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CLEAN WATER AND SANITATION

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International Centre for
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Sustainable Management

Water Security and the Sustainable Development Goals

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GLOBAL WATER SECURITY ISSUES SERIES

Water Security and the Sustainable Development Goals

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Water Security and the Sustainable Development Goals

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GLOBAL WATER SECURITY ISSUES SERIES

FOREWORD

Maria C. Donoso
Director of UNESCO IHP

Freshwater is a prerequisite for all life on our planet, an enabling or limiting factor for any social and technological development, a possible source of welfare or misery, cooperation or conflict. The past decades, this valuable resource has been experiencing numerous anthropogenic pressures, which originate from a rapid population growth and urbanization, a change of consumption patterns as the living conditions improve, variations in climate and pollution patterns.

Recognizing that the results of pressures, such as unsustainable consumption patterns, increase of water related disasters and environmental degradation, could be detrimental and needed to be addressed, the international community ensured that the role of water is elevated and reflected accordingly to the post 2015 development agenda. Consequently, Goal 6 of the 2030 Agenda for Sustainable Development (SDG 6) was dedicated to water. Similarly, water related hazards have a prominent presence in the Sendai framework and also provision of sustainable water related services is a substantial part of the new urban agenda.

According to the SDG 6 synthesis report (2018), 844 million lack basic water services, 2.1 billion lack safely managed drinking water, 4.5 billion lack access to safely managed sanitation and 892 million still practice open defecation. Only 27 per cent of the population in least developed countries has access to soap and water for handwashing on premises.

In this context, UNESCO works to build the scientific knowledge base to help countries manage their water resources in a sustainable way through. This is accomplished through the International Hydrological Programme (IHP), the only intergovernmental programme of the UN system devoted to water research, water resources management, and education and capacity building. The IHP, having a forward-looking view, dedicated its current eighth phase on water security.

To achieve water security, we must protect vulnerable water systems, mitigate the impacts of water-related hazards such as floods and droughts, safeguard access to water functions and services, and manage water resources in an integrated and equitable manner. Surprisingly, though, a variety of topics regarding water security have not been extensively researched internationally. There is an urgent need to conduct extensive research on emerging and future global water security issues in the context of the internationally agreed goals and targets.

In response to this need, UNESCO and the International Centre for Water Security and Sustainable Management (i-WSSM) are collaborating in the launching of the Global Water Security Issues (GWSI) Series. This publication series will shed light into water security issues that need to be researched and will facilitate knowledge exchange on them, adding value to UNESCO's efforts in supporting member states achieve water security by providing the scientific base required to face water security challenges. The series aims in going further than reporting on scientific progress on the matter, by supporting also policy making, thus rendering it unique and original. Furthermore, the publication will contribute to strengthening international science cooperation for peace, sustainability, and social inclusion. It will help improve knowledge and strengthen capacity at all levels to secure water resources.

Considering the theme for World Water Day 2019 is 'Leaving no one behind', and as sustainable development progresses, everyone must benefit. In this spirit, I believe the GWSI series will provide meaningful approaches to water security as a driver for a better future for all.

To conclude, I wish to thank i-WSSM, all authors, editors, and staff involved in publishing this series for the future of our planet.

Director of the Water Sciences Division, a.i.
Secretary of the International Hydrological Programme (IHP)
UNESCO

FOREWORD

Yang Su Kim
Director of UNESCO i-WSSM

Water challenges are increasingly impacting every region around the world facing the effects of climate change, urbanization, as well as natural disasters. Confronted with the on-going water-related challenges, addressing water security can be a practical approach to deal with the complex and interconnected challenges and enhance sustainability, development and human welfare.

Over the years, 'Water Security' has gained international attention since the International Hydrology Programme (IHP) placed an emphasis on 'water security' during its eighth phase, being implemented between 2014-2021, in line with
the eight-year Medium-term Strategy of UNESCO (2014-2021). For instance, 'Water Security for Peace and Development' is the main theme of ninth World Water Forum which will be held in Senegal in 2021.

Surprisingly, though, a variety of topics regarding water security have not been researched in depth. There is an urgent need to conduct extensive research on emerging and future global water security issues, document these studies and disseminate them.

In response to demand, UNESCO and UNESCO International Centre for Water Security and Sustainable Management (i-WSSM) co-published the Global Water Security Issues (GWSI) series with the aim of providing a starting point for discussion on a range of issues that collectively fall under the umbrella of water security, identifying the present issues, broadening discourses, bringing regional cases to the center, and sharing diverse perspectives.

The first edition of the GWSI series, 'Water Security and the Sustainable Development Goals', provides rich explanations on the related issues of water security while taking into context various aspects such as technology, society, economy, environment, and governance.
The first edition sheds lights on how the approaches to water security play important roles to achieve multiple priority development areas including good health and well-being, clean water and sanitation, climate action, and conservation and restoration of ecosystems.

It is timely that UNESCO and i-WSSM have decided to work collaboratively in order to disseminate global water security issues. I wish to extend my gratitude to the IHP for their dedication to water security and for the remarkable collaboration. Also, I give my sincere thanks to the authors, editors, reviewers, and staffs for their contributions.

Just as water is central to every aspect of life on earth, water security must lie at the heart of the new vision we forge for sustainable development for the century ahead. In this respect, the GWSI series makes an important contribution to addressing the challenges of water security and disseminating the issues to broader areas. I hope that the GWSI series encourages people around the world to actively contribute to enhancing water security and achieving the sustainable development goals. For a sustainable and prosperous future for all, the current water challenges we face require collective action.

Yang Su Kim

Director of UNESCO International Centre for Water Security and Sustainable Management

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ABBREVIATIONS & ACRONYMS

3Ts	Tariffs, Taxes and Transfers
4MRRP	4 Major River Restoration Project (Korea)
A/R	Afforestation and Reforestation
ACLED	Armed Conflict Location and Event Data
ADB	Asia Development Bank
AFOLU	Agriculture, Forestry and Other Land Use
AHREP	Andhikhola Hydel and Rural Electrification Project (Nepal)
AMI	Advanced Metering Infrastructure
AMM	Automated Metering Management
AMR	Automated Meter Reading
ANA	National Water Agency (Brazil)
APCE	Asia-Pacific Centre for Ecohydrology
API	Application Program Interface
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BPC	Butwal Power Company Ltd (Nepal)
CARE	Cooperative for Assistance and Relief Everywhere
CBA	Community Based Approach
CCB	Community and Biodiversity Standard
CDHRI	Cairo Declaration on Human Rights in Islam
CDM	Clean Development Mechanism
CERs	Certified Emission reduction
CHE	Ebro River Basin Confederation in English, CHE by its Spanish acronym
CHRH	National Council of Water Resