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WATER AND ECONOMY

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Water Monographies

WATER AND ECONOMY

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EDITORIAL

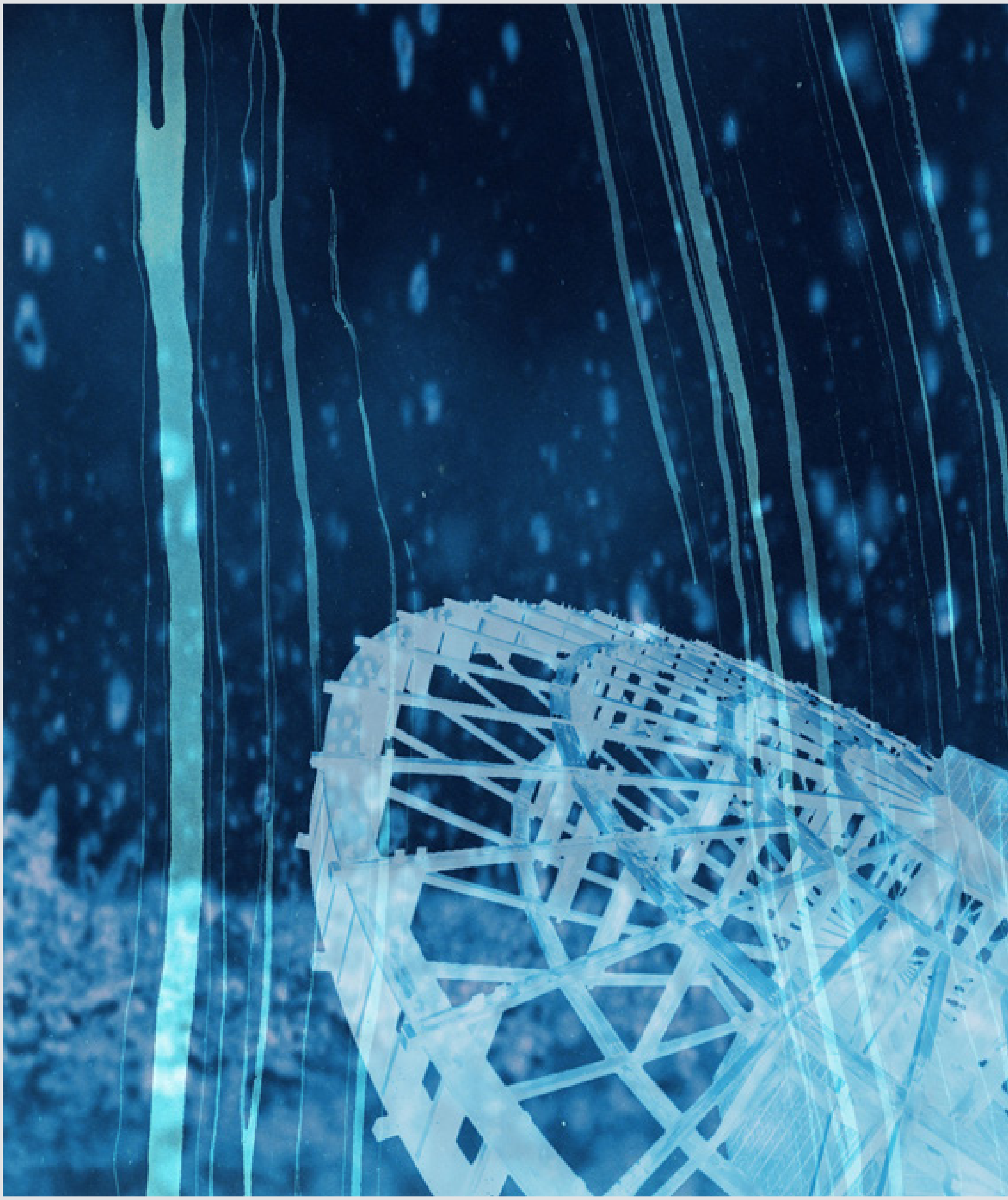
Water is everything. It is the main component of our body, and its consumption is essential to remain alive (along with the oxygen in the air). Water not only conditions our health and our access to food on a daily basis, it also conditions all economic activities to a greater or lesser extent – in the first place, the generation of energy. The sustainable and sufficient provision of drinking water and sanitation gives access to health and a life dignified enough to avoid the worst individual and social psychopathies. It can be stated that the first step towards eradicating extreme poverty must always be to provide communities with sustainable access to drinking water and sanitation in their specific area, by means of the most autonomous systems possible.

Supposing we have eradicated the extreme poverty that hinders the possibility of leading a dignified life, the development of new economic activities would require an additional provision of water. In other words, a community's economic development is limited and conditioned by the provision of water. When we imagine a newly created community, designed in such a way that its resources are strictly adjusted to its needs, in addition to their basic need of a supply of water for themselves and for food production, any further productive activities would generate a growing need for water. In such a closed system, the circularity of the processes and the simultaneous (holistic) consideration of all activities would allow for the optimization of natural resources in general, and water in particular; but in spite of this, and even more obviously in a closed system, growth and development would be limited by the need to have access to enough additional water for each step forward. Even if a new global analysis allowed for new optimisations, the marginal needs for water would never amount to zero.

Thus, the analysis of each area as a closed system would present a budget of virtually zero for water, both for the current situation and for the realistic planning of the economic and demographic growth of an area; and it would show clearly and directly the need for water in each situation, making growth sustainable, rather than precarious. We could speak of a negative water footprint aiming to optimize the planning processes.

Water is everything, and therefore, it must be put at the centre of the debate on the economic future of territories and their communities.

Ramiro Aurín



Water is vital not only for every form of life, but also for every step forward. (© Illustration: Hiroshi Kitamura)

CIRCULAR WATER ECONOMY:

MANDATORY DIRECTION

Ángel Simón Grimaldos

KEYWORDS:
CIRCULAR ECONOMY
INDUSTRIAL ECOLOGY
SUSTAINABILITY
WATER
ENERGY
SERVICES
WASTE

The concept of circular economy has many variants and a rich assembly of historical antecedents based on industrial ecology research. In "Strategies for Manufacturing", taken to be the starting point of industrial ecology, Robert Frosch and Nicholas Gallopolous (1989) established a comparison between industrial and biological ecosystems. The set of ideas presented by Frosch and Gallopolous, based on a biological analogy in different degrees and shapes, has been examined in a variety of ways. Among these are the "Four Laws of Ecology" by Commoner (1971), the notions of closing and slowing loops (Stahel & Reday-Mulvey, 1981), the industrial and socioeconomic metabolism (Ayres, 1994), and the "cradle to cradle" (as opposed to "cradle to grave") approach by McDonough and Braungart (2002).

To put it in a nutshell, we could state that circular economy is an economic concept interrelated to sustainability, which aims to keep the value of products, materials and resources (water, energy…) in the economy as long as possible, and to reduce the generation of waste to the minimum. It is about implementing a new circular economy – as opposed to a linear economy – based on the principle of "closing the life cycle" of goods, services, waste, materials, water and energy.

ASPECTS OF CIRCULAR ECONOMY

Circular economy is the intersection of the environmental and economic aspects of production processes.

The linear system of our economy (extraction, manufacture, use and disposal) has reached its limits. In fact, we can begin to glimpse the depletion of a number of natural resources and fossil fuels. In this situation, circular economy offers a new society model that uses and optimizes the stocks and flows of materials, energy and waste, with the aim of attaining resource efficiency.

In a context of shortage and fluctuation of costs of raw materials, circular economy contributes to ensuring their supply and the reindustrialization of the national territory.

Fig. 1. Floodable park La Marjal, Alicante.

The waste of some people becomes the resource for other people. Goods must be designed in order to be deconstructed at the end of their first life. Circular economy manages to turn our waste into raw matter – the paradigm of a new system for the future.

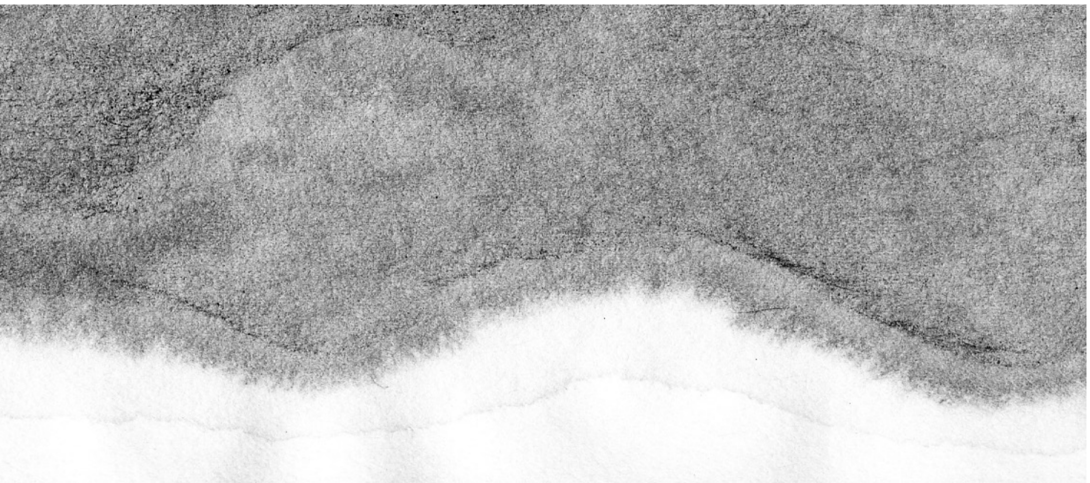
Last, but not least, circular economy creates employment. In Spain, waste management is generating thousands of jobs, and there isn't the slightest sign of this situation having peaked. Circular economy is intrinsically a system that creates local and non-transferable employment, as its effective implementation requires bringing the circular activity to the point of consumption.

BENEFITS OF CIRCULAR ECONOMY

The development of a circular economy should contribute to minimizing the use of resources, reducing waste production and to limiting energy consumption. It must also participate in the productive re-orientation of countries. In fact, besides environmental benefits, this emerging activity creates wealth and employment (and this includes the field of social economy) throughout the territory, and its development should help in the acquisition of a competitive advantage in the context of globalization.

«Towards an Eco-Efficient Europe» is one of the seven flagship initiatives within Europe's 2020 strategy that aims to create smart, sustainable and inclusive growth. Today it is the main strategy in Europe for generating growth and employment, with the support of the European Parliament and the European Council.

This flagship initiative offers a framework for long-term measures, and, in a coherent manner, also for medium-term measures, among which can already be identified a strategy destined to turn the EU into a «circular economy» based on a recycling society, which will not only



reduce waste production, but will use waste as a resource.

In 2014, the then European Environment Commissioner, Janez Potocnik, during the «3rd International Economic Forum (IWF) – Resource Efficiency», observed that it is necessary to transform Europe into a resource efficient economy: «But efficiency alone is not enough… So an integral part of the EU approach to resource efficiency must be moving away from the linear economy – where we extract materials from the ground, manufacture products, use them and then throw them away – towards a circular economy – where waste and by-products are pumped back into the production cycle as secondary raw materials.» In essence, «using waste as a major, reliable source of raw material for the European Union is essential».

«There is a strong economic and business case for circular economy and resource efficiency… In fact, the European Commission, as a collegiate body, has adopted resource efficiency as a central pillar of its structural economic strategy – Europe 2020.»

WATER, AN EXAMPLE OF CIRCULARITY

Water is in many ways an example of circularity. During the past 3,800 million years, water on Earth – 1,400 million km^3 – has continuously circulated through multiple stages and processes of the hydrological cycle, impelled by the energy of the sun. In the past 100 years – only an instant in planetary time – human activity has begun interrupting this well-adjusted circularity, endangering both our future prosperity and the health of our planet.

We live in a «blue» planet, but most of the water is not in a shape or place that is available to us. It is almost entirely sea water – only 2,5% is fresh water, and most of that is out of our reach, enclosed in layers of ice, glaciers o deep underground aquifers. The real percentage accessible to us is 0,007 % of the total. Fortunately this is a small fraction of a very large quantity, so that in fact there is more than enough fresh water to satisfy the needs of the human population. The challenge lies in the management of the fresh water actually available (leaving aside, for now, desalinization, which creates what we may call a «new resource», although unfortunately this option normally implies a high carbon footprint).

In many areas in the world this challenge is not being sufficiently met, consequently leading to a multiplicity of lost opportunities and negative impacts. These consequences inevitably become more serious as the level of economic development is reduced.

Indeed, it is the least developed countries that suffer the most extreme consequences of lack of management of water resources. In many African countries, people must walk for many hours every day in order to collect water from sources that are often contaminated. This task is normally undertaken by women, who are more vulnerable to violence, or by children, who thereby compromise their education. Bad quality water brings disease. Even worse, according to the UN water-related diseases cause the death of more than 3.4 million people annually, most of whom are children under the age of 5.

Our experience in a project in the Amialco Otomí community in Mexico, in which we collaborated, proved how the implementation of a simple circular management system – water collection, purification and reuse of grey water for orchards, dry composting toilets and faecal composting for agricultural use – in the family unit, in an arid place, with almost no drinking water available, reduced 90% of health problems, and, together with all the other effects of this intervention, almost doubled the family income. Numerous examples in the first world are often less dramatic at a personal level, and more determinant at a planetary level.

It is therefore more reasonable to think that following through on the postulates of circular economy to its last consequences is not only an option, but the only option.

Water is of vital importance from the point of view of natural capital – lakes, rivers, wetlands, underground waters and oceans – and it has a real economic impact. Therefore, the circular economic link here us to preserve and enhance this natural capital. In the first place, instead of continually contaminating the water sources, regenerative practices must be applied to the parts of the natural water cycle under human management.

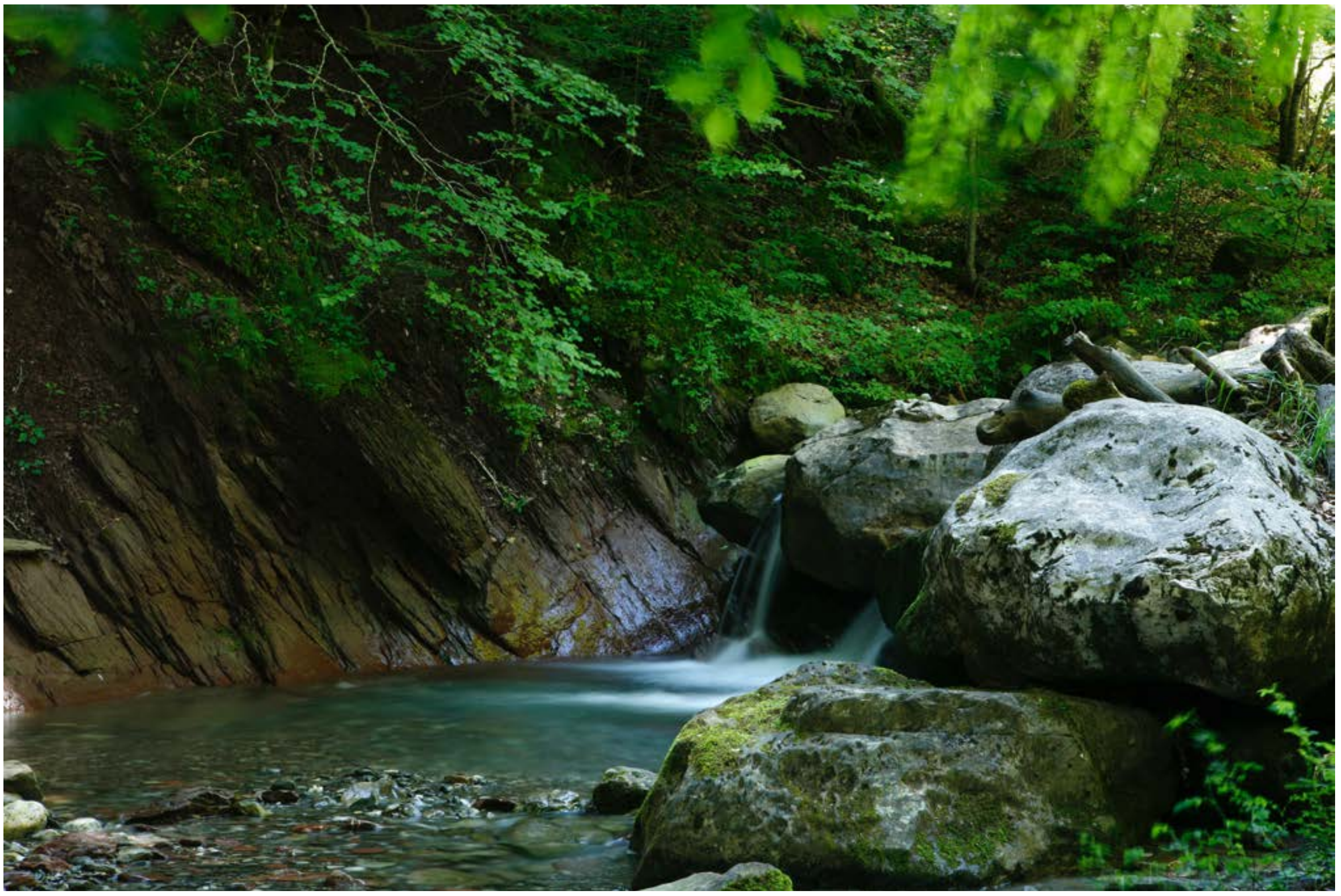
In the second place, water is a resource. Its presence is an essential condition for the generation of energy, for industrial processes and for agriculture. We therefore need to find a way of uncoupling economic growth and increased consumption. In essence, we need to use water without consuming it. This means that the production processes must be designed in such a way as to maintain efficient and effective water cycles.

Lastly, water is sold as a product. After being submitted to high levels of purification to be turned into tap water or bottled water, it is then after its consumption immediately transformed into wastewater.

How could we make water circulate at its maximum value and eliminate the concept of «waste»? The answer lies in the extraction of valuable materials, nutrients and energy from wastewater before it is destined to another use, or returns safely to the natural water cycle. We could say that we use water in a linear way: we apply costly purification processes before «using» it, and then we apply even more expensive purification processes before discharging it downstream. This system presents a number of inefficiencies, leakages and dysfunctions that have detrimental effects on human health and the environment.

We must reconsider our present model and explore the transition to a more circular system for various reasons:

— Supply risks: The growing world population is increasingly more and more urban. The demand for water is growing by 2% every year. 25% of cities already suffer from water stress. By 2040 the world demand could be 50% higher than the supply.
— Economic damage: The World Bank has identified many regions where water shortage could hinder economic growth. In India,



the cost for inadequate water and sanitation economy is estimated to be 6,4% of the GDP.

— Structural waste: The way in which we currently use water is mostly ineffective. Agriculture represents 70% of world fresh water use, but only 40% of this fresh water reaches plants. The water that Mexico City loses every year due to pipe leakage is enough to supply the whole of Rome. Both these technological problems have been solved.

— Degraded natural systems: 20% of the rivers in the world no longer reach the sea. Half the rivers and lakes in the world are contaminated by wastewater, threatening the natural life within them. Dead areas caused by nutrient runoff are a common characteristic of coastal areas. Water pollution causes an average 250 million cases of disease annually.

— Climate change risks: Weather becomes more and more unpredictable as global temperatures increase, provoking more intense rains in some areas, and more droughts in other areas. The climate event that might occur once every 100 years will take place, in the future, 3 times every 20 years.

And if there are strong reasons for us to access a circular economy as a way out of the impasse we find ourselves in, there are also paths that lead to it as a natural evolution of our system:

— Regulatory Pressure: The UN's Sustainable Development Goal 6 aims «to improve water quality and increase safe recycling and reuse». China's Ten-Year Plan aims to improve water management and to protect the aquatic environment. Policies on corporate responsibility regarding water use, which are increasingly being adopted by big enterprises, evaluate the impact of corporate operations in world water resources.

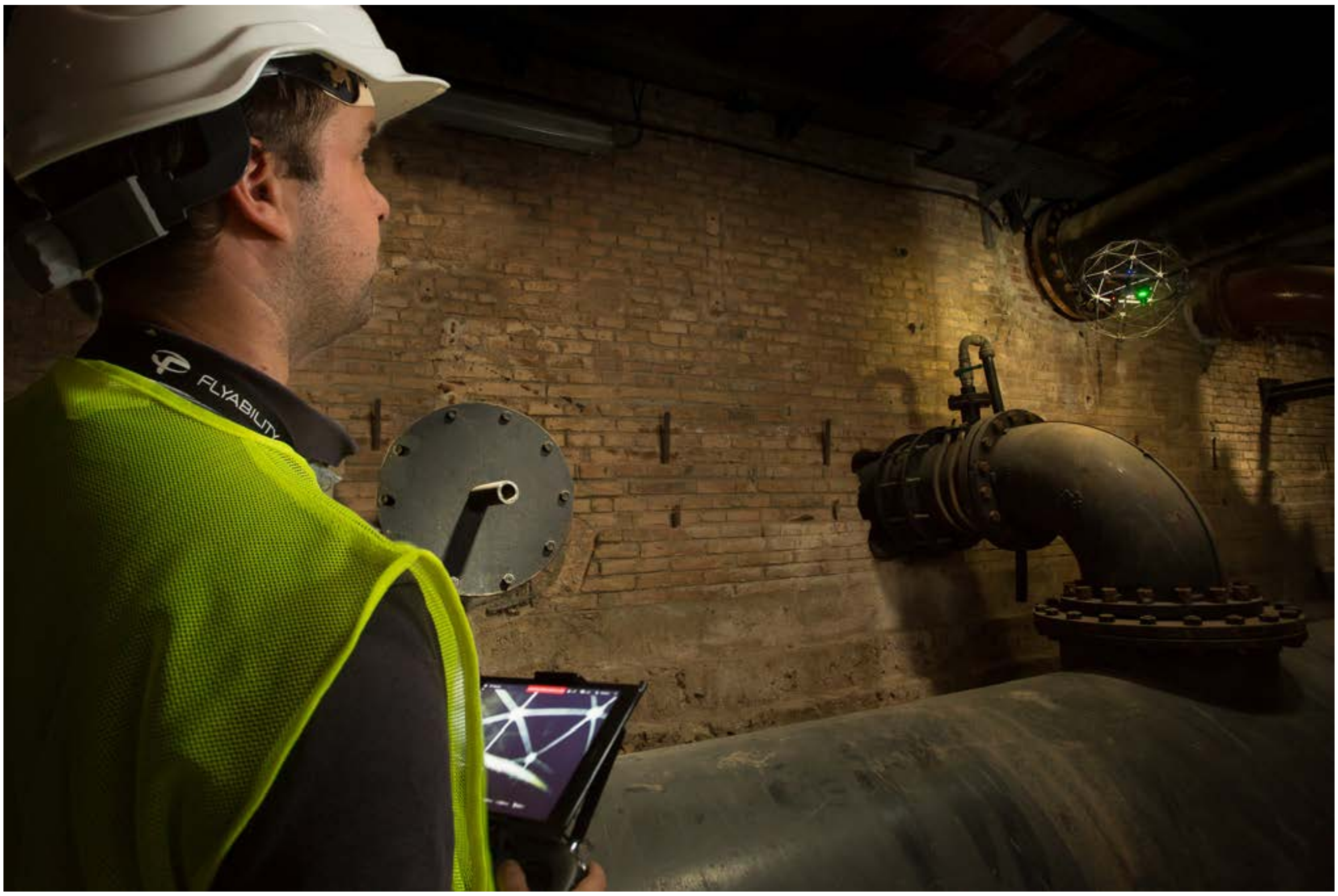
— Technological Progress: Smart sensors, combined with «big data» analysis, allow firms, facility managers and city authorities to administrate water more effectively. New technology in resource recovery allows for the extraction of a wider range of useful materials from wastewater.

— New Business Models: In the future, public services will not only be able to purify, provide, collect and treat water, but they will also be able to extract and sell resources from wastewater. Wastewater treatment plants could become biofactories taking in a wide range of organic materials in order to turn them into useful products or by-products, or to exploit them energetically.

Consequently, these are some ideas that could immediately be implemented to our relationship with water in the context of a circular economy:

— Systemic Thinking: Water resource management must be approached with a holistic and systemic mind. One good example is found in the influence land management in river basins has on the water sources providing water to cities. It is estimated that improving only 0.2% of agricultural practices in these lands worldwide would improve the water quality of 600 million city dwellers. This approach is often not only cheaper than building more expensive treatment plants, but also improves the health and the way of life of communities and rural habitats. Regenerative agriculture is another example of systemic thinking applied to water: highly degraded land increases up to 30 times its infiltration rate. On the other hand, an agriculture that predominantly aims at increasing the soil's organic content generates bountiful benefits, for instance, it reduces or even eliminates the need for irrigation, as has been shown in some areas in Brazil, by adopting methods of ecological revitalization.
— Approaching closed loop systems: This is to try to keep water resources within the system, allowing them to be used again and again. Closing the loop invariably generates additional benefits, beyond the reduction of water consumption. There are numerous successful examples of this across the globe. When applied to intensive water use enterprises, such as catering laundry companies, hospitals, etc., the installation of water recycling plants for the initial washing cycle, and for its use in the following rinsing cycle, leads to a reduction of 30% in the general use of water. A secondary benefit is that recycled water retains heat, eliminating the need to increase water temperature during the rinsing cycle. Also, the higher temperature in the rinsing cycle opens the pores of sheets and towels, reducing the duration of the final drying stage. Therefore, as a consequence of a greater usage of water, the demand for energy is significantly reduced. In economic terms, the savings amount to 25%.

Closed water systems may be absolute or partial, and they may work at all city levels – 30% of the water demand in Singapore is provided, via recycling, by the wastewater industry. In Qatar a gas liquefaction



facility recycles 450,000 m^3 daily, that is, 50% of the demand of the whole country. The Solaire building in New York recycles 750,000 wastewater litres daily. This reduces in 50% the demand for water, 60% of the volume of wastewater discharge, and it also reduces significantly the building's demand for energy.

If resources in wastewater could be exploited, the treatment of wastewater, instead of creating costs that blocks the possibility of its generalized reuse, could become a revenue generating «resource factory» that facilitates reuse, with the consequent positive impact on the present and future availability of fresh water resources – present, because reused water makes available for a different use the water which it has substituted, and future, because contamination by untreated wastewater has been avoided.

«Cascade value» is a term used when referring to biological nutrients in circular economy. When applied to wastewater, it refers to the value extraction process, with a series of stages that begin with high value products, such as specialized chemical products, followed by fertilizers, energy, water and biosolids. This final product is essential to close the loop and to contribute to nutrient regeneration in the planet's soil. New technologies are still being developed to extract high value materials, but energy and nutrient recovery from wastewater is already quite well established.

At country level, the vast hidden movement of water in products and crops across the world is sometimes referred to as «virtual water». It has been estimated that India exports 38 thousand million cubic metres of virtual water annually in its cotton exports alone. This amounts to 85% of the demand of its entire vast population. By modifying the way India produces cotton, for instance, using more effective irrigation techniques, and being more specific in the use of fertilizers and other consumables, this quantity of virtual water could be reduced by a third.

Fig. 6. La Marjal, the first floodable park of Spain.

Evolving towards a circular water economy consists in stimulating the natural water cycles, firstly by synchronizing ourselves with them, and then optimizing them, instead of changing to a more costly paradigm that, most probably, would prove to be less sustainable.

Nature already circulates water effectively, and has processes that regulate the flux, maintain high quality and ensure (within an order) against drought. Using nature as a mentor, applying the existing knowledge and the principles of circular economy, such as systemic or holistic thinking, closed loop systems and value retention, we may avoid the water crisis that many predict, and ensure a future with enough water for all, in an adaptive (resilient) context, insofar as technology and an innovative (holistic and systemic) governance will allow us to use the same water again and again, thereby interfering less and less with nature, both in the removal of water from its natural cycle and in its delivery after having been used.

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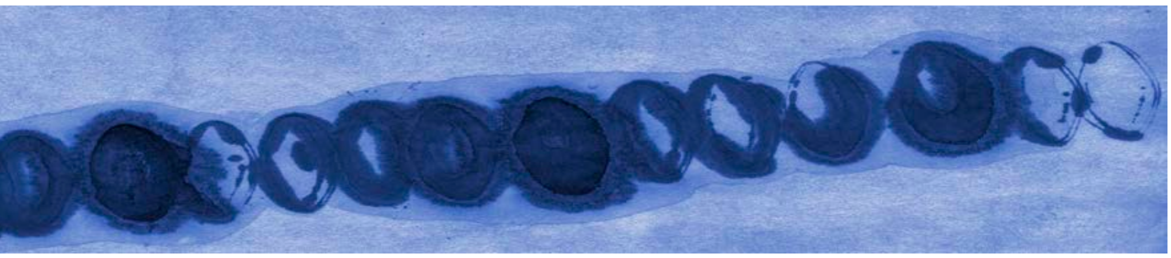
Civil Engineer
President of the AQUAE Foundation

THE UNITED NATIONS GENERAL ASSEMBLY

HAS PROCLAIMED A THIRD DECADE, THE UNITED NATIONS INTERNATIONAL DECADE FOR ACTION: «WATER FOR SUSTAINABLE DEVELOPMENT» (2018-2028)

Sirodjidin Aslov and Josefina Maestu



KEYWORDS:
UNITED NATIONS
THIRD DECADE
SUSTAINABLE DEVELOPMENT
WATER FOR LIFE
GREEN TECHNOLOGY
PARTNERSHIPS
DISSEMINATION OF KNOWLEDGE

The United Nations General Assembly during its seventy-first session approved Resolution A/C.2/71/L.12/Rev.1 on a new International Decade for Action: «Water for Sustainable Development» (2018-2028). The Resolution agreed was the result of a long process of technical and political negotiation masterly led by the President of the Government of Tajikistan, with different partners. The Resolution has received an amazing level of support, as reflected in the fact that it was overwhelmingly co-sponsored by 189 member states.

The Resolution works well because:

1. *It acknowledges the unfinished Water and Sanitation Agenda and the centrality of water in Sustainable Development* as the main motives to justify a new Decade for Action.
   In the Resolution it is explained that «the lack of access to a safe drinking water source, basic sanitation and sound hygiene, water-related disasters, water scarcity and water pollution will be further exacerbated by urbanization, population growth, desertification, drought and other extreme weather events and climate change, as well as by the lack of capacity to ensure integrated water resource management… The many water-related ecosystems are threatened by poor management and unsustainable development and face increased uncertainty and risks due to climate change and other factors».
   The centrality of water is explicit in the resolution as it emphasizes that «water is critical for sustainable development and the eradication of poverty and hunger; that water, energy, food security and nutrition are linked; and that water is indispensable for human development, health and well-being and a vital element in achieving the Sustainable Development Goals and other relevant goals in the social, environmental and economic fields».

2. *It sets the objectives of the Decade* in line with the internationally agreed water-related Goals and targets agreed in the 2030 Agenda.
   The Resolution establishes the substantive objectives of the Decade «a greater focus on the sustainable develop-

ment and integrated management of water resources for the achievement of social, economic and environmental… including those contained in the 2030 Agenda for Sustainable Development». Special importance is given to improving efficiency of water usage at all levels, as well as to considering the inter-linkages between goals, especially the water, food, energy, environment nexus.
As a Decade for Action, some very specific action goals have been included such as «the implementation and promotion of related programmes and projects, as well as the furtherance of cooperation and partnership at all levels».
There are still concerns on gender issues, which was a focus of the Water for Life Decade (2005-2015), as the Resolution recognises that «there is slow progress in advocating for, and addressing existing gaps in, gender mainstreaming and the empowerment of women, which hamper the achievement of sustainable development goals and targets».

3. *It calls to build explicitly on experience* of the Water for Life Decade (2005-2015) and other UN and non-UN processes.
The Resolution mentions the need to build on the Water for Life Decade – including the SG report on the Decade and new processes set in 2016, noting: «the establishment of the High-level Panel on Water by the Secretary-General and the President of the World Bank».
Acknowledges «the importance of International Years, Days and the International Decade for Action: «Water for Life» (2005-2015) itself, as well as the Resolution on the human right to safe drinking water and sanitation».
The Resolution reminds us that there has been progress so far and that we can build on what we have learnt. It provides some specific references for the substantive implementation of the Decade. It calls for the use of «the United Nations World Water Development Report, Water for a Sustainable World; the report of the annual international UN-Water conference held in Zaragoza (Spain) in 2015, on the theme «Water and Sustainable Development: from Vision to Action»; the UN-Water advice on the means of implementation of the water-related Sustainable Development Goals; the work of the Advisory Board on Water and Sanitation; the outcomes and the Ministerial Declaration of the Seventh World Water Forum, held in Daegu and Gyeongbuk (Republic of Korea); the outcomes of the High-Level Interactive Dialogue at the Sixty-Ninth Session of the General Assembly, held on 30 March 2015; the Declaration of the High-level International Conference on the Implementation of the International Decade for Action: «Water for Life» (2005-2015), held in Dushanbe on 9 and 10 June 2015; the call for action of the high-level symposium on the Sustainable Development Goal 6 and targets: «ensuring that no one is left behind in access to water and sanitation», held in Dushanbe on 9 and 10 August 2016; and the Addis Ababa Action Agenda, which seeks to develop and implement holistic disaster risk management at all levels, in line with the Sendai Framework for Disaster Risk Reduction (2015-2030).

4. *Establishes a focus on the Means for Implementation* including partnerships.
The Resolution recalls that as this is a Decade for Action, it will need to focus on the means of implementation, and «encourages the development, dissemination, diffusion and transfer of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed, and for the stepping up of international cooperation and collaboration in science, research and innovation for the sustainable development of water resources at the local, national and regional levels, including through public-private and multi-stakeholder partnerships, and on the basis of common interest and mutual benefit… Reaffirming that the Addis Ababa Action Agenda of the Third International Conference on Financing for Development is an integral part of the 2030 Agenda for Sustainable Development and that the full implementation of the Addis Ababa Action Agenda is critical for the realization of the Sustainable Development Goals and targets».
In line with the 2030 Agenda, it emphasises the important role of partnerships. Changing and promoting action needs to be based on involving different types of actors. The Resolution therefore acknowledges «the importance of deepening cooperation and partnership at all levels for the achievement of the internationally agreed Development Goals on water and sanitation». It also provides some guidance on where to start, as it notes that we can build on the «national, regional and global efforts and partnership initiatives developed to implement the International Decade for Action: "Water for Life", (2005-2015)».

5. *It provides an implementation model for the Decade.*
It provides some guidelines in relation to the implementation model of the Decade, and «encourages Member States, relevant United Nations bodies, the specialized

agencies, the regional commissions and other organizations of the United Nations system, as well as other relevant partners, including the private sector, to contribute to the International Decade for Action: "Water for Sustainable Development" (2018-2028)».
It recognises that there are many organisations out there ready to contribute to implementation, «Recognizing the important role of relevant initiatives and multi-stakeholder partnerships in building political support and encouraging investment in water and sanitation».
The Resolution makes clear that implementation needs to involve all stakeholders, and not only institutions and organisations, and «stresses the importance of the participation and full involvement of all relevant stakeholders, including women, children, young people, older persons, persons with disabilities, indigenous peoples and local communities, in the implementation of the Decade at all levels».

6. *It describes what activities can be useful* at global, regional and national level, in support of the Decade.
Activities may include those for «improving knowledge generation and dissemination, facilitating access to knowledge and exchange of good practices, generating new information relevant to the water-related Sustainable Development Goals, pursuing advocacy, networking and promoting partnership and action by different actors to implement the water-related Goals and targets in coordination with existing initiatives, and strengthening communication actions at various levels for the implementation of the water-related Goals».

7. *It gives specific tasks to the Secretary General of the United Nations* to insure successful implementation of the Decade. «It asks the SG to plan and organise, coordinate with other UN processes, facilitate implementation and promote mobilisation of financial resources».
The Secretary-General has to «plan and organize the activities of the Decade at the global, regional and country levels, taking into account the outcomes of the International Decade for Action: "Water for Life" (2005-2015), and the work of the high-level political forum on sustainable development and other relevant United Nations structures, as well as the High-level Panel on Water».
Calls for the Secretary-General and other entities of the United Nations system: «to facilitate the implementation of the Decade in cooperation with Governments and other relevant stakeholders».
The Secretary-General would need to «continue efforts to promote the mobilization of financial resources and technical assistance and to strengthen the effectiveness and the full utilization of existing international funds for the effective implementation of the water-related Sustainable Development Goals and targets».

8. *Aware of the importance of creating and maintaining momentum, it establishes specific milestones:*
The Resolution proclaims the commencement and the end of the Decade, and declares «the 2018-2028 period International Decade for Action: "Water for Sustainable Development", to commence on

World Water Day, 22 March 2018, and terminate on World Water Day, 22 March 2018». The Resolution establishes the date for the midterm review in 2022, and «has decided, in accordance with Economic and Social Council Resolution 1989/84, to review the implementation of the Decade at its seventy-seventh session, and in this regard also decides to consider, at its seventy-third session, the future arrangements for a comprehensive midterm review of the Decade».

9. *It establishes a procedure to improve integration and coordination in the context of the United Nations.*

It calls for an improvement in the way water and sanitation is included in the UN agendas of the General Assembly and ECOSOC, «Recognizing that water-related issues, including relevant Sustainable Development Goals and targets, need to be better reflected in the agendas of the General Assembly and the Economic and Social Council».
In order to advance it calls for further dialogue on how to improve the necessary integration and coordination in the context of the UN, it «requests the President of the General Assembly to convene, during the seventy-first session, a working-level dialogue to discuss improving the integration and coordination of the work of the United Nations on water-related goals and targets … and a subsequent working-level dialogue to take stock of the discussions at the first dialogue and to exchange views on the relevance of possible next steps in this regard». This dialogue needs to involve all and not only the UN system: «It has decided that the dialogues shall be ad hoc, informal, inclusive, open-ended and interactive, with the participation of countries, relevant regional and international organizations, relevant United Nations system entities, UN-Water and other relevant stakeholders».

WHAT NEXT?

The 2030 Agenda calls for change and transformation. Different processes at international, regional and national levels are rapidly being proposed and being put in place to support implementation and monitoring of progress of different SDGs.

The proclamation of the United Nations International Decade for Action: «Water for Sustainable Development» (2018-2028), is the response from and for the water community, and in the name of Sustainable Development. This is because of the centrality of water and the many inter-linkages water has in insuring the achievement of many of the SDGs.

The main responsibilities for implementation lie with the national and sub-national actors but international initiatives can provide support and help in different ways. The new Decade for Action provides, for instance, a framework for coordinated planning of the actions of the UN system entities and those of stakeholders and national authorities. It also provides a framework for vertical integration of national (and sub-national), regional and international actions, insuring that they reinforce each other, taking into consideration the key diversity in the different regions of the world. The Decade makes a clear statement of the importance of partnerships and cooperation among stakeholders at all levels, in contributing to the 2030 Agenda water related goals.

Under the leadership of the Government of Tajikistan, the diplomats of the 189 Permanent Representations to the United Nations in New York have created a framework for getting organised and taking action with regard to water and sanitation for people and the planet. It is to be hoped we will live up to the expectations.

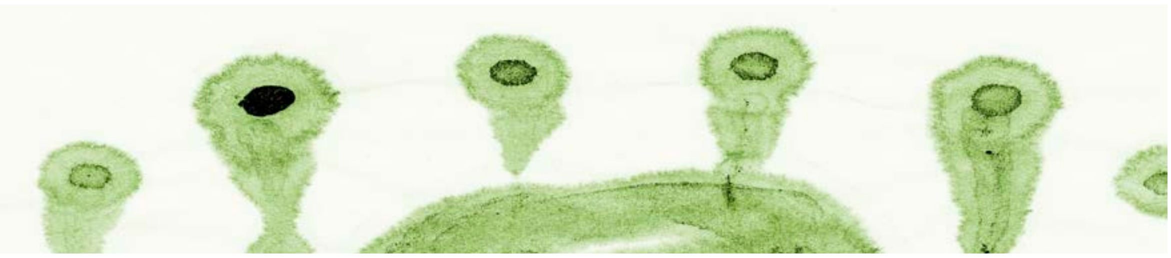
Sirodjidin Aslov
Minister of Foreign Affairs,
Government of Tajikistan

Josefina Maestu
Former Director of the United Nations Office
to support the International Decade for Action
«Water for Life» (2005-2015)

THE IMPORTANCE OF R&D

IN BALANCING A RELIABLE WATER SUPPLY WITH A HEALTHY ENVIRONMENT

Peter Goodwin and Andrew W. Tranmer



KEYWORDS:
WATER RESOURCES
WATER EFFICIENCY
SUSTAINABILITY
EMPLOYMENT
WATER RESEARCH

ABSTRACT

One of the greatest challenges facing society is the ability to maintain and improve the quality of life within a healthy earth system. Ecologists have further defined this challenge as sustaining not just a resilient ecosystem but also a desirable ecosystem that retains the features and species deemed necessary to achieve this quality of life. Within such a framework, the water-related challenges are numerous, including pressures from population growth and related land use alteration, climate change, catastrophic events, sea level rise, water quality and emerging contaminants, transboundary political challenges, and invasive species. Collectively, these challenges must be addressed by management and policy decisions informed by science and engineering knowledge that is relevant, credible, legitimate and delivered in a timely manner. Further the operating environment for water managers are often very complex and dynamic socio-environmental systems where difficult decisions must be made in under significant uncertainty and the health of the natural environment requires a long-term commitment to monitoring and synthesis of myriad data streams. Therefore, balancing the availability of water quantity and quality for irrigation, municipal, industrial, navigation and ecological needs requires the application of new monitoring, modeling and communication techniques and ensuring the future workforce is prepared to embrace these technologies and adapt to this rapid pace of advancement of knowledge.

INTRODUCTION

The worst thing that can happen is not energy depletion, economic collapse, limited nuclear war, or conquest by a totalitarian government. As terrible as these catastrophes would be for us, they can be repaired within a few generations. The one process ongoing… that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly that our descendants are least likely to forgive us.

E.O. Wilson, 1985

This insight given over 30 years ago, anticipated what is perhaps the greatest long-term challenge facing society today, how to facilitate economic growth and development within a healthy earth system. Water professionals in the private sector, managers in water agencies and researchers in universities and research institutes must play a prominent role in addressing this challenge. It is now very unusual for a water resources project to address a single function or objective such as flood management or water treatment but rather it is likely that projects will be linked ultimately to this major fundamental challenge. The 1992 Dublin principles helped the Global Water Partnership (www.gwp.org) to establish the foundation of integrated water resource management (IWRM) as a process which "promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". The subject of ensuring knowledge is structured in a manner to inform this type of complex decision-making, preparing the engineering and scientific workforce to work in interdisciplinary teams and the timely integration of emerging technologies are explored herein. The world is not running out of water, but the increasing demands on a finite supply, make water a scarce commodity in many regions and there are many drivers of change (WWAP, 2009; NRC, 2012) and some of the most prevalent are described in the following section. In most regions, precipitation is not predictable on a seasonal or multi-year timeframe resulting in water either being a scarce commodity when inadequate storage exists or occasionally arriving as catastrophic floods. The assumption of stationarity in hydro-climatic variables should be evaluated along with all other assumptions (Milly *et al.,* 2008; Brekke *et al.,* 2009). External drivers of change affecting a reliable water supply or sustainable natural ecosystem include climate change, population growth, catastrophic events (such as earthquakes, war, volcanic eruptions, toxic spills, flood or extreme drought), diminishing water quality and land use changes that are invariably irreversible. Additional pressures on achieving the balance between development growth and a healthy earth system include invasive species that complicate the management of native threatened or endangered species and socio-political issues around transboundary transfers and water rights. Management decisions are particularly complicated in many regions due to the non-stationarity of the entire system. It is not possible to develop definitive prescribed actions as the system is dynamic and highly complex with many potential future trajectories. It is difficult to identify clear cause-effect relationships and management requires a more adaptive approach where continuous monitoring and research can inform progress toward desired outcomes and quantifiable objectives.

Adopting this longterm perspective with adequate monitoring to verify progress, enhance understanding of the complex water system is often difficult as politically appointed leaders and elected responsible bodies are anxious to see progress and demonstrate solutions within their tenure, but understanding the response of management actions to the environment and water supply system may take many decades and not the short duration between election cycles. Therefore, water resources management requires a sustained commitment to monitoring, adequate analysis of results, integration and refinement of models, adaptive management and a transparent reporting system to inform current and future policy-makers. Water engineers and scientists currently (and must continue to) lead the planning, implementation and monitoring of measures to meet water supply demands and concurrently understand the consequences of different actions through the context of sustainability and how society and species are likely to adapt to changing conditions.

DRIVERS OF CHANGE

Water managers do not manage static water systems but are faced with highly dynamic and complex systems that experience major fluctuations on both the supply and demand. The primary drivers of change include changing populations, climate change, land use change, declining water quality, and emergence of new contaminants that may be cause for human health concerns (examples include microplastics and persistent organic pollutants). Other drivers include catastrophic events such as floods, droughts or toxic spills that can alter the ecological regime. The water manager also has to be aware of invasive species that influence native aquatic species that must be protected. These factors combine to complicate decision-making in the water sector, but also provide the opportunity to the water engineer to play a greater role in analyzing and influencing the future of river basins. Other drivers of change include growth in international trade can alleviate stress in water resources in some areas while exacerbating stress in other regions (for example through agricultural products) and social drivers (for example changes in lifestyle and rapid rise in living standards).

Population Growth: the world population is predicted to increase 33% by 2050, reaching 9.7 billion people (UN DESA, 2015a,b). During that period, 2.3 billion people will be living in environments with severe water stress, especially in Africa and Central Asia (OECD, 2012). Currently, two thirds of the world's population lives in areas that experience water scarcity for at least one month a year and a further 500 million people live in areas where water consumption exceeds the locally renewable water resources by a factor of two (WWAP, 2017). By 2050, food demand will increase by 60% and growing urban populations will require expanded municipal water supplies and sanitation services (Alexandratos and Bruinsma, 2012; WWAP, 2017). Some major metropolitan areas have experienced aquifer drops between 10-300 m, including Bangkok, Manila, Mexico City, Madras, Chicago, Beijing, and Shanghai (Foster *et al.,* 1998; USGS, 2003). In addition, diminished water quality from sewage, industrial, and agricultural discharge compromises available resources and endanger human health and ecosystem function. Clean, dependable, and sustainable water resources are fundamental to improved living standards, expanded economic prosperity, increased job growth, and civil conflict reduction (Hsiang *et al.,* 2013; Gleick, 2014; WWAP, 2016). To maintain these societal standards, improvements in water storage, delivery, sanitation, and efficiency will be critical to address the projected 40% discrepancy between supply and demand (UNEP, 2011d).

Direct human use is often accounted for in water management, but understanding the consequences of water diversions and withdrawals to biodiversity and ecosystem services that humans rely on for food, water, recreation, and quality of life must be further researched. Examples of diminishing ecosystem services include reduced numbers of pollinators, decline of marine derived nutrients from anadromous fish migration and loss of coastal wetlands and estuaries that a myriad of ecosystem services from fisheries to flood risk reduction. A mechanistic understanding of physical and biological processes is critical for advancing impacts of climate change and anthropogenic actions to ecological communities (Urban *et al.,* 2016; Wohl, 2016). An example of comprehensive studies to understand a complex ecosystem and the balance between water supply reliability in San Francisco Bay-Delta in California (Delta Stewardship Council, 2012 and SFEI, 2012, 2016)

The training, practice, and research in the science and engineering communities must incorporate a transdisciplinary approach to improve management of complex and rapidly changing systems (Hering *et al.,* 2013; DeFries and Nagendra, 2017).

THE ROLE OF SCIENTIFIC RESEARCH AND TECHNOLOGY

In the face of these serious challenges surrounding the capacity to sustain a healthy earth environment and the need to facilitate development and economic growth, a common question is whether technological advancements can solve the current environmental concerns. This can only be evaluated and advances made through not just inter-disciplinary or transdisciplinary research but by convergence of disciplines and technologies (NRC, 2014). Research and development have led to sweeping advances in low-cost microsensors, remote communications, open source numerical models, treatment technologies, and computing capabilities that have increased the speed and spatial and temporal density of how environmental variables are monitored, interpreted, managed, and archived. Even with such rapid advancements, the predictive capabilities for physical and biological processes are limited given the complexity and uncertainty of these systems (Rittel and Webber, 1973;

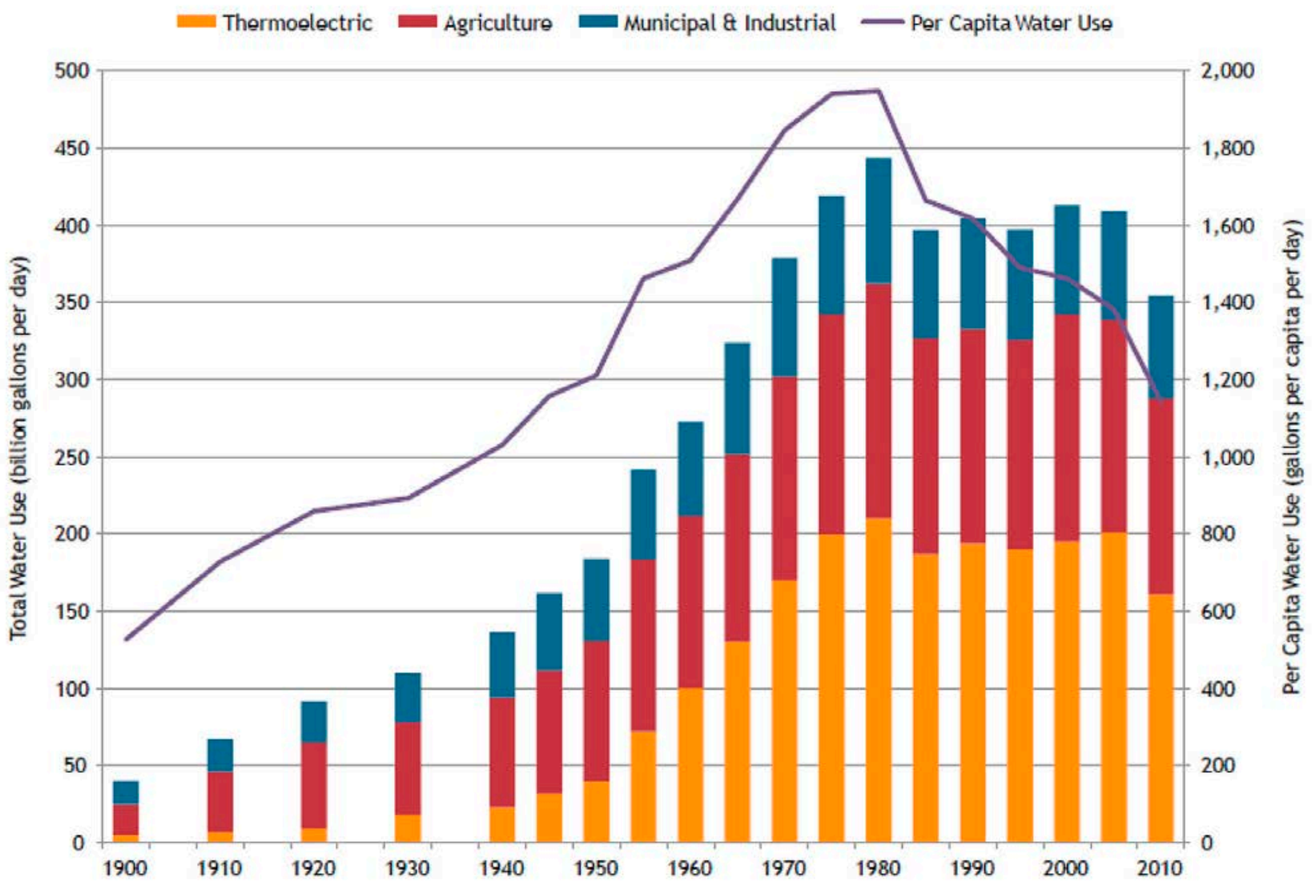
Urban *et al.,* 2016; DeFries and Nagendra, 2017). Further mechanistic understanding of these fundamental processes is required if predictive capacity is to be improved.

The United States reflects the weaknesses in water strategy in many regions of the word, Gleick (2016) identifies five prevalent issues that can be addressed and guided by R&D:

1. Basic water science and data collection.
2. Critical water infrastructure is decaying toward obsolescence.
3. Links between water conflicts and national security.
4. Basic safe water and sanitation.
5. Climate change impacts on water resources and systems.

North America has a hydrologic gradient from East to West and North to South that defines its management challenges. In the U.S., northern and eastern regions have historically faced water quality challenges, whereas western and southern regions have issues of quantity, but population growth and urban development, intense land use, and climate change are complicating those historic trends. Within this climatic setting, the population has increased while overall water use has declined, resulting in increased efficiency over the last three decades (PacInst, 2015). Since the peak water use in 1980, U.S. water demand has changed over time in a conversion from municipal to thermoelectric uses, with agricultural demand remaining relatively constant (Figure 1). Thermoelectric use is currently the largest single use in the U.S. (160 bgd) mostly sourced from surface water (PacInst, 2015). Agricultural efficiency has increased since 1980, through more efficient crops and micro-irrigation techniques that have allowed a reduction in water use with a concomitant increase in irrigated acres (PacInst, 2015). Additionally, per capita municipal demand has diminished through greater industrial efficiency and decreased domestic use (Rockaway *et al.,* 2011; Maupin *et al.,* 2014).

Fig. 1. Total water use (freshwater and saline water), by Sector (1900-2010).



Notes: Municipal and Industrial (M+I) includes public supply, self-supplied residential, self-supplied industrial, mining and self-supplied commercial (self-supplied commercial was not calculated in 2000-2010). Agriculture includes aquaculture (1985-2010 only), livestock and irrigation. Between 1900 and 1945, the M+I category includes water for livestock and dairy.

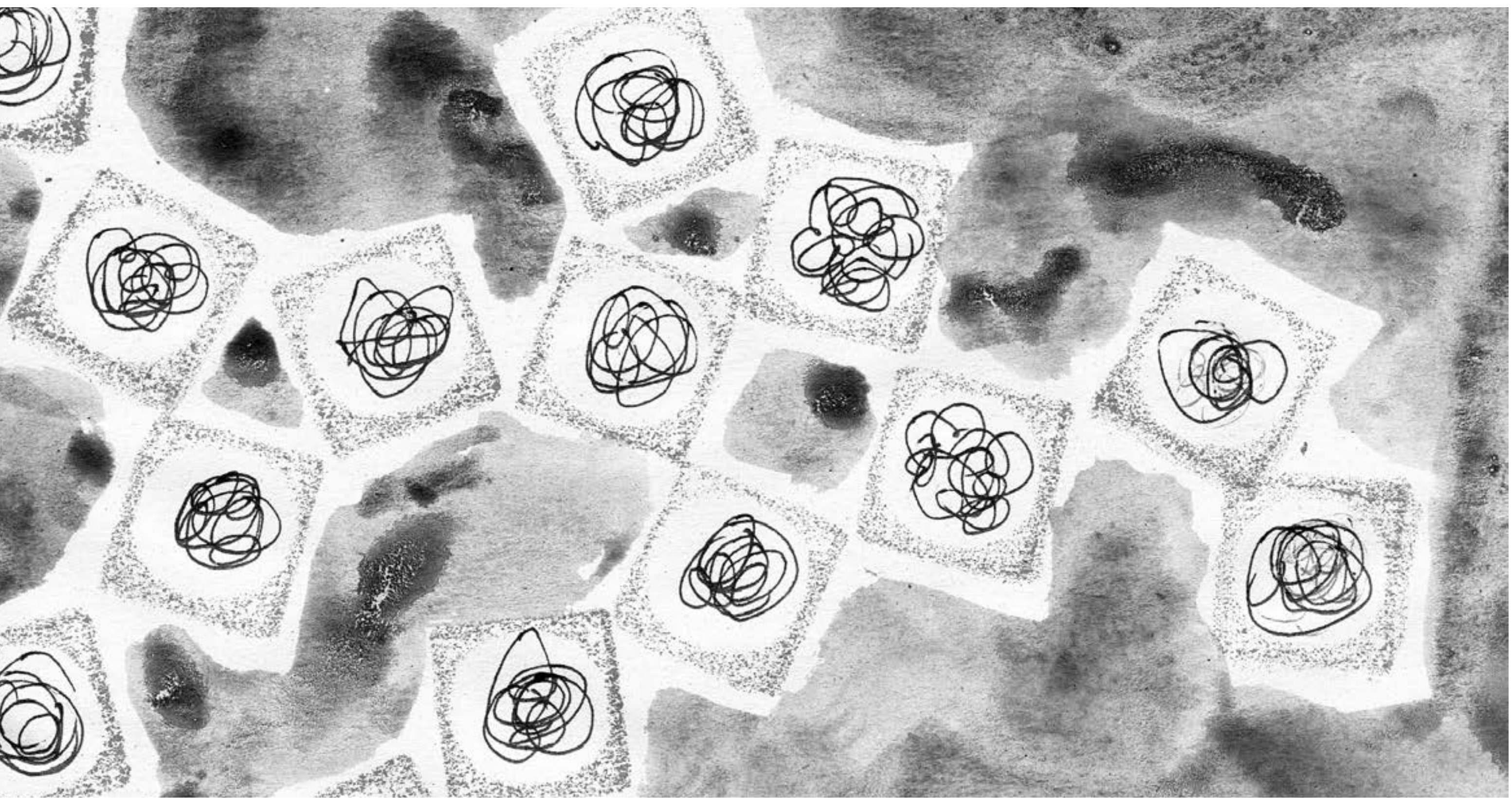
Sources: Data for 1900-1945 from the Council on Environmental Quality (CEQ) (1991). Data for 1950-2010 from USGS (2014a). Population data from Williamson (2015).

An Integrated Water Resource Management (IWRM) approach to maintaining water quality within a watershed can alleviate many quantity issues, but success hinges on development of new monitoring and treatment technologies, complex data management, and an advanced workforce to synthesize and model large-scale processes. Investments in research and development in water efficiency can assist issues of both quantity and quality via enhanced water availability, delivery, and quality. To inform IWRM under climate change and other drivers, sensors and data synthesis can be structured into three levels of activity:

1. Long-term monitoring networks are critical for detecting and quantifying climate change and its impacts to both physical and biological systems (Brekke *et al.,* 2009; Urban *et al.,* 2016).
2. Increased resolution and finer scale of downscaled climate models to assess extreme meteorological possibilities and impacts to physical and biological systems (Milly *et al.,* 2008; Brekke *et al.,* 2009; Urban *et al.,* 2016).
3. Region specific climatic impacts to guide flood risk, reservoir operation, crop management, structural safety, and end user demand (Brekke *et al.,* 2009).

SOCIETAL PERCEPTION AND THE ROLE OF WATER MANAGEMENT

In the U.S. peak water demand occurred in 1980, resulting in continuous improvements in water efficiency over the last three decades (PacInst, 2015). Efficiencies in thermoelectric cooling, agricultural practices, and municipal demand have allowed for a reduction in water use with a concomitant increase in population, irrigated acres, and industrial output (Rockaway *et al.,* 2011; Maupin *et al.,* 2014; PacInst, 2015). As water use changes with societal demands, so too does perception about water resources and availability. Recent droughts such as experienced in California bring issues of extreme weather and water scarcity to the forefront of societal concerns. Global surveys of threats facing humanity illustrate the perception of what crises face regional communities with respect to likelihood and severity. In the past five years biodiversity, population dynamics, pollution, and water scarcity have risen to the top of concerns about global crises that threaten the survival of mankind (Asahi, 2016). Alternative surveys identify population dynamics,



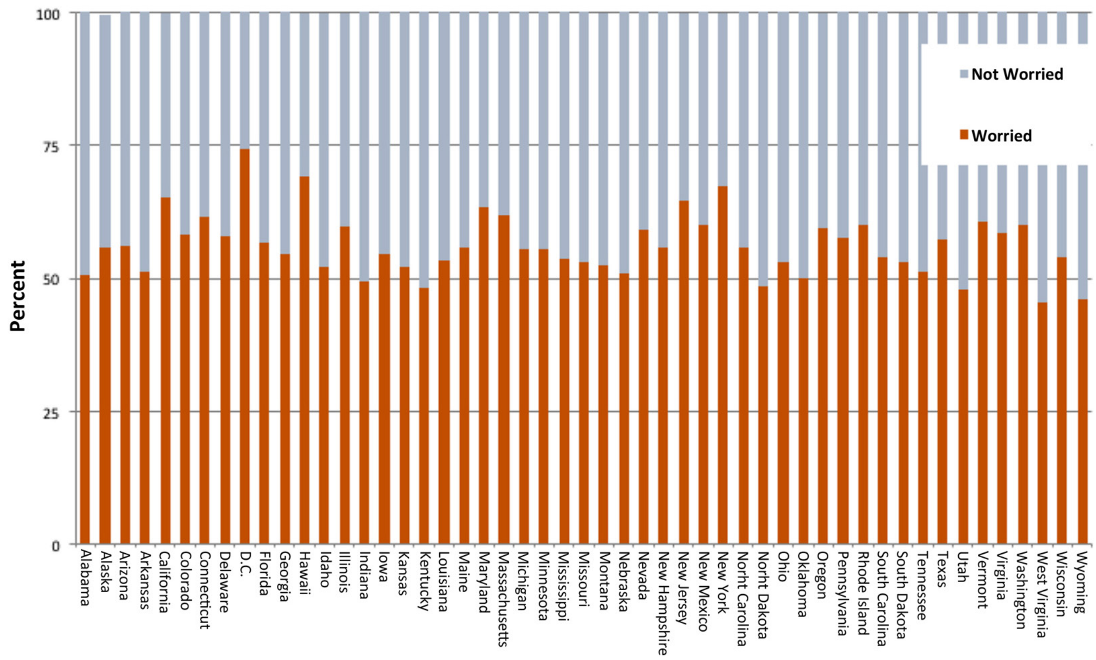


Fig. 2. Percent of U.S. population, by state, in 2016 worried about climate change (data from Howe *et al.,* 2015).

extreme weather events, and water crises as the critical environmental challenges facing the world (WEF, 2016). All of these potential global crises are posed in the context of likely climatic change, leading each community to reevaluate the reliability and security of its available water resources. Understanding community priorities, informing society and engaging communities and the full spectrum of stake-holders become an important component of water resources management. In recent years this has led to the rise of socio-environmental science as a key discipline in the implementation of IWRM (for example, Kliskey *et al.,* 2016) and anticipation in user behavior.

In the U.S., state populations have variable perceptions of the threats arising from climate change depending on multiple factors including recent experience of an extreme event and the reliance of the state economy on natural resources and agriculture (Figure 2). Other factors influencing public perception is based on geographic location, hydrologic availability, established infrastructure, economic dependence on freshwater resources, and ideological beliefs (Howe *et al.,* 2015; Hamilton *et al.,* 2016).

The U.S. is subject to this diversity of opinions and faces substantial political and technical hurdles to forming a sustainable water management strategy, including an aging water infrastructure, contaminant and water quality problems, and uncertainty from regional climate change, which can collectively be addressed by investment in research and development (Gleick, 2016; ASCE, 2017). The potential cascading effects of climate change may impact many sectors of water resources, which complicate decision-making for water managers that are responsible for maintaining water supply, water quality, ecosystem management, navigation, hydropower, minimum flood hazard, and coastal resilience (Brekke *et al.,* 2009). Communication of the issues and consequences of non-action will also require the foundational elements for sustainable water resource management, including accurate data and models, visualization, credibility of the science, latitude to make operational changes, that combine to articulate alternative futures for communities (Brekke *et al.,* 2009; Yarnell *et al.,* 2015; Gleick, 2016).

WATER EFFICIENCY AND CONSERVATION

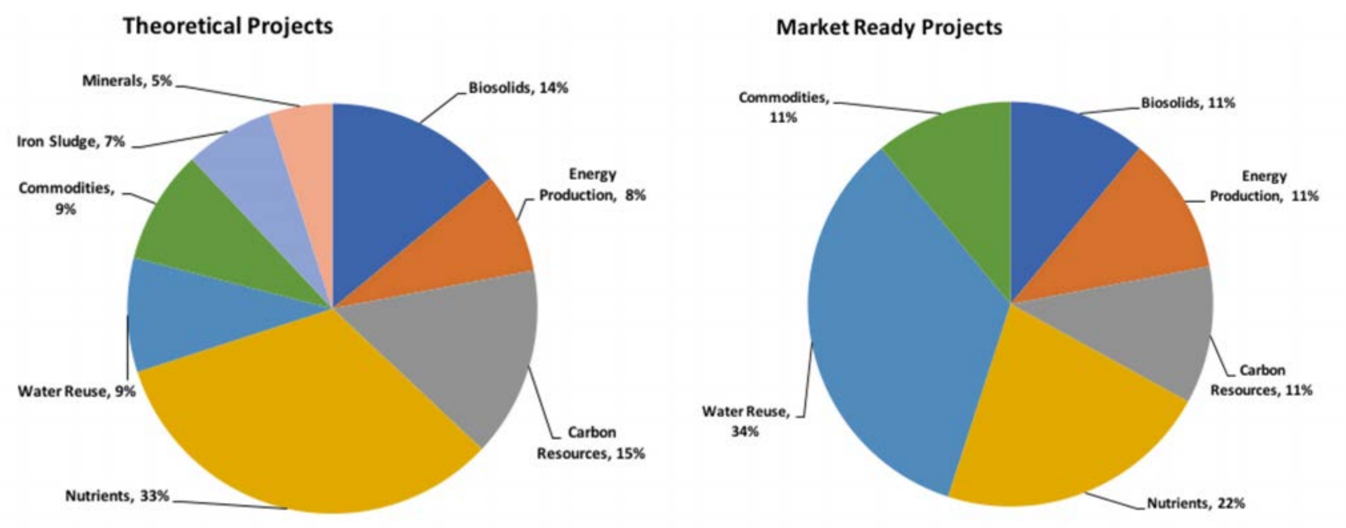
Principal consideration in water efficiency should detail the primary sources, transport pathways, and residency times of water in the watershed through a conjunctive administrative approach that connects surface and groundwater resources. The American Society of Civil Engineers has identified many threats to drinking water arising from pollution, depleted aquifers, and inadequate storage; therefore, a landscape and systems perspective that integrates the capture and transport of water for direct use, the energy requirements for water treatment and recycling, and potential improvements for alternative uses is critical for a reliable water supply for communities experiencing changes in climate, population dynamics, and land use. Even apparently simple information to inform management such as a closed water budget is problematic. In closed water systems such as urban water distributions systems this can be done with reasonable accuracy driven by research initiatives such as ReNUWIt (http://renuwit.org) and Smart UWSS (http://smartuws.ust.hk). At the river basin scale, there have been major advances to measure evapotranspiration remotely over different land use types that are used for administration of water management (for example the Idaho Department of Water Resources in the United States https://www.idwr.idaho.gov/GIS/mapping-evapotranspiration/). However, details of water extractions, return flows from agriculture, exchange between groundwater and surface water throughout the year often confound accurate estimates or the water budget. The systems perspective of a watershed allows efficiencies can be identified, for example, a textile factory in India increased its water efficiency by 80% through changing it chemical processing approach and lowering trace metal content in its wastewater, allowing for direct reuse in local agricultural irrigation (WBCSD, 2006).

Storage and delivery of primary water resources in the U.S. is becoming increasingly expensive due to aging infrastructure and mounting rehabilitation costs. An estimated 15,500 of the 90,580 dams in the U.S. are categorized at high risk from large floods and earthquake damage, costing upwards of $64 billion to restore or update to modern standards (ASCE, 2017). Such costly reinvestment may prohibit development of new primary storage facilities and more efficient gains can stem from improved hydrologic modeling and prediction, irrigation efficiencies, and recycling strategies.

Passive and active capture and conveyance systems provide high potential for improved water quality and available quantity through the development of green infrastructure, direct grey water reuse, smart technology stormwater networks, and monitoring and maintenance of delivery lines (Hering *et al.,* 2013). In the U.S. alone, there is over 1 million miles of drinking water lines that waste nearly 2 trillion gallons of water annually from leaks and broken mains. Enhanced leak detection technologies and real-time pressure sensors will more effectively facilitate system management and pipe replacement (Allen *et al.,* 2011; Kunkel and Sturm, 2011). An additional 1.3 million miles of private and public sewer lines require management and updates (ASCE, 2017), providing an opportunity for installing dedicated grey water and nonpotable delivery service lines from treatment facilities.

Centralized collection facilities like wastewater treatment plants and flood retention ponds provide key facilities for resource recovery and water recycling (LADWP, 2017). Currently, 14,748 wastewater treatment plants manage waste disposal for 76% of the population in large and small communities throughout the U.S., with an estimated 56 million additional users in the next 20 years (ASCE, 2017). Fundamental research is required to improve effluent quality, increase resource recovery, and lower energy costs at such facilities. In a recent survey of 185 international water research industry projects into efficiency and resource recovery, nutrients received the largest percentage (33%) of theoretical investigations for recovery from

Fig. 3. Distribution of water research recovery topics that translate to market ready solutions (GWRC, 2015).



drinking water, wastewater, and ambient water (GWRC, 2015). Translating those studies to market ready applications changes the distribution, with water reuse having the highest amount of market ready solutions (34%) followed by nutrient recovery (22%). However, large knowledge gaps still exist concerning the efficacy of treatment for the reuse of water in both potable and non-potable applications. Emerging contaminants in the forms of trace metals, organic compounds, and microplastics (<300 µm) all have substantial impacts on ecological and human health and must be investigated further (Tuetten *et al.,* 2009; Storck *et al.,* 2015; Furlong *et al.,* 2017).

Another promising front in research and development of freshwater resources is desalination and reverse osmosis technologies (WERF, 2016). While large coastal communities may have similar challenges in sourcing their ocean water in areas free from contaminants, the water quantity aspects of desalination are becoming more tangible. A new desalination plant in Ashkelon, Israel is producing fresh water at $0.50 USD per cubic meter owing to improved reverse osmosis technologies that facilitate reduced seawater pumping costs (WBCSD, 2006). Globally, the desalination industry is slated to expand at an estimated 8.1% growth rate between 2014 and 2020, with countries in the Middle East investing heavily in large-scale desalination plants (GWI, 2015). Subsequent water-related industry surrounding these solutions will focus on engineering, law, finance and the environment (WWAP, 2016).

REAL-TIME ENVIRONMENTAL FLUX MONITORING OF FLOW, NUTRIENTS, AND CONTAMINANTS

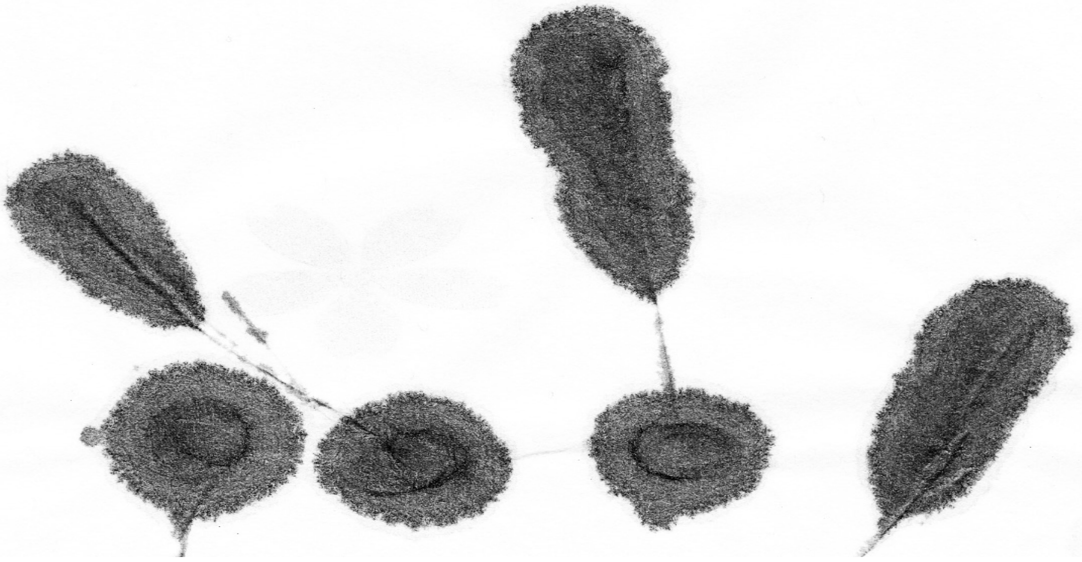
Increased environmental monitoring is critical to understanding the magnitude and scope of the factors challenging water quantity and quality, yet current monitoring networks in many parts of the world are insufficient to provide the necessary data. As an example, the distribution of water quality stations in Africa is 100% lower than in other regions of the world (UNEP, 2016), even though diminished water quality from organic compounds impacts fisheries and food security for an estimated one seventh of all river reaches (UN Water, 2016). Improved water use efficiency (and water quality) will occur as understanding of losses and fluxes through the environment increases, especially as real-time environmental observations increasingly guide water operations (Krause *et al.,* 2015; Tranmer *et al.,* in review). Such real-time management at the large spatial scale will extend to stormwater and graywater management, emerging contaminants, and persistent organic compounds (WERF, 2016; Furlong *et al.,* 2017), while fine scale analysis will occur for energy and water use and waste streams in individual buildings and municipal structures (IBM, 2015; ReNUWIt, 2017). A further area of rapid expansion is the area of citizen science, where communities can deploy low cost sensors to track key water quality parameters that can support water management and engage communities (Borden *et al.,* 2016).

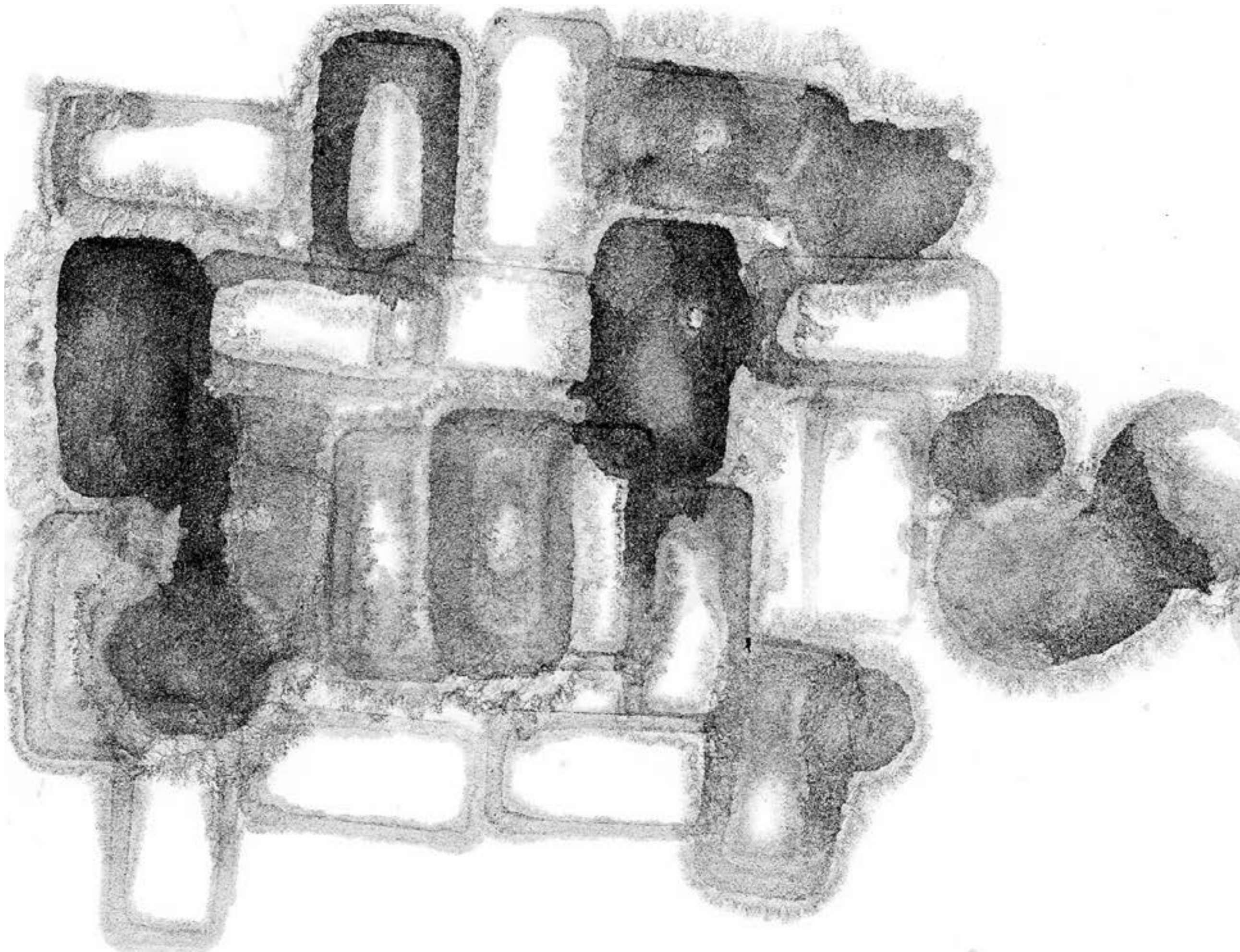
The rapid increase in monitoring technologies has created data streams that must be processed, verified, analyzed, stored securely and interpreted. This has created the need for professionals and infrastructure to manage the data. Models have also taken on an ever-increasingly important role to capture the current knowledge about a watershed, enable predictions to be made about future conditions, guide the design of monitoring programs, quantify uncertainty and inform decision-makers on short term operational issues or longer term infrastructure planning. The integration of different models to inform for example, economic ramifications of a particular decision or how different aquatic species might respond to alternative management strategies is an area of rapid development (NSF, 2015).

URBAN ADVANCEMENTS

Advancements in urban water use efficiency require a multifaceted approach that addresses monitoring, planning, communication, and social awareness. China has recently initiated an ambitious "Sponge Cities" program to utilize a mix engineering solutions and green infrastructure to reduce urban flooding, enhance storage capacity, and improve water quality in 80% of urban areas by 2030 (NL, 2016). In the U.S., thermoelectric power production is the single biggest water user (~45%) (Maupin *et al.,* 2014; PacInst, 2015), which can be curtailed as power plants become more efficient and coal fired plants get phased out. For domestic and industrial uses, ongoing research and development in technological improvements exist across the watershed and regional scales, to include new monitoring technologies, improved data resolution, network-capable smart sensors, and comprehensive big data analysis (IBM, 2015; WERF, 2016; ReNUWIt, 2017). Microsensor technology allows improved resolution of environmental constituents like nitrogen and phosphorus as well as the hydrologic pathways they utilize (Rundel, *et al.,* 2009; Caceres *et al.,* 2017). Deployment of networked sensor arrays will increasingly be used to understand the efficacy of conveyance and treatment facilities of environmental concern like wastewater treatment plants, sewage and stormwater systems, green infrastructure, and constructed wetlands (Shuster and Rhea, 2013; Hering *et al.,* 2013; EPA, 2015). Next generation methods for wastewater treatment and bacterial monitoring will improve resource recovery efforts from wastewater to include direct potable reuse, nutrient recovery, and energy production (Tchobanoglous *et al.,* 2011; Hering *et al.,* 2013; WERF, 2016). Additional investment to bring environmental data to public awareness on issues of water quantity and quality will further improve efficiency measures. Interactive cell phone apps can provide domestic efficiencies through monitoring household water usage via smart appliances, soil moisture in residential and commercial landscaping, and social awareness forums such as Facebook, Twitter, etc.

Increased planning, modeling, and program development will be required at local and state levels to store data and results as well as synthesize information for the public concerning available water resources and conservation efforts, such as the California Data Exchange Center (http://cdec.water.ca.gov/). Public information and education programs can promote sustainable conservation practices that include green infrastructure, rain water harvesting, groundwater recharge, landscape alternatives, reclaimed water for irrigation, cooling towers, and industrial processes (NRC, 2012; EPA, 2016). Free or low cost watershed management tools for water operations require further development to connect water entities of neighboring basins and downstream users (WERF, 2016). Free science based applications are currently available in the U.S. for assisting small and large communities in managing their urban runoff and downstream water quality, such as the EPA Green Infrastructure Modeling Toolkit (www.epa.gov/water-research/green-infrastructure-modeling-toolkit). Additional research into increasing the participation of water-based citizen science programs, with an emphasis on built in quality control procedures, will facilitate governmental data collection programs as well as improve public outreach and communication with community leaders. Cell phone platforms can create a low cost public monitoring network to quickly identify areas of environmental concern and provide information to water managers on how to respond. For example in-situ field evaluation of water quality parameters through a cell phone measurement identifies high bacterial or heavy metal concentrations in the river near the municipal water intake that can guide plant managers to use groundwater sources until contamination is remediated.





AGRICULTURAL ADVANCEMENTS

In rural communities and developing nations, agricultural and irrigation practices can be modified for substantial gains. Globally, irrigation accounts for 70% of water use with large predicted increases in water use for industry and energy production as countries develop (WWAP, 2017). In Africa, agriculture is based on dry farming techniques and less than 5% of its cultivated land is irrigated (World Bank, n.d.) In 2010, Africa's population surpassed the 1 billion mark and is projected to double by 2050 (AfDB/OECD/UNDP, 2015); therefore to feed the burgeoning population, nominal rainfed agriculture can be improved through irrigation and water reuse programs. In the U.S. a major improvement in irrigation efficiency transpired through the conversion from flood irrigation to center pivot sprinklers. Irrigation schedules are driven by improved monitoring and model-based information. Hydrologic and soil monitoring has expanded from sparse regional estimates from soil moisture profiles, lysimeters, and evapotranspiration meters to farm and field localized microsensors that report crop specific needs as well as water quality parameters for incoming canal water and outgoing drainage effluent. Monitoring water quality over the irrigation event provides critical information to monitor nonpoint source pollution and provide management alternatives (WERF, 2016).

Additional tools and models to achieve best agricultural management practices are increasingly available through state run online resources. California provides the California Irrigation Management Information System (CIMIS) that integrates hourly weather station information throughout the state with geostationary satellite cloud cover data to produce crop specific evapotranspiration rates and irrigation schedules (Hart *et al.,* 2008; www.cimis.water.ca.gov/ Resources.aspx). New crop models can predict various crop yields and potential irrigation requirements based on climatic variability from expected El Niño–Southern Oscillation effects (Nigoyi *et al.,* 2015).

Some decision management tools for agricultural regions extend past water use efficiency to include irrigation investment, pest management, water quality, cover crop selection, frost risk, etc. to provide complete field management, such as the U2U support tools (AgClimate4U.org). These growing online water networking platforms allow farmers and industry partners to share data, new technologies, strategic failures, as well as participate in pilot and research projects (WERF, 2016).

Additionally, distributary and receiving water bodies can provide increased benefits to water quality and nutrient management. River corridor restoration, through increased floodplain and wetland connectivity, restored oxbows, and hyporheic fluxes can reduce nutrient and sediment loads to downstream users (EPA, 2016; WERF, 2016). The direct effects of stream and wetland restoration for nutrient and sediment management provide disparate results that depend on incoming nutrient loads, regional climate, biogeochemical factors in the stream and riparian zone, as well as relict nutrient composition of the soil from historic land use (Sharpley *et al.,* 2013; Pinay *et al.,* 2015; Davis *et al.,* 2015). Greater research is needed to identify biogeochemical processes and quantify nutrient fluxes through the aquatic-terrestrial interface in wetlands and riparian corridors.

WORKFORCE DEVELOPMENT AND EMERGING SKILLS REQUIRED IN WATER DISCIPLINES

Globally, 1% of the total labor force works directly in the water sector, with water supply and wastewater facilities operators employing about 80% of the workforce (Estache and Garsous, 2012; UNESCO-UNEVOC, 2012). These positions, in turn, support an estimated half of the world's workforce in water dependent industries, including agriculture, forestry, fisheries, transportation, energy production, water-intensive manufacturing, recycling, and construction (WWAP, 2016). Current challenges to meeting water availability are limited primary water resources for expanding populations, noncompliance with conservation policies, underexploited water recycling strategies, and a shortage of qualified professionals for water related jobs (NRC, 2012; ILO, 2011; UN-WATER, 2014, WERF, 2016). Therefore, in addition to technical aspects of research there is a need to design training methods and tools to improve worker qualifications and strengthen institutional capacity of governments, water resource managers, and nongovernmental organizations (WWAP, 2016).

Workforce development and research centers: Sustainability is a major focus of municipal, corporate, and academic institutions, with an emphasis on water resources, green infrastructure, and alternative energy production. Positions in sustainability address resource conservation, improve efficiency, environmentally responsible technologies, environmental and social education, and strategic planning and design. Globally, the most in-demand sustainability occupations include (Degree Prospects, 2017):

1. Sustainability Consultants.
2. Environmental Scientists.
3. Environmental Engineers.
4. Campus Sustainability Directors or Managers.
5. Corporate Social Responsibility/ Sustainability Professionals.
6. Green Building Professionals.
7. Water Engineers and Scientists.
8. Agriculture and Food Scientists.

The renewable energy field (solar, wind, geothermal, and biofuels) employed 8.1 million people in 2015 with an additional 1.3 million in large hydropower operations. China alone accounts for half of the global hydropower employment, with 209,000 people in small hydropower and 690,000 in large hydropower projects (IRENA, 2016). The largest amount of renewable energy jobs were located in China, Brazil, United States, India, Japan and Germany. From the perspective of sustainability, great overlap in water resources and energy production exist. For example, in California about 20 percent of California's electricity is consumed by water-related energy use, including potable water storage, conveyance, treatment, and distribution as well as wastewater collection, treatment, and discharge (California Energy Commission, 2005). As an alternative, employing wastewater reclamation for potable activities at strategic locations in the state could provide an estimated net energy savings of 0.7 to 1 TWh/yr. At a power cost of $0.075/kWh, the savings would be on the order of $50 to $87 million per year (Schroeder *et al.,* 2012). Because of such potential gains, the Bureau of Labor Statistics (2016-17) estimates job growth in the field of environmental engineering to be almost double the national average (Figure 4). Other water related fields show variable job growth in relation to total U.S. job growth, with strong growth predicted in fields that monitor, research, and facilitate efficiencies in environmental and water resources.

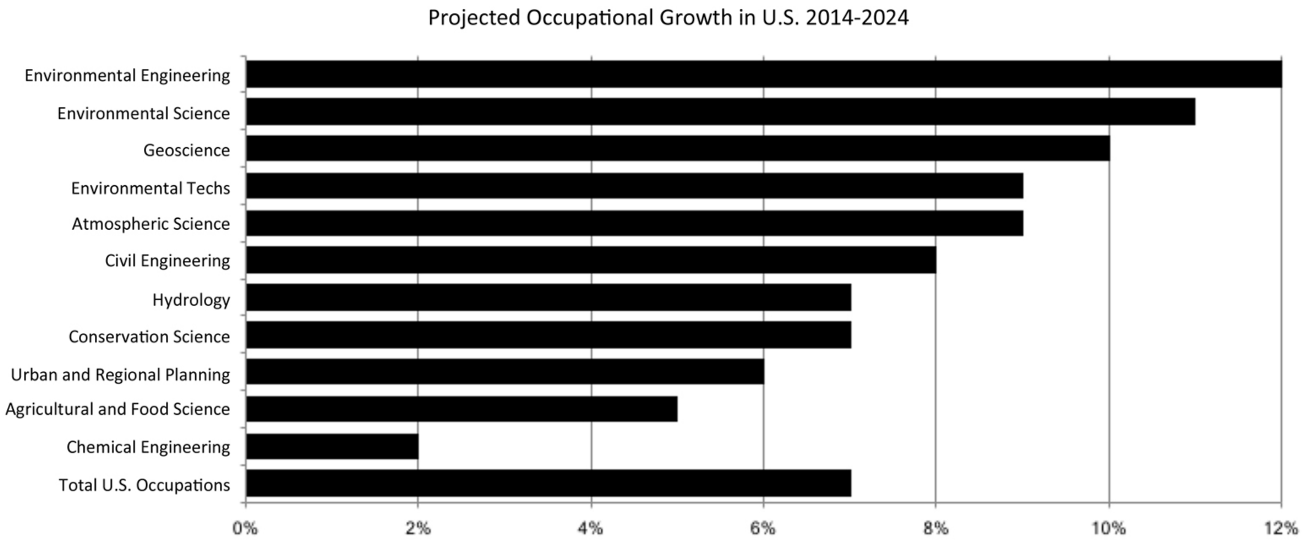


Fig. 4. Estimates for U.S. job growth for the period 2014-2024. Source: U.S. Bureau of Labor Statistics, 2016-2017.

CONCLUSIONS

This is a challenging period for water managers as they operate within complex and dynamic socio-environmental systems The effects of climate change, changing land use patterns in river basins, increasing or relocating populations all combine to place pressures on existing water supply, water treatment and flood management infrastructure. Secondly, many communities recognize the importance for a reliable water supply but also wish to ensure that this is achieved within a healthy environment that preserves biodiversity and features of the environment that protects human health and supports cultural, recreational and food provisioning values.

Recent and current technological advances and a more interdisciplinary trained workforce are now able to articulate, analyze and visualize alternative futures to enable communities to make informed decisions about reliable water supplies and how the physical environment is likely to evolve. Emerging monitoring technologies, often in real time, through remote sensing, distributed point sensors and tracking of biota enable progress or deviations from expected future conditions to be tracked in a transparent manner. These technologies and the synthesis of monitoring data inform adaptive management, adjust for unintended consequences, update predictions and be able to clearly communicate to the public, managers and elected officials.

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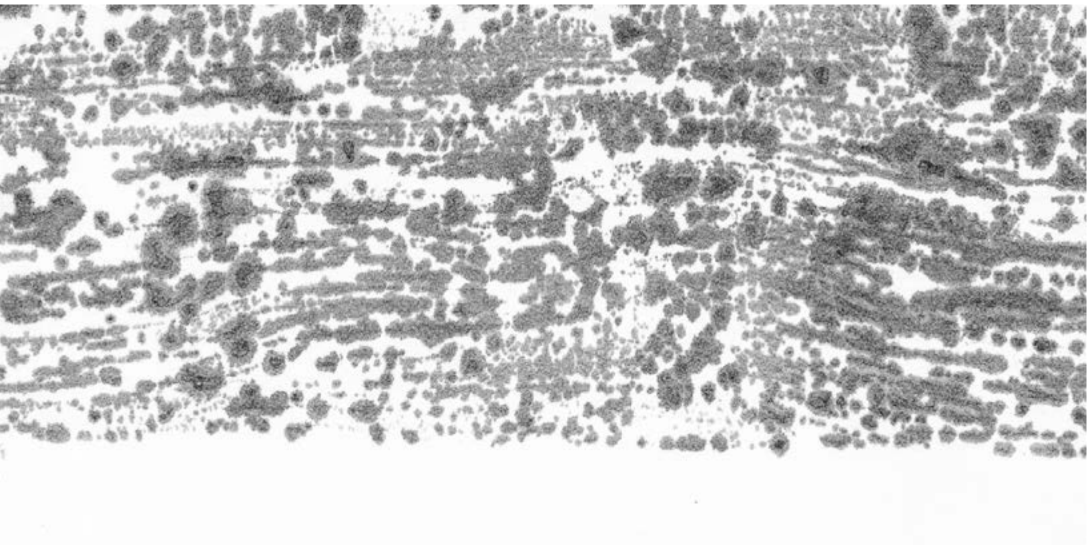

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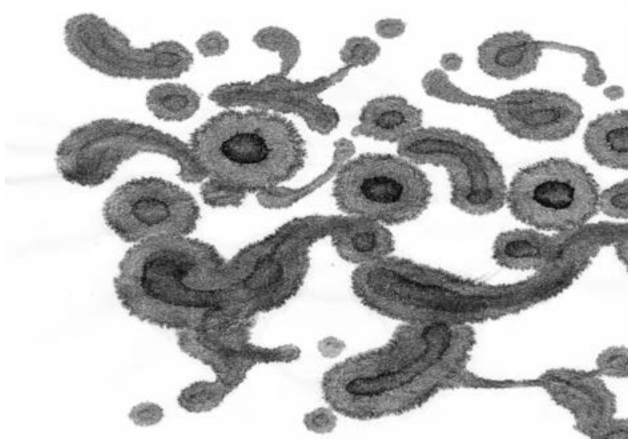
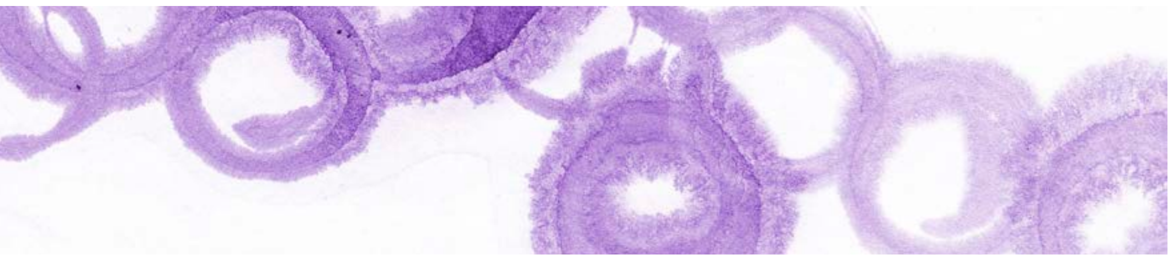


IT IS WELL WORTH RECOGNIZING THE VALUE OF WATER

Tomás Ángel Sancho Marco



KEYWORDS:
WATER CRISES
ENVIRONMENT
CLIMATE CHANGE
WATER AND JOBS
4IR
WATER SAFETY

PRELIMINARY CONSIDERATIONS

Owing, perhaps, to the traditional feeling that water drops down from the sky, provided by the Almighty, and to the humble feeling associated with the liquid element,[1] until well into the C20th the economic value of water and its contribution to socio-economic development has been ignored – and even more so, its environmental values and contribution to associated ecosystems.

Although the importance of water has always been recognized,[2] we have had to wait for the rapid evolution experienced in the past decade for water to assume, fortunately, a central role in our considerations of the future. Successive reports from the United Nations (World Water Development Reports, begun in 2003), attention from the most relevant organisms and seminars, World Water Forums, and the specific inclusion of water in the Sustainable Development Goals (SDGs 6) have without doubt opened a path in the right direction, although water-related issues still require further elaboration.

Water, in its relevant role for life and sustainable development, remains in many ways a non-quantified substrate, invisible to a large part of the world population, who still believe it comes out of taps and runs along pipelines by itself, failing to take account of the enormous work, effort and dedication this implies, and the value it has. Therefore it is necessary to keep making progress along the path chosen, and to accord to water the value it has and brings, making this explicit in the official statistics and accounting of the different countries and production agents. This will pay off, as it will enable the adoption of the decisions required, which current studies and reflections deem to be very necessary.

Indeed, it is most relevant that in the past few years Water Crises are considered to be one of the main risks for humanity in the near future. The World Economic Forum, in their annual reports on Global Risks (GRPS), has been showing in the last seven editions how water stands out among a group of interconnected environment-related risks, along with extreme weather events and climate change. Environment-related risks are again at the forefront of the global risk landscape this year (see Figure 1), with every risk lying in the higher-impact, higher-likelihood quadrant. Environment-related risks are also closely interconnected to other risk categories.

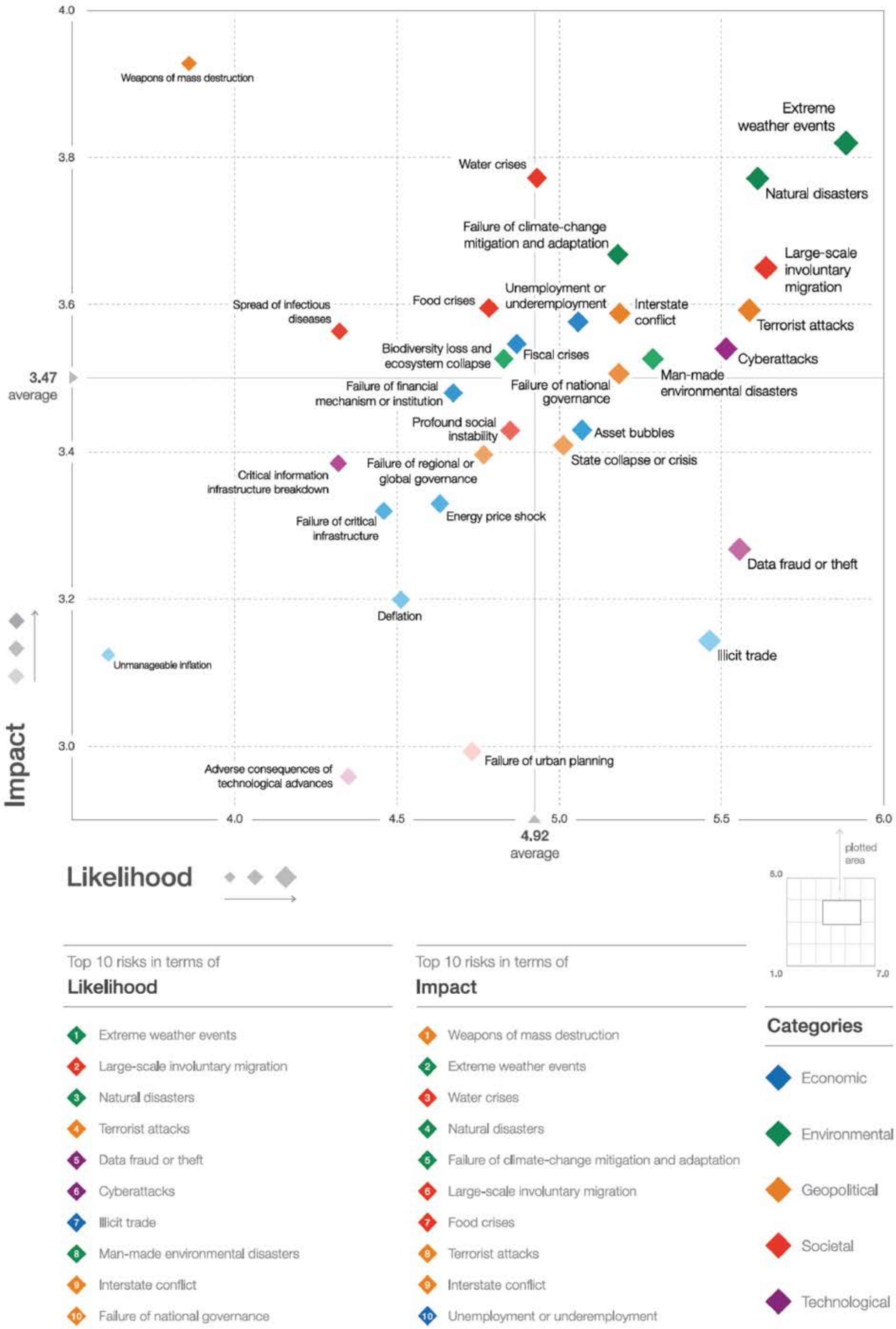


Fig. 1. Global Risk Landscape 2017, World Economic Forum.

Four of the top ten risk interconnections in this years GRPS involve environmental risks, the most frequently quoted being the pairing of «water crises» and «failure of climate-change mitigation and adaptation».

This shows that inefficient management of «common global resources» – oceans, atmosphere, and climatic system – can have huge consequences, both locally and globally. For instance, changing weather patterns or water crises can trigger or fuel geopolitical and societal risks, such as domestic or regional conflicts and involuntary migrations, especially in geopolitically fragile areas.

A recent report of the World Bank *(High and Dry: Climate Change, Water and Economy)* highlights that water scarcity, aggravated by climate change, could hamper economic growth, cause new migrations and light the spark of new conflicts. Nevertheless, most countries can neutralize the negative impacts of water scarcity by taking action to allocate and use water resources more efficiently.

The report offers the following key findings:

- Water scarcity, aggravated by climate change, could cost some regions up to 6% of their GDP, spur migration and spark conflict.
- The combined effects of growing populations, rising incomes, and expanding cities will see demand for water rising exponentially, while supply becomes more erratic and uncertain.
- Unless action is taken soon, water will become scarce in regions where it is currently abundant –such as Central Africa and East Asia– and scarcity will greatly worsen in regions where water is already in short supply –such as the Middle East and the Sahel in Africa. These regions could see their growth rates decline by as much as 6% of GDP by 2050 owing to water-related impacts on agriculture, health, and incomes.
- Water insecurity could multiply the risk of conflict. Food price spikes caused by droughts can inflame latent conflicts and drive to migration. Where economic growth is impacted by rainfall, episodes of droughts and floods have generated waves of migration and statistical spikes in violence within countries with contaminated water and inadequate sanitation.
- The negative impacts of climate change on water could be neutralized by better policy decisions, with some regions standing to improve their growth rates by up to 6 % with better water resource management.
- Improved water stewardship pays high economic dividends. When governments respond to water scarcity by boosting efficiency and allocating up to 35% of scarce water resources across sectors to more high-value uses, such as the most efficient agriculture practices, economic losses decline drastically, and may even disappear in some regions.
- In the world's extremely dry regions, more far-reaching policies are needed to avoid inefficient use of water. Stronger policies and reforms are needed to cope with deepening climate stresses.
- Thoughtful policies and well-placed investments can yield large benefits in improved welfare and increased economic growth. There are three overarching policy priorities that can help lead countries down the road to water-secure and climate-resilient economies:

— Better planning for water resource allocations;
— Adopting incentives to increase water efficiency;
— Investing in infrastructure for more secure water supplies and higher availability.

In this context, the 2016 WWDR, *Water and Jobs,* has contributed to dispel one of the failings in the recognition of the value of water: its relationship to labour. Water is an essential component of national and local economies, and it is needed to create and maintain jobs across all sectors of the economy. Half of the global workforce is employed in eight water and natural resource-dependent industries: agriculture, forestry, fisheries, energy, resource-intensive manufacturing, recycling, building and transportation.

Sustainable water management, water infrastructure and access to a safe, reliable, and affordable supply of water and adequate sanitation services improve living standards, expand local economies, and lead to the creation of more decent jobs and greater social inclusion. Sustainable water management is also an essential driver of green growth and sustainable development.

Conversely, neglecting water issues runs the risk of imposing serious negative impacts on economies, livelihoods and populations with potentially catastrophic and extremely costly results. Unsustainable management of water and other natural resources can cause severe damage to economies and to society, thus reversing many of hard-won gains in poverty reduction, job creation and development.

The analyses made in the *Water and Jobs* Report have enabled it to be estimated that more than 1.4 billion jobs, that is, 42% of the world's total active workforce are heavily water-dependent. It is estimated that 1.2 billion jobs, or 36% of the world's total active workforce, are moderately water-dependent. These are sectors that do not require access to significant quantities of water resources to carry out most of their activities, but for which water is nonetheless a necessary component in part(s) of their value chains. Examples of sectors with moderately water-dependent jobs include construction, recreation and transportation. In essence, 78 % of jobs constituting the global workforce are dependent on water.

But this is totally hidden in the official statistics and no GDP percentage is allocated to water in any country or region… As the same report brings outs, in terms of jobs and employment, few statistics reflect the current reality of work. They tend to simplify the core situation (often owing to their objectives, measurement methods and conceptual frameworks), resulting in partial coverage, insufficient detail and an incomplete analysis of complex topics. One of the greatest challenges is gathering data and information concerning informal, part-time and/or unpaid work. Another challenge lies in identifying the level of «water-dependency» for any given job.

Data from the *World Input-Output Database* (WIOD) could be analysed to derive evidence on how dependent the whole economy is on water supply and how many jobs are created when a government increases or improves its water supply, estimating backwards and forwards linkages of water supply and related sectors, to calculate total multiplier effects of potential investments in a given sector.

So there remains a lot to do to recognize the *real* value of water; and yet, it pays off to continue in this direction, for in this way decisions will be made – justified and accepted by civil society – for a better future for humanity and to improve our livelihood.

WATER IN SPAIN AND ITS SCARCELY RECOGNIZED VALUE

According to the studies assembled in Spain's White Paper on Water (MMA, 2000), only a small fraction of total natural resources (110,000 hm^3/year), around 7%, would need to be used to satisfy the different demands for water if the natural system was not artificially altered. As a consequence of the regulation infrastructure built in Spain during the C20th, especially in its second half, there has been a considerable increase of profitable volumes, which currently amount to 36% of natural inflows, compared to the previous 7%.

This change has evidently favoured the development of economic activities in the country, as is shown in the Figure 2. Yet, the conducting of an analysis that quantifies and evaluates such a contribution in terms of GDP is still pending.

Although some overall figures are beginning to be provided, it also remains to rigorously evaluate and quantify Spain's hydraulic heritage. This would enable reaching an approximation of an estimate for the necessary investment in maintenance. The need to improve knowledge in this field, and to consequently to apply the necessary economic resources to keep such an important asset for our country in service, is evident.

Today's take-off by the Spanish economy is incomprehensible without attributing a great part of it to water and its availability. But water is absent from the official accounts, because in the input-output charts for the agri-food sector, the energy sector, the tourism sector, and other parts of the industry or service sectors nothing is attributed to the water factor: its availability is still being taken for granted. Hence, its economic and social relevance (including for job creation) is only understandable by means of a *reductio ad absurdum:* if we went back to natural conditions, to reducing its availability to 7% (less than 8,000 hm^3/year), what would the economic and job picture look like? Urban and domestic uses would already be consuming more than 60% of this availability… How to reduce the rest of production activities, in the primary, secondary and tertiary sectors, without ruining national economy and employment levels?…

This applies even more when the spatial unbalance is so great: in Spain

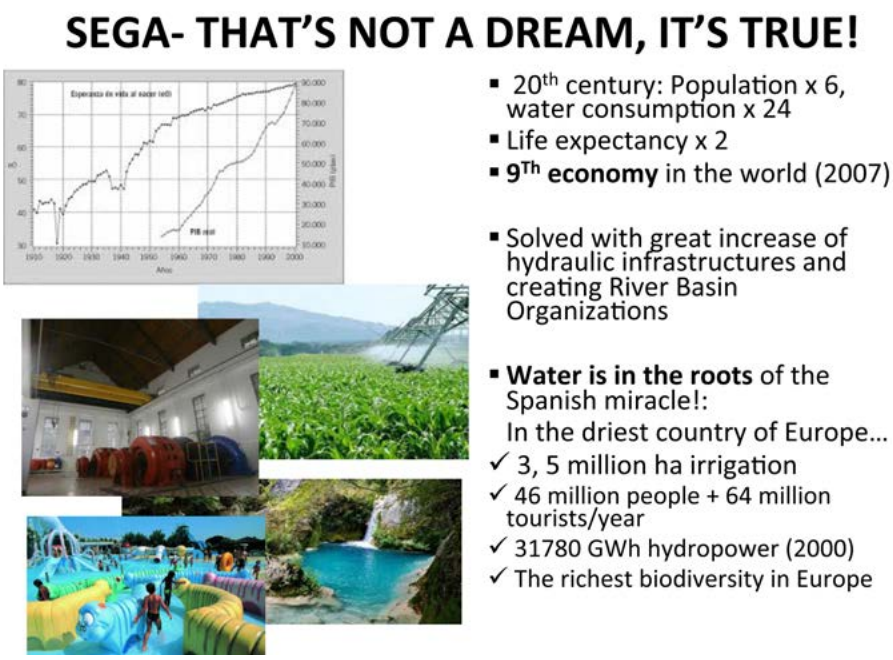


Fig. 2. SEGA –Spanish Water Governance System–: keys and achievements.

the distribution of rainfall across the different regions is very irregular, and its seasonality must also be considered. Furthermore, it so happens that water demand is at its height when rain is most scarce, and areas in most need of water are also the most water-deficient. Clear examples of this are tourism in Andalusia in the summer, or the production of fruit and vegetables in «Europe's orchard», on Spain's east coast, which may find development affected by lack of water. If we add to all this that, owing to the climate change, the forecast is a rise in temperatures and a decrease in rainfall, which will be most prevalent in the most vulnerable areas, water will become an increasingly limiting factor.

Spain generates most of its gross national product in historically dry areas, namely the Mediterranean coast and the islands.

In 2007 a study of the Ministry of Environment estimated that each cubic meter of water invested in the Spanish economic sectors yielded 27.50 euros of added value. In 2015, businesses that most rely on the liquid element represented 22.7% GDP and more than a third of exports. In the last Active Population Survey, one in five active Spaniards worked in a water-intensive sector.

According to the INE's statistics on water use (measuring the balance between water extracted from the environment and then returned to it), most of the liquid element used in Spain (around 70%) goes to agriculture and livestock farming. It has become the first country with localized irrigation per surface, and the second per percentage (after Israel). We have gone from irrigating more than half the surface, to less than 27%. The result is an almost incomparable efficiency. Irrigation takes 15% of the usable agricultural area and represents 60% of the final production.

After dwellings, the third most important sector in water use is industry; but the expense here, in terms of water flow balance, is only 2.25%. Industry has closed cycles to spend less, and a great part of industrial use is what is called non-consumptive

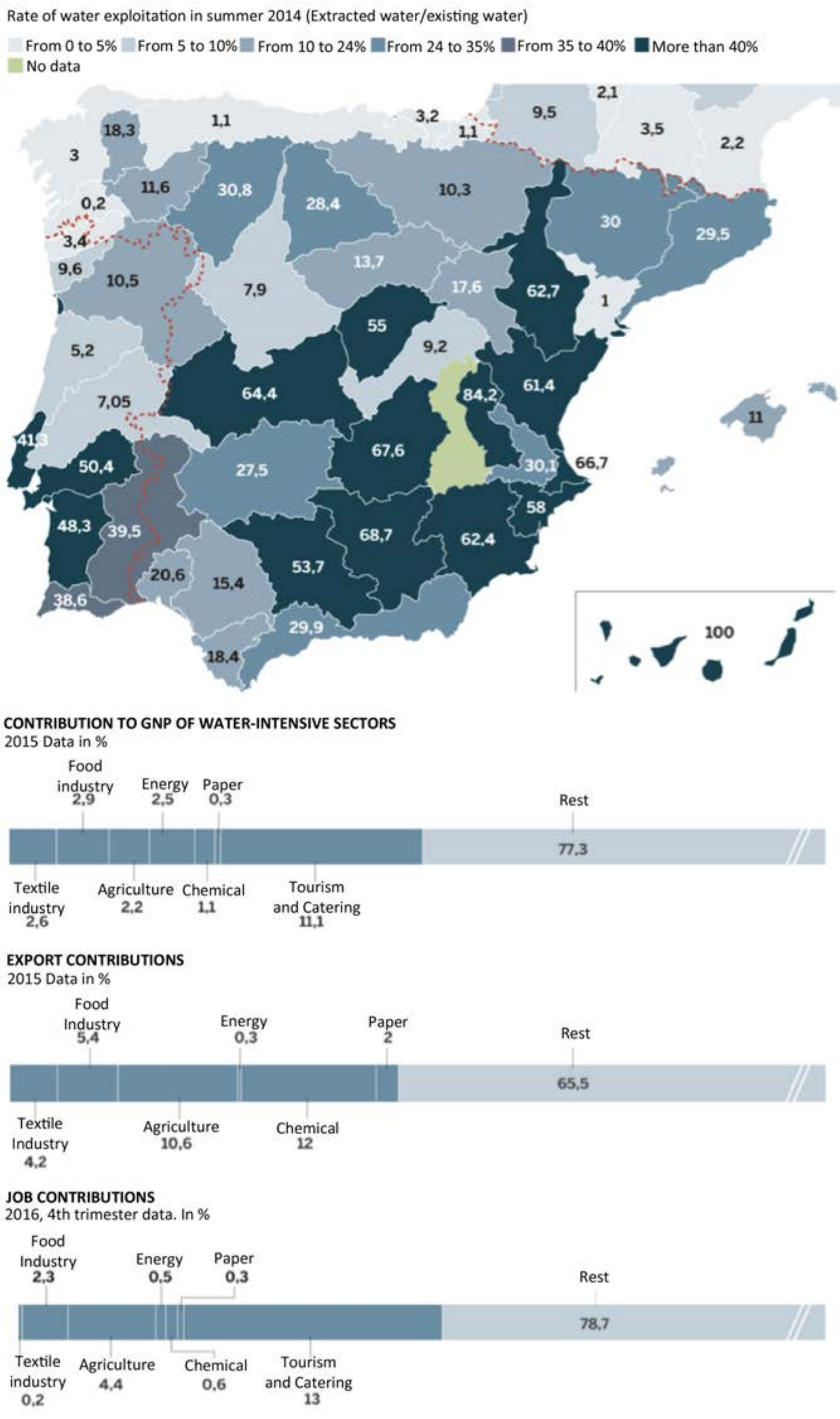
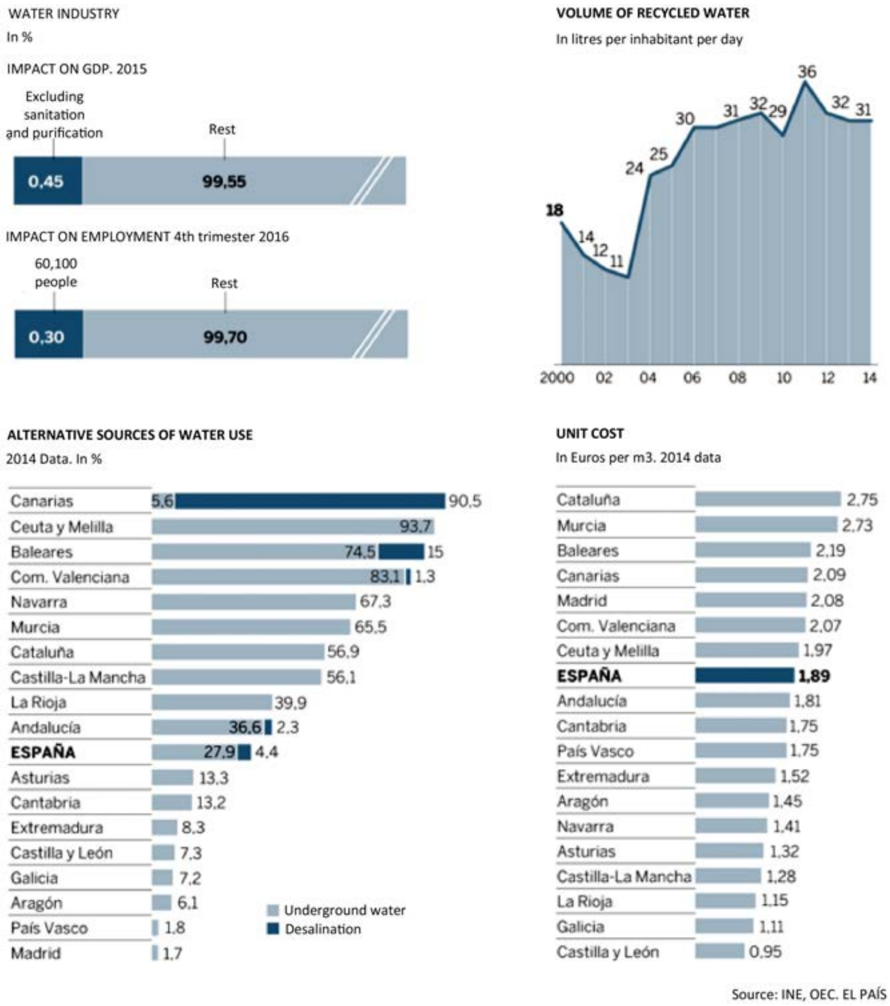


Fig. 3a. Industrial water exploitation in Spain. River Basins and recycled water.

Fig. 3b. Industrial water exploitation in Spain. River Basins and recycled water.



use. Water for industry and energy accumulates, but is not consumed. In any case, the experience of Spanish factories in managing the liquid element turns into an ideal testing ground: for instance, the American multinational chemical corporation Dow has installed in Spain its centre of global water technology, with an investment of 20 million euros and 50 employees.

The food, drink and tobacco industry is the leading water consumer for obvious reasons: rare is the recipe that does not include water at some stage. It is followed by the paper and cardboard industry. In the 1960's the quantity of water used by this sector was around 120 cubic meters per ton of produced paper. Today, the figure is around 5 cubic meters. 9 of 10 litres used by the sector return to the environment; according to Aspapel, 95% of that quantity returns to Nature purified. Aspapel also claims to have reduced its water use by 32% in the last 15 years, while increasing its production by 20%.

The chemical industry is another sector that collects a lot of water from the environment, and great attention must be paid to its treatment of water, for qualitative reasons and possible impact on the state of water bodies. And another important sector in Spain is the automobile industry; being very job-intensive, it requires the highest quality water (purified and conditioned at the factory) especially for painting processes that are carried out with the liquid element as binder.

SOME EXPERIENCES AND LEARNED LESSONS

Here are some of the experiences I've had during my professional career:

Guadalope basin, right bank of the river Ebro

In the 1970's the Integral Use of the Guadalope Basin Plan was approved. It entailed increasing regulation of the river by means of new basins and the expansion of the irrigation area from the existing 10,000 Ha to a total of 30,000 Ha, in an area with good crop returns, due especially to the ecological peach for packaging (designation of origin Calanda).

Later on, and before this Plan was developed, the construction of the coal-fired power station Teruel, property of the public energy company ENDESA, was approved. This plant would revitalize the economically depressed mining area in the province of Teruel. The power station, located in Andorra, would take water (14.2 hm^3/year) from the new Calanda dam on the River Guadalope. The water concession granted by the basin organisation to ENDESA was contested by the River Guadalope Irrigation Central Union, who claimed this use was not contemplated in the Integral Use Plan. Parallel with the legal dispute, the irrigators demanded to be indemnified with 50 million pesetas (old currency), but failed to come to an understanding with ENDESA.

Fig. 4.- Thermal power plant Teruel, Andorra.

In 1980, the works having already been built, the final sentence arrived from the Supreme Court: it rewarded the perseverance of the Irrigation Union, with President Antonio Soler at its head, and the legal expertise of their lawyer, the renowned Eduardo García de Enterría. The solution arrived at was an agreement whereby ENDESA financed the part corresponding to the users of the hydraulic works contemplated in the Integral Use Plan, including the lining of the irrigation pipelines, to the sum of more than 1,000 million pesetas! There was frenetic activity in the 80's regarding the construction of a new dam – Civán or Caspe – and the modernising of the irrigation network. Prefab metal floodgates were installed, and there was an increase in irrigation and coal extraction. The area saw a significant increase in employment and income … all thanks to «Saint Endesa», as the locals put it.

Lessons learned: the value of planning, of the organisation of user groups, of legal security in the water field… and the relativity of the value of water. If at the beginning 50 million pesetas (3.52 pta/m^3) was an investment Endesa did not want to make to obtain the cooling water from the specific power plant (additional to the work of collection and channelling), it ended up investing 25 times more (above 90 pta/m^3), because water was essential for running the thermal power station. Ah! The hidden value of water…

Of course in the official accountancy for the plant's production water is an item that has never been included – entries have been restricted to energy and mining activities.

Finding a location for a paper industry

In the 1990's, the President of the Autonomous Region of Aragón, Santiago Lanzuela, a sensible, wise and honourable man, was the President of the Ebro Water Confederation. He asked for my opinion and counsel to find an adequate location for a new SAICA paper plant that implied a significant investment and a good number of jobs. His idea was to locate it towards Teruel – as we have stated, it is an Aragonese region low in population density and economic activity. I had not doubts at all, however, about vigorously advising him to change his mind and locate the plant on the waters of the Ebro, downstream from Zaragoza, where it wouldn't conflict with any other use, the supply would be safe and water quality would not be a problem. The industrial complex

Fig. 5.- SAICA, paper plant, El Burgo de Ebro.

SAICA III was finally located there, and still produces good results.

Lessons learned: Production investments require safe water, and industries must take into consideration water availability and the need to purify its discharges in deciding its location, which must also be compatible with water planning. The investor shies away from any risks – including the environmental risk. And water managers and planners must know where there are clearances in order to foster sustainable development. This is more important than the possible subsidies investors may benefit from by being located in depressed areas. And the different administrative levels must collaborate and reach a prior understanding to avoid situations of already executed actions, which are inadequate and illogical.

Accounts of the Segura irrigation

The high added value of the Segura irrigation is well known, and that its fruit and vegetable production provides Europe with high quality fruit and vegetables, both fresh and canned.

But justice has never been done to water as a production factor, as it is absent from the macroeconomic accounting. And yet the water deficit of the Segura Basin is always seen as a worrying factor, especially for the Murcia region, which insists in solving its structural deficit in order not to see its GDP and socio-economic conditions diminished.

Some studies have now been presented that are beginning to state the economic value of water, although this needs to be specified further. In particular, the UCAM's Chair of Entrepreneurship in the agri-food sector, with the collaboration of the Banco Santander, has presented a study *(Approximation to the dimensioning of the Agri-Food System in the Murcia Region: Characterisation, contribution to the economy and employment in the agri-food and auxiliary sectors),* which aims to put figures on the reality of the regional agri-food sector. The study, based on the «from farm to fork» outlook adopted by Eurostat, incorporates goods and

Fig. 6. Orchard of Murcia.

services that are at some moment or other part of the value chain of the production cycle.

As the Study reflects, in the Murcia region the importance of the agricultural sector is mainly based on irrigation, as it is the Autonomous Region that most irrigates its total surface (16%), and whose plantations produce more than 90% of the final agricultural production. Thus the importance of having access to quantity and quality water resources – in the short, mid and long terms – to guarantee the development of the Region. Without water, there is no activity, nor the necessary food for society. The Segura Basin is structurally the most deficient in Spain, and needs external inputs to cover its demands.

As for the characterization of regional agriculture, the Study shows that an arid climate with limited water resources has always characterized the bases of the agricultural sector in the Murcia region. This circumstance, owing to the creativity and effort of the Murcian people, including in terms of technological innovation, has led to Murcian agriculture being positioned as one of the most advanced agricultures in the world, with a broad and varied product range, and a high added value.

Its most outstanding characteristics may be summarised as a significant process of agricultural specialisation, a high agricultural employment rate, and a rather small family-type exploitation that structures the rural area, preserves its conservationist character and sustains the populations that supports it. Ultimately, it is a competitive system, with few subsidies, eminently export-oriented, respectful of the environment and meeting the highest possible requirements as regards food safety and quality.

As to the economic quantification, the summarized data offered by the Study are the following:

- The vegetable production value of the Murcia region reached an annual average (2011-2013) of 1,412 million €.
- The Murcia region has an ample production specialisation in growing fruit and vegetables. These represent 95% of the vegetable production value (40.3% fruit and 54.7% vegetables). Both types of farming amount to a production value of 1,341 million €.
- Fruit and vegetable production is not widely represented in the European Union, yet in Spain it represents around 60% of the vegetable production, and in the Murcia region, above 90%. Hence more than 90% of fruit and vegetables exported from Spain are destined for E.U. countries.
- The production value of the agricultural (and livestock farming) industries amounts to 2,225 million €.
- The production value of the agri-food industry amounts to 5,438 million €.
- The agri-food system brings with it 27.9% of the regional employment (146,700), and the contribution to salaried employment corresponds to 28.4% (123,200 employees).

Lessons learned: Technology helps extend available water, especially when it yields high returns. With these data we can estimate that, conservatively, without linking the effect to the added value of the rest of the agri-food production chain (which as we have stated, declines without water), and not taking into account other irrigation areas in the Segura Basin that do not belong to the Murcia region, agriculture production, in terms of sales, amounts to around 1,500 million €. The irrigation surface in the Segura Basin is 262,393 Ha. Thus, production per hectare is around 5,700 €/Ha.

In the River Segura the objective allocation (PHS) is 1,546 hm^3. As the average consumption per m^3 is 5,891 m^3/Ha, it means 0.970 €/m^3.

Ultimately, the cost of 0.30 €/m^3 the irrigators present as the average affordable cost for water means allocating 31% of that value to water, which we find acceptable.

Another lesson: Not offering enough of this natural resource leads to the unsustainable use of groundwater, which is cheaper, but brings environmental problems owing to over-use.

TOWARDS THE FUTURE

As stated in the above-quoted World Bank Report, *High and Dry,* adequate policies and investment plans are needed in the water sector, as these can help lead countries down the road to a water-secure and climate-resilient economy.
These include:

- Optimizing the use of water through better planning;
- Adopting incentives to increase water efficiency;
- Investing in infrastructure to expand safe water supply and availability.

Solutions on water safety must be long-term and based on governance, and must encompass equally all the actors involved: public and private sectors, and social agents. Also, it is indispensable to coordinate sectorial policies so that attending to the demands of a specific sector does not prejudice water governance. In the same way, short-term decisions, taken for tax or ideological or other reasons, must be give way to a long-term vision.

In Spain, laws guarantee water supply for human use. Nevertheless, challenges lie in such areas as wastewater treatment, where there are shortages as much in the dimension of infrastructure, as in maintenance and technology. And all of this occurs in a context of decline in investment in maintenance, which is especially serious in a country where the big hydraulic works must be considered a net equity that yields so much, and in which today the water supply and sewage networks are obsolete in around 40% of cases.

Also, what we have stated shows the need in Spain to carry out integrated and sustainable planning for water resources, taking into account both the needs of all regions, and the different water uses, and setting up as one of the goals a solidary and equitable distribution of water throughout the territory. Article 45.2 of the Spanish Constitution is expressly based on indispensable collective solidarity, to help establish a rational use of all natural resources, with the aim of protecting and improving the quality of life, and defending and restoring the environment.

Equity, as a general principle in water planning, can be interpreted in the territorial sense, or from the point of view of the users. The first option implies planning water infrastructures in such a way that the allocation of flows to the different regions contributes to a reduction of the differences in income and quality of life between fragile rural areas, developed rural areas and urban areas. The second option means equilibrium must be maintained between the different groups of users so that the benefits of one group do not have a negative effect on another group, and do not distort the markets.

Specifically, dams and reservoirs play a very important role in regulating water availability, and guaranteeing the supply in times of draught, when demand is higher. In the planning process for a dam, what needs to be taken into consideration are, on the one hand, the future demands for water that the socio-economic development of the region may bring, and on the other, the differential distribution of social impacts, and insuring it is not always the same people who receive all the negative – or positive – impacts derived from the execution of the infrastructure. Therefore, the principle of equity is achieved if, for instance, the dam improves the quality of life of the most deprived members of society, or if re-housed people desire and obtain a better economic and social position in their new location.

The current situation and sensitivities show ever more clearly the need to face primarily, not so much the technical problems, but those related to social issues. It is very necessary to transmit to society transparently and clearly the situation, the problems and the possible solutions to water-related problems – and this on a global scale, not only in Spain. There can be no doubt that participatory and well-informed planning is an adequate and globally recognised path for these processes. Education is

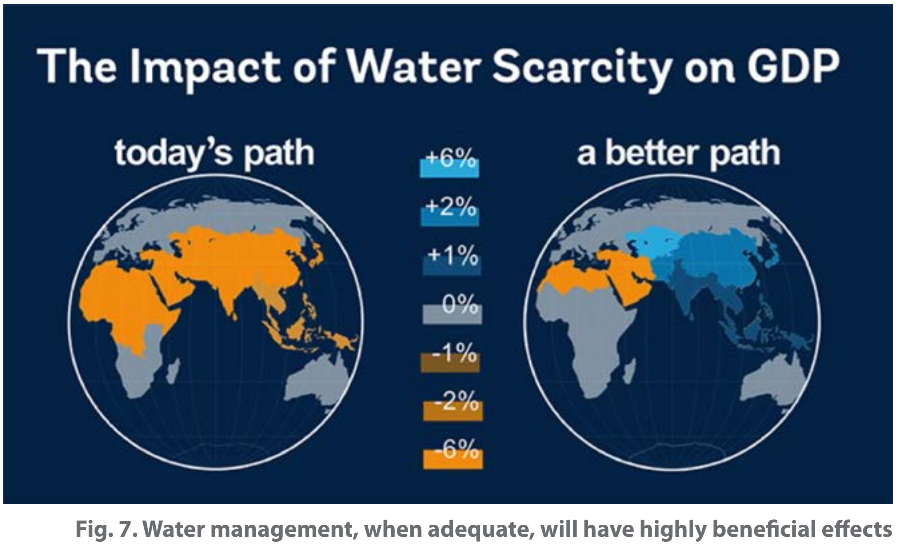
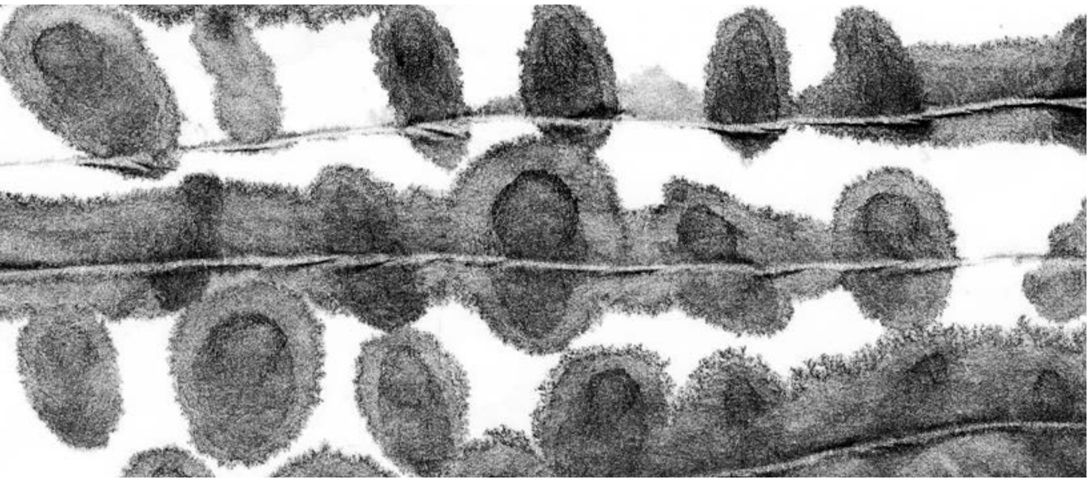


Fig. 7. Water management, when adequate, will have highly beneficial effects (forecast of the World Bank Report).



required to the same extent as communication is required.

Here in our country we must accept that water is a public good that needs to be promptly and firmly regulated. The sooner the water strategy is adjusted to this reality, the better. Adaptation implies adopting policies that follow the following summarized criteria: 1. Avoiding water waste with instruments such as setting deterrent prices for specific ends, and as a last resort, applying selective rationing measures (albeit not for drinking water); 2. Programming investment in irrigation, reservoirs, water-recycling, purification and desalination – water expectations for the next 5 years alone mean it is advisable to keep all technological options open; 3) The principle «Who contaminates, pays» is not enough to confront the water challenges now: contamination and waste must be prevented.

On the other hand, within the context of an advanced economy and progress, with the Fourth Industrial Revolution (4IR) shaking up the interdependent set of critical physical infrastructure networks on which we all depend –transport (road, rail, waterways, airports); energy (electricity, heat, fuel supply – gas, liquid and solid); digital communications (landlines and mobiles); water (supply, wastewater treatment, flood protection); and solid waste (collection, treatment, disposal) – brings huge opportunities for innovation, but also complex risks.

The value of a physical infrastructure network increases with its scope. In resource networks (energy, water), connecting more people can help build resilience and leverage economies of scale.

With the crisis of public finance, governments and regulators must invent mechanisms to leverage private funding, while trying to avoid inflexibility and the requirement of cost-efficiency, which the financing of the public-private infrastructure has pursued in the past. It is not yet clear how the needs of the enormous investment in certain types of infrastructure will be covered.

Water could also transition from centralized networks towards more distributed systems. New materials and sensor technologies allow treatment at the household or community levels, creating opportunities to 'harvest' rainwater and directly reuse wastewater. For the time being, economies of scale still favour large, centralized plants in existing urban areas; they also allow utilities to monitor water quality centrally and address failures quickly. Relying on localized water storage would also create challenges during prolonged periods of drought. But centralized networks are costly to create, and the balance of costs and benefits is beginning to tip in favour of distributed water systems if cities can be planned for these systems from the outset – something to bear in mind for developing countries with their growing urbanization processes.

Governments are increasingly recognizing that this fragmented approach is becoming unfit for purpose in the 4IR. As networks become interconnected – for example, as digital technologies enable the routing of vehicles and the management of electricity and water demand – a «system-of-systems» approach to governance is needed. That requires appropriate sharing of information among network operators, and also requires regulators adopt common principles across networks.

While the 4IR is creating complex new challenges for planners and regulators, it is also providing powerful new tools for monitoring and analyzing system performance on hitherto unprecedented spatial and temporal scales – and testing resilience through simulation. Modeling exercises in a virtual environment will never give infallible results, but the exercise of constructing and testing models can in itself help to expose vulnerabilities in systems resilience. Alongside their traditional role of minimizing the harmful effects of natural monopolies, infrastructure regulators in the 4IR should be paying more attention to systemic risks, building technical capabilities and standards for information sharing and stress-testing. All of this in a context of climate change.

FINAL CONSIDERATIONS

In a recent conference[3] on water governance in the context of climate change, the Norwegian politician Brundtland, responsible for introducing the concept of sustainable development into the world agenda, called for a global and coordinated answer to the challenge faced by the whole world: «For the year 2030, population growth will mean the worldwide demand for food will grow by 50%; energy by 45%, and water by 30%». In fact, this international expert claimed the lack of water could lead to a significant drop in the world's GDP, and warned that «Water is a worry we share in common, which will have a direct and indirect effect worldwide», to the extent that there is a risk that «by 2025 more than 3,000 million people may be affected by a water crisis». In this sense, there is consensus among experts: climate change challenge makes it a priority to guarantee water safety, something that has not received enough thought and for which we are at least 20 years late.

Brundtland urged all countries to remain committed to fighting climate change and to develop the Paris Agreement. «We must take our commitment to confronting climate change very seriously, because economic development and the weather must be united», concluded the Norwegian politician, pointing out that «the relevance of the UN is today at stake and is more important than ever»; because the answer to the challenges presented by climate change can only be delivered effectively from a global perspective.

