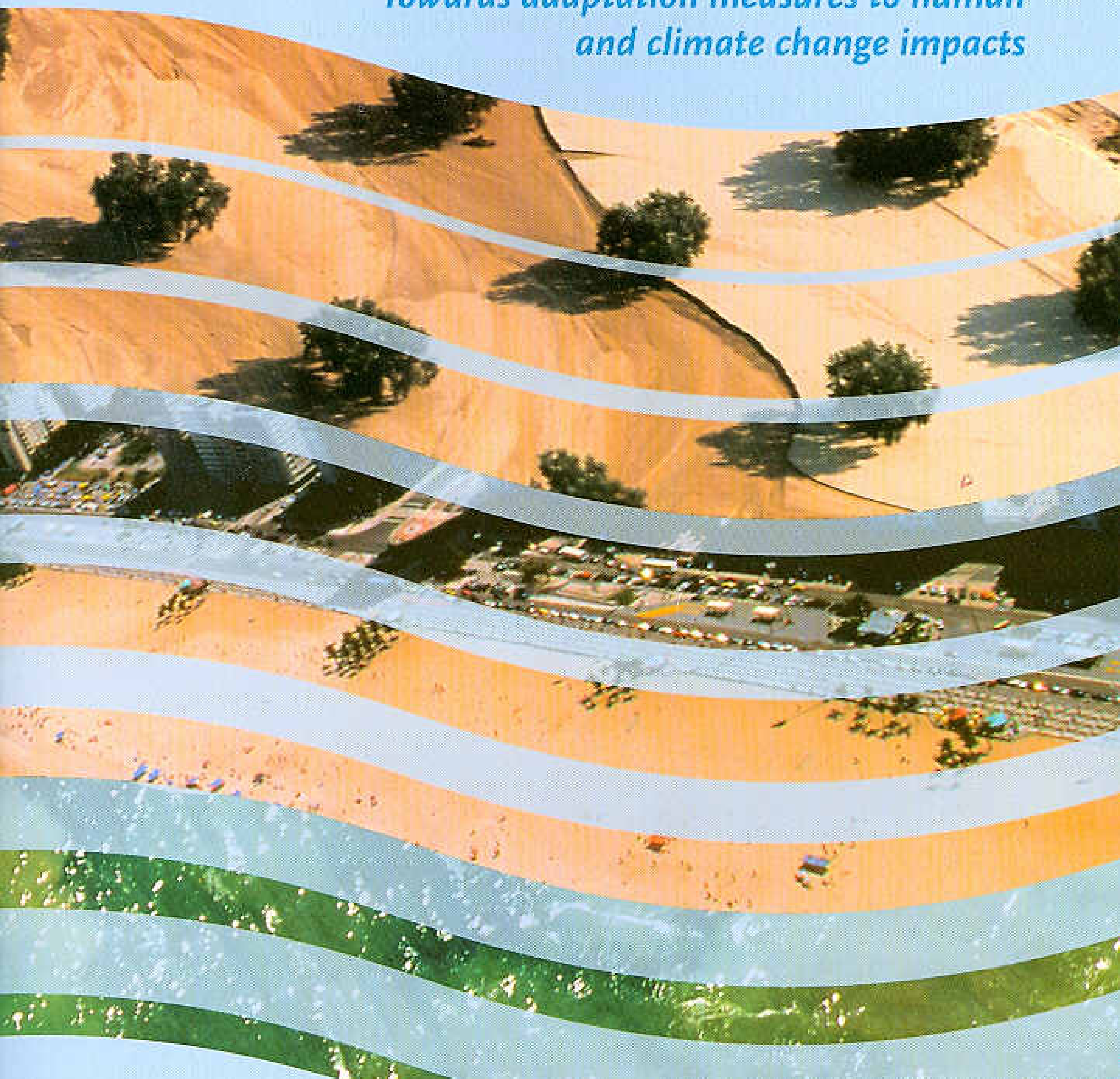
United Nations
Educational, Scientific and
Cultural Organization

Water Programme for Environmental Sustainability

2006–2009

Towards adaptation measures to human and climate change impacts



With the support of

Ministry for the Environment, Land and Sea of Italy

Global changes brought on by climate change, urbanization, ozone depletion, population growth, expansion of infrastructure, migration, land conversion, pollution are altering the Earth and the way it functions.

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***Yann Arthus-Bertrand*/La terre vue du ciel**

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Preface

UNESCO's intergovernmental scientific cooperative programme in hydrology and water resources is presently the only broadly-based science programme of the UN system in this area. It was established because both the international scientific community and governments, realizing that water resources are often the primary limiting factors for the peaceful development in many regions and countries of the world, saw the need for an internationally coordinated scientific programme focusing on water, namely the International Hydrological Programme (IHP) of UNESCO. It has had a prime role as a catalyst in promoting cooperation in water science and water resources management.

UNESCO's IHP also draws attention to the societal aspects of our water resources while also emphasizing the study of the occurrence and distribution of water within the natural environment. The addition of the social dimension underlines the need for improved, more efficient assessment and management of our water resources, which in turn requires a much more accurate knowledge of the hydrological cycle.

Without question, water is an indispensable element for the proper functioning of the biosphere. In fact, it is such an important part of the environment that it impacts heavily on socio-economic sectors. Human and economic developments are impossible without safe, stable water supplies. But water can also have destructive impacts and these too need to be understood. Competing water uses (too often misuses) have often resulted in unsustainable situations such as depleted supplies, falling water tables, shrinking lakes, reduced streamflows and quality degradation. This has led to situations in which the water available is unsuitable for many potential uses. These problems are primarily the results of human activities, and are occurring with increasing frequency and in a much more widespread manner.

In recent years, water issues have become central to the international political agenda. This development is driven by the widely-shared conviction that the coming decades may be characterized by increasing water shortages in many parts of the world. As a result of competing uses and misuses, there has been increasing concern in many parts of the world regarding the existence of major water stresses and looming water crises. In this respect, internationally shared water resources (about 50% of the world's freshwater) could become the source of competition or even conflict. Without question, water is an indispensable element to the proper functioning of the biosphere.

Unfortunately, in practice water resources have tended to be planned and managed in a very fragmented manner. Surface water and groundwater, for example, are too often considered separately in development activities, there being as yet an inadequate understanding of their common interdependence. These water sources are all too regularly planned and managed without consideration of other resources.

The need for proper planning and management of water resources calls for a process called integrated water resources and management (IWRM). There are numerous definitions of IWRM, often defined by individuals that are not experts in the field. But in general, IWRM can be said to address the complex issues and changes of the physical, chemical and biological behaviour of the entire hydrologic cycle, including their interrelationships with various other natural phenomena and human activities.

The Plan of IHP has been designed to guide programme activities and the development and testing of methods and procedures contributing to the solution of the identified water-related problems. IHP recognizes the need for a shift in thinking about water from fragmented compartments of scientific inquiry to a more holistic, integrated approach.

In response to these challenges, UNESCO and the Italian Ministry for Environment, Land and Sea (IMELS) have joined efforts to contribute to the achievement of the UN Millennium Development Goals. They have launched the 'Water Programme for Environmental Sustainability' (WPA II), which seeks to examine and develop the potential for sustainable management of water resources, to become a catalyst for protecting the fragile environment of water scarce regions, and to foster regional peace and development through dialogue, cooperation and participatory management. We wish to thank the Department for Environmental Research and Development of the IMELS for having proposed its support and its partnership.

Alice Aureli
Responsible for the Groundwater Resources activities
at the Secretariat of the International Hydrological Programme
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Foreword

Water and sanitation are inextricably linked to the eradication of poverty and to the achievement of sustainable development.

The 'Water Programme for Environmental Sustainability' provides additional resources to alleviate water scarcity and to identify adaptative measures to remediate human and climate impacts on groundwater resources.

Over the last thirty years, numerous major conferences and international agreements have provided the broad background for today's water resources policies and decision-making. In the last decade, many international conferences have discussed and agreed upon the steps required to speed up the implementation of Agenda 21.

Water for sustainable development was discussed at the intergovernmental level in the sixth session of the Commission on Sustainable Development in 1998, and a broad consensus was reached on key water issues. Further international water meetings (such as the 4th World Water Forum in Mexico City in 2006) served as important forums for multi-stakeholder dialogue and generated new recommendations on how to address mounting water challenges.

The United Nations Millennium Declaration and the preparatory process leading up to the World Summit on Sustainable Development further affirmed the role of water as a key to sustainable development and the urgent need for immediate action (Millennium Goal 7). Furthermore, the World Summit on Sustainable Development reaffirmed in 2002 that water and sanitation are inextricably linked to the eradication of poverty and to the achievement of sustainable development. Hence, the need to provide focus and impetus to action in the water sector, and to increase access to water and sanitation for the poor. For the world's underprivileged citizens, the right to safe water supply and adequate sanitation remains a promise unfulfilled. Millions of people still lack access to safe water supply and to basic sanitation and, as a result, every year many of them die from diseases associated with inadequate water supply, sanitation and hygiene.

Foreword

In addition to the role that improving access to domestic water and sanitation plays, water's role as a resource for agriculture, energy and industry is essential to fighting poverty and hunger. Energy services that allow for heating, cooking and illumination are not only a blessing to the activities of daily life, they are also critical inputs to agriculture and the types of small-scale productive activities that are a significant component of the rural economy in disrupted areas. Similarly, access to key factors of production, including water, is critical to the viability of activities that can act as a ladder out of poverty.

People in arid areas are uniquely vulnerable not only to drought and other natural disasters, but also to economic and social changes. Achieving sustainable development has particularly significant implications for reducing poverty and hunger. Limited and unreliable access to water is a determining factor in agricultural productivity in many regions, a problem rooted in rainfall variability that is likely to increase with climate change. Today, underperforming irrigation systems and poor water management practices worsen the water shortages that already exist in many countries, which are being increasingly exacerbated by climate variability and change in climate patterns. The latest report of the Intergovernmental Panel on Climate Change (IPCC) concludes that by 2020 between 75 million and 250 million people in Africa will be suffering from scarce freshwater supplies, with food security likely to be further compromised.

Meeting the water and sanitation targets of the Millennium Development Goals (MDGs) is necessary to make real progress against poverty and to avoid temporary or permanent environmental deterioration. Climate change will only exacerbate these problems, leading to wider potential impacts on ecosystems.

Attaining the MDG targets will take a combination of strong national action – guided by nationally prepared and owned strategies and action plans – complemented and supported by international action.

Governments have to recognize the importance of the MDGs as a national priority for the strategic planning of national development, keeping in mind that the bulk of the problem lies in mobilizing people at local and regional levels and involving them in the solutions to the problems. Yet international agencies and countries that share commitments to the MDGs, can clearly play a key supporting role in helping countries realize their own nationally-determined goals, strategies and action plans.

With this in mind, the Italian Ministry for the Environment, Land and Sea (IMELS), is combining forces with UNESCO-IHP to help pave the way towards the attainment of Goal 7 of the Millennium Declaration. In 2005–07, this successful partnership inspired the 'Water Programme for Africa, Arid and Water Scarce Zones'. IMELS and UNESCO are now launching the second phase of their collaboration.

The 'Water Programme for Environmental Sustainability' further advocates and mobilizes international support, providing additional resources to alleviate water scarcity and to identify adaptive measures to remediate human and climate impacts on groundwater resources.

In its support of this programme, the Italian Ministry is reaffirming its strong commitment to the promotion of international partnerships towards the achievement of global sustainable development, as has already begun in Central and Eastern Europe, the Mediterranean Region, China, Central and South America, and in the Pacific Islands.

Corrado Clini
Director-General
Department for Environmental Research and Development
Italian Ministry for the Environment, Land and Sea

UNESCO and the Italian Ministry for Environment, Land and Sea (IMELS) have joined efforts to contribute to the achievement of the UN Millennium Development Goals

UNESCO International Hydrological Programme (IHP)

The United Nations Educational, Scientific and Cultural Organization (UNESCO) established the International Hydrological Programme (IHP) in 1975. IHP is the only intergovernmental programme of the UN system devoted to the scientific study of the hydrological cycle and to formulating strategies and policies for the sustainable management of water resources. IHP was conceived as an evolving programme, ready to adapt to society's needs and transformations. It is implemented in six-year phases, in order to promptly identify emerging problems, alert decision-makers, raise public awareness, and provide the necessary resources to respond with appropriate actions. Considering that properly managing and protecting our planet's water resources are prerequisites of sustainable development, UNESCO has decided to give a high priority to IHP as a prominent UNESCO vehicle for meeting the UN Millennium Development Goals (MDGs).

Water education and the advancement, sharing, and application of scientific knowledge are the pillars of sustainable development. As a chief component of UNESCO and its mandate, education is a major objective for IHP. IHP Water Education and Training (WET) activities emphasize institutional capacity-building, research and information networking, especially at the university, postgraduate and continuing professional education levels, thereby reaching a wide community of water specialists and the general public. IHP has created a network of university chairs and regional and international training centres. These centres are a cornerstone of UNESCO's strategy to improve scientific understanding of the water cycle and water resources management.

They have launched the 'Water Programme for Environmental Sustainability' (WPA II), which seeks to examine and develop the potential for sustainable management of water resources, to become a catalyst for protecting the fragile environment of water scarce regions, and to foster regional peace and development through dialogue, cooperation, and participatory management

The partnership

Italian Ministry for the Environment and Land and Sea (IMELS)

The Ministry for the Environment, Land and Sea (IMELS) was established in 1986 with the task of assuring the promotion, conservation and recovery of environmental conditions, as well as to conserve and utilize natural heritage, and defend natural resources from pollution with particular regard, *inter alia*, to the following areas:

- Identification, conservation and improvement of natural protected areas; the protection of biodiversity and biosecurity; implementation and management of the Washington Convention on International Trade in Endangered Species of Flora and Fauna (CITES) and relative EU regulations; protection of the sea and coastal environment.

- Waste management and reclamation of polluted sites; protection and management of water resources.

- Promotion of long-term policies for sustainable development at national and international levels.

- Supervision, monitoring and restoration of environmental conditions that meet fundamental public interests and have positive environmental impacts, with particular reference to the prevention and elimination of environmentally harmful violations, and prevention of and protection from air, noise and electromagnetic pollution and industrial risks.

- Soil protection.

The structure of the Ministry for the Environment, Land and Sea was recently changed to encourage the Ministry's role as a driving force for sustainable development rather than as a Ministry of prohibitions and restrictions. The Ministry is divided into six offices and two commissions – the Commission for Evaluating Environmental Impact and the Technical Scientific Commission. The offices are broken down as follows:

Department for the Protection of Nature
- Management and preservation of protected natural areas
- Guidelines for the protection of land and marine ecosystems
- Guidelines for the protection and monitoring of biodiversity
- Management of genetically modified organisms.

Department for the Quality of Life
- Management of water resources
- Prevention of water pollution
- Implementation of methodologies for integrated waste management
- Prevention and reduction of waste production.

Department for Environmental Research and Development
- Promotion of bilateral and multilateral cooperation in accordance with Multilateral Environmental Agreements
- Coordinating the participation of the Ministry in European and international fora
- National and European Sustainable Development Strategy
- Information and Education.

Department for Environmental Safeguards
- Managing pollution and industrial risk and environmental impact assessment
- Study, research and activity in the field of environmental impact
- Technical administrative support to regional and local planning
- Monitoring, licensing and assessing of accidents deriving from hazardous activities.

Department for Land Protection
- Managing policies on hydrological risks and cartographic systems
- Coordinating technical committees for national, regional and inter-regional catchment areas
- Developing guidelines on national soil protection.

Department for Internal Services
- Human resources management
- Budget and financial affairs
- Informatization and data processing.

Challenges around water

Water and sustainability

Water is essential for all aspects of life. It is essential to the well-being of humankind, a vital input to economic development, and a basic requirement for the healthy functioning of all the world's ecosystems. Clean water supply for domestic purposes is essential for human health and survival; indeed, the combination of safe drinking water supply, adequate sanitation and hygienic practices like hand-washing is recognized as a precondition for human health and overall reductions in morbidity and mortality rates, especially among children.

Yet according to the 2007 Millennium Development Goals Report, half of the world's population lacks adequate water purification systems and clean water supplies, and an estimated 1.6 billion people are denied access to improved sanitation.

Given these trends, the world is likely to miss the target to halve, by 2015, the proportion of the population without sustainable access to safe drinking water[1] and basic sanitation by almost 600 million people. Water scarcity, poor water quality, and inadequate sanitation negatively impact food security, livelihood choices, and educational opportunities for poor families across the developing world.

The global consumption of water is doubling every twenty years, and it is estimated that in 2025, if present rates of water consumption are maintained, 5 billion out of the world's 7.9 billion people will be living in areas where it will be difficult or even impossible to meet basic water requirements for drinking, cooking and sanitation. The supply of safe drinking water is of vital importance because of the high risk of contracting life-threatening diseases from polluted or contaminated water sources or as a result of the absence or improper use of sanitation facilities.

Global population numbered 6.1 billion in 2000 and is currently growing by a net increment of some 77 million people per year. By 2025, the United Nations Population Division, in its 2000 Revision of the world's population prospects, estimates that total world population will be of the order of 7.9 billion. The impact of this growth will be concentrated mainly in less-developed countries, where currently some 1.2 billion people – the majority of whom are women and children – are living in extreme poverty. In other words, the bulk of population growth will accrue in the regions of the world least able to absorb large increments of people, thereby increasing migration, and threatening sustainable development and the quality of life.

Freshwater is distributed unevenly, with nearly 500 million people suffering water stress or serious water scarcity. Under current trends, two-thirds of the world's population may be subject to moderate to high water stress in 2025. In the intervening period, it is expected that the world will need 17% more water to grow food for the increasing populations in developing countries, and that total water use will increase by some 40%. Both shortages and uncontrolled excesses of water can be life-threatening, and the essential balance in-between must look to achieve appropriate priorities, equity and economy in the dispensing of this most vital resource.

UNESCO/NOPD Isidro Magana

Yann Arthus-Bertrand/La terre vue du ciel

Yann Arthus-Bertrand/La terre vue du ciel

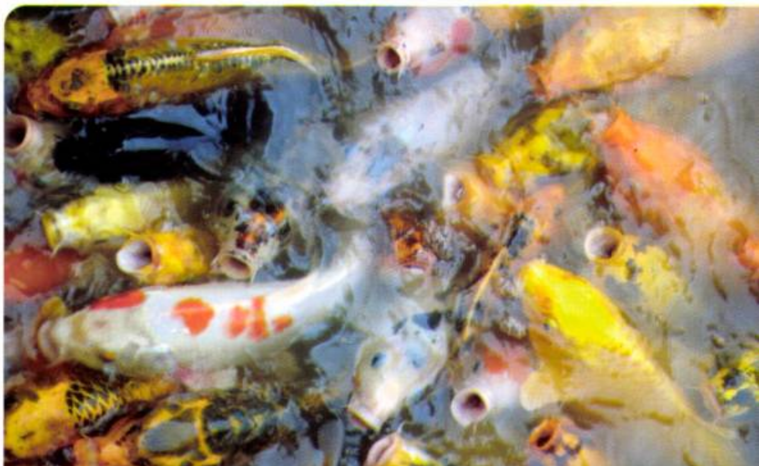
The Millennium Development Goals (MDGs) and the Implementation Plan of the World Summit on Sustainable development reconfirmed the critical nature of water problems, setting key targets on access to safe water and improved sanitation. Meeting the components of the MDGs referring to water and sanitation is necessary for real progress against poverty and to avoid temporary or permanent environmental deterioration.

Surface water resources are scarce in arid and water scarce zones like Africa and the Middle East. Taking into account the fact that groundwater resources are non-renewable, society's livelihood is here more than ever dependent on the ability to manage and share this rare resource, particularly where access to water and sanitation is meeting particular stringent conditions.

People in arid areas are uniquely vulnerable not only to drought and other natural disasters, but also to economic and social changes. Achieving sustainable development has particularly important implications for reducing poverty and hunger. Limited and unreliable access to water is a determining factor in agricultural productivity in many regions, a problem rooted in rainfall variability that is likely to increase with climate change.

1 The Joint Monitoring Programme (JMP) of WHO and UNICEF defines 'safe drinking water' as water with microbial, chemical and physical characteristics that meet WHO guidelines or national standards on drinking water quality. 'Safe' water sources are household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater. The JMP refers to 'access to drinking water' when the improved water source is less than 1km away from its place of use and when it is possible to reliably obtain at least 20 litres per member of household per day.

Yann Arthus-Bertrand/La terre vue du ciel



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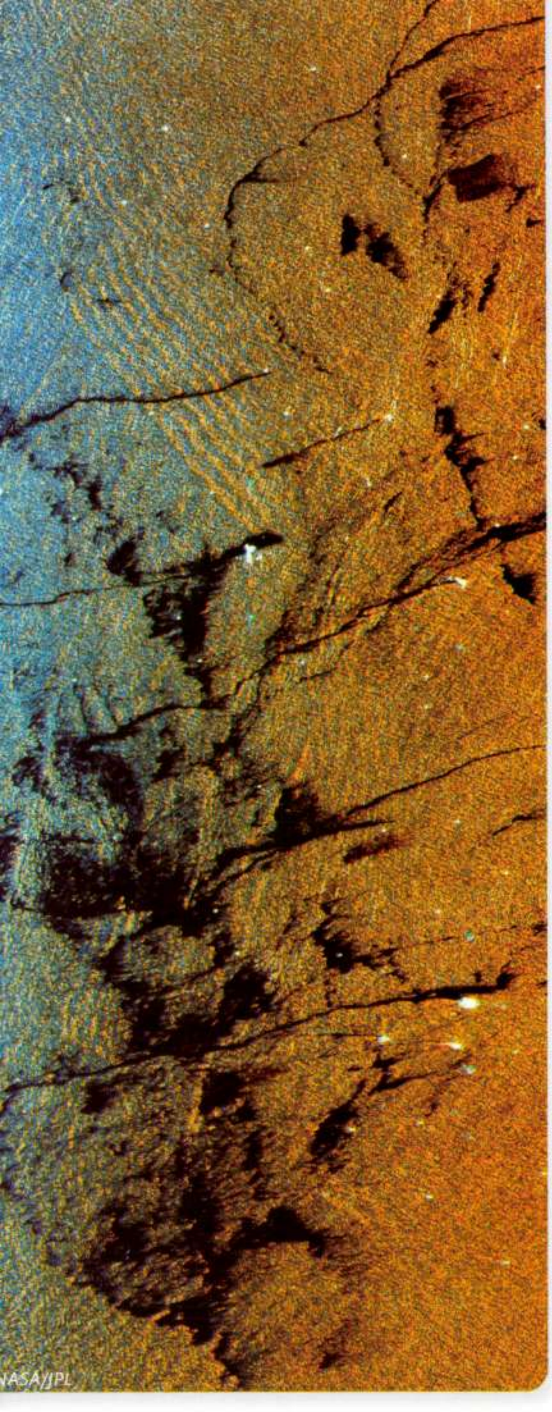


NASA/JPL

Management of water resources is by no means a new problem and the control and use of water has been a matter of importance from time immemorial. Water access, rights and use for household, agricultural and industrial production purposes have long been prominent issues.

The provision of safe drinking water becomes a greater challenge as socio-economic development and population growth place increasing demands on limited water resources. Overall demands for water are growing rapidly, with the need to promote agricultural, mining and industrial development, as economies in the region develop and diversify away from subsistence agriculture towards more commercial agriculture and manufacturing-based industries. The impacts of such developments on water resources can be severe, both in terms of water demand and potential for pollution.

The alarming decline in predicted water availability is likely to be a common feature of water resources in the future. This makes it all the more urgent that people in water scarce regions make every effort to ensure the careful and sustainable management of available water resources, since opportunities for development of new sources of water to meet future shortfalls are, and will remain, limited.

Monitoring networks are limited in their scope and functionality, and data management infrastructure generally is inadequate, with only a few exceptions

To date, the focus of most water management strategies has almost invariably been on the increase in supply of water without much attention to the management of demand. What is urgently required is an integrated approach to freshwater management to determine the best means of reconciling competing demands with limited supplies.

Water and its coordinated development, management and use, including investments in water infrastructure, is a crucial prerequisite for achieving the MDGs as a whole. The target set by the World Summit on Sustainable Development in Johannesburg for countries to develop integrated water resources management (IWRM) and water efficiency strategies by 2005 provides an opportunity to foster planning processes based on the Millennium Development Goals with consideration of water resources.

Among the factors contributing to the water crisis in developing countries are the incomplete understanding of requirements for sustainable water stewardship, the gaps in local capacities – scientific, educational, institutional, managerial and political – and the failure to put into place the full suite of enabling systems needed to achieve sustainability.

UNESCO/ML Bonsirven-Fontana

Institutional capacity within the region is weak, partly due to a lack of human resources capacity and expertise, but also due to lack of coordination by the multiple institutions that have responsibilities or influence over water resources. Data insufficiency is a critical weakness in developing countries. This includes basic hydrological and water quality data, data on present and projected water uses and impacts, and data relating to the water environment and aquatic ecosystems.

To date, the focus of most water management strategies has almost invariably been on the increase in supply of water without much attention to the management of demand

Monitoring networks are limited in their scope and functionality, and data management infrastructure generally is inadequate, with only a few exceptions.

The objectives of the combined efforts of local and international agencies must therefore aim to improve awareness and understanding of water issues and solutions, to contribute to the resolution of the capacity deficit through capacity-building programmes, and to

help establish sustainable systems and practices through directed technical and scientific assistance.

A combination of strong national action – guided by nationally prepared and owned strategies and action plans – complemented and supported by international action is thus necessary, recognizing the primacy of action at the national and sub-national levels – as close as possible to where the problems and opportunities lie.

National IWRM strategies and processes can establish an enabling framework that encourages water management and services that advance the Goals. The starting point has to be national action – to recognize the MDGs as priority national development goals, to prepare strategies and action plans for their achievement, to open opportunities for community action, and to mobilize public awareness and support, especially for sanitation and hygiene.

That said, there is clearly a key supporting role for international agencies and actors as well as for developed countries that share the commitment to the MDGs. UN organizations, multilateral institutions, bilateral donors, and international NGOs must provide strong and effective assistance towards the achievement of the water supply and sanitation target and for water resources management and development. They have a major, but supporting, role to play in helping countries realize their own nationally-determined goals, strategies and action plans. In particular, they can be advocates, catalysts, mobilizers of international support, and – especially for the poorest countries far from meeting the goals – providers of additional resources.

United Nations system organizations involved in water and sanitation and their Member States must therefore ensure that the UN system organizations engaged in such functions have, both individually and collectively, the organizational capacity, mandate, staffing and resources needed to carry out these functions, and that they provide leadership and strategic guidance to the international community in these areas.

UNESCO/Bernard Nantet

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater

Adaptation and water scarcity

Water is indispensable to sustain life on Earth. It is needed in large volumes in virtually any human activity. Therefore, adverse changes in availability of water, in both quantity and quality, are of considerable concern. Changes in climatic variables, such as temperature and precipitation, have significant impacts on water resources and hence on societies and ecosystems.


nn Arthus-Bertrand/La terre vue du ciel

Climate change is expected to account for about 20% of the global increase in water scarcity. Countries that already suffer from water shortages will be hit hardest. Significantly, there will be major increases in water scarcity even if the water impacts of climate change prove to be neutral or enhance the world's hydrological budget. With neither being reasonably expected to happen, the impact of a changing climate will affect not only bulk water availability, but also worsen the extremes of drought and floods. With no mitigation of climate change, it is predicted that by 2100 severe droughts will occur on a yearly basis.

The latest report of the Intergovernmental Panel on Climate Change (IPCC) concluded that humankind's emissions of greenhouse gases are more than 90% likely to be the main cause, and that climate change is 'unequivocal' and may bring 'abrupt and irreversible' impacts. The report goes on to project that between 75 million and 250 million people will suffer from scarce freshwater supplies, and that yields from rain-fed agriculture could be halved. Average temperatures will rise by as much as 6.4°C by 2100, potentially disrupting the hydrological cycle.

Climate change has impacted, and is likely to impact even more strongly in the future, all hydrological processes and regimes. Climate systems and the water cycle are closely linked, so that a change in any one of these systems induces a change in the others.

Climate change could significantly affect the hydrological cycle, altering the intensity and temporal and spatial distribution of precipitation, surface runoff, and groundwater recharge, with various impacts on different natural ecosystems and human activities. Arid and semi-arid areas are particularly vulnerable to changes in water availability. The impacts on water resources could be sufficient to lead to conflicts among users, regions and countries.


Yann Arthus-Bertrand/La terre vue du ciel

Sea-level rise will cause saline intrusion into coastal aquifers. Shallow coastal aquifers are at greatest risk. Groundwater in low-lying islands therefore is very sensitive to change. For many small island states, such as certain Caribbean islands, seawater intrusion into freshwater aquifers has been observed as a result of over-pumping of aquifers. Any sea-level rise would worsen the situation.

Coastal human populations in many countries have been growing at double the national rate of population growth. It is currently estimated that about half of the global population lives in coastal zones, although there is significant variation among countries. Changes in climate will affect coastal systems through sea-level rise, increases in storm-surge hazards and possible changes in the frequency and/or intensity of extreme events.

Climate change will exacerbate these problems, leading to potential impacts on ecosystems and human coastal infrastructure. Large numbers of people are also potentially affected by sea-level rise, and millions would be forced to migrate in the absence of adaptation measures.

Adaptation to climate change has risen up the political and scientific agenda in recent years. The issue has received increasing attention within the UNFCCC, and programme activities are expanding through international and national level initiatives such as the creation of a GEF Adaptation Fund, UNDP's Adaptation Policy Framework, the National Adaptation Programme of Action (NAPA) for Least Developed Countries and the emphasis on adaptation in the fourth Assessment of IPCC.

Community-based adaptation activities are working to link climate change into sustainable development. Indeed, there are many examples of projects enhancing the capacity of communities to deal with the effects of climate variability and extreme events, some of which specifically focus on reducing the vulnerability of communities to the adverse effects of climate change.

Climate change will influence water security, and affect the demand for water. Water demand is generally increasing due to population growth and economic development, but is falling in some countries because of increased efficiency of use.

Irrigation – which accounts for some 80% of global water use – is the most climate-sensitive water user, and the shifting pattern of irrigated crops in response to climate change is likely to have major effects on the spatial and temporal pattern of water demand, as well as the need for increased water storage. Industrial and municipal demand will likewise be affected and further accentuated through the migration of people from increasingly water scarce regions to those where water is plentiful.

Semi-arid and arid areas are particularly exposed to the impacts of climate

The greatest vulnerabilities are likely to be in unmanaged water systems and systems that are currently stressed or poorly and unsustainably managed

change on freshwater. The greatest vulnerabilities are likely to be in unmanaged water systems and systems that are currently stressed or poorly and unsustainably managed. The latter can be due to policies that discourage efficient water use and protection of water quality, inadequate watershed management, failure to manage variable water supply and demand, or lack of sound professional guidance. In unsustainably managed systems, water and land uses can add stresses that heighten vulnerability to climate change.

Climate change will also affect the supply side of water resources management. Total global precipitation is likely to increase during the next century, although this increase will not be uniform across the world. Overall, global warming will likely lead to reduced water availability in countries that are already water scarce and an increase in the variability with which the water is delivered.

Water resources, like the climate, are subject to extreme variability. Extreme weather events like droughts and floods are relatively frequent occurrences, and many rivers do not have year-round flow. This makes it difficult and expensive to store water in order to meet shortfalls, and leaves people more vulnerable to natural disasters.

Hydrological variability and extremes are at the heart of the challenge of achieving basic water security. This challenge will be compounded by climate change, and will require significant adaptation everywhere. This will be the case particularly in poor countries lacking the institutions and infrastructure to manage, store and deliver their water resources.

In many of the poorest countries, particularly in sub-Saharan Africa, the currently unmanaged levels of climate variability are many times greater than predicted climate change. While many developed countries are focusing on climate change **mitigation**, developing countries are more focused on **adaptation** to current climate variability. In all cases, however, adaptive capacity – both social and physical – will need to be enhanced to protect the poorest and most vulnerable populations.

Given the limited technical, financial and management resources possessed by developing countries, adjusting to shortages and/or implementing adaptation measures will impose a heavy burden on their national economies. There is evidence that flooding is likely to become a larger problem in many temperate and humid regions. This will require adaptation practices not only to droughts and chronic water shortages but also to floods and associated damage.

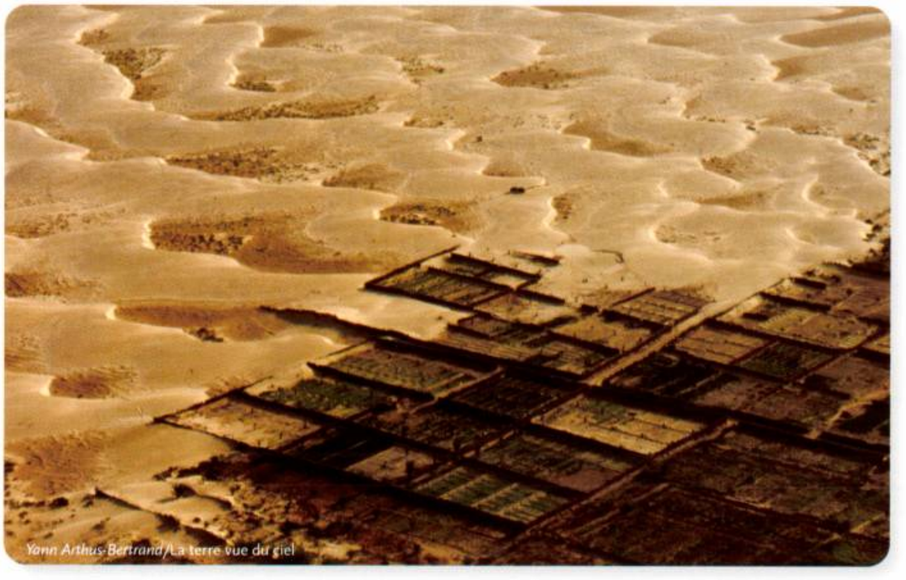
Flood magnitude and frequency could furthermore increase in many regions as a consequence of increased frequency of heavy precipitation events, which can increase runoff in most areas as well as groundwater recharge in some floodplains. Land-use change could aggravate such events. Streamflow during seasonal low-flow periods would decrease in many areas due to greater evaporation; changes in precipitation may exacerbate or offset the effects of increased evaporation.

The projected climate change would degrade water quality through higher water temperatures and increased pollutant load from runoff and overflow of waste facilities. Quality would be degraded further where flows decrease, but increases in flows may mitigate to a certain extent some degradation in water quality by increasing dilution. Where snowfall is currently an important component of the water balance, a greater proportion of winter precipitation may fall as rain, and this can result in a more intense peak streamflow which in addition would move from spring to winter.

Integrated water resources management (IWRM) is increasingly regarded as the most effective way to manage water resources in a changing environment with competing demands. IWRM essentially involves three major components: consideration of all potential supply-side and demand-side actions, inclusion of all stakeholders in the decision process, and continual monitoring and review of the water resources situation. Integrated water resources management is an increasingly used means of reconciling different and changing water uses and demands.

Integrated water resource management can adapt to the hydrologic effects of climate change and to additional uncertainty so as to lessen vulnerabilities, and will also enhance the potential for adaptation to change. Adaptive capacity (specifically, the ability to implement integrated water resources management), however, is very unevenly distributed across the world.


NASA/GSFC/LaRC/JPL/MISR Team


Yann Arthus-Bertrand/La terre vue du ciel

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...adaptive capacity – both social and physical – will need to be enhanced to protect the poorest and most vulnerable populations

The project

Programme objectives

The overall aim of the Water Programme for Environmental Sustainability (WPA II) is to contribute to ensuring environmental sustainability as set forth by the 7th Millennium Development Goal (MDGs). The agreed target for this goal is to integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources.

With these objectives in mind, the project's intention is to support this process through:

- *Contributing to the achievement of water security in water-stressed environments by providing rural and urban populations with freshwater*
- *Satisfying water needs for food production with more efficient, integrated water management*
- *Identifying adaptation measures to change in climate patterns, and assess their effectiveness*
- *Improving health and quality of life based on food and water security*
- *Alleviating poverty by providing water and sanitation services.*

To achieve these objectives the WPA II Project will set up regional training capacities, pilot projects and technical workshops, in an effort to strengthen the capacity of national institutions, create reinforced technical capabilities, and develop projects that could serve as examples of best practices.

The topics of the courses vary from, for example, remediation of distressed aquifers, to integrated coastal management, or from fostering reuse wastewater in irrigated agriculture to improvement of wetlands sustainable management, all according to established national or regional priorities.

The central aim is to building the capacity of sector organizations, knowledge centres and other institutions active in the fields of water, the environment and infrastructure, in both developing countries and countries in transition.

The project is meant to contribute to the education and training of professionals, to assist in the identification of priorities for action, and to provide tools for planning and management of water resources with a view to adoption and replication of the transferred knowledge.

The WPA II project aims to implement its components in a coherent and transparent manner through the establishing of a consultation mechanism with the respective water resources and environmental ministries, universities, and UNESCO-IHP National Committees of the countries involved.

As such, the individual activities within the project are not isolated, but part of integrated, long-term, multi-sectorial programmes, with each activity complementing others within existing national and regional programmes.

This action-oriented process will contribute to the development, replication, and scaling-up of best practices. It focuses on the development and implementation of demand-driven local and nationally-owned priority projects, assessing at the same time the existing regional capacity of sustainable management of water resources and environmental protection.

Specific objectives

The sustainable management of water resources has been recognized as one of the key challenges of this century. Lack of adequate water supply can drastically reduce the economic and social development of a region while population growth and human activities have serious impacts on the quality and quantity of existing resources.

Taking this into account, and considering the above-mentioned wider programme objectives, the UNESCO-IMELS project will focus on improving the management of groundwater resources as a tool to overcome climate variability and increase both water storage facilities and water supply capacity.

With this in mind, the specific objectives of the Water Programme for Environmental Sustainability (WPA II) are as follows:

1/ *Establish best practices on remediation of climate variability and change impacts on water resources*

2/ *Enhance capacity in managing water resources and protecting groundwater resources*

3/ *Boost understanding of the role of groundwater in supporting wetlands*

4/ *Elaborate methodologies that contribute to the management of surface and groundwater dependent ecosystems in coastal zones*

5/ *Develop case studies that can provide best practices for fostering cooperation in developing conflict resolution measures*

6/ *Contribute to institutional strengthening and develop the IWRM capacity of water professionals to better manage groundwater resources*

7/ *Publicize and disseminate best practices.*

Geographical scope

Appropriate case studies and pilot projects were developed with the goal of duplicating good practices and establishing a network of arid and water scarce area specialists that could exchange experience and knowledge. In all these regions, UNESCO-IHP has established consultation mechanisms with water and environment-related institutions. IHP is convening periodic regional coordination meetings to evaluate priorities for Integrated Water Resources Management and protection of the environment. The results of these consultations have been considered when defining the objectives of WPA II, which are designed to respond to regional needs.

Duration of the project

The project 'Water Programme for Environmental Sustainability: Towards adaptation measures to human and climate change impacts' (WPA II) was initiated in September 2007, and is set to finish in September 2009.

Project funding

The project is implemented within the framework of the UNESCO-Italy Partnership, and enjoys the financial contribution of the Italian Ministry for Environment, Land and Sea (IMELS).

The activities

Integrated Water Resources Management and sustainable management of coastal aquifers and wetlands in the Mediterranean: **feasibility study in Algeria**

Background

UNESCO/F Rizzo

The present water situation in the Middle East and North African countries is precarious. Population growth and economic development have overwhelmed traditional water management practices and people suffer from water scarcity and water pollution to varying degrees throughout these regions. Where water has been relatively abundant, individual sectors have developed and used water with little regard for impacts elsewhere. But as demands have increased, water quality has deteriorated and affected other users and the environment. Current fragmented approaches often fail to take account of competing demands for water, and the need to protect this common resource.

By 2025, one-third of the populations of developing countries will be experiencing water distress. Algeria, with an annual rainfall of 300 mm and 1100 mm, will be particularly touched by problems of water availability. Agriculture, which absorbs 80% of the available water resources, will have to face a reduction in its consumption, posing a potential risk to national food safety.

Algeria is characterized by semi-arid and arid climates with low precipitation and frequent water deficits. Water supply for domestic use and irrigation has become critical. At the moment, 1300 million m^3 water per year is used for drinking water supply and 1800 million m^3 for irrigated agriculture.

Economic development and steady population growth over the past decades have resulted in higher demands for water, and consequently in increased production of wastewater. With a population of 33 million people, a large amount of raw and treated wastewater is generated, which remains unused. Under the prevalent water scarce conditions this represents a resource to be exploited for agriculture. There are about thirty-six domestic wastewater treatment plants with a production of 550 m^3 per year, but the majority of these are either not functioning or functioning poorly. The result is pollution of water sources used for irrigation and other purposes. Under the current national situation, great importance is attached to the exploration of alternative sources of water for agriculture, to avoid undermining the availability of freshwater. The reuse of treated wastewater to increase water supply in Algeria is therefore emerging as a national priority. There is strong political will to regard wastewater as a valuable resource for the future. In the light of the present critical situation regarding water supply for domestic use and irrigation, wastewater reuse is becoming viewed as one of the most prominent exploitable resources, and an economic opportunity for crop producers.

The activities implemented in Algeria under WPA II respond to a government need for technical assistance regarding human and institutional capacity-building in integrated water resources management, with special regard to wastewater reuse for irrigation purposes. They stem furthermore from the outcome of the UNESCO 'Training Course on Wastewater Management and Reuse for Agriculture', held in Algiers during September 2005, which recommended specific follow-up actions to assist the Algerian Government to carry a feasibility study centered on two sites – Réghaia and Constantine.

Constantine

The wastewater treatment plant (WWTP) at Constantine comprises both primary and secondary treatment. It has the capacity to treat 800 l/s (69,000 m^3/day for 400,000 inhabitants), but is currently treating 400 l/s.

The treated sewage is directly discharged to agricultural fields. The levels of nutrients (nitrogen and phosphorus) were said to be within international norms for irrigation application. No information was available on pathogen levels.

Réghaïa

The wastewater treatment plant (WWTP) of Réghaïa has only primary treatment in place. In the pilot area, untreated sewage is directly discharged to the receiving water bodies, thereby contributing to the decline of water quality. The problem is especially acute in the city of Réghaïa since wastewater is discharged directly into Lake Réghaïa, a unique environment that has been severely damaged by pollution.

This daily discharge is estimated at around 80,000 m³ of treated wastewater. As a result the lake suffers from anoxic conditions and accompanying methane production. The situation poses a threat to human health as untreated water from the receiving bodies, despite the legislative ban, is commonly used for irrigation.

UNESCO/L Stravato

Réghaïa lake (top); example of anoxia in the lake (bottom left)
Agricultural practices by local farmers with water extracted from the lake (bottom right)

Objectives

The overall objective of the proposed project is to **promote the integrated wastewater management concept and to recycle (treated) wastewater in irrigated agriculture** with a view to protecting human health and the environment and contributing to a better quality of life in Algeria. Specifically, the project aims to:

- Investigate and propose a feasible solution, including a financial plan, for the problem of wastewater management and use for irrigation in the pilot areas of Réghaïa and Constantine
- Develop a preliminary design and investment plan for the optimal solution to enable Algerian authorities to tackle pollution control and reuse of wastewater
- Guide authorities to identify and apply for funding so as to implement these actions
- Promote the application of verified technologies and management approaches in wastewater treatment and use in irrigated agriculture
- Elaborate further norms for Algerian legislation to enable the reuse of treated wastewater for productive uses (agriculture)
- Integrate social, economic and financial aspects within plans to reuse treated wastewater in agriculture (tariffs, cost recovery, etc.)
- Enhance the skills of Algerian experts in the above areas through the development of feasibility studies, the delivery of capacity-building training, and the facilitation of knowledge sharing
- Lay the basis for wider application of the concept in Algeria by establishing a multi-stakeholder platform to support the dissemination of project results and further exchange of expertise.

UNESCO/Pierre A Pittet

Proven technologies will be adapted to the local situation, and knowledge-sharing from lessons learned from developing countries on recycling wastewater in irrigation will be applied

Activities

Four images of the Réghaïa wastewater treatment plant

The feasibility study addresses the issue of sanitation (WWTP), waste-water management and its use for irrigation in Algeria. It focuses on two components:

1/ *Preparation of a feasibility study for integrated wastewater management and use in agriculture in the two pilot areas: the Lake Réghaïa and Constantine*

2/ *Carrying out related capacity-building and information dissemination activities.*

The feasibility study will lay down strategies and identify methodologies for two pilot projects centered mainly on the reclamation and recovery of Lake Réghaia in Northern Algeria, and partially on the upgrading of the waste-water treatment plant in Constantine.

The project will use an integrated approach to wastewater management by addressing industrial source pollution control, collection and disposal of urban wastewater, wastewater treatment, and improving the quality of receiving water bodies. Proven technologies will be adapted to the local situation, and knowledge-sharing from lessons learned from developing countries on recycling wastewater in irrigation will be applied.

A capacity-building element is also envisaged, focusing on different aspects of wastewater and re-use opportunities for agriculture (planning, technological options, context analysis). Training on management of wastewater plants and wastewater reuse will be also addressed, as well as municipal wastewater management issues. Opportunities, technologies and guidelines for wastewater reuse in agriculture will be explored, as well as ways to enhance stakeholders and institutional participation.

The proposed technical assistance project will model water quantity and quality,

UNESCO/F Dal Chiel



analyse environmental and socio-economic impacts, elaborate measures for risk mitigation, establish learning alliances, deliver capacity-building training, and have direct involvement with multi-stakeholder groups in project activities and ensure wide dissemination of project results. Detailed activities are:

Activity 1/ *Project set-up*
Identification and consultation with all stakeholders at national and local levels; finalization of needs assessment.

Activity 2/
Data collection and construction of a Geographic Information System (GIS)
Collating and elaborating information to characterize the two pilot sites in terms of wastewater management, surface water quality objectives and agricultural practices. Will include: pollution sources in Réghaïa catchment area, the hydrological catchment area and surface waters, the urban area and sewer network, the Réghaïa wastewater treatment plant and Lake Réghaïa. Also, agricultural practices and irrigation management, water quality, sanitation and health risks, user perceptions of wastewater, and data preparation for analysis and interpretation.

Activity 3/
Construction and testing of the integrated wastewater model for Réghaïa and the WWTP model for Constantine
Will include short-flow and water quality survey in Réghaïa; development of models for Réghaïa and Constantine (urban area and the sewer networks, hydrological basin and the rivers, wastewater treatment plant, Lake Réghaïa).

Activity 4/ *Simulation of different treatment options*
Identification and assessment of technical options to optimize the wastewater system in the Réghaïa area and reduce the pollution of the receiving water bodies.

Activity 5/ *Preliminary design of the selected wastewater management schemes for Réghaïa and Constantine*
Development of the preliminary design of the best scheme for wastewater management and reuse in agriculture for Réghaïa and Constantine. Document the identified technical solutions concerning both the wastewater infrastructure and adjustment of the current irrigation networks; cost estimation.

Activity 6/
Action and financial plans for the implementation of proposed projects
Preparation of detailed action and financial plans. Undertake study on the possibility of financing the identified actions through the private sector, government funding or international funding.

Activity 7/ *Design and delivery of capacity-building training*
Development of tailor-made capacity-building programme; interactive workshops, combining theory with case studies and practical working group exercises.

Activity 8/ *Dissemination of project results and information sharing*
Organization of international seminar; design of dissemination tools (website, leaflets, CD-ROM); preparation of guidlines to further support implementation of similar actions.

Expected outcomes

The implementation of the project will bring about the following results:

- Development of **feasibility studies for integrated wastewater management and wastewater use in the areas of Réghaïa and Constantine**, including action and financial plans. The studies will be developed so as to serve as a basis for proposals on financing the actions to be implemented.

- Delivery of **capacity building workshops**, targeting relevant stakeholders at national, regional and local levels, aiming to strengthen their skills for future implementation of projects in the areas of integrated wastewater management and wastewater use in irrigated agriculture.

- For all actions whose implementation is foreseen in the short-term (i.e. up to three to five years), a **detailed action** and **financial plan** will be developed for the **preparation of an application for funding** to be submitted to international financial institutions.

- Building of **multi-stakeholder platforms (MSP)** for practical experience-sharing to help in consensus-based project implementation, prioritization of actions in the two pilot areas, selection of technical options for wastewater treatment and reuse, and laying the basis for future replication of project results.

Climate change and human impacts on the sustainability of groundwater resources: **quantity and quality issues, mitigation and adaptation strategies in two case studies in Brazil**

Background

Brazil possesses one of the world's largest freshwater reserves. This represents an extremely important natural asset, notwithstanding the country's biodiversity and the beauty of its rivers and lakes. However, issues related to the water's geographic and seasonal distribution still pose a challenge for millions of Brazilians. Although Brazil has plentiful water resources, they are unevenly distributed across the country, imposing huge restrictions on the poorest segments of society. More than a third of the population does not have reliable access to the supply of drinking water in the north-eastern region of the country.

The pollution of rivers and other water sources in metropolitan regions continues unabated. The country also faces social and economic losses through perennial flooding, particularly in high-risk urban areas densely inhabited by low-income families and where basic drainage and sanitation services are poor or non-existent.

During the last decade, water scarcity and pollution in Brazil have generated increasing attention from both the government and civil society. However, significant accomplishments have been achieved over the last forty years – Brazil has expanded its water supply and sanitation services to serve an additional 100 million and 50 million Brazilians respectively. Over the last seven years, the area under irrigation has grown by approximately 34%, leading to benefits in the production of food, the creation of jobs, and in income generation.

Climate variability and human activities could significantly impact groundwater resources in the country. Therefore, the evaluation of those impacts and the definition of appropriate mitigation and adaptation measures are required.

The Intergovernmental Panel on Climate Change (IPCC) scenarios for temperature and rainfall for the next 20-50 years in Brazil predict significant warming across the country, and a possible reduction in annual rainfall in portions of the north-eastern region and the Amazon. In addition, there are risks of overexploitation and contamination of groundwater resources in vulnerable agricultural areas.

Fostering the development and improvement of management of water resources is necessary now, more than ever, to satisfy Brazil's social and economical needs. In this context, it is essential to extend water supply and sanitation infrastructure to those lacking reliable access and good quality service.

Groundwater plays an important role, supplying cities, industries and irrigation schemes. Groundwater is very often the primary source of water for drinking and irrigation. Yet at the same time, population and economic growth have led to increased demands on the world's groundwater aquifers. Efficient management of these aquifers requires the integration of a multidisciplinary approach incorporating legal, institutional and socio-economic aspects.

Activities

The project will consist of the identification of groundwater potential and vulnerabilities in two selected river basins, as well as the existing and future impacts and risks to their sustainable use, with particular focus on those related to climate change and human activities.

Appropriate groundwater models will be used for the estimation of groundwater recharge and nutrient leaching under different climatic and land/water use scenarios. Climate scenarios will include worse case (IPCC A2), best case (IPCC B2), and intermediate scenarios, reflecting present trends. The IPCC scenarios for Brazil will be downscaled to the basin level, so that appropriate temperature and precipitation series can be established.

The land-use/management scenarios will consist of a 'business-as-usual' scenario, an optimistic scenario, where land and water management would improve in the selected basins, and a worse-case scenario, with the increase of land- and water-use intensity without proper management. A combination of land-use/management and climate change scenarios could be used to span the different possibilities.

Two hydrologic models will be used in the project: a one-dimensional model looking at vadose-zone processes (percolation and leaching) at smaller scales, and a three-dimensional model, examining the integration of surface and subsurface processes at a larger scale. In addition, basin level water-balance computations and base-flow analyses will be carried out to assess interaction between ground and surface water.

The project will also involve the evaluation of management tools and measures to tackle impacts, as well as the development of technologies, tools and alternatives that could be used by institutions and stakeholders in Brazil, allowing for replication in similar regions.

Economically speaking, the adaptation and mitigation measures suggested by the climate and hydrology studies will be assessed in terms of efficiency, equity and justice, by referring to economic, environmental, social and institutional issues. A theoretical or empirical approach will be used, according to the available information.


Yann Arthus-Bertrand/La terre


UNESCO, Luis Alberto

Fostering the development and improvement of management of water resources is necessary now, more than ever, to satisfy Brazil's social and economical needs... it is essential to extend water supply and sanitation infrastructure to those lacking reliable access and good quality service

In short, the main activities will be:

1/ *Development of two case studies on aquifer systems coping with climate change in order to set up best practices guidelines and methodologies on adaptability measures for aquifer management to be duplicated in the region.*

2/ *Enhancement of best practice methodologies to overcome climate change impacts on groundwater resources through the use of appropriate adaptability measures.*

Objectives

The purpose of this project component is to promote reflection upon and address relevant issues on groundwater, and to offer alternative approaches and paths to be followed in the search for sustainable management. The principle aim is for these activities to become a vehicle of useful and continuous debate that can contribute to the achievement of poverty reduction, social inclusion, preservation of natural heritage and sustainable economic growth.

In order to achieve sustainable management of water resources in the country and the region, the project sets out the following objectives:

- Support the development of adaptation measures to overcome climate change impacts on water resources
- Strengthen groundwater resources management components at country or local level, including aquifer assessment and management
- Improve coordination between Brazilian and Italian institutions and experts
- Develop and facilitate exchange of knowledge and expertise
- Provide knowledge on groundwater management and protection
- Facilitate aquifer integrated management approaches during

implementation of two pilot projects, including mobilization of stakeholders to address groundwater resources management and protection needs

- Harvest and evaluate global experience, taking into account hydrogeological and socio-economic diversity
- Understand the hydrologic relationships between control and response variables in groundwater systems under the impact of climate change and human activities
- Identify mitigation and adaptation measures for groundwater management under those impacts
- Evaluate hydrological adaptive and mitigation measures in terms of replication potential, sustainability, impacts on both global and regional climate change, and equality in access to groundwater, both in quantitative and qualitative terms
- Disseminate best-practice elements internationally with the organization of short courses and study tours as well as through the provision of training course proceedings.

Yann Arthus-Bertrand/La terre vue du ciel

Expected outcomes

It is expected that the project will yield the following results:

- Establishment of a Brazilian and Italian group of experts working jointly on two aquifer management case studies
- Quantitative evaluation of climate change and human-induced effects on the groundwater sustainability of two aquifer basins
- Identification and evaluation of hydrological adaptability measures in terms of replication potential, sustainability, and impacts on both global, regional and local climate change
- Equity assessment in access to groundwater, both in quantitative and qualitative terms, referring to growth rates for economic sectors, and to well-being indicators for health, poverty, etc. for social segments
- Training and capacity-building of stakeholders and institutions in the regions studied
- Recommendations to decision and policy makers based on project results
- Organization of final training course
- Publication and dissemination of project results (e.g. reports, publications, web pages, internet conferences and training course proceedings) among targeted institutions and stakeholders.

Yann Arthus-Bertrand/La terre vue du ciel

The pollution of rivers and other water sources in metropolitan regions continues unabated

NASA/GSFC/METI/ERSDAC/JAROS, and US/Japan ASTER Science Team

Limited access to water is a key factor in agricultural productivity in many regions, a problem rooted in rainfall variability that is likely to increase with climate change.

Adaptation measures to climate change impacts on coastal aquifer systems in the Caribbean: **case study in Jamaica and Trinidad and Tobago**

Background

Some of the world's most diverse and productive habitats encompassing extensive areas of complex and unique ecosystems are found in the Caribbean. The coastal areas include coastal plains, littoral zones, mangroves, coral reefs, sea grass beds and river deltas, which are an important source of food production and support a variety of economic activities such as fisheries, tourism and the related activities of recreation and transportation.

Coastal aquifer systems have been over-exploited and polluted in urban areas, while in rural areas with increasing population pressures the risks to their sustainability and integrity are on the increase... At present there are no policy initiatives through which aquifer remediation can take place

Coastal aquifer systems (CAS) are one of the more susceptible components, and are at present neither sufficiently well-managed nor fully understood by national institutions. They have been overexploited and polluted in urban areas, while in rural areas with increasing population pressures the risks to their sustainability and integrity are on the increase. The latter is particularly true for coastal groundwater-dependent ecosystems. At present there are no policy initiatives through which aquifer remediation can take place.

Groundwater in most islands is particularly sensitive to sea-level rise. Water supply is sensitive to precipitation patterns and changes in storm tracks, which also heavily impact aquifers, where freshwater lenses are often very narrow. Increased temperatures and dryness may also affect water quality by promoting the mineralization of organic nitrogen in water recharge supplies. The lack of infrastructure and human capacity to manage groundwater use is one of the reasons for increased vulnerability to the impacts that climate change is having, and will have, on groundwater resources in these countries.

Seawater intrusion can significantly limit the amount of potable groundwater available to coastal communities. Management of the water resources available to such communities is increasingly being studied using an interdisciplinary scientific approach that includes geophysical methods, existing and new information, and conceptual hydrogeological models as input for complex *groundwater modelling. Calibration and validation of groundwater flow models depends on an accurate knowledge of water table elevations, the nature of the fresh-saline water interface at depth, and the spatial variation of hydrologic parameters and variables (including permeability, porosity, storability and concentration).*

The cross-cutting role of the hydrological cycle – to make water available, to sustain terrestrial, fresh- and coastal marine water ecosystems, and ecological and socio-economic functions, to accommodate biodiversity and secure natural resources for development – needs to be well-understood within the framework of the Caribbean area.

Systems are coming under growing, identifiable stress from population growth, economic development and encroaching infrastructure and accumulation of contaminants and other human-induced factors. As a result, the need to identify and address the root causes for deterioration of groundwater quality is becoming increasingly pressing.

With the new challenge of protecting aquifer systems, particularly under changing climatic conditions, groundwater represents a strategic factor, potentially assisting in adaptation practices, bridging climate variability, and securing necessary water availability for wetlands, water bodies and anthropogenic use.

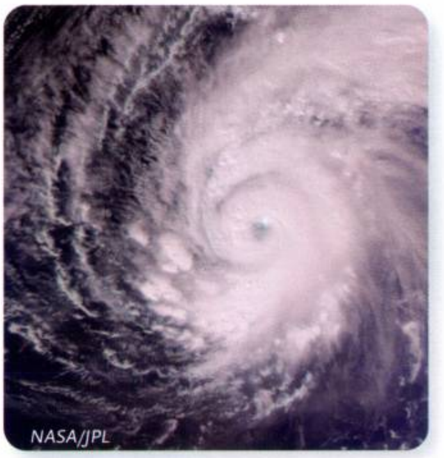
Activities

The project will consist of identifying groundwater potential and vulnerabilities in two selected pilot sites, as well as the identification of suitable adaptability measures for their sustainable use, particularly for those related to climate change and human activities.

Appropriate groundwater models will be used for the estimation of groundwater recharge and nutrient leaching under different climate and land/water use scenarios. The climate scenarios will include worse case (IPCC A2) and best case (IPCC B2). The land-use/management scenarios will consist of a 'business-as-usual' scenario, an optimistic scenario – where land and water management would improve at the selected sites, and a worse-case scenario – with the increase of land and water use intensity, without proper management. A combination of land-use/management and climate change scenarios could be used to span the different possibilities. In addition, water-balance computations at the site level and base-flow analyses will be undertaken to assess interactions between ground and surface water.

The project will also involve the evaluation of management tools and measures to tackle the identified impacts, as well as the development of technologies, tools and alternatives which could be used by institutions and stakeholders


UNESCO/Daniel Martin


NASA/JPL

in the participating countries, allowing for replication in similar regions.

The adaptation and mitigation measures suggested by the climate change and hydrology studies will be assessed in terms of efficiency, equity and justice, by referring to economic, environmental, social and institutional issues. A theoretical or empirical approach will be used, according to the available information.

The challenge addressed under the project is to assess, develop and disseminate practical hydrogeological and multidisciplinary adaptation measures for the sustainable management of coastal aquifer systems.

