Facing the Challenges

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THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 4

VOLUME 3

UN WATER Report

UNESCO
United Nations Educational, Scientific and Cultural Organization

World Water Assessment Programme

UN WATER

Facing the Challenges

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VOLUME 3

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"We can't solve problems by using the same kind of thinking we used when we created them."

Albert Einstein

FOREWORD

by Olcay Ünver, Coordinator, United Nations World Water Assessment Programme

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From its first edition in 2003, the *United Nations World Water Development Report* (WWDR) has shown how decisions made in every realm of life and work can have an impact on our water resources. Rapidly changing conditions across the globe are creating new pressures on water, and introducing new uncertainties and risks for its use and management. The resilience of societies to cope with these challenges varies greatly, largely determined by their institutional and legal frameworks and the availability of financial and human resources.

Case studies are a significant part of each WWDR. Collectively, they illustrate the challenges that confront policy-makers and water managers around the globe, and how they are responding to them. The present volume, Facing the Challenges, features concise summaries of fifteen case studies compiled over a period of three years, providing 'snapshots' of water management and use today in diverse regions of the world. These case studies, by design, closely complement the other volumes of the 2012 *World Water Development Report 4,* as most of the factors influencing water resources management discussed in those volumes can be observed, in one form or another, in the pages presented here.

Since the launch of the United Nations World Water Assessment Programme (WWAP) in 2000, the number of case studies has continuously risen. Overall, 58 regional studies at the basin or national level have been completed so far, through partnerships with national bodies worldwide. The mobilization of key stakeholders is also important to the development of case study projects. As we move forward, WWAP will continue working with national partners and other stakeholders to develop further case studies of water management and use in diverse countries and river basins, to achieve as wide a regional coverage as possible.

This volume constitutes a valuable contribution to the international community. The experiences and policies it describes provide different perspectives for all those working towards sustainable development – not only water professionals, but managers and decision makers at all levels, and researchers from within or outside the 'water box'[1] – helping all to make informed decisions with better knowledge.

Olcay Ünver
Coordinator, United Nations World Water Assessment Programme

Note

1 The concept of the 'water box' is used in the third edition of the *World Water Development Report* to describe the specific sphere (the 'water sector') to which questions of water management are too-often confined.

SUMMARY

Case study development process and highlights of the findings

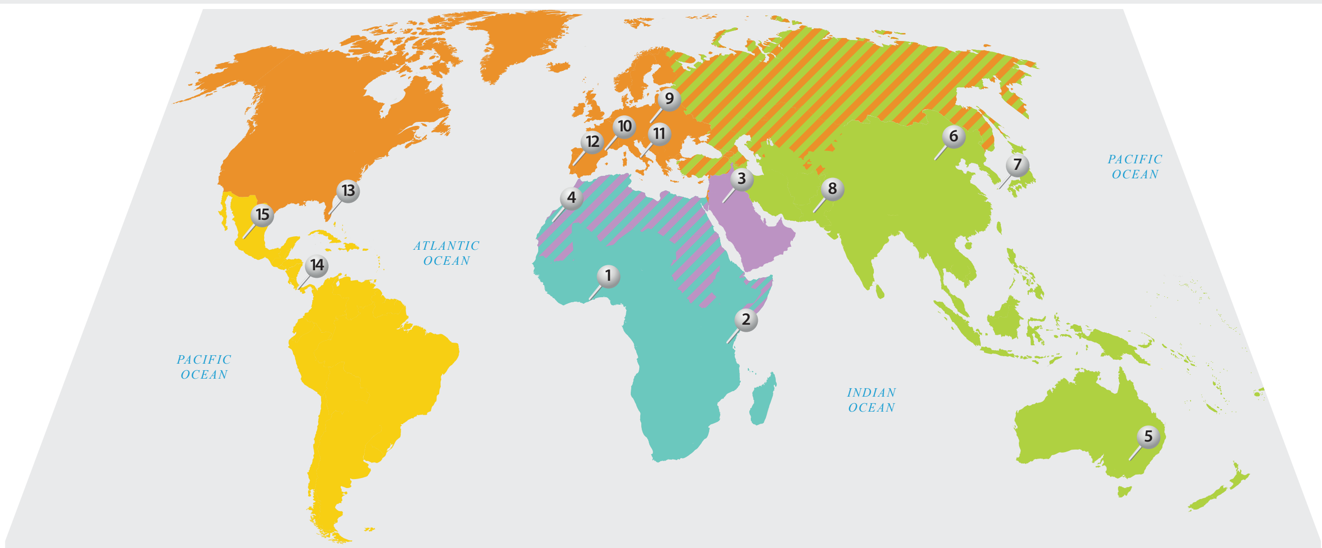
This fourth edition of the *United Nations World Water Development Report* (WWDR) features 15 case studies from different geographies of the world. For the first time, there are pilot studies from North America (St Johns River Basin, Florida, USA) and the Middle East (Jordan). As with previous volumes of the WWDR, the focus continues to be on the common challenges that the countries and regions included are facing: the management and allocation of freshwater resources, shortcomings in institutional and legal frameworks, environmental degradation, declining water quality, and the risks posed by climatic variations and climate change.

The regional distribution of case studies that are featured in this volume is shown in the map below.

Eight of these pilot projects (See map below, case studies 2, 5, 6, 10, 11, 12, 13 and 15) have been conducted at the river basin level, while the others showcase national efforts. Although the majority of the countries that participated in the development of these case studies are new WWAP partners, five of them – China, France, Italy, Mexico and the Republic of Korea – have also contributed to earlier volumes of the WWDR. We would like to express our deep appreciation to all our country partners for their significant input.

This volume presents concise summaries of these 15 case study reports, the original versions of which represent approximately one thousand pages. The amount of work that went into preparing the full

Regional distribution of the case studies



AFRICA	ARAB STATES	ASIA and the PACIFIC	EUROPE and NORTH AMERICA	LATIN AMERICA and the CARIBBEAN
1. Ghana 2. Kenya-Tanzania (Mara River basin)	3. Jordan 4. Morocco	5. Australia (Murray-Darling basin) 6. China (Yellow River basin) 7. Korea (Jeju Island) 8. Pakistan (with special reference to the Indus River basin)	9. Czech Republic 10. France (Marseille Provence Métropole Urban Community) 11. Italy (Tiber River basin) 12. Portugal (Tagus River basin) 13. United States of America (St Johns River basin, Florida)	14. Costa Rica 15. Mexico (Lerma-Chapala basin) Countries included in both Africa and Arab States Regions of UNESCO Countries included in both Europe/North America and Asia/Pacific Regions of UNESCO

case study reports and their concise summaries is noteworthy: on average each report went through two iterations to ensure the quality of the final studies.

The areas covered by the case studies vary greatly. In this edition, Jeju Island, Korea is the smallest in size (approximately 1,850 km^2) whereas the Yellow River basin, China (approximately 795,000 km^2) and the Murray–Darling River basin, Australia (more than a million km^2) are the two largest.

The concise summaries provide a snapshot of reality. They present the current situation of water resources and their use in each area covered through a common framework that includes the state of the resource, how water resources are utilized, competition among sectors, legal and administrative frameworks, the status of ecosystems, impacts of climate change and climatic variations, water related disasters, and more. Boxes highlight important recent events (the catastrophic flood in Pakistan, the recent drought in the Murray–Darling basin), key water-related projects (ecosystem conservation efforts in Jordan, sediment load reduction in the Yellow River basin, attempts to introduce payment for ecosystem services in the Mara River basin) and the structure and functioning of river basin organizations (the Lerma–Chapala Basin Council in Mexico, river basin district administrations in Portugal).

Regardless of a country's level of development, water resources management and protection are areas where constant improvement is sought. Australia has produced a blueprint for water reform in its 2004 National Water Initiative, while on Jeju Island (Republic of Korea) there is a clear understanding of the importance of integrated water resource management for effective planning. Strict control of water allocation at the district level in the Yellow River basin ensures the flow of the river throughout its course, and especially to its lower reaches. The government of Pakistan is working to reform irrigation water management in the Indus River basin, and in the St Johns River basin (Florida, USA) the Watershed Restoration Act has helped control problems of pollution. The 2000 EU Water Framework Directive is being implemented by all European nations, with different countries currently at different stages of completing its requirements.

Climate change and climatic variations are likely to pose challenges of varying degree and intensity. While several models suggest likely scenarios, some countries have already started experiencing the effects of climate change in the shape of more frequent and intense water-related natural disasters (e.g. floods, droughts, mudslides, tornados). Almost all of our case study partners reported increasing variability in the occurrence of such events. All of these countries, without exception, have mechanisms and legislations in place for disaster mitigation, however, their institutional and financial capacity to respond when such disasters strike are closely linked to their level of economic development.

Cooperation among riparian countries in the context of international water resources is critical for the sharing and protection of scarce water resources in an era of increasing climatic variability and climate change. Jordan and Israel reached an agreement on water rights in the Jordan River basin in their 1994 peace treaty. In the case of Spain and Portugal, the Albufeira Convention applies to several transboundary rivers and covers issues such as the exchange of information, pollution control and prevention, the evaluation of the transboundary impacts of water uses, and conflict resolution and the assignment of rights. The Convention allows for future revisions to ensure the achievement of environmental objectives set at basin level and to integrate climate change adaptation measures. Cooperation is vital for shared water resources in the national context, too. The Yellow River basin crosses nine provinces of China, however the 1987 Water Allocation Scheme and 2006 ordinance have created the basis for regulating water use to satisfy demand in all provinces and improve environmental conditions, especially in the lower reaches of the basin.

Water and food security are among the most important issues of concern not only in arid regions, such as Jordan and Morocco, but also in regions that are well endowed in terms of water resources. In Ghana, for example, the absence of adequate storage and agro-processing facilities leads to losses of perishable crops. Overall, increasing demographic pressures and climatic variations, such as floods and droughts, that affect crop yields are other drivers that diminish food security.

The case studies reveal that approaches towards sustainable utilization of water resources are evolving in the direction of integrated water resources management (IWRM). The need to integrate surface water and groundwater resources within basins and to balance competing sectoral interests with the needs of ecosystems are increasingly accepted at all levels of governance. However, considerable progress is necessary to make the IWRM approach a mainstream objective at the global level. The same observation applies to the attainment of the Millennium Development Goals (MDGs), for which there are blatant regional disparities.

The case studies clearly highlight the diversity of circumstances, challenges and priorities facing different regions. Consequently, efforts towards attaining wider coverage will continue in subsequent editions of the WWDR, as additional case study partners are sought.

CHAPTER 37

Ghana

Acknowledgements Kodwo Andah, Ben Ampomah,
Christine Young Adjei, Winston Ekow Andah

Location and general characteristics

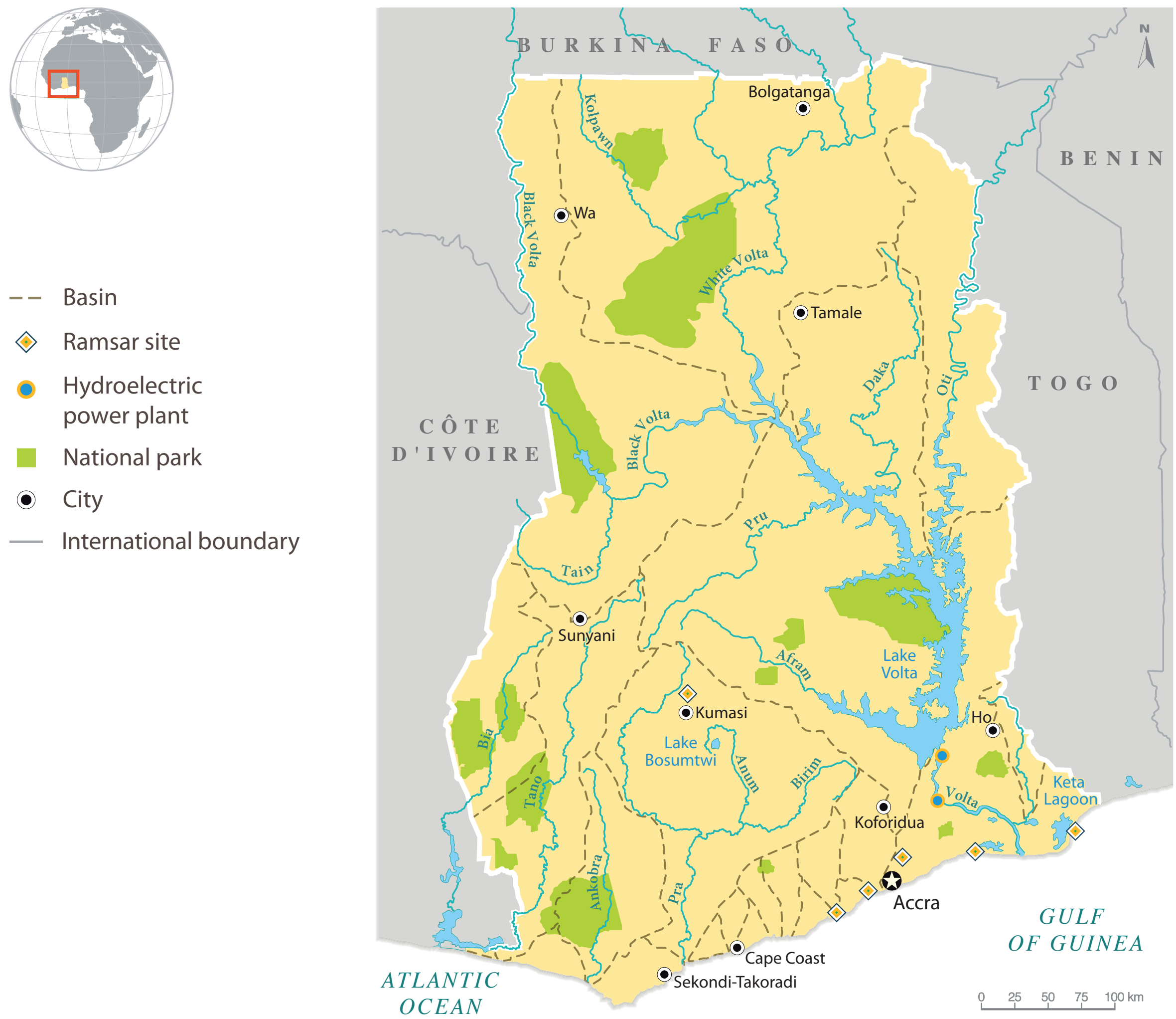
The Republic of Ghana (Ghana from here on) is located in West Africa. It is bounded to the north by Burkina Faso, to the east by Togo, to the west by Côte d'Ivoire and to the south by the Gulf of Guinea and the Atlantic Ocean (Map 37.1). The country extends over an area of 238,540 km^2, and it has 24.3 million inhabitants (2010). The national capital, Accra, is home to about 2 million people (2009).

The topography consists mainly of rolling plains, escarpments and low hill ranges. The highest elevation in Ghana, Mount Afadjato in the Akwapim–Togo Ranges, rises 880 m above sea level. Ghana has a warm, humid tropical climate. Mean annual temperatures range from 26°C near the coast to 29°C in the extreme north. The highest annual rainfall is 2,150 mm in the extreme south-west of the country, and this reduces progressively to a low of 800 mm in the south-east and about 1,000 mm in the north-east. Disparity in the geographical and seasonal distribution of precipitation causes water stress at the local and regional levels. For example, even in the high rainfall belt in the south and west, water scarcity in the dry season can last three to five months. In the northern and the south-eastern regions, where rainfall is the lowest, the dry season continues over eight to nine months.

Ghana has a relatively diverse and rich natural resource base – principally gold, diamonds, manganese ore, and bauxite. Gold and cocoa are Ghana's top two exports, and the country has been an oil exporter since 2010.

MAP 37.1

Ghana



Water resources availability, their use and management

Ghana is drained by three main river systems. These are the Volta, South-Western and Coastal river systems, which respectively cover 70%, 22% and 8% of the country. The Volta river system consists of the Oti and Daka rivers, the White and Black Volta, and the Pru, Sene and Afram rivers. The south-western river system comprises the Bia, Tano, Ankobra and Pra rivers. The coastal river system includes the Ochi-Nakwa, Ochi Amissah, Ayensu, Densu and Tordzie rivers. The total annual runoff from all the rivers combined is 56.5 billion m^3 of water, of which 40 billion m^3 is accounted for by the Volta River. Approximately 40% of total water resources availability originates outside Ghana's territory.

The only significant natural freshwater lake is Lake Bosumtwi, which has a surface area of 50 km^2, and a depth of 78 m. Lake Volta, which is the reservoir of the Akosombo Dam, is one of the world's largest artificial lakes, and it covers an area of 8,500 km^2.

In 2000, total water withdrawal was approximately 980 million m^3. Of this, about 652 million m^3 (66%) was used for irrigation and raising livestock, 235 million m^3 (24%) was used for water supply and sanitation, and 95 million m^3 (10%) was used by industry. Non-consumptive water use for generating hydroelectricity (only at the Akosombo Dam), is around 38 billion m^3 per year (FAO-Aquastat, n.d.). The consumptive water demand for 2020 is projected to reach 5 billion m^3.

Agriculture forms the most important segment of the economy (Box 37.1), accounting for about 30% of gross domestic product (GDP) and about 55% of formal employment. Industry, including mining, manufacturing, construction and electricity generation, accounts for about 20% of GDP. The services sector has been growing fast, and now generates half of national GDP (2010). Poverty rates in the country are not evenly dispersed.

While Ghana has over 50,000 boreholes and hand-dug wells, the country's groundwater resources are not well studied. However, annual renewable capacity is estimated to be around 26 billion m^3 (2005). In the Volta basin, annual groundwater use is approximately 90 million m^3. Measurements in other basins similarly showed that actual use is well below groundwater recharge. Groundwater abstraction is projected to increase by approximately 70% in order to meet the water demand in 2020.

Since the beginning of the 1980s, the Government of Ghana has introduced a number of policy reforms that were specially intended to improve efficiency in rural, urban and irrigation water use as well as to attain measures of environmental protection and conservation. The key problem was the absence of a holistic water policy that included all aspects of water resources management. The Water Resources Commission, which was established in 1996 to regulate and manage the use of freshwater resources and to coordinate policies in relation to them, responded to this challenge by introducing the draft Water Policy in 2002. A wider consultative process was initiated later in 2004 to incorporate policies that were specific to water supply and sanitation services. The draft Policy was further enhanced through integration of the principles of environmental assessment to promote the sustainability of natural resources. In 2007, the National Water Policy – which took an integrated water resources management approach as one of its core principles – was approved. The policy recognizes the various cross-sectoral issues related to water use, and the links to other relevant sectoral policies such as those on sanitation, agriculture, transport and energy (MWRWH, 2007). This holistic approach makes the water policy complementary to the national Poverty Reduction Strategy and the 'Africa Water Vision' put forward by the New Partnership for Africa's Development (NEPAD).

In terms of institutional framework, water sector reforms that started in the 1990s led to the establishment of Ghana's Environmental Protection Agency in 1994, and the Water Resources Commission in 1996. The Public Utilities Regulatory Commission was launched in 1997 to regulate and oversee the provision of utilities. Ghana Water Company Limited was set up in 1998 to provide water supply to urban areas. The same year, the Community Water and Sanitation Agency was established to administer rural water supplies.

Climate change, water-related disasters and risk management

Ghana often experiences floods and droughts, particularly in the northern Savannah belt. The country faced widespread floods in 1962 and 1963. Then

BOX 37.1

Agriculture and food security

In Ghana, overall sustained economic and agricultural growth has been accompanied by rapid poverty reduction. Growth has created a vibrant market for local farmers, and higher incomes have reduced poverty and led to increases in food demand. Thanks to economic reforms that began in 1983, Ghana was able to turn its agriculture sector around. A stable economy, market liberalization, and improved infrastructure have restored incentives to farm, which has both benefited small farmers and encouraged some large-scale investment in cash crops such as pineapples and palm oil. After 1983, agriculture grew at an average annual rate of 5.1%. Food supply has been growing faster than the population growth rate, making Ghana largely self-sufficient in terms of staples. At the same time, food prices have fallen. More accessible food helped to lower the rate of undernourishment from 34% in 1991 down to 8% by 2003. Child malnutrition also declined, with the proportion of underweight infants falling from 30% in 1988 to 17% in 2008. The proportion of the population living in poverty fell from 52% in 1991 to 28.5% in 2006, with rural poverty falling from 64% to 40% over the same period. The most recent estimates suggest that only 10% of the urban population lives below the poverty line (IFAD, n.d.). Overall, Ghana is on track to achieve the Millennium Development Goal of halving poverty and hunger (MDG 1).

However, in spite of these developments, food security is not in place in Ghana. Of 19,000 km^2 of potentially irrigable land, only 338 km^2 is irrigated (2007). In addition, the rehabilitation of many of the irrigation schemes is long overdue. Another challenge facing Ghana is losses in perishable crops as a result of the absence of adequate storage and agro-processing facilities. Climatic variations, such as floods and droughts that affect the crop yield, and a rapidly growing population also have a negative impact on food security.

Source: FAO-Aquastat (n.d.).

between 1991 and 2008, there were six major floods. The 1991 flood affected approximately 2 million people and the catastrophic floods in the north in 2007 affected more than 325,000 Ghanaians, with close to 100,000 requiring assistance to restore their livelihoods (UN-ISDR/WB, 2009). In 2011, there were many floods across the country, especially in the eastern and northern regions. Scientific studies suggest that the periodicity of 5.6 years is highly significant for flood occurrence. At the opposite end of the spectrum, Ghana also experienced significant droughts in 1977, 1983 and 1992. In fact, the 2007 flood was followed immediately by a period of drought that damaged the initial maize harvest. The economic impact of water-related disasters at the national and regional levels is not well documented.

With international support, Ghana developed national climate change scenarios and climate change vulnerability assessment studies for water resources and the coastal zone. Major findings were that over a 30-year period from 1961 to 1990, temperatures rose by about 1°C, rainfall was reduced by 20%, and stream flows dropped by 30%. Flow reductions of between 15% and 20% were observed for simulations using climate change scenarios for 2020; and reductions of between 30% and 40% were observed for simulations using climate change scenarios for 2050. The simulations predicted that the reduction in groundwater recharge would be between 5% and 22% by 2020, and between 30% and 40% by 2050. The maize yield was predicted to decrease by about 7% in 2020. It was found that millet yield would probably not be affected because it is more tolerant of higher temperatures.

It was found too that irrigation water demand could be affected considerably by climate change. The simulations revealed that in the humid part of the country, the increase in irrigation water demand could range from about 40% (2020) and 150% (2050) of the base period water demand. For the dry interior Savannah, the corresponding increase in irrigation water demand in 2020 and 2050 could be about 150% and 1200% respectively. Hydropower generation could also be seriously affected by climate change. The projected reduction of the amount of electricity generated by 2020 can be about 60%. In the coastal zone, over 1,000 km^2 of land may be lost due to sea level rise, which could be as high as one metre. Consequently, over 130,000 residents living along the east coast are considered to be at risk. Important wetlands, especially in the Volta Delta, may be lost as a result of land erosion and inundation. Increased water depths and the salinization of lagoons as a result of sea level rise could have a negative impact on the feeding of migratory and local birds.

Confronted with water-related and other natural hazards, the Government of Ghana, with the help of donor support, is in the process of developing strategies and strengthening its institutional capacity in disaster risk management. Disaster risk reduction is the responsibility of the National Disaster Management Organization (NADMO), established in the Ministry of the Interior. NADMO functions under a national secretariat and comprises a network of ten regional secretariats, 168 district/municipal secretariats and 900 local offices. Since its inception under parliamentary Act 517 in 1996, NADMO has contributed considerably to disaster management across the country. However, its activities and response capacity on the ground are constrained by a lack of adequate funding (NADMO, 2011). The 1997 National Disaster Management Plan was revised in 2009 along with a parliamentary amendment to Act 517. In order to accomplish its objectives, NADMO has set up technical sub-committees to cover all types of disasters including geological and hydro-meteorological events, pest and insect infestations, bushfires and lightning, disease outbreaks and epidemics.

Water and health

Even though 90% of people in urban areas have access to safe drinking water, only about 32% had home connections in 2008 – compared to about 40% in 2000. This drop in coverage is because infrastructural development is falling behind the rate of population growth and urbanization. The coverage in rural areas in 2008 was 60%.

The portion of population that has access to improved sanitation facilities is very low. In 2008, it was only 18% in urban areas and 7% in rural areas (UNICEF, n.d.*a*). Close to 40% of all public schools have no access to safe drinking water; and about 50% of public schools have no toilet facilities (2011). As a result, water-related diseases, such as malaria, schistosomiasis, guinea worm and lymphatic filariasis are common. According to the World Malaria Report (WHO, 2009) there were 3.2 million reported malaria cases in 2008. Of those cases, approximately 1 million affected children under the age of five. Malaria is a nationwide problem that claims the lives of approximately 20,000 children every year. The annual economic burden of malaria is estimated 1% to 2% of GDP (UNICEF, n.d.*b*). Other communicable diseases such as cholera and yellow fever are also widespread in Ghana and cause epidemics from time to time. As a combined result of these problems, life expectancy is about 58 years.

It is estimated that 51.5% of the population lives in urban settlements, and in 2007, approximately 5 million people were living in slums with limited or no water supply (UN-HABITAT, 2008). This led to the emergence of water vendors to service such deprived areas, who are now grouped under the Private Water Tanker Owners Association. Unfortunately, those who rely on water tankers usually pay more than ten times the official rate for piped water and end up spending over 10% of their income on potable water. To improve the situation, a Water Sector Rehabilitation Project was initiated in 1992. Furthermore, the Water Sector Restructuring Programme (2003–2009) was implemented to improve the provision of water by building new production and transmission facilities and rehabilitating the existing ones in urban areas. Consequently, water production by Ghana Water Company Limited increased steadily from 205.2 million m^3 to 231.77 million m^3 between 2003 and 2009. Since 2006, it has carried out major expansion and rehabilitation works on a number of urban water supply systems throughout the country. It must be noted that the unaccounted for water (i.e. non-revenue water) in the water supply network is still around 50% (MWRWH, 2009).

Environment and ecosystems

There is a lack of information on the wealth of Ghana's biodiversity. So far, about 2,974 indigenous plant species, 504 fish species, 728 bird species, 225 different types of mammals, and 221 species of amphibians and reptiles have been recorded. Some 16% of Ghana's land has been designated as forest reserve, national park or other wildlife reserve. Five wetland areas – the Densu Delta, the Songor, the Keta Lagoon Complex, the Muni-Pomadze coastal wetlands and the Sakumo Lagoon – are Ramsar sites of international importance. Other wetlands located in the forest and wildlife reserves of the Mole National Park, the Black Volta, the Sene, the Bia and the Owabi Wildlife Sanctuaries are also protected (FAO-Aquastat, n.d.). Despite these efforts, increasing pressure from agricultural expansion, mining, timber extraction and other socio-economic factors have had a negative impact on the environment and the ecosystems. It is estimated that the country is experiencing a rapid deforestation at about 220 km^2 per year. In economic terms, the loss of biodiversity through deforestation and land degradation is estimated to cost about US$1.2 billion annually (Agyemang, 2011). This is partially the result of uncoordinated implementation of sectoral socio-economic development policies. The situation warrants urgent action if further environmental degradation is to be averted (Ministry of Environment and Science, 2002).

Even though industrial water demand accounts for around 10% of annual water use, industrial activities are the main source of pollution. This adds to water stress and impairs the health of society. Mining is the industrial activity that contributes most to pollution. The 2008 report of Ghana's Commission for Human Rights and Administrative Justice stressed that 82 rivers and streams in five mining communities in Ghana had either been polluted, destroyed, diverted or dried-up as a result of mining companies. In its 2010 evaluation report, Ghana's Environmental Protection Agency concluded that mining companies' observation of environmental standards is poor. This is caused by environmental laws that are not sufficiently strict on pollution prevention. The major concern lies not with the big mining firms, whose activities are easy to monitor, but with illegal small-scale miners whose activities are neither registered nor monitored.

Water and energy

Ghana has one of the highest rates of electrification in Africa. Access to electricity in urban areas is close to 70%, and almost 30% of rural households are connected. On average, access to electricity in Ghana is about 60% (IEA, 2009). There are two main large dams in operation in Ghana with a combined hydropower generation capacity of 1,072 MW: the Akosombo Dam (134 m high) and the Kpong Dam (29 m high). These plants harness approximately 58% of the country's 10,600 GWh/year hydropower potential. The construction of the 400 MW Bui hydropower plant on the Black Volta began in 2005 and is expected to commence energy production towards the end of 2012. Sites for a further 17 potential hydroelectric power plants have been identified, and feasibility studies have been carried out. Once these projects are phased in, fluctuations in the supply of electricity caused by droughts will stabilize.

