuring performance have also contributed to weak accountability and transparency. These obstacles are often rooted in misaligned objectives and poor management of interactions between stakeholders. (p.15)

The report on Americas' Water Agenda (Regional Process of the Americas, 2012) provides a similar diagnosis:

It is important to emphasize that in contrast to the institutional strength and stability in Canada and the USA, the social perception studies on the role of public institutions in Latin America and the Caribbean (LAC) demonstrate low credibility. Different factors not always attributable to the institutions have had an influence on this: the magnitude of the challenges faced, institutional weakness, the scarcity of economic resources, preconceived judgments and ideological notions with respect to the role of the State, the regulation and participation of the private sector, the weakness of civil society organizations, the perception of seizure of the institutions by interested sectors and the problems associated with globalization.(p.6)

Some years before, the same problems were pointed out in Jouravlev (2004) on the status of drinking water and sanitation services on the 21st century [translation from Spanish]:

Despite the differences to be expected in a region that is home to many different countries, reforms have many common features, such as; institutional separation between the roles of sectorial policymaking, economic regulation and the management of the systems; the deepening and consolidation of decentralization in the provision of services; the general interest in promoting private participation, the development of new regulatory frameworks, and the demand, born out of the 1980s crisis, that services should aim to be self-financed, and when in place, subsidy plans should be set up to help low-income groups.

These coinciding diagnoses can be summarized as weak governance and a lack of leadership. In short a public urban water service for a big city is a project common to all its inhabitants and can only be carried out successfully with sound governance and leadership. Given that water and the nature of human beings are the same regardless of country boundaries, the differences between national water policies depend on the strength of their governing institutions and political structures as well as on other cultural and economic factors. From a strictly technical point of view the problem is not unduly difficult in the big cities, however, the story is different in rural areas where a priori scale savings are not possible to make water supply economically feasible.

In order to easily overcome these handicaps, some existing problems have to be solved, the difficulty of which will vary according to the country, although some already have plans in place. Even when plans exist, it helps in taking into account these handicaps, which are reviewed over.

8.5.1 Lack of professional capacity of political decision makers

Decision makers, besides applying common sense and being honest, must give priority to sound solutions for citizens and especially for future generations. They ought not to be guided by short-term goals and self-interest, but will require training and good foundations on which to build. With this in mind they will boldly identify decisions for the future, abandoning the short-term visions that have become commonplace, and will strive for mid- and long-term solutions.

8.5.2 Lack of training for managers and engineers

In the urban water cycle three different decision levels exist: political, managerial and mechanical. These last two refer respectively to those controlling finances and human resources and those carrying out technical decisions. However, current training opportunities for staff are not sufficient to deal with the complexity of urban water supply. Since economic resources are often lacking, these managers and engineers with little training have to identify optimal cost-benefit solutions. This is highlighted in the OECD (2012) report, in which it is said that in two-thirds of the LAC countries studied, the capacity gap is a big handicap to the effective implementation of water policies.

8.5.3 Lack of environmental knowledge amongst citizens

State financing of large water infrastructures and the principle that water is a public good have fostered the belief amongst citizens that they have a universal right to good-quality tap water at little or no expense. Water as such has only an environmental and opportunity cost, but the infrastructures needed to carry the water to the citizen has high economic costs which must be paid by water users. Without this, recurrences continue to happen: a progressive deterioration of the infrastructure that benefits nobody. Another aspect to be considered is that the tariffs ought to be progressive to help the economically weakest gain access to water they need with any loss in water quality.

The lack of public knowledge about real water costs makes the need to increase water tariffs a poorly understood issue. This is regrettably part of a political debate when it should be a 'state' affair given that the survival of the city is at stake. The average citizen is intelligent and, if given the right information, is likely to be able to see the difference between opportunistic and self-interest policies, and those which are honestly beneficial to the population. This is of crucial importance in order to separate water from the political arena as much as possible.

8.5.4 Allocating responsibility

Fragmented institutions, with diverse points of view of the same issue, make for difficult decision making. This problem is highlighted in all reports where water problems are analysed in any detail. As water is such a key issue, all politicians try to include it in their agendas, or avoid it as much as possible in the case of serious conflict. Drinking water's increasing complexity has favoured an increase in the number of government departments involved in managing the issue: water, environment, health, industry, mining, etc. This makes for cumbersome and bureaucratic governance. More nimble and operative structures are needed in order to solve the plethora of water problems.

Involving users in water affairs may be an interesting approach. An approach is that adopted in Buenos Aires, where AySA has had considerable success doing specific work with lower-income sectors, through the methods of 'participatory models of governance' (MPG) and the 'Water+Work Plan' (Plan agua más trabajo), and to a lesser extent to 'Sanitation+Work Plan', which is reflected by joint action with neighbourhood communities, municipalities, government agencies, and social organizations. The company performs most of the financing of projects and provides technical supervision and neighbours help with labour, receive technical training, participate in workshops on proper use, and receive a discount on their bills (Lopardo and Lentini, 2010).

8.5.5 Lack of water service standards

In order to have a good-quality water service, objectives are needed and have to be made explicit. Management indicators (Alegre et al., 2006) allow them to be set with relative accuracy. For example, when defining the minimum water pressure that has to be guaranteed at demand peak, one must take into account the acceptable percentage of losses. This is needed to evaluate the present situation and set future targets. Independently of objectives set by financing organizations (Krause et al., 2012), which are establishing water service quality evaluation systems, the corresponding country authority (or regulator if it exists) should be the one to set the detailed objectives.

8.5.6 Unclear pay rules when the service is externalized

The public–private urban water management debate is intrinsic to the service and continues to cause debates. In 1875, the city of Birmingham (UK) bought the service from the private enterprises that had started them, arguing that 'the quantity and quality of water to be supplied to the public are matters of greater importance than making profits and should be controlled and managed by representatives of the people and not by private speculators' (Thackray, 1990). Shortly afterwards the story was repeated. In 1898 the city of Amsterdam bought the private company because of problems with financing the necessary extensions to the network arguing that the private company was more interested in making profits than in supply' (Swemmer, 1990). After more than a full century the debate continues, with those who defend public involvement bringing forward similar arguments.

Circumstances in LA have made the above commented issue a conflictive one (Castro, 2007; Ducci, 2007; ISF, 2008). At the same time that public management is preferred, there is also a need to attract and obtain private investment. This explains why prestigious institutions revisited the problem and proposed guidelines for developing reasonable agreements (Solanes and Jouravlev, 2007; OECD, 2009). This will not be elaborated upon further here, but will undoubtedly continue to be debated in all countries for many years to come (Jones et al., 2004; Boland, 2007).

8.5.7 Political prices and criteria

The lack of clear criteria used to establish the final price to be paid by citizens for the water service is probably the largest Achilles' heel of the urban water cycle. Since not all costs are recovered, a large part of the infrastructure has to be financed with public funds of diverse origins or with subsidies. Since this means large money sums passing through a few hands it is not rare that corruption occurs (Solanes and Jouravlev, 2005). Thus, clear criteria for self-financing are needed, in such a way that the sustainability of these water services is guaranteed by honouring the cost recovery principle as promoted by the Water Framework Directive in the European Union (OJEU, 2000), and also with an equitable tariff system to protect the weakest, without compromising efficiency. This equity is crucial given the large inequalities in LA.

8.5.8 Poor transparency in urban water management

Since water is a public good that is essential for life, it has to be flawlessly managed. There is an ethical obligation for transparent management, and this is even more serious for water supply. Countries have to establish the means needed to accomplish this goal. It would be recommendable that all money coming from urban water should be invested in water, and not be used for other needs, as often happens due to biased political interference. An efficient regulation service is one of the best ways in which to accomplish this goal, much as efficiency is a key strategy in order to reach a more sustainable future (BNA, 2012)

8.6 Conclusions

Providing a quality drinking water service, adequate sanitation and correct treatment of wastewater is a very complex problem, especially in LA where the population, especially in urban areas, has expanded rapidly. It is even more difficult considering that the current situation is far from desirable. The root of the problem is neither economic (scale economies allow for the provision of good quality and sustainable water services at a reasonable cost) nor technical (current engineering can deal with the most complex problems). The handicaps to be overcome are a severe lack of governance and of institutional leadership which are currently unable to deal with the rapid evolution. Since the path to be followed is well known, it is hoped that improvement of the current situation and avoidance of the serious consequences of not doing anything could be seen in the near future. LA citizens deserve the best quality service at the lowest possible cost though the differing characteristics of each country must be taken into account before any plan is implemented.

Acknowledgements

Special thanks to Andrés Benton for his help obtaining information on Mexico City. Complementary data are found in other chapters of this book and in the supporting reports contributed by the different country teams.

References

ADERASA (2012). Asociación de Entes Reguladores de Agua y Saneamiento de América. *Informe anual 2012*. Asunción, Paraguay: Grupo de Trabajo Regional de Benchmarking.

Aieta E.M. & Berg J.D. (1986). A review of chlorine dioxide in drinking water treatment. *Journal American Water Works Association,* 78 (6): 62–72.

Alegre, H., Baptista, J.M., Cabrera Jr., E., Cubillo, F., Duarte, P., Hirner, W., Merkel, W. & Parena, R. (2006). *Performance Indicators for Water Supply Services*. Second edition. London, IWA Publishing.

AWWA (2012). *American Water Works Association Buried no Longer: Confronting America's water infrastructure challenge*. Denver, Colorado.

Barraqué, B. (2004). Water policies in Europe after the Framework Directive. In: Cabrera, E. (ed.). *Challenges of the New Water Policies for the XXI Century*. pp. 39–50. Balkema.

BNA (2012). Business News Americas. *Efficient Water Use in Latin America: Good business for all*. Infraestructure Intelligence Series.

Boland, J.J. (2007). The business of water. *Journal of Water Resources Planning and Management*. ASCE, May–June: 189–191.

Buchberger, S. (2011). *Research & Education at the Nexus of Energy and Water*. Environmental Engineering Program,University of Cincinnati.

Cabrera, E. (2007). Los cortes de agua y el racionamiento racional en épocas de escasez. In: Cabrera, E & Babiano, L. (eds). *'La sequía en España. Directrices para Minimizar su Impacto'*. pp.212–231, Ministerio de Medio Ambiente de España.

Cabrera, E., Cobacho R., Espert V. & Soriano J. (2013). *Assessing the full economic impact of domestic water tanks*. International Conference on Asset Management for Enhancing Energy Efficiency in Water and Wastewater Systems. Marbella, Spain, IWA.

Cabrera, E. & Custodio, E., (2013). Urban water, an essential part of integrated water resources. In: Martínez-Santos, P., Aldaya, M.M. & Llamas, M.R. (eds). *Integrated Water Resources Management in the 21st Century: Revisting the paradigm*. Boca Ratón, FL, CRC-Press. Forthcoming.

CAF (2011). Cooperación Andina de Fomento. *La infraestructura en el desarrollo integral de América Latina. Diagnóstico estratégico y propuestas para una agenda prioritaria*. XXI Cumbre Iberoamericana de Jefes de Estado.

CAF (2012). Cooperación Andina de Fomento. *Agua potable y saneamiento en América Latina y el Caribe: metas realistas y soluciones sostenibles*. Propuestas para el 6° Foro Mundial del Agua.

Castro, J.E. (2007). *La privatización de los servicios de agua y saneamiento en América Latina*. Buenos Aires, Nueva Sociedad.

Charalambous, B. (2011). The hidden costs of resorting to intermittent supplies. *Water* 21: 29–30.

CNA/WWC (2006). Comisión Nacional del Agua and World Water Council. *Water Problems in Latin America*. Mexico, 4th World Water Forum.

den Blanken, M. (2009). *Asset Management. A necessary tool for a modern water company.* Miami, LESAM. Leading-Edge Conference on Strategic Asset Management.

Ducci, J. (2007). *Salida de operadores internacionales de agua en América Latina*. Banco Interamericano de Desarrollo.

EPA (2009). Environmental Protection Agency. *Drinking Water Infrastructure Needs Survey and Assessment*. Washington DC, Office of Ground Water and Drinking Water. Fourth Report to Congress. EPA 816-R-09-001.

GTAS (2003). Grupo de Trabajo sobre Agua y Saneamiento. *Cómo lograr los objetivos de desarrollo del milenio con respecto al agua y saneamiento: ¿Qué será necesario?* Proyecto Milenio. New York, UN.

Hantke-Domas, M. & Jouravlev, A. (2011). *Lineamientos de política pública para el sector de agua potable y saneamiento*. Santiago de Chile, Chile, CEPAL.

ISF (2008). Asociación Catalana de Ingeniería sin Fronteras. *Con el agua al cuello. Ascenso y caída de las multinacionales en Sudamérica: El proceso de mercantilización de la gestión del agua. El caso de la inversión española en el Cono Sur. Barcelona.*

Jones, S.A., Houghtalen, R.J., Jones, D.T. & Niblick, B. (2004). Privatization of municipal services: Sustainability issues of production and provision. *Journal of Infrastructure Systems ASCE*: 139–148.

Jouravlev, A. (2004). *Los servicios de agua potable y saneamiento en el umbral del siglo XXI.* Santiago de Chile, Chile, CEPAL. Recursos Naturales e Infraestructura número 74.

Kastl, G., Fisher, I., Sathasivan, A., Chen, P. & van Leeuwen, J. (2003). *Modelling water quality from source water to tap by integrated process models*. Townsvillle CD-ROM: 1799–1804: MODSIM, Integrative Modelling of Biophysical, Social and Economic Systems for Resource Management Solutions.

Kirmeyer, G.J. & Martel, K. (2001). *Pathogen Intrusion into the Distribution System*. Denver, Colorado, American Water Works Association.

Krause, M., Cabrera, E. Jr. & Cubillo, F. (2012). AquaRating: An innovative system for assessing utility practice and performance. *Water* 21: 65–66.

Lopardo, R.A. & Lentini, E. (2010). *Supply and sanitation: serving the urban unserved in Latin America, with a special focus on Argentina*. Presented in the Seventh Biennial Rosenberg International Forum on Water Policy. Buenos Aires. [Online] Available from: http://rosenberg.ucanr.org/documents/argentina/Lopardo%20Final%20Paper.pdf [Accessed September, 2013].

McGuire, M.J. (2013). *The Chlorine Revolution: water disinfection and the fight to save lives.* Denver. American Water Works Association.

MHLS (2010). Ministry of Healthy Living and Sport. *Comprehensive Drinking Water Source-to-tap Assessment Guideline*. Victoria, British Columbia, Canada.

OECD (2009). Organisation for Economic Cooperation and Development. *Private Sector Participation in Water Infrastructure*. Checklist for Public Action. Paris.

OECD (2012). Organisation for Economic Cooperation and Development *Gobernabilidad del Agua en América Latina y el Caribe: Un enfoque multinivel*. Paris.

OJEU (2000). Official Journal of the European Union. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

OMS (2002). *Organización Mundial de la Salud. Agua para la salud: un derecho humano:* Centro de Prensa Organización Mundial de la Salud. [Online] Available from: www.who.int/mediacentre/news/releases/pr91/es/index.html. [Accessed May, 2013].

ONU (2011). Organización de las Naciones Unidas. *Millennium development goals: 2011 progress chart.* [Online] Available from: www.un.org/milleniumgoals/pdf(2011)¬MDReport201. [Accessed May, 2013].

Pearce-Oroz, G. (2011). *Los desafíos del agua y saneamiento rural en América Latina para la próxima década*. Washington, World Bank.

Perlo, M. & Gonzalez, A. (2009). *¿Guerra por el agua en el Valle de México.* 2ª Edición. Mexico DF, Mexico, Universidad Nacional Autónoma de México.

Regional Process of the America (2012). *Americas' water agenda: targets, solutions and the paths to improving water resources management*. February 2012. Available at: www.gwp.org/Global/GWP-CAm_Files/Americas'%20Water%20Agenda.pdf

Robinson, K., Infante, R. & Trelles J. (2006). *Agua, saneamiento, salud y desarrollo. Una visión desde América Latina y el Caribe*. Documento Preparatorio del IV Foro Mundial del Agua. Mexico.

Rossman, L. A. (2000). EPANET 2: *User´s Manual.* Cincinnati, Environmental Protection Agency.

SACM (2012). Sistema de Aguas de la Ciudad de Mexico. *El gran reto del agua en la ciudad de México. Pasado, presente y prospectivas de solución para una de las ciudades más complejas del mundo.* [Online] Available from: issuu.com/politicaspublicas/docs/aguadf [Accessed July, 2013].

Schafer, C.A. & Mihelcic, J.R. (2012). Effect of storage tank material and maintenance on household water quality. *Journal American Water Works Association*, 104 (9): E521–E529.

Solanes, M. & Jouravlev, A. (2005). I*ntegrando economía, legislación y administración en la gestión del agua y sus servicios en América Latina y el Caribe*. Santiago de Chile, Chile, CEPAL.

Solanes, M. & Jouravlev, A. (2007). *Revisiting Privatization, Foreign Investment, International Arbitration and Water*. Santiago de Chile, CEPAL.

Swemmer, F.F. (1990). Water supply and water resources management. In: Schilling, K.E. & Porter, E. (eds). *Urban Water Infrastructures*. Kluwer Academic Publishers. pp. 173–188.

Thackray, J.E. (1990). Privatization of water services in the United Kingdom In: Schilling, K.E. & Porter, E. (eds). *Urban Water Infraestructures*. Dordrecht, The Netherlands, Kluwer Academic Publishers. pp. 33-41.

Totsuka, N., Trifunovic, N. & Vairavamoorthy, K. (2004). *Intermittent Urban Water Supply under Water Starving Situations*. Proc.30th WEDC International Conference. pp. 505–512. Vientiane, Lao.

UNICEF/OMS (2012). *Progresos en materia de saneamiento y agua potable. Informe de actualización 2012*. Programa Conjunto UNICEF/WHO de Monitoreo del Abastecimiento de Agua y Saneamiento.

Yepes, G., Ringskog, K. & Sarkar, S. (2001). The high cost of intermittent water supplies. *Journal of Indian Water Works Association*, 33(2).

9

WATER, ENERGY, BIOENERGY, INDUSTRY AND MINING

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Highlights

- Hydropower is the main energy source in the Latin American (LA) region as a whole (52%), although not in all countries and its relative weight has decreased. It still has growth potential, but new projects will face growing physical, economic and social barriers, including environmental restrictions, the rights of native and local inhabitants, and biodiversity conservation. In some locations hydropower may reduce water availability and security for other uses.

- Fuel energy production may compete for a large part of available water resources in some of the highly populated and semi-arid and arid areas, even when they use closed-cycle water cooling or are placed at coastal areas. Nuclear energy and other forms of energy production are less developed and their effect on water resources is local. Some interesting geothermal energy production exists.

- Mining and related industrial sectors stand amongst the fastest-growing industries in the region. They may be water resource intensive and consequently affect water availability and security when located close to urban areas or in arid areas. So their water needs and consumption, together with their wastewater and mining residues, are becoming stressful factors and a significant source of pressures in numerous basins in the region. In some cases non-renewable groundwater reserves are consumed. In some areas artisanal and small mining activities cause some serious pollution problems to downstream water resources, as is the case of gold mining.

- Industry, energy production and mining together consume 8 to 15% of water resources in the seven considered LA countries.[1] Water consumption relative to available water resources is respectively 4 to 9% for industry, 2 to 5% for energy production (hydroelectric energy water consumption not included) and up to 6% for mining. Water economic productivity in Chile may range from 3 to 10US$/m^3.

- Crops grown for biofuels are increasingly becoming major export products, with a large production in Brazil, and Argentine being now the second largest exporter. Many countries in LA are promoting the cultivation of crops for biodiesel and bio-alcohol. Water resources and land used for these crops compete with land for food production. Especially concerning are projects in dry areas where intensive irrigation is needed.

1 This chapter focuses mainly on Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru.

9.1 Introduction

This chapter focuses on two topics that are usually considered separately. First, the amount of water required by energy-producing plants. Second, two economic sectors – mining and industry – are also water-demanding and are experiencing tremendous growth in the Latin American (LA) region. A detailed treatment of both would request at least a chapter for each of these topics, but being the focus of the volume water and food security, a review of data and their analysis from this narrower perspective has been chosen.

For the most part this chapter refers to continental LA, and specifically to the seven Ibero-American countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Peru) that have provided data from their country reports.[2] However, the discussion goes beyond political boundaries in order to consider different geographical and climatic areas. Except for the large islands of Cuba, Hispaniola (the Dominican Republic and Haiti) and Puerto Rico, the Caribbean area consists of small islands with specific characteristics that introduce quite different circumstances for water resource security, which in some cases involve seawater desalination as an important complementary source. For this reason, they will not be included in what follows. Unless otherwise indicated, in this chapter only mobile water resources (blue water) are considered. Water use refers to water supplied to the activity and water consumption is the part of water used that is not available afterwards due to evaporation, impaired quality or disposal into the sea or a water body that has no further possible use downstream.

Water is needed for many human activities beyond drinking purposes, urban services and the production of food and fibres. It is also used for industrial processes – including food processing and fuel production – and for mining. Additionally, water resources are used for energy production and consumed whilst energy is also needed to make water available for use and for the treatment and safe disposal into the environment thereafter. There is competition for using and securing water resources between all these demands. The important related topic of water security in urban areas is considered in Chapter 8. Except for agriculture, bio-fuel production – a particular form of water intensive agriculture – and hydroelectricity – which uses large water flows but consumes a small part – the other activities often demand a moderate fraction of LA countries' water resources.

Although water consumption for energy, industry and mining may only be a small percentage of the countries consumption, it could be locally significant, especially in small basins and in the arid and hyper-arid areas of LA. This consumption may also be economically and socially important, and therefore water quantity and quality should be guaranteed. Industrial and mining activities may generate wastewater and by-products that could have a large negative impact on water resources quality and on the environment. Circumstances are quite different from one country to another and even inside a given country, as shown along this book, so generalizations may be meaningless. Thus, country

2 These country reports include data and analyses carried out by the project partners. A summary of the consortium and specific represence is include in the volume´s foreword and introductory section.

comments give only a coarse and blurred picture – sometimes too biased – that has to be afterwards considered in more detail taking into account actual territorial circumstances and local situations.

Data and analysis provided here serve to give a general overview of the situation in the first decade of the 21st century. Most LA countries are under fast development and, in spite of fluctuations and some political instability in some of them, conditions have and will continue to improve. The associated industrial and mining development – partly fostered by current high prices for minerals in many of the LA countries – contributes to increased water resources use and consumption and energy demand but also to a more efficient use in economic terms. Estimates of future evolution trends can be found in WEC (2010) and Jiménez-Cisneros and Galizia-Tundisi (2012).

This chapter does not try to present a detailed bibliographical review of energy – including bio-energy, industry, mining activities and water use but instead to contribute to an evaluation of how the associated water needs may affect water and food security in LA. This is done by examining existing data in the reports of the partner countries amongst other sources of information and personal experience. Partners' reports are cited as LA-country (2012) except when specific data are attributed to particular authors (see footnote 2). A general overview is first presented, followed by specific comments on water use and consumption in energy production, industry and mining, which leads to some considerations on water security from the point of view of the activity undertaken and subsequently of general human water needs.

9.2 General overview

Table 9.1 shows some basic data on water use for energy, industry and mining. Hydroelectricity has a large water use (demand) but only a small fraction is consumed. While traditional mining may demand rather large water quantities that are disposed of, modern mining is predominantly a water consumer since internal recycling is important. However, the fraction of water that is disposed of may be unusable and, what is more, may impair water quality downstream, which is equivalent to additional water consumption.

The economic productivity of water is an important driver for water rights acquisition in areas where the resource is scarce, but there are other factors to be considered such as legal restrictions, existing rights – local customs and rights may already be in place amongst natives – and social pressure.

The average economic productivity of water use has been estimated for Chile (Table 9.2) and is markedly higher in industry and the mining sector, e.g. for copper production the value may exceed 50US$/$m^3$. This in turn explains the pressure they impose in order to get water resources when they are scarce, as is the case in the northern part of the country. This may also account for the fact that the companies involved have a greater capacity to purchase water rights in order to secure their supply (see Chapter 13). The very low productivity of water for energy production derives from the fact that in Chile a large fraction of energy production is hydroelectric power that uses large water flows but only consumes a small fraction. If actual water consumption is considered, which is highly variable from one plant to another, the economic productivity of water becomes much higher. Besides, many hydroelectric plants use water resources in remote areas, where no other significant productive uses exist except forestry, fishing and landscaping. Associated externalities are a cost that is often not accounted for. Jiménez-Cisneros and Galizia-Tundisi (2012) gives an average water use productivity in Mexico of 78US$/m^3, varying from 1.3US$/m^3 in agricultural states to 100US$/m^3 in the Federal District, where urban and industrial uses dominate.

Table 9.1 General data for the first decade of the 21st century (values rounded up)

	SURFACE AREA	POPULATION	USABLE WATER			WATER USED		WATER CONSUMED			% OF WATER CONSUMED FOR			
	1000km^2	Million	km^3/yr	mm/yr	% GW	km^3/yr	mm/yr	km^3/yr	mm/yr	m^3/cap./year	ENERGY [3]	INDUSTRY	MINIG	TOTAL
MEXICO	1,973	117	550	279	29	—	—	80	40	683	5	4	0.07	9
COSTA RICA	51	4.7	110	2,157	30	25	490	0.5	10	106	—	—	—	
COLOMBIA	1,142	46	2,640	2,312	20	1,200	1,051	11	10	239	2	5	—	7
BRAZIL	8,515	197	10,110	1,188	19	—	—	58	7	294	—	—	—	
PERU	1,285	29	2,046 [1]	1,592	13	32	25	20	16	690	2	4	2	8
CHILE	756	17	1,060	1,402	14	140	185	15	20	882	[2]	9	6	15
ARGENTINA	2,780	40	1,750	629	14	650	233	190	68	4,750	[2]	6		6

1 1.8% of this amount in the Pacific area, where most human and industrial activities are done
2 Included in industry
3 Consumption by evaporation in surface reservoirs for hydroelectricity in generally not considered

Source: own elaboration based on LA–Argentina (2012), LA–Brazil (2012), LA–Chile (2012), LA–Colombia (2012), LA–Costa Rica (2012), LA–Mexico (2012), LA–Peru (2012).

Table 9.2 Economic productivity of used water in Chile

USE	AGRICULTURE AND FORESTRY [1]	HUMAN SUPPLY	INDUSTRY	MINING	ENERGY
US$/m^3	0.3	2.4	7.4	4.5	0.02

1 Soil (green) water not included

Source: LA–Chile (2012).

9.3 Energy and water

9.3.1 Energy for water

Energy is needed to abstract, pump, transport and treat surface and groundwater. The specific energy consumption (kWh/m^3) may become significant due to:

- pronounced altitude differences, such as sloping land in urban areas, physical barriers to be overcome in mountainous areas, or when groundwater levels are deep in highly transmissive and intensively exploited aquifer systems, especially under arid conditions
- long distance transportation to supply large urban and industrial areas from remote sites

- high salinity or presence of unwanted components, such as nitrates, fluoride or arsenic; energy-consuming treatments such as membrane processes are used to reduce their concentration
- sewage water treatment before discharge, to a degree that depends on the assimilation capacity of the surroundings and the environmental requirements; energy consumption increases with treatment intensity, and especially when the water is to be reused via water reclamation
- improved irrigation methods that need pressurized water.

In order to produce the energy needed, water resources are also used and consumed. In order to have a complete picture, the energy consumed during the construction of the water works and that for their maintenance and repair should also be included and distributed along the life time of the works. This includes energy to produce the cement and iron consumed and for excavation, drilling and earth movement. Generally this energy is a small fraction of that spent on the cumulative water production over time, but not always, and should appear in the energy footprint, albeit seldom known or considered.

9.3.2 Water to produce energy

Large water flows are needed to produce any source of energy except for wind and sea energy and direct conversion of solar radiation. Results from a wide-ranging survey are shown in Table 9.3. Some comments on the common energy sources follow.

Table 9.3 Energy and water in Latin America and the Caribbean (LAC) in 2005

ENERGY SOURCE	PRIMARY PRODUCTION (10^{15} J)	ELECTRICITY GENERATION (10^3GWh)
TOTAL WORLD	**460**	**10,100**
TOTAL LAC	**25.4**	**909**
COAL AND LIGNITE	1.3	29
OIL (1)	14.6	88
NATURAL GAS	5.0	105
NUCLEAR	0.2	20
HYDROPOWER AND GEOTHERMAL	—	629
BIOMASS (2)	4.3	36
SOLAR AND WIND	—	2

1 1.2 x10^{15}J of production are from non-conventional fossil sources using 4.0km^3 of water
2 2.7 x10^{15}J of production is non-traditional

Source: modified from WEC (2010).

9.3.2.1 Hydroelectricity

Hydroelectricity is a renewable energy that still has a large potential for further development in LA. It is often considered environmentally friendly but there are important side effects to be evaluated. Hydro-energy plants modify the natural water regime and this has quantity, quality, environmental and health consequences – externalities – and may imply a loss of other opportunities for water use, as well as human displacements and the creation of territorial barriers. On the beneficial side, dams may facilitate the interconnection of otherwise isolated areas and evaporated water helps to stabilize the local climate.

Although hydroelectricity is often presented as an example of a non-consumptive water use, there is an associated consumptive use of water that should be taken into account. This refers mostly to the fraction of the used water lost to evaporation, especially when extensive water storage areas are needed in flat areas located in warm and arid climates. Evaporation rates up to 1m/year are common and may be exceed 2.5 m/year in some areas. In flat areas this may be significant for downstream river basin resources. These water losses can be added to the water consumption footprint of energy production.

Water resources consumption due to evaporation associated with hydroelectric production range from 0.04 to 210m^3/GWh, with median values ranging from 2.6 to 5.4m^3/GWh (Torcellini et al., 2003; Freedman and Wolfe, 2007; WEC, 2010), depending mostly on the surface area exposed to evaporation, relative to the stored volume, climate, timing of storage, and the altitude difference between the reservoir level and the turbine discharge point. Water consumption increases from mountain environments to lowlands. From data in Mekonnen and Hoekstra (2011) considering thirteen hydroelectric plants in South America, covering very large to medium-size ones and from deep storage reservoirs to shallow ones, the following water specific consumptions in m^3/MWh produced can be gathered: 22 to 36 in Argentina (flat areas), 2 to 111 (median 12) in Brazil (from flat areas to narrow valleys), 0.1 in Chile (a narrow valley in a cold area), and 0.1 to 1.0 in Colombia (deep valleys). Comparing with total usable water resources, evaporation from these dams is a negligible quantity in Chile and Colombia, 0.13% in Brazil and 0.3% in Argentina, at the country level. Larger percentages refer to the river basin where the dams are located. Other results derived from other sources are: 0.9m^3/MWh (70m^3/yr/GW installed) in Colombia (Jiménez-Cisneros and Galizia-Tundisi, 2012), which means a river flow loss of approximately 0.5 to 1%; 14 and 24m^3/MWh for the large hydroelectric plants of Itaipú (95,000GWh, 14GW) and Tacuruí (8.4GW) in Brazil; 0.6m^3/GWh (4% of usable water and 25% of water used) in Costa Rica (LA–Costa Rica, 2012). For reversible hydroelectric plants used for energy regulation these values can be higher.

9.3.2.2 Thermoelectricity

Electricity production in thermal plants may demand and consume large water flows. Thermal efficiency depends on thermodynamics – predominantly on the maximum temperature – and may vary from approximately 0.30–0.35 for nuclear and old coal plants, 0.40–0.45 for critical state coal and oil plants and 0.45–0.50 for combined-cycle gas turbines. The heat that is not converted into electricity is transferred to the environment by means of water. Air cooling greatly reduces water consumption but is expensive and thus it is mostly restricted to areas with scarce water flows, such as in some geothermal plants and isolated coal mines.

Thermoelectric plants may use an open cooling water cycle when a large water flow is available, generally a river, or sea water for plants on the coast, as is the case in Mexico.

Waste heat is transferred to the water with a temperature increase of a few degrees, which has to be compatible with ecological restrictions at the disposal site. Discharged water slowly cools to environmental temperature by evaporation, which implies some flow decrease and an increase in salinity. Water use may vary from 30 to $60m^3/s/GWe$ (We=W of electrical power), depending on the admissible temperature increase in the outflow water, or a little less for thermally efficient nuclear plants. Flows can be halved in sea water cooled plants when a higher temperature increase in discharged water is allowed.