At the WCCE, we firmly concur with these thoughts, taking account of the importance of the contribution of engineering to water, as well as collaborating in the effective recognition of water's value, its availability and efficient use, its integrated planning and management, and its governance. As partners of UN Water, we have resolved to boost a positive dynamic that will enable us to successfully meet the ODS 6 challenges and the aims of the Paris Agreement. We are seriously committed to this – our future is at stake!

Tomás Ángel Sancho Marco
Civil Engineer
WCCE Former President
– World Council of Civil Engineers –
FYSEG Managing Director
–Fulcrum and Sers Engineering Group–

Footnotes

1. Saint Francis of Assisi, *Canticle of the Creatures* (C13th): «Laudate si, mi Signore, per sor'Acqua,/ la cualè e multo utile et humile et pretiosa et casta» («Be praised, my Lord, through Sister Water,/ So very useful, humble, precious and chaste…».
2. *European Water Charter,* 1968: «Without water, there is no life possible».
3. IV Forum on Water Economy, Spain 2016.

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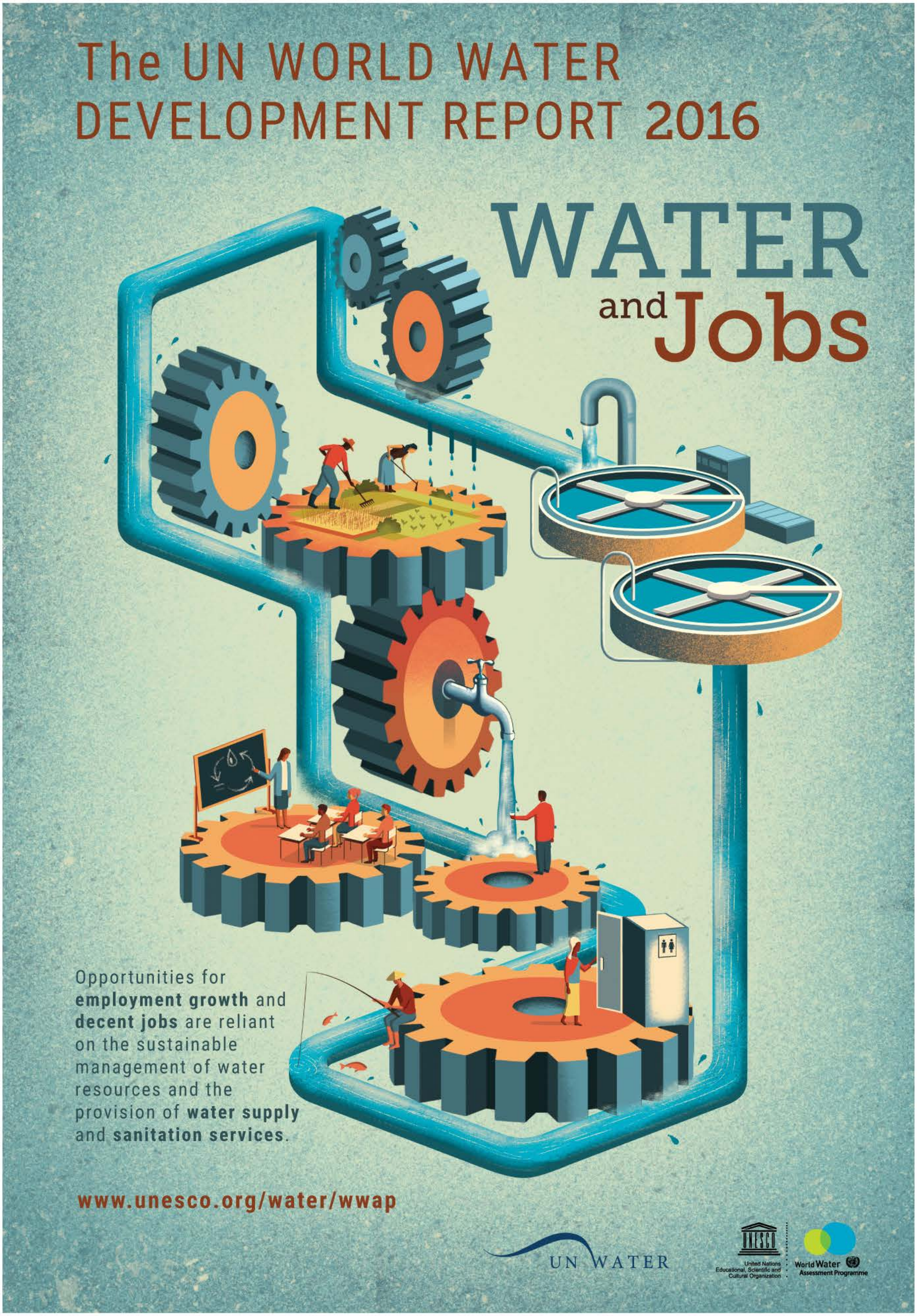
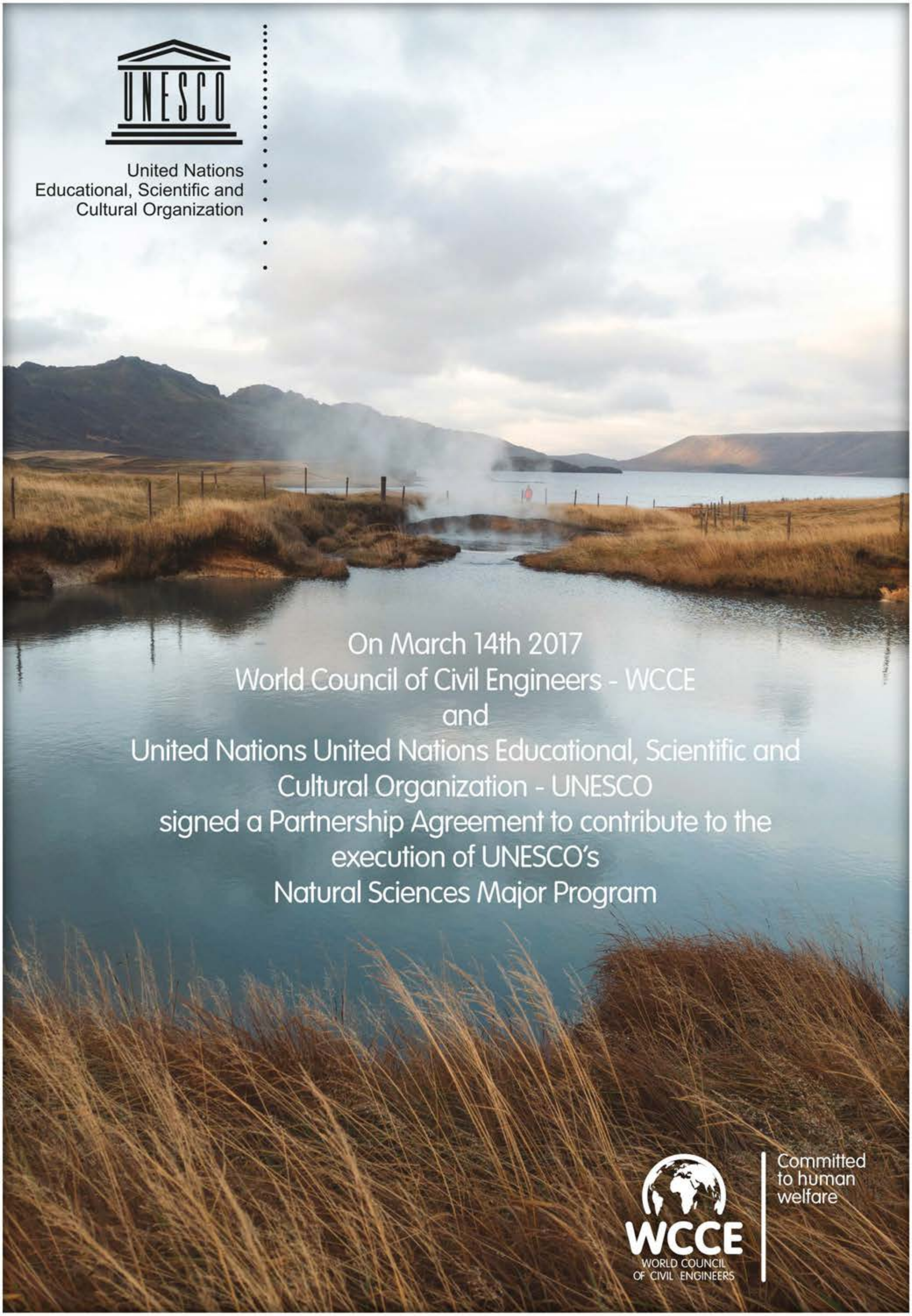

The UN WORLD WATER
DEVELOPMENT REPORT 2016
WATER
and Jobs
Opportunities for **employment growth** and **decent jobs** are reliant on the sustainable management of water resources and the provision of **water supply** and **sanitation services**.
www.unesco.org/water/wwap
UN WATER
United Nations Educational, Scientific and Cultural Organization
World Water Assessment Programme


United Nations
Educational, Scientific and
Cultural Organization
On March 14th 2017
World Council of Civil Engineers - WCCE
and
United Nations United Nations Educational, Scientific and
Cultural Organization - UNESCO
signed a Partnership Agreement to contribute to the
execution of UNESCO's
Natural Sciences Major Program
WCCE
WORLD COUNCIL
OF CIVIL ENGINEERS
Committed
to human
welfare

TOWARDS INTEGRATED WATER RESOURCES MANAGEMENT:

CAF'S GROWING COMMITMENT TO WATER

Víctor Arroyo

KEYWORDS:
Sustainable development
comprehensive water management
social inclusion
equality
water and sanitation services
human right to water
productivity
sustainable development goals
social development projects
knowledge management

Water is a vital resource for the development of production activities such as agriculture, energy production, tourism and industry. It is a crucial element in the partnership agendas for the collaboration of funding bodies and their cooperation with States, to foment productivity and contribute to guarantee human welfare. In fact, the lack of access to adequate sanitation and safe drinking water is one of the main factors that accentuate the precarious conditions in which a large part of the world's population still lives, especially people living in rural or peri-urban areas. Investing in water is an intelligent decision to help further the productive social inclusion of the most disadvantaged inhabitants. CAF, as the Development Bank of Latin America, which is one of the most inequitable and difficult areas in the world, has as its priority objective to support member countries in increasing the coverage of sanitary and water services, and thereby at the same time contributing to strengthen the institutional and governance aspects of the companies responsible for water management in the region, so that these services may be sustainable and help tip the balance in favour of social and economic equality.

Being an entity that offers financial solutions and promotes the exchange of knowledge for the sake of development, our institutional approach recognizes the importance of macroeconomic stability, the active participation of the private sector and the stimulus it offers for the microeconomic efficiency in the region, within the framework of preserving the environment and promoting social inclusion. Social exclusion is reflected mainly in the lack of access to basic services, and especially to water, so that facilitating access to this service represents one of the strategic sectors for investment: in the past 10 years, more than 6,000 million US$ have been approved for programmes and projects of water and sanitation development.

Fig. 1. Beneficiary of the Programme MY WATER in the Pando Department, Bolivia. Photo by Osvaldo Valverde, CAF.

A COMPREHENSIVE APPROACH TO THE HYDROLOGICAL CYCLE AS STARTING POINT

The hydrological water cycle possesses a unique nature, and is crucial for economic and social development. Water is a natural resource that moves through time and space – in a continuous cycle of evaporation and rainfall – and it is found on the surface of the earth, percolating into it. But it also gathers in glaciers, lakes and wetlands, and underground. This is why water-use must be understood in the context of the hydrological cycle and the river basins as the geographical spaces that determine the surface runoff, as well as the processes that govern the soil's chemistry and the answers of the ecosystems to the climatic signals. In Latin America we have more than a third of the freshwater resources of the planet, while the region has only 600 million inhabitants – less than 10% of the world population. Nevertheless, more than 30 million Latin Americans still have no adequate access to safe drinking water.

Water management must follow the natural logic of the water cycle in a holistic, systematic and unifying approach, known as Integrated Water Resources Management (IWRM). This concept, consecrated in the Dublin Statement made during the International Conference on Water and the Environment in 1992, has been a catalyst in formulating the global agenda for water and development. This contemplates the need to:

1) Recognise that freshwater is a vulnerable and finite resource, crucial in sustaining life, development and the environment. This furthermore assumes that water management must be based on a participative approach, involving users, planners and decision-makers in the formulation of policies at every level, with the understanding that women play a key role in water provision, management and protection. Last, but not least, it means accepting as a principle that water has an economic value

Fig. 2. Wastewater treatment plant.

in all its competitive uses, and therefore must be recognised as an economic asset.

2) Adopt an integrated approach to the development and management of water resources as a starting point in the path towards achieving the goal of reducing poverty, food-safety, economic progress, and advancing development and ecosystem protection levels. IWRM provides a sustainable approach to confront the fundamental water challenges, and their links to other industries, such as agriculture and energy; additionally, it provides the tools to prevent and control the effects of flooding, mitigating the effects of drought and water-borne diseases. Effectively, the key is to attain equilibrium between the availability of water supply and the demands of the different water uses, through efficient coordination and the implementation of adequate policies to support it. For this a decisive participation from outside the water sector is needed, generally from legislators and public-sector managers in government finance, economy and planning, these being key actors for any transformative agenda.

In order to improve water supply in Latin America, obviously the efforts to build the necessary infrastructure must be increased. But, at the same time, it is necessary to work on a better management of the demand in order to avoid an exaggerated consumption, which implies an inefficient use of the resources and the energy necessary to produce them. To rely on the abundance of water in the region would be a terrible mistake, for this natural resource is not necessarily always available due to the seasonal rainfall distribution and climatic variability. In addition, the resource is not always available close to the demand centres; on the contrary, very often it is far away or in other river basins. In Peru, for instance, 85% of urban and productive demand is on the coast, which only holds 2% of the water in the country. In the case of Mexico, 80% of the urban demand is found at 1,000 m altitude, where only 20% of the country's water resources. CAF has conducted studies that estimate that until the year 2030 investments above 250 million US$ will be needed to achieve universal coverage and lay the foundations for water security in the region's cities.

As to water demand, the levels of consumption and losses observed in Latin America are very high compared to the best industry standards, which poses a multidimensional challenge that includes a serious education task and establishing the appropriate incentives through adequate tariff and cost-recovery management.

THE HUMAN RIGHT TO WATER, A PRINCIPLE OF EQUITY AND SOCIAL INCLUSION

In 2010, following the consultation process initiated in the Rio de Janeiro Summit in 1992, access to water and sanitation was declared a Human Right and it motivated in recent years, especially in Latin America, a significant increase of sectoral investments with the aim of achieving the widest possible access to water and sanitation for its inhabitants, although the progress in facing this ever greater challenge, is uneven. Under this approach, human right to water implies everyone's right to physical access without discrimination, with the right to have a sufficient quantity of water, of adequate quality, at affordable rates and under acceptable technological criteria. Sanitation also requires achieving universal access, with sanitation facilities inside or in the vicinity of every home, in an environment of hygienic and safe conditions, also at accessible rates and with technologies in accordance with the inhabitant's mores and cultural patterns.

In spite of the fact that Latin America achieved the target of meeting the Millennium Development Goals on water, investment in works on infrastructure, such as abstraction, pipes and storage, which guarantee safe drinking water, have been bypassed. Furthermore, on the one hand it is necessary to recognise that a comprehensive approach to water management allowing a sustainable use of the resource has not been fully adopted. On the other hand, if we consider separately the progress made in terms of urban and rural goals, the results for the latter are still not sufficient to reduce the existing gap between them.

As to sanitation, one of the big chores pending in the region – the goal of halving the proportion of people who do not have access to basic sanitation – has not been met by several Latin American countries. This presents a more complex challenge that implies working in different fields, including generating demand and changes in the citizens' behaviour.

There is no doubt that in spite of the progress made in the past few years in this respect, we cannot think of sustainable development without a significant reduction of Latin America's levels of inequity, reflected in improvements on income distribution. With an 80% urban population, the region's equity does not answer to this degree of urbanisation, nor to its countries' economic development levels, making it an absolute necessity to promote structural changes in different fields, taking into account that a model of economic growth that reduces poverty, but maintains inequity, is not sustainable. This is why human capital must be strengthened by means of a competitive approach to equity, and efforts at generating decent and more diverse jobs must be doubled. But in order to establish a link between qualified offer and decent jobs there first need to be improvements in the economic and social infrastructures, especially in the public services, which are the basis of inclusive development.

The access to water services and sanitation is a requisite for guaranteeing social justice and human dignity, to which everyone aspires and is entitled. Because of the crosscutting nature of water, access to these services directly favours food security and people's health, with positive externalities for education and employment, motors of economic and human development. Not having access to these services accentuates the already high levels of vulnerability of some inhabitants, especially in rural and peri-urban areas, to diseases such as diarrhoea and dysentery, the recurrence of which normally has an impact on school attendance and labour productivity.

The Millennium Development Goals (MDGs) for the 2030 Agenda, established by the United Nations as a whole, and approved by most countries in September 2015, lay down a significant challenge as regards the human right to water and sanitation: universality orientated not only to access to both services, but also in a fair and accessible condition, with an adequate hygiene and under the concept of an efficient use and comprehensive management of water resources. This is our target for the coming years.

WATER, EMPLOYMENT AND PRODUCTIVITY

The human right to water and sanitation decree has been a turning point in the history of providing water and sanitation services. In assuming such an important commitment, the countries have also set the goal of achieving universal water and sanitation coverage in homes, schools and work places, the latter being a main source of production. The 2016 United Nations World Water Development Report (WWDR) states that *investing in water is a win-win proposal from the economic, social and environmental points of view.* If these investments made by governments, cooperation agencies or the private sector are made within the framework of a comprehensive management of water resources, not only could we make better progress towards a green economy, but it could also give a boost to the human capital involved in this sector. Especially in Latin America, we must encourage this vision with a gender

Fig. 3. Sprinkler irrigation technology in the Department of Santa Cruz, Bolivia. Photo by Osvaldo Valverde, CAF.

perspective: to include women in decision-making posts regarding water management, not only because women represent an essential part of the workforce historically excluded from this professional sector, but also because women could lead the change towards achieving human right to water without discrimination, generating more opportunities in education, employment and training for those women who, being in great part dedicated to domestic chores related to water, lose more time because of the inefficiency of these services. This would contribute to reducing the inequalities that still persist in Latin American society, and it would also be a step forward towards real equality and a more diverse and better-trained labour market.

On the other hand, if we take into account that Latin America has 28% of the world's soil for agriculture, and a third part of the fresh water on the planet, two enormous privileges representing an enormous potential to increase food production; and in addition, we stress that women represent half the workforce in agricultural production, and play a key role in family-based agricultural livelihood, it is obvious that wider gender equality would contribute in great measure to achieving food safety and to vast economic potential in the region. Even beyond this gender approach, the agricultural sector in the region will have to face another important challenge: to contribute to food production that will increase to 60% in order to satisfy the growing demand due to the population growth that will reach 9,000 people in the world in 2050. Taking into account that irrigated farming will be key to the region being able to make an important contribution to overcome this challenge, we cannot overlook that greater investments are needed in the irrigation infrastructure and to guarantee water availability for farming, and that it is urgent to deepen our efforts in strengthening institutions in order to increase water productivity in agriculture and gain a wider access to international markets. An attainable 30% increase in water productivity could reduce in great measure water-use for crop irrigation, reducing at the same time the pressure on water resources and environmental degradation, and improving safe water conditions. From central and local governments, the private sector and multilateral agencies we must foster innovating and implementing new irrigation technologies that will contribute to improve the agricultural productivity, and at the same time generate a boost in human capital training in the sector, within the framework of the new farming paradigms.

On the other hand, and in order to have a better understanding of the importance of water for employment, and the vital interrelation between these two elements, it should also be noted that, according to the 2016 United Nations WWDR, *78% of workplaces constituting the world workforce depend on water.* For this reason, the lack of access and the precariousness of drinking water and sanitation services are important obstacles to the growth of the labour market, and therefore hamper a country's economic development. To invest more in water and efficiently manage the water resources will be, without any doubt, an important challenge for Latin America in the coming years, and it will also be a unique opportunity for economic growth and social development. According to the CAF studies, the region must invest 0.3% of the annual GPD until 2030 – an easily assumable investment for the countries in the region – in order to improve the water and sanitation service, and close the gap in this respect in the urban areas; while it could at the same time advance in the rehabilitation of basic infrastructures and expanding supply sources to cover the additional demand for 100 million new inhabitants in cities. In addition, it is necessary to maintain the operating costs, equivalent to 0.5% of the annual GPD. From an economic point of view, this investment is profitable because it is inferior to the cost of bad quality water, for example in Colombia, where it has been calculated that this has an impact of 1% of its annual GPD. For all these reasons, efficient water management must be the driving force for productivity and inclusive development in Latin America.

DEVELOPMENT PROJECTS IN THE SECTOR, THE MAIN TRANSFORMING TOOL

Promoting social inclusion in Latin America by increasing the population's access to high-quality public services and goods, such as water and sanitation that contribute to improving the inhabitant's welfare and quality of life, especially among the poorest, is one of our institution's main goals. From a comprehensive vision of the water cycle, CAF supports stakeholder countries through preparation and financing studies, projects and investment programmes that contribute to improving the population's quality of life through four main lines of action: river basin management and protection, basic drinking water services and basic sanitation, flood management and control, irrigation and agricultural development. In addition we aim to create the necessary conditions to ensure adequate management and sustainability of basic services through strengthening the institutionalism and governance of companies and responsible agencies in water management in the region.

As a Latin American multilateral agency, CAF analyses the problem at a regional level, and country-by-country, to then devise a collaboration agenda and a plan of action in technical assistance and

Fig. 4. Wastewater treatment plant.

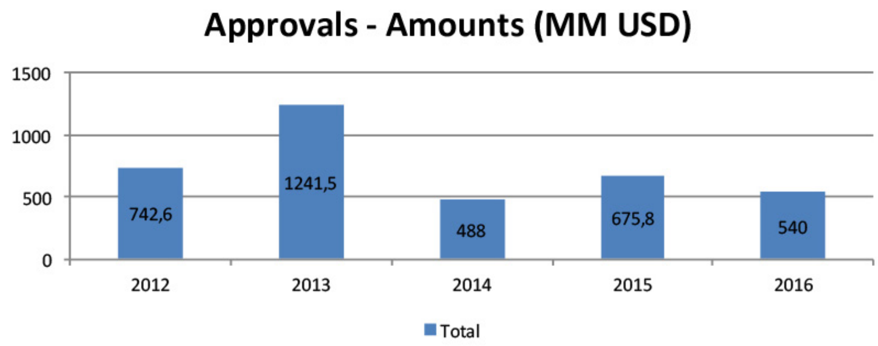


Fig. 5. Amounts of the CAF approvals for water and sanitation projects and programmes (2012-2016).

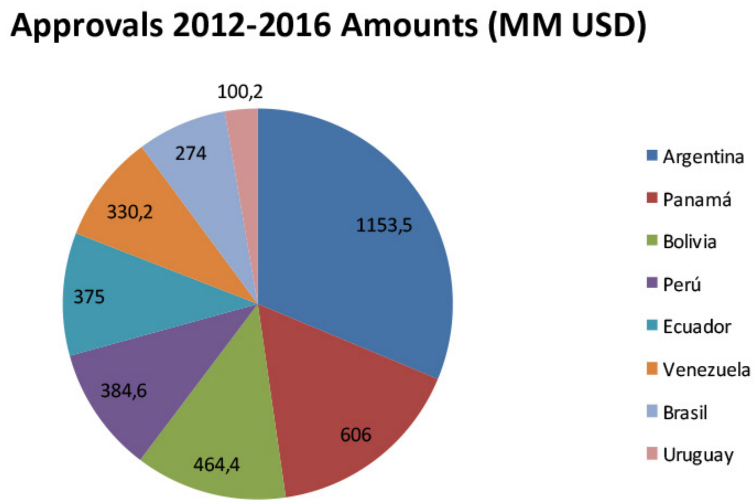


Fig. 6. Amounts of CAF approvals for water and sanitation projects and programmes, distributed by countries (2012-2016).

funding, coordinated with the national authorities, and also to identify possible allies capable of contributing to improving the implementation of the projects. With this outlook close to 80 programmes and projects have been funded in the water sector in the past 15 years. In a period of 5 years, covered between 2012 and 2016, more than 3,500 US$ have been approved for this sector.

At the moment CAF is the main multilateral funding entity in the sector in countries such as Ecuador, Bolivia, Panama and Venezuela.

In order to support Latin American countries in achieving access to water and sanitation, CAF has implemented programmes at a national level, such as Mi Agua in Bolivia, which since 2011 has contributed to more than 120,000 families in rural areas having access to water and sanitation, and another 80,000 having access to stable irrigation systems. Led by the Ministry of Environment and Water, and implemented by the National Fund Project for Productive and Social Investment (FPS) of Bolivia, the programme focuses on rural populations of less than 2,000 inhabitants, where there are more precarious infrastructures.

In the past 5 years Bolivia has registered significant progress in access to water and sanitation, but there is still a long way to go in order to succeed in helping all Bolivians, especially those living in rural areas, to have safe access to this basic service. In the case of Mi Agua, part of the programme funds is destined for building and improving irrigation systems to increase productivity for small and medium-scale farmers. This is intended to increase their income and improve the life conditions of rural families. Since the year 2009 until today more than 600 million US$ have been invested in the water sector in Bolivia.

As mentioned earlier on, a challenge in the region is progress in sanitation systems. In fact, today approximately 1 in 6 Latin Americans does not have access to sanitation, a situation that is even more acute in rural areas. The region needs to double its efforts to reduce this gap, that as well as making decent the people's quality of life, it will imply a substantial improvement in the structural conditions of public health.

In addition, in Latin America 70% of wastewater is discharged in nature without treatment, which has an obvious potentially negative impact on health, conservation of natural resources, the environment and the production sector, especially for more vulnerable populations with bad-quality service. Nevertheless, in the region there is already more consciousness of this reality, and action is being taken in this respect. A clear example of this the Panama Sanitation Programme (PSP), the main investment project of environmental sanitation implemented in the country aiming to improve public health and quality of life through two key strategies. In the first place, to reduce the contamination of urban rivers and channels in Panama, Arraijan and La Chorrera, through building and expanding the sanitary sewer system; secondly, to recover environmentally the Panama Bay with the construction and implementation of the whole infrastructure of water sanitation and treatment in the mentioned areas.

It is worth stressing that the programme, which has received CAF contributions and funding of over 550 million US$, has outlived government and administrative changes, to finally become in actual fact a State programme; and it has a comprehensive vision of a sanitation system, because it includes the collection of wastewater through a sewer system, as well as a network of wastewater receptors and collectors that carry it to the treatment plant.

With the PSP framework, progress has been made in building important works such as the Juan Diaz Wastewater Treatment Plant, which will enable the treatment of wastewater from 400 thousand inhabitants. And with the expansion of this plant it is estimated that the number of beneficiaries will increase to a million. The PSP contemplates building a total of three plants, which it is expected will have a treatment capacity of 7 cubic meters per second.

OPERATIONAL INNOVATION AND KNOWLEDGE MANAGEMENT AS NECESSARY COMPLEMENTS

A strategic decision taken by CAF's Vice-President of Social Development has been to link the funding programmes with the knowledge agenda, with the aim of improving the quality of the projects, both in their preparation and in the execution and operation phases. Developing knowledge-related activities in the water sector is another strategic priority for our institution, ensuring the funding has the biggest impact in the countries' development.

This link between the Knowledge Agenda and the Credit Operations aims at offering CAF's clients knowledge and innovation products at the highest level of international development practice. In this sense, there has been work on identifying and implementing actions with instruments to add more value to the funding programmes within a continuous learning process, based on evaluation of the operations throughout the project's cycle, as well a systematic internalisation of the lessons learned during the cycle.

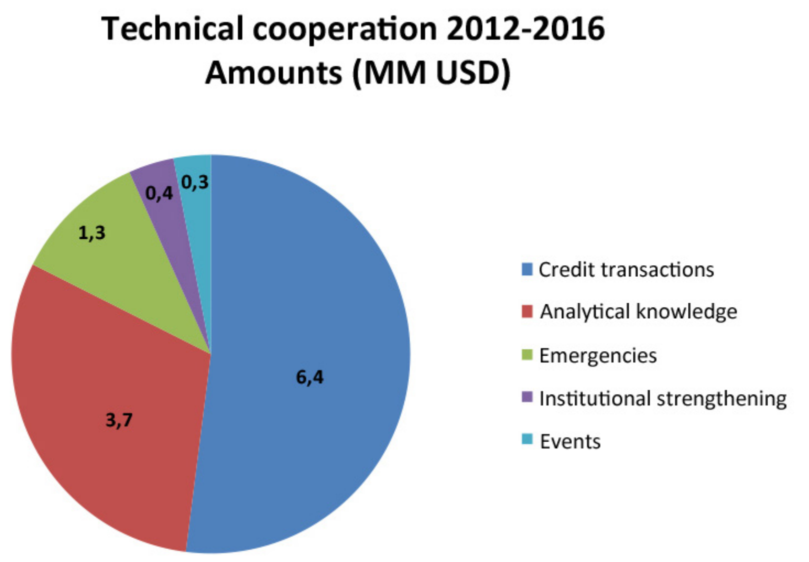


Fig. 7. Amounts of the CAF approvals for water and sanitation Technical Cooperation (2012-2016).

A large part of this Knowledge Agenda is implemented through the technical cooperation funds at the disposal of the institutions, which represent non-refundable loans to complement our support to the development of Latin American countries via 5 main axes: 1) pre-investment studies and monitoring water and sanitation credit transactions; 2) analytical knowledge, including reports, publications, strategic plans and sectoral analysis; 3) emergencies, humanitarian assistance and planning prevention for disasters, such as droughts and floods; 4) institutional strengthening, comprising workshops, training and launching of strategic, operational and improvement plans in collaboration with official agencies; 5) organising forums and events at regional and international levels.

The implemented plan to increase and make visible CAF's actions and activities includes key participation in the international and regional forums with the greatest influence and impact. Internally, the approach has been to consolidate a management model for the projects cycle aimed at operational credit improvement and strengthening technical and institutional skills. At a communicative level, our strategy is based on positioning the institution's messages with specialist PR representatives in the different regional spaces, presenting close and useful perspective for the specialised and general audience in order to contribute to the public debates currently taking place in the Latin American development area.

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Vice-Presidency of Social Development
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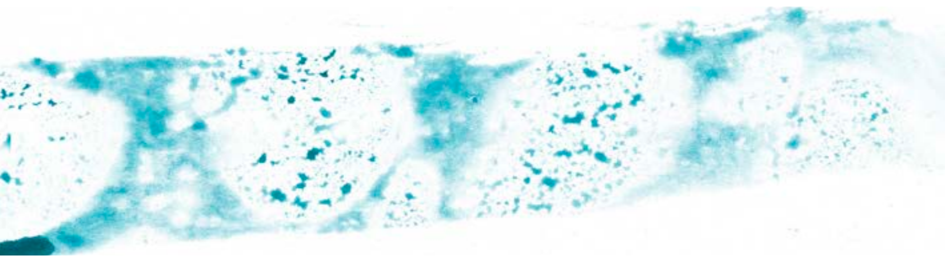
CANAL DE ISABEL II

MANAGEMENT MODEL FOR THE 21st CENTURY

Belén Benito Martínez



KEYWORDS:
SUSTAINABILITY
PUBLIC MANAGEMENT
TARIFF STRUCTURE
COMPREHENSIVE WATER CYCLE
SUPRA-MUNICIPAL MODEL

OUR HISTORY

Canal de Isabel II was built 165 years ago to meet a technical and social challenge: to make viable the growth of Madrid as Capital of Spain.

In the mid-19th Century, Madrid had only 10 litres a day per person to cover the needs of the whole population: drinking, bathing, cleaning, irrigation… It was a time of water-sellers and water-transport. As opposed to other European capitals, Madrid did not have a great river or a lake that could facilitate a trustworthy source of water supply.

In 1848, Juan Bravo Murillo, Minister of Education, Commerce and Public Works, ordered from engineers Juan Rafo and Juan de Ribera a study of possible solutions for Madrid's water supply, including a previous analysis of the projects reported during the last century.

Rafo and Ribera wrote *Memoria sobre la conducción de aguas a Madrid* (Memoir on the pipe-systems conveying water to Madrid), and on June 18, 1851, after Bravo Murillo had been named President of the Council of Ministers and Minister of Finance, Queen Isabel II signed the Royal Decree for carrying out of the necessary works to supply water to the capital of the Kingdom. Article 3 of the Royal Decree led to the creation of the Administrative Council, and consequently, of the Company.

The solution included the building of a dam in the Lozoya River, at Pontón de la Oliva, before it flows into the Jarama River – 70 km of pipes, and a regulating tank holding enough water to ensure 5 day's water use.

On June 24 1858, seven years after the Company's foundation, the water reached the Campo de Guardias' reservoir.

The engineers designed and the Government promoted infrastructures capable of carrying 328.000 m^3 of water on a daily basis, demonstrating an extraordinary vision of the future, or as we would say today, long-term thinking.

This was followed by a series of events that led Canal de Isabel II to be the Company it is today.

Fig. 1. Guadalix Syphon. Clifford (around 1854).

CANAL ISABEL II TODAY

In 2012, Canal de Isabel II was constituted as a limited company, maintaining its character of public company – the shareholders include the Community of Madrid and 111 Madrilenian municipalities – assuming the management of the Public Entity Canal Isabel II, created in 1851.

We therefore continue to be the Community of Madrid public company in charge of the total management of the comprehensive water cycle in the Madrilenian region, including the activities concerned with management as such, but also, recovery management, inspections, provision of other services to the clients, and general commercial activity.