Conclusions

Ghana is well endowed with freshwater resources. However, disparity in distribution causes water stress, which is further worsened by the uncertainties posed by climate change, climatic variation, rapid population growth, environmental degradation and pollution. Thanks to continuous economic growth, the country is on track to meet the Millennium Development Goal (MDG) on eradicating extreme poverty and hunger. However, roughly 40% of rural dwellers remain poor. One of the most critical challenges facing the country is very poor access to improved sanitation facilities. Combined with a less than ideal water supply network, diseases such as malaria, cholera and yellow fever are widespread, causing significant numbers of casualties. Food security is another concern that leaves the country at the mercy of climatic variations and makes it dependent on imported food to feed its growing population. Increasing the amount of cultivated land (both rainfed and irrigated), improving the irrigation infrastructure and developing the agro-industry are crucial issues that require both national investment and international donor support. Mining activities, while creating considerable amount of income, are among the main causes of water quality degradation. Strengthening environmental protection laws and enforcing them requires urgent action. Inadequate and unreliable data on water resources and their use is the major roadblock to sustainable development.

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Except where otherwise noted, information in this concise summary is adapted from the *Case Study Report of Ghana* prepared in 2011 by Kodwoh Andah (unpublished).

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CHAPTER 38

Mara River Basin, Kenya and Tanzania

Acknowledgements Nathan Karres, Iman Yazdani, Maria C. Donoso, Michael McClain

Location and general characteristics

The Amala and Nyangores rivers originate in Kenya's Mau Forest and converge to form the Mara River (Map 38.1). Other tributaries, the Engare, Talek and Sand also flow into the Mara to form the transboundary Mara River basin.

The Mara River is about 400 km long and drains into Lake Victoria in Tanzania, which makes the river part of the larger Nile basin. The Mara River basin covers an area of approximately 13,750 km^2, of which 65% is located in Kenya and 35% in Tanzania. The amount of annual rainfall in the basin varies from 1,400 mm in the hills of the Mau Forest to 500–700 mm in the dry plains of north-west Tanzania.

Approximately 840,000 people live in the basin (2010) – the majority of whom are have settled in rural areas. The Kenyan part of the basin is home to 558,000 and the remaining 282,000 inhabitants live in the Tanzanian portion of the basin. According to projections, by 2030, the overall population in the basin could almost double to as much as 1.35 million.

Poverty is a major concern in the basin. In Kenya, nearly half of the basin's population lives below the poverty line[1]. On the Tanzanian side, the rate of poverty is around 40%. In general, those living in the basin earn their living from growing food crops (36.1%), cash crops (9.6%), livestock production (5.9%), fishing (9.5%) and business enterprises (11.4%).

Water resources and their use

As a result of insufficient data, there are only rough estimates of the water potential of the Mara River. The lower estimate is approximately 475 million m^3 per year, which only takes into account the flow rates of its two main perennial tributaries, the Amala and the Nyangores. A higher, and probably more accurate estimate based on data from more of the tributaries and a gauging station, is around 950 million m^3 per year. The total annual water demand in the Mara River basin is approximately 23.8 million m^3 per year (2006). Irrigated agriculture is the major user of water throughout the basin followed by domestic consumption and livestock production (Table 38.1).

TABLE 38.1

Water use in the Mara River basin (2006)

Use	Water demand (m^3/year)
Large-scale irrigation	12,323,400
Domestic	4,820,336
Livestock production	4,054,566
Wildlife	1,836,711
Mining	624,807
Tourism	152,634
Total	**23,812,454**

MAP 38.1

Mara River basin

While water use is significantly less than the basin's potential, the intra-annual variability in supply and poor and outdated agronomic practices, lead to problems meeting the demand. Furthermore, the frequency of water shortages and their severity is likely to increase in parallel with the expansion of irrigated land in the basin. Presently, 51% of the water demand is linked to a few big farms in Kenya. These farms produce mainly maize, beans, gum trees and wheat.

Biodiversity, tourism and the potential impact of climate change

Within the basin, there are important habitats that support the region's vibrant biodiversity. Among the most important of these are the Mau Forest, the Mara Swamp and the Mara–Serengeti eco-region, which is a UNESCO World Heritage Site. The Mara–Serengeti alone contains over 90 mammals and more than 450 bird species. There have been conservation programmes in the basin implemented by the Kenyan and Tanzanian governments as well as regional and international institutions. However, despite these efforts, the condition of the habitats continues to decline. For example, over the past few decades, the Mau Forest has been reduced by 23% as a result of forest clearing for tea plantations, farming and timber harvesting. Even though there are laws protecting the buffer zones, the corridor of riverine forest along the Mara River has been greatly degraded by grazing and cultivation in both Kenya and Tanzania.

Socio-economic demands such as a growing tourism sector are adding to the problem. The number of tourists visiting the Masai Mara National Reserve in Kenya and the Serengeti National Park in Tanzania rose from approximately 190,000 in the 1990s to over 600,000 in the early 2000s. The growing concerns are clearly highlighted in the management plan of the Masai Mara National Reserve, which states:

> The Reserve is faced by unprecedented challenges. Inside the Reserve, escalating pressures from tourism development and growing visitor numbers … are leading to a … deterioration of the natural habitats on which the Reserve's tourism product is based … Outside the Reserve, there is growing pressure from local communities to use the Reserve's pastures and water sources for livestock, because of the diminishing supplies of these resources in the wider ecosystem and deteriorating community livelihoods …

All these issues point to a need for an integrated transboundary strategic planning approach to biodiversity conservation and water resources management in the basin.

Protecting the environment and ecosystems is essential for ensuring the sustainable development of both nations. Consequently, Florida International University within the framework of the Global Water for Sustainability (GLOWS) programme conducted an environmental flow assessment in three pilot sites in the basin. The study concluded that in the years when precipitation is normal (compared to the long-term average of mean annual rainfall), sufficient water exists to satisfy the needs of the human population and nature. However, during periods of drought, especially in the upper and middle reaches of the river, natural flow is well below the threshold required to meet the established reserve for environmental needs. This means that no water can be allocated for other uses (domestic, industrial, tourism, agriculture, etc.) and it is necessary to construct reservoirs to meet these demands. While the study is limited in scale, it clearly demonstrates the vulnerability of both the human and the wildlife populations in the basin.

Climate change can complicate matters further. Scenarios predict that the flow in the Upper Mara River may decrease significantly as a result of increased ambient temperature and less rainfall. This can have a serious impact on both human livelihoods and ecosystems. In fact, the importance of the Mara River is that it is the main source of water for the migrating animals of the Mara–Serengeti eco-region, especially during the dry season. Statistical analysis of rainfall data reveals that droughts are likely to occur every seven years in the basin. Depending on the severity of the conditions, 20% to 80% of the migrating wildebeest may die. With a 50% die-off rate, it will take approximately 20 years for the animal population to recover, while with an 80% die-off rate, there may be no population recovery at all. Such ecologically disastrous conditions would have severe repercussions for tourism in the Mara River basin as well, which in turn would affect the Kenyan and Tanzanian economies. The climate change scenarios also predict an increase in periods of intense rainfall which would result in an increased erosion and a drop in water quality caused by higher sediment content in the river. The best management practices that are proposed as a part of the 'Payment for Ecosystem Services (PES)' schemes (Box 38.1) include preserving riparian buffers, reinforcing river banks by planting trees and decreasing grazing as potential remedies to alleviate erosion problem.

Water and health

A large percentage of the population in the Mara River basin does not have access to a safe drinking water supply or adequate sanitation facilities (Table 38.2 and Table 38.3). Surveys conducted in the Trans Mara and Bomet districts of Kenya's Rift Valley Province revealed the lack of sewer infrastructure, with pit latrines being the only faecal disposal method available to the population. In general, the majority did not have any knowledge of basic sanitation or hygiene.

In Bomet, approximately 56% of households draw their drinking water from the Mara River during the dry season and 46% of households are forced to fetch water from water points that are between 1 km and 5 km away. Only 36% of households in Bomet reported any form of water treatment prior to consumption. As a consequence of over-reliance on unprotected water sources and poor hygiene practices, rates of diarrheal disease and intestinal worms are very high in both districts. Unfortunately, the unfavourable conditions described above are similar on the Tanzanian side of the basin.

Water resources management and regulations

Kenya's most recent constitution, adopted in August 2010, sets the foundation for the sustainable use and efficient management of natural resources. It articulates the obligations that the individual and the state have to the environment. Moreover, it also enables the formation of a National Land Commission which, among its other duties, has supervisory responsibility for land use planning throughout Kenya. The new constitution mandates the decentralization of government, allowing for effective governance at the district or basin level.

TABLE 38.2

Rate of access to water resources in the Mara River basin

	Piped water (%)	Spring/well (%)	Rain harvesting (%)	River/stream (%)	Pond/dam/lake (%)	Other (%)
Kenya: Rift Valley Province*	22.8	36.3	1.2	29.3	4.7	5.5
Tanzania: Mara Region	14.2	63.2	-	6.6	15.6	-

**The Mara River basin lies within the southern section of the Rift Valley Province*

TABLE 38.3

Rate of access to sanitation facilities in the Mara River basin

	Conventional sewerage (%)	Pit latrine (%)	Septic tank (%)	No latrine (i.e. open defecation) (%)	Other (%)
Kenya: Rift Valley Province*	3.3	73.3	2.2	20.7	0.4
Tanzania: Mara Region	1.9	77.6	-	20.3	-

**The Mara River basin lies within the southern section of the Rift Valley Province*

Kenya Vision 2030 (formulated in 2007) and the Water Act (2002) constitute the main elements of the country's national water policy. Kenya Vision defines the goals and strategies of the country between 2007 and 2030 with particular attention to compensation for environmental services and the provision of incentives for environmental compliance. The Water Act allows for the establishment of the Water Resources Management Authority, which has a mandate to manage and protect river basins. It also encourages communities to participate in water management at the basin level and aims to ensure that sufficient and good-quality water is available to satisfy basic human needs and to protect ecosystems. The 1999 Environment Management and Coordination Act and the 2009 National Land Policy also play a part in water and biodiversity conservation in Kenya.

But Tanzania's constitution, unlike Kenya's, does not explicitly contain provisions for land and the environment. However, there are other major national legal instruments such as the Tanzania Development Vision 2025 (launched in 2000), the National Water Policy (2002), the Water Resources Management Act (2009) and the National Environmental Policy (1997). All these underpin the conservation of biodiversity and the regulation of water resources in the country.

Vision 2025 is Tanzania's national development blueprint. It projects fast growth while effectively reversing current adverse trends in environmental resources such as forests, fisheries, biodiversity as well as fresh water and land resources. Universal access to safe water is also a part of Vision 2025. The National Water Policy promotes decentralizing water resource management through integrated water resources management, involving water user associations and the private sector in decision making, ensuring the sustainable use of water resources through economic incentives such as appropriate pricing mechanisms, and establishing institutions such as the National Water Board, the Basin Water Boards and Basin and Sub-basin Water Committees.

The National Environmental Policy emphasizes sustainability and the conservation of natural resources and allows for economic instruments (such as PES, potentially) as approaches to environmental resource protection. The Water Resources Management Act gives effect to the 2002 National Water Policy and includes

BOX 38.1

Payment for ecosystem services

The ecosystems in the Mara River basin contribute significantly to the region's economy by providing valuable services without the need for any direct human labour or input. Payment for Ecosystem – or Environmental – Services (PES) is a mechanism to integrate this intrinsic wealth or productivity within an economic system.

In principle, the PES mechanism would allow for sustainable land use within the basin without the need for outside funding. The Mara River basin presents an ideal scenario for implementing a PES scheme because of the conflict of interest between the farmers upstream and wildlife tourism downstream. This 'vying for benefits' creates an opportunity for the transfer of ecosystem-based benefits to the upstream farmers in the form of economic support for the improvement of agricultural practices.

The first step towards a PES mechanism was taken in 2006 as a part of the project, Transboundary Water for Biodiversity and Human Health in the Mara River Basin. A feasibility study identified market-financed PES as the most appropriate methodology for economically incentivizing conservation efforts.

Thanks to surveys, analyses, and stakeholder meetings, the project has made considerable progress towards the development and eventual implementation of a PES mechanism. A final document is expected in 2012, which would present the culmination of the consensus-building process. However, while current policies in Kenya and Tanzania are generally supportive of PES schemes, they lack any concrete instruments in terms of laws and regulations for PES agreements. This observation presents an important challenge for translating a theoretical PES mechanism into a functional market-based system. Although existing legal and contractual mechanisms in both countries may enable the formation of a basic framework for a PES scheme, the introduction of supplemental regulations seems necessary.

legislation related to transboundary water resources management. This Act also allows for the creation of the Lake Victoria Basin Water Office, which is responsible for management of the Mara River.

Conclusions

The Mara River Basin is facing the mounting challenges of water scarcity, pollution and environmental degradation as a result of agricultural expansion, intensification of irrigation, population growth and the increasing impact of tourism. The main competition for water resources in the basin is between irrigated agriculture and the Masai Mara and Serengeti Wildlife areas.

Limited access to safe drinking water supply and practically the absence of a sanitation infrastructure add to widespread poverty through a heavy burden of disease. Legislation to address issues related to water and other natural resources is gradually being developed and put in place in both Kenya and Tanzania. Their implementation can help to operationalize mechanisms such as Payment for Ecosystem Services (PES), which can create sustainable financial support for efforts to conserve and protect natural resources.

Unless appropriate action is taken, growing problems will have a direct impact on the livelihoods of local people as well as on the national economies of both countries.

Notes

1 The Kenyan poverty line is set at approximately US$1.50 per day for rural populations and US$3.50 per day for urban populations.

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Except where otherwise noted, information in this concise summary is adapted from the *Case Study Report of the Mara River Basin in Kenya and Tanzania,* prepared in 2011 by the Global Water for Sustainability (GLOWS) Programme, Florida International University, supported by USAID (forthcoming).

CHAPTER 39
Jordan

Acknowledgements Maysoon Al-Zubi

Jordan: Gardens created in the middle of the Wadi Rum desert (29°33′ N, 35°39′ E)

Location and general characteristics

The Hashemite Kingdom of Jordan (Jordan from here on) is located in the eastern Mediterranean and bordered by Syria to the north, Iraq to the north-east, the Kingdom of Saudi Arabia to the east and south, and the West Bank and Israel to the west (Map 39.1). Jordan's population is around 6.3 million and it has a surface area of approximately 90,000 km^2. The Jordan Rift Valley, a narrow strip of highlands (with a maximum elevation of 1,600 m above sea level), the steppe, the desert zone and the Dead Sea (426 m below sea level in 2010) are the most distinctive topographical features.

Climate varies significantly from one region to another. The west of Jordan has a Mediterranean climate, characterized by dry hot summers, mild wet winters and extreme variability in rainfall during the year as well as from year to year. The climate in the highlands is characterized by mild summers and cold winters. Aqaba Governorate and the Jordan Rift Valley have a subtropical climate – hot in summer and warm in winter. The steppe and the steppe desert regions have a continental climate with large variations in temperature.

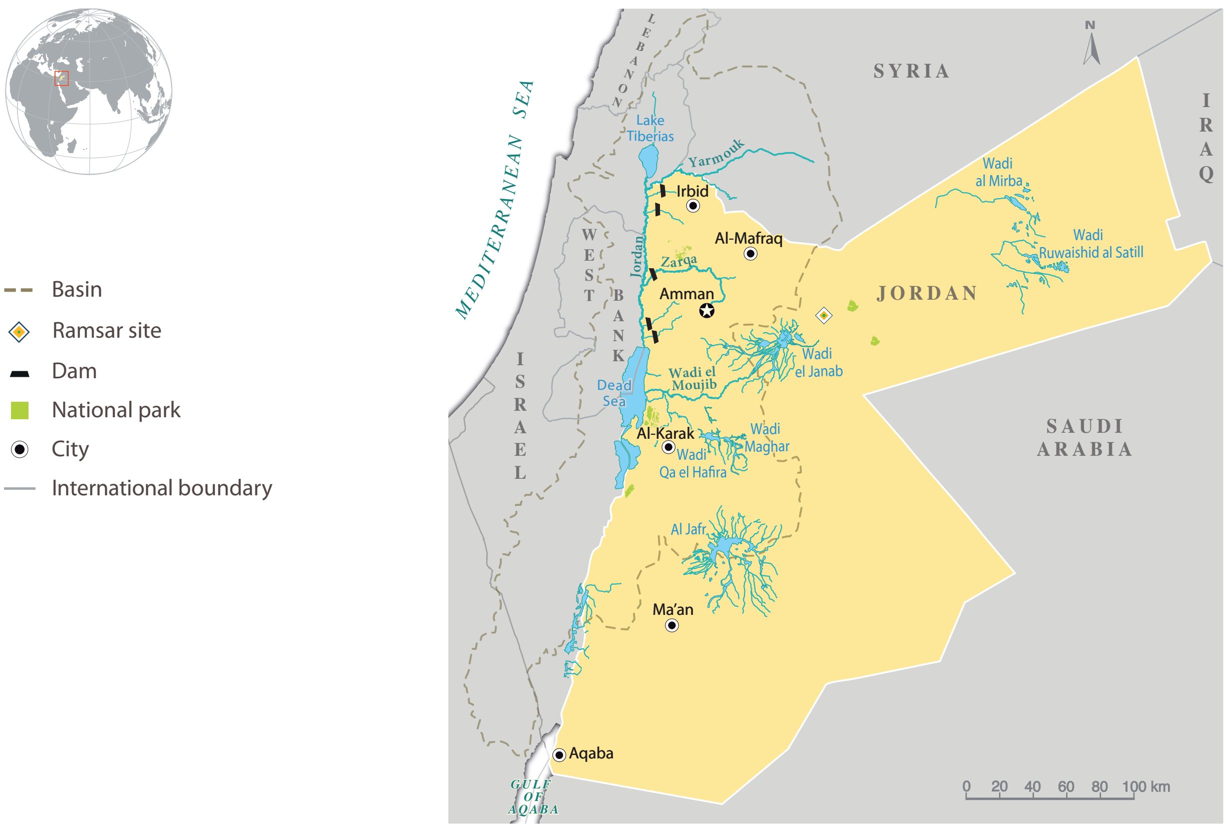
Precipitation in the country is very limited and ranges from 30 mm to 600 mm annually. Some 93.5% of the country has less than 200 mm of rainfall, and only 0.7% of the country has annual precipitation of more than 500 mm. Most of the rainfall occurs between November and April, and, in general, decreases considerably from west to east and from north to south. Overall, 83% of the country is composed of desert and desert steppe.

Water resources availability and their use

Jordan is one of the most arid countries in the world. While the average annual rainfall is approximately 8.2 billion m^3, 92% of this is lost through evaporation. Total internal renewable water resources are seriously limited. At an estimated 682 million m^3/year, the country is far below the water poverty line. Developed surface water potential was approximately 295 million m^3 in 2007, and is projected to reach 365 million m^3 by 2022.

MAP 39.1

Jordan River basin



On average, rivers constitute 37% of the national water supply. Jordan's most important surface water resources, the Jordan River and its main tributary, the Yarmouk, are shared with neighbouring countries. The Zarqa River, the second main tributary of the Jordan River, flows entirely within the territory of Jordan. The Yarmouk River is particularly critical as it accounts for almost 50% of the country's surface water resources. Allocation of these trans-boundary water resources has been one of the most difficult regional issues. Jordan and Israel reached an agreement on water rights in the Jordan River basin in their 1994 peace treaty. A joint water committee was also formed as a permanent institution charged with implementing the agreement.

Total internal renewable groundwater resources are approximately 450 million m^3/year, with a safe yield of 275.5 million m^3 (FAO, n.d.). At present, aquifers are being exploited at about twice their recharge rate. In particular, groundwater abstraction for agriculture is beyond sustainable limits, resulting in an annual groundwater deficit of 151 million m^3 (2007). The problem is worsened by the fact that there are hundreds of illegal wells. The protection of aquifers is critical as groundwater constitutes approximately 54% of the national water supply.

Agriculture is practised over 3% of the national territory (2005), whereas potentially cultivatable land is estimated at around 10% or 8,800 km^2 (FAO, n.d.). Water availability and soil quality are the main obstacles to the further expansion of agriculture. As a result of scarcity, only about 800 km^2 of land, mainly confined to the Jordan Rift Valley, is irrigated (2006). In an effort to maximize water-use efficiency, improved irrigation systems are being introduced. In fact, 60% of the irrigation in the Jordan Rift Valley, and about 85% in the highlands is through micro-irrigation. Even so, the agricultural sector still uses about 574 million m^3 of water, which corresponds to 60% of annual water use in Jordan (2009). In spite of consuming large quantities of water, agriculture contributes just 3% of Jordan's gross domestic product (GDP). Municipal water demand accounts for about 33% of overall consumption (approximately 315 million m^3). This demand is met largely from aquifers. Water use by industry and for livestock production is relatively insignificant at 39 million m^3 and 7.5 million m^3 respectively. While tourism accounts for approximately 1% of water use, the contribution of the sector to GDP was 10.6% in 2009 (Kreishan, 2010).

In addition to surface water and groundwater, other sources, such as fossil water, treated wastewater (110 million m^3 in 2009) and brackish water, are also used in Jordan. Overall, revenue collection systems are weak and more than 42% of the water delivered to the municipal water supply system cannot be accounted for. In addition, tariffs are low and do not cover total operation and maintenance costs.

A significant increase in population has led to a sharp decrease in per-capita water availability, which dropped from 3,600 m^3 in 1946 to 145 m^3 in 2008. It is projected that by 2022, the population may exceed 7.8 million, and total water demand may reach 1,673 million m^3. If current and planned projects are fully implemented, including the Disi water conveyance plan, the Red Sea-Dead Sea canal project, and plans to increase the use of treated wastewater, Jordan's current water deficit of 659 million m^3 (2009) could be reduced to 457 million m^3 by 2022.

In order to cope with water scarcity, 28 dams with a total storage capacity of 368 million m^3 were constructed between 1950 and 2008. At the same time, locations were identified for a number of reservoirs that would give the potential to add 444 million m^3 to Jordan's water storage capacity.

Climate change and its likely impact

Water is a scarce resource in Jordan, and a high population growth rate of approximately 2.3% per year is leading to growing demands from both agriculture and the municipalities.

Analyses of climate change scenarios indicate that Jordan will experience more frequent droughts during the twenty-first century as a consequence of year-round increases in temperature that may reach as high as 3°C (±0.5°C) in winter and 4.5°C (±1°C) in summer by the end of the century. The same climate change simulations show little or no change in precipitation to offset these big increases in temperature. In addition to this, runoff is expected to decrease over most of the country, except for the region south of the Dead Sea (RSCN, 2010). This could have a serious impact on water and food security. In fact, the results of a vulnerability assessment showed that climate change could have a significant impact on agriculture, particularly on wheat and barley production, which depend heavily on rainfall. The expansion of arid rangelands with decreased vegetation will have implications for grazing, as well. This will affect livestock production, and will have a consequent negative impact on the diet and income of poor farming households.

Water and settlements, water reuse

Over the past 60 years Jordan has become highly urbanized. The percentage of the population living in cities increased from 39.6% in 1952 to 78% in 2009 (UNICEF, n.d.). This increase is largely the result of internal migration, combined with an influx of refugees and migrants, mainly from Palestine and Iraq. Out of Jordan's twelve governorates, 65% of the population lives in Amman, Zarqa and Irbid. In terms of its regions, 91% of the population lives either in the north (Irbid, Jerash, Ajlum and Mafraq) or in central Jordan (Amman, Zarqa, Balqa and Madaba).

During the International Drinking Water Supply and Sanitation Decade (1981–1990), Jordan's government carried out a number of significant wastewater management projects. These were primarily related to the improvement of sanitation. This has raised the level of sanitation services, improved public health, and strengthened pollution control of surface water and groundwater in the areas served by wastewater facilities. According to the WHO/UNICEF Joint Monitoring Report (WHO/UNICEF, 2010), 96% of the population had access to a safe water supply, and 98% had access to improved sanitation in 2008. Approximately 64% of the population is connected to a sewerage network that collects wastewater for treatment and re-use. In 2008, approximately 100 million m^3 of effluent was processed in treatment plants. As a result of low water availability, treated wastewater represents a significant portion of the river flow in various parts of the country.

Sewerage systems for collecting a greater quantity of wastewater are expanding in parallel with population growth and increased water consumption. It is estimated that by 2022, approximately 250 million m^3 of wastewater will be generated. With proper treatment, this represents an important source of water that can be used for purposes other than for drinking.

Water quality, environment and ecosystems

The quality of surface water and groundwater has deteriorated significantly because of pollution. This is most notably the result of overuse of agrochemicals, over-pumping of aquifers, seepage from landfill sites and septic tanks, improper disposal of dangerous chemicals, and demographic pressure. Because of the diminishing per-capita water supply and quality issues, wastewater reuse has been an effective method of reclaiming a percentage of scarce water sources. Since the early 1980s, the general approach has been to treat the wastewater and then either discharge it into the environment – where it mixes with freshwater flows and is indirectly reused downstream – or to use the resulting effluent to irrigate restricted, relatively low-value crops (USAID, n.d.). However, the increasing dominance of effluent in the water balance, and the overloading of wastewater treatment plants, has raised concerns about the health risks and environmental hazards associated with wastewater reuse. To minimize such risks and their implications, effluent quality standards were set in 1995 and revised in 2003 (MEDAWARE, 2005), and most wastewater treatment plants have been upgraded to meet these standards. However, there is still a constant need to monitor the treatment plants and improve their capacity.

Because of its arid climate there are only a few large natural wetlands in Jordan, the best known being Azraq Oasis in the eastern desert. This large desert oasis, which formerly covered some 120 km^2, has diminished significantly as a result of over-exploitation of groundwater and the construction of dams on the major wadis. Similarly, the seasonal marshes in the Al Jafr area are also diminishing because of agricultural activities. Consequently, many aquatic species are endangered in Jordan (Budieri, 1995). Deforestation and desertification are other important environmental issues that require attention. To raise awareness about water use and environmental degradation, new literature is being introduced into the school curriculum (HKJ, n.d.). In terms of legislation, the Environment Protection Law No. 52 (2006) and the National Environmental Strategy (1992) form the main pillars of environmental protection in the country. As a novel approach, eco-tourism has also been introduced in Jordan to demonstrate that local development and efforts for conservation of nature can go hand-in-hand (Box 39.1).

Water resources management and the national strategy

Jordan's National Water Strategy is a set of guidelines that define the country's vision up to 2022. The Strategy aims to ensure the sustainability of water resources by balancing supply and demand through improved water resources management. The over-arching priority

BOX 39.1

A new era in conservational thinking

The development of the eco-tourism sector is being spearheaded by a long-established non-governmental organization, the Royal Society for the Conservation of Nature (RSCN). The RSCN is entrusted by the government with the protection and management of Jordan's special ecosystems. For several decades, the RSCN managed its protected areas as isolated, fenced sanctuaries that were guarded from the general public and had little involvement from local communities.

This all changed in 1992 with the Rio Summit and the Biodiversity Convention. As a signatory to the Convention, Jordan was the first country in the Middle East to be awarded a multi-million dollar pilot project under the Global Environment Facility (GEF). The project was to develop a regional model of integrated conservation and development. It was focused on the Dana Nature Reserve in southern Jordan, where the creation of the protected area in 1994 was linked to the socio-economic development of the local community. This pioneering initiative ushered in a new era in conservation thinking, which the RSCN continues to lead today.

The number of tourists to RSCN sites exceeded 137,000 in 2010, generating approximately US$1.7 million in revenue. In the same year, over 16,000 people from poor rural communities were supported by this tourism for nature conservation scheme. This revenue stream also covered over 50% of 2010's conservation costs.

Source: From Aziz and Szivas (2011)

of the National Water Strategy is 'to achieve national water security and to serve the overall development objectives' set out in the Strategy (HKJ, n.d.). Priority is given to the further development of land and water resources in the Jordan Rift Valley, which is the food basket of the country. The strategy recognizes the critical problem of the excessive use of aquifers, and highlights the need for limiting water abstraction to levels that are sustainable over the long term. Controlling, and even reducing, water consumption in all sectors is also one of the main pillars of the strategy.

In this context, farmers' water user associations play a key role in protecting water resources from pollution, increasing the efficiency of the irrigation infrastructure, and minimizing operation and maintenance costs – all of which are part of the National Water Strategy. As a specific response to the over-consumption of groundwater resources, the Highland Water Forum was created in 2010 with the aim of achieving the sustainable management of aquifers in the highlands. Moreover, as an overarching target the Forum promotes stakeholder dialogue focusing on sustainable groundwater management in Jordan.

Because Jordan shares all of its surface water resources with riparian countries, pursuing bilateral and multilateral cooperation with neighbouring states, and advocating regional cooperation are among the issues that are highlighted in the water strategy.

A number of policy papers have been drawn up within the framework of the National Water Strategy. These identify the main threads of water resources management. The four policy papers are the Water Utility Policy, Irrigation Water Policy, Groundwater Management Policy, and Wastewater Management Policy. The National Water Strategy and the four policy papers, coupled with a comprehensive investment programme, chart a road map for sustainable development (HKJ, n.d.).

Until 1987, water resources were managed by two independent authorities, the Water Authority of Jordan for water supply and sewerage, and the Jordan Valley Authority for irrigation and development in the Jordan Rift Valley. In 1987, the two authorities were brought together under the umbrella of the Ministry of Water and Irrigation. The National Water Strategy sets out the mission and key priorities of the Ministry.

Conclusions

Jordan is among the poorest countries in the world in terms of water resources. Consequently, priority is given to structural investments which help to develop more of its water potential. However, increasing demand and a growing population have pushed water consumption beyond sustainable limits and have led to over-use of groundwater resources. Climate change projections point to the possibility of a further reduction in water availability. As things stand, adequately addressing the challenge of an increasing water deficit requires both supply-side and demand-side measures, such as better water management, enhancing water use efficiency, awareness raising to change water consumption patterns, redefinition of water allocation priorities (such as limiting or reducing agricultural water use), and the development of technologies for use of non-conventional water resources (i.e. waste-water recycling). Reversing the trend of water-quality degradation is important to protect public health, while ensuring the sustainability of ecosystems and protecting scarce water resources. The National Water Strategy is a major policy document and its priorities are undoubtedly the correct ones. However, achievement of its goals will require the continuation of institutional changes to allow an integrated approach to water management issues.

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CHAPTER 40

Morocco

Acknowledgements Abdelhamid Benabdelfadel, Youssef Filali-Meknassi

Morocco: Dades Gorges (31°26′ N, 6°01′ W)

Location and general characteristics

The Kingdom of Morocco (Morocco hereafter) is located at the north-west end of the African continent. It covers an area of 710,850 km^2 and has 31.5 million inhabitants (2009). It is bordered by the Mediterranean Sea to the north, the Atlantic Ocean to the west, Algeria to the east and Mauritania to the south.

Morocco's mountainous territory has an average elevation of 800 m. The highest point in North Africa (4,167 m above sea level) is found in the High Atlas Mountains in the centre of the country. The long coastline, alluvial lowlands, mountain chains, high plateaus and the Sahara desert make for a wide variety of landscape.

Most of northern and central Morocco has a Mediterranean climate with cold winters and hot, dry summers. The southern part of the country has semi-arid to desert climate. Therefore, the rainfall regime is highly variable both spatially and temporally. Annual precipitation ranges from 2,000 mm in the north to 100 mm or less in the south-east along the Sahara. The River Draa, which rises in the Atlas Mountains, is the longest river in the country and runs for approximately 1,100 km before draining into the Atlantic Ocean at Tan-Tan. Other important rivers are the Sebou and the Moulouya.

Water resources and their use

Morocco's rivers are fed by rainfall and they are torrential in nature. Other than the Moulouya in the north which discharges into Mediterranean Sea, almost all the major rivers flow to the Atlantic or disappear in the Sahara. The annual water resources potential of the country is approximately 22 billion m^3, of which 82% corresponds to surface water and 18% to groundwater. Water availability per capita is around 700 m^3 – which puts the country into the 'water scarce' category. Surface water resources throughout the country are characterized by a very large annual and inter-annual variability which is marked by alternating wet and dry periods, interspersed with exceptionally wet and dry years. This means that reservoirs need to be built to regulate river flow and to store water for dry seasons. Currently, there are 130 large dams with a total capacity of 17 billion m^3.

There is also a clear disparity in terms of distribution of surface water resources. A few basins in the north (the Sebou, the Loukkos, and the Tangérois, for example) which cover merely 7.3% of the country have approximately half of its surface water resources. There are many aquifers in Morocco with good water quality. However, 66 out of 103 aquifers tested are considered partially or fully brackish. Overall, brackish water potential is estimated at about 570 million m^3 per year.

Agriculture is one of the main pillars of Morocco's economy. The agricultural sector generates approximately 20% of national gross domestic product (GDP) and creates employment for up to 40% of the population (80% in rural areas). Cereals (wheat, barley and maize), sugar beet, sugar cane, citrus fruit, grapes and livestock are the main agricultural products. Approximately 95,000 km^2 of land is cultivated including 15,000 km^2 of irrigated land. Groundwater is of paramount importance to agriculture as 75% of irrigation water is abstracted from wells. While the renewable groundwater capacity is estimated at 3.6 billion m^3/year, actual consumption has surpassed the sustainable limits and reached approximately 5 billion m^3.

Other sources of income are tourism and fisheries. In 2009, 8 million tourists visited Morocco generating approximately US$6 billion of income. While tourism constitutes an increasingly important sector for the national economy, the consumption of water by touristic activities is also growing.

Overall, water consumption in Morocco has risen beyond the level of the currently developed renewable water resources potential. In 2008, annual water demand was 13.5 billion m^3. Of this, 2 billion m^3 came from non-renewable groundwater resources. As a result of over-exploitation coupled with changes in climate, the water level in many aquifers dropped by 20 m to 60 m. The agricultural sector is by far the largest user of water, accounting for 90% of demand. This is followed by municipal needs, which constitute just 8%. By 2030, the water deficit (that is the use of non-renewable sources) is expected to reach 5 billion m^3.

Climate change and disasters

Statistical analysis of hydrometeorological data shows that rainfall increases in October and November and decreases in spring. While winter rainfall seems to be declining, this was not statistically significant. An analysis of variations in temperature between 1960 and 2000 revealed an increase of up to 1.4°C in the south-east and in the Midelt region of central Morocco, but the warming trend in the north was less significant. A temperature increase of 1°C or higher was recorded over two-thirds of the country in summer; and a similar warming trend was observed in winter temperatures. Climate observations also show that the semi-arid zone has been progressing northwards over the past few decades. A worrying trend is that water resources availability has decreased by 16% since 1981 (Figure 40.1). Estimates of possible climate change impacts on water resources indicate an average decrease in water resources in the order of 10% to 15% by 2050.

Flood and drought have also become more pronounced. In the past 35 years, Morocco has faced more than 20 periods of drought – the worst in recent history – with some lasting five years or more. Floods have also had a socio-economic impact on society that is stronger than before. This is not only because of the individual floods tend to be worse, but also because of population growth, urban development, and expanding agricultural, industrial and tourism activities in vulnerable areas. The record rainfall of 2,685 mm at Jbel Outka and the exceptional floods in the Ouergha River basin (maximum discharge of 7000 m^3/s), are only a few examples of extreme events that took place between 2008 and 2011. Frequent floods and droughts have also led to increased land erosion.

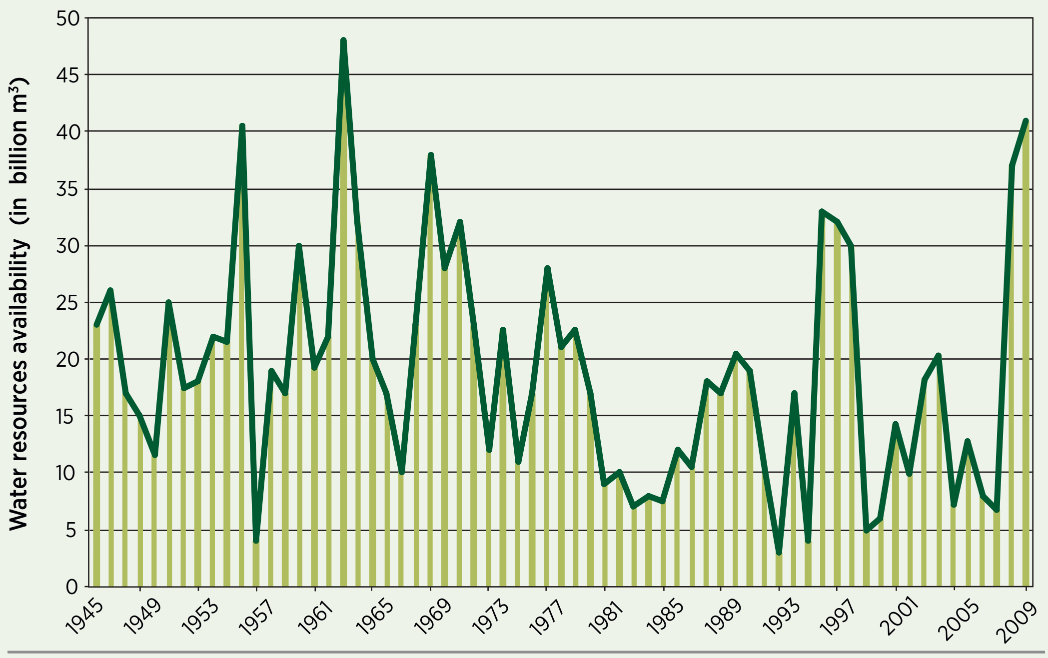
As a part of the United Nations Framework Convention on Climate Change (UNFCCC), Morocco formulated its first national communication in 2001, and its second in 2009. These communications provided details on the national inventory of greenhouse gas emissions and mitigation options including the action plan. It is estimated that by 2030, the annual total mitigation potential of these measures will be equivalent to 52.9 million tonnes of CO2.

In 2009, the National Plan to Fight Against Global Warming (Le Plan National de Lutte Contre le Réchauffement Climatique) was introduced. The Plan comprises mitigation and adaptation measures and identifies a number of priority areas for action, including water resources, agriculture, forestry, desertification, fisheries, coastal land use, health and tourism.

The national water strategy includes an action plan to 'reduce vulnerability to water-related natural hazards and adaptation to climate change'. The measures covered in the plan include improving weather forecasting, the development of warning systems in major basins and sites vulnerable to flooding, the integration of flood risk plans for land use, urban planning and watershed management, and the development of financial mechanisms such as insurance and natural disaster funds.

FIGURE 40.1

Fluctuation in water resources availability between 1945 and 2010



Water resources management and institutional aspects

Since the 1960's, the National Water Policy in Morocco has been oriented towards the development of water resources. This has been done through constructing the major water infrastructure projects – such as large reservoirs and water transfer schemes – that ensure the continuity of the water supply that the country relies on. Increasing demand necessitated an improvement in the way scarce water resources were being managed. Water Law 10-95 (enacted in 1995) represents the legal basis for a forward-looking water policy, which takes into account both supply-related and demand-related issues. Notably, it defines water as a public property and calls for an integrated, participatory and decentralized water resources management mechanism through the establishment of nine river basin agencies. The Water Law requires the preparation of national water management plans and river basin water management plans. It also addresses the issue of cost recovery through water abstraction charges (user-pays), and introduces a water pollution tax (polluter-pays).

Because groundwater resources are so important, the protection of aquifers is an important element of the Water Law. To this end, several measures are being planned, including pricing as an instrument; setting protected zones where groundwater abstraction is banned or limited; imposing strict procedures for granting drilling permits; increasing human, financial and institutional capacity to be able to better enforce the rules and control mechanisms; and improved monitoring of groundwater availability and utilization. Promoting scientific research and the artificial recharge of aquifers are also among the issues that are under consideration.

For better medium-term and long-term planning, the National Water Plan was established to integrate the various regional plans in order to develop a vision of integrated water resources management. The Plan has two overarching targets: developing a national strategy based on the 1995 Water Law, and formulating and adopting specific action plans and investment programmes.

The Water Resources Division of the Ministry of Energy, Mines, Water and Environment (de l'Energie, des Mines, de l'Eau et de l'Environnement – SEEE) is the lead government department responsible for planning and implementing the national policy on the development, management and preservation of water resources. The Division is also charged with the protection of the environment, and oversees the work of the nine river basin agencies. The national bureau for electricity (Office National de l'Electricité) and the national office for drinking water (Office National de l'Eau Potable) both come under the auspices of the same ministry. The Supreme Council for Water and Climate (Conseil Supérieur de l'Eau et du Climat) formulates the general guidelines of national policy on water and climate.

Significant progress has been made on the implementation of the Water Law. However, further improvement of the regulatory and institutional framework, including the revision of certain provisions of the Water Law (such as wastewater discharge at sea, desalination, recycling of wastewater and the protection of wetlands) is anticipated. Establishing a legal framework that aims for a more rational system of abstraction charges and enforcement of water policy is equally critical – especially with respect to controlling the allocation of water and restricting its use.

To address current and imminent challenges, a new national water strategy was launched in 2009 to strengthen existing policies. Its main tenets are water demand management and better valuation; further development of water resources and an improvement in the way they are managed; the preservation and protection of water resources and the environment; the mitigation of risks and a reduction in the vulnerability to water-related hazards; regulatory and institutional reforms; and the modernization of information systems and capacity improvement.

The protection of the environment and ecosystems

Morocco has many wetlands that are located mainly in the mountains and along the coast. Studies conducted locally and nationally on ecosystems and biodiversity identified 160 sites of ecological and biological significance – including 24 internationally recognized Ramsar sites. Morocco's wetlands are home to many species of amphibians, reptiles and mammals, and they have a global importance as passageways for migratory birds. Unfortunately, the ecosystems are under an increasing threat caused by the degradation of water quality, as a result of domestic, agricultural, and industrial pollution as well as prolonged and recurrent droughts. To limit and reduce such threats, a number of strategic plans have been developed – the National Strategy for Sustainable Development, the National Strategy for the Conservation and Sustainable Use of Biodiversity, the National Action Plan for the Environment, the National Strategy on Water, the Master Plan for Integrated Management of Water Resources and the Development Strategy for Mountain Areas.

Pollution – notably domestic and agricultural pollution and, to a lesser extent, industrial and solid waste – is a major concern in Morocco. In 2011, nearly 700 million m^3 of wastewater from settlements was discharged into nature without treatment. Agricultural pollution has caused elevated nitrate concentration in water bodies, notably aquifers. Because of this, protecting the quality of water resources is a strategic priority, which is strengthened through introduction of various programmes such as the National Sanitation and Wastewater Treatment Programme, the National Programme for Rural Sanitation, the National Programme for Prevention Against Industrial Pollution, and a number of other programmes.

Water and health

Some 57% of Morocco's population live in urban areas where 98% have access to safe water (WHO/UNICEF, 2010). In rural areas too, the coverage has been increasing substantially from 14% in 1994 to over 83% in 2010. However, merely 25% of rural dwellers enjoy piped water at home. Coverage of the sewerage system exceeds 70% nationwide, but only 52% of rural dwellers have access to improved sanitation. As a result, diarrhoea and other gastrointestinal diseases continue to be a cause of morbidity and mortality especially among rural children in the lowest income groups, and particularly during the summer season (Ministère de la Sante, 2005).

Conclusions

Morocco's complex climate and hydrology mean that efficient water resources management is vital. Many important water resources development projects, including the construction of large dams and water transfer projects, have been implemented to meet the demand that is necessary for the country's socio-economic development. This is further backed by long-term national planning activities that were initiated in 1980s, and regulatory and institutional advances (for example, Law 10-95) that focus on integrated, participative and decentralized water resources management. However, the scarcity of water resources is being exacerbated by climate change and the over-exploitation of aquifers. The low value attributed to water, particularly in agriculture, and the deterioration of water quality are important problems that remain to be tackled. The new water strategy launched in 2009 to reinforce critical aspects of water policy is intended to address current and imminent challenges.

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Except where otherwise noted, information in this concise summary is adapted from the *Morocco Case Study Report* prepared in 2011 by Abdelhamid Benabdelfadel, Chief of the Division of Water Resources, Secretariat of State within the Ministry of Energy, Mines, Water and the Environment, in charge of Water and the Environment (unpublished).

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CHAPTER 41

Murray–Darling basin, Australia

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Acknowledgements Marc Leblanc, Albert van Dijk,
Sarah Tweed, Bertrand Timbal.

Location and general characteristics

The Murray–Darling basin lies in south-eastern Australia and is formed by the Murray River (2,530 km) and its three main tributaries: the Darling (2,750 km), the Lachlan (1,450 km) and the Murrumbidgee (1,700 km) (Map 41.1). Covering more than a million km^2, or approximately 14% of the continent, the Murray–Darling basin spans most of New South Wales, Victoria, parts of the states of Queensland and South Australia, and the Australian Capital Territory – which includes the country's capital, Canberra. The basin is home to approximately 2 million people.

The topography of the basin is dominated by vast plains, bounded to the east and south by the Great Dividing Range, Australia's most substantial mountain range, which reaches a maximum elevation of 2,228 m above sea level.

The basin has a variety of climatic conditions and diverse landscapes ranging from the sub-tropical far north to the cool, humid uplands to the east, the temperate south-east and the hot, semi-arid and arid western plains, which account for more than two-thirds of the basin. Rainfall is summer-dominated in the north and winter–dominated in the south.

Water resources availability

Approximately 86% of the water currently used in the basin is surface water, with groundwater providing the rest. Water availability varies greatly across the basin and almost 80% of the vast catchment area contributes little or no water to the rivers. The main run-off comes from the southern and eastern boundaries of the basin. Average annual water consumption in the basin is approximately 11 billion m^3, which equates to 48% of the annual surface water potential of the basin. Currently, 84% of the water is used for agriculture and 3% is used by the MDB's towns and cities. The remainder is lost during the storage and transfer of irrigation water (Table 41.1).

To satisfy increases in water demand during the second half of the twentieth century, many structural works were built across the basin. The total water storage capacity in reservoirs rose from 2 km^3 in the 1930s to approximately 35 km^3 in 2007. This latest figure corresponds to about 150% of the average annual water availability in the basin. Surface water use in the basin grew with the increase in public and private storage capacity up to the mid-1990s, when the Murray–Darling Basin Ministerial Council imposed an upper limit on surface water diversions (Figure 41.1).

MAP 41.1

Murray–Darling basin

TABLE 41.1

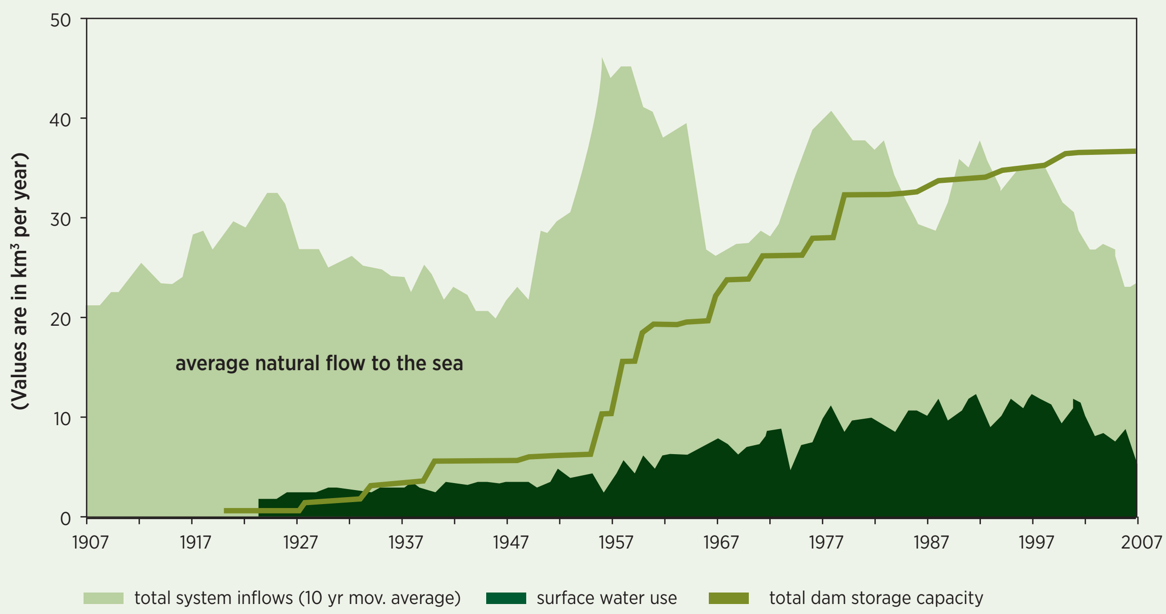
Surface water use in the Murray-Darling basin*

Surface water use	km³/year	% of overall
Net irrigation diversions	9.51	84
Rural stock and domestic	0.08	<1
Urban	0.32	3
Channel and pipe loss	1.24	11
Stream flow loss due to groundwater pumping	0.18	<2

** According to 2006-07 water sharing, water entitlements and irrigation portfolios*

FIGURE 41.1

Total system inflows, surface water use and dam storage capacity in the Murray-Darling basin



Water and agriculture

The Murray–Darling basin is Australia's food bowl. Agriculture is practised approximately in 80% of its area, accounting for about 40% of the country's total agricultural production. The main crops are cotton, rice, wheat, corn, grapes, citrus fruit and other fruit trees. Cattle and sheep production and irrigated dairy farming are also common sources of income. The amount of water used to maintain livestock-related agricultural activities corresponds to around half of Australia's total water consumption and around 60% of total agricultural water use.

Water management at the national level and in the basin

An increase in water diversions led to concerns about the health of the basin and its environmental flows. But because water allocations are governed by separate legislation and policies in the five states that share the basin, achieving the necessary environmental targets is posing a real challenge.

Since the 1990s there has been a progressive shift towards integrated water resources management in the basin. In 1993, the Murray–Darling Basin Commission was established to promote and coordinate the equitable and sustainable use of water across the basin. It was replaced in 2008 by the Murray–Darling Basin Authority, which acts as a government statutory agency. The basin's water resources are managed by the Murray–Darling Basin Authority in conjunction with the states and territories that make up its catchment area. The its main responsibilities are to measure and monitor water resources in the basin; to prepare, implement and enforce the management plan; to set surface and groundwater abstraction limits; and to develop a water rights information service to facilitate water trading.

Because Australia has a federal government system, it was necessary to have national agreement to ensure that there would be compatibility in the way each of Australia's state and territory governments was measuring, planning for, pricing and trading water. To this end, the National Water Initiative was signed by the Council of Australian Governments in 2004. It is an intergovernmental agreement signed by all of Australia's state and territory governments and is the country's blueprint for water reform. Established under the National Water Initiative, the National Water Commission is an independent statutory body that is responsible for helping to drive national water reform and advise governments on water issues. The commission's specific functions in the context of the Murray–Darling basin include monitoring the effects of interstate trade in water access entitlements in the southern part of the basin, advising the various National Water Initiative signatories about these effects, and auditing the effectiveness of the Murray–Darling basin water management plan.

Climate change and climatic variability

The severe drought that affected most of south-eastern Australia (including the southern part of the Murray–Darling basin) began in 1997 and continued for twelve years. This caused significant economic losses across the region (Box 41.1). The average annual rainfall deficit of this drought is similar to that of the 1935–1945 drought. However, the recent drought has led to a much stronger decrease in runoff and groundwater recharge. This can be explained by a change in rainfall patterns during the recent drought: lower inter-annual variability and less rainfall in autumn and winter. The drought ended with rains that caused some of the highest floodwaters on record in 2010–2011.

The semi-arid to arid nature of the region means that it already has very high natural hydroclimatic variability – adding the effects of climate change to this poses an even greater challenge. A comprehensive project commissioned by the federal and state governments suggested that, under a median scenario, surface water availability across the entire Murray–Darling basin would decline by 11% by about 2030 as a result of climate change. The projected reduction in water availability would reduce surface water use by 4%. However, water use in the driest years would be affected far more – by up to 50% in the basin in Victoria.

The greatest impact of climate change is likely to occur close to the mouth of the Murray River, including in the Chowilla floodplains, the Coorong national park and lagoon ecosystem, and the Lower Lakes. The outflows from the Murray River are already affected by current water diversions that reduce annual natural outflows by 40%. And these are projected to drop by an estimated further 30% by 2030. From an ecological point of view, the impact of water diversions on a river basin is often greater than the effects of climate change. However, the combined effects of both the water diversions and climate change could more than double the average duration between beneficial floods. This would have a significant impact on wetlands and their associated ecosystems. Towards the end of the twenty-first century, the impact of climate change could significantly increase, depending on emissions scenarios. What is even more concerning is that the current trend in greenhouse gases emission is alarmingly in excess of most scenarios that are currently considered in climate change projections.

Water and the environment

There are nearly 30,000 wetlands in the Murray–Darling basin that are important for native fish and the feeding and breeding of local and migratory water birds. The major wetlands located along the Darling basin include the Macquarie marshes, the Great Cumbung Swamp, the overflow lakes of the Paroo River, the Narran lakes, and the Gwydir wetlands. The largest wetlands on the Murray are the Barmah–Millewa, Gunbower and Koondrook–Pericoota wetlands, the Chowilla floodplains and the Lower

Lakes and Coorong Lakes systems at the interface with the Southern Ocean (Map 41.1).

Sixteen of the Murray–Darling basin's wetlands are identified as internationally important and listed under the Ramsar Convention. Similarly, the *Directory of Important Wetlands in Australia* includes approximately 200 sites in the basin. There are a large number of nationally and internationally significant plant and animal species in the basin. However, as a result of pollution and modified river flows associated with large-scale water resources development, 95 species are listed as threatened, more than half of its native fish species are considered to be in need of attention and fish populations are estimated to be only about 10% of predevelopment levels.

The 1997–2009 drought exacerbated the severity of these problems. For example, the record-low flows at the outlet of the Murray–Darling led to a sharp decline in inundated areas. It also led to a degradation of water quality as a result of increased salinity, which caused severe ecological and significant socio-economic impacts. During the drought, the water level at Lake Alexandrina, which is the largest water body in the Lower Lakes system (Map 41.1), dropped

BOX 41.1

Drought's heavy toll on Australia

During the 1997–2009 drought, surface water storage dropped to less than 10% of storage capacity and groundwater declined by as much as 100 km^3. This imposed severe water restrictions on both urban communities and farmers who depend on irrigation. Overall estimates of the economic cost of this drought are not readily available, though some studies have estimated aspects of it.

Agricultural exports account for one-fifth of total Australian exports. In 2002, drought was estimated to have lowered gross domestic product (GDP) by 1.6% (more than US$10 billion), of which around 1% was the result of reduced agricultural export. The drought was also implicated in a 1% national decline in employment and wages.

Regional impacts were much stronger, with gross regional production down by more than 15% and employment dropping by more than 3% in the worst-affected regions of the Murray–Darling Basin. The Australian Reserve Bank estimated that the 2006–2007 dry year in Australia reduced GDP by almost 1%, whereas farm GDP fell by around 20%. More recently it was estimated that between 2000 and 2007, the gross value of irrigated agriculture fell by approximately US$ 140 million per year. During the periods 2005–2006 and 2007–2008, the total area of irrigated land fell by 42%.

Production of cotton and rice in the Murray-Darling basin (100 = average annual production for 1990-2000)

by about 1.2 m and the salinity level increased six-fold. The exposure of lake beds that are naturally rich in iron sulphides caused the production of sulphuric acid – threatening the rich flora and fauna of the lake's ecosystems.

The salinization of land and water resources is also environmental problem in the basin. Salt concentrations in soil water and groundwater are predominantly high in the basin because of the concentration of cyclic salts caused by millennia of evapotranspiration. This natural condition has been further aggravated by the extensive land clearance that started in the nineteenth century to increase the amount of land available for farming. Crops and pasture allowed more groundwater recharge than did the area's native vegetation, which caused rising levels of saline groundwater to contaminate the land and the surface water. The area affected by dryland salinity in the Murray–Darling basin states (including sites outside the basin) was estimated at 6,400 km^2 in 1997.

Conclusions

The Murray–Darling basin covers a vast area that is roughly equal to the size of France and Germany combined. Extensive agricultural practices have made the basin the food basket of Australia and a major source of income. However, usage patterns have put great stress on water resources and have passed beyond the critical limit of sustainable use. Land and water resources development have altered the hydrological conditions, caused environmental degradation and significantly affected ecosystems.

In recent decades, water management objectives have shifted from large-scale development of the water resources for irrigation to environmental concerns. In parallel, water governance is gradually moving to a coordinated and integrated management that is shared between the state and the territory governments in the basin catchment area. The severe drought that lasted more than a decade from 1997 to 2009 caused significant economic and environmental damage, and brought the tension between agricultural and environmental objectives to a head. However, the National Water Initiative and the recently established Murray–Darling Basin Authority give hope that water consumption patterns will be reevaluated with a view to improving hydrological conditions to a point where they can sustain the social, ecological and economic systems that depend on them.

References

Except where otherwise noted, information in this concise summary is adapted from the Case Study Report, *The Murray–Darling Basin: A Major Food Bowl In Crisis – Lessons from the Past and Challenges Ahead*, prepared in 2011 by Leblanc et al. (forthcoming).

CHAPTER 42

Yellow River basin, China

Acknowledgements Hongqi Shang, Feng Sun, Yangbo Sun, Hui Pang, Wu Dong, Ruipeng Son, Zhen Gong, Hai Jin, Zhao Hao, Jing Xu, Ramasamy Jayakumar, Ke Liu, Hao Liu, Bing Wang

© Yellow River Conservancy Commission (YRCC)

The Yellow River basin was covered in detail in the case study volume of the third edition of the *World Water Development Report* (WWAP, 2009). In agreement with the Yellow River Basin Commission, a follow-up study was developed to provide up-to-date information where possible and to further focus on critical challenges such as climate change, erosion, sediment transport and water quality.

Location and general characteristics

The Yellow River, the second-longest in the People's Republic of China (called 'China' from here on), rises in the western part of the country at 4,700 m above sea level. It runs through northern and central China, where the temperate continental monsoon climate is dominant. The southeastern section of the basin has a humid climate, whereas the north-western areas are considerably drier. The river passes through nine provinces – Qinghai, Sichuan, Gansu, Ningxia, Inner-Mongolia, Shaanxi, Shanxi, Henan and Shandong – before draining into the Bo Hai Sea (Map 42.1). Geographically, the Yellow River traverses the Tibetan Plateau (upper basin), the Loess Plateau (middle basin) and the North China Plain (lower basin).

The Yellow River basin covers an area of 795,000 km^2, which is home to approximately 110 million inhabitants – or about 8.7% of China's population in 2000. However, the population is unevenly distributed, with about 70% living in the lower third of the basin. Regarded as the cradle of northern Chinese civilization and the heart of modern China's political, economic and social development, the Yellow River is known as 'the mother river of China'.

Water and land resources in the basin

The average surface water potential of the Yellow River basin is 57 billion m^3 and average groundwater potential is about 38.5 billion m^3. In 2009, water consumption in the basin was 39.3 billion m^3, of which over 78% came from surface water and almost 22% from groundwater resources. Since 1980, the rate of groundwater exploitation has increased rapidly, reaching unsustainable levels. In fact, 65 locations spread over an area of nearly 6,000km^2 have relatively large groundwater depressions.

There are 163,000 km^2 of potentially cultivable land in the basin. Of this, 120,000 km^2 (or 15% of the basin territory) is cultivated, including 75,000 km^2 of irrigated land. Since the 1950s, the importance of agriculture to the economy has declined and other sectors are making a bigger contribution to the gross domestic product (GDP) of the basin (Table 42.1). Many new industrial cities have been founded: Xining, Lanzhou, Yinchuan, Baotou, Huhehot, Taiyuan, Xi'an, Luoyang, Zhengzhou and Jinan. However, agriculture still accounts for 75% of water demand.

MAP 42.1

Yellow River basin

TABLE 42.1

GDP of provinces in the Yellow River basin (2006)

Provinces	Agriculture (million US$)	Industry (million US$)	Service Industry (million US$)	Total GDP (million US$)	Increase since 2000 (million US$)
Qinghai	68	241	237	546	435
Sichuan	4	3	3	10	8
Gansu	224	957	846	2,027	1,736
Ningxia	101	441	354	896	705
Inner Mongolia	271	1,889	1,146	3,306	2,625
Shaanxi	455	2,822	1,792	5,069	3,969
Shanxi	218	2,406	1,277	3,901	3,164
Henan	369	1,908	1,033	3,310	2,645
Shandong	205	1,296	994	2,495	2,011
Yellow River basin	1,915	11,963	7,682	21,560	17,298

Climate change

Between 1961 and 2005, annual average precipitation in the basin decreased slightly – by, on average, 12 mm every ten years. However, this trend was significant at only nine of the 51 stations. Over the long term, the amount of precipitation in January may increase by less than 7 millimeter by 2100. Based on scenarios, the rainfall in the middle and lower reaches of the basin might be higher than in the upper reaches. During the same period, the annual mean air temperature across the basin increased at a rate of 0.3°C every ten years. Over 90% of the monitoring stations (53 of 58 stations) showed a significant increase in the annual mean air temperature. To give an example, at the Menyuan and Hezuo stations, both of which are located in the upper Yellow River basin, the average air temperature in 2004 was 1.14°C higher than in 1960. According to models, January mean temperatures could increase by as much as 5.0°C by 2100. Significant warming could reduce the availability of the water resources (Zhang et al., 2008). Consequently, better water management and the adaptation of technology to improve the efficiency of water use will need to be considered to prevent a critical water shortage in the basin in this century and beyond.

Concerns about environmental degradation and water-related disasters

Water pollution is a severe problem in the basin. In 1997, only 17% of the course of the Yellow River was fit for drinking water. This had a direct negative impact on human health and the basin's ecosystems. In 1982, more than 80% of the 96 algae types found in the Yellow River were either severely or moderately polluted. Furthermore, analysis of historic data since the 1980s shows a reduction in the number of fish species and total fish quantity in the river (Ru et al., 2010).

The Yellow River Conservancy Commission (YRCC), one of seven commissions of the Ministry of Water Resources in China, was set up to address the problem of water quality and manage water resources in the basin (Box 42.1). The YRCC has introduced the following measures:

- Setting a maximum pollutant discharge quantity for the provinces according to the inflow of the Yellow River;
- Strengthening the water quality monitoring on the provincial boundary; and,
- Enforcing the legislation on water pollution prevention and protection.

Thanks to these efforts, the water quality in the main stream of the Yellow River has improved considerably. In 2006, approximately 60% of the course of the river was in the 'good quality' category. And between 2002 and 2006, the areas of the river that were ranked as 'bad quality' fell from 21.1% to 3.1%.

Erosion in the basin occurs mainly along the Loess Plateau, and is a major problem. The plateau covers an area of 640,000 km^2 with average thickness of loess soil ranging from 50 m to 300 m. The volume of sediment in the Yellow River that originates from this region is about 1.2 billion tonnes per year. That accounts for 60% of China's total soil erosion and 10% of the world total. In fact, it is the yellow colour of the suspended sediments that gives the river its name. While the erosion in the loess soil band is a natural phenomenon, it has increased greatly as a result of the environmental degradation caused by human activities, especially deforestation, overgrazing, and over-cropping (Box 42.1).

While a portion of the heavy sediment load is transported to the sea, most of it is deposited on the riverbed and onto the banks. Consequently, the river flows in a channel that is higher than ground level. To give an example, the riverbed is 20 m above ground level in Xingxiang city, 13 m above in Kaifeng city, and 5 m above in Jinan city. The total region where the land is lower than the riverbed covers some 120,000 km^2 and is home to approximately 90 million inhabitants. Because dike breaches could result in devastating floods, the levees on the Yellow River floodplain are regularly maintained and rebuilt. However, all these efforts would not be enough to cope with a major catastrophe such as a 100-year-flood which could cause significant socio-economic damage. A major flood in 1938 affected 12.5 million people and claimed 890,000 lives. Today, approximately 1.9 million people living in the inner flood plain of the lower part of Yellow River basin are facing imminent threat.

Water resources management

As a result of a substantial increase in water demand in the upper and middle reaches of the basin, parts of the river course were dry twenty-one times between 1972 and 1999. In 1987, in an attempt to strike a better balance between supply and demand, China's State Council set up the Yellow River Water Allocation Scheme. This was followed in 2006 by an ordinance to regulate and control water volume in the Yellow River. This ordinance puts water extraction from the Yellow River under state control in order to satisfy demand and improve environmental conditions by ensuring flow, especially in the lower reaches of the basin, (Zhao, 2006). It also aims to promote socio-economic development in the basin.

The ordinance foresees an integrated water allocation scheme. It vests in the YRCC the responsibility of drafting the annual water-use plan in consultation with

BOX 42.1

Sediment management strategies in the Yellow River basin

The Yellow River Conservancy Commission is an agency of the Ministry of Water Resources. It is in charge of managing land and water resources in the basin, including protecting its ecosystems. The YRCC operates within an established legal and regulatory framework to plan, implement and maintain soil and water conservation programmes.

Since the mid-1950s the Commission has put a number of large-scale land management projects into operation in the basin, particularly in the Loess Plateau region. This has included constructing dams, afforestation and terracing efforts, and converting cropland on slopes into grazing land. In general, the key strategies aimed at managing sediment load in the Yellow River basin include:

- Soil conservation works – afforestation, terracing and constructing barriers;
- Improving land use practices – regulating cropping on slopes, enhancing tillage practices, etc.; and
- Commissioning engineering works to control flows and reduce sediment deposition in the river system.

These activities coupled with flood control support have been successful in reducing the sediment load of the Yellow River. However, the soil conservation projects in the Loess Plateau are expected to reduce river runoff by as much as 2 billion m^3 by 2030. Given the increasing demand for water, the reduction in water availability will add to existing competition between sectors for this precious resource.

Source: Adapted from UNESCO and IRTCES (2011).

eleven provinces and autonomous regions. The plan sets the quota for each province according to river flow forecasts. These quotas are then updated on a monthly basis taking into consideration actual water availability in the river. The provincial governments are responsible for the allocation of water resources in their jurisdiction, within the limits of their quota. To ensure that the water allocation system functions properly, administrative and legislative measures are backed by technical methods. For example, during the flood season, all reservoirs are operated in an integrated manner to regulate the river flow and subsequent water distribution. In addition, online river information systems allow accurate observation of water availability along the course of the Yellow River. They also allow the allocation scheme to be adapted to guarantee the water rights of the provinces in the lower reaches of the basin.

Since 1999, there has been no cut-off of the flow in the lower Yellow River basin, and environmental flows have increased by 1 billion m^3 in the low-flow season. Overall, the total flow[1] reserved for sediment flushing and environmental needs has reached approximately to 20 billion m^3. Consequently, estuary wetlands have increased in size by 253 km^2, and biodiversity has improved.

Conclusions

The challenges described in the previous *World Water Development Report* have not changed in the past three years. Consequently, water quality, environmental degradation, the unsustainable use of water resources (notably groundwater) and sediment transport are still high on the agenda of the Yellow River Conservancy Commission (YRCC). On the positive side, measures taken by the YRCC to limit pollutant discharge and to enforce legislation have helped to improve water quality in the river. As a result of the allocation scheme, river flow in the lower basin has met the minimum level required to flush the sediment and sustain basic ecosystem needs. The physical characteristics of the Loess Plateau mean that sediment transport will continue to be a problem in the basin. However, management practices, particularly afforestation and tillage, have reduced sediment loads in the Yellow River and its tributaries. In spite of progress made in various fields, the growing imbalance between supply and demand will require hard choices to be made in order to address diverging needs and reduce water consumption in agriculture, while making other sectors more water efficient.

Notes

1 The *United Nations World Water Development Report 3* (WWAP, 2009) reported that the minimum flow required to flush out sediment is calculated at 14 billion m^3, and an additional 5 billion m^3 is necessary for other environmental requirements.

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CHAPTER 43

Jeju Island, Korea

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Acknowledgements Yongje Kim, Gi-Won Koh, Sung Kim, Jae Heyon Park

Location and general characteristics

Jeju Province is the largest island in the Republic of Korea (Korea from here on). Located off the south-west coast of the Korean peninsula in the South Korea Strait, this self-governing province is home to approximately 567,000 inhabitants, and has a surface area of 1,848 km^2. Right in the centre of the island, volcanic Mount Halla is Jeju's dominating geographical feature (Map 43.1), and tops 1,950 metres at its highest point. Jeju Province has two main cities, Jeju in the north and Seogwipo in the south. In total, there are seven towns and five districts on the island. Jeju's gross domestic product (GDP) is slightly lower than that of the Korean mainland. It also has a low population growth rate (0.45% in 2005), and is not subject to significant migratory movements.

Although relatively small, Jeju Province has both sub-tropical oceanic and temperate climates, with a mean annual rainfall of 1,975 mm. About 60% of annual precipitation occurs during the summer monsoon between June and September. A low evapotranspiration rate and high permeability of geologic formations allow year-round recharge of groundwater, as approximately half of the annual rainfall (1.58 billion m^3) permeates into the ground.

Water resources and their use

While surface water potential is 260 million m^3, it is ephemeral in character. Therefore, groundwater is the primary source of water on the island, and it is heavily drawn on. In 2010, annual abstraction corresponded to 20% of estimated safe yield (Table 43.1).

TABLE 43.1

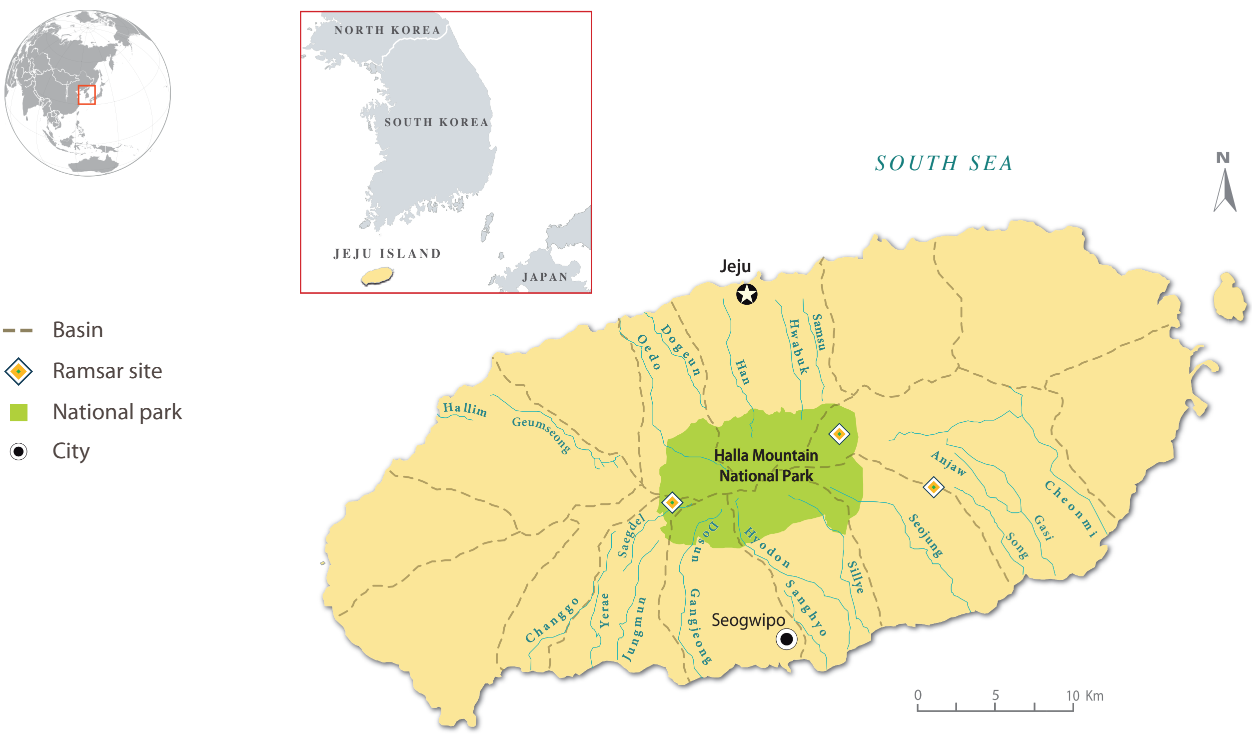
Groundwater development and use in Jeju Island

Consumption	Amount (m^3/d)	%
Domestic	202,000	57.1
Agriculture	144,000	40.7
Industry and others*	8,000	2.2
Total+	**354,000**	**100.0**

** Food processing, etc.*
+ Estimated safe yield: 1,768,000 m^3/d

MAP 43.1

Jeju Island



Agriculture is practised over 31% of the island. The most important agricultural products are oranges and mandarins, followed by other crops such as beans, radishes, garlic and potatoes. Rice is cultivated on an almost negligible scale. Between 1970 and 2002, the size of the agricultural area increased at a rate of 0.5% per year. However, since then there has been a declining trend, which is expected to continue.

The area of irrigated land is approximately 380 km^2, which corresponds to 71% of the total cultivated area as of 2003. Although more agricultural land can be irrigated, the availability of water is the limiting factor. While drip irrigation and sprinklers are used, there is still the possibility of improving efficiency. Overall, 98.8% of irrigation water is drawn from aquifers. Unfortunately, groundwater contamination as a result of agricultural activity is evident in coastal areas. Measurements indicate that 18% of groundwater resources have increased levels of nitrates, sodium, magnesium, calcium and sulfate, which are the chemical components of the fertilizers used. Livestock production also contributes to pollution levels.

Climate change, climatic variations and water-related natural disasters

Analysis of rainfall over the past eighty years shows a slightly increasing trend in annual precipitation and rainfall intensity. Annual precipitation increased from 1,360 mm in the 1930s to more than 1,500 mm in the 1990s. The extreme value of daily precipitation has also increased by 95 mm between 1951 and 2008. The daily precipitation of 542 mm recorded during typhoon Nari in September 2007, corresponded to the rainfall intensity of a once-in-a-thousand-year event.

There has been a 1.6°C increase in average winter temperatures since the 1930s. As a result, both the depth of snow at high elevations (such as Mount Halla) and the total number of days of snowfall have been trending downwards. Since 1960, the average annual rate of sea-level rise around Jeju Island has been approximately 6 mm, which is about three times the global average. Because of this rise and the accompanying sea water intrusion, the quality of groundwater is deteriorating – particularly around the coast where the population density is the highest.

In terms of water related natural disasters, from 1991 to 2000, Jeju Island was hit 23 times by typhoons. The seasonal variation in precipitation results in floods in summer and drought during other seasons. In fact, heavy rainfall, often accompanied by typhoons, brings about 70% of annual precipitation between April and October. Over the last 30 years, the frequency and the intensity of floods and droughts has been increasing (Figure 43.1). The socio-economic impact of such natural disasters is further aggravated by land-use changes, especially due to development in mountainous areas. For example, in September 2007, heavy rainfall from Typhoon Nari caused a major flood necessitating the evacuation of more than 14,000 inhabitants. Thirteen people lost their lives in the floods and the cost of property damage was around US$120 million. This prompted local government to revise the existing master plan to provide better protection against extreme events (Box 43.1).

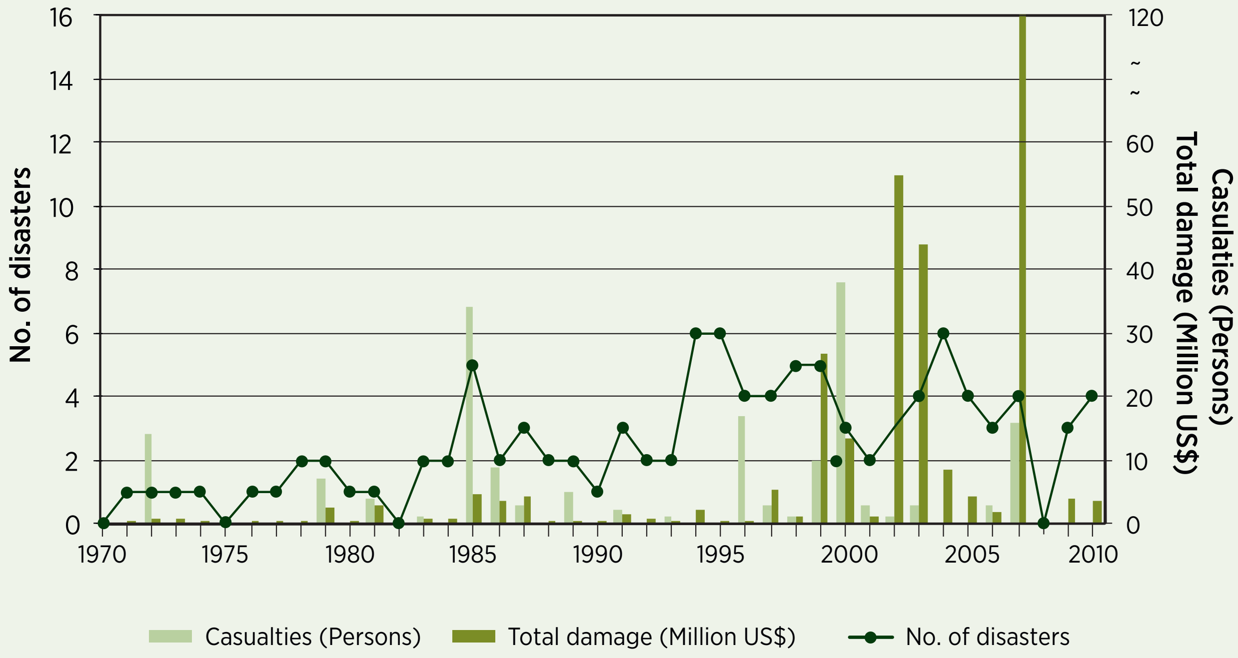
Even though the annual mean precipitation is high in Jeju, the Island often experiences drought caused by the large variations in rainfall. Consequently, to be able to better manage groundwater resources and carry out drought impact assessments, a comprehensive real-time monitoring network has been put in place to collect information on critical variables, notably the groundwater level. The information collected allows the authorities to take appropriate action, such as limiting the use of groundwater to minimize the risk of degradation of aquifers through sea water intrusion and contamination.

Water resources management

All aspects of water management, from resource development to policy making and implementation, are the direct responsibility of the water and sewage administration of the local government. Growing concerns about how to protect groundwater resources from over-pumping and potential seawater intrusion prompted the development of a special Act in 1991, which laid the framework for groundwater management and regulated the drilling of wells. Other administrative measures included regular water-quality inspections across the island, and a tax increase for groundwater use. In 1996, the Jeju Water Resources Development Plan led to the establishment of a multi-region water supply system. The first phase of the system was completed in 2000, ensuring a supply of 145,000 m^3 of water a day from fourteen groundwater abstraction sites on the east of the island. The second phase was launched in 2002. Given the importance of groundwater resources, in 2004 the local government put a specific management plan in place to promote

FIGURE 43.1

Jeju Island: water-related disasters 1970 to 2010 *



** Including typhoon, flood, and heavy snow; Casualties include victims, death and disappearances.*

the improved maintenance of wells, more efficient use of water in agriculture, and the diversification of water resources development. Following structural reforms in 2006, a heavily fragmented city and county approach to water-resources management was abandoned and replaced by the consolidation of all functions in the Jeju Water Supply and Drainage Management Headquarters. This, in addition to better management of water supply, helped in the standardization of environmental practices through the adoption of ISO 14001. Within this context, sewage-related operations, previously administered by cities, were integrated into regional systems in 2008, to ensure a more environmentally conscious overall approach.

Water pricing is also geared towards discouraging the misuse of scarce water resources. In line with guidelines set by central government, those water rates have been increasing gradually, with the eventual aim of reaching full cost recovery. As of 2006, the unit price of water corresponded to 62.5% of its estimated cost.

The local government has plans to invest over US$780 million over a time span of twenty years (2004–2025) on water supply and infrastructure improvement. A limited portion of these funds will come from the private sector. In fact, public private partnerships and privatization of certain services, such as the operation of sewage treatment plants, are becoming more and more common. As a result, a range of strategies is currently under development to promote greater involvement by the private sector.

Water and ecosystems

Jeju Province is rich in flora and fauna. For example, the Gotjawal Forest (located on the middle slopes of Halla Mountain) covers approximately 12% of the island and is listed as an internationally important wetland under the Ramsar Convention. The near-shore of the island provides a thriving environment for its 627 reported invertebrate animal species, a much higher number than in other parts of Korea. The warm currents and coral reef formations along the southern shore provide an ideal habitat for some 300 different

BOX 43.1

Management tools against extreme events

With growing population density, extended land use, and more frequent weather extremes, Jeju Island is becoming much more vulnerable to water-related disasters. Consequently, the local government established a comprehensive master plan for flood control in 2006 which shifted the emphasis in extreme-event management to an approach which emphasized sharing the watershed with nature. This involved the preparation of site-specific flood control plans that combined both structural (such as stream-bed dredging, building of embankments, dams, etc.) and non-structural measures (including a flood forecast and warning system), the improvement of residential land-use planning, and the introduction of a flood insurance system that took into account the effects of climate change.

However, the heavy socio-economic loss associated with Typhoon Nari prompted the expansion of that coverage to include individual streams in 2008. For the first stage of the plan, a general disaster prevention scheme was developed for four streams (the Han, the Byeongmun, the Sanji, and the Doksa) in the old section of the capital, Jeju-si, where the typhoon damage was most severe. As a result, 11 flood mitigation reservoirs, with a total volume of 1,577,000 m^3, were planned and partially constructed. Near the Han stream, two of these reservoirs were connected to artificial groundwater recharge systems to augment the replenishment of this vital resource. Debris barriers and screens were also put in place to prevent the clogging of channels in the stream.

species of fish. The island is also home to many bird species, mammals, reptiles, and amphibians. Unfortunately, uncontrolled hunting in the past, along with over-use of agricultural chemicals and rapid urbanization, has done considerable and irreversible damage to ecosystems. In terms of eco-parks, Mulyeongari-oreum in Seogwipo-si became the first protected area in Korea with the enactment of new wetland protection laws in 1999.

Water and settlements

Since the 1990s, the number of inhabitants living in the island's rural areas has remained the same while its urban population has steadily increased. In 2005, approximately 70% of the island's population lived in urban settlements. In terms of access to safe drinking water, almost all the population, irrespective of whether it is urban or rural, is served (Table 43.2). Average water consumption per capita per day is 340 litres (2005). Minimizing losses from infrastructure is among the main priorities of the local government.

In 2005, 72.3% of the island's population was connected to centralized waste-water treatment facilities. At 96.1%, coverage in urban areas is significantly higher than in rural settlements, where only 18.5% of the population is connected. A substantial effort will be required by the local administration to improve this service in rural settlements while keeping up with the urban growth. The daily capacity of all sewage treatment facilities is 178,479 m^3 (2005), operating at approximately 70% of their design capacity.

TABLE 43.2

Access to improved water supply in Jeju Province

	Population (person)	Water supply capacity (m^3/day)	Water supply rate (%)	Daily water consumption per capita (litre)
Jeju Province	559,747	316,548	100.0	340
Urban areas	387,885	207,600	100.0	357
Rural areas	171,862	108,948	99.9	302

Allocating water between uses and users

With the exception of the period during the summer monsoons, most of Jeju's rivers and streams are ephemeral in character. However, near the coast and across the mid-slopes of Mount Halla, groundwater discharge from fractures in the bedrock forms numerous springs. Historically, villages were established in areas where such springs were abundant. As a result, communities learned to share surface water and groundwater in peace through the centuries. However, with increasing demand, conflicts have begun to arise. While the constitution of Korea and local laws in Jeju provide basic judicial and administrative guidance in terms of developing groundwater, springs and streams, the lack of specificity as to fair use and allocation remains a problem that needs to be addressed with urgency.

Conclusions

Thanks to investment, the of Jeju Province has made significant progress in terms of socio-economic standards, with its inhabitants boasting the highest longevity in the country. Aquifers have long provided a dependable supply of fresh water for development needs. However, current levels of use, coupled with challenges such as pollution, seawater intrusion, and increasing demand, mean that more effective planning through integrated water resource management is essential. There will also be need for additional legislation, supported by practical mechanisms for the allocation of limited water resources among competing sectors. Jeju Island is one of the areas in Korea with the highest rainfall, and hydro-meteorological data shows a trend towards increasing intensity. The master plan for flood control and continuing improvements in infrastructure provide a strong basis for disaster mitigation in the future. Overall, the necessary financial and human resources are in place to address the water-related challenges facing Jeju Island.

References

Except where otherwise noted, information in this concise summary is adapted from the Republic of Korea Case Study Report, *Time for Solutions: An Assessment of Water Development in Jeju, Korea,* a WWAP study prepared for the fourth edition of the *United Nations World Water Development Report* by the Ministry of Land, Transport and Maritime Affairs, Republic of Korea, 2011 (forthcoming).

CHAPTER 44

Pakistan, with special reference to the Indus River basin

Acknowledgements Kozue Kay Nagata, Arslan Syed

Location and general characteristics

Pakistan is bordered by Afghanistan to the north, the Arabian Sea to the south, China to the north-east, India to the east and the Islamic Republic of Iran to the south-west (Map 44.1). There are three major geographical areas: the northern highlands, the Indus River plain and the Balochistan Plateau. The northern highlands include parts of the Himalayas. The Indus Plain, made up of alluvium deposited by the Indus River and its tributaries, stretches from the Salt Range to the Arabian Sea. The Balochistan Plateau is composed of dry hills and deserts that run from north-east to south-west.

Pakistan has a surface area of 800,000 km^2 and a population of approximately 185 million people (2010). The country is divided into four administrative provinces: the Punjab, Sindh, Khyber Pakhtunkhaw and Balochistan, as well as several areas with special administrative status.

In general, the climate is arid, and mean annual precipitation ranges from less than 100 mm in parts of the Lower Indus Plain to over 750 mm in the Upper Indus Plain. The Monsoons and the western disturbances – extratropical storms that originate in the Mediterranean – are the major sources of rainfall, two-thirds of which usually falls between July and September. On the Indus Plains, most of the rain falls during the Monsoons in early July.