In order to meet this challenge, it is opportune to define the interdependencies between climate change and aquifers, and to prepare guidelines for effective management and protection of groundwater resources and dependent ecosystems, groundwater being the most relevant source of freshwater supply in the region.

The achievement of these objectives will benefit from the establishment of a joint partnership between UNESCO-IHP and the Caribbean Community Climate Change Centre, which was officially opened in August 2005. The Centre is the key node for information on climate change issues and the region's response to managing and adapting to climate change in the Caribbean. It is located in Belmopan, Belize. The Centre is already a strong partner of IMELS.

The project will support two pilot studies with distinct climates, geology, soils, vegetation and land-use/management. These will comprise of:

1/ The Erin aquifer in the south-western region of Trinidad

2/ The Rio Cobre Basin in the south-central region of Jamaica.

In short, the main activities will be:

- *Development of two case studies in two selected aquifer systems with the aim of duplicating best practices*
- *Enhancement of best adaptation practice methodologies to overcome climate change impacts on groundwater resources*
- *Preparation of guidelines for effective management and protection of coastal aquifer systems and groundwater dependent ecosystems*
- *Training Course on Coastal Aquifer Sustainable Management*
- *Preparation of a brochure and other public awareness material for dissemination.*

Objectives

The principal objective of the project is to develop and implement a Groundwater Management Model to assess and manage the costal aquifer system on a continuous basis, and to make recommendations on best adaptability practices for the protection and development of sites coping with climate change.

To achieve these objectives the following will be required:

- Compilation of research literature pertaining to the relationships between climate change and groundwater resources


UNESCO/Gary Masters

- Involvement of stakeholders and others interested in groundwater resource issues with the process and findings of national assessments
- Development of a community-based programme that will provide a consistent framework and process for community teams to use in educating citizens about the importance of the issue
- Incorporation of climate change forecasts and policy responses into water resources management to sustain groundwater supplies
- Contribution to the efforts being made to achieve the Millennium Development Goals
- Promote and encourage research, knowledge management, and the exchange of experience and expertise on the impacts of climate change on groundwater resources
- Raise awareness at the national decision-making level of existing and potential threats to coastal aquifer systems
- Strengthen capacities in Caribbean countries to facilitate the transfer of information and adoption of appropriate technologies and methodologies for the identification of hazards and risk management.

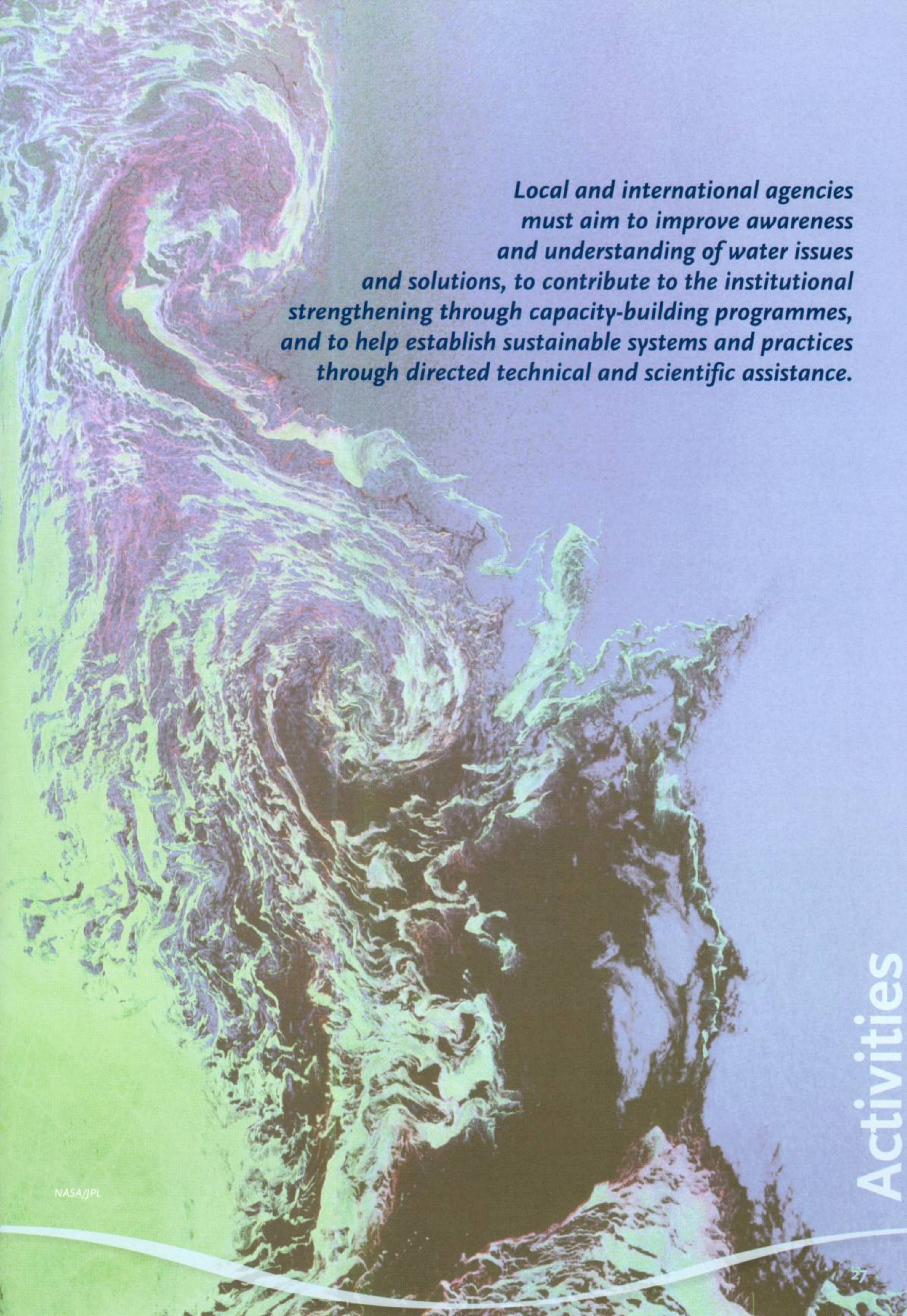
The Caribbean Community Climate Change Centre in Belize (CCCCC) will be the Regional Coordinating Agency for the project.

Expected outcomes

The main outcomes will be:

- Quantitative evaluation of climate change and human-induced effects on the groundwater sustainability of the two pilot sites
- Best practice guidelines for management and protection of coastal aquifer systems and groundwater dependent ecosystems
- Suitable mitigation and adaptation measures for groundwater resources management
- Evaluation of hydrological adaptability measures in terms of potential replication, sustainability, impacts on both global and regional climate change, and equity in access to groundwater, both in quantitative and qualitative terms, referring to growth rates for economic sectors, and to well-being indicators for health, poverty etc. for social segments
- Training and capacity-building of stakeholders and institutions in the regions studied
- Recommendations based on project results to decision and policy makers
- Dissemination of project results (e.g. reports, publications, web pages and internet conferences).

Local and international agencies must aim to improve awareness and understanding of water issues and solutions, to contribute to the institutional strengthening through capacity-building programmes, and to help establish sustainable systems and practices through directed technical and scientific assistance.



NASA/JPL

Integrated river basin and coastal zone management: **coastal aquifers in Montenegro**


UNESCO/Alexis N Vorontzoff

Background

Montenegro has good quality and abundant underground and surface waters (unlike most of the Mediterranean region, where water shortages are present). This is mainly due to rich rainfall and relatively well-preserved water resources.

Compared with the available resources, water consumption levels are high, especially during the summer when water resources are limited. This shortage is exacerbated by the poor condition of the water distribution network; about half of the drinking water is lost before reaching the consumer. The country has only two water treatment plants of which only one, in Podgorica, is functioning. Elsewhere in the country municipalities pump their wastewater either into streams and rivers or infiltrate it into the ground.

Water shortages occur particularly in the coastal area during peak summer periods, while rural areas receive insufficient levels of coverage from public water supply systems (with poor water quality control for water from the rural water supply systems and other sources).

Quality of drinking water is regularly monitored for the public water supply systems in Montenegro, and quality requirements are in line with WHA and EU standards. In the coastal region only 56% of the population is connected to the sewerage network. The effluents are either discharged into the sea untreated or infiltrate into the ground from leaking network pipes. Discharge of communal and industrial wastewater into natural recipients occurs with almost no treatment – with the exception of some industrial plants and Podgorica communal wastewater.

Despite the existing pressures, surface waters are, generally speaking, of good quality.

Preservation of the quality and integrity of water resources is a significant challenge, especially bearing in mind the fact that water pollution and inadequate water abstraction in karst regions such as Montenegro can have permanent and serious consequences.

The coastal areas of the Republic of Montenegro are occupied by a number of communities, of which six municipalities are the largest, including Herceg Novi, Kotor, Tivat, Budva, Bar and Ulcinj. The population permanently resident in these communities reaches almost 165,000, but being important tourist resorts, peak population in the high season can significantly exceed this number .

UNESCO is contributing in Montenegro to another Italian sponsored initiative: the ADRICOSM-STAR project. Targeting the Montenegro coastal area, it aims to develop and partially implement an integrated coastal area, river and urban water management system. It also deals with transboundary issues such as the Bojana/ Buna river delta, managed by both Montenegro and Albania.

UNESCO has joined the ADRICOSM Partnership – a Type II Initiative, launched at the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 by the Italian Ministry for the Environment and Sea. The Partnership implements several projects based upon an integrated monitoring and modelling approach for the Adriatic coastal areas and overall river catchments, connecting land surface, underground and urban water systems with the marine environment for the assessment and management of the marine ecosystem and the water resources.

Despite the existing pressures, surface waters are, generally speaking, of good quality

UNESCO is contributing to the Partnership by coordinating the project component 'Aquifer Systems Model: simulation of aquifer flow that contributes to the coastal marine and submarine discharges in the Bojana Bay delta area'.

Objectives

The major environmental problems of interest addressed by the ADRICOSM Partnership are:

- Coastal area and river basin water quality
- The complex surface and underground water system and its influence on the coastal area
- Sediment transport, quality and distribution in the Bojana river and coastal area
- Management of water resources and water-ways (in particular the Bojana River)
- Planning of investments and emergency management in the coastal area.

The ADRICOSM Partnership has two general objectives:

1/ Efficiently organize, evaluate and coordinate multinational research, development and implementation programmes that advance the understanding, monitoring and predictive capabilities in the Adriatic Sea area for the establishment of integrated coastal areas and river basin management systems

2/ Consolidate the monitoring and prediction system by involving users of the research products.

Within this framework, the objectives of UNESCO's component are two-fold.

Firstly, to develop a mathematical model of the aquifers discharging into the Bojana Bay area and to simulate annual fluxes discharging into the Adriatic. UNESCO's specific component will contribute to developing a mathematical aquifer system model that supports the monitoring and forecasting system for urban and non-urban water impacts on the marine environment.

The second objective is to develop a package of responses for consideration, leading to increased resilience of the coastal marine ecosystems, in connection with the IPCC climate change scenario impact studies.

These will increase the sustainability of the coastal regions of Montenegro through sound and improved management of local aquifers, such that local environmental gains can be achieved in response to the anticipated significant economic growth expected in the coming years.

Activities

The ADRICOSM Project will explore each compartment via an observational and modelling programme for the urban, surface and underground water and coastal currents in the Bojana river catchment and Montenegro coastal area. Particular effort will be put into the monitoring and modelling of the Bojana river delta area and the modelling of the underground water system. In addition, atmospheric hydrological modelling will be developed for surface run-off in order to increase predictive capabilities.

Furthermore, with the anticipated increase in climatic variability in the region and frequent flood and drought events, the water in local aquifers can be a driver for environmental sustainability – both from the socio-cultural aspect, as well as from the perspective of coastal and marine biodiversity. The high quality, karstic springs, many of which are submarine, support a diversity of coastal and marine ecosystems. These ecosystems are at threat from rapid urbanization and climatic changes. The project coordinated by UNESCO will assist in reinforcing the resilience of coastal ecosystems through a vulnerability assessment of the coastal aquifers, and will provide solutions for adoption by the municipalities, through a process of public participation.

The project activities will be managed and implemented in several parts, in response to the ADRICOSM Programme, and will be based around the following components:

I/ Scoping and problem definition

II/ Identification of key model parameters and design criteria

III/ Capacity development to adopt and implement the model and its findings.

It is expected that the ***Component I*** activities will include:

- Compilation of an information database (hydrogeology, socio-economic, etc.)
- Identification of data gaps
- Field reconnaissance survey (limited to essential needs)
- Field data collection (as appropriate through Montenegro authorities)
- Identification of all relevant water resources and aquatic habitat issues
- Qualitative assessment of coastal zones including saline intrusion and contamination in the catchment areas of the coastal spring systems
- Identification of stakeholders in the project area
- Preparation of Scoping Report and key issues.

The Bojana river (right) delta & basin (below)

Component II activities will commence as soon as the Scoping Report has been adopted by the main stakeholders and will commence with the development of the model structure, including:

- Definition of the model system based on an agreed conceptual framework
- Definition of the modelling grid to be adopted for the area under consideration, including spatial and vertical distribution
- Design of the model flux zones that will indicate the zones of aquifer discharge from the terrestrial component into the marine
- Hydrological inputs to the systems, from precipitation, recharge zones, river-bed infiltration and outputs due to abstraction, natural outflows to rivers and stream and submarine seepages.

Once the model development approach and initial configuration of the simulation system have been presented in an interim report and reviewed by the local authorities, ***Component III*** will carry out capacity development and strengthening, including any necessary model implementation. Activities will include:

- A series of informative and educational workshops
- Outreach and public information
- Presentation of approaches and planned model simulation runs
- Simulation of the required scenarios for the IPCC
- Final report on the project implementation.

Expected outcomes

- A developed and validated model of the aquifer system that contributes to the marine discharges to the coastal currents in the Montenegro coastal area
- Protected and sustainable coastal aquifers – and the ecosystems dependent on them – as part of the long-term response to future climate variability
- Strengthened capacities of governmental agencies
- Higher resilience of coastal ecosystems
- Availability of planning tools with wider regional and national application
- Reduced environmental costs.

With anticipated increase in climatic variability in the region and frequent flood and drought events, the water in local aquifers can be a driver for environmental sustainability – both from the socio-cultural aspect, as well as from the perspective of coastal and marine biodiversity

Sustainable management of coastal aquifers and protection of groundwater-dependent wetlands: **case study in Morocco**

Background

In Morocco, inadequate water supplies and wastewater disposal, both in quantitative and qualitative terms, pose a health hazard to the population. At the present time, only two-thirds of Morocco's 29 million inhabitants have year-round access to safe drinking water.