With business figures around 865 million euros, and almost 2,600 employees, it provides services of varying significance to the municipalities comprising the Community of Madrid:

- It provides water to 6,20 million residents in 170 municipalities, implying coverage of 96.30% of the whole population. In 2016 it supplied 491 hm^3 to the population.
- It treats wastewater in all the municipalities of the Community, which implies serving a population of 6.43 million inhabitants. The volume of treated wastewater in the last 12 months has reached 498 hm^3.
- It supplies treated wastewater to 21 municipalities, higher than last year's 12 hm^3.

But Canal de Isabel II also forms a corporate group of 33 investee companies, stretching beyond the Community of Madrid to the rest of Spain – Cáceres, Lanzarote and La Graciosa –, and Latin America.

In 2016, the Canal Corporate Group supplied more than 10 million inhabitants in 5 countries – Spain, Colombia, Ecuador, Peru and Brazil – and provided commercial services to almost 90 million inhabitants in Spain and Latin America.

Chart 1 Main Canal de Isabel II facilities	
Number of reservoirs	14
Capacity of the reservoirs (hm^3)	946
Number of drinking water treatment plants	14
Global treatment capacity (daily hm^3)	4.55
Number of large regulating tanks	33
Length of supplying networks (km)	17,366
Length of reclaimed networks (km)	14,784
Number of wastewater treatment plants	157
Length of regenerated water networks (km)	510
Number of wastewater regeneration plants	22

SUPRA-MUNICIPAL MANAGEMENT

165 years of history have served to constitute the territory management model Canal has today.

As soon as the project was presented in 1851, different municipalities requested to be supplied from the

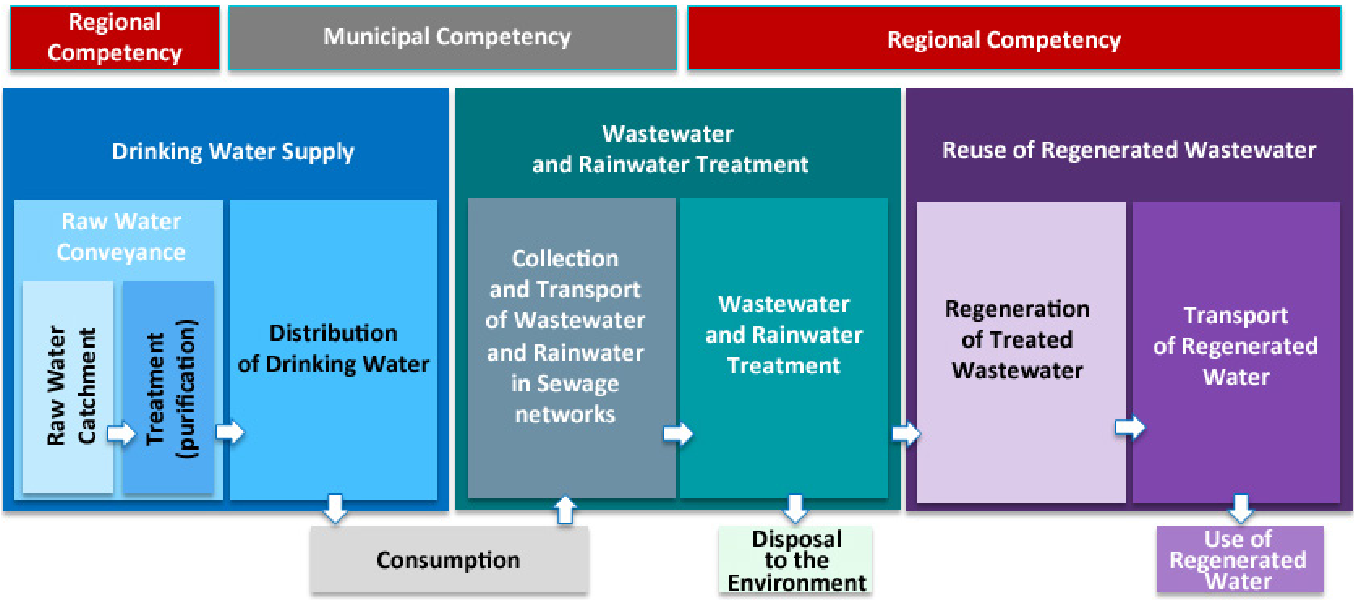


Fig. 2. Competency distribution.

future pipes. Additional legislation enabled the villages situated by the future canal to profit from it, improving both their drinking water supply and their sanitary conditions.

Municipalities further away from the original layout were gradually incorporated, which demanded the processing, financing and implementation of numerous infrastructures: dams in Puentes Viejos, El Villar, El Vado, Canal del Jarama…

In 1963, the population supplied reached 2.3 million inhabitants, distributed in the capital, and 17 municipalities. By then municipalities on the metropolitan outskirts, such as San Sebastián de los Reyes, Alcobendas, Leganés and Getafe had already been incorporated to the «Canal System».

Later on, in view of the evidence for the advantages derived from a single management, the assets, responsibilities and duties of other independent supplies were aggregated.

It is true that the competency holders are different in each of the supplied services, which is why it has been necessary to legally articulate a structure allowing the Company to assume these competencies.

On the one hand, an essential factor is the transfer of Canal de Isabel II to the Community of Madrid – we may remember that it was founded as a private company, and that from 1977 onwards, it became a public company under the aegis of the Ministry of Public Works. That same year saw the promulgation of Law 17/84 of December 20, which regulates water supply and sanitation in the Community of Madrid, establishing its competencies in the comprehensive water cycle, and determining, among other things, that: a) water conveyance and treatment services are in the interest of the Community; b) water tariffs should be the same in the whole region; c) investments to be made in each municipality may be paid by means of an additional quota in the water bill. This law, together with the subsequent laws that amended and modified it, incorporated some innovative facets in water management, especially the mandate to establish a sustainable tariff.

On the other hand, signing agreements with the city councils, specifying the responsibilities of each party, has sustained this legal structure of collaboration.

The drought situation in 1981 and 1983 – that raised in the Madrid municipalities doubts about their ability to cover growing water needs, about the new legislation, and about the recent incorporation of Canal in the Community of Madrid – precipitated an extraordinary increase in the signing of agreements with the city councils: if in 1984 there were 83 municipalities which had signed an agreement with Canal de Isabel II, in 2016 there were already 174, out of the 179 that constitute the Community of Madrid.

It should be noted that only a sufficiently flexible agreement model facilitates subscription. The Canal de Isabel II agreement models with the city councils are extremely flexible, and they are adjusted to each case, depending on the needs of the municipality. Upstream water supplies are established, the municipality being in charge of distribution and commercialization; or there are commercial agreements, where the municipality distributes, and Canal is responsible for charging the client, or, in the most comprehensive agreements, the company takes care of water supply and distribution, maintenance of conveyance networks, and charging the bills.

Comprehensive water cycle management requires large investments in infrastructures, both to extend the scope of the territorial supply, as well

Fig. 3. Construction of the second main distribution network.

as to attend to regulatory adjustments, and modernize and enlarge the facilities.

Investments must be planned taking into consideration all the infrastructures in the area, and in coordination with urban planning and territorial development policies. To ensure the company's economic and financial sustainability, investments must also take into account the economic variable in the programming. Without any doubt this coordination – also Canal's responsibility – is more effective with a supra-municipal design.

In addition, in order to be sustainable and to guarantee the proper provision of the service, an intensive activity in infrastructures demands a large corrective and preventive maintenance budget, also covering replacement.

A figure: investments approved for 2017 to enlarge and improve the region's general water supply and sanitation systems have reached 184 million euros – a 1.32% increase in relation to the investments made in 2016. The current expenditures expected in 2017 amount to 456 million euros (0.4% more than last year's).

Supra-municipal territorial management results in major savings, both owing to the possibility of differentiated population centres sharing the infrastructures, and to the obvious advantages in operating shared systems: personnel, large-scale purchases, etc.

In short, the joint management of all the municipalities in the region provides synergies and economies of scale, as becomes patently clear when compared with other companies providing services in scattered municipalities in other regions:

Chart 2

Comparison between operating companies

Magnitudes	Acciona Agua	FCC Aqualia	Canal de Isabel II
Population (inh.)	780,236	7,919,000	6,209,514
Supply Networks (km)	4,860	36,027	17,366
Number of employees	2,761	7,329	2,592
Annual Revenues (million €)	114.20	568.66	861.30
Ratios	**Acciona Agua**	**FCC Aqualia**	**Canal de Isabel II**
Inhabitants per employee	283	1,081	2,396
Inhabitants per Network km	161	220	358
Revenues per Network km	23,498	15,784	49,597

Source: DBK 2016, end-2015 data.

COMPREHENSIVE WATER CYCLE

Supply

If at the beginning the services provided by Canal de Isabel II were limited to water conveyance and distribution, in time, they included additional services stemming from the need to improve the quality of the water distributed, and to reclaim the water before disposing it in the river bed.

Thus, in the 1960's Canal began building the first treatment plants, Torrelaguna, Majadahonda, Bodonal, Jarosa and Navacerrada, achieving 14 plants that today ensure a correct water treatment for human consumption.

Needless to say 14 water treatment plants would not suffice to supply water to a population of more than 6 million inhabitants, in a territory of 8,000 km^2, without having the aforementioned supra-municipal model.

Treatment

In the decade 1980-1989, having moved beyond water-sellers, and after developing some local treatment networks, and exhausting, in may cases, the capacity to purify river basins, Canal installed the first wastewater treatment plants. The urban growth and the tightening of the legislative framework have forced a steady increase in the number of plants, reaching the 157 that today constitute the water treatment depot managed by Canal de Isabel II. In this case, the unification of the discharges from different population centres in common plants becomes complicated, due to the natural river basin management of wastewater, but even in this field the number of plants treating water from various municipalities is negligible. In any case, the comprehensive management of such a high number of treatment plants optimizes operating costs, reinforcing once again the benefits of the territory model described above.

Recycling

To close the circle, in the last few years we have endowed the plants with tertiary treatments to regenerate the purified wastewater, and recycle it for secondary, urban and industrial use. Canal considers that the recycling of purified wastewater is an essential factor in the comprehensive management of this resource, and it contributes to the net increase of water availability in regions where this service is supplied. The inclusion of this third phase – a phase not always considered in water cycle management – allows the conservation of this natural resource for potable use, substituting it, where the legislation permits, for irrigation, flushing and industrial processes.

Sludge and Waste

But the water cycle, as conceived by Canal Isabel II, is something more. Sludge, Waste and Energy constitute an essential and inseparable part of water cycle management, and they significantly contribute to its efficiency in economic terms.

The activity involved in water supply and treatment generates a substantial amount of waste and sludge, which we also manage with great efficiency. Non-hazardous or recyclable waste, hazardous waste, sludge from EDAR and ETAP fit for agriculture, unfit sludge, and pre-treatment waste – all these

Fig. 4. EDAR of the Culebro Stream.

constitute the array of «by-products» generated by the water cycle.

Removal or, when applicable, joint treatment of waste and sludge produced in the two hundred plants we operate, implies, once again, the possibility of rationalising operating and investment costs. It also implies the possibility of consolidating Recycling, Recovery and Reuse policies. Ultimately, it is necessary to apply efficient waste management in the framework of Circular Economy.

It is true that nowadays around 99% of the more than 433,000 tons of sludge generated in water treatment, and drinking water plants are fit for agronomic recovery. But it is not less true that legislative tendencies that have been maturing for years will tighten the conditions for agricultural use, with the possibility of this practice being completely banned.

In this framework, Canal implemented in 2010 the Loeches Sludge Processing Unit, where part of the sludge produced is treated trough thermal drying, using the heat produced from the cooling of the cogeneration engines, and electric energy is generated for its own consumption and network sales. Another part is processed to obtain compost, a product used in gardening, agriculture and landscape restoration.

In 2016 the plant received 51,000 tons of sludge, 42,000 of which were treated in the thermal drying facilities. This resulted in the production of 7,500 tons of dry sludge that has been commercialized as fertilizer, and 540 tons of unfit dry sludge destined to the energy assessment in cement plants. The remaining 9,200 tons were composted.

As an annexed facility to the drying plant, Canal has a landfill for pre-treated waste. In 2016, almost 8,700 tons of pre-treated waste from different EDAR facilities were deposited in a landfill cell, with the subsequent saving of gate fees into other landfills in the Community.

Energy

In the Energy field, it is true that the legislative ups and downs in the last few years may have softened the tendency Canal initiated in the last quarter of the 20th Century. Nevertheless, persuaded that the pairing of water-energy is indivisible, our company continues to profit from the energy resource the comprehensive water cycle provides.

Today Canal de Isabel II is the company in the Community of Madrid with the largest installed electricity generation capacity: 84 megawatts. Up to November 2016, electric energy generation has exceeded 230,000 MWh, equivalent to slightly more than 60% of the energy consumed during this period. This generation has managed to prevent the emission of 56,000 tons of CO_2 into the atmosphere.

8 hydropower plants, the first built in 1912, with a total installed power of more than 37 megawatts, operate almost all year round in coordination with the population's provision needs; guidelines for diverted and turbinated water are established monthly following the criteria of satisfying the market, reducing waste, and enhancing hydropower production.

Canal has also opted for the installation of micro-turbines in the pipes – 8 as per today – in order to profit from the pressure differences between the different sources and the supply chain. 2 other micro-turbines were installed at the waste disposal point to produce an effluent suitable to the natural environment.

The biogas, generated in the plants endowed with anaerobic digestion treatments, besides being used for the sludge heating process, is also used to feed generators to produce electrical energy. Today there are 13 functioning facilities with a 25 MW installed power, but according to our energy planning, this number will be increased.

Finally, in 2016, the co-generation plant (19,8 MW) associated with the aforementioned Loeches Sludge Processing Unit, discharged 72,790 MWh to the grid, amounting to 18% of our total power consumption.

THE TARIFF MODEL

The tariff structure established by Canal more than 30 years ago, includes 2 essential components, included in the Water Framework Directive: 1) financing the services that ensure

Fig. 5. Loeches UTL heat exchangers.

all the variable and fixed costs are recovered; 2) a change of behaviour by transferring the incentive to the consumer in order to meet the environmental goals. This latter component includes the following goals: a) to incentivise saving a limited natural resource such as water: *The more one saves, the less one pays;* b) to establish a principle of proportionality in accordance to the level of generated pollution: *The one who contaminates, pays.*

This structure also takes into consideration other basic principles: social wellbeing, responsibility, simplicity, transparency, equality and unity.

Having applied these principles, the tariff established by Canal de Isabel II is characterized by:

1. Being universal, identical in all the municipalities served within the scope of the Autonomous Community, and at the same time, dissolving the differences between the rural and the urban environments.
2. Covering the costs of each of the water services: conveyance, distribution, sewage, treatment, and when applicable, reuse.
3. Having a block-structure to which growing (progressive), and different rates are applied according to the period of the year (seasonality).
4. Differentiating the various usages – domestic, commercial industrial – of the resource and the pollution that may be released into the system.
5. Having a pairing structure, composed of a set term (services fees) and a variable term depending on the volume of consumed water (consumption fees).
6. Being sensitive to situations of *water shortage* (as in *power shortage*), and meeting them through a social tariff, the number of whose target consumer has been growing in recent years.

We are persuaded that only a territorial and service model similar to the one described above can allow a tariff design like the aforementioned.

RESULTS

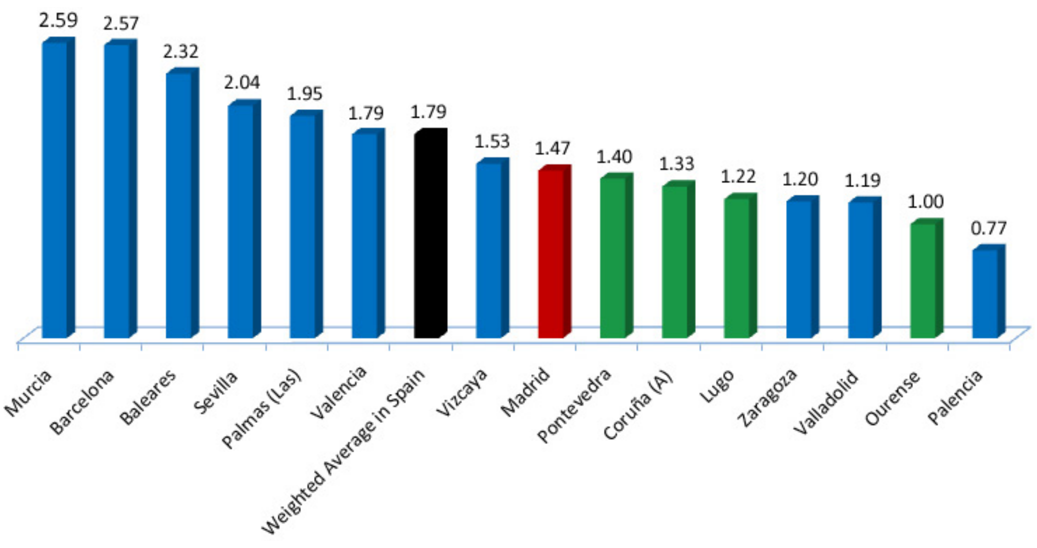
It would be absurd to advocate and defend this model without indicators endorsing satisfactory results for their implementation. These results manifest in different aspects.

In terms of consumer satisfaction, for instance, as well as assessments through satisfaction surveys – the last one having a score of 7.8 – one reference is that Madrid is the Autonomous Community with the lowest consumption of bottle water.

In relation to the prices provided, the following graphic speaks for itself.

To conclude, here are two efficiency indicators: hidden leaks and damage to the water supply network have diminished in the past 10 years, and this must clearly be associated with the pace maintained in infrastructure investment and expenditure.

Fig. 6. Price for water management services (supply and treatment) for domestic clients in some Spanish provinces in 2016 (€/m³ without VAT). Source: National Study of Water Tariffs AEAS-AGA (2016).



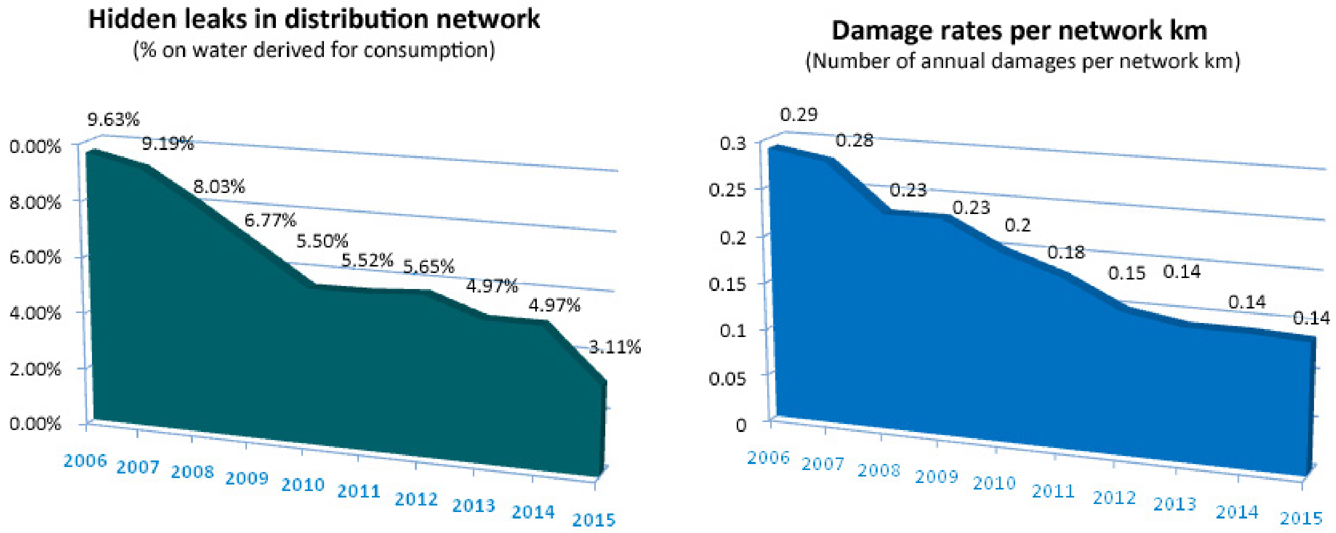


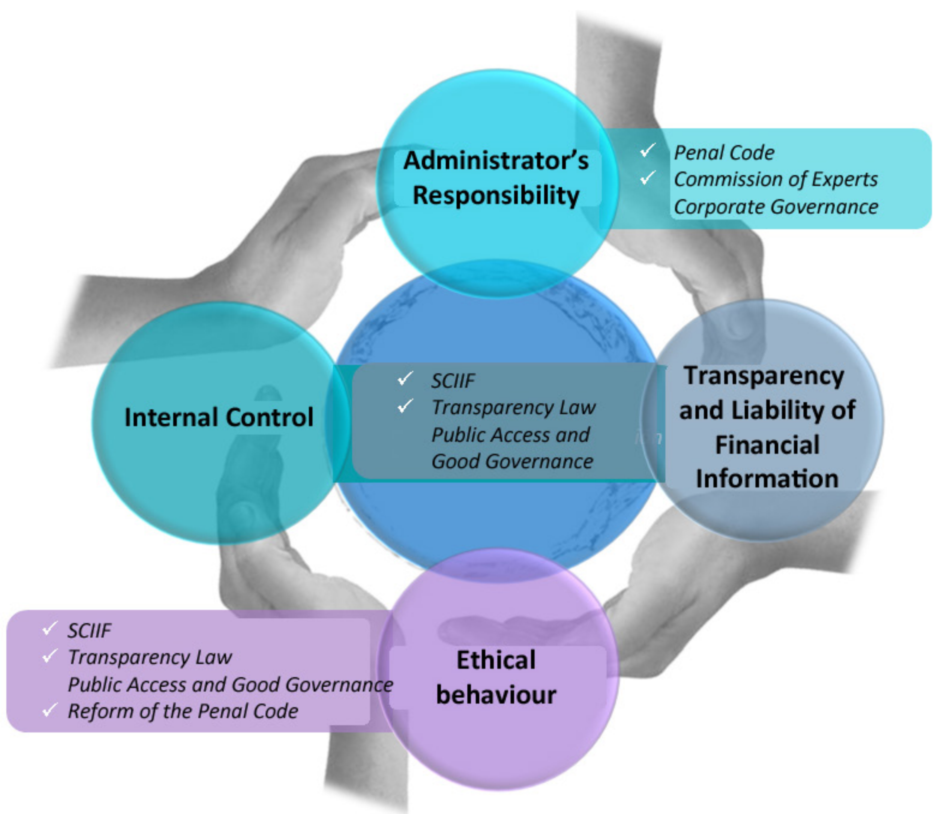
Fig. 7. Efficiency indicators.

GOVERNANCE

Canal de Isabel II has in the recent years reinforced its strategy of Good Governance. Administrator's responsibility, ethical behaviour, transparency and reliability of the financial information and internal control orientate this strategy.

The transparency and efficiency goal in the organisation and management have led us gradually to incorporate better practices exceeding the applicable standards to non-listed companies – as for instance, our interior financial information control system, the Internal Audit function, the creation of the Audit Comity, and the Risk Management System.

Fig. 8. Corporate Governance.



Company Organisation and Governance Bodies

The company organisation and the governance bodies of Canal de Isabel II essentially respond to the requisites derived from its legal nature as a public limited company, from its creation in June 2012.

The governance bodies of Canal are the General Board, in which all the shareholders are represented (Canal de Isabel II Public Entity, Madrid City Council, and the remaining City Councils), and the Management Board. Canal de Isabel II Public Entity is owned 100% by the Community of Madrid, and it is answerable to the Ministry of Presidency, Justice and Government Spokesperson.

Owing to the characteristics of the entity's shareholders – 100% public – the composition of the Management Board responds in most part to its nature, with 6 Nominee Directors, and 3 Independent Directors. The Directors may not incur in incompatibilities, thus guaranteeing absolute transparency and avoiding the build-up of potential conflicts of interest.

Ethical Behaviour

In line with the mentioned strategy, in the past 5 years we have been developing a project to strengthen our commitment to ethical and integrity principles, by incorporating the best practices with the ambition of making sure our action and value principles constitute, in the future, an integrity and good governance framework that will guarantee management responsibility. In order to orientate and encourage ethical professional practices, Canal has a Code of Conduct, comprising the values and principles of the company, its implementation and compliance being mandatory for all the personnel.

Transparency and Internal Control

In 2015, in compliance with the provisions of the Transparency, Access to Public Information and Good Governance Law 19/2013, dated December 9, we have promoted the Transparency Web Site, containing all the information required by law in regard to Active Publicity, as well as the means to guarantee Exercising the Right of Access to Public Information.

By way of reinforcement and improvement of the internal control of the organisation, and incorporation of new practices in corporative governance, in 2013 we began implementing the Internal Financial Information Control System (SCIFF).

Consumer's Ombudsman

Canal is the first Spanish company dedicated to comprehensive water cycle management to have a Consumer's Ombudsman. Creating such a figure shows the will to improve the support and the services we provide our clients, offering them one more opportunity to have their case analysed and studied once again, so that they may solve discrepancies that have been unsolved by following the ordinary procedure.

Risk Management

Canal's Risk Management System aims both to ensure the knowledge and control of the corporation's activities, and to minimize the company's economic, social and environmental impact, and guarantee the fulfilment of the established strategic targets. The System includes both the financial risks and the non-financial risks.

Added to the System is the creation of the Audit Comity, the Management Board's delegate body, whose responsibility is to supervise the risk control and management policy. We have, in parallel, considered the convenience of having a Compliance Function as reinforcement of the company's lines of defence.

CANAL IN THE FUTURE: NEW CHALLENGES

The main future challenge for Canal is probably to maintain the sustainability of its management model, adapting it to the evolution of the environment. Components of this evolution include: climatic change, the growing shortage of this natural source, the environmental goals to be reached, the vertiginous technological renovation, and the new needs of consumers.

Fig. 9. The Three Canals: Jarama, La Parra and Atazar.

Water is a strategic and limited natural resource. To guarantee that everyone has equal access to this resource, in quantity and quality, is one of the main challenges we face.

The climatic characteristics in our operational area are rainfall irregularity and scarcity. Since 1993-1994, the average contributions from our rivers to our reservoirs has been almost 18% less than the historical series of rates we had been managing (since 1913), while in the meantime our population has grown from 5.5 million inhabitants in 2003, to 6.2 million today.

The future trend will be to have more demand for water, probably in a more controlled fashion than in the last decade, the supply being nevertheless more costly due to the effects of climatic change on the supply. Also, the pressure on the resource will cause a deterioration in its quality, and we shall have to address the permanent actualization and adaptation of the treatment plants in order to maintain a supply with the same quality as the one we have been providing.

In the field of sustainable growth, the biggest challenge Canal has already been working on is to comply with the quality goals established by the Water Framework Directive. It is a challenge demanding a solid technical and economical effort, because it requires producing new treatment infrastructures, and improving the existing ones.

In relation to this field, but also with the universal access to water, we must continue to increase the available resource, using technological developments for reclaiming wastewater in view of their subsequent reuse, not only at an urban level, but also in the industrial field.

Tomorrow's challenges demand planning in an orderly fashion today, and properly maintaining the necessary infrastructures, which makes it vital to maintain the necessary investment drive.

We shall be able to meet these challenges if we continue maintaining the excellence and training level of the professionals who constitute Canal de Isabel II.

Belén Benito Martínez
Civil Engineer
Canal de Isabel II Chief Operating Officer

ANALYSIS OF EFFICENCY
IN THE INTEGRATED WATER CYCLE SERVICE: THE SPANISH CASE

Lorenzo Dávila Cano

KEYWORDS:
EFFICIENCY
COST-RECOVERY
UNIFIED REGULATION
SELF-FUNDING SERVICES
INVESTMENT RECOVERY

INTRODUCTION

Two of the most important challenges for safe drinking water and sewage service providers (public, private or mixed) are: 1) to reach the self-funding goals through the companies' revenue; 2) to attain a cost-efficiency structure, defined as the minimum operating costs, to gain the required level of coverage, quality and remuneration in the production factors (Capital and Labour).

In order to analyse progress and achievements, both in Cost-Efficiency and Self-Funding, it is necessary to make a prior revision of efficiency and productivity theory, to understand the recognized efficiency criteria for companies providing public services: (i) Coverage Level, (ii) Quality of the supplied services and products, (iii) Cost-Efficiency, and (iv) Degree of Self-Funding. It is also necessary to recognize the relationships among the aforementioned criteria in order to establish guidelines that will help reach the goals intended for each criterion. Such relationships have impacts that must be quantified in order to determine the transference degree to the users (in terms of quality and affordable rates) reached by the supplying company by achieving its efficiency goals.

The present document aims mainly to describe and analyse the behaviour of self-funding and cost-efficiency in the last 12 years, bearing in mind that public, private and mixed companies have suffered the consequences of the Spanish economic crisis since mid-2007. It is to be noted that the integrated water cycle is one of the most capital-intensive industries. Building the necessary infrastructure to comply with the regulatory standards requires large investments, both in OPEX (costs incurred during the normal course of the activity), and in CAPEX (new investments and replacements). We shall analyse these in this document in order to determine the investment evolution and its impact on efficiency in the years to come.

Efficiency criteria are applicable to every type of company model (public, private or mixed) used for the provision of integrated water cycle services – because all inefficiency leads to higher tariffs. Although the characteristics of natural monopoly presented by this industry would imply a lack of incentive to improve cost-efficiency and self-funding, it is in this aspect that the regulator exercises his skills to compensate for this market failure (derived from the market power the operator would have due to its monopoly status). The regulator must lead companies to incorporate efficiency criteria management in their policies as though they were operating in a market of perfect competition. For this it is necessary to have a regulation that offers continual support in measuring the industries' efficiency, promoting an adequate gathering of information, the selection and calibration of the most suitable measuring models for establishing comparisons between operators under every model of integrated water services, with the aim of identifying the efficiency degrees of each.

Efficiency in public services

In the last few years the concept of efficiency has been gaining importance as public services providers adapt themselves more and more to the political, macroeconomic and social circumstances, and especially as the concept of «Safe Drinking Water» as a product, and not as a natural resource, has become more relevant in the economic and social policies of the different States. Water consumption, regardless or its use, is only part of what is known as the Integrated Water Cycle, implying the journey of water from its collection from Nature in an unrefined state to its availability in every home as safe drinking water, and its journey back to Nature as purified water.[1] The phases involved in the water cycle are: collection, treatment, supply, sanitation (sewage), and purification.

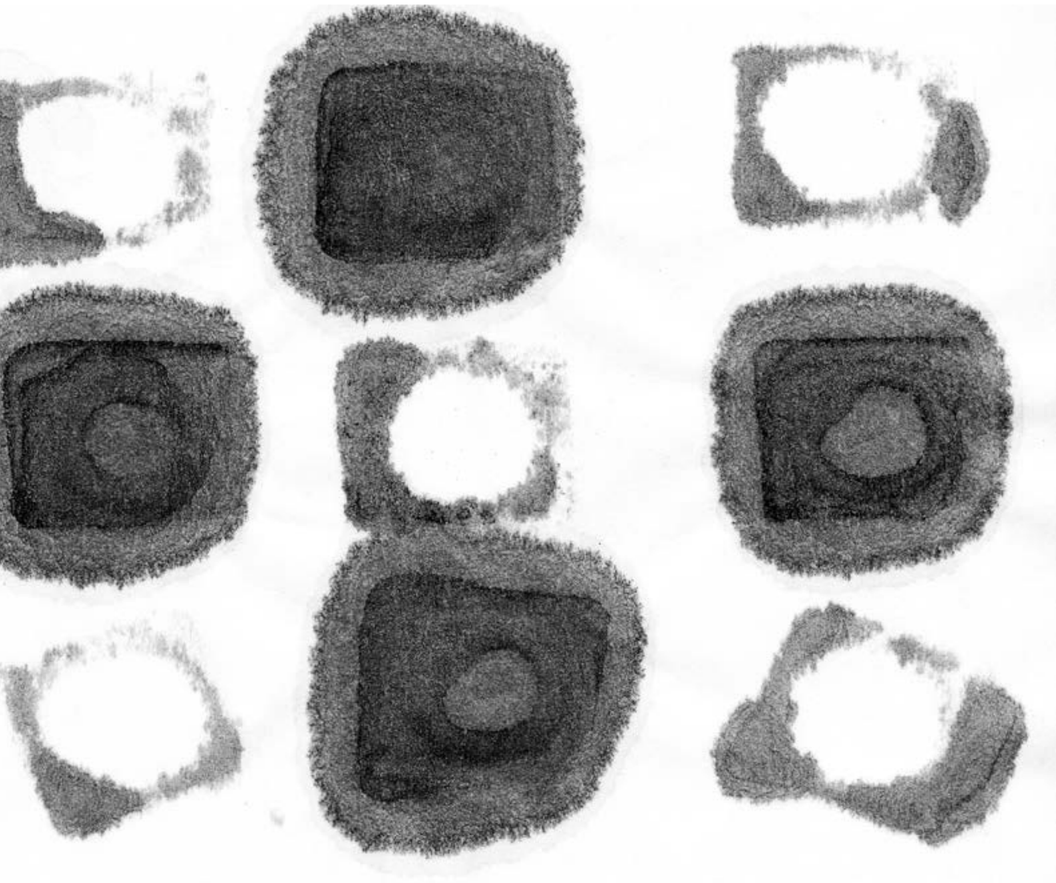
An inadequate provision of this service (Integrated Water Cycle) will have a social and economic impact, with the natural monopoly in which these companies operate as catalyst for market power, making it necessary to have a regulating system endowed with the necessary tools to support the operators in Efficiency Management, a term we will now define.