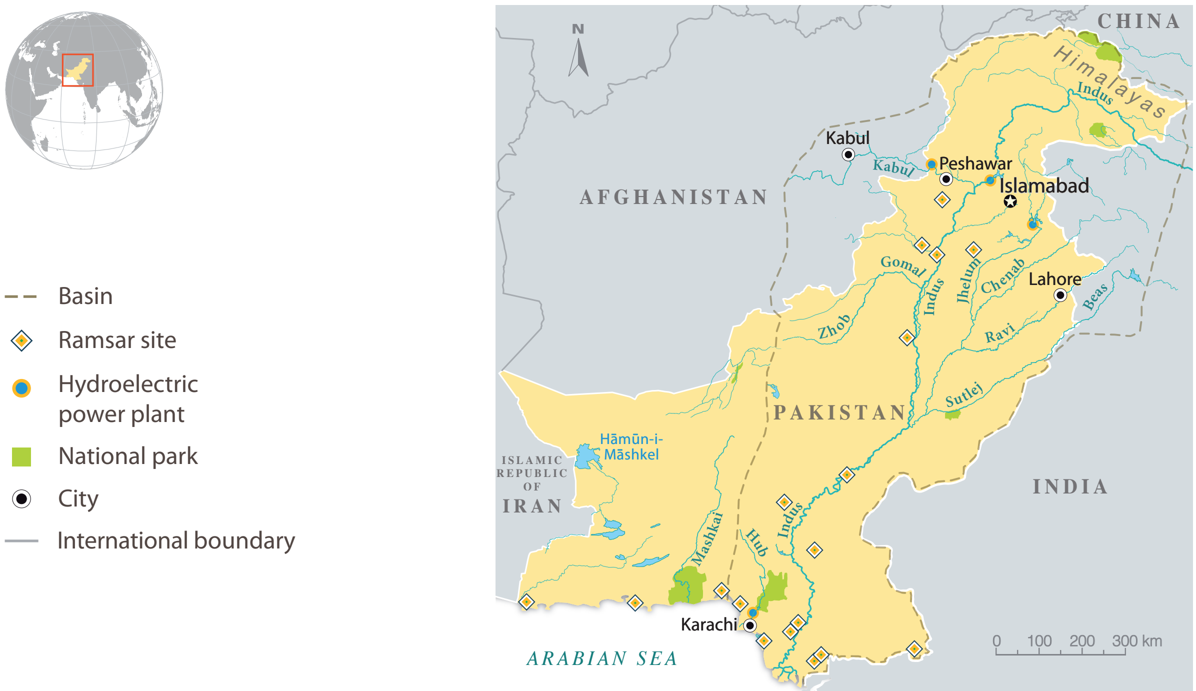
Originating in the mountains of the Tibetan Plateau, at an altitude of 5,000 m above sea level, the Indus River is Pakistan's most important source of fresh water. With a drainage area of approximately 1.1 million km^2, the Indus River basin covers approximately 65% of the territory of Pakistan (FAO–Aquastat, 2011*a*), and extends into the neighbouring countries of India, China and Afghanistan.

Water resources and potential impact of climate change

The Indus River and its tributaries (the Jhelum, the Chenab, the Ravi, the Sutlej, the Beas and the Kabul) have an average combined potential of 190 billion m^3 of water. The 1960 Indus Basin Treaty gives Pakistan exclusive use of three western rivers (the Indus, the Jhelum and the Chenab), whereas three eastern rivers (the Ravi, the Sutlej and the Beas) are allocated to India (Map 44.1). The Permanent Indus Commission, with a representative from each country, serves as the regular channel of communication on matters relating to the implementation of the Treaty, particularly the exchange of data and information. Most of the rivers

MAP 44.1

Indus River basin



outside the Indus River basin are insubstantial streams, which flow only during the rainy season and do not contribute significantly to the availability of surface water.

Beneath the Indus River basin is an aquifer extending over an area of 160,000 km^2. While the safe yield is estimated to be about 68 billion m^3, the volume of groundwater abstraction by different sectors, including domestic consumption, is already approaching 62 billion m^3 (FAO–Aquastat, 2011*b*). Over the last two decades, groundwater has played an important role in sustaining irrigated agriculture in Pakistan, with more than 50% of the irrigation water coming from more than one million privately owned wells. However, the current rate of use is not sustainable, and groundwater levels are declining in many areas.

Himalayan glaciers are the major source of the freshwater that feeds the Indus River and its tributaries. According to climate change scenarios, following an initial period of high flows caused by accelerated glacial melt, it is predicted that the amount of water flowing into the Indus River system may decrease by as much as 30% to 40% within the next two decades. Furthermore, the effects of climate change and siltation may reduce already-low reservoir capacity in the basin by 30%. The overall reduction in water availability may potentially have a serious impact on irrigation. This, in turn, may affect food security nationwide. There is already concern about forecasts that increasing temperatures may reduce grain yields in Asia by 15% to 20% by 2050 (IFPRI, 2011).

Climate change is also expected to affect the South Asian monsoon. According to the Intergovernmental Panel on Climate Change (IPCC), an increase in rainfall of up to 24% may amplify the frequency and magnitude of floods. The 2010 flood (Box 44.1) is an example that illustrates how devastating the socio-economic impact of such calamities can be at the nation-wide level. A more recent example, the 2011 flooding of Sindh province, has affected 5.4 million people to date. The number of deaths has reached 223 and over 600,000 homes have been damaged or destroyed. Nearly 300,000 people, the majority of whom are women and children, are currently living in camps (OCHA, 2011). These extreme events clearly demonstrate that planning and mitigation measures are required if the country is to be prepared to cope with climate change and climatic variations.

Water and agriculture

In Pakistan, 220,000 km^2 of land (approximately 27% of the country) is cultivated. Irrigation is used on 80% of arable land nationwide, and is practised mainly in the Indus River basin. The irrigation system in the Indus River basin is one of the largest in the world, with a total of 59,000 km of canals. Overall, almost 90% of all agricultural production is supported by irrigation. Livestock production is also widespread, particularly in Balochistan province, where it is responsible for almost 40% of agricultural income.

While agricultural yield grew at an average annual rate of 4.5% over the last decade, its contribution to gross domestic product (GDP) has been steadily decreasing over the years. In 2010, its share was down to 19.6%, while the service sector has grown to 53.7% and industry to 26.8%. However, the importance of agriculture lies in the fact that it employs about 44% of the nation's workforce, supports about 75% of the population and accounts for more than 60% of export earnings.

Irrigation has had a negative impact on soil fertility in the basin as a result of waterlogging (oversaturation of soil by groundwater) and soil salinization, which between them have already affected over 20,000 km^2 of land. These problems result from a combination of several factors, including seepage from unlined earthen canal systems, inadequate provision of surface and sub-surface drainage, poor water management practices, and the use of poor quality groundwater for irrigation.

A social problem linked to irrigation is the inequity of water distribution. The operation of the basin's irrigation system is based on a continuous water supply and is not related to actual crop water requirements. The distribution of water from the canal outlets is done on a seven-day rotational system (locally known as *warabandi*). Farmers are allowed to take an entire flow of the outlet once in seven days, and for a period proportional to the size of their land holding. However, the *warabandi* system discriminates against 'tail-enders', who end up getting 40% or less water than 'head-enders'. This has serious implications not only in terms of equity but in terms of crop productivity.

As a result of age and neglect, much of the infrastructure in the basin's irrigation system is in poor shape, resulting in considerable losses across the system and low performance in carrying water to the lower reaches of canals. Many elements of the vast hydraulic system are now reaching the end of their design lives and have to be rehabilitated or replaced at an estimated cost of around US$ 60 billion. Unfortunately, there is a huge backlog of deferred repair and maintenance, a problem which was aggravated by the floods of 2010 (Box 44.1).

Agriculture is the primary user of water resources. In fact, agriculture took 96% of the 183.5 billion m^3 of water used in 2008, followed by municipal and industrial uses (FAO–Aquastat, 2011*b*). Projections clearly show that water supply in the Indus River basin will gradually begin to fall short of demand, with the requirement for irrigation water expected to rise to 250 billion m^3 in 2025, as against availability of 190 billion m^3. This imminent challenge calls for more efficient use of water in agriculture, the adoption of water-conservation measures, and the augmentation of water storage capacity in order to prevent problems feeding the growing population.

Water and health

Access to safe drinking water and sanitation in Pakistan is an issue that requires considerable attention and investment. In 2008, about 95% of the urban population had access to water supplies (WHO/UNICEF, 2010*a*), but only some 55% of that number had household connections. In rural areas, almost half of the population uses water from sources that are not properly suitable for human consumption – sources such as streams, canals, village ponds, and springs. In fact, an estimated 62% of the urban population and 84% of the rural population do not treat their water prior to use. In national terms, the rate of access to sanitation is 45% (WHO/UNICEF, 2010*b*). Given this low value, it will be difficult to achieve the national target of 90% coverage by 2015. The financial cost of the disease burden that is linked to lack of safe drinking water and proper sanitation is equal to approximately 2% of Pakistan’s GDP.

Among the reasons for such low rates of access to water supply and sanitation are low tariffs and inadequate revenue collection. These problems result in meagre investment and the degradation of water and sanitation infrastructure caused by a lack of periodical maintenance. In fact, water-related public investment corresponds to only 0.25% of GDP (ADB–APWF, 2007). Consequently, tariff adjustment that better reflects the true value of water and covers the cost of service provision is considered vital if current challenges are to be addressed.

Poverty is a serious problem in Pakistan. Some 60% of the population lives on less than two dollars a day, while another 22% lives on less than one dollar a day. More than 38% of children under five are malnourished, with 13% of those severely underweight. Poor health in children is linked directly to lack of education for women. As a result of substantial gender inequality, the literacy rate for women is just 35%, compared to 59% for men. And broadly speaking, while there has been some success in the fight against poverty, the devastation caused by the massive flood in 2010 (Box 44.1) is likely to have had a detrimental effect on this trend.

Water and energy

The potential of hydropower generated by the Indus River is estimated at 35,700 MW and over 55,000 MW for the entire Indus River system. While only 15% of that overall potential of the Indus River is currently being tapped, the completion of projects that are already underway or at the planning stage will mean that the overall hydropower generation capacity of Pakistan can be increased to 25,000 MW.

With demand growing at an annual rate of 10%, and the absence of any hydropower development since 1975, the energy mix in Pakistan has shifted towards carbon-based sources. This has led to more expensive electricity, and shortages that affect every sector of the economy, particularly industry. Coal reserves remain as a potential source for thermal energy generation.

Environment and ecosystems

Despite its generally arid climate, there are more than 225 significant wetlands in Pakistan. Of these, 19 are internationally recognized under the Ramsar Convention. The Indus River and its floodplains form the main axis of these wetlands, both man-made and natural, which cover a total area of approximately 7,800 km^2. In addition, the Thar, Thal, Cholistan[1], Kharan and Indus Valley deserts also support a wide range of animal and plant species. In all, there are 18 threatened

BOX 44.1

The 2010 Flood in Pakistan

Pakistan experienced torrential rainfall between mid-July and September 2010. This caused the worst floods since 1929, which affected the entire country. The socio-economic impact of the disaster was overwhelming. According to the National Disaster Management Authority (NDMA), 1,700 people died and over 20 million were displaced. Many of those displaced suffered from various maladies, including at least 700,000 cases of acute diarrhoea, 800,000 cases of acute respiratory infection, nearly a million cases of skin disease, and almost 183,000 cases of suspected malaria. Flash floods and landslides triggered by the rain caused severe damage to infrastructure, urban settlements and agricultural production.

According to the World Bank–Asian Development Bank joint damage and needs assessment the overall recovery and reconstruction cost associated with the floods is expected to be between US$8.74 billion and US$10.85 billion, which includes estimated costs for relief, early recovery and medium to long-term reconstruction.

Source: Adapted from ADB ReliefWeb (2010) and CNN (2010).

species of wetlands dependent mammals, including the Indus River dolphin. There is now a very real threat to the twenty bird species, twelve species of reptile, two endemic species of amphibian, and more than 190 indigenous freshwater fish species that are supported by Pakistan's wetlands.

The Indus River basin wetlands, in addition to their intrinsic value as a rich source of biodiversity, also contribute to the fight against poverty through the raw materials they produce that help to sustain subsistence living.

While forest cover is only around 6%, businesses associated with forestry employ almost half a million people. Fuel-wood production, which provides one third of the country's national energy needs, is unfortunately one of the major causes of shrinking forests. The continuing loss of forest habitat, and the associated fauna and flora, have serious implications for the region's ecosystems, as well as for the fight against poverty.

The water quality of the Indus and its main tributaries deteriorates towards their downstream end as a result of municipal and industrial contaminants and return water from irrigation, which is polluted with fertilizers. However, the dissolved oxygen level in all rivers remains higher than the threshold value of 5 mg/l.

Water resources management

At the federal level, the Ministry of Water and Power is responsible for water and energy-related issues. The Water and Power Development Authority was established in 1959 as a government-owned public institute for the planning, design and implementation of irrigation, drainage and power projects.

Up to 1997, the distribution of irrigation water to farmers, the collection of water fees, and the repair and maintenance of the irrigation infrastructure was the responsibility of the Provincial Irrigation Departments. However, following a governmental reform, backed financially by the World Bank, to address problems in irrigated agriculture and water management, the Provincial Irrigation Departments were transformed into newly established autonomous Provincial Irrigation and Drainage Authorities. As a part of this reform, at the main and branch canals level, commercially oriented Area Water Boards were established. At the same time, the operation and management of the system at distributor and minor levels was handed over to independently elected farmer organizations. Overall, a total of 340 farmer organizations have been formed, of which 257 have taken over the management of irrigation systems. These organizations are responsible for collecting water charges, settling water-related disputes, and supplying irrigation water equitably and efficiently to users. While collection of revenues increased initially, it gradually fell back (in some cases by as much as 50%), because of the lack of technical assistance provided to farmer organizations by government agencies, and insufficient funds being allocated for their efficient functioning. Unfortunately, this situation raises questions about the long-term sustainability of farmer organizations in Pakistan.

Conclusions

The Indus River system is the lifeblood of Pakistan. It is the major source of freshwater that allows the country to thrive in an otherwise arid environment. Irrigated agriculture is the only way to secure the food production that is necessary to feed a growing population. However, the country is now facing critical problems, such as deteriorating infrastructure that causes significant losses during irrigation water transfer, low agricultural productivity, and a water management system that is unable to adequately address the challenges on the ground. Water-use projections show clearly that under a business-as-usual scenario, water demand will exceed supply by 2025. Climatic variations and climate change, coupled with low water storage capacity, may further aggravate this situation. Consequently, it is crucial to develop new strategies and policies that take into account the potential effects of projected climate change, with a view to promoting sustainable water use in all sectors. This will help to ensure food security, help in the fight against widespread poverty, and help to protect the environment.

Notes

1 Cholistan Desert was covered as a case study in *United Nations World Water Development Report 3* (WWAP, 2009), http://webworld.unesco.org/water/wwap/wwdr/wwdr3/case_studies/pdf/Case_Studies_AsiaPacific.pdf#page=13

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CHAPTER 45

Czech Republic

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Acknowledgements Jaroslav Plainer, Michal Vrabec, Josef Hladný

Location and general characteristics

The Czech Republic is an inland country located in central Europe. Its neighbours are Poland to the north-east, Germany to the west, Austria to the south, and Slovakia to the south-east (Map 45.1). The total area of the Czech Republic is around 79,000 km². In 2008, its total population was approximately 10.5 million. Its highest point is Sněžka, at an altitude of 1,604 m above sea level, is situated in the mountains in the north of the country. The lowest point is in the Labe Valley, where the Labe River leaves the Czech Republic, at an altitude of 115 m above sea level. The average air temperature of the country is 7.5°C.

TABLE 45.1

Basic characteristics of major river basins in the Czech Republic

	Elbe basin	Morava* basin	Oder basin
Extent of the basin (km²)	51,410	24,109	4,715
Average annual discharge (m³/s)	309	59.6	48.1

**Morava basin at Strážnice, upstream of the Dyje river*

Water resources, their use and management

Because of its relatively high altitude and climatic conditions, the Czech Republic receives an average of 674 mm of precipitation annually. There are more than 3,600 rivers that have basins of 5 km² or larger. These include the sources of a number of major European rivers, such as the Elbe (Labe in Czech), the Oder (Odra in Czech) and the Morava, which is a tributary of the Danube. The Elbe has the largest basin in the Czech Republic, followed by the Morava and the Oder (Table 45.1). These rivers discharge into the North Sea, the Black Sea, and the Baltic Sea, respectively.

Groundwater resources tend to be unconfined, or slightly artesian in character, and usually not very deep below the surface. The largest usable aquifers are located in the lowlands. Groundwater accounts for approximately 6% of total available water, therefore its importance in terms of overall water supply is relatively low. Because of its high quality, however, groundwater is frequently used as drinking water.

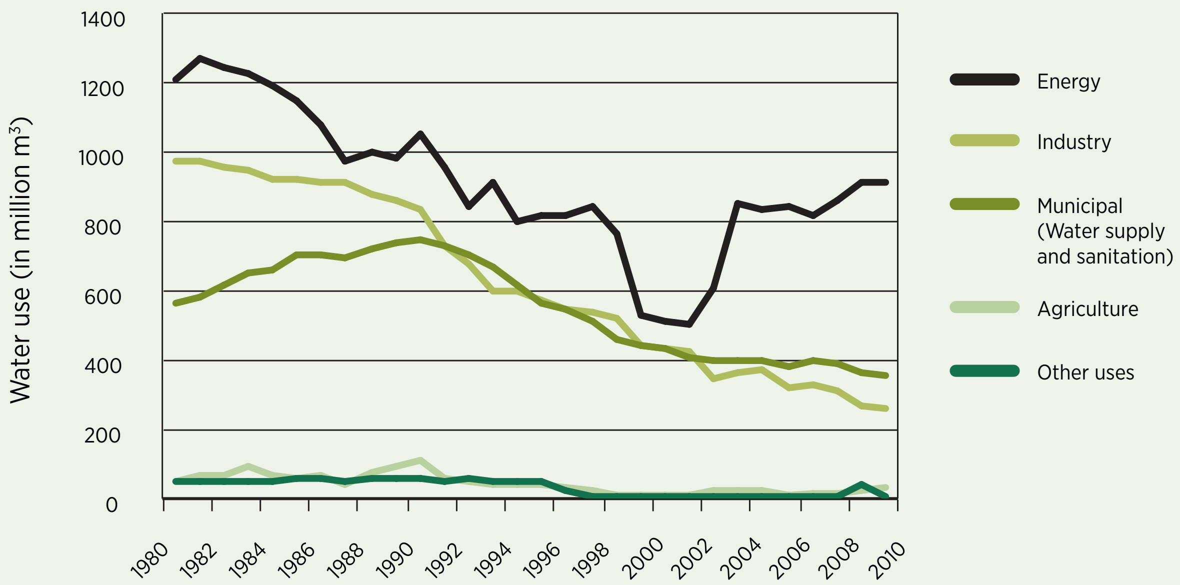
The highest demand for surface water comes from the energy sector, mainly for use in thermal and nuclear power plants. The levels of demand for water for industrial use, drinking water and sanitation (including settlements and animal farms) are broadly comparable. Agricultural demand is low because crop production mainly depends on rainfall. With the exception of energy production, there has been a declining trend in water use in all sectors since 1990 (Figure 45.1). Rising water prices and the

MAP 45.1

Czech Republic

FIGURE 45.1

Surface water abstraction in the Czech Republic between 1980 and 2009



increased use of advanced technology have both contributed to this decline. For example, in 2004, water abstraction was almost 35% less than in 1991. In parallel, the unit price of drinking water and water for sanitation rose from approximately US$0.25 in 1991 to US$3.0 in 2009. As a net outcome, wastewater generation dropped by 26% between 1991 and 2004.

Water resources management in the Czech Republic involves local, regional and national authorities. At national level, responsibility is spread between the ministries of agriculture, the environment, the interior, health and transport. The management of important watercourses such as the Vltava, the Elbe, the Ohře, the Morava and the Oder is entrusted to the River Basin Boards established by the government. Their main task is to operate and maintain the major water structures, such as dams, reservoirs, weirs and locks. In that context, key legislation includes the Water Act (No. 254/2001 Coll.) and the Water Supply and Sewerage Systems for Public Needs Act (No. 274/2001 Coll.). In 2010, Act No. 150 came into force, amending the Water Law. These acts, together with the European Union Water Framework Directive, established the framework for community action in the field of water policy.

Climate change and hydrologic extremes

While there are climate change scenarios for central Europe, none of these has been able to produce reliable models that can be used to predict changes in precipitation and hydrological conditions. In fact, there have been no statistically significant trends available for monthly or annual precipitation in the Czech Republic since 1961 (EEA, 2011).

Floods are frequent, but are not a regular phenomenon. In the period from 1990 to 2010, their frequency increased somewhat, and the floods in 1997 and 2002 were among the most serious in the country's history. There is a comprehensive mechanism in place for flood prevention, emergency response, and protection, which involves local, regional, and national authorities. The Central Flood Protection Committee, which operates at the highest level, is appointed by the government. In line with the EU Flood Directive (2007/60/EU), the Czech Republic is in compliance with the requirements of flood risk assessment. This is a process in which the country has drawn on its experience and previous knowledge in the field of natural disaster related risk management.

Drought also occurs infrequently in the Czech Republic. Short periods of drought occur mostly in the second half of the vegetation season. The worst drought in the twentieth century was in 1947, when the recorded rainfall deficit in Bohemia during the vegetation period reached almost 45% of the long-term average. Within the last 135 years, there have been five vegetation seasons with similar rainfall deficits.

Water and the environment

Water used in industry and for the production of electricity is returned almost entirely to the rivers. However, discharged water is 'thermally polluted' (that is, it is warmer than the ambient temperature of normal water bodies). Such elevated water temperature may cause variations in dissolved oxygen levels, which adversely affects ecosystems. The influence of other types of industry – particularly chemical, pulp-paper, and steel factories – on water quality was significant in the past because of the absence of wastewater treatment systems. However, in the 1970s, water quality began to improve gradually, as a result of restrictions on industrial wastewater discharge and the introduction of advanced treatment technologies. In 1971, the proportion of pollution caused by industry was approximately 57% or 79,400 tonnes[1]. By 1990, this proportion had dropped to almost 30% or approximately 49,000 tonnes.

From the 1950s, growth in agriculture and the increased use of fertilizers, insecticides and herbicides caused soil and water pollution. Following the political changes that took place in 1989, agricultural policies that had been part of the former socialist regime's 'planned economy' were abandoned. Agricultural modernization, as well as the privatization and restitution of property, led to reduced water demand from the agriculture sector. Overall, agricultural production has dropped by about 30%. Further development of agriculture has been affected by the Czech Republic's membership of the European Union (EU). As a combined result of these changes, the use of artificial fertilizers has been dropping.

Alongside the social and political changes of 1989, the principles of environmental protection have been introduced and implemented rigorously. The Nature and Landscape Act (No. 114) came into force in 1992, and the Programme for Revitalization of the River Systems was introduced the same year. The Czech Republic joined the EU in 2004, and since then has been bound by the EU Water Framework Directive. This has also contributed to an overall improvement in environmental conditions.

Conclusions

Apart from local shortages, the availability of water resources is sufficient in the Czech Republic. In the 1960s and 1970s, water quality deteriorated rapidly as a result of booming water demand and discharges of wastewater from industry, agriculture and human settlements. However, political reforms initiated in the 1990s began to reduce that demand, and the associated pollution. This positive trend gained further momentum following EU accession. The national water management policy reflects the top priorities of the country: sustainable management of freshwater resources and the protection of ecosystems. Czech Republic is now working towards meeting the targets of the EU Water Framework Directive.

Notes

1 This measurement indicates the corresponding BOD_5 value. BOD_5 is an index used to assess aquatic organic pollution and commonly used to monitor organic load for environmental and process control in industry.

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Except where otherwise noted, information in this concise summary is adapted from the Czech Republic Case Study Report, *Water and Water Resources in the Czech Republic*, prepared in 2010 by the Czech National Committee for the International Hydrological Programme of UNESCO (forthcoming).

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CHAPTER 46

Marseille Provence Métropole Urban Community, France

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Acknowledgements Marseille Provence Métropole
– Water and Sanitation Agency

Location and general characteristics

The Marseille Provence Métropole (MPM) Urban Community was created in 2000 and is home to approximately one million inhabitants. The MPM is located in the Provence-Alpes-Côte d'Azur region of France on the shores of the Mediterranean Sea. It covers a surface area of 607 km^2, comprising the city of Marseille and eighteen municipalities, concentrating 23% of the region's population on just over 2% of its territory (Map 46.1). Marseille alone, France's second-largest city after Paris, extends over an area of 240 km^2.

The MPM lies in the temperate zone and has a Mediterranean climate. Average annual rainfall is around 550 mm, which is concentrated into a period of approximately 80 days, mostly in the spring and autumn months as violent, localized precipitation. The area is subject to summer droughts.

Water resources, their management and sanitation

The regional proverb *Eici, l'aigo es d'or* (here, water is gold) clearly illustrates the shortage of the resource. In fact, the lack of water, and the health consequences that underlie this, have been the principal cause of severe epidemics in the past, such as the outbreaks of bubonic plague in 1347 and 1720, and the cholera epidemics in 1834 and 1884 – all of which resulted in significant numbers of deaths.

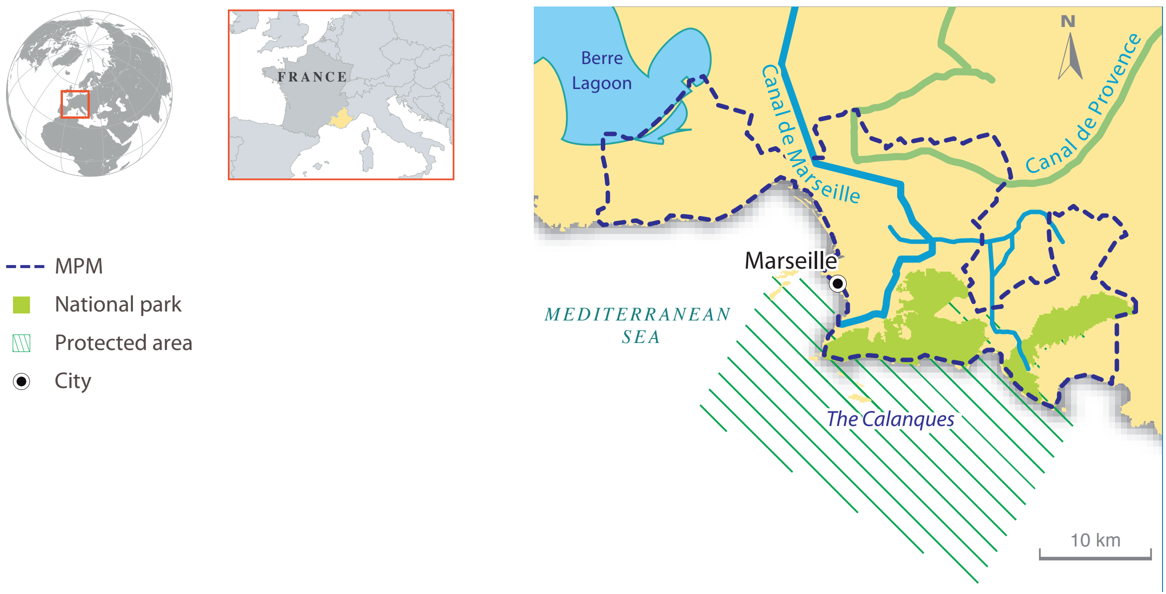
To alleviate water scarcity, a diversion canal, locally known as Canal de Marseille, was begun in 1838 to transfer the flow of the Durance River to the city of Marseille. Today, the main artery of the canal is 97 km long and its minor arteries extend over 195 km. The canal system comprises two dams, a number of underground canals and twenty aqueducts. The capacity of the canal has almost tripled since the middle of the nineteenth century, from 5.75 m^3/s to 15 m^3/s – although the flow varies depending on seasonal conditions and on an allocation agreement between the City of Marseille and the national utility company, Electricité de France.

On average, the canal provides 193 million m^3 of water per year to 1.2 million inhabitants in 36 municipalities. Today, the canal accounts for two-thirds of the water brought to Marseille, with the rest coming from the Verdon River through the Canal de Provence. Underground water resources are also used in the MPM to increase water availability in Marseille and to provide drinking water to the towns of Aubagne and Gemenos. As a result, protection zones are being established to minimize the risk of pollution of surface water and groundwater resources, including the network of the Canal de Marseille.

Annual water consumption in the MPM is about 100 million m^3, 95% of which is processed in wastewater treatment plants before being released back into the

MAP 46.1

Marseille Provence Métropole Urban Community



environment. Since 1942, Marseille's water supply has been managed by the Société des Eaux de Marseille. This has included the operation of the Canal de Marseille, as well as the production and distribution of drinking water. The Societe des Eaux de Marseille, a private company, also manages water supply in 15 of the MPM's municipalities. Marseille's first large-scale sewer system, the combined length of which is 346 km, was completed in 1896. The sewer network has been extended, improved and modernized over the past hundred years.

The first physico-chemical treatment plant was put into service in 1987. In 2008, the MPM Urban Community completed the construction of one of the world's largest underground biological treatment facilities – an investment of some US$270 million. Since 1981, the management of the City of Marseille's sanitation system (sewage and storm-water) has been delegated to a private company. In seventeen of the other MPM municipalities, sanitation services are also almost exclusively provided by private companies on an operation and maintenance basis.