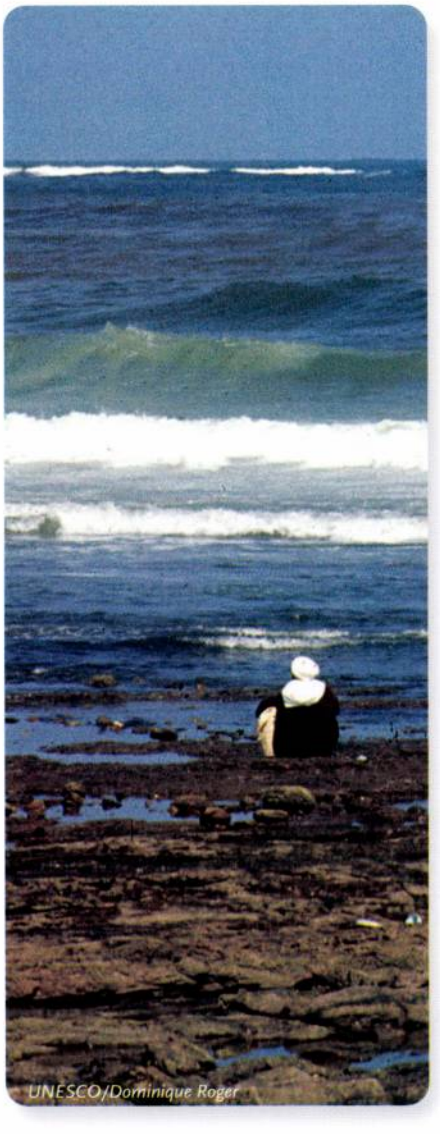
Climatic change combined with population growth will increase pressure on the available water resources. Impacts on these resources will affect surface and groundwater supplies for domestic, irrigation, industrial, water-based recreation, and other uses.

Average annual rainfall is 340 mm, but varies from more than 450 mm in the north, where rain-fed agriculture is possible, to less than 150 mm towards the south-east, where irrigation is absolutely necessary. Over 50% of the precipitation is concentrated on only 15% of the country's area. Per capita water allocation is around 700 cubic metres annually.

Available water resources in Morocco are estimated at around 30 km^3/year, out of which 16 km^3 of surface water and 5 km^3 of groundwater are considered to represent water development potential. Of the total water availability, 90 % is withdrawn for agricultural purposes. The most important rivers are equipped with dams, allowing surface water to be stored for use during the dry seasons.

Groundwater resources are contained in thirty-two deep aquifers and forty-six shallow aquifers. Groundwater is generally overexploited leading to lower water tables and deterioration in water quality. Around 50% of groundwater resources are located in the north and centre of the country. Underground water sources are of poor quality due to high salinity and nitrate concentrations. As with other countries in the region, the major pollution sources for surface water and groundwater are municipal wastewater discharge, industrial effluents and agricultural activities. The uncontrolled discharge of solid waste also contributes to the degradation of water quality.

Wetlands and ecosystems dependent on groundwater are particularly fragile in the coastal areas where exploitation and unsustainable water resource management practices threaten their sustainable development. Therefore, an accurate knowledge of coastal aquifer characteristics and dynamics is necessary to assess the vulnerability of the aquifer systems and to set up appropriate methodologies for efficient management and protection of groundwater resources and groundwater-dependent wetlands and ecosystems.

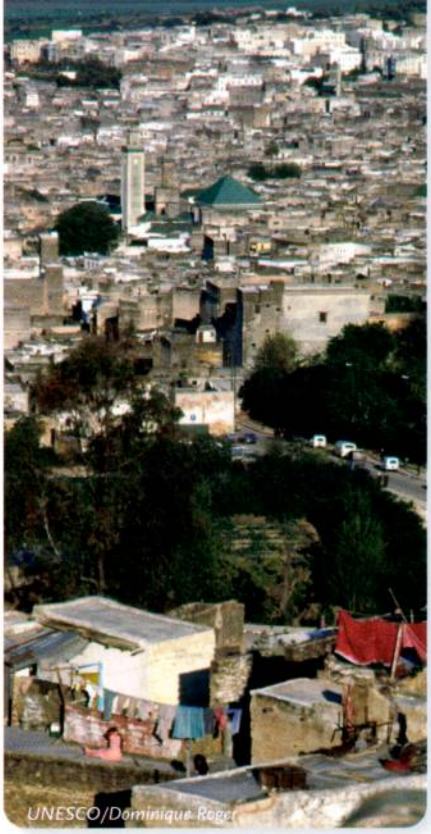

UNESCO/Dominique Roger

The protection and conservation of the Mediterranean wetlands can only be carried out with an integral knowledge of their geological and hydrogeological properties and dynamic functioning.

Knowledge bases for the study and subsequent classification of wetlands should not be based only on functional elements, such as hydrologic factors; elements concerning origin and wetland structure, such as geological, hydrogeological and geomorphic factors, should also be analysed.

It is intended that classification of wetlands be based mainly on hydrogeologic characterizations of these ecosystems. This is due to the interest in understanding and valuing the close relations between groundwater and wetlands.

This project intends to promote the implementation of the Ramsar recommendations, as approved during the 8th Meeting of the Conference of the Parties (Valencia, Spain, 2002), where the assembly adopted Resolution VIII.19 on Wetland Cultural Heritage – 'Guiding principles for taking account the cultural values of wetlands for the effective management of sites'. The principles provide detailed guidelines for site management, as well as specific advice for each category of cultural value.


UNESCO/Dominique Roger

This project should therefore be considered a major opportunity to acquire the necessary knowledge on interactions between groundwater resources, Mediterranean wetlands and the sustainable management of water resources in coastal areas.

Objectives

In order to establish a framework for environmental, sustainable management of coastal water resources in Morocco, the project will address the following objectives:

- Development of new methodologies for the sustainable management of coastal groundwater resources including the evaluation of aquifer characteristics, vulnerability mapping, and identification of external hazards and risks
- Enhancement of water resource management capacities in the country and region through training and capacity-building actions
- Linking up with other activities to be developed by other components of the present UNESCO-IMET project on coastal aquifer vulnerability, with the aim of enhancing cooperation between Morocco, Algeria and Tunisia in coastal aquifer management
- Improvement of north-south transfer of knowledge and expertise and dissemination of case study results.

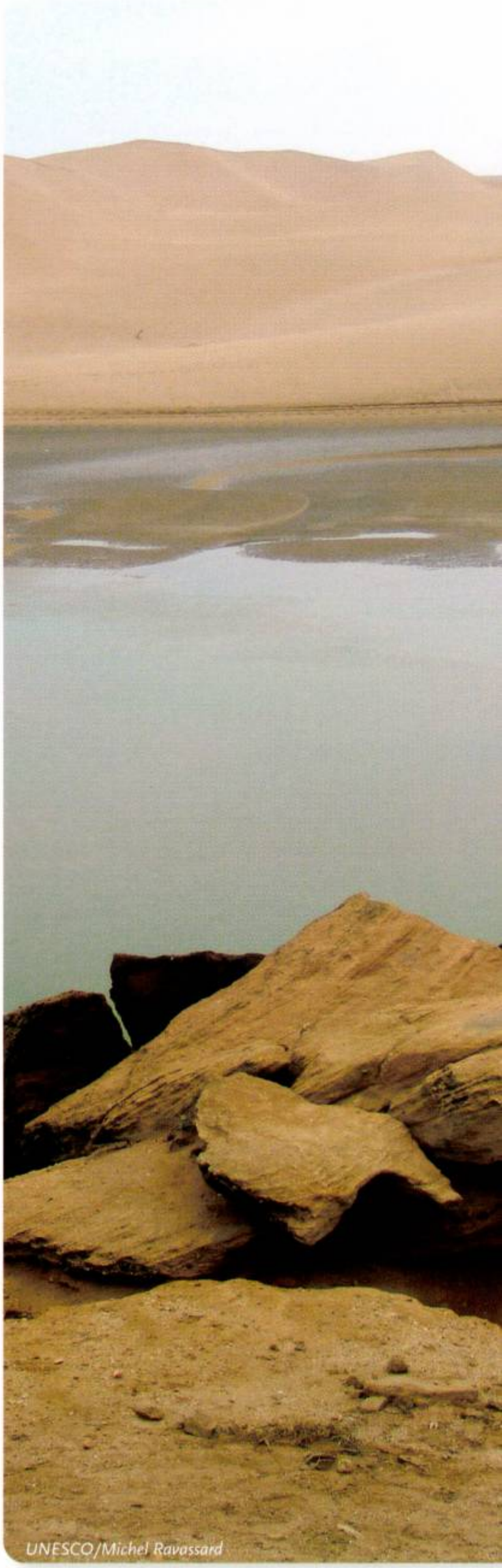
At present, only two-thirds of Morocco's 29 million inhabitants have year-round access to safe drinking water

Activities

- *Analyse the geological and hydrogeological characteristics of the Morocco wetlands, in order to classify and typify them from a hydrogeological perspective*
- *Establish a methodology for the preparation of a vulnerability map of one selected coastal aquifer supporting a coastal wetland*
- *Establish a training course on aquifer vulnerability mapping with the support of Italian experts*
- *Set up a north-south coordination mechanism to transfer knowledge between Italian and Morocco related institutions.*

Expected outcomes

- Methodologies and mechanisms for sustainable management of groundwater and wetlands
- Methodology for coastal aquifer vulnerability mapping and training material.


UNESCO/Michel Ravassard

Adaptation measures to overcome climate change impacts: case study on aquifer recharge management in Tunisia

Background

Tunisia is a middle-income country located on the southern rim of the Mediterranean Sea. It has a population of little more than 10 million that is growing at about 1.1% per year. Tunisia has a semi-arid climate and few renewable natural resources. With per capita freshwater availability of around 450 m³, Tunisia is one of the most drought-stressed countries in the Middle East and North Africa (MENA) region. The annual rainfall varies from 600 mm in the north (400 mm in Tunis) to 100 mm in the southern region. The population is relatively urbanized, with 58% living in urban areas on the northern and eastern coasts.

The hydrographic system in Tunisia is dense in the north with the Medjerda River being the most important water course. This zone is also where principal irrigation development and flood protection works have been carried out.

As in most other water-stressed countries, agriculture accounts for the bulk of water consumption. Excessive groundwater extraction in coastal regions has resulted in saline intrusion in many areas, leading to groundwater being rendered unsuitable for further irrigation. Water quality, especially salinity, is a serious constraint. Saline irrigation water reduces crop yields and requires the installation of costly drainage systems to maintain soil fertility. The effect of salinity on the water balance is an important consideration for Tunisia's water resource planning. With an increasing population, rapid urbanization, and rise in living standards, developing additional water resources is imperative.

Wetlands and ecosystems dependent on groundwater are particularly fragile in coastal areas where exploitation and unsustainable water resource management practices threaten their sustainable development. Therefore an accurate knowledge of the characteristics and dynamics of coastal aquifers is necessary to assess the vulnerability of the aquifer systems, and to set up appropriate methodologies for the efficient management and protection of groundwater resources and groundwater-dependent wetlands and ecosystems.

As a direct corollary of the above, UNESCO will focus on the Ghar El Melh lagoon for the Tunisian component of WPA II .

The Ghar El Melh lagoon is a Mediterranean water body, situated in north-eastern Tunisia. Due to a combination of the shape of the coastline and alluvium deposits from the Medjerda River, this small gulf has become progressively closed from the marine environment, causing the lagoon to adopt its present morphology. The coastal barrier separating the lagoon from the Mediterranean Sea was interrupted, allowing a permanent hydraulic communication across a local opening. The lagoon ecosystem has suffered progressive deterioration due to human activities in the surrounding area and within the lagoon itself. This has led to a reduction in biodiversity resulting mainly in a decrease in fish resources and production.

Objectives

The necessity of preserving this important water resource requires local authorities to gain a complete understanding of the vulnerability of the aquifer system so as to develop forms of sustainable exploitation, as well as innovative adaptation techniques to mitigate the effects of climate change and climate variability.

Hence, the objective of this project is to assist Tunisian counterparts in undertaking a complete assessment of the salinization problem and intrinsic or natural vulnerabilities – in other words, the specific susceptibility of an aquifer system to ingest and diffuse hydro-vectored contaminants whose impact on the groundwater quality is a function of space and time.

With per capita freshwater availability of around 450 m^3, Tunisia is one of the most drought-stressed countries in the Middle East and North Africa region

Activities

The assessment of the intrinsic vulnerability has to be performed through a classic zoning technique via a geographic information system (GIS), using available parameters elaborated by a count point system model. Detailed activities include:

Data acquisition, GIS data elaborations
All the collected available data necessary to evaluate aquifer vulnerability will be added to a database, enabling a global overview of available data, and identification of any area with insufficient data coverage.

All the collected data will be eventually integrated with new surveys, elaborated using the GIS system, to reconstruct hydrogeological structures and compare their hydrogeochemical characterization.

Mapping of hazardous points and individuation of the main targets of risk
A comprehensive database with hydrogeological data wells and springs and hazardous points will be created in collaboration with Tunisian partners. This will be the starting point for evaluating groundwater vulnerability to pollution and saline intrusion, and to assess the global risk. This will be accomplished by georeferencing using GIS and by adding all the information concerning the products, waste, water used for industrial processes, domestic use and hydrogechemical characteristics.

Water Balance: estimation of availability of groundwater resources
The GIS system will enable understanding of the aquifer water balance, and allow an insight into marine salt-water intrusion into coastal aquifers and an estimation of groundwater resource availability. An estimation of the water balance that could be exploited without damaging the aquifer system will also be carried out. The limits of the aquifers and their hydrogeological characteristics (permeability, transmissivity, depth to water, conductivity, thickness, etc.) will thereby be delineated and identified. This will be the basis for defining usage (agricultural, industrial and human supply) and quantity for use.

Expected outcomes

The project will formulate a replication methodology for the preparation of the vulnerability map of the selected coastal aquifer that supports the Ghar El Melh lagoon.

The outputs supplied to decision-makers consist of a groundwater vulnerability integrated map of the single involved municipality territory, and the option of performing dynamic scenarios of any area in the investigated zone to enforce proper actions to prevent contamination impacts. Authorities will thereby have a powerful tool to develop adaptation measures to climate change impacts on water resources.

Evaluation of groundwater vulnerability to pollution and saltwater intrusion

Groundwater vulnerability to pollution will be evaluated using parametric methods. Vulnerability is linked to the capacity of an aquifer to defend itself from a pollutant, which infiltrates from the surface. This is therefore linked to the time of travel from the surface to the groundwater. The first step is the Intrinsic Vulnerability Map. To obtain this, the collected data regarding Contamination Spreading Centres (CSC) due to human activities are overlapped using GIS.

It is clear that groundwater quality depends on its chemical characteristics. Therefore, in coastal areas, it is important to study saltwater intrusion and understand its interaction with aquifers.

Global risk assessment

Once all the previously described steps have been completed, an assessment to evaluate the global risk of the aquifer will be undertaken – a combination of the single risks and their effects on pollutant distribution. On the basis of this, it will be possible to define a water plan to use and defend the water resource.

Activities will also include a training course on aquifer vulnerability mapping with the support of Italian experts. The training activities may also include a capacity-building component on aquifer artificial recharge and management of aquifer recharge enhancement (MAR).

It is clear that groundwater quality depends on its chemical characteristics. Therefore, in coastal areas, it is important to study saltwater intrusion and understand its interaction with aquifers

The latest report of the Intergovernmental Panel on Climate Change (IPCC) concluded that humankind's emissions of greenhouse gases are more than 90% likely to be the main cause, and that climate change is 'unequivocal' and may bring 'abrupt and irreversible' impacts.