When water resources are scarce, the other commonly used cooling method is the closed water cycle, in which heat is transferred to an external water flow closed circuit that is cooled by water evaporation in natural or forced convection, high cooling towers. Water consumption is the sum of evaporated water, leakages and the renewal of water in the circuit to prevent salinity build-up via evaporation. Approximately 0.5 to 0.7L/s/MWe are consumed, depending on plant thermal efficiency, which equates to 1.8 to $2.5m^3/MWhe$, and $8m^3/MWhe$ for older plants. Some average water consumption values are given in Table 9.4. In most cases the presence of a thermoelectric plant may produce a significant decrease of resources in small river basins or aquifers. Water disposed of may affect local water salinity and also carry with it corrosion products and in-plant treatment chemicals that may be of some concern if not duly treated before discharge. Water recycling in the cooling system is generally three to ten times the water use for a low salinity water supply. These figures are within the same range of results from other studies carried out in the US (Averyt et al., 2011) and Spain (Hardy et al., 2012).

Table 9.4 **Average water consumption rates for thermoelectric plants with closed cooling**

TYPE OF PLANT	COAL	OIL	COMBINED CYCLE TURBINE	NATURAL GAS AND MIX	NUCLEAR	HYDROPOWER
$m^3/MWhe$	1.8 [1]	1.2	1.2	0.7	2.7 [2]	1.0 [3]

1 Part of water used for handling of ashes
2 Lower operating temperatures
3 The value for hydropower is actually highly variable while the other figures have a small range

Source: modified from WEC (2010).

9.3.2.3 Geothermal electricity generation

Geothermal electric energy production is significant in some countries such as Mexico, Costa Rica, El Salvador, Nicaragua and Guatemala, and is currently receiving a push in Chile, even though some former projects were not completed due to legal and environmental restrictions. Geothermal production uses closed water cooling units that require water. Air cooling is used when geothermal water is too saline and no other sources of fresh water are available. Waste heat per unit of power is greater than in conventional thermoelectric plants due to the lower thermodynamic efficiency. Most of the water produced is re-injected to avoid pollution problems and to recharge the geothermal aquifer. Some production data are shown in Table 9.5.

Table 9.5 Geothermal energy in some representative LA countries

COUNTRY	MEXICO	EL SALVADOR	NICARAGUA	COSTA RICA	GUATEMALA
EXISTING POWER (MWe)	850	105	70	125	24
% OF COUNTRY ELECTRICITY	3.2	20	17.2	10.2	3.7

Source: own ellaboration.

Water consumption is highly variable. As a reference, in the Salton Sea geothermal fields (3.2GWe) in the USA, water use is 2.2hm^3/yr or approximately 1.2L/MWe. Studies carried out in Australia indicate that this consumption may be about 2.5L/s/MWe (Clark et al., 2010). Thermo-solar energy production also needs cooling water, which ranges from 0.26 to 0.9m^3/MWh.

9.3.2.4 Energy from biomass

Biomass is generally used for heating, including industries, especially those that produce it, such as sugar, paper and cellulose factories, but in small quantities it is also used for electricity production. Part of this bioenergy is derived from forest products, mostly consuming soil (green) water, and vegetal wastes from agricultural production. Water is needed for in-plant energy production, mostly to generate process heat and electricity, with little thermodynamic efficiency compared to large thermal plants. This is due to the often low working temperatures and the small, non-optimal units. Energy is also needed for collection, transportation and temporal storage of wastes and products. Similar processes are applied in the less common plants used to transform forest bio-matter into gas and liquid fuels. World biofuel (biodiesel and ethanol) production reached 100hm^3 in 2010 (HLPE, 2013). This source claims that seventeen LA countries have adopted biofuel policies with specific targets and mandates for transport fuels. Biomass transformation is reported to produce 2% of energy in Costa Rica, 4% in Chile and is significant in Mexico.

9.3.3 Water and land needs to produce biofuels

Renewable energy production is a priority for the 21st century and an important part of it is solar energy captured through biosynthesis. This requires vegetal biomass that consumes large quantities of water, besides land and nutrients. In humid climates crop production is mostly rain-fed but in semi-arid and arid areas irrigation is needed, and consequently this is a source of conflict for the often scarce available water resources.

The planned production of bio-matter to be transformed into fuel – biodiesel and bioethanol amongst others – is currently important in some LA countries (Balat and Balat, 2009; Saulino, 2011). It has been well established in Brazil since the 1970s, and has recently received a push in Argentina (Nass et al., 2007; CADER, 2010, 2011), Colombia, Peru and there is some small production in Paraguay. This refers mostly to the intensive cultivation of maize, sugar cane, other grains, sunflower, and soybeans. Besides water for irrigation, when it is needed, and that used to produce the nutrients – often imported from other areas – water is also needed for the production process in a factory, plus the energy embedded in the facilities and the machinery. The social and economic benefits and the energy balance are not always clear, even if private gains are obtained and there is a good prospect for exporting, mostly to the United States, Europe and Japan. Many different interests and points of view are involved. For many there is a threat to food security and income on a national scale and worldwide, and further the energy used in the production is considered a waste of fossil fuel.

Bioethanol (bioalcohol) was considered as an alternative motor fuel in Brazil as early as the 1930s. Its industrial production started in the 1970s with the programme PROALCOOL. Up to 10% of ethanol can be mixed with gasoline without modifying the motor or it can be used directly or with up to 10% gasoline in modified engines. In LA it is predominantly produced in Brazil, but also in Argentina since 2009 (Babcock and Carriquiry, 2012) for domestic consumption, and is starting in Peru, Colombia and Costa Rica, mostly from sugar cane. Current production in hm^3/yr for Argentina, Brazil, Colombia and Peru are respectively 0.28, 29, 0.3 and 0.14 (USDA, 2011). The characteristic sugar cane's specific mass production is 75,000kg/ha/yr, and yields 6–8 $m^3/ha/yr$ of alcohol. Approximate data for sugar cane is provided in Table 9.6.

Bio-alcohol can also be produced from corn, other grains and lignocellulose, but at a higher cost. Some data on prices are given in Table 9.7.

Table 9.6 **Sugar-cane production and crop area**

COUNTRY	No.mills	CANE PRODUCTION (10^6 t/yr)	SURFACE (10^3 ha)	% CROP AREA	BIO-ALCOHOL (hm^3/yr)
BRAZIL	350	460	9,000	4	20 [1]
ARGENTINA	30		50	1.5	0.2
PERU	1	9.3	69	1.3	0.1 [2]

1 85% for internal use, of which 90% is as biofuel
2 ongoing project; 90% for export to the EU
Source: own elaboration based on technical unpublished data.

Table 9.7 **Approximate costs of producing bio-alcohol and comparative cost of oil**

	SOURCE BIOALCOHOL					OIL
	SUGAR-CANE	CORN	BEAT	WHEAT	LIGNO-CELLULOSE	
US$/L	25-50	60-80	60-80	70-95	80-110	80

Source: own elaboration based on technical unpublished data.

Costs and possibilities are country specific and depend on factors ranging from rainfall and water availability to soil value and the calculation methods used. Crops need nutrients and may produce important externalities, so the real gain and sustainability is open to debate. Brazil claims the energetic value of the bio-alcohol they produce is approximately

8–10 times that of the fuel used in the production. Crop yield has improved by a factor of 1.6 and fossil fuel consumption in the production has decreased by a factor of 0.75.

Biodiesel is produced from oleaginous plants (mostly soybeans) in Argentina (Hilbert el al. 2012), and from palm oil and castor oil in Brazil. It is added to diesel fuel at 5%–7%, with the prospect of attaining up to 10%. Current production in hm^3/yr in Argentina, Brazil, Colombia and Peru is 2.90, 2.65, 0.54 and 0.03 respectively (USDA, 2011). Although Brazil started production earlier (in 2005), Argentina having only started in 2009 (Hilbert et al., 2012) is currently the world's second largest producer after the USA and the main world exporter.

Water consumption in the factories producing biofuel varies between 4 and 6L/L (volume of water/volume of biofuel), which could be cut down to 2.5 by improvement in production. These data can be compared to 2.5 to 5.5L/L to produce petrol, and the 1.9L/L minimum thermodynamic requirements to produce inorganic alcohol. However, the main water consumption is due to irrigation, which ranges from 0 in fully rain-fed areas to 800 to 2000L/L for irrigated crops in arid areas. National water values often only consider water resources (blue water) consumed and thus results vary greatly according to the country or region.

A key element of biofuels production is related to the land and soil (green) water needs. HLPE (2013) compiled the following ranges in $ha/m^3ge/yr$ (ge = gasoline equivalent): for ethanol it is required 0.300 from sugar cane, 0.465 from corn and 0.470 for cellulosic material; for biodiesel, 1.540 from jatropha and 0.310 from palm oil. This means that to produce 1 hm^3/yr of sugar cane approximately 300,000ha of cropland is needed.