The concept of efficiency

Conceptually efficiency is to reach a goal at the lowest cost (be that social, economic, etc). Minimizing the cost implies being able to measure it in order to verify having attained the efficiency goal. As regards public services, namely the Integrated Water Cycle, what is aimed at in demanding efficiency from an operator, be it public, private or mixed, is that it provides quality service at the lowest cost, with specific goals of coverage and an adequate degree of self-funding.

The ECLAC (Economic Commission for Latin America and the Caribbean) Natural Resources Department has undertaken several studies of different experiences in the provision of integrated water services,[2] and has made progress towards the identification and standardisation of crucial factors regarding efficiency, determining that an efficient provision of the service can be achieved at different costs.

Fig. 1. Efficiency criteria.
Source: Prepared by the author on the basis of Hantke-Domas & CEPAL, 2011.



Minimizing the cost in order to achieve a specific goal requires performance evaluation criteria. From a practical point of view, there is no absolute criterion for efficiency. What one must do is look for decision-makers who do similar things and establish the best practices by comparison. The best practices are then used as a guide for action by decision-makers who are proving relatively less productive or more costly.

In costs, as in production, there are better and worse practices. There are bad practices that are a consequence of production decisions: a material waste of consumables involves higher costs. But another side of this is entirely economical. Let us imagine there is no material waste, but that the wrong decisions are made when purchasing the product. In this case there will be possible gains in allocative efficiency. The best practices in cost efficiency involve looking at price signals and making efficient money allocations as an answer to those stimuli.

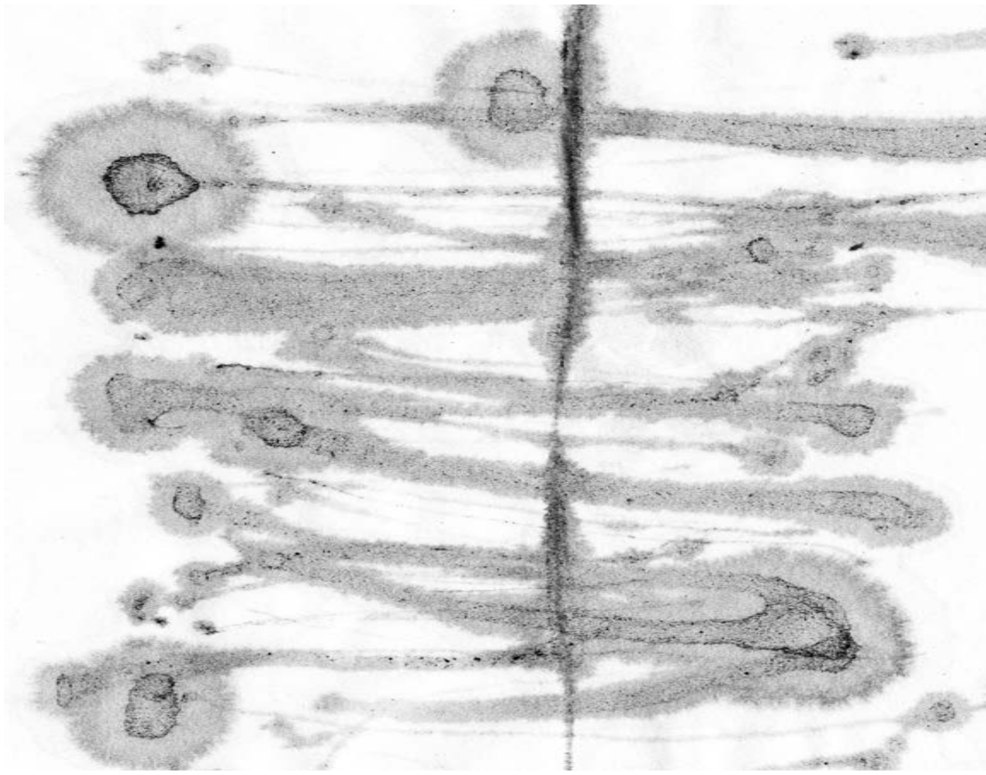
Therefore, having both the concept of production efficiency (the use of material consumables, measured by means of Production Functions), together with the concept of allocative efficiency (the use of economic stimuli or «relative prices», substituting the expensive with the cheap, measured by Cost Functions), we reach the notion of Total Efficiency (Productive and Allocative).[3]

In practice efficiency measurements can be developed by comparison, a technique that although it has remained unchanged, brings a new way of measuring factors that has an impact on both technical and allocative efficiency. This is why Benchmarking is defined as a systematic and continual process of comparatively evaluating products, services and processes related to decision makers. The sector's aim is to gather the best practices from a group of competitors that will be used as reference. Therefore, Benchmarking's goals are to increase the industry's efficiency, quality and transparency.

Nonetheless, the use of partial productivity and average cost indicators is not the only, nor the most precise tool used for performance and identification signals from less productive units. In fact, *in the Spanish market we find specific structural characteristics, defined as «efficiency challenges»* (presented here below), *that lead to the use of more sophisticated econometric techniques, where we find ourselves using efficient borders,* as we will explain further below.

Spanish market efficiency challenges

In this section we will analyse some crucial elements in order to understand the challenges the water sector faces in Spain if it wants to have an efficient model of service supply as regards costs, quality and self-funding. Although, in principle, these challenges do not depend on the type of public, private or mixed property model, but rather on the institutional and structural conditions, the truth is that public companies do not have management autonomy allowing them to make progress towards efficiency. Public companies depend on subsidies that may conceal inefficiencies, thereby transmitting to the market wrong signals that have a negative impact on the demand for this service. These elements are:



Decentralisation

In the Spanish context there is an over-fragmentation of Integrated Water Service providers, and this can be a hindrance in promoting quality services, and especially, cost-recovery. This in turn limits the possibility of guaranteeing investors recovery on their investments in replacements or new infrastructures demanded by the service. Furthermore, decentralisation may attract political goals that outweigh efficiency criteria – for instance, using the tariffs financed by public budgets as a mechanism for drawing voters, and therefore generating budgetary tensions.

Decentralisation also complicates regulatory tasks. This service in particular must have a specific regulation, adapted to the principles of a service of general interest, such as universal coverage, quality and self-funding. With this structure it is impossible for a regulator to control more than 2,000 operators, and less so in specific legal situations where special laws govern different autonomous regions. The exercise of transparency on which the efficiency criteria are founded cannot be achieved within this framework. Information, being very segregated and affected by different political pressures, leads to dispersal in standards and does not allow for the comparative use of information to obtain efficiency benefits.

Therefore, as opposed to the significant experiences carried out in Chile or the United Kingdom, among other countries, where action aims at the centralisation of regulation activities as regards tariffs, Spain has a high degree of tariff decentralisation and there is an evident politicization of the local public companies.

Economic regulation

The logical structure of service provision, where supply of the same service by two companies in the same geographical area cannot be efficient, because it would entail two inefficient and unprofitable drinking water and sewage networks at an unaffordable cost, leads to a natural monopoly for this service. For this reason, as opposed to a perfect market, it is necessary to have efficient economic regulation to intervene against this market failure.

In such circumstances economic regulation is established with the aim of controlling the monopoly's market power, and this is where, in Spain, through the design of efficiency policies, the existence of a unified regulator could pressure a service supply company to operate in alignment with an open market, particularly regarding the principles of universality and service quality.

If we review the common legal principles in the most advanced regulating systems (USA & UK), we observe they have opted for some basic principles applicable to the regulating processes:

- Protection of property rights and investor's expectations. Private investors with property invest with special and legitimate interest in obtaining benefit. Economic regulation must ensure it does not exceed the legal limits that protect

property, as this would eliminate the investor's incentives and rights.
- Reasonable investment recovery. Regulatory decisions cannot affect the provider in a way they irrationally prevent sufficient economic compensation. (This is based on: (1) financial equilibrium; (ii) favourable attraction of capital; (iii) comparable benefits.)
- Transfer prices. Transactions between a service provider and its related companies must occur at market price.

Information

For any regulating model it is essential that companies maintain a very high level of transparency regarding economic information. The problem to be solved here is the asymmetry of information between the regulated and the regulator, if we want to be able to apply a control strategy with precise data that will stimulate operators in attaining maximum efficiency in their operation.

The unification of accounting information proposed by the IFRSs (International Financing Reporting Standards) and IASs (International Accounting Standards) supports, at an international level, reinforcement of financial information. This will enable not only the establishment of a performance comparison locally, but also with comparable countries, so as to analyse and learn from other companies with better performances.

Economies of scale

In such an over-fragmented sector as this one in Spain, it is obvious that a process of vertical integration – whereby companies involved in different phases of the production process enter into association, ensuing the company obtains comparable advantages over various other service providers within the same process – would be very advantageous. In fact, economies of scale allow the high cost of investments, operations and maintenance in plants and networks to be transferred to the users at significantly lower prices or tariffs in comparison with any other service provision technology.

In Spain we find different operators, in different phases of the cycle, who are providing funding at various degrees, according to their infrastructure and operational needs. This hinders the regulator's task of gathering the information that will allow him to act in such a way that service providers may make progress in their efficiency models. From an operational point of view it is obvious that a process of vertical integration would first provide savings in the Integrated Water Cycle general management, and then, most probably, generate more economy scales assisting the achievement of the self-funding goal.

FINANCIAL EFFICIENCY CRITERIA IN SPAIN

At present Spain presents a cost-recovery problem, as has been identified in studies undertaken by different authors.[4] Due to the high decentralisation and diversity among service suppliers, it is not currently possible to determine the exact degree of cost-recovery. Depending on the company's typology, we are talking about a range of between 52% and 96%, with an average of 80%. This implies that in order to reach cost-recovery, tariffs would have to rise between 52% and 96%.

It is clear that the quickest and least complex solution would be to transfer all this difference to the users by raising the tariffs, but one must bear in mind that in Spain the Integrated Water Cycle structure could improve in terms of efficiency in different aspects – financial, operational, tariff, among others. This would allow operating at efficient costs, and thus reduce the tariff gaps between service providers in Spain at present. In this way the effort would be made both on the demand side and the offer side and the tariff deficit would not be placed all on the same side of the scale, as it is today, and covered by public budgets.

In reviewing the behaviour of the current figures in Spain, it is patently clear that there remains a lot to do in terms of efficiency, and this implies the regulator and its structure, the companies (especially the clearly more efficient public management companies, as we will prove further down), and the demand.

Investment and revenue

According the last National Survey on Safe Drinking Water and Sanitation in Spain in 2010,[5] 4,582 hm^3 were billed, which represents an annual average increase of 4.6%, in comparison to 2008, when 4,198hm^3 were billed.

If we project the invoiced water to 2020 on the basis of compound annual growth in the past few years, we can see an increase of around 38.6% in water demand, in comparison with 2010. It showed similar behaviour from 2004 to 2010, with an increase of 34.8% in comparison with 2004. We may take the billing increase in hm^3 as a demand indicator, and compare it to the investments needed to cover the resulting levels.

The investments needed to maintain this level of turnover (demand) according to the needs of investment in the past, amount to 12,000 million euros for 2015-2020.

Investment and actual losses

Both actual losses and apparent losses are a part of Non-Registered Water. Actual losses, as percentage of water supplied to the network, are an indicator of economic efficiency widely used by operators. The indicator includes losses through leakage in the distribution network and supply connexions, and through broken pipelines.

According to chapters VI and VIII of the General State Budgets, owing to adjustments made by the Central Government to lower the still high public deficit derived from the different crises in Spanish economy since 2007 – actual investments have been restricted. This (projected) deviation for the next few years carries relevant operational consequences, as do Actual Water Losses.

On the Figure 2 you can see how from 2007 to 2011, investment decrease has had a negative impact on the volume of Actual Water Losses, showing a reverse in the variables. Investment decrease mainly undermines maintenance of the distribution network, and any progress in leak and fraud detection programmes.

It is in this kind of area that the regulator and the service suppliers must make progress together, by establishing lines of action that permit the attainment of higher degrees of operating efficiency, with the aim of contributing, from the offer side, to the services' self-funding based on a cost-efficient model.

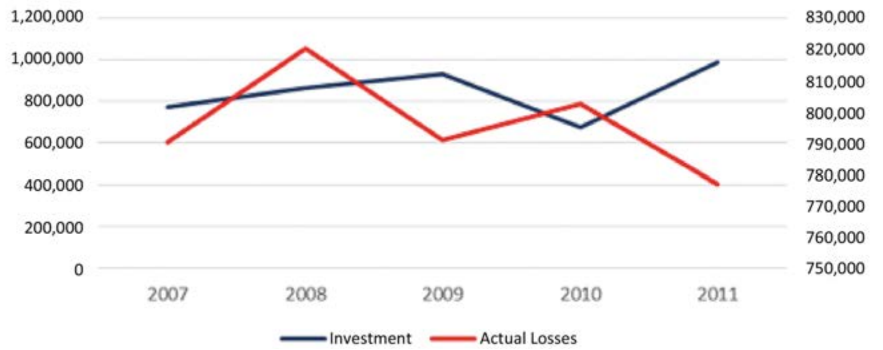


Fig. 2. Actual losses and investment.
Source: prepared by the author with INE and AEAS data.

Chart 1						
Actual losses compared to investment and revenue						
Concept	**Total 2007-20011**	**2007**	**2008**	**2009**	**2010**	**2011**
Real losses (thousand m^3)	3,980,993	790,169	820,398	791,029	802.502	776.895
Average price (€/m^3) turnover/registered water	1.38	1.17	1.24	1,37	1,50	1,61
Recovery fee (40%) (thousand m^3)	1,592,397	316,068	328,159	316,412	321.001	310.758
Cost-recovery in (thousand €)	2,193,801	370,108	407,275	434,907	480.588	500.923
Percentage/ turnover	9.0%	8.4%	8.8%	9.0%	9,5%	9,2%
Percentage/ investment (cap. VI-VII PGE)	41.0%	30.9%	26.0%	30.1%	48,6%	69,7%
Source: Prepared by the author with INE data.						

Let us bear in mind that a decrease of 40% in the Actual Losses for 2011 would mean 9.2% of the total water supply revenue, and 69.7% of the investments in water supply and sanitation (according to INE data).

Tariff / investment ratio

The data on investments made per registered and supplied cubic meter show the participation of investment recovery in the Integrated Water Cycle tariff. According to the last AEAS 2010 survey, the price for the average m^3 in Spain was 1.83, and according to the computed data, 0,198 euros would correspond to investment recovery (10.9% of the 2010 price). According to the projection data, the participation should grow to 0,45 euro/m^3 in 2020, which means an 8.56% annual compound increase, leading to a necessary tariff raise, for lack of a management model that promotes the regulator's efficiency, a point analysed down below.

Fig. 3. Estimate of the participation of investment recovery in the tariff (€/m^3).
Source: Prepared by the author with INE and AEAS data.

EFFICIENCY ANALYSIS THROUGH ECONOMETRIC MODELS

Under this heading we will compare through econometric models the relation between the management model and the production variable in every company as regards capital resources, labour and intermediate consumption. The information has been gathered from the SABI database.[6]

At first we considered making the estimation using the Translog production function, having previously compared it with Cobb-Douglas' much used, typical efficiency function; but in this case we rejected this approach because it did not fit in properly with our aim.

Stochastic production frontier function with technological efficiency effects – Translog

The effects of the Stochastic Production Frontier's technological efficiency are modelled in terms of variables in water management, such as the type of management and the experience. We consider the Translog Stochastic Frontier with neutral technological progress, where technical efficiency is modelled by (an unbalanced) panel data.

We follow the specification models of Batesse and Coelli (1995), and Huang and Liu (1994), who estimate the inefficiency levels of the different economic actors and explain their inefficiency in terms of possible explanatory variables. Some advantages of this approach are: 1) it avoids the inconsistency problems generated by the two-phase model used in other empirical studies when analysing the determinants of inefficiency; 2) it allows the introduction of two uncorrelated types of error, with one of them allowing for error measurements and other forms of noise in the model, and the other non-parametric approach considering the inefficiency levels are due to inefficiency itself – Murillo-Zamorano's study (2004) is excellent on efficient frontiers. The model can be expressed in the following way (1):

$\gamma_{it} = exp(f(x_{it}, \beta) + V_{it} - U_{it}); i = 1,\ldots,N, t = 1,\ldots,T$

where Y_{it} is the logarithm of the company's production function, *i-th in the period t-th*. $f(x_{it}, \beta)$ is a given function of the production vector's k × 1 de (transformations) x_{it} production of *i-th* in the observation period *t-th* and a vector of unknown parameters, β. V_{it} is a vector of random variables to measure production's statistical errors, assuming they are *iid*, $(V_{it} \overset{iid}{\sim} N(0, \sigma^2_v))$ and are independent of U_{it}, where U_i is a random variable understood as production's technical inefficiency and, being *iid* changed into cero, $U_i \overset{iid}{\sim} N^+(z_{it}\delta, \sigma^2_u)$.

The general model is based on the following formula (2):

$$\gamma_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_{kk} k^2_{it} + \beta_{ll} l^2_{it} + \beta_{mm} m^2_{it} + \beta_{kl} k_{it} l_{it} + \beta_{km} k_{it} m_{it} + \beta_{ml} m_{it} l_{it} + \beta_t t + V_{it} - U_{it}$$

where k_{it} is the (log of) capital stock, l_{it} is the (log of) labour and m_{it} is the (log of) natural resource. t is the time trend; in other words, it is the variable introduced to measure Hicks-neutral technological change. According to these models, technical inefficiency is defined as (3):

$$U_{it} = z_{pit}\delta + W_{it} = \delta_0 + \sum_{n=l}^{N} \delta_p z_{pit} + \delta t + W_{it}$$

where z_{pit} is the 1 × m vector of the variables' explanatory technical inefficiency in a period of time *i*; δ is a m × 1 vector of unknown coefficients; and W_{it} is a random error term assumed to be independently distributed and truncated towards a normal distribution with a mean of cero and variance of σ^2_W, the truncation point being $-z_{pit}\delta$. Thus, the technical efficiency is defined as: $TE_{it} = exp-U_{it}) = exp(-(\delta_0 + \sum_{p=1}^{J} \delta_p z_{pit} + \delta_{it} t + W_{it}))$ given the model's assumptions, the individual agent's technical inefficiencies are calculated by its conditional expectations: $TE_{it} = E[exp(-u_{it}) | \varepsilon_{it}]$. Relative technical efficiency measures at the production function frontier of year *t-th* may be expressed as: $TE_i = E(Y^*_i | U_i, X_i) / E(Y^*_i | U_i = O, X_i)$.

The model's parameters have been estimated through the Maximum-Likelihood (ML) method. Thus, we have used Battese and Corra's parametric setting (1977), replacing σ^2_V with σ^2_U with $\sigma^2 = \sigma^2_V + \sigma^2_U$ with $\gamma = \sigma^2_U / \sigma^2_V + \sigma^2_U$. The γ parameter must be between 0 and 1, where the initial value may be obtained using an iterative maximization process.

In order to measure the result, the production of good and services, we have taken into account the sales of each of the analysed companies. Production variables are the intermediate cost incurred by the company in the production process. To measure the labour we have used labour costs. The labour variable is more problematic, because we do not have information on different years. This production variable is an approximate labour quantification. The capital measure is the fixed costs. These three production variables represent the amount of labour, capital and consumption used in each of the sectors for generating benefits. These variables have been converted into actual euros using deflectors from the National Statistic Institute (INE).

RESULTS

Chart 3 shows the model's results estimated simultaneously according to the ML (Maximum Likelihood – equations 2 and 3) estimated method. The data used, as we have mentioned before, are unbalanced panel data from the period 1991-2016:

As mentioned in the previous section, the results presented in Chart 3 assume a Translog stochastic production function; we have furthermore verified the significance of this specification with the Cobb-Douglas specification (H_0: $\beta_{kk} = \beta_{ll} = \beta_{mm} = \beta_{kl} = \beta_{km} = \beta_{ml} = 0$), rejecting ($\chi^2(6) = 591.34$) at 1% significance.

The factors that explain the changes in the technological inefficiency model are also shown in Chart 3, where the negative signs of the estimations imply that the variable has a positive effect on efficiency.

Chart 3

Results of the estimation. Translog

Production frontier	Estimated coefficient	Standard error
β_k	0.115	(0.034) ***
β_l	0.338	(0.076) ***
β_m	0.511	(0.060) ***
β_{kk}	0.021	(0.002) ***
β_{ll}	0.114	(0.013) ***
β_{mm}	0.102	(0.005) ***
β_{kl}	-0.021	(0.008) ***
β_{km}	-0.028	(0.006) ***
β_{ml}	-0.186	(0.014) ***
β_t	-0.001	(0.001)
β_o	0.967	(0.198) ***
Equation U_{it}		
δ_1 **(Experience)**	-0.270	(0.055) ***
δ_{2_1} **(Private)**	-4.039	(0.737) ***
δ_{2_2} **(Mixed)**	-3.122	(0.691) ***
δ_3 **(Trend)**	-0.097	(0.031) ***
δ_o	1.228	(0.564) **
Equation V_{it}		
δ_{vo}	-3.886	-0.055 ***
σ_v	0.143	-0.004 ***
Log-likelihood	347.55	
N. firms	47	
N. observations	832	

δ_{2_3} = dummy omitted: Public; Significance levels = ***1%, **5%, *10%.

Source: Prepared by the author with SABI data.

Therefore, we have the following significant results:

1. The *experience* variable indicates that *an increase in experience increases technical efficiency in every company.*
2. Also, it is important to observe the effect this type of management has on efficiency – *a significant positive effect in terms of private management efficiency in comparison with public and mixed management.*

Figure 4 shows technical efficiency forecasts for experience and type of management.

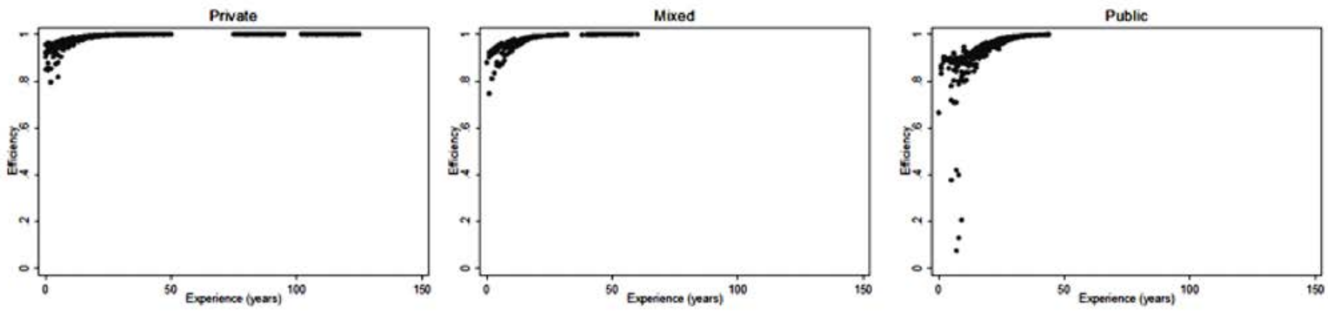


Fig. 4. Technical efficiency prediction for experience and type of management.
Fuente: Source: Prepared by the author with SABI data.

CONCLUSIONS

When comparing the management models at present considered to be the most advanced, we find a clear discrepancy with national policies. Firstly, while other nations are in the trend of tariff unification and management under efficiency criteria, Spain is submerged in a dense administrative structure that does not help us to obtain the necessary information to develop models permitting comparison – a vital element in mitigating the natural monopoly conditions under which the sector operates.

Secondly, the distribution of competences (State, Regional, Local) is a problem when trying to comply with the Water Framework Directive policies on self-funding. We observe the tariffs in Spain do not cover 100% of the costs, which implies the regulator should adopt regulating models that incentivise the operators to look for efficient management that will contribute to lower the actual tariff deficit, so as try to transfer an effective cost to the users that will serve as a stimulus to a rational demand – when inefficiencies, covered by public budgets, appear in management and the regulating model, a wrong signal is given to the users by the price. The user, on the other hand, should not be weighed down with extra charges due to the aforementioned inefficiencies. Hence, price adjustment must include the participation of the three market sectors: the Regulator, the Offer and the Demand.

The Water Framework Directive poses a challenge for the sector in Spain. Firstly, it must comply with Article 9 referring to cost-recovery in water-related services. Secondly, it must assume responsibility to preserve the environment, and carry out plans to raise awareness among the users that «who contaminates, pays». Thirdly, it must develop a broad and sufficient economic analysis containing long-term offer, demand and investment forecasts, as indicated in Annex III of Directive 2000/60/Ce of the European Parliament and the Council. Lastly, it must obtain, from an economic point of view, a price that sends the right signals to the users so that the demand becomes more rational and optimizes the use of water.

Lorenzo Dávila Cano
PhD Economist
INEO CORPORATE partner

Footnotes

1. SSO (Spanish Statistical Office) Information Bulletin 1/2008.
2. ECLAC has fostered the study and promotion of efficiency in the water sector. Among the main studies: *Fomento de la eficiencia de las empresas estatales de agua potable y saneamiento* (Fernandois, 2009); *Lineamientos de política pública para el sector de agua potable y saneamiento* (Hantke-Domas and Jouravlev, 2011); *Eficiencia y su medición en prestadores de servicios de agua potable y alcantarillado* (Ferrero *et al.,* 2011).
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5. Biannual survey carried out by the Spanish Association of Water Supply and Sanitation (AEAS). Available at www.aeas.es
6. Iberian Analysis Balance Sheet, from which 43 companies, classified under CNAE 2009 (only primary codes), have been selected: 3,600 – Water collection, treatment and distribution, operating in towns with more than 50,000 inhabitants including all the provincial capitals with more than 40 workers, on the Iberian peninsula, for the time period between 1991 and 2013.

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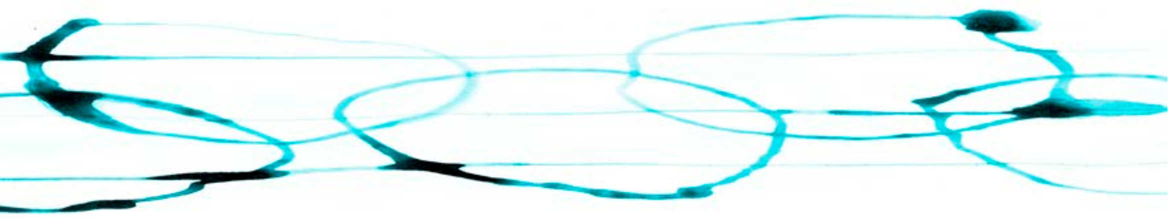
ROLE AND RESULT OF THE ECONOMIC ANALYSIS
OF RIVER BASIN PLANS IN SPAIN

Josefina Maestu and Alberto del Villar



KEYWORDS:
HYDROLOGICAL PLANS
ECONOMIC ANALYSIS OF WATER USES
FUNDING A PROGRAMME OF MEASURES
COST OF WATER SERVICES
COST-RECOVERY

THE ROLE OF THE ECONOMIC ANALYSIS OF RIVER BASIN PLANS IN EUROPE

Since the year 2000, when the Water Framework Directive was approved, water economy has played an important role in Europe's planning procedures. The WATECO guide, elaborated in the context of the common implementation strategy, lists and develops different necessary economic analyses in the context of the planning process.

On the whole, we must make the following economic analyses:

- An analysis of water services (Water Supply), as stated in the Cost-Recovery in Water Services Report (article 9 of WFD, article 11 and annex III). This includes analysing environmental costs and their forecast (Annex III WFD).
- An economic analysis of water use, according to Article 5 of the WFD, where water demand and other key factors in the plan are analysed in order both to forecast the demand and to make a hypothetical prediction of the future pressures on water use.
- A cost-effectiveness analysis of the Measures Programs, according to Article 11 and Annex III of the WFD. And a disproportionate cost analysis, according to Article 4 of the WFD. In accordance with the European Directive, economic decision-making is necessary for selecting the plan's measures, establishing exemptions in attaining the environmental goals, and classifying the water bodies as heavily modified or artificial.
- Establishing the funding strategy that, although there is no explicit mention of it in the Directive, is related to the analysis of cost-recovery for water services, as well as to decision-making on environmental goals and selecting the measures to be taken.

The *economic analysis of water services* is made in the Cost-Recovery in Water Services Report, a report that then serves to characterise the demand of these services.

The cost-recovery report analyses the cost-benefit structure in each of the water services, as well as the structure of the investment funds provided by different public and private stakeholders, and the financial flow between them. The Directive also establishes the need to make an analysis of the water-pricing incentive effect, according to the demand's elasticity, and how the price system takes into account the environmental and water-resource costs. This information serves to incorporate economic tools and take other measures for pressures on water use.

The *economic analysis of water use* tries to characterise «water use/ demand» through different socio-economic activities (uses). The demand forecasts have always proved essential to determine the works that need to be done in order to be able to service its intended purposes (irrigation, supplies, leisure, energy). In the context of the Water Framework Directive, knowing the key factors and their expected development allows making hypothetical forecasts of future water use pressures, and this, in turn, helps in calculating the gap between the expected conditions of water bodies – our goal being a good condition. The analysis of the economic value of water use (irrigation, industry, tourism, energy) is essential for knowing the real impacts of the measures applied to economic activity, information that must be used in the selection of measures, the decisions on exemptions from reaching goals, and the decisions on the economic viability of new supply-measures.

Cost-efficiency and disproportionate cost analyses offer tools to support a decision. By choosing the lower cost measures, they serve to prioritise the measures that could prove useful for attaining the environmental goals. They also contribute to establish the environmental target level, as they allow justifying less ambitious goals,

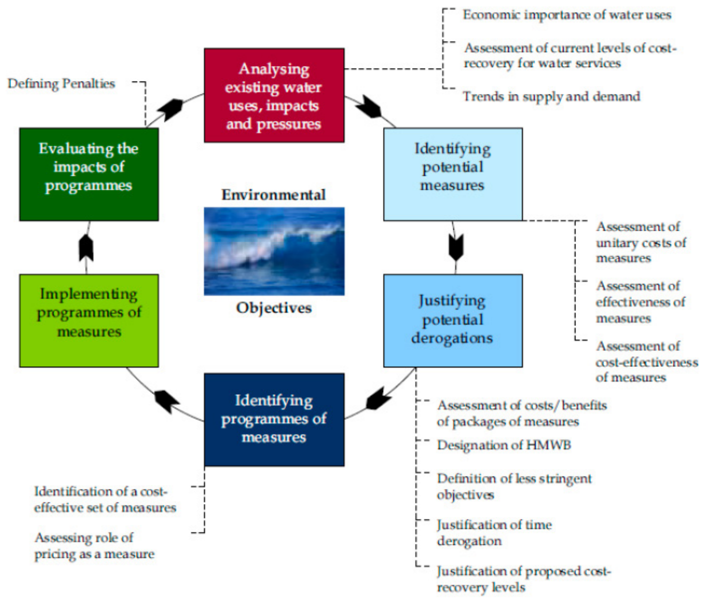


Fig. 1. The role of economic analysis in the planning cycle. Source: WATECO Guide 2002.

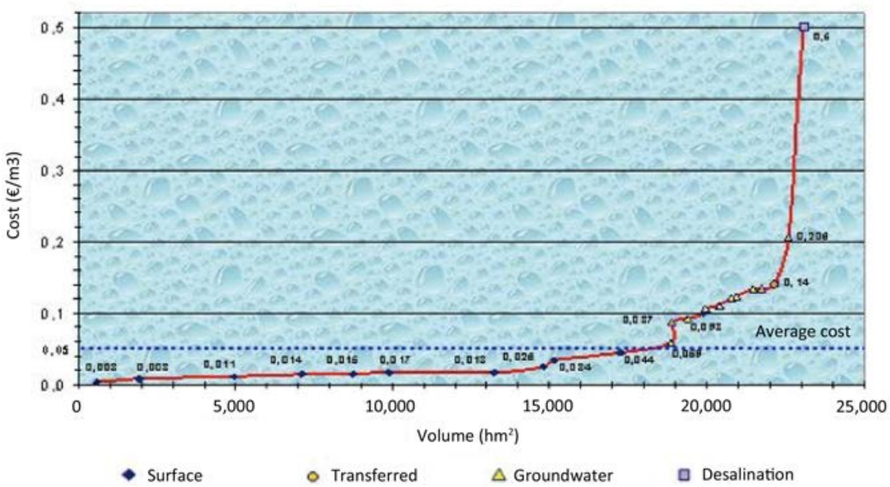


Fig. 2. Water supply structure (Year 2008). Source: MIMAM (2007a).

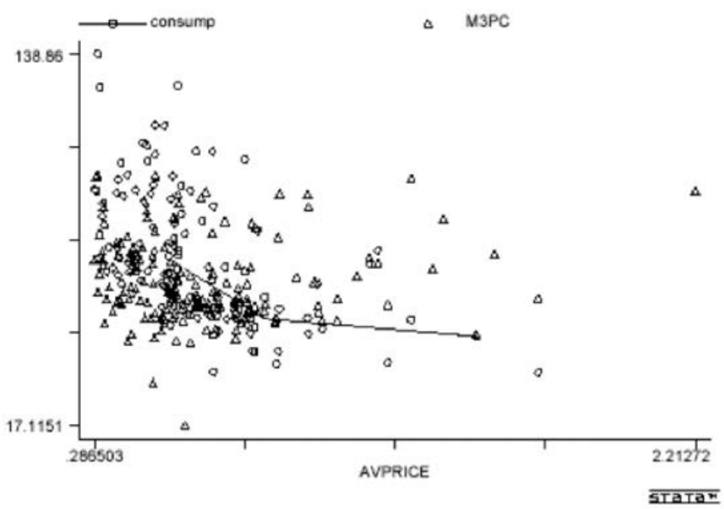


Fig. 3. Water demand curve (Year 2007). Source: MIMAM (2007a).