Yann Arthus-Bertrand/La terre vue du ciel

Climate variability and adaptation measures: managing groundwater resources through artificial recharge in Viet Nam

Background

The distribution of water resources in Viet Nam during the year is highly variable due to unevenly distributed monsoon rainfalls. High variations combined with limited storage and flood control infrastructure result in devastating floods in the wet season and extreme low flows in the dry season. About 70-75% of the annual runoff is generated in three to four months.

Groundwater recharge in the country is estimated at 48 km³/year. Over 50% of these resources are located in the central part of the country, about 40% in the north, and 10% in the south. A large amount of water is stored in unconsolidated alluvial sand and gravel geological formations found in plains and valleys. A substantial part of these resources (estimated at 35 km³/year) returns to the rivers as base flow. The exploitable reserves (the volume of flows of satisfactory quality which can be extracted economically given the present technology) are estimated at about 6–7 km³/year.

Due to high climatic variations between the wet season and the extreme low flows in the dry season, the Vietnamese Government is looking for new ways to store excess water from wet seasons in groundwater systems to reuse during the dry season for agriculture and drinking water. Under these circumstances, artificial recharge appears to be the most suitable solution.

The present activities are a follow-up to the project carried out under the First Phase of the UNESCO–Italy Partnership ('Water Programme for Africa, Arid and Water Scarce Zones' 2005–07).

The project positively contributed to the development of Managed Aquifer Recharge (MAR) in Viet Nam with the involvement of several Vietnamese scientists from different scientific institutions, in terms of applied research, participation in local training courses organized in the project framework, and participation in international meetings and workshops.

In particular, a pilot project on artificial recharge was implemented in the Binh Thuan province (central-eastern Viet Nam). The area was affected by severe desertification as a result of clear-cutting of the tropical forest in 1975, leading to shortage during the dry season, and rapid runoff and high evaporation rates in the wet season.

Having geologically and hydrogeological assessed the area, drilled four observation wells and undertaken related pumping operations, the project demonstrated that the use of artificial recharge through bank filtration techniques was viable for the production of approximately 200 m³/day of potable water.

Activities

The new activities represent the follow-up to the First Phase as mentioned above, which achieved the following results:

- *Assessment methodologies and effectiveness of groundwater management through groundwater recharge technologies*
- *Supplying two villages periodically affected by long-standing droughts with good quality water.*

One of the main features of the current Second Phase of the partnership is addressing climate variability by identifying adaptation measures, best practices on ecosystems rehabilitation, and remediation techniques to restore aquifer systems and groundwater storage capacity.

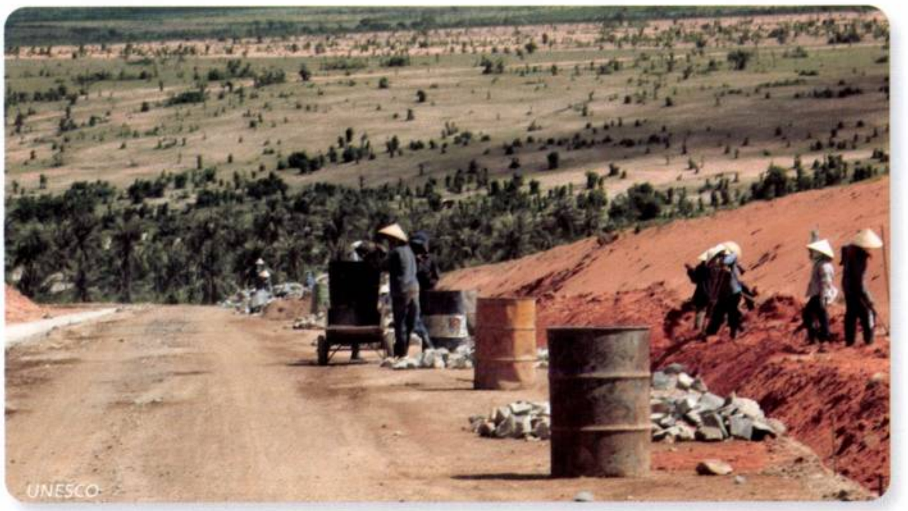
The present Viet Nam component will include the development of extensive geological, geophysical and hydro-geological investigations. These will include, among others:

- *Acquisition and interpretation of existing data*
- *Groundwater quality and quantity analysis (chemical, bacteriological and isotopic analyses) together with meteorological observation (rainfall and evaporation).*

The selected site is the Hong Phong sub-district (Bac Binh district, Binh Thuan province), located about 25 km north east of Phan Tiet. The area of approximately 300 km^2 encompasses three villages.

The activities foresee also a capacity-building programme, the organization of training on the sustainable use of groundwater resources, and the integration of social, environmental and economic aspects. Training will be held at the University of Ho Chi Minh and the Geophysics Institute of the University of Hanoi. This will enable knowledge transfer and experience exchange on groundwater resources management by artificial recharge with local scientists.

A dissemination component is also envisaged which should enable the general public to access information about artificial recharge, and its role with regard to water management.


UNESCO


UNESCO/G Arduino

Objectives

The overall objective of the project is to bring relief to the water scarce afflicted area of the Hong Phong sub-district, and to identify suitable best practices for groundwater management.

The above-illustrated activities will identify viable portions of the project area, introduce groundwater recharge solutions and assess their effectiveness, as an overall contribution to the multiple water needs of the Binh Thuan province (poor water supply and desertification).

Expected outcomes

The project will provide access to further information and establish a network of young scientists actively involved in groundwater management through the organization of a training course.

The capacity-building workshop will provide a preliminary analysis of the consideration of water issues within the complex process of sustainable development as related to a specific area: South-East Asia.

In particular, this project will provide Vietnamese scientists with a case study on climate variability adaptation measures. This review will contribute to the identification of the best and most viable practices for artificial recharge management.

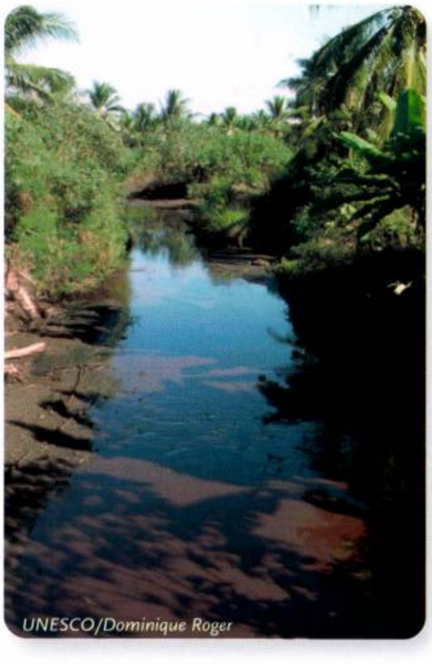
The Trialogue Model as a tool for building capacity and harvesting best practices in the field of **groundwater management in southern Africa**

Background

Yann Arthus-Bertrand/La terre vue du ciel

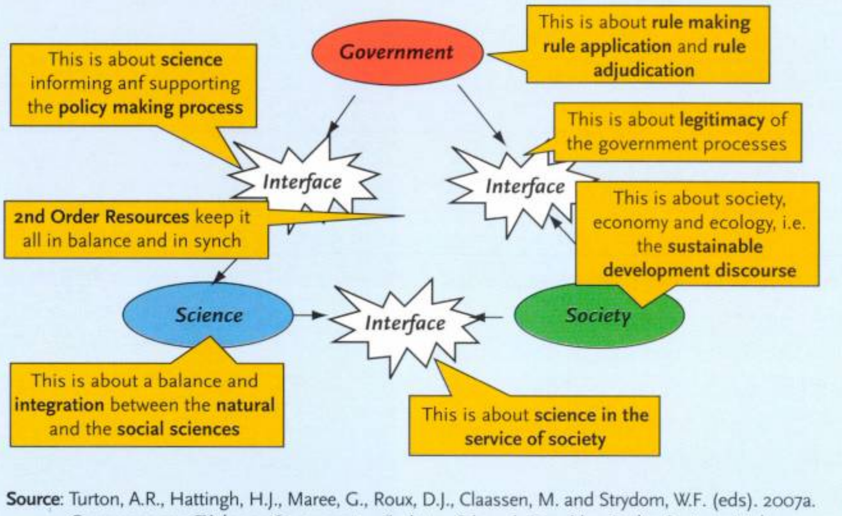
A significant portion of the water resource-base of the southern African region is groundwater – specifically where poverty levels are high and vulnerability to external shocks such as those being anticipated by global climate change are expected to be the greatest. This places groundwater in a specific category that is as yet largely unexplored. A specific hydrological reality in this regard is groundwater recharge and the conversion of precipitation to either infiltration or runoff. In fact, the region has the lowest conversion of precipitation to recharge and runoff in the world. In recent work undertaken in the region, a non-linear relationship was found to exist between precipitation and recharge. This poses serious questions for decision-makers in the region where economic growth is needed for political stability, but where resource constraints already limit this potential growth, because changes in rainfall can push large areas across the 'threshold' of 450 mm. This propels the problem of groundwater management to the highest level of strategic-management in southern Africa.

Government is responsible for making authoritative decisions on behalf of society. Society consists of organized groups such as economic actors, but also individuals as citizens. Science consists of both formal and traditional knowledge structures. The real significance of these three actor-clusters is the interface that exists between each. More importantly, it is the quality of these interfaces that drives the outcome of unanticipated shocks to the system like global climate change. This model has been applied to groundwater by exploring different roles that government can allow science to play in reaching an acceptable and non-contested outcome.



UNESCO/Dominique Roger

Figure 1: *the Trialogue Model showing the three actor-clusters and interfaces*



Source: Turton, A.R., Hattingh, H.J., Maree, G., Roux, D.J., Claassen, M. and Strydom, W.F. (eds). 2007a. *Governance as a Trialogue: Government – Society – Science in Transition*. Berlin: Springer Verlag.

Objectives

The objective of the proposed project is to develop core capacity in the southern African region in the field of groundwater management using the Trialogue Model to generate adaptive solutions that are socially acceptable, technically feasible and politically stable in their outcome.

For the purpose of this project proposal, 'transboundary water issues' is defined as 'the management needs arising from the problematique associated with the natural flow of water across an artificial jurisdictional boundary'. This means that there are three distinct levels of scale that will be dealt with separately:

1/ International (natural flows across international political borders where sovereignty becomes a key factor)

2/ Sub-national (natural flows across sub-sovereign jurisdictional boundaries such as provinces)

3/ Inter-sectoral (natural flows across sectoral boundaries where each sector might be governed by different ministries with competing objectives).

UNESCO/Inez Forbes

Activities

In order to reach the stated objective, a series of activities are planned as follows:

Activity 1/

Building a team of trainers and facilitators to develop the capacity at present locked away in different components of southern African society. A sub-task is the development of a database of expertise and needs in the region.

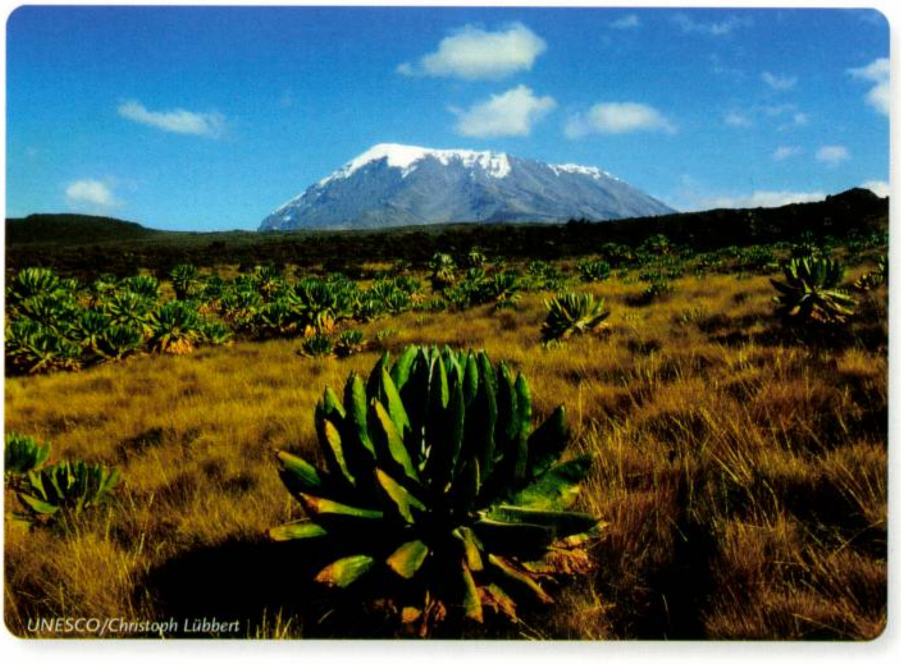
Activity 2/ *Stakeholder Workshop*

This will bring together select individuals from three distinct actor-clusters – Government, Society and Science – commensurate with the Trialogue Model, in a workshop that is highly interactive and therefore conducive to the transfer of skills and knowledge across the three 'interfaces' of the Trialogue. That workshop will consist of five sessions as follows:

- *Opening plenary session*
  The objectives are explained and the ice is broken
- *Parallel Session 1*
  International level focusing on transboundary issues arising from state sovereignty
- *Parallel Session 2*
  Sub-national level focusing on transboundary issues arising from sub-sovereign provincial jurisdictions
- *Parallel Session 3*
  Inter-sectoral level focusing on mine and industrial water flowing into the agricultural and domestic sectors where different government departments are involved
- *Closing plenary session*
  The objectives will be revisited and the conclusions presented.

Activity 3/ *Project wrap-up*

This will involve report writing and dissemination of the workshop results to all stakeholders and the finalization of all administrative matters arising from the funding contract.



UNESCO/Christoph Lübbert

Expected outcomes

The outcomes of this project will be as follows:

Activity 1

- A database of expertise and needs in the groundwater field in the southern African region
- A core team of qualified trainers and facilitators with the necessary expertise, credibility and legitimacy to perform their work in the region.