9.4 Water for industry

Industry covers a large and variable group of activities, many of which depend on the specific economy of the country or region. Industrial areas are highly variable in LA, from heavily industrialized zones, such as São Paulo (Brazil), Mexico City and Monterrey (Mexico), where the metal sector and petrochemical industries are present, to other areas in which industry is relatively less important and a large proportion of the factories are for food processing. Water needs and the environmental impact are thus quite different. Often thermo-power plants and treatment plants for minerals that are not in the mining area, such as smelters, are considered as industrial plants.

A large proportion of industrial factories are small to medium size, in or around towns, and thus water demand and use is generally included in urban water and the disposal of used water goes to the municipal sewage system. Whilst large self-supplied factories and industrial areas can be found, most of them are oil refineries, chemical plants (which include fertilizer production and natural and artificial textiles), sugar factories ('ingenios') and biofuel production plants processing rain-fed or irrigated agricultural production. In some cases tanneries (leather factories) may be important, as is the case in some areas of

Mexico, Peru and Argentina. Food-processing industries often use water from the supply network while the production of bottled water and refreshments is partly supplied by the municipal network and partly self-supplied, as commented in Box 8.8 of Chapter 8.

Even if factories generally demand a small fraction of the total resources, they may pose important burdens on their surroundings since they are competing for the scarce local resources. This may become locally unpopular and provoke reactions from citizens and the mass-media. Furthermore, in the absence of strict environmental regulations or when the enforcement of such regulations fails, whether it be due to powerful lobbying groups or public administration weaknesses, factories are likely to pollute both surface and groundwater.

Water use data vary from country to country and over time due to continuous improvements in water use efficiency, to reduce production costs and due to environmental pressure to save scarce water resources. Some industrial processes are especially water intensive, such as the production of paper, cellulose, petrochemicals and artificial fibres. In Chile, a 40 m^3/t water demand for paper production is mentioned, where it was formerly of 110m^3/t (LA–Chile), and this value can still be greatly reduced further, as shown by the experience in Spain. In Mexico, about 50% of water for industrial use is for cooling and 35% for industrial processes, and an important fraction of it is wasted. Also in Mexico, the main oil-related industry uses approximately 230hm^3/yr, about half surface water and half groundwater. The water/product ratio is 1.0 for refining, 0.6 for basic gas and oil products and 4.7 for petrochemical products. The water needs for fuel production and processing are shown in Table 9.8. The industrial water use in Mexico for the principal water demanding industries is given in Table 9.9. Self-supplied industries use 3,100hm^3/yr (45% groundwater) and thermoelectric units use 4,100hm^3/yr (12% groundwater), and both of them use 9% of the country's water resources.

Table 9.8 **Water needs for fuel production, including processing**

FUEL MINERAL	COAL	URANIUM	CRUDE OIL	NATURAL GAS
m^3/MJ content	335	184	3,809	218

Source: WEC (2010)

Table 9.9 **Industrial water use in Mexico for the main water-intensive sectors.**

INDUSTRY	SUGAR	CHEMICALS	OIL	PAPER AND CELLULOSE
% of industrial water use	40	22	7	8
% of industrial water consumption	35	21	6	8

Source:Jiménez-Cisneros and Galizia-Tundisi (2012)

River pollution due to the combined effect of wastewater from urban centres and industry produces important problems in some areas. Worldwide known problems are those of Lerma River and Chapala Lake (Mexico DF), Tieté River (São Paulo, Brazil), the highly polluted Tigre, Matanza–Riachuelo and Reconquista river stream systems around Buenos Aires (Argentina) where a special organization has been formed to try to control it (Autoridad de Cuenca Matanza–Riachuelo, ACUMAR), and downstream Bogotá (Colombia). Except for coastal Buenos Aires the other urban areas are continental and their effect on water resources is therefore greater.

In Mexico, in order to treat 2,500hm^3/yr of wastewater 1,650GWh/yr are used; of this total 900hm^3/yr are from factories, consuming 600GWhe/yr (Jiménez-Cisneros and Galizia-Tundisi, 2012). Total energy consumption for the water cycle is approximately 13,500GWhe/yr, or 7.1% of Mexican energy consumption.

9.5 Water for mining

Mining is an important sector in many LA countries. It is a key source of income and employment and is a sector which is on the rise given the increasing world demand for some metals (see Chapter 5). LA countries are very important world producers of silver, copper, molybdenum, zinc, aluminium, strontium, gold, iron and nickel. In Chile, copper contributes 90% of the economic value of the country's mining, US$ 9 billion to the GNP and produces US$ 45 billion in exports. LA countries supply 51% of the world's silver, 45% of its copper and overall 25% of the world's metal market. The production of lithium, a series of secondary metals and coal are also important, as well as gems. Classical mining areas are those of San Luis Potosí (Mexico), Zacatecas (Mexico), Ouro Preto (Minas Gerais, Brazil), and several Andean areas of Chile, Peru, Bolivia, Argentina and Colombia. La Guajira (Colombia) is an important world coal producer. There are large companies but also numerous small, even artisanal ones, especially for precious metals and gems. They attract 32% of the world's economic investments in mining. Mining activities can be seen as both producers and consumers of water, this second aspect being a serious problem in some areas. Most new mines exploit large and deep pits. Some new mining activities exploit existing natural brines in 'salares' (salt pans) to extract dissolved substances such as lithium and potassium, and also nitrates in some cases.

Mining by means of underground galleries or deep open pits may intersect aquifers or induce the infiltration of river or lake water. This is avoided as much as possible, sometimes with artificial impermeable barriers, but often water drainage cannot be controlled or is the result of operation failures. Pumping out this water is often a costly, energy intensive activity and water has to be disposed of. This produces desiccation problems in some areas and inundation in others, alongside quality problems since pumped water may be acidic or have excessive loads of some undesirable components. This water and that produced inside the mine area, including tailings (mine dumps) drainage, has to be disposed of. A fraction of mine water production is often used for mine operation and dust control.

Open pits become evaporation surfaces that may consume 1 to 2m/yr of water depth, depending on the area. Rainfall may be scarce in many of the arid mining areas of the Americas, often less than 100mm/yr or even as low as a few mm/yr, and thus this may compromise during a long time and even forever the future water resources, as has been observed in the arid and hyper-arid areas of Peru, northern Chile, western Bolivia and northwestern Argentina.

Water is needed for the operation of the mines, mostly to supply mineral leaching areas and mineral processing, but also for dust control. This is a moderate quantity but may become a serious demand in arid and hyper-arid areas. Mineral concentrates are often transported from inside the mining plants and to further away facilities in order to process the final product or to ship it. This transportation can be done by means of pipelines as slurries, thus using large water flows that are often not returned to the mine. This increases mining water needs – a serious challenge in arid areas – and may be a water quantity and quality disposal problem at the processing plant.

Numerous improvements for in-mine water use efficiency through recycling have been introduced to reduce water use. However, mining continues to be a serious challenge in many arid areas where it is necessary to provide enough water to the mining sector whilst preserving human supply, protecting the local environment and avoiding the spread of air and water-borne contamination. Long water transfers have been or are being planned to make mining possible, although excess water disposed of by the mine may become an added problem to the local environment. Current use of water in mining is given in Table 9.10.

Table 9.10 Current water consumption in mining (values rounded up)

COUNTRY	MINING	WATER CONSUMPTION		
	% of GNP	hm^3/yr	% [3]	Comments
CHILE	12	260	8.8	growing; mostly for copeer [1]
PERU	6	210	2	growing
MEXICO	1.6	55	0.07	[2]
ARGENTINA	3.2			

1 Economic productivity of used water: 4.4US$/$m^3$; 1950$hm^3$/yr used; other sources show up to 300hm^3/yr

2 27hm^3/yr consumed, 26hm^3/yr disposed of; 74hm^3/yr recycled; 2% of employment

3 Percentage of available water resources

Source: Jiménez-Cisneros and Galizia-Tundisi (2012), LA–Chile (2012); LA–Mexico (2012); LA–Peru (2012).