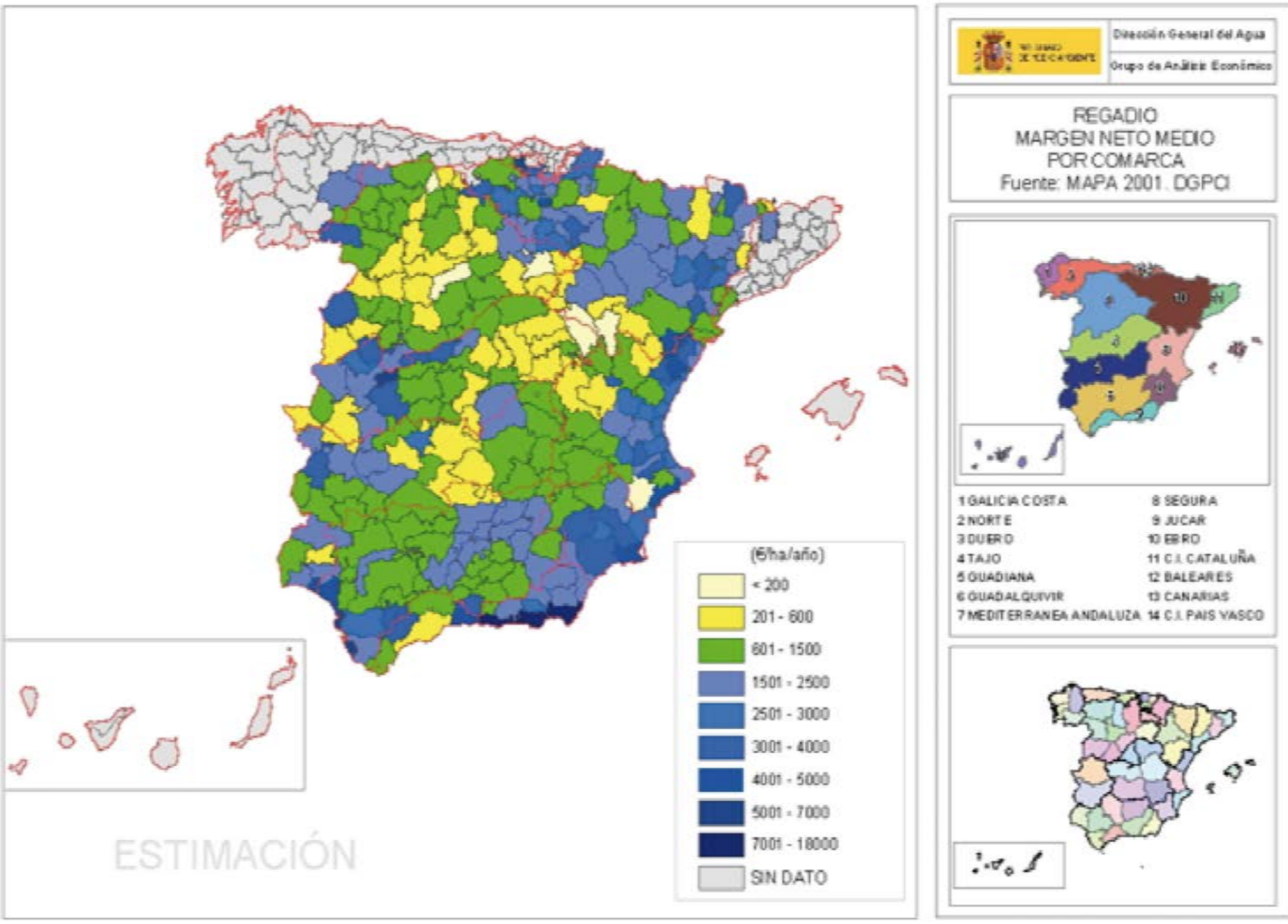


Fig. 4. Average net margin on irrigated crops by region. Source: MIMAM (2007b).

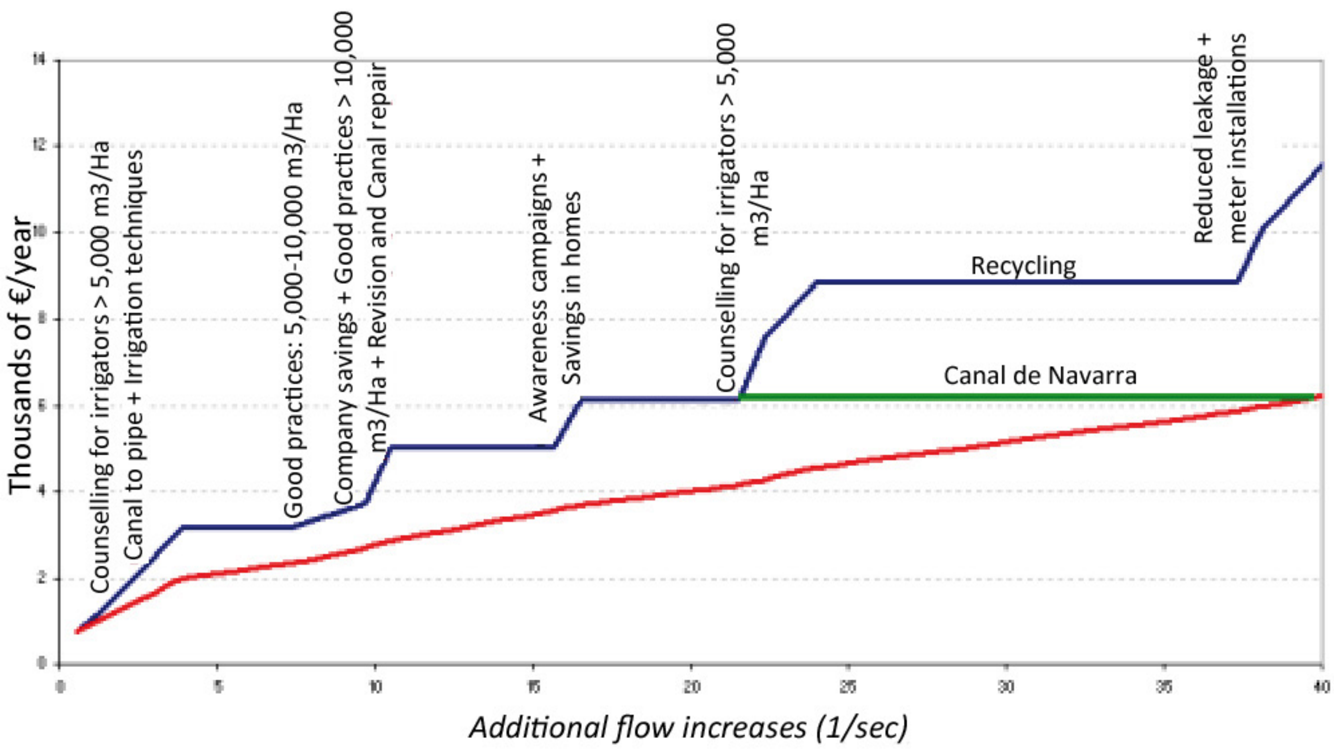


Fig. 5. Cost-efficiency analysis, Cidacos River Basin. Source: MIMAM (2007b).

either because of a lack of payment capacity, and/or of their economic and social impact, and/or of the benefits not justifying the costs.

The Plans include programming the investments of the selected measures. The *plan funding strategy* considers the financial capacity of the different public and private shareholders, as well as additional funding opportunities, especially for measures ensuring cost-recovery through pricing.

WHAT DO WE KNOW ABOUT WATER-USE IN SPAIN?

Water is a vital input for economy and economic growth, and for individual and collective wellbeing. Water is essential for our wellbeing and for the production processes, not only in irrigation, an agricultural activity, but also in industrial activities, including energy. Water is vital for preserving the ecosystems.

The European Directive considers that the demands of the water services imply certain pressures that have a significant impact on water bodies – the good state of which we depend on – and can endanger their preservation. These demands also endanger the activities' sustainability, and furthermore condition the ecosystems' capacity to produce environmental services unrelated to water uses (such as fencing erosion processes, desertification, maintaining biodiversity, leisure services, etc.).

According to the information on the second cycle of water plans in Spain (2015-2021), all production activities in all the river basin districts (except the Internal Basins in Catalonia, and the archipelagos) use around 26,960 Ha^3 (2015 data). This means an average of about 745 m^3 per inhabitant per year.

Water use per inhabitant presents considerable variations depending on the district, this is explained by the importance of irrigation and energy uses in some districts, as shown in Figure 6. It increases in the Duero, Guadiana and Ebro districts, to 1,998, 1,478 and 1,642 m^3 per inhabitant per year. At the other end of the scale, in the Northern Spain and Tajo districts, per capita water use is much more reduced (between 143-360 m^3 per inhabitant per year).

Chart 1

Volumes of water consumed through its different uses

Districts	Volume of water (thousands m^3)				
	Urban	Industry	Agriculture	Other	Total
Eastern Cantabrian	233,870	35,610	2,840	700	273,020
Western Cantabrian	256,000	128,100	74,700	2,750	461,550
Galicia Coast	225,760	56,000	31,190	32,747	345,697
Miño Sil	97,990	17,280	319,710	1,030	436,010
Duero	287,100	163,420	3,871,810	7,910	4,330,240
Tajo	602,610	181,250	1,929,370	86,780	2,800,010
Guadiana	166,080	48,600	1,915,770	0	2,130,450
Tinto, Odiel and Piedras	49.421	41,722	171,279	2,255	264,677
Guadalquivir	379,450	43,400	3,356,770	35,840	3,815,460
Guadalete-Barbate	107,943	17,200	306,387	6,240	437,770
Mediterranean Basins Andalusian	344,900	28,800	989,300	29,700	1,392,700
Segura	231,700	9,000	1,545,900	11,300	1,797,900
Júcar	524,700	123,370	2,580,660	12,080	3,240,810
Ebro	70,700	29,100	5,084,900	48,600	5,233,300
Total	**3,578,224**	**922,852**	**22,180,586**	**277,932**	**26,959,594**

Source: Prepared by the authors on the basis of the Annexes to the River Basin Plans. Figures in thousands of cubic metres. It does not include the following districts: the Inner River Basins of Catalonia, the 2 archipelagos, and the 2 African areas. Other uses, per area, correspond to other leisure (golf courses) and consumptive energy uses.

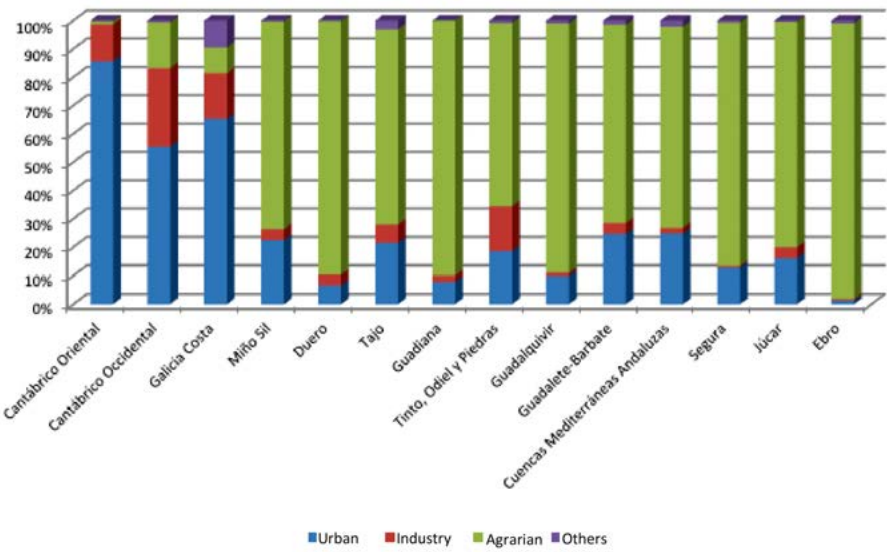


Fig. 6. Volume of water for associated uses in percentages. Source: Prepared by the authors on the basis of the Annexes to the River Basin Plans. It does not include the areas Inner River Basins of Catalonia, the 2 archipelagos, and the 2 African areas. Other uses, per area, correspond to other leisure uses (golf courses) and consumptive energy.

WHAT DO WE KNOW ABOUT THE COST OF PRODUCING WATER SERVICES AND THE COST-RECOVERY OF SUCH SERVICES IN SPAIN?

According to the Water Framework Directive, the water services include:

- Collection and storage of surface waters services (dams and other water regulation or production works by desalinisation or recycling).
- Groundwater extraction services (wells and pumps).
- Water-transport services (primary and secondary canals).
- Water-distribution services for domestic, industrial and irrigation use (water treatment and downstream distribution networks).
- Collection (sewage), treatment (purifying) and wastewater disposal services.

Spain's institutional framework for the provision and funding of these water services is very complex, and different stakeholders participate in supplying or financing each one of these services at every administrative level.

According to the information on the second cycle of water plans in Spain, in 2012 the total cost of all these water services amounted to 12,623 million euros in financial costs, and 1,859.56 million euros in environmental costs. This figure represents a cost per inhabitant of approximately 270€ per year, and 1.21% of the Gross Domestic Product. The estimate revenue the different stakeholders received for supplying water services amounted to 8,575.07 million euros for all the services, which explains why part of the costs are subsidised or simply (in the case of environmental costs) don't affect the uses that cause them.

According to the information gathered in Spain's plans, the cost-recovery levels from the different services are generally high. The plans show that in most analysed services the cost-recovery levels are higher than 70%, and in some cases, they are almost 100% (for services supplied as self-services). Cost-recovery is lower for upstream services, especially where non-conventional resources are used (desalinisation and recycling). The cost-recovery levels are also lower in the water distribution services for agricultural irrigation, because there has been considerable public investment in action to reduce leakage from distribution networks.

The higher costs are found in the distribution services downstream, especially the urban services, although they also include the irrigation services. Therefore, although the cost-recovery levels for upstream water services are lower, this does not affect in the same measure the global ratio of cost-recovery. These cost-recovery levels only represent 10% of the total financial cost, and the revenue obtained for the supply of such services represents 8% of the total income for supplying water services.

Therefore, even if the biggest water consumers in Spain are the irrigation users, the truth is that when we refer

Chart 2
Institutional framework of Spain's water services

Service	Stakeholders (relevant or funders in infrastructures)	IINSTRUMENTS FOR «COST-REDUCTION»
Reservoirs and Transport Upstream (surface water)	River Basin Organisations, State Companies, and other Stakeholders	Tariff Regulation Fee for water use
Groundwater	Basin Organisations, Irrigation Associations and private users (self-services)	The tariffs set by the councils The tariffs set by the CCRR
Urban Supply	Councils, Municipal Associations, Autonomous Communities and Others	Supply tariff
Collection of Urban Wastewater	Councils, Municipal Associations, Autonomous Communities and Others	Sewage tax
Treatment of Urban Wastewater	Councils, Municipal Associations, Autonomous Communities and Others	Sanitation fee Service tariffs
Distribution of Irrigation Water	Irrigation communities and associations	Spills and tariffs/ contribution of irrigation communities (that include the amount of Fee and Tariff payment to River Basin Organisms)
Wastewater Discharge Control	River Basin Organisations	Wastewater Discharge Control Fee

Source: Ministry of Environment (2007).

Chart 3
Synthesis, Spain's Cost-recovery for Water Services per service (2012).

Services	Costs			Revenue	Cost-recovery	
	Financial	Environmental	Totals		Financial	Total
Upstream surface water services	1,032.12	285.79	**1,317.91**	711.40	69%	54%
Upstream groundwater services	310.41	33.94	**344.34**	274.53	88%	80%
Downstream water distribution for irrigation	911.55	238.80	**1,150.35**	550.24	60%	48%
Urban supply	3,163.38	43.18	**3,206.56**	2,625.57	83%	82%
Self-services	2,238.40	503.76	**2,742.16**	2,129.11	95%	78%
Recycling	59.46	11.94	**71.40**	35.01	59%	49%
Desalinisation	148.75	9.00	**157.75**	101.53	68%	64%
Collection and treatment outside public networks	253.42	45.43	**298.85**	222.98	88%	75%
Collection and treatment inside public networks	2,645.74	687.71	**3,333.45**	1,924.69	73%	58%
Total	**10,763.23**	**1,859.56**	**12,622.79**	**8,575.07**	**80%**	**68%**

Source: Prepared by the authors on the basis of the Memoirs of the II River Basin Plans (2016-2021). Figures in millions of € and in percentage.

to service supply costs, proportions change. Water supply costs for urban uses (upstream and downstream, including treatment and purifying services) represent 53% of full costs, while service water supply costs for agricultural use represent 30% of full costs.

Regarding cost structure, according to the reported figures for Spain's second phase hydrological plans, it is noteworthy that in urban uses collection and transport services represent only 22% of the final costs, against downstream services that represent 78%. In the case of the cost structure of water supply for irrigation, collection and transport services represent 67% of the full costs, while the services downstream represent a third part of the final costs.

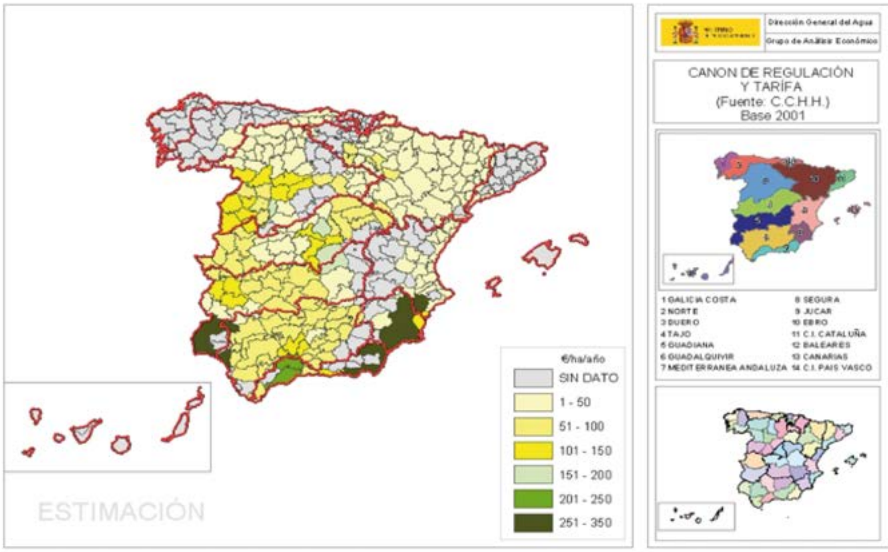


Fig. 7. Average amount of the Regulation Fee and the Tariff for Water Use. Source: Ministry of Environment (2007).

WHAT DO WE KNOW ABOUT THE VALUE OF WATER IN SPAIN'S PRODUCTION ACTIVITIES?

The way to measure the value we obtain for water use is through calculating its apparent production: that is, *the average yield for volume of water used in the different production processes per unit of gross value added.*

In irrigated agriculture and the production of hydroelectric energy, above all, water use depends in great part on the activity value, so that measuring and comparing the GVA obtained for m^3 (apparent productivity) and comparing it dry-land activities, for example, is relevant. Yet, this is not so in a considerable part of industrial activities and services; in these cases, what is relevant for water management and planning is to know the intensity of water use, i.e., the number of used m^3 needed to obtain a specific production level. This would be the result of choosing a more significant production structure in certain activity sectors that consume more or less water.

The information gathered on Spain's hydrological plans shows the value added generated by each economic activity on each district (excluding the inner river basins of Catalonia and the Canary Islands), which in aggregate terms amounts to 743,859 million euros. The service sector is the most important in Spain, with 70% of production value, followed by the industrial sector, with 16%, and the agricultural sector, with 3% of the total. Other sectors provide the remaining 11% of the GVA.

Considering the volumes of used water, we can estimate that Spain's average apparent productivity per cubic meter of water *would be 27.59 €*. The industrial sector obtains an average 131.01 € per cubic meter used, while the primary sector only obtains an average 0.94€ per cubic meter used.

The Northern districts, using less water in activities related to the primary sector, have a higher apparent productivity than the rest, where the participation of agriculture in water uses is more significant. The district were the apparent productivity is the highest is the Cantábrico Oriental, obtaining *188.22 €* per used m^3, almost seven times the national average.

At the other end, there are the districts of Duero and Guadiana, reaching respectively an *average 9.89 € per m^3 and 10.15 € per m^3*. In the case of the Tajo river basin, agriculture uses almost 70% of the total water use (and represents 0.9% of the district's GVA); but the average productivity in the river basin is nevertheless relatively high, since it reaches *71.32 €/m^3*.

The information on apparent productivity in irrigation and other uses allows us to access the ability to pay for the water services in certain irrigable areas (in accordance with its crop structure), and the economic impact that selecting certain measures which will affect the different sectors could have. For this, it is necessary to go beyond basin-scale data, and to know the apparent productivity at local-scale (see Chart 6).

Chart 4					
Gross Value Added by sectors in each district (2012)					
District	**GVA (M€)**				
	Services	**Industry**	**Agriculture**	**Other**	**Total**
Eastern Cantabrian	32,754	14,001	386	4,248	**51,389**
Western Cantabrian	21,196	6,756	583	3,188	**31,723**
Galicia Coast	36,701	7,736	1,621	3,469	**49,527**
Miño Sil	9,545	3,173	710	1,709	**15,137**
Duero	27,488	6,884	2,735	5,703	**42,810**
Tajo	150,000	25,000	1,700	23,000	**199,700**
Guadiana	13,955	3,859	1,340	2,465	**21,619**
Tinto, Odiel and Piedras	5,482	1,724	469	721	**8,396**
Guadalquivir	48,581	6,901	2,961	7,718	**66,161**
Guadalete-Barbate	13,919	2,777	507	1,853	**19,056**
Mediterranean Basins	32,173	3,253	1,866	4,546	**41,838**
Segura	22,416	5,713	1,506	2,733	**32,369**
Júcar	61,555	14,391	2,155	10,561	**88,662**
Ebro	47,891	18,735	2,327	6,519	**75,472**
River Basins of Catalonia	n/d	n/d	n/d	n/d	**n/d**
Balearic Islands	n/d	n/d	n/d	n/d	**n/d**
Melilla	n/d	n/d	n/d	n/d	**n/d**
Ceuta	n/d	n/d	n/d	n/d	**n/d**
Canary Islands	n/d	n/d	n/d	n/d	**n/d**
Total	**523,655**	**120,904**	**20,866**	**78,433**	**743,859**

Source: Prepared by the authors on the basis of the Annexes to the River Basin Plans. Figures in millions of euros. It does not include the following districts: the Inner River Basins of Catalonia, the 2 archipelagos, and the 2 African areas.

Chart 5				
Average apparent productivity per sector and district (2012)				
District	**Average apparent productivity water use**			
	Industry	**Agriculture**	**Rest**	**Global**
Eastern Cantabrian	393.18	135.92	157.74	188.22
Western Cantabrian	52.74	7.80	94.24	68.73
Galicia Coast	138.14	51.97	155.39	143.27
Miño Sil	183.62	2.22	113.65	34.72
Duero	42.12	0.71	112.51	9.89
Tajo	137.93	0.88	250.95	71.32
Guadiana	79.40	0.70	98.87	10.15
Tinto, Odiel and Piedras	41.33	2.74	120.04	31.72
Guadalquivir	159.02	0.88	135.57	17.34
Guadalete-Barbate	161.44	1.66	138.12	43.53
Mediterranean Basins Andalusian	112.96	1.89	98.02	30.04
Segura	634.82	0.97	103.50	18.00
Júcar	116.65	0.84	134.35	27.36
Ebro	643.81	0.46	456.08	14.42
Total	**131.01**	**0.94**	**156.14**	**27.59**

Source: Prepared by the authors on the basis of the Annexes to the River Basin Plans. Figures in €/m³ do not include the following districts: the Inner River Basins of Catalonia, the 2 archipelagos, and the 2 African areas.

Chart 6								
Cubic hectometres used per profitability ranking per m^3 (Net Margin) (78% irrigation hectares)								
Demarcación	**<0.02 €/m^3**	**0.02 - 0.20 €/m^3**	**0.20 - 0.40 €/m^3**	**0.40 - 0.60 €/m^3**	**0.60 - 1.00 €/m^3**	**1 - 3 €/m^3**	**>3 €/m^3**	**Overall total**
Duero	495	1,202	334	113	11	1	0	2,158
Ebro	401	1,499	768	675	45	23	0	3,410
Guadalquivir	733	1,151	1,012	443	155	21	16	3,532
Norte	1	2	0	8	0	0	0	12
Guadiana	1,001	496	78	256	62	157	0	2,051
Júcar	119	581	391	583	206	12	8	1,900
Segura	54	272	174	271	171	51	19	1,013
Mediterranean Basins Andalusian	97	42	38	11	39	11	93	331
Tajo	299	463	16	47	24	104	0	954
Canary Islands	7	1	0	0	36	32	0	76
Overall total	**3,208**	**5,710**	**2,812**	**2,407**	**751**	**412**	**137**	**15,437**
& Usage	21%	37%	18%	16%	5%	3%	1%	100%
& GVA pm	1%	11%	17%	28%	12%	15%	16%	100%

Source: Own elaboration (GAE), MIMAN 2007 b.
Note: Guadiana includes the TOP Area.

WHAT DO WE KNOW ABOUT THE COST-EFFICIENCY OF THE PLANNED MEASURES?

The approved measures for Spain's river basin plans have a total investment cost in the different investment planning cycles of around 65,957 million euros, of which 39,378 million euros stem from measures related to the achievement of environmental goals, and the rest, with a value of 26,580 million euros, from measures for the provision of water services. A part of these environmental investments has already been implemented before 2015 (around 11,924 million euros), and the other part is pending between 2016 and 2033 (27,453 million euros).

If we consider the full cost of the 11,815 environmental measures in all planning cycles, the total amount is 3.33 million euros at a national level, but with a high variability depending on the district.

The average indicator of the efficiency cost of achieving environmental goals is approximately an average of 11.91 million euros for improving each water body, with a considerable variation between districts (between 2.9 and 107 million euros depending on the district).

HOW MUCH DO MEASURE PROGRAMS COST AND HOW ARE WE GOING TO FINANCE THEM?

The funding strategy allows for the programming the investments, and helps ensure their viability and implementation within the established deadlines. It must be considered that this strategy influences the very process of planning, for it influences the selection of measures the implementation of which the budgetary ceilings permit, and therefore, the decisions on whether the environmental goals will be achieved.

The planning considers that the funding responsibility for the different measures in Spain's river basin plans falls on different public and private stakeholders. Each one is responsible for the implementation of certain measures, and has an assigned budget for his investments.

Chart 7

Funding the MP by type of stakeholder 2002-2033 (euros)

Organisation / Actor	2002-2008	2009-2015	2016-2021	2022-2027	2028-2033	Total
MAGRAMA	0	262,077,961	4,063,617,161	3,318,085,338	2,283,003,840	9,926,784,301
Other AGE	0	11,245,000	25,725,187	14,371,973	0	51,342,160
Autonomous Organisations (MAGRAMA)	2,101,623	1,099,722,726	2,139,150,753	1,942,050,302	4,291,927,320	9,474,952,724
SEIH and SEIASA	28,987,970	454,138,103	1,025,556,585	546,485,855	65,600,000	2,120,768,513
Autonomous communities	47,349,609	2,520,607,287	8,597,641,358	5,678,059,756	1,606,908,085	18,450,566,094
Local entities	186,403	458,077,948	1,769,006,263	1,644,908,416	208,025,945	4,080.204,976
Other	0	928,836,665	2,229,894,145	1,746,176,551	1,940,862,459	6,845,769,820
Total	**78,625,604**	**5,734,705,690**	**19,850,591,452**	**14,890.138.192**	**10,396.327,649**	**50,950,388,587**

Source: Prepared by the authors on the basis of the Annexes to the River Basin Plans.

It is noticeable that within the National State Administration, MAGRAMA is the main stakeholder. It is directly responsible for 19% of the full funding of the plans (9,927 million euros), and through its OOAA, for another 9,475 million euros, to which must be added the sum corresponding to the SSEE (SEIH and SEIASA), worth 2,121 million euros (4% of the total).

CONCLUSIONS

Economic analyses are an important part of the planning process. The scale on which these analyses are made will determine their usefulness within the planning processes, both for analysing the effectiveness of the pricing tools, improving efficiency in water use, and assessing the value to be obtained for water use, and at what cost. The selection of the most cost-efficient measures will mean that the relatively more costly measures may be relegated; or in some cases they will be considered as disproportionate costs, especially if they have a negative impact on socio-economic activities.

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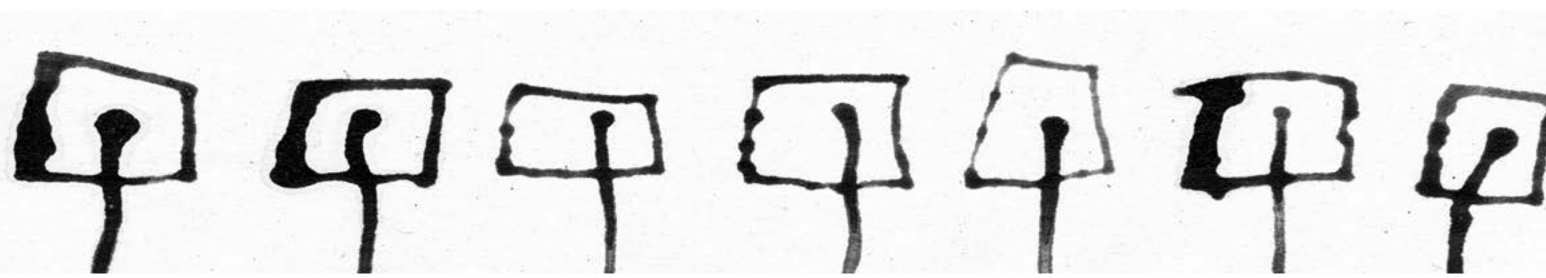

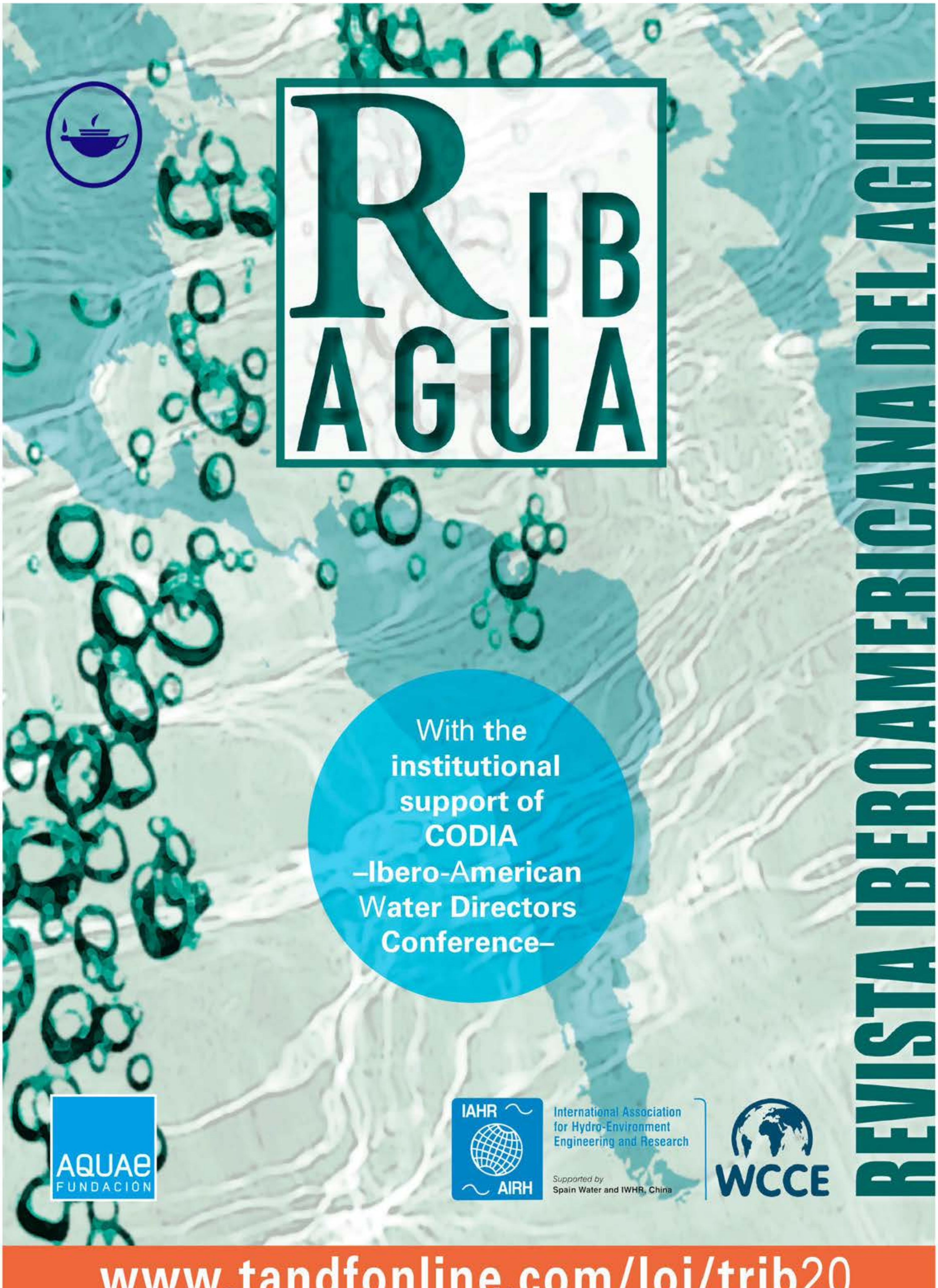
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