Activity 2

- A workshop in which the key question stated in the word box above is answered
- An experienced set of facilitators familiar with the core problems and with the necessary skills to be involved in future capacity-building exercises
- A coherent set of issues that reflect the key concerns of each of the three actor-clusters in the Trialogue – Government, Society and Science

UNESCO/Béatrice Petit

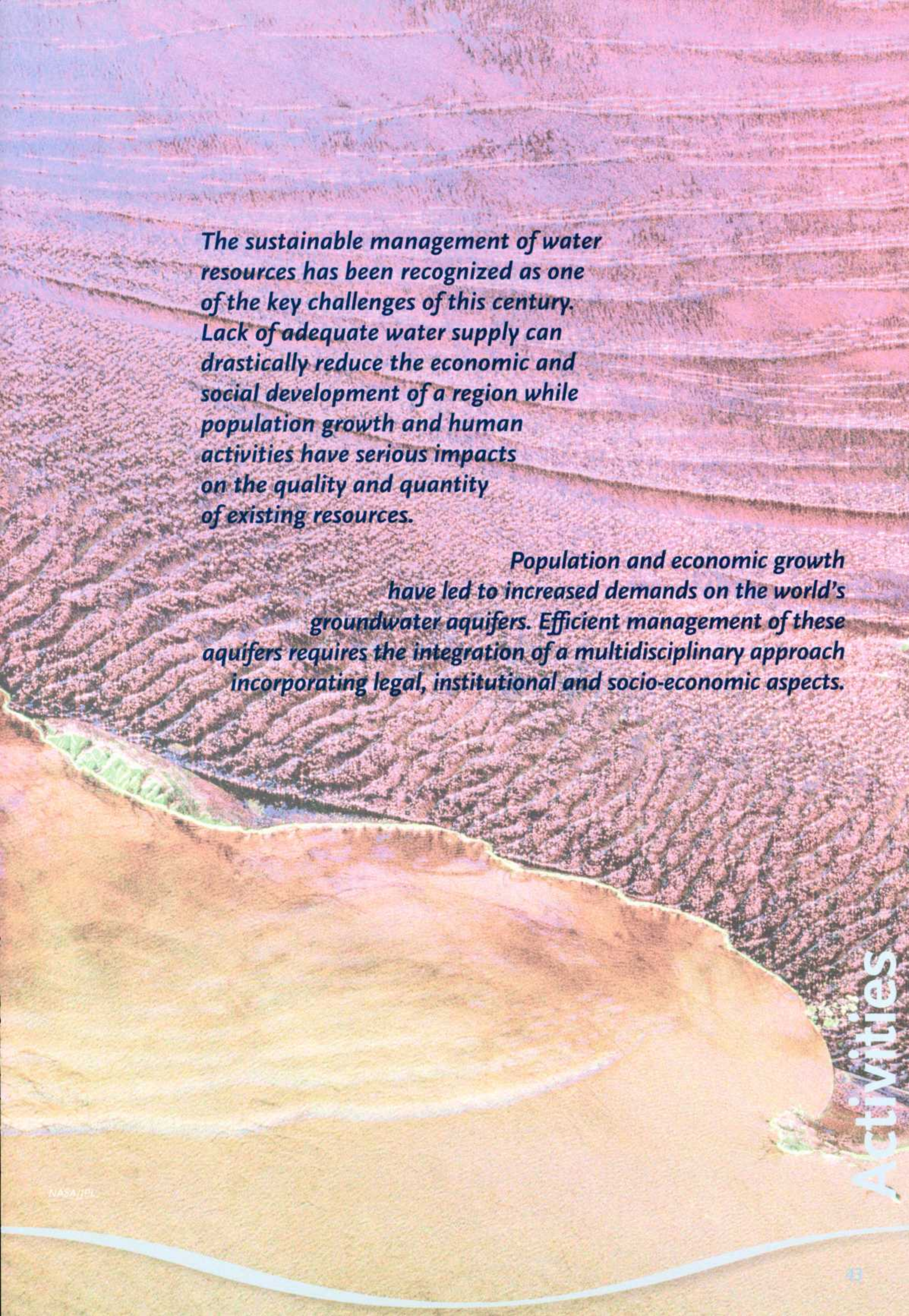
UNESCO/Salvatore D'Angelo

- An experience recorded and shared by all participating stakeholders – many of whom will be key decision-makers or opinion leaders in their respective actor-clusters
- A report of best practices gathered during the process
- A report on best practices and experiences that will become the foundation of future capacity-building programmes in the region.

Activity 3

- An accurately recorded product that captures the key lessons learned and makes it available for dissemination to all key stakeholders.
- A training manual listing best practices for future use in the region.
- Completed staff work to the full satisfaction of the donor.

Yann Arthus-Bertrand/La terre vue du ciel



NASA/JPL

The sustainable management of water resources has been recognized as one of the key challenges of this century. Lack of adequate water supply can drastically reduce the economic and social development of a region while population growth and human activities have serious impacts on the quality and quantity of existing resources.

Population and economic growth have led to increased demands on the world's groundwater aquifers. Efficient management of these aquifers requires the integration of a multidisciplinary approach incorporating legal, institutional and socio-economic aspects.

Activities

Setting up methodologies for environmental sustainability in support of the United Nations Convention on Climate Change and the Kyoto Protocol

NASA/GSFC/Craig Mayhew & Robert Simmon

Background

Global electricity demand is rising, particularly in the developing world, where population and economic growth are greater than in developed countries and where the rate of migration from rural to urban areas is significantly higher. Developing and developed countries alike can be expected to continue using their abundant coal reserves. In the absence of action, carbon dioxide (CO_2) levels can be expected to continue increasing. Most climate change scenarios suggest that reductions in CO_2 emissions as required by the Kyoto Protocol cannot be achieved by only increasing efficiency, switching to non-fossil fuels, and cutting outputs of CO_2.

Over the past years geological storage of carbon dioxide has gained much interest as a viable and technically feasible means of reducing the emissions of CO_2 into the atmosphere and mitigating climate change.

When describing CO_2 in geological formations and oceans, the term 'CO_2 storage' is used. It is now commonly accepted that 'sequestration' refers only to the terrestrial storage of CO_2. Underground storage of CO_2 – that is, the storage location and long-term isolation from the atmosphere – has taken place for many years as a consequence of injecting CO_2 into oil fields to enhance recovery. Pilot and demonstration projects are underway that adopt technologies for CO_2 storage in:

- *salt-water reservoirs*
- *unminable coal beds*
- *depleted oil and gas fields.*

Reductions in CO_2 emissions as required by the Kyoto protocol cannot be achieved by only increasing efficiency, switching to non-fossil fuels, and cutting outputs of CO_2

Deep saline aquifers

Deep salt-water reservoirs have the potential to provide significant worldwide storage capacity at relatively little cost. Confidence is growing that CO_2 could be stored safely for thousands of years in carefully selected reservoirs.

Sedimentary rocks such as sandstone and limestone have sufficient porosity to be considered for CO_2 storage. Many of these reservoirs contain salt-

Recent studies suggest that the storage capacity of geological reservoirs in north-west Europe alone could be as high as 800 Gtonne CO_2

water. If CO_2 is injected into these reservoirs some will dissolve in the saline water and become widely dispersed in the reservoir. Injected CO_2 can also react with the minerals within the reservoir and form solid carbonates. The most suitable reservoirs are those at depths greater than 800 m, as the CO_2 will behave more like a liquid than a gas, enabling the storage of greater amounts.

Recent studies suggest that the storage capacity of geological reservoirs in north-west Europe alone could be as high as 800 Gtonne CO_2. Research activities are underway in Europe and Australia to map and assess the storage capacity of offshore saltwater reservoirs while similar research in Canada and the United States is looking at onshore saltwater reservoirs. However, further investigation is needed to assess worldwide potential.

Open issues

For CO_2 storage the priority is to establish its credibility and acceptability for safe, reliable, long-term storage and as a cost-effective solution. Storage permanence, the environmental risks involved, and necessary monitoring are still open issues. Certain potential storage sites may not leak at all, while others may do so at an unforeseen rate. At the moment, insufficient information is available to quantify leakage from CO_2 storage sites. It is possible, however, to quantify upper limits for leakage and to draw conclusions from these theoretical limits and the experimental information available so far. Modelling studies should carefully evaluate aquifer properties such as thickness, porosity and permeability.

Safety and environment

Geological storage needs to be able to deliver large capacity with reliability and safety. The risk of a large-scale sudden release of CO_2 can be avoided by careful selection of storage reservoirs. For example, storage in regions that are liable to tectonic or seismic activity should be avoided. Any selection procedure needs to consider:

- Integrity of the overlying cap rock
- Regional geology and possible faulting
- Groundwater flow
- Retention time
- Risk elements
- Good methods for risk assessment.

The central issue is to gain public acceptance for CO_2 capture and storage. Two key areas will need to be demonstrated: that the technology is safe and that its environmental impact is limited. Safety can be demonstrated to some extent through monitoring programmes at CO_2 injection operations that are currently underway. However, while early results from these injection operations indicate leakage is not occurring, such programmes do not necessarily provide confidence in the long term, in other words, 1000 years after injection has ceased. Risk assessment (RA) studies can assist the development of monitoring programmes for injection sites, relying on predictions of the long-term fate of the injected CO_2 and assessing the potential for leakage in both the short and long term.

Monitoring and verification

The monitoring of CO_2 injected into geological formations is an important part of the overall risk management strategy for geological storage projects. As CO_2 storage becomes more widely implemented, regulatory bodies will require that detailed monitoring programmes are put into place to ensure that the health and safety of both operating staff and the general public are assured. It must also be possible to verify the amount of CO_2 being stored, which will require sophisticated monitoring. In addition, if organizations wish to gain credits for the CO_2 that is injected, monitoring of the injected CO_2 will be necessary to ensure that emission reduction credits can be validated and any leakage be accounted for in both the credit awards and in national inventories.

Research activities are underway in Europe and Australia to map and assess the storage capacity of offshore saltwater reservoirs while similar research in Canada and the United States is looking at on-shore saltwater reservoirs

The sampling of groundwater and the soil between the surface and water table may be useful – among others (measurement of technical parameters, seismic surveys, etc.) – for directly detecting CO_2 leakage. Surface-based techniques may also be used for detecting and quantifying surface releases. However, it is becoming clear that no single technique would be sufficient to meet all the different monitoring needs. Therefore, there is a need to focus on monitoring programmes rather than individual techniques.

Role of hydrology

Hydrogeologists have for a long time been dealing with issues associated with CO_2 injection schemes, such as: regional flow systems with layered aquifers, inter-phase mass transfer and associated miscible transport and complex geochemical reactions. Hydrogeologists are therefore ideally positioned to contribute vital research to determine the suitability of this proposed solution to the problem of global warming. If this technological solution is to succeed, hydrogeology can provide assurances and make credible assessments of environmental risks to help it achieve public acceptance.

Activities

In view of all the above, it will establish an international expert group under its leadership to improve knowledge of aquifer systems in view of carbon mitigation. UNESCO will provide a forum for experts and decision-makers to discuss the role of CO_2 storage in geological formations. It is foreseen that this expert group will:

1/ exchange information and create networks

2/ perform a study of selected case studies of carbon storage in deep-saline aquifers

3/ weigh the different methodologies adopted, and evaluate the employed practice

4/ address barriers and critical issues that may hamper the advancement of carbon storage in deep saline aquifers

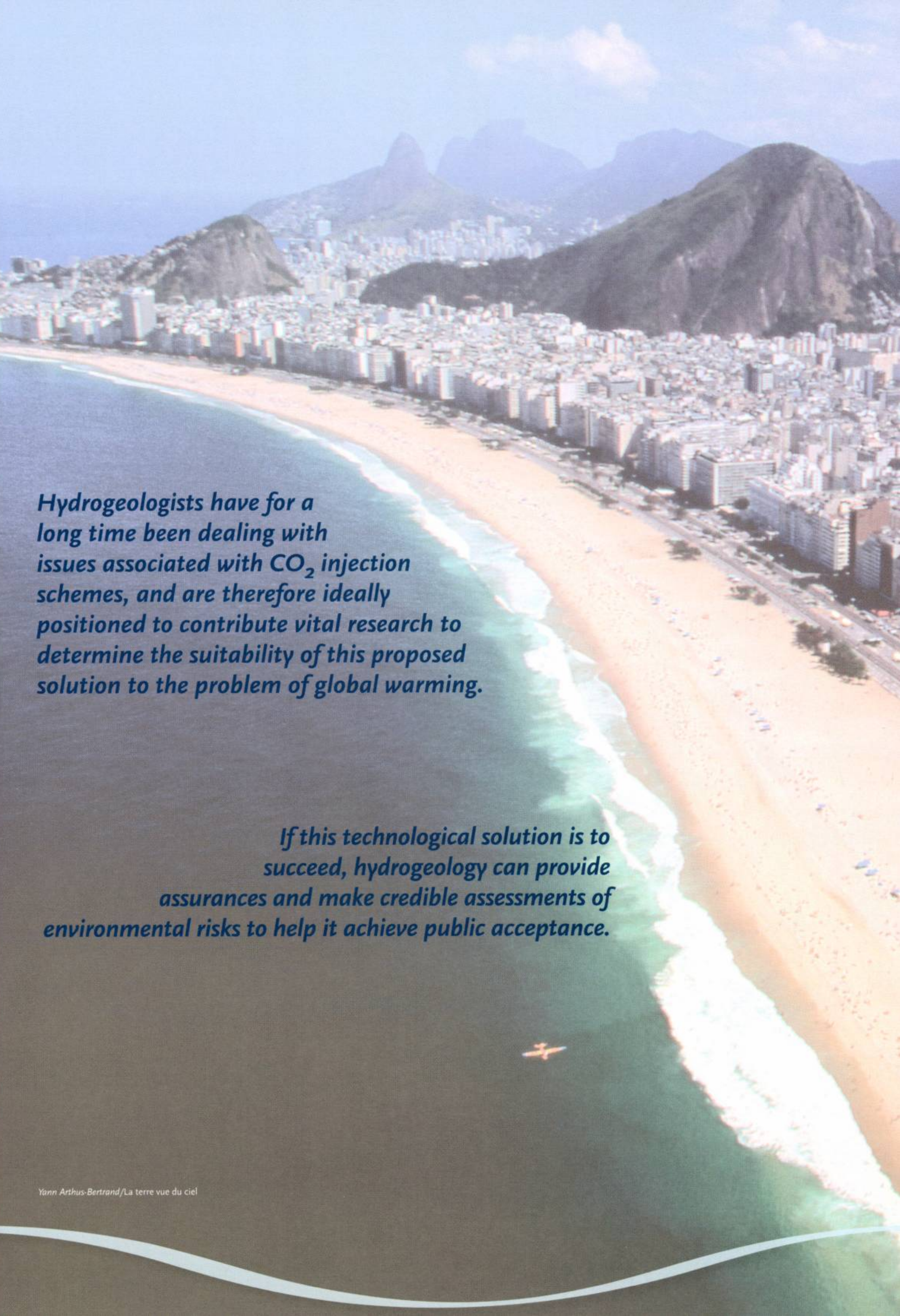
5/ elaborate proposals, draft guidelines and introduce recommendations for the wider deployment of such technologies, including to developing countries.

Objectives

The main objective is to contribute to the identification of guidelines on aquifer systems for the use of carbon storage in saline aquifers as a vehicle to reduce the impact of climate change. This is to be achieved by improving the present understanding and knowledge of all problems linked to this technology. This is also important in order to get the regulatory mechanisms in place.

Expected outcomes

- A series of policy options and re search requirements and pilot case studies for the effective adoption of this technology in light of the objectives of the UN Framework on Climate Change and relevant Millennium Development Goals.



Hydrogeologists have for a long time been dealing with issues associated with CO_2 injection schemes, and are therefore ideally positioned to contribute vital research to determine the suitability of this proposed solution to the problem of global warming.

If this technological solution is to succeed, hydrogeology can provide assurances and make credible assessments of environmental risks to help it achieve public acceptance.

Yann Arthus-Bertrand/La terre vue du ciel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If we take up the challenge, the positive impact will reverberate far beyond better access to clean water. Every dollar invested in water and sanitation yields an estimated seven dollars worth of productive activity. And that comes on top of the immeasurable gains in cutting poverty, improving health and raising living standards.

Ban Ki-moon

UN Secretary-General's message on World Water Day 22/03/2008

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