The most important supply problems appear in the arid and hyper-arid western coastal areas of South America, especially in the Tarapacá (Region I) and Antofagasta (Region II) areas of Chile. Important water rights purchases have been made at prices between 75,000 and 225,000US$/L/s (see Chapter 13). In 2006 this prompted one of the large companies operating in the area to invest approximately 160 million US$ to obtain 500L/s of fresh water at a coastal seawater desalination plant for leaching sulphide mineral concentrates. With a total investment of 870 million US$, water is pumped up to an altitude of 3200m through a 170km pipeline.

Mining carried out by large companies is generally much less water consuming and produces less water quality degradation per unit of production and per unit value of production than small-scale and artisanal (informal) mining. This last point is common practice in many areas, especially in the Andean region and to exploit secondary mineral accumulations ('placeres') in alluvial deposits and other sediments, or through small underground mining. They are widespread in the wet areas of eastern Peru and Colombia. This mining contributes more employment per unit of production and per unit value (but under poor working and health conditions) than large mines, but it may be highly detrimental to the local environment and water resources. To extract gold, amalgamation with mercury (quicksilver) and cyanide treatment is carried out, and consequently serious mercury and cyanide pollution is produced in rivers, lakes and groundwater. These small-scale and artisanal activities are often poorly controlled, and become important environmental (Hajeck and Martínez Anguita, 2012) and social problems to which governments often turn a blind eye, especially if the native population and poor people are involved in the mining.

Although environmental restoration is possible and mining permits are currently under consideration, the current situation shows that the impact of past activities, failings and unaccounted situations often appear during and after mine operation. Post-mining correction activities carry the risk of not being executed since in many cases the responsibility is passed from the mining companies to governments as money transfers.

One of the largest water resources problem, affecting especially groundwater resources and their relation with the water cycle, is the lack of knowledge and trained personnel, during the mine's operation and especially after its closure. Trained persons are scarce in many countries and are employed preferably to support direct mining activities, which is the priority and are much better paid posts. Thus, it is not rare that governmental organizations in charge of environmental control and regulation are not able to keep a stable workforce due to the higher salaries offered by mining companies. This is a common situation in LA.

Water consumption in copper mining is currently 0.3 to 1.2m^3/t of treated mineral, with an average value of 0.75m^3/t. This is a clear improvement compared to 2 m^3/t some years ago; there are hopes that this will be reduced to 0.05m^3/t. Current consumption is approximately 75 to 100 L/kg of refined copper and the apparent water economic productivity is approximately 80US$/$m^3$.

Gold production in Colombia is 56t/yr. In the Porce River basin, in the highlands (LA–Colombia, 2012), with 4,000 hm^3/yr of water resources, gold mining uses 0.5hm^3/yr to produce 3t/yr by using 80–100t/yr of mercury, but actual water consumption is from 0.5 to 1.5hm^3/kg of gold produced when the flow needed to dilute the pollutants is considered. Water productivity is around 460US$/$m^3$.

Oil extraction is an important mining activity in LA, mainly in the large basins on the eastern side of the Andes Range, from Peru to Colombia–Venezuela, including the central Amazonia in Brazil, as well as in a series of formations in Mexico and southern

South-America, in Argentina and Chile. Water use for abstracting the oil is generally small and highly variable, depending on the circumstances. Oil is abstracted jointly with large flows of often saline and highly contaminated water, which is mostly re-injected to enhance production or is just disposed of safely. Failings or accidents may contaminate groundwater resources and later surface water resources too, for a long time. Secondary and tertiary oil recovery is done by water injection, generally using small flows. Also small flows are needed for advanced gas recovery by 'fracking', which is currently being considered in LA. Chemicals used are an environmental concern and a poorly understood source of pollution. CO_2 injection into deep formations to reduce its emissions into the atmosphere is being considered in Brazil. This needs water for treatment and cooling, and especially to produce energy for the capture process at the plant. The water resources impact of these small amounts will likely be important in the future in water scarce areas.

As is the case of diverse regions of the world and especially in arid and semi–arid areas, as discussed in Chapter 2, in some of the dry areas of LA groundwater reserves in some of the large aquifers are being depleted due to intensive exploitation, at a rate much higher than renovation (Custodio, 2010, 2011). This groundwater withdrawal due to mining activities is happening in the hyper-arid areas of the Andean Region, comprising coastal Peru, northern Chile, southwestern Bolivia and northwestern Argentina, where groundwater renovation is scarce or nil. Groundwater abstraction is for the most part to supply the mining of metal ores and also for brine extraction in salt pans ('salares') used to exploit some solutes such as lithium, potassium and nitrates. The sustainability of small springs and groundwater discharges that are important for some human settlements and of ecological and touristic value, such as high altitude wetlands ('bofedales'), is of special concern. Rainfall in the intermediate depressions is a few mm/yr on average and the scarce recharge is produced occasionally by some sporadic floods in gullies whose headwaters are in the highlands ('altiplano'). Even though rainfall in the altiplano is scarce, a combination of almost bare soil of low humidity retention (mostly young acidic ignimbrites) and rainfall retention in the seasonal snow cover favour some recharge that manages to sustain some springs which yield water with a very long turnover time (Acosta et al., 2013).

9.6 Discussion and conclusions on water security for energy production, industry and mining activities and for human uses in LA

What have been presented in the preceding sections are general considerations on water use and consumption in the different sectors of energy production, industry and mining, with specific references to LA countries and regions, and especially to the seven countries that have contributed reports. For many aspects data have not been found and an in depth bibliographical search has not been performed. Thus, part of the comments and warnings are qualitative and their relative importance remains speculative. Additionally it should be noted that part of the data was obtained from reports that have not been checked or are not always well defined.

Not all of the sectors – energy production, industry and mining – are similarly present in all LA countries. In Argentina, Brazil, Paraguay, Chile, Colombia and Costa Rica hydroelectricity is an important energy source, while in Mexico coal, oil and thermoelectricity contribute a larger fraction of the country's needs. Only Argentina has operating nuclear plants, although their contribution to the country's total energy needs is small.

Hydroelectricity may consume water by evaporation in the storage reservoirs, which is often a small fraction of river flow, but in some cases it may be large enough to affect downstream water security by reducing flow, increasing salinity and modifying seasonality. Specific water consumption for energy production varies over a wide range, from less than $1m^3$/GWh to more than $100m^3$/GWh, depending on local conditions. At the national scale this amounts to 0.1% to 4% of total water resources, although in some cases, particularly in warm, flat areas it can be up to 25%.

In thermoelectric plants, cooling – in open and closed cycles – is generally done with river water, but in Mexico marine water cools important power plants located in coastal areas. Geothermal plants along the western mountainous areas of LA are in arid regions and use closed cycle cooling fed with groundwater or air cooling. These cooling needs water consumption may be a significant fraction of local surface and groundwater resources, which in arid areas can compete against other water demands for a large share. Thus, water security may become an important consideration for the plant operation, for the downstream local population and for the environment.

The production of biofuels may introduce an important water demand where irrigation is needed, which may in turn have a great impact on local and downstream local water security. This would be especially true in semi-arid and arid areas and furthermore in the areas from where the water resources are to be taken. It seems that some projects on the Pacific side of South America may create important local water imbalances or require expensive water conveyance systems and energy-consuming water imports from further afield areas for the sake of income from biofuel exportation.

Water security considerations for industry are as varied as the involved activities. In many cases they are connected to urban water supply and share their water security circumstances, as explained in Chapter 8. This includes part of the production of bottled water and refreshments that are common in LA, Mexico being a world leader in per capita production and consumption. Large industrial establishments, which include thermoelectricity production, have their own water supply. Other important water-independent industries are those related to refineries, large chemical plants, smelters for iron, aluminium and other metals, textiles, leather and large sugar plants, amongst others. Comments made above for energy water security also apply here. Additionally water security for populations and the environment has to consider the pollution generated by these plants – something which is highly dependent on the types of activity and technology – and also on the existence and enforcement of legislation and civil society action. Circumstances vary largely in LA. Large industrial concentrations are found in several places in Mexico, Brazil and

Argentina, and large sugar plants ('ingenios') in Colombia. The impact of water security on the population also depends on the location of these industrial plants. Many of them are close to the coast – large lakes do not exist – and have less downstream water security impact, but others are far inland and are often at high altitude (São Paulo, Bogotá, Mexico City) and thus have a higher impact on downstream water security.