To ensure that the water supply is secure, potential risks are constantly being evaluated – to prevent, for example, accidental pollution and failure in the purification plants or distribution network. Such studies have provided the basis of preparation of a five-year water plan. The plan is submitted to the MPM Urban Community's elected representatives, who select the projects that are to be carried out. The first MPM plan was approved in 2006, and represented an investment of US$165 million. The goal of this plan was to identify the weaknesses of the region's drinking water supply system and help to rectify them. Some 85% of the analysis section of this plan was achieved, and 65% of the project implementation was completed by the end of 2010. The MPM Urban Community is now preparing a second five-year plan, this time with the objective of ensuring water security for all the member municipalities. The budget for the new plan has not yet been established.

Climate change and risk management

Although water resources are limited, occasional heavy rainfall in the autumn and winter may cause severe floods. The Durance River in particular has caused frequent and violent floods. Similarly, intense precipitation causes floods in Marseille. To address these challenges, the MPM, on behalf of the City of Marseille, has introduced a strategy that combines regulatory arrangements and crisis management. Other developments too have helped to mitigate climate change effects – an extensive hydrographic network with sensors transmitting data in real time, river channel improvements and the construction of flood control reservoirs. Currently, the retention capacity of the reservoirs in Marseille is 130,000 m^3 and the MPM Urban Community is studying the feasibility of constructing 27 more to provide an additional storage of 200,000 m^3.

In the field of risk management, raising public awareness and involving local residents are high priorities. For example, in the district of Saint Loup, an SMS-based information system was set up following the mudslides in 2009. This is to inform residents of hazardous situations as quickly as possible and to make them an integral part of civil security operations.

While analysis of hydrometeorological data gathered by the MPM Urban Community does not show any specific trend that points to climate change, the likely consequences of climate change – such as rises in sea levels and the accelerated melting of the snow and ice that feed the rivers bringing water to the MPM – could be serious. Swollen rivers could flood because the storage capacity of reservoirs might not be sufficient to regulate higher flow rates, and rising sea levels could cause seawater intrusion into coastal aquifers and sewer system weirs. Recent studies point out the need to identify flood prone areas and adapt water works to be able to mitigate the effects of a potential change in rainfall regime. On the other hand, the flooding of coastal settlements is less likely because of Marseille's topography.

Environmental protection and use of modern technology

Environmental protection and the optimization of water use is a permanent priority for the MPM Urban Community. Consequently, the following measures has been taken:

- Unused water in the Canal de Marseille is now returned to the environment;
- Inspections to detect infrastructure leaks are carried out periodically;
- Out-dated lead connections have been changed;
- The sewer network is maintained regularly; and
- Street-cleaning vehicles are specially designed to minimize water use.

FIGURE 46.1

Evolution of water consumption in the MPM from 1995 to 2009

As a result, average annual water use in the MPM has remained relatively stable over the years (Figure 46.1). The MPM Urban Community also deals with wastewater management through operating 2,525 km of sewerage networks and 10 wastewater treatment plants. Moreover, it monitors the impact that discharges have on the marine environment.

Drinking water production and wastewater treatment plants in the MPM are upgraded regularly in line with regulatory requirements and technological advances (Box 46.1). For example, the drinking water production plant at Sainte Marthe, which was built in 1934, still complies with current standards. In addition, the sewage treatment plant at Ensuès-la-Redonne has been using advanced bio-reactor technology since 2009. However, in spite of the sophisticated technology utilized, treated wastewater is not re-used in the MPM because of potential environmental and sanitary risks.

All major modernization projects as well as maintenance operations are subject to public consultation. These are submitted for approval to the Regional Committee for the Environment and to the regional and national commissions that oversee sites with a recognized natural, ecological or cultural value. This can lead to changes in the proposed projects. For example, a project to modernize the sludge facility of the Marseille wastewater treatment plant, which is located in in the

BOX 46.1

The use of renewable energy in the MPM

As a part of its environmentally conscious approach, various sources of renewable energy are used to reduce emissions in the MPM. For example, the Sainte Marthe drinking water plant is equipped with a turbine that generates enough electricity for the facility to be self-sufficient[i]. Another turbine was installed on the Batarelle main, downstream of the Vallon Dol reservoir[ii]. The Marseille wastewater treatment plant uses thermophile anaerobic digestion to produce methane that is used in the plant for thermal processes, or, when economically feasible, to produce electricity[iii].

The MPM Urban Community is also studying the possibility of capturing the energy that is contained in wastewater through the installation of heat exchangers. Implementation of these innovative methods is being prioritized in the construction of new infrastructure or in modernizing the current sewer network. The sites are selected according to their potential in terms of connected population equivalent (PE)[iv].

[i] *Mean annual electricity production at Sainte Marthe: 3 million kWh or 266 TOE*

[ii] *Mean annual electricity production at Batarelle: 820,000 kWh or 70 TOE*

[iii] *Production of biogas in the sludge treatment plant: 10 million Nm³ in 2010, or 6300 TOE.*

[iv] *PE is an estimation of the organic biodegradable load that will be entering a treatment plant. Thus, it is an estimate of the usage of sewage facilities and not a measure of population.*

classified site of the Calanques, had to be modified to adapt to the biological characteristics of the local flora and fauna.

To ensure environmental flow, the MPM Urban Community agreed to allocate water from the Canal de Marseille to compensate for low water levels in rivers such as the Arc and the Touloubre, following discussions with local stakeholders and representatives of relevant governmental organizations.

Conclusions

The Marseille Provence Métropole (MPM) is home to a large urban community in a region where water is rather limited. Local efforts to secure freshwater resources and proper sanitation infrastructure began more than a century ago. The ambitious projects that have been carried out since have allowed the people in the region to enjoy high living standards, free of the diseases that prevailed in the past. The canals (Canal de Marseille and Canal de Provence), in conjunction with groundwater resources, provide a sufficient quantity of water to meet the growing demand. The challenge is to minimize the environmental footprint of this urban conglomerate, which has approximately one million inhabitants. Use of modern technology, the introduction of innovative approaches, and the handling of operation and maintenance by the private sector makes the MPM Urban Community confident of its ability to overcome the difficulties it faces.

References

Except where otherwise noted, information in this concise summary is adapted from the Marseille Provence Métropole Urban Community (MPM) Case Study Report, *Managing Water and its Risks, from Mountain to Sea*, prepared in 2011 by the Water and Sanitation Agency of the Marseille Provence Métropole Urban Community (forthcoming).

CHAPTER 47

Tiber River basin, Italy

Acknowledgements Giorgio Cesari, Remo Pelillo, Giorgio Pineschi, Giuseppe Bortone, Katia Raffaelli, Maurizio Baudone, Francesca Caparrini, Enzo Di Carlo, Sergio Paderi, Raniero De Filippis, Luca Fegatelli, Mauro Lasagna, Angelo Viterbo, Nicola Berni, Mario Smargiasso, Emidio Primavera, Sabrina Di Giuseppe, Tiziana Di Lorenzo

Location and general characteristics

The Tiber River begins the in the northern part of the Apennine Mountains in Italy and travels about 400 km before draining into the Tyrrhenian Sea (Map 47.1). The river runs through the Italian capital, Rome. The Tiber River basin covers an area of about 17,500 km^2, which crosses six administrative regions. Almost 90% of the basin lies in the regions of Umbria and Lazio, and the remainder falls within the regions of Emilia–Romagna, Tuscany, Marche and Abruzzo. The basin lies fully in the Central Apennines District , which includes all the regions of the basin and Italy's newest region, Molise (Table 47.1).

The Tiber River basin has approximately 4.7 million inhabitants (2009), some 60% of whom live in Rome. Overall, 83% of the population is composed of urban dwellers. The topography of the basin varies from lowlands to highlands and is mainly characterized by a temperate climate with hot, dry summers and cool, wet winters. The highest precipitation in both the Tiber River basin and the Central Apennines District is usually recorded in the autumn and spring, with a peak in early winter and a dry season during the summer.

Water resources availability and their use

The annual average discharge of the Tiber River into the Tyrrhenian Sea is 225 m^3/s or approximately 7 billion m^3 (calculated on a long-term average) (Cesari, 2010). Depending on the hydrologic conditions, the maximum discharge can exceed 1500 m^3/s or can be as low as 60 m^3/s. Groundwater availability in the basin is about 3.5 billion m^3.

With the exception of the Emilia–Romagna region, the basin and its immediate surroundings are mainly characterized by small farms (Table 47.2). Irrigation is practised through sprinklers, drip systems and canals over a combined area of 2,100 km^2, which corresponds to approximately 8% of agricultural land in the five regions. The most commonly cultivated products are fruit and vegetables (such as cereals and potato) and tobacco.

The territory is not very industrialized. However, there are important steelworks in Terni and beverage, tobacco, agro-processing and paper factories in the basin. Since the 1990s, industrial activity has been reducing gradually, and the services sector has become the main contributor to the region's gross domestic product (GDP) (Table 47.3).

In the largely rural Emilia–Romagna region, agriculture is the sector with the highest water demand, followed by municipal use and industry. In fact, irrigation accounts for 66% of overall water consumption. In other regions, agricultural water demand is relatively low. However, generally speaking, all regions are implementing various projects to improve water

MAP 47.1

Tiber River basin and Central Apennines District

TABLE 47.1

Extent of regions and distribution of the Tiber River basin

Region	Proportion of national territory (%)	Proportion of Central Apennines District (%)	Proportion of Tiber River basin (%)
Emilia–Romagna	7.45	0.08	0.1
Tuscany	7.63	3.46	6.7
Umbria	2.81	22.37	46.8
Marche	3.11	12.17	1.2
Abruzzo	3.57	25.31	3.7
Lazio	5.72	36.26	41.5
Molise	1.47	0.36	-

TABLE 47.2

Basic regional statistics about agricultural land use (2007)

Region	Average land holding size (km^2)	Irrigated area (km^2)	Cultivated area (km^2)	Irrigated/cultivated area (%)
Emilia–Romagna	1.28	2,966	10,525	28.20
Tuscany	0.10	472	8,064	5.90
Umbria	0.09	244	3,394	7.20
Marche	0.10	245	4,964	4.90
Lazio	0.07	861	6,740	12.80
Abruzzo	0.07	345	4,340	8.00

TABLE 47.3

Contribution of various sectors to GDP at the national, Central Apennines District and Tiber River basin levels

Sector/Region	Italy	Central Apennines District	Tiber River basin
Agriculture, Forestry, Fishing	2.5%	2.0%	1.7%
Industry	27.2%	22.0%	19.8%
Services	70.3%	76.0%	78.5%

demand management and to reduce seasonal water deficits. Umbria and Tuscany have facilitated access to information by developing databases on water use that are linked to online portals. Similarly, Emilia–Romagna introduced an 'Irrinet' service to reduce water consumption in agriculture, and has achieved successful results (Box 47.1). This region has also had its successes in the municipal sector, with a 7% drop in water use between 2002 and 2006. Umbria is aiming to increase public awareness of the need to reduce water consumption and has made improvements to its infrastructure to minimize water loss from the network.

In 2005, Rome's municipal water requirement was approximately 450 million m^3, and in the rest of the Tiber River basin it was about 80 million m^3. The same

BOX 47.1

Developing knowledge and capacity: Irrinet and Irrinet plus

The 'Irrinet' project, which aims to reduce irrigational water use, is an initiative of Emilia–Romagna region and part of the 2007–2013 Rural Development Programme. The Irrinet service is freely available on the internet and provides irrigational advice using data from the Regional Agency for Environmental Protection (Agenzia Regionale per la Protezione Dell'Ambiente – ARPA), the region's geologic, seismic and soil service, and the experimental activities of the consortium of the Canale Emiliano–Romagnolo.

Based on their geographical location, it is possible to indicate to farmers when to irrigate and how much in order to achieve the highest productivity. It has been estimated that the Irrinet service has helped to save about 50 million m^3 of water between 2006 and 2007. Since 2009, Irrinet has evolved into Irrinet Plus, which provides farmers with further information specifying the economic benefits associated with a particular irrigation routine that uses an intuitive advisory system. This project provides institutions with a practical instrument for managing the water demand for irrigation and helping farmers to use the right amount of water to minimize the risk of overuse. Also, institutions can monitor the irrigational water consumption, thus facilitating water rationing especially in drought periods.

year, water use for drinking and sanitation in the wider Central Apennines District was around 1.2 billion m^3, 90% of which was withdrawn from springs and aquifers. In general, a significant increase in water use is not expected and there are plans to reduce water consumption by as much as 8% by 2015.

In the Central Apennines District, there are approximately 40 dams, over 30 of which are hydroelectric power plants (HEPP) with an installed capacity of 1,400 MW. HEPPs in the TRB are mainly concentrated on the Tiber and Nera Rivers. About 8% of national electricity production comes from hydropower in the region, and almost all the power that is produced is consumed locally. While hydropower generation is a non-consumptive water use, it requires about 40 billion m^3 per year, and therefore adds to the competition from other sectors. Although a reduction in the production of hydroelectricity could increase water availability for other water users, it would have a negative impact on the national target of producing 20% of energy from renewable resources (Cesari et al., 2010).

Climatic variability, climate change and risk management

The Intergovernmental Panel on Climate Change (IPCC) predicts that the Mediterranean region in general will suffer from a reduction in water resources availability. In addition, the most severe climate change scenarios for central Italy – where a 6°C to 8°C increase in temperature is forecast by 2080 – foresee a decreasing trend in rainfall throughout the year, most notably between October and April where precipitation could drop by as much as 50%.

These predictions are partially confirmed by measurements. Data collected between 1952 and 2007 show a consistent trend of gradually decreasing annual precipitation (mainly in winter, with falls of up to 30%) with rising surface temperatures. Throughout the TRB, the amount of precipitation has decreased by 2 billion m^3 in the same period. While there have been exceptionally dry years (2007) and exceptionally wet years (2008), the Tiber River basin, in general, has experienced prolonged dry periods. In fact, major drought events that affected the entire basin occurred in 1955, 1971, 1987, 1990, 1993, 2003 and 2007. The droughts at the turn of the twenty-first century did not get much attention from the point of view of water scarcity. Instead, what were highlighted were the weaknesses in supply systems – including poor flexibility in the operation of reservoirs – and the lack of integrated management.

Floods are usual along the Tiber River. There were frequent floods in the first decade of the millennium, fortunately none of them was a major event and losses were economic in nature.

Because climate change is expected to exacerbate droughts and floods, there are policies and structural measures in place in Italy and throughout the Tiber River basin to deal with disaster mitigation and disaster preparedness. For example, at national level, the Local Action Programme uses meteorological and agro-meteorological indicators to highlight risks related to drought and desertification that could have an impact on agriculture, the environment and society in general. In the Emilia–Romagna region, 460 additional small reservoirs were built after the Programme identified that there was insufficient capacity to meet agricultural water demand in dry periods during the summer. The national civil protection service runs simulations to forecast water requirements under different climate scenarios and issues drought alerts. Regions are also cooperating to alleviate seasonal water shortages. For instance, in Tuscany and Umbria, extensive studies on water sharing led to an agreement between the regions for the joint use of the Montedoglio reservoir, which is located in the upper Tiber River basin.

Flood management is ensured through national directives that include early warning systems, and there are regional offices to implement the necessary measures. Legislative Decree 49, which came into force in 2010, transposed the EU Floods Directive (2007/60) into national law. In fact, the Tiber River Basin Authority had anticipated the contents of the EU directive and had already developed a planning tool (in line with Law 183/89 on soil protection) for the identification of flood-prone areas and the level of risk exposure. However, two main requirements of the Floods Directive remain to be implemented in the Central Apennines District: public participation in the planning process and the economic analysis and development of civil protection plans. Regarding public involvement, the Tiber River Basin Authority participated in the EU project 'integrative flood risk governance approach for improvement of risk awareness and increased public participation (IMRA)' to develop a method of risk communication and participation in local communities that are located in flood-risk areas.

Policy framework and decision-making

At national level, the 1933 Italian Royal Decree recognized water resources as a public good. In 1989, Law 183 established major basin authorities and identified the river basin as the basic unit for water resources management, water pollution control and soil protection activities. In 1994, Law 36 introduced a reform under which municipal utilities were aggregated into Optimal Territorial Areas which are responsible for the management and supply of water services such as wastewater treatment, sanitation and the provision of drinking water.

Legislative Decree 152 was introduced in 1999 to protect water resources by preventing and reducing pollution, and improving water quality. This Decree delegated certain responsibilities to the regions. Accordingly, each region had the right to make its own laws, and shared the responsibility for local implementation with the provinces (sub-units of the regions). In 2006, Legislative Decree 152 incorporated the contents of the EU Water Framework Directive and replaced the 1999 Legislative Decree 152. The new decree set out for the creation of a Central Apennines District Authority, with several ministries (Environment, Infrastructure and Transport, Economic Development, Cultural Heritage, Agriculture, Civil Function and Civil Protection) and regions (Emilia–Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzo and Molise) as members. Although the Central Apennines District Authority remains to be established, some of its functions (such as the coordination and implementation of the district River Basin Management Plans) have been temporarily assigned to the river basin authorities including the Tiber River Basin Authority. As an ongoing process, with the full implementation of the EU Water Framework Directive and Floods Directive, CADA will take over as the TRBA will merge into this Authority.

The regional governments have adopted strategies to reverse the current trend of environmental degradation and to integrate sustainable development principles into their work programmes. These strategies, which form a part of the Central Apennines District Management Plan (Piano di Gestione del Distretto dell'Appennino Centrale) are defined by the Regional Plan for Water Protection (Piano Regionale di Tutela delle Acque) and identify both quality-related and quantity-related measures that make up a holistic approach. The regions have also developed other strategies to address matters not included in the water protection plan, including natural disaster risk management, agricultural development, environmental protection, and energy production from renewable resources.

A comprehensive approach involving the close interaction of district and regional authorities is followed to prevent pollution and to protect water resources. It is the responsibility of the district authority to balance water availability with water demand. To do this, it defines appropriate goals and priorities. The regions then define the actions that are necessary to achieve those targets, including recovering the cost of water supply and sanitation services. The district authority audits these actions to ensure compliance with the goals and priorities. Once the actions are approved, the regions adopt and implement the Regional Plan for Water Protection.

In terms of water resources management, regional governments plan for and manage the services that are provided. For irrigation purposes, each district's rural development plan is taken as basis for helping to improve irrigation networks, wastewater treatment plants and aqueducts. For electricity generation, regional governments prepare plans to develop renewable energy sources, and identify the areas that are most suitable for the construction of hydroelectric power plants.

Water and the environment

The heavy and uncontrolled exploitation of surface water and groundwater resources has had a negative impact on water quality in the basin. Fertilizers used in agriculture along with municipal and industrial pollution have all added to environmental degradation. In 2010, 61% of rivers and 69% of lakes in the TIber basin were assessed to be of sufficient quality or higher. But during the summer, when there is little rain and demand for water peaks, the flow of the some streams is sustained mainly by wastewater returns. The Regional Plan for Water Protection aims to address environmental and water-quality related problems by holding open discussions with the participation of all stakeholders in an effort to identify appropriate actions. Furthermore, the Central Apennines District management plan emphasises EU Directive 42/2001 on strategic environmental assessment regarding the main drivers of water consumption and pollution, such as agriculture, industry, hydropower and drinking water.

The central and regional governments are proactive when it comes to finding solutions to environmental challenges. This is because their overarching objective is to maintain the quality of water resources (which is an integral part of the Central Apennines District Management Plan and the Regional Plan for Water Protection). For example, the Abruzzo and Umbria Regions are implementing their action plans to combat the high level of nitrate pollution, which is a common problem in Italy. These plans focus on the correct use of fertilizers and promote best practices – such as suggesting the appropriate amount of fertilizer to use for various crops, recommending the best periods during which to use it, and advising on the best ways of storing and transporting it. The action plans do this through direct communication with farmers and landowners. In addressing the issue of nitrate pollution, the Central Apennines regions put significant emphasis on public participation. Communication tools such as websites, information sheets and meetings are used to facilitate better interaction between local authorities and stakeholders. This approach also aims to inform stakeholders and help them to tackle the problems associated with nitrate pollution.

An ongoing project in the Marche Region in cooperation with the major Italian energy distribution company, Enel, aims to determine the degree to which increasing the amount of water discharge from dams affects the quality of surface water resources and the recharge rate of aquifers, especially in dry periods. The findings of this project will contribute to a better understanding of how to adjust minimum environmental flow requirements – an area where experimental research is lacking.

Conclusions

The water resources of the Central Apennines District and the Tiber River basin are important for the socio-economic development of central Italy and the country's capital, Rome. Agriculture, which is practised throughout the basin, is the sector with highest water requirement, accounting for over 60% of annual water demand. The sector contributes little to regional GDP, however, and is one of the sources of the ongoing problem of nitrate pollution. Consequently, regional authorities have been implementing projects to curb agriculture's impact on the environment and to reduce the amount of water it uses. Declining water availability, caused by climatic variability and climate change, has also necessitated a revisit of current water policies on allocation and supply. Implementing the EU Water Framework Directive, which was on hold until recently, can help to address the aforementioned challenges of seasonal water scarcity and environmental pollution, while improving public participation in decision making.

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Except where otherwise noted, information in this concise summary is adapted from the *Tiber River Basin Case Study Report*, prepared in 2011 by the Tiber River Basin Authority and Regional Services (forthcoming).

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CHAPTER 48

Tagus River basin, Portugal

Acknowledgements Manuel Lacerda, Simone Pio, Santa Clara Gomes, the Office for International Relations of the Ministry of Agriculture, Sea, Environment and Spatial Planning, Portugal, DHV, S.A., Hidroprojecto – Engenharia e Gestão, S.A., Laboratório Nacional de Engenharia Civil (LNEC), International Centre for Coastal Ecohydrology (ICCE), Instituto Nacional de Recursos Biológicos, I.P./IPIMAR; Biodesign, Lda., ARH do Tejo team

Location and general characteristics

The River Tagus has its source in Spain and flows into the Atlantic Ocean near Lisbon in Portugal. The Tagus River basin is home to 9.5 million people and covers an area of 80,550 km² – almost one-third of which is in Portugal. At 1,100 km long, the Tagus is the longest river in the Iberian Peninsula and it is an important source of water for both Spain and Portugal. The capitals, Madrid and Lisbon, rely on the Tagus River basin for their water supply, which further increases its critical value.

This case study focuses on the lower section of the basin, which is situated in Portugal (Map 48.1). In 2008, approximately 3.5 million people were living in this area. The basin is subdivided into 23 sub-basins, three of which (Tejo Superior, Erges and Sever) are transboundary.

Water resources, their use and potential effects of climate change

Portugal has a mild Mediterranean climate with distinct wet seasons in autumn and winter. Annual precipitation in the basin varies from 2,700 mm in the mountainous north-east to 520 mm in its westernmost regions. Generally, in summer most of the smaller rivers dry up, whereas intense precipitation in the autumn and winter months often causes floods. However, the flow regime of the Tagus and its tributaries is quite irregular as a result of rainfall variation from year to year as well as on a seasonal basis.

In the study area, the surface water availability (6.3 billion m³) in average is higher than the groundwater potential (3 billion m³) (ECOSOC, 2011). However, groundwater use predominates in the majority of the sub-basins.

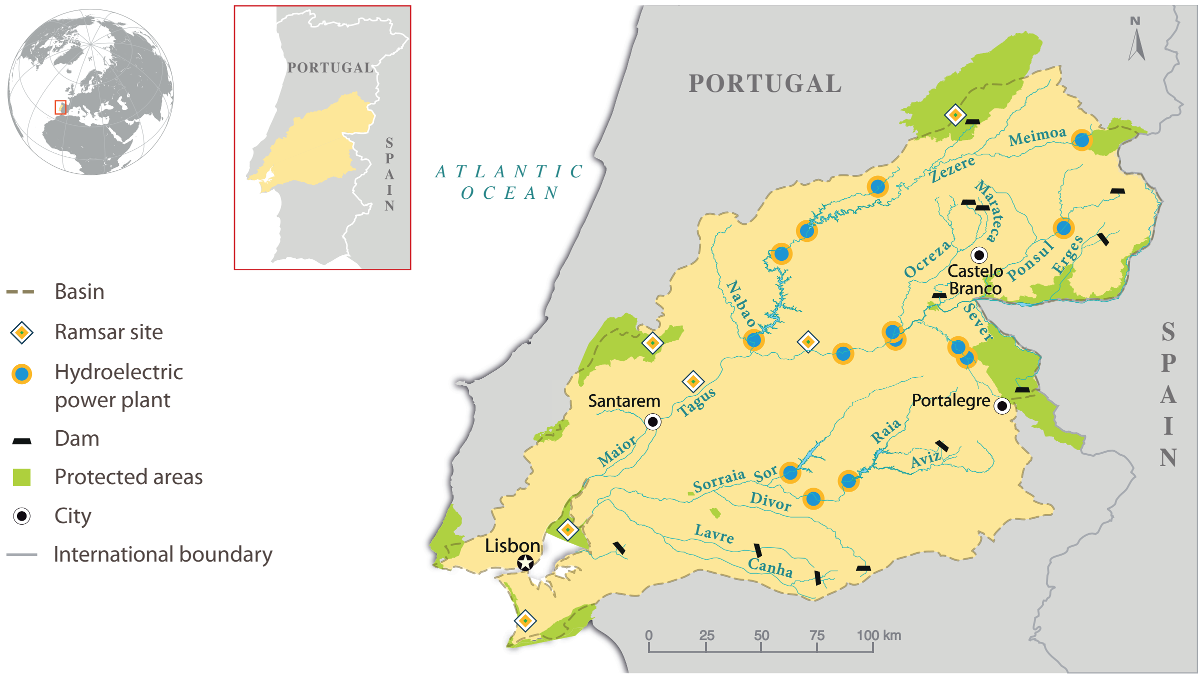
While agriculture and agro-forestry employ only 2.7% of the labour force, approximately 45% of the river basin is given over to farming and forestry. The water requirement of this sector (944 million m³) accounts for 65% of the total water demand in the basin. The remainder is largely used by municipalities (27%) and to a much lesser extent, by industry (6%).

Overall, the local water stress caused by the seasonal and other temporal variations is more of a concern than water availability. In order to cope with this problem, over 30 dams have been built with a total storage capacity of 2.3 billion m³.

Climate change scenarios indicated a potential decrease in the amount of precipitation in the order of

MAP 48.1

Tagus River basin



100 mm per year, particularly in the centre of Portugal and to the south. The regional model, however, predicts a 20% to 50% increase in precipitation in winter. This pattern of change may substantially increase the risk of floods. The prediction is that by 2100, the annual mean runoff from the Tagus River basin will be 10% to 30% lower. Such a reduction implies longer periods with low flow, and that is likely to have a negative impact on agriculture and tourism. It is also expected that a reduction in water availability will affect ecosystems, energy production and water quality which is extremely important in terms of human health, ecosystem services and other water uses.

To analyse the long-term trends, Portugal's national water authority (Instituto da Água – INAG) carried out a climate assessment on the period from 1931 to 2000. This study revealed that Portugal's mean annual air temperature had been increasing since the 1970s. Precipitation data for the same period showed a weak decreasing trend that became more pronounced after 1976. Analysis of data also showed an increase in the frequency of both heavy precipitation events and severe and extreme droughts – particularly in the southern regions between 1990 and 2000.

The national water authority assessment also pointed out the imminent threat of rising sea levels. About 75% of Portugal's population lives along the coastal zone, and 85% of gross domestic product (GDP) is generated there (Santos et al., 2002). In accordance with Portugal's 2004 National Climate Change Programme, and its adaptation strategies, a number of complementary actions have been taken including enacting the new Water Law (2005), a revision of the Strategic Plan for Water Supply and Sanitation for 2007–2013 (PEAASAR II, MAOTDR 2006), a revision in 2007 of the original National Climate Change Programme, and the Scenarios, Impacts and Adaptation Measures (SIAM 1 and SIAM 2), research project (Santos et al. 2002; Santos and Miranda, 2006; da Cunha, 2007).

Transboundary cooperation

Spain and Portugal share several rivers. The Albufeira Convention applies to the Minho, Lima, Douro, Tagus and Guadiana rivers and covers issues such as the exchange of information, pollution control and prevention, the evaluation of the transboundary impacts of water uses, the assignment of rights and conflict resolution. The Albufeira Convention is administered by the Commission for the Application and Development of the Convention. This is an intergovernmental technical commission coordinated by the foreign ministries of both riparian countries, with technical support from their environment ministries. Under the Convention, which came into force in 2000 and was revised in 2008, Spain guarantees to release 2.7 billion m^3 of water to Portugal measured at the downstream section of the Cedillo dam. This corresponds to approximately 37% of the annual average river flow (modified hydrologic regime). The current text of the Convention allows for future revisions of the established hydrologic regimes in order to ensure the achievement of the environmental objectives set at basin level and to integrate the climate change issue and adaptation measures.

Environmental status and legal framework

The River Tagus flows into the Tagus estuary, one of the largest estuaries in Western Europe. Because of its rich biodiversity and variety of habitats, the estuary is protected under the EC Directive on the Conservation of Wild Birds, which also makes it part of the Natura 2000 network. It is also classified as nature reserve under Portuguese national legislation.

Water quality in the basin continues to be an issue that demands attention. A series of consultations with stakeholders was conducted as a part of the preparation of a river basin management plan. These consultations identified nutrient enrichment, pollution (organic, microbial, heavy metals, dangerous substances) and eutrophication as the most significant issues influencing water quality degradation in the basin. The preliminary water status assessment shows that 54% of the surface water bodies and 66.7% of the groundwater bodies are classified as good or excellent (ARH do Tejo, 2011).

Nutrient enrichment, particularly in the form of nitrogen and phosphorus, is mainly the result of fertilizer use in agriculture and wastewater discharge from other sectors (including municipal use). To reduce nitrate concentrations in water bodies, the Code of Good Agricultural Practice was drawn up and steps have been taken to raise farmers' awareness by means of nationwide training initiatives. The code sets out general guidelines, mainly with a view to helping farmers to rationalize the use of fertilizers. It also proposes a range of growing techniques and methods that protect surface water and groundwater from pollution (EEA, 2010). A national strategy for agricultural and agro-industrial wastewater treatment (Estratégia Nacional para os Efluentes Agro-Pecuários e Agro-Industriais) was approved in 2007 to define environmentally sustainable solutions and to ensure the reduction, or the elimination of the pollution being caused by discharges from agro-industrial activities.

In relation to reducing urban pollution, the second phase (2007-2013) of the Strategic Plan for Water Supply and Wastewater Treatment (Plano Estratégico de Abastecimento de Água e de Saneamento de Águas Residuais – PEAASAR II) was adopted to make further progress towards attaining the objectives of the EU directives (MAOTDR, 2006). PEAASAR II aims to optimize the management and environmental performance of water supply and sanitation utilities to reduce costs and to maximize efficiency. In 2009, the sewage treatment plant connection rate was 79% in the basin, against a national target of 90% (ARH do Tejo, 2011).

Water resources management and institutions

The first water resources planning exercise took place during the EU Water Framework Directive co-decision procedure (1997–2000). It resulted in the preparation of Portugal's national water plan as well as fifteen separate river basin plans and two regional water plans. Work is still ongoing on the formulation of the revised national water plan and the river basin management plans.

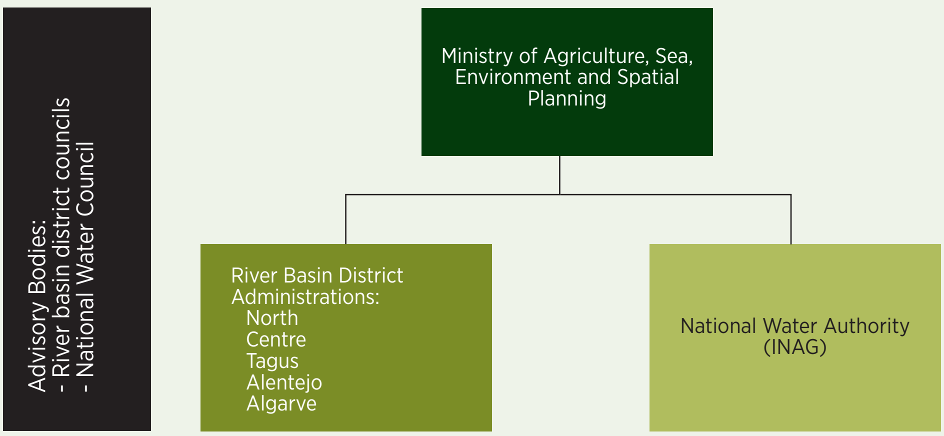
The Water Law was adopted in 2005 as part of the EU Water Framework Directive implementation process (Box 48.1). The law has a broader scope than the EU Directive as it includes all the elements of the integrated water resources management approach, including both quantitative and qualitative aspects, as well as mitigating the effects of extreme events. To complete the legal framework on water resources management, a number of additional regulations were also introduced, notably Decree 226–A (2007) on the

BOX 48.1

The Water Law and the river basin district administrations

The Water Law, adopted in 2005, established a new institutional model in Portugal. It is based on five river basin district administrations and Portugal's national water authority, the Instituto da Água (INAG), which is responsible for water resources planning and coordination in all parts of the country. The district administrations are in charge of water resources management at the basin level – in particular, they look after planning, licensing, infrastructure management, monitoring, and information and communication activities.

In this configuration, the river basin district councils and the National Water Council are the advisory bodies. The district councils provide advice to the district administrations and are composed of representatives from central government, municipalities, the private sector and civil society. The National Water Council makes its recommendations at the governmental level, particularly to the Ministry of Agriculture, Sea, Environment and Spatial Planning. All five river basin district administrations function according to the principles of stakeholder participation (user associations, for example), transparency, coherence, responsiveness and accountability.



establishment of a licensing system for water resources uses, Decree 348 (2007) on the establishment of water users associations and Decree 97 (2008) on the establishment of an economic and financial regime for water resources. Decree 97 aims to implement the 'polluter-pays' and 'user-pays' principles, and integrates the social and economic values of water as well as the environmental aspects of water resources management.

Conclusions

Annual, seasonal and geographic variability in the levels of rainfall the Tagus River basin receives causes water stress at a local level. However, the current challenge facing the basin is to improve the quality of water resources. The interests of the agricultural (such as large-scale irrigation) and agro-industry sectors often conflict with the environmental standards set by the EU Water Framework Directive, leaving water managers and decision-makers with a number of complex problems. While resource availability has been improved by constructing many large dams, this has also caused significant changes in the flow regime, which have had consequences for the ecosystems.

Climate change and climatic variability are concerns in a transboundary setting. Consequently, it is important to assess the water allocation agreement between Portugal and Spain based on climate change studies and to meet environmental objectives set by EU Water Framework Directive. Portugal has been making significant efforts to address current and imminent challenges by developing national strategies and implementing programmes that are holistic and broader in scope than the Directive. It is critical to keep up this momentum as the Tagus River basin lies at the heart of both Portugal and Spain.

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Except where otherwise noted, information in this concise summary is adapted from the *Tagus River Basin Case Study Report,* prepared in 2011 by the Administração da Região Hidrográfica do Tejo, Ministério do Ambiente e do Ordenamento do Território (forthcoming).

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CHAPTER 49

St Johns River basin, Florida, United States of America

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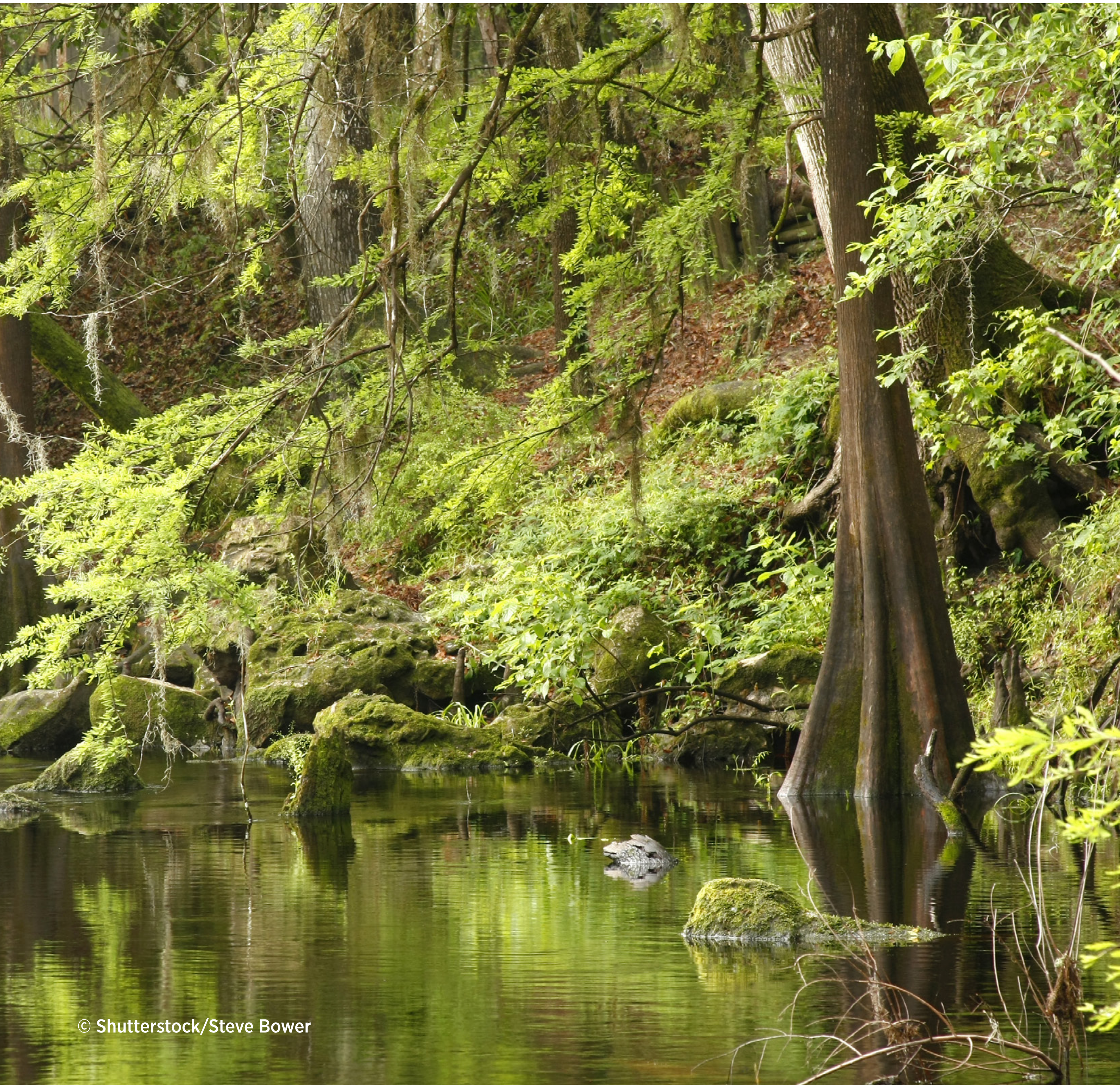
Acknowledgements Radha Pyati, Heather McCarthy, Gretchen Bielmyer, Stuart Chalk, Daniel McCarthy, Gerry Pinto, Lucinda Sonnenberg, Patrick Welsh



Location and general characteristics

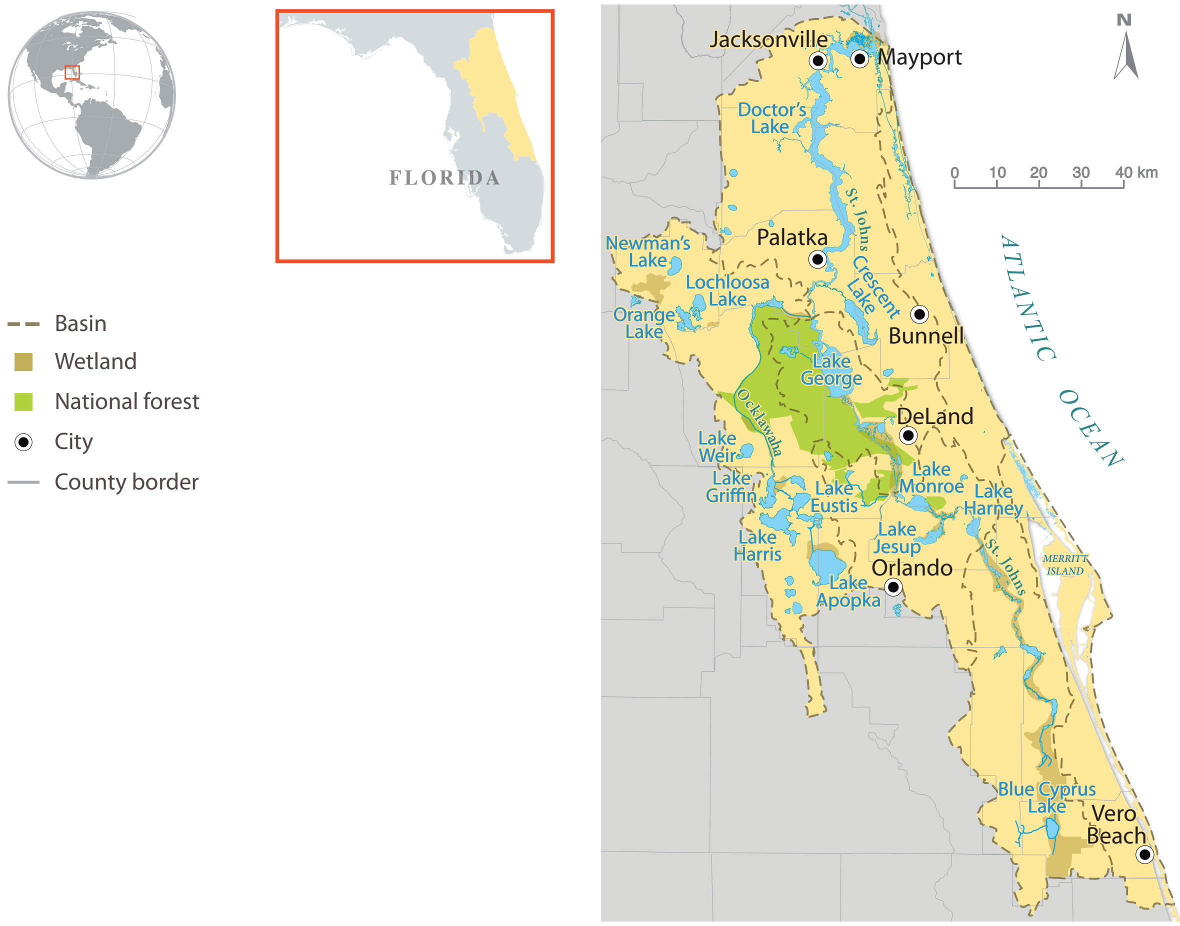
The St Johns River basin lies in central and northern Florida – the most south-easterly state in the United States of America. The river, which is composed of upper, middle and lower sub-basins, rises in Indian River County in Central Florida and flows into the Atlantic Ocean at Mayport, Jacksonville (Map 49.1). The St Johns is one of very few rivers in the USA that runs from south to north. The major tributaries that feed into it are the Ocklawaha River, Dunns Creek, Black Creek, the Wekiva River and the Econlockhatchee River. Over its 500 km long journey, the river flows very slowly as the total drop (the difference in altitude between the source and point of flow into the ocean) is merely 10 metres. Jacksonville, the largest city in the basin, has a population of about 800,000 (2009). Moreover, some sections of the Orlando metropolitan area also lie in the basin. With a drainage area covering 32,000 km^2 or about 25% of Florida, the St Johns River basin is home to approximately 4.7 million inhabitants (St Johns River Water Management District, 2011*a*).

Water resources and their use

St Johns River lies within a humid subtropical zone and rainfall typically occurs in late summer and early autumn. The average annual precipitation in the basin is approximately 132 cm per year and the average annual discharge at the mouth of the river is around 7.5 billion m^3. The Floridan aquifer is an important groundwater source that extends over an area of 259,000 km^2, which includes all of Florida and parts of Georgia, Alabama, Mississippi and South Carolina. Nearly all the drinking water for central and northern Florida, including the St Johns River basin, comes from this aquifer (Marella and Berndt, 2005). The population of the basin is growing rapidly – between 1950 and 2000, the number of inhabitants in Florida increased six fold. The amount of water withdrawal from this aquifer has also steadily increased, and

MAP 49.1

St Johns River basin



reached approximately 5.5 billion m^3 per year in 2000. Nearly 78% of this water was withdrawn in Florida. While a study by the US Geological Survey is currently underway to determine how sustainable current rates of water withdrawal are, the St Johns River Water Management District estimates that the level of abstraction of groundwater is about to reach the limit of sustainable use (District, 2005). The matter of quantity is further complicated by the fact that water quality is threatened by saltwater intrusion and the introduction of contaminants to the aquifer.

The various categories of water uses are listed in Table 49.1. According to projections, by 2030, agricultural consumption will decrease by 12%, whereas municipal consumption (that is, the demand for the public water supply) may increase by as much as 10% (St Johns River Water Management District, 2005.)

In terms of importance, agriculture is second only to tourism in Florida's economy. Important agricultural activities include growing oranges and other citrus fruit as well as cattle ranching for both beef and dairy products. Florida possesses 68.1% of the market share of orange production in the USA. These activities are all typical of the St Johns River basin.

Climate change and climatic variability

Precipitation patterns in Florida are dependent on larger-scale climatic anomalies such as El Niño and the Atlantic Multidecadal Oscillation. Climate change could amplify the effects of these anomalies and make rainfall patterns even more unpredictable. However, in the southern parts of the state, the effects are expected to be a decrease in rainfall during both the dry and the wet seasons, a loss in dry season refugia[1] and saltwater intrusion. Sea level rise, a phenomenon associated with the melting of polar ice caps as a result of global warming, poses a significant threat to the St Johns River basin because of its low-lying nature. According to estimates, sea levels in Florida may rise by as much as 35 centimetres by 2080. The general consequences of this include the inundation of low-lying areas and salt-water intrusion into aquifers and estuaries. Preliminary results of modelling studies being conducted near the mouth of the St Johns River indicated that areas of open water and estuary channels may already be elevated and the marshes near the river mouth are likely to be inundated more frequently. However, only a small area of the marsh would actually change from being 'regularly submerged' to 'fully submerged'.

TABLE 49.1

Annual water use by category in the St Johns River basin, 2010

Category	Freshwater (million m^3)	Saline water (million m^3)	Water reuse (million m^3)	Total water use (million m^3)	%
Public supply	742.29	0.00	0.00	742.29	40.26
Domestic self-supply and small public supply systems	93.62	0.00	0.00	93.62	5.08
Commercial/industrial/ institutional self-supply	134.52	3.84	31.32	169.68	9.20
Agricultural irrigation self-supply	570.95	0.00	10.57	581.52	31.54
Recreational self-supply	88.03	0.00	157.48	245.51	13.32
Thermoelectric power generation self-supply	11.18	0.00	0.00	11.18	0.61
Total	**1,640.59**	**3.84**	**199.37**	**1,843.80**	**100.00**

Note: Source of domestic self-supply is assumed to be groundwater and domestic self supply is an estimate. Estimated amounts are based on best available data at the time of publication.
Source: St Johns River Water Management District (2011a).

Droughts, floods and hurricanes are the natural disasters that cause socio-economic losses in the State of Florida. The 2004 and 2005 hurricane seasons were especially notable for the frequency of major storms and the extent of hurricane damage. The 2004 season included four major storms that caused the highest cumulative single-year damage costs in Florida's history (Malmstad et al., 2009)[2].

Droughts and floods also have a significant impact on the St Johns River basin. Tropical storm Fay deposited over 40 cm of rain in a five-day period in Brevard County in 2008. The water level rose by approximately two metres in Seminole County in four days, setting a record. Overall, the storm led to severe flooding in the middle section of the basin and caused damage of an estimated half a billion dollars over three neighbouring states, Florida, Georgia and Alabama (Stewart and Beven, 2009). In spite of uncertainty in predicting the impact of climate change on meteorological extremes, there is a possibility that these events will become both more frequent and more severe.

Environment and ecosystems

The St Johns is a blackwater river. Dissolved organic matter from decaying plants in swamps dissipates across the basin reducing the depth of light penetration and giving the river its dark colour. Other issues that affect water quality and environmental conditions in the basin are slow flow, salinity fluctuation, marshland destruction and human-induced pollution (St Johns River Water Management District, 2011*b*).

The river's extremely low gradient slows the flow, holds back drainage, decelerates the flushing of pollutants and intensifies flooding and pooling of water along its length. This creates numerous lakes and extensive wetlands throughout the St Johns River basin. The retention time of the water (and its dissolved and suspended components) in the river is around three to four months. The high retention times of pollutants have severe impacts on water quality.

A number of salty springs feed into the basin and cause localized areas of elevated salinity (>5 ppt) in otherwise freshwater sections of the river. Reverse flows triggered by weather conditions and massive ocean tides cause the river to flow in an upstream direction. And this too results in abrupt changes in salinity. Reverse flows have been detected as far as 257 km upstream. Such variations in salinity have profound hydrological and ecological effects.

Wetlands are vital to the Northeast Florida ecosystem. However, in the Upper St Johns River basin, the marshes have been drained to grow citrus fruit and for animal husbandry. Trends in wetland coverage cannot be accurately established because of insufficient and inconsistent information. On the other hand, since 1988, the St Johns River Water Management District and the U.S. Army Corps of Engineers have restored and enhanced more than 600 km^2 of marshes in Indian River and Brevard counties (St Johns River Water Management District, 2011*b*). However, because of habitat loss, increased boating traffic and drought, some species such as the Florida manatee, the wood stork, the shortnose sturgeon, the piping plover, the Florida scrub jay and the eastern indigo snake continue to be vulnerable and face extinction.

Every year, more than 14,000 tonnes of nitrogen and phosphorus enter the St Johns River – mainly as a result of the disposal of partially treated sewage (St Johns River Water Management District, 2011*c*). Other significant pollution sources include farms in the agricultural areas of Flagler, Putnam and St Johns counties. Agricultural runoff from farming areas carries animal waste, fertilizers and pesticides into the river. Storm water from urban areas also takes pollutants such as lawn fertilizers, sediments, pesticides and trash into the river. Consequently, nutrient levels in the river's main stem and faecal coliform levels in the tributaries exceed limits set by water quality standards. In addition, because of the river's slow flow, the lower St. Johns River in particular is facing pollution problems. These include the growth of algal blooms which block sunlight from reaching underwater vegetation, produce toxins, deplete dissolved oxygen and endanger fish and other wildlife. Efforts are ongoing to reduce nutrient loading by setting a total maximum daily load (TMDL), by drawing up a Basin Management Action Plan, through collaboration between government and industry and public education.

Water resources management

Federal laws on water resources include the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). The CWA, which was passed in 1972 and amended in 1977 and 1978, shifted the focus of pollution control from being solely oriented towards water-quality standards to looking at ways of limiting effluent from point sources. Following the CWA, the SDWA was passed in 1974 and amended in 1986. With it came the establishment of monitoring and water-quality standards for all public water supply systems. In the State of Florida, the Florida Department of Environmental Protection (FDEP) and other entities implement these efforts.

In 1972, the Florida Legislature passed the Florida Water Resources Act, which established five water management districts in the state, supervised by the FDEP. Each district was tasked with managing water resources in its basin, granting permits for water use, developing and implementing flood control and drought planning projects, performing technical and scientific evaluations of water resources in the basin and acquiring land to protect water resources and habitats. The St Johns River Water Management District is one of these five districts.

Unfortunately, in the years since it was passed, the FWRA has not been able to assure water availability or quality. This is because many exceptions have been made to the laws – mostly in order to enable population growth and land development in Florida – which have significantly weakened the impact of the Act. The 1972 CWA had more direct impact on water quality issues but some of its provisions, particularly on TMDLs were not actively enforced by the U.S. Environmental Protection Agency (EPA) until citizen lawsuits in the late 1990s forced the agency to start collecting information from states on water resources that did not meet quality standards.

Florida's enforcement of TMDLs effectively began in 1999 with the passage of the Watershed Restoration Act. Following that law, all the water bodies in the state were organized into basins, which were further collected into groups. The basins were assessed in a five-year cycle to address their TMDLs. Basically, the TMDL programme establishes total amounts for a number of pollutants (both point sources and non-point sources). These total amounts are the maximum levels that can be absorbed by a specific water body without breaching the water quality standards set to protect human health and aquatic life. Once a TMDL is drafted and approved (which includes a time period for public comments and discussion), it is implemented through a Basin Management Action Plan, which prescribes strategies such as wastewater treatment improvements, redirecting wastewater discharge toward reuse, prescribing best-management practices in agricultural, urban, and rural settings, and facilitating environmental education. Nutrient TMDLs have been successfully established for the lower, middle and upper basins. In addition, Basin Management Action Plan have been developed for a large number of water bodies and pollutants, including several within all stretches of the river and its tributaries. However, the lower St Johns River basin is the only section of the river with a nutrient Basin Management Action Plan which it adopted in 2008.

Conclusions

Despite high levels of rainfall, water supply has become a contentious issue in Florida. The growing population and ever greater demands for water are putting increasing pressure on water resources, notably on the Floridan aquifer system that provides drinking water for five states. The river's slow flow and continuous disposal of partially treated wastewater mean that both phosphorus and nitrogen levels generally exceed EPA recommended standards in both the main stem of the St Johns River and its tributaries. Dissolved oxygen concentrations also fall below the site-specific minimum standard in several tributaries. Consequently, water quality in both surface and groundwater is becoming a major concern. Although institutions are in place both federally and at state level, a lack of enforcement of the legislation up to the 1990s has caused basin-wide degradation. While restoration and prevention activities by state and local governments in the St Johns River basin are ongoing, there is a clear need to compound these efforts by involving other governmental agencies, organizations and the public.

Notes

1 Refugia are the water-holding areas that offer refuge to a variety of species during a dry season.

2 Hurricanes Charley, Frances, Ivan and Jeanne caused a combined damage of US$49 billion in Florida.

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CHAPTER 50
Costa Rica

Acknowledgements José Miguel Zeledón, Juan Carlos Fallas, Carlos Romero, Carlos Vargas, Sadí Laporte, María Elena Rodríguez, Fabio Herrera, Andrei Bourrouet, Federico Gómez-Delgado

Location and general characteristics

Costa Rica is located in the narrowest part of Central America, bordered by Nicaragua to the north and Panama to the south. To the east, it forms a coastline with the Caribbean Sea and to the west, with the Pacific Ocean (Map 50.1). The surface area of the country is around 50,000 km^2.

Costa Rica's population in 2010 was slightly over 4.6 million – about 59% of whom live in urban areas. The capital, San José, is the largest city in the country, with a population of 1.6 million. There are seven provinces – Alajuela, Cartago, Guanacaste, Heredia, Limón, Puntarenas and San José (FAO–Aquastat, n.d.). The provinces are divided into six regions for planning purposes – Chorotega, Huetar Atlantic, Huetar North, Central Pacific, Central and Brunca.

There are many volcanoes in the country, some of which are still active. The Poás (2,708 m above sea level), located in the Central Highlands, is one of Costa Rica's largest and most active volcanoes (Arenal.net, n.d.).

The country lies in a humid tropical zone. While the amount of rainfall varies from one basin to another, Costa Rica has annual average rainfall of 3,300 mm (UNESCO IHP, 2007). In general, the north of the country on the Pacific side is drier than the Caribbean region, which is humid almost all year round. The rainy season extends from May to November on the Pacific side, and from May to February on the Caribbean side. Forests cover approximately 25,000 km^2, or approximately half the country's land surface.

Water resources availability and their use

There are 34 river basins in Costa Rica, ranging in size from 200 km^2 to 5,000 km^2 (FAO–Aquastat, n.d.). Unfortunately, reliable information is available for only 15 of those basins. The country has total renewable water resources of slightly more than 110 billion m^3 (MINAET, 2008*a*). Of this, surface water accounts for 73 billion m^3.

Research initiatives begun in the 1960s helped to identify 58 aquifers across the country, 34 of which are coastal. As a result of seasonal shortages in the availability of surface water and growing pollution, the exploitation of groundwater has become more common. According to estimates, annual water demand is approximately 23.5 billion m^3 (2010), almost 88% of which is met by aquifers. Consequently, the

MAP 50.1

Costa Rica

sustainable exploitation of groundwater resources is of great importance.

The Central region has the biggest demand for water in the country because more than half the population lives here and there is a high concentration of industrial and economic activity (Mora Valverde, n.d.). Nationwide, generating hydroelectricity accounts for 80% of total water demand, followed by agriculture at 16%. The remaining 4% is used for drinking water, and by industry and tourism. Given that the water used for hydropower generation returns to the flow without loss, agriculture remains the largest user (3.2 billion m^3) in terms of actual consumption. In 2008, agricultural activities were practised over approximately 4,190 km^2 of land (8% of national territory), 920 km^2 of which were irrigated. Some 70% of the irrigated land is developed by the private sector, and the most important agricultural products grown are coffee, rice, African palm, sugar cane, banana and pineapple (SEPSA, 2009).

The sectors that contribute most to economic growth are industry at 32.5% and agriculture at 14% (MINAET/IMN, 2009). Unfortunately, 80% of water contamination originates in these two sectors. Urban settlements are also a big source of pollution because only around 3% of wastewater is treated prior to being disposed of into nature (FAO–Aquastat, n.d.).

According to various scenarios, water demand may substantially increase by 2030 to reach approximately 109 billion m^3, the upper limit of freshwater availability in the country. However, the energy sector will continue, by a large margin, to be the major (non-consumer) water user, processing 100 billion m^3 in hydroelectricity generation. Consequently, the main challenge will not be water scarcity but to plan for water use in an integrated fashion to be able to satisfy the demand of all sectors.

Natural disasters, national strategies and climate change

Central America and the Caribbean region are highly vulnerable to extremes of climate. Of 248 hydrometeorological disasters between 1930 and 2008, some 85% were floods, tropical storms, landslides or mudslides, while 9% were droughts.

Because of the steep slopes of the mountainous terrain, rivers run fast in the central part of Costa Rica, and are known to cause violent floods. Urban development, deforestation, and channel modification, especially in the Caribbean slope and the South Pacific, have worsened these conditions, causing floods to affect ever larger human settlements, agricultural areas, infrastructure, and nature reserves. Consequently, between 1994 and 2003, approximately 120,000 people and 17,000 housing units were reported to have been affected by floods, landslides, and windstorms. As recently as 2010, heavy rain and mudslides affected over 2,000 km of national roads, and caused US$242 million worth of damage. The same year, over 3,000 houses were damaged, at an estimated cost of US$50 million. The loss to agriculture was in the vicinity of US$40 million. To a lesser extent, the country is also prone to drought. In fact, recurring droughts in 1997 and 1998 and again in 2001 caused a combined economic loss of US$18 million.

Risk management in Costa Rica has gone through a process of institutionalization. The 1969 Emergencies Act led to the establishment of the National Commission for Risk Prevention and Emergency Response (ComisiónNacional de Prevención de Riesgos y Atención de Emergencias) and the National Emergency Funds. Later amendments to the law required the integration of risk management into the planning activities of all national institutions as well as into all national development policies.

Costa Rica is understandably concerned with the likely effects of climate change. Current climatic models indicate the possibility that, by 2100, temperatures may have increased as much as 3.8°C, precipitation may have decreased by up to 60%, and the sea level may have risen by as much as one metre (World Bank, 2009). Under a business-as-usual scenario (that is, no reduction in carbon emissions), by 2100, the cumulative cost of climate change in Central American countries is estimated to reach approximately US$52 billion (2002 US$ reference). In Costa Rica alone, additional investment of as much as US$3.4 billion may be required for the adaptation of sectors relying on water and biodiversity for the provision of their services. Given that heavy financial burden, and the potentially severe implications of climatic extremes, a National Strategy on Climate Change has been established and is being overseen by the Ministry of Environment, Energy and Telecommunication (MINAET). This strategy aims to improve overall efficiency in all sectors, with the goal of reducing greenhouse gases. The strategy document also estimates that the largest amount of investment (71%) needs to be made in the energy sector, followed by agriculture (21%), to compensate for the effects of climate change (Box 50.1). These two sectors have traditionally been financed through external funds. The most important source of internal funding for climate change adaptation is the National Fund for Forest Financing (Fondo Nacional de Financiamiento Forestal), established by the Forestry Law and linked to payment for ecosystem services. In line with the 'Peace with Nature' initiative, promoted by President Oscar Arias Sánchez, Costa Rica has pledged to become a carbon neutral country by 2021.

Water resources management: National strategy and water policy

Costa Rica's national strategy has the overarching aims of boosting economic development and increasing human welfare, in harmony with the environment (MINAET, 2008*b*). Integrated water resources management (IWRM) is central to this strategy. As a result, the State has established a number of guiding principles for water policy that identify water as a public good, and access to drinking water as a human right under the constitution. Other important issues identified by the strategy document include the equitable use of water resources, the improvement of water infrastructure and the application of technology to improve the efficiency of water use and curb water pollution. It also highlights the importance of the economic valuation of water, the promotion of integrated, decentralized, and participatory basin management programmes, and the protection of water resources for human well-being and the protection of ecosystems.

The National Water Policy seeks to harmonize the priorities of economic growth, poverty reduction and nature conservation through IWRM, the aim being to ensure that both water quantity and quality meet the demands of sustainable national growth (MINAET, 2009). In terms of national water security, the policy has six strategic priorities: increasing the competitiveness of domestic industry, promoting holistic water management, ensuring the sustainable use of water resources, creating a water culture, mitigating the effects of climate change, and involving public participation in decision-making processes.

There are a number of institutions involved in implementing and overseeing the National Water Policy. MINAET is the lead agency responsible for implementing the 1942 Water Law. The Water Board (Dirección de Agua) and the National Register of Concessions are other national bodies that support MINAET's efforts through promoting the rational use of water resources and centralizing inquiries for water abstraction. The National Service of Groundwater, Irrigation and Drainage (Servicio Nacional de Aguas Subterráneas, Riego y Avenamiento) is a public agency that promotes sustainable agricultural development through efficient management and the use of surface water and groundwater. The Costa Rican Water and Sewer Institute (Instituto Costarricense de Acueductos y Alcantarillados) provides drinking water and sanitation services in both urban and rural settlements. The Institute also aims to conserve river basins and to reduce water pollution. The Costa Rican Institute of Electricity (Instituto Costarricense de Electricidad) is the main operator providing electricity and telecommunications services.

In terms of a legal framework, the Water Law, which has been relied on to regulate all aspects of water use is outdated. The reality is that in a time of increasing demand for water and growing competition among different sectors for the resource, it no longer provides sufficient means to manage and protect the country's water resources. In recognition of this, MINAET is drafting a water bill to modernize the current water management policy.

Poverty, access to water supply and sanitation services

According to the 2010 National Household Survey (INEC, 2010) approximately 21% of Costa Rica's population lives in poverty, while 6% face extreme poverty every day. The incidence of poverty in rural areas is significantly higher at 26.3% than in urban areas at 18.3%. There is a marked difference also in terms of gender equality, with the number of men in work significantly higher than the number of women (71.4% and 39.4%, respectively). This illustrates the greater difficulty that women face in the labour market and in gaining access to employment.

In general, 99% of the population has access to safe drinking water (2009), almost all of which is piped to their premises. In rural areas, the rate of access is 92%. Access to improved sanitation is equally high at 95%. However, only 40% of the urban population and 4% of rural dwellers are served by the sanitation infrastructure (WHO/UNICEF, 2010).

Protection of Environment and Biodiversity

Costa Rica, in spite of its small size, accounts for approximately 6% of the world's biodiversity. That is because of its geographical location and its varying landscape, which ranges from islands and beaches to rainforests (Embassy of Costa Rica, n.d.). Since the middle of the last century, Costa Rica has developed an extensive network of protected areas, totalling approximately 26% of its land surface. Cocos Island and La Amistad, for example, are two renowned national parks which have received international recognition as UNESCO World Heritage Sites.

Costa Rica, as a signatory to 45 international environmental treaties, has also enacted a number of regulatory instruments such as the Organic Law, drawn up by the Ministry of Environment and Energy (1993), the Environment Law (1995), and the Forestry Law (1996). The Biodiversity Act (1998) deals specifically with the protection of biodiversity and endangered species. The National System of Conservation Areas, which operates within the MINAET, is responsible for promoting the conservation of biodiversity and the sustainable use of forests, mangroves, wetlands, and forest plantations (Embassy of Costa Rica, n.d.). In addition, the National Biodiversity Institute was established in 1989 as a private, not-for-profit, organization to carry out monitoring and research. Its key aims are the establishment of a biodiversity inventory, the promotion of conservation activities, and the provision of data which inform decision-making in relation to the protection and sustainable use of biodiversity.

Costa Rica has pioneered the use of 'payment for environmental services', by establishing a countrywide mechanism –locally known as Pago de Servicios Ambientales – to charge users for the environmental services they receive. In spite of initial difficulties caused by the reluctance of service users to pay for conservation, the programme is now well established within Costa Rica and widely perceived as successful (Pagiola, 2006).

In line with the Peace with Nature initiative, which aims to make Costa Rica carbon neutral by 2021, 93.6% of electricity is generated using renewable sources of energy, notably hydropower. Similarly, the 2007–2021 strategic plan developed by the Costa Rican Institute of Electricity (Instituto Costarricense de Electricidad) foresees further development of hydropower through the construction of dams with the minimum possible environmental impact, and the use of alternative sources of power such as wave, wind and geothermal energy. This plan will require an investment of US$1.4 billion (2005 US$ reference).

However, the other side of the coin is that population growth, the expansion of urban settlements, industrial development and the intensification of agricultural

BOX 50.1

Potential implications of climate change on agriculture

In 2008, approximately 20% of cultivated land in Costa Rica was irrigated. A vulnerability study has been conducted in the three most important river basins, the Reventazón, the Grande de Terraba and the Grande de Tárcoles, using climate scenarios in which temperatures increase by 1°C to 2°C, with changes in precipitation of ±15% on the Pacific side and ±10% on the Atlantic side. Results predict that marked variations in water flow will occur in these areas, which will affect agriculture especially during the transition between the dry season and the rainy season.

There is also expected to be an increase in floods, which will have a direct impact on irrigation systems and lead to more soil erosion. At the same time, there will be an increase in the frequency of droughts in some parts of the country, leading to less water for irrigation.

According to an analysis of the vulnerability of water resources to climate change, the country's most vulnerable regions are those where most land is used for agriculture, or areas where there is conflicting land use. In 2009, Costa Rica's Second National Communication to the United Nations Framework Convention on Climate Change examined several adaptation measures concerning water resources. These included the following: water storage facilities, the protection of aquifers, the monitoring of water resources, water rationing and projects aimed at increasing water efficiency in irrigation.

Source: Modified from the World Bank (2009).

activities, including livestock production, have all led to an increase in the amount of contaminants. These range from industrial, agricultural, and solid waste, to agro-chemicals and sewage, and they are being discharged into Costa Rica's water bodies. Nationwide, only 3.6% of sewage is treated. Consequently, many streams, rivers, and aquifers are polluted to varying degrees.

An example of this complex and growing problem is the Tárcoles River basin, which is home to 51% of the population and 85% of the country's industries. Severe pollution in the major rivers of this basin and in some tributaries of the Virilla River (such as the María Aguilar, the Torres and the Tiribí rivers) has considerably limited water availability in the most economically developed region of the country. While this is an impediment to sustainable development, it also raises serious health and environmental concerns (GWP, 2011).

Conclusions

Costa Rica, with average annual water availability of 24,000 m^3 per capita, is well endowed in terms of water resources. While rainfall is abundant, seasonal shortages in surface water have prompted the widespread exploitation of aquifers. However, greater use of water in all sectors, combined with increasing population density, has led to the contamination of rivers and some aquifers, such as those in the Central Valley, where more than half the population lives.

On the positive side, Costa Rica is the first country in the world which has pledged to become carbon neutral by 2021. This aspiration goes hand in hand with the efforts to protect the country's rich biodiversity and environment. Almost 94% of electricity production already comes from renewable resources, and the government aims to promote further diversification into renewable forms of energy such as wave, wind and solar power, in addition to hydroelectricity.

Costa Rica is also a pioneer in Latin America in terms of the implementation of Payment for Ecosystem Services, which, in turn, generates national funds for climate change adaptation. The major challenges are to update the obsolete Water Law, improve legislation and mechanisms that deal with extreme events, and reduce poverty. Enhancing hydrometeorological information by extending research and monitoring activities to all the river basins, ensuring the sustainable use of groundwater resources, extending sanitation coverage, and curbing pollution, are some of the issues that now require further attention at national level.

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CHAPTER 51

Lerma–Chapala basin, Mexico

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Location and general characteristics

The Lerma River is the longest inland watercourse in the United Mexican States (Mexico from here on). It rises at about 3,800 m above sea level in western central Mexico. After covering a distance of 750 km, the Lerma flows into Lake Chapala (1,510 m above sea level), which is the largest natural lake in Mexico. The entire Lerma–Chapala basin is located in a high altitude area with mountain chains and extensive valleys. It covers a total area of 54,451 km^2 and includes portions of five States: Mexico, Queretaro, Michoacán, Guanajuato and Jalisco.

Overall, the climate in the basin is warm. However, it ranges from semi-hot and humid in the central and southern areas, to dry and temperate in the northern areas. The winters are relatively cold, and the summers are semi-humid. Depending on the location, rainfall varies from around 270 mm to more than 1,000 mm per year, with 825 mm being the average. Most rainfall occurs in the high plateaus and peaks between April and early October, with the second half of the season (from mid-June until mid-October) usually bringing the heaviest rainfall.

The Lerma–Chapala basin is home to approximately 10 million people. In 2005, population density in the basin was roughly four times the national average. In terms of productivity, the basin generated 11.5% of Mexico's gross domestic product (GDP) in 2009. Industry represents almost 25% of the basin's contribution to the national economy. The automobile industry is particularly advanced, with 50% of the country's automobile production located here. Economic activity is concentrated in specific cities such as Leon, Silao, Toluca, Queretaro, Morelia, Irapuato, Salamanca and Celaya. As a result, more than 50% of the basin's total value-added production takes place in just seven of its 127 municipalities.

Water resources availability and their use

Compared to other river basins in Mexico, the Lerma–Chapala basin is not rich in terms of water resources. The Lerma River has average annual water potential of 4.9 billion m^3. During the dry season, which extends from early November until mid-May, it becomes a shallow river with a modest flow. Lake Chapala itself is a shallow tropical lake, with mean depths of 7.2 m, and never deeper than 18 m along its 1150 km^2 influence area. The lake is the most important water source for the Guadalajara Metropolitan Area, providing almost 75% of its water supply. Its water level drops rapidly in response to over-use of water, and recharges rapidly in the rainy season.

There are 40 aquifers in the basin, with a combined annual renewable capacity of 4.1 billion m^3. Groundwater is a crucial resource in the basin and is used heavily. In 2004, for example, 79.3% of all water rights in the Lerma–Chapala basin were granted in

MAP 51.1

Lerma–Chapala basin

relation to groundwater resources. Because of this substantial use of aquifers, overdrafting has been a concern since the early 1970s. Today, about 70% of aquifers in the basin, most notably in Guanajuato, are being pushed beyond their sustainable limits. In fact, since the 1980s, water demand has commonly exceeded availability almost every year. Overall, total annual abstraction exceeds recharge by approximately 1.3 billion m^3 (2011). When this is combined with water-quality degradation and immigration, it is clear that the current water availability per person, which stood at 932 m^3 in 2010, is likely to worsen.

The basin boasts the highest rate of agricultural land use in Mexico, thanks to a combination of fertile soil and favourable climatic conditions. In 2000, approximately 30,000 km^2 of land (56% of the basin) was allocated to agriculture. Rainfed agriculture is most common, practised over 41% of the basin, while the rest of the cultivated land (15%) is irrigated. Maize and sorghum are the main crops and are planted on 65% of the agricultural land. Water demand from this sector accounts for roughly 80% of all water abstraction, whereas the sector's contribution to GDP is around 5%. By comparison, water demand from industry accounts for less than 4% of overall water use, while the sector generates around 23% of the basin's GDP (2009).

To improve water efficiency in all sectors, water tariffs have been increased to reflect more accurately the real cost of service provision and maintenance. Between 1989 and 1994, the price of irrigation water increased ten-fold. In addition subsidies were offered favouring farm investments that led to more efficient water use. Unfortunately, public interest is waning because the pay-out is seen as insufficient, and in some areas, tariffs are still well below real costs. Furthermore, because the water revenue goes straight to the Mexican Federal Treasury, and regions do not benefit directly, people's willingness to pay remains limited. Consequently, there is an immediate need to define appropriate mechanisms for the redistribution of water revenue.

Climate change and water-related disasters

Since the early 1920s, there has been a gradual increase in the difference between mean summer temperatures and mean winter temperatures – or, in other words, warmer summers and colder winters. Such trends can be seen clearly between 1985 and 2010, when average temperatures rose by almost 2°C in spring and summer, and dropped by a similar average in winter.

Rainfall patterns also indicate a movement towards extremes: less precipitation during the dry season, with more violent storms; and greater surface run-off in the wet season. Overall, in the 40-year period up to 2010, annual rainfall and surface run-off has decreased by some 3.6%. Since the 1900s, analysis of long-term rainfall data indicates a series of alternating wet and dry periods, each lasting several years. Droughts occur in the basin almost every decade and may last up to five years or more. The most recent drought, which lasted for 10 years from 1993 until 2003, is a notable example. In 2002, the water level in Lake Chapala dropped to 14% of its capacity, the second-lowest level recorded since data collection began in 1934. The worst droughts usually occur in the northern sub-basins where the climate is drier.

Greater climatic variations have affected the opposite end of the spectrum too, leading to more frequent floods. Heavy rainfall (defined as 20% or more above the monthly or yearly average), of an intensity that leads to flooding disasters, typically returns every three to six years. The probability of floods is higher in the southern part of the basin; however, such events also affect the central and western portions of the basin, with considerable damage to urban settlements, industry and farmland.

Over 500 dams and reservoirs in the basin provide structural safeguards against water-related natural disasters. However, increasing vulnerability, specifically to floods, calls for the adoption of a basin-wide integrated strategic plan that combines both legislative and engineering measures.

Water and settlements: Health issues and poverty

The Lerma–Chapala basin is highly urbanized and an estimated 77% of the population is concentrated in its cities. In addition, the water resources of the basin are used not only by the 10 million inhabitants of the basin area itself, but also by an additional 5.5 million people living outside the basin in the metropolitan areas of Mexico City and Guadalajara. Total annual water demand is around 1.1 billion m^3. Of this, 73% is supplied from groundwater resources. The water tariff in the basin ranges from US$0.04 to US$0.12, the average being US$0.09. Tariff systems are designed to benefit the poor and marginalized groups, and, as a result, charges for low water consumption are relatively insignificant. Overall, collected fees cover only around 50% of operating costs.

Water-related diseases have been on the decline since the early 1930s. At the same time, the 1991 Clean Water Act required local water utilities to meet national water quality standards. Consequently, morbidity and mortality caused by water-related diseases are nowadays practically negligible. However, problems do persist in remote rural areas, which often also suffer from low incomes, low level of education, poor infrastructure, and water scarcity. Approximately 1.5 million basin inhabitants live below the national poverty line (2008), and the global financial crisis is expected to add to this problem. However, extreme poverty and famine are non-existent in the basin.

Environment, ecosystems and water quality

Mexico is very rich in terms of plant species, animals, and micro-organisms. The region in which the Lerma–Chapala basin is located fosters a wide diversity of flora and fauna thanks to the varying landscape, with its mountains, lakes, the extensive marshes of the Toluca Valley, and the Lerma River itself. Overall, there are over 7,000 species of flora and fauna in the Lerma–Chapala basin, including more than 800 species of mammals, birds, reptiles, amphibians and fish. The basin is particularly distinctive in its freshwater fish endemism, as 30 of the 42 species of fish found here are unique. In addition, according to the National Ecology Institute of Mexico, 988 plant species found here have value either from an economic or from an ecological point of view.

There are 12 protected areas, including the Monarch Butterfly Sanctuary in Michoacán, the Nevado de Toluca area in the State of Mexico, and the Sierra Gorda in Queretaro, listed as Common Heritage of Mankind. Unfortunately, changes in land use patterns stemming from urbanization, as well as agricultural and industrial development, have put increasing pressure on this environment and its ecosystems. For example, untreated effluent has caused serious local and regional pollution in the basin. By 1989, most of the rivers in the basin were polluted, and 90% of the reservoir of Chapala Lake was unsuitable for drinking or for breeding fish. Groundwater quality also changed dramatically, with several aquifers affected by contamination from urban settlements and industrial zones. Given this critical situation, the federal government and the five state governments in the river basin signed an agreement in 1989 with four main objectives: formulation of a new water allocation policy, treatment of raw municipal and industrial effluents to improve water quality, increased efficiency in the way water is used, and the protection and conservation of the water resources of the basin. In line with this agreement, the first phase of the Regional Water Treatment Plan was put into effect, with the aim of constructing 48 new treatment plants for municipal wastewater. In 1993, the second phase of the Plan was agreed by the Lerma–Chapala River Basin Council, with the aim of enlarging those treatment plants and allowing them to treat 10,835 l/s of effluent. Taking those two stages together, the aim was that about 80% of all municipal wastewater would be treated.

The first phase was started during the 1990s and continued during the first decade of the millennium. However, most of the programme has not been implemented yet. The second phase is facing financial difficulties. In general, the basin has the largest water treatment capacity in the region and since the 1990s, new treatment facilities and technical improvements have been introduced. While there is progress, and water quality has improved in the basin overall, the four objectives of the 1989 agreement have yet to be accomplished. This slow progress has been attributed to poor enforcement of laws, lack of political support, inadequate financing, the lack of a water culture based on the 'polluter pays' principle, and a lack of awareness in society about the importance of water.

Another environmental problem that affects 36% of the basin is soil degradation, including loss of fertility and erosion. The former is the more critical as it has an impact on 26% of the basin area – with serious consequences for agricultural production. Unfortunately, there are no large-scale soil conservation projects or capacity building programmes for farmers to address these problems.

Water resources management and legislation

In Mexico, water is the property of the nation and its management is the responsibility of the federal government. Article 27 of the Constitution sets out the main guidelines for water resources management and land resources management. A federal water law, derived from this article, was enacted during the 1960s. This was followed by the National Water Plan in 1975. In 1989, the National Water Commission (Comisión Nacional del Agua - CONAGUA) was established as the federal water authority responsible for overall planning, management and the development of national water resources. Its broad responsibilities included the allocation of water among its users, the collection of water tariffs, and the planning, construction, and operation of hydraulic works.

In 1992, the National Water Law was enacted to improve water management. One notable aspect was the establishment of a water rights system and the creation of a public registry enabling users to buy and sell water rights (Arreguín-Cortés et al., 2007). The National Water Law also provided the legal foundation for the creation of river basin councils (RBCs) as coordinating agencies. As of 2010, 26 RBCs were established. Being at the forefront of the national water resources development agenda, the first basin council in Lerma–Chapala was created as early as 1993, bringing water users from different sectors together. Today, its composition is much larger, with representatives of federal, state and municipal government, water user associations and social organizations (Box 51.1).

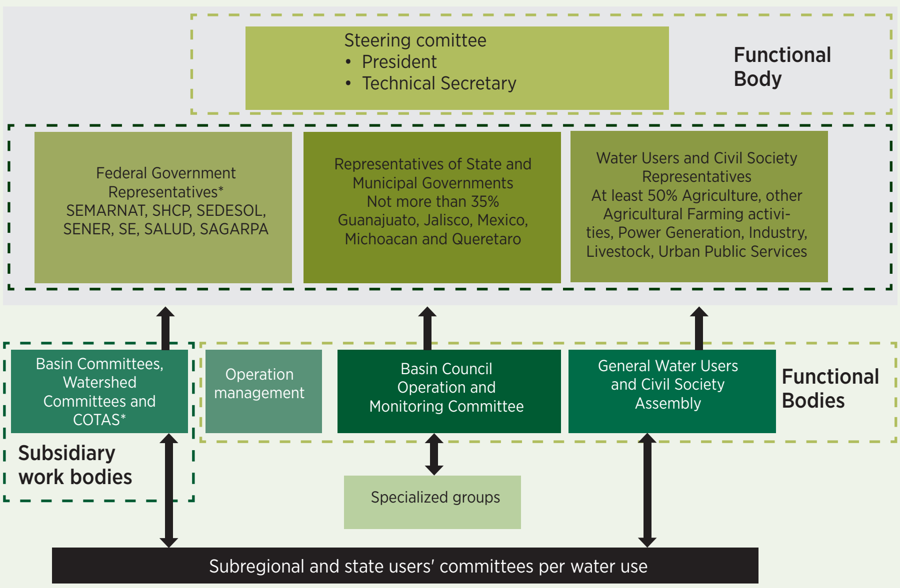
BOX 51.1

The Lerma–Chapala River Basin Council

River basin councils in Mexico derive their legitimacy from the National Water Law. They have the sustainable and integrated management and protection of water resources as their ultimate target. The Lerma–Chapala River Basin Council, one of 26 river basin councils in Mexico, coordinates action among government institutions and stakeholders. To accomplish this goal, it brings together government officials, water users and representatives of NGOs. By definition, the council is a consultative body that can propose programmes for implementation and specific actions to address challenges, and survey their performance. It is also entitled to intervene to conciliate problems between users and to recommend specific actions to CONAGUA, though it is not entitled to make decisions.

The Lerma–Chapala River Basin Council is neither a regulatory body nor a service provider. It is a forum within which stakeholders can meet one another, and meet government officials, to examine complaints, search for solutions, raise issues, and promote projects of varying scope. In summary, the council is a mechanism for identifying problems and dealing with competition and conflicts.

Lerma-Chapala River Basin Council Composition. 2008



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Ministry of Environment and Natural Resources (Secretaría de Medio Ambiente y Recursos Naturales – SEMARNAT)

Ministry of Finance and Public Credit (Secretaria de Hacienda y Crédito Público - SHCP)

Ministry of Social Development (Secretaria de Desarrollo Social - SEDESOL)

Ministry of Energy (Secretaría de Energía - SENER)

Ministry of Economy (Secretaria de Economía - SE)

Ministry of Health (Secretaria de Salud - SALUD)

Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación - SAGARPA)

Technical Groundwater Committee (Comité Técnico de Aguas Subterráneas – COTAS)

In 1994, CONAGUA became a part of the Environment, Natural Resources, and Fishing Secretariat, which had the aim of intensifying national efforts towards sustainable development. In 2000, this became the Ministry of Environment and Natural Resources (Tortajada, 2005). In 2004, the National Water Law was revised so that water rights, and their transmission from one user to another, could be identified and tracked more easily. The same revision introduced integrated water resources management (IWRM) with a conflict resolution dimension. The reform also allowed for the creation of river basin organizations (which are regional administrative branches of CONAGUA) and bolstered the role of river basin councils as autonomous consultative bodies. However, in spite of continuing efforts, a centralized (top-down) management approach still prevails. This calls for further emphasis on the promotion of IWRM.

Conclusions

The Lerma–Chapala basin has experienced strong demographic and economic growth, with a high increase in water demand. Unfortunately, that demand has now reached the point at which it has surpassed the current limit of renewable water resources availability. While increasing water efficiency in all sectors is desirable, reducing agricultural water consumption from its current level of 80% of all water abstracted is a necessity for sustainable development in the basin. Worsening pollution load has led to degradation of the environment and of water resources. Efforts to augment the capacity of wastewater treatment plants have helped to improve water quality and environmental conditions. However, the Regional Water Treatment Plan, which was initially introduced in the early 1990s, has yet to be implemented fully. Poor enforcement of laws, mainly stemming from lack of political support and inadequate financing, is an important dimension of continuing pollution. The revised National Water Law is an important milestone because it clearly introduces the integrated water resources management (IWRM) approach. On the other hand, central management of water resources continues to operate in parallel. For that reason, the ongoing process of strengthening the roles of river basin organizations and river basin councils constitutes a strategic priority both nationally and locally. At the basin level, successful implementation of IWRM is crucial because it is the first step to minimizing the negative effects of climatic variability, and stopping unsustainable levels of water use – allowing holistic and effective management of the basin's limited resources. Consequently, tough measures that regulate water resources demand and improve the efficiency of water use and reuse are essential, and are gradually and successfully being implemented.

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Except where otherwise noted, information in this concise summary is adapted from the 2011, *Lerma–Chapala Basin Case Study: A Fruitful Sustainable Water Management Experience*. Mexico City, CONAGUA (National Water Commission, Mexico) (forthcoming).

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WWDR4

The United Nations World Water Assessment Programme (WWAP) is hosted by UNESCO and brings together the work of 28 UN-Water members and partners in the triennial *World Water Development Report* (WWDR).

This flagship report is a comprehensive review that gives an overall picture of the world's freshwater resources. It analyses pressures from decisions that drive demand for water and affect its availability. It offers tools and response options to help leaders in government, the private sector and civil society address current and future challenges. It suggests ways in which institutions can be reformed and their behaviour modified, and explores possible sources of financing for the urgently needed investment in water.

The WWDR4 is a milestone within the WWDR series, reporting directly on regions and highlighting hotspots, and it has been mainstreamed for gender equality. It introduces a thematic approach – 'Managing Water under Uncertainty and Risk' – in the context of a world which is changing faster than ever in often unforeseeable ways, with increasing uncertainties and risks. It highlights that historical experience will no longer be sufficient to approximate the relationship between the quantities of available water and shifting future demands. Like the earlier editions, the WWDR4 also contains country-level case studies describing the progress made in meeting water-related objectives.

The WWDR4 also seeks to show that water has a central role in all aspects of economic development and social welfare, and that concerted action via a collective approach of the water-using sectors is needed to ensure water's many benefits are maximized and shared equitably and that water-related development goals are achieved.

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UN-Water is the United Nations (UN) inter-agency coordination mechanism for all freshwater related issues. It was formally established in 2003 building on a long history of collaboration in the UN family. It currently counts 29 UN Members and 25 other international Partners. UN-Water complements and adds value to existing UN initiatives by facilitating synergies and joint efforts among the implementing agencies. See www.unwater.org

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United Nations Educational, Scientific and Cultural Organization

World Water Assessment Programme

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