Mining is an important activity and a great source of income in many LA countries such as Mexico, Colombia, Venezuela, Brazil, Peru, Chile, Argentina and Bolivia. Some mines are in areas with plenty of water – where the problem is how to get rid of it – but others are in semi-arid areas with water supply problems (e.g. central Mexico, northern Colombia, northeastern Brazil) and in arid and hyper-arid areas (northern Chile, northwestern Argentina, eastern Bolivia, southern Peru) where water resources are very scarce and groundwater with very slow renovation (up to several thousand years) is used and partly mined. Water security for mining is an important concern, so in some cases seawater desalination at the coast has been introduced. For example in northern Chile costly desalinated seawater is pumped to the highlands where the copper mines are located. In the case of mining, water security can be solved when mining can support the involved cost of procuring and producing water given the current high prices of metals.

From the point of view of human water needs, mining may become an important threat in arid and semi-arid areas, but may also generate large benefits. Mining may seriously interfere with water security of locals by reducing river and spring flow, even exhausting them, or in other cases damage wetlands. This is a complex situation as changes in the groundwater resources are slow and delayed, which may pass unnoticed for years. Detailed hydrogeological studies are therefore needed to measure this impact over time. Thus, it is important to know the pace of recovery after a mine closes; it may be that this rate is too slow to be significant. It is relatively common that open pit mines are not refilled as they may be conceivably re-opened in the future or is not considered in their mining permit; thus this can leave a large and deep lake capable of evaporating large water flows if groundwater seepage is enough or if surface water gets in when barriers fail. This may reduce local and downstream water resources and even exhaust springs and small streams. There is little information on this issue, especially due to poor monitoring since many large mining activities are relatively young and the evaluation is complex owing to weather and climate variability.

From the water quality point of view, mining may affect the water security of inhabitants and of the environment, both local and downstream. This is due to the disposal of water with high salinity, acid and/or containing diverse unwanted and noxious solutes derived from minerals – diverse heavy metals – or from concentration and processing, such as flotation compounds, and quicksilver (mercury) and cyanide in the case of the many gold mines in LA, especially the small and artisanal ones. This is a common situation in Colombia – where the supply and even agricultural use of water from many rivers is jeopardized – and the Amazonian side of Peru. The situation is less acute in the case of well-operated modern mining, where wastewater disposal is relatively small and controlled.

Industry, energy production and mining together consume 8 to 15% of water resources in the seven considered LA countries. Water consumption is respectively 4 to 9% for industry, 2 to 5% for energy production (hydroelectric energy consumption not included) and up to 6% for mining. Water economic productivity for these uses may range from 3 to 10US$/m^3. It is a high value when considering direct costs and benefits but if externalities are considered the economic picture may change, depending on the social discount rate that is applied.

Acknowledgements

Several experts have explicitly contributed data: Bárbara Soriano (CEIGRAM/UPM, Madrid), Maria-Josefa Fioriti (Subsecretaría de Recursos Hídricos, Buenos Aires), Jorge Benites Agüero (Autoridad Nacional del Agua, Lima), Luis Alberto Pacheco-Gutierrez (UNAM, Coyoacán, Mexico). Lucia de Stefano (FB/UCM) and Bárbara Willaarts (FB/UPM, Madrid), Enrique Cabrera (UPV, Spain), and Blanca Jiménez-Cisneros (UNESCO-PHI, Paris) have contributed useful comments.

References

Acosta, O., Guimerà, J., Custodio, E., Ansón, I. & Delgado, J.L. (2013). *Contribución al conocimiento de la hidrogeología de las cuencas intraandinas del N de Chile,* Congreso Hidrogeológico Argentino, La Plata, Argentina.

Averyt, K., Fisher, J., Huber-Lee, A., Lewis, A., Macknick, J., Madden, N., Rogers, J. & Tellinghuisen, S.(2011). *Freshwater use by U.S. power plants: Electricity's thirst for a precious resource. A report of the Energy and Water in a Warming World initiative*, Cambridge, Union of Concerned Scientists.

Babcock, B.A. & Carriquiry, M. (2012). *Prospect for corn ethanol in Argentina Center for Agricultural and Rural Development.* pp. 1–30. Ames, Iowa, Iowa State University.

Balat, M. & Balat, H. (2009). Recent trends in global production and utilization of bio-ethanol fuel. *Applied Energy,* 86: 2273–2282.

CADER (2010). Cámara Argentina de Energías Renovables. *State of the Argentine biofuels industry,* Buenos Aires, Argentina. pp. 1–24. Report 4° Trim.

CADER (2011). Cámara Argentina de Energías Renovables. *Estado de la industria argentina de biodiesel*. Buenos Aires, Argentina. Report 4° Trim.

Clark, C.E., Harto, C.B., Sullivan, J.L. & Wang. M.Q. (2010). *Water use in the development and operation of geotermal power plants,* Environmental Science Division, Argonne National Laboratory. [Online] Available from: www.osti-gov/bridge. [Accessed June, 2013].

Custodio, E. (2010). Intensive groundwater development: A water cycle transformation, a social revolution, a management challenge. In: Martínez–Cortina, L., Garrido, A. and López–Gunn, E. (eds). *Rethinking Water and Food Security.* pp. 259–298. Botín Foundation–CRC Press.

Custodio, E. (2011). Hidrogeología en regiones semiáridas y áridas,VII Congreso Argentino de Hidrogeología–V Seminario Hispano–Latinoamericano, Temas Actuales de la Hidrología Subterránea/Hidrogeología Regional y Exploración Hidrogeológica. *Salta*: 1–17.

Freedman, P.L. & Wolfe, J.R. (2007). *Thermal Electric Power Plant Water Uses; Improvements Promote Sustainability and Increase Profits,* Presented at the Canadian-US Water Policy Workshop, Washington, DC, 2 October 2007; pp. 1–11.

Hajek, F. & Martínez de Anguita, P. (2012). ¿Gratis? Los servicios de la naturaleza y cómo sostenerlos en el Perú. *Servicios Ecosistémicos Perú:* 1–436.

Hardy, L., Garrido, A., Juana, L. (2012). Evaluation of Spain's water–energy nexus. *International Journal of Water Resources Development,* 28 (1): 151–170.

Hilbert, J., Sbarra, R. & López Amorós, M. (2012). *Producción de biodiesel a partir de aceite de soja: contexto y evolución.* Buenos Aires, Ediciones INTA.

HLPE (2013). *Biofuels and food security: A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*, Rome, FAO.

Jiménez-Cisneros, B. & Galizia-Tundisi, J (Coord.) (2012). *Diagnóstico del Agua en las Américas,* Mexico.,Red Interamericana de Academias de Ciencias (IANAS) and Foro Consultivo Científico y Tecnológico (FCCyT). [Online] Available from: www.foroconsultivo.org.mx/home/index.php/libros-publicados/diagnosticos-y-analisis-de-cti/991-diagnostico-del-agua-en-las-americas. [Accessed February, 2013].

LA–Argentina (2012). *Report of Argentina*. Contribution to the Water and Food Security in Latin America project. Water Observatory Project Madrid, Spain, Fundacion Botín.

LA–Brazil (2012). *Report of Brazil*. Contribution to the Water and Food Security in Latin America project. Water Observatory Project Madrid, Spain, Fundacion Botín.

LA–Chile (2012). *Report of Chile.* Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain, Fundacion Botín.

LA–Colombia (2012). *Report of Colombia.* Contribution to the Water and Food Security in Latin America project. Water Observatory Project. Madrid, Spain, Fundacion Botín.

LA–Costa Rica (2012). *Report of Costa Rica.* Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain, Fundacion Botín.

LA–Mexico (2012). *Report of Mexico.* Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain, Fundacion Botín.

LA–Peru (2012). *Report of Peru*. Contribution to the Water and Food Security in Latin America Project. Water Observatory Project Madrid, Spain, Fundacion Botín.

Mekonnen, M.M. & Hoekstra, A.Y. (2011). *The water footprint of electricity from hydropower.* Institute for Water Education, UNESCO-IHE. Research Report Series number 51.

Nass, L.L., Pereira, P.A.A. & Ellis, D. (2007). Biofuels in Brazil: an overview. *Crop Science, 47*(6): 2228–2237.

Saulino, F. (2011). *Implicaciones del desarrollo de los biocombustibles para la gestión en el aprovechamiento de agua*. pp. 1–67. Santiago de Chile, CEPAL.

Torcellini, P., Long, N. & Judkoff, R. (2003). *Consumptive water use for US power production,* Golden. Technical Report number NREL/TP-550-33905.

WEC (2010). World Energy Council. *Water for energy.* pp. 1–51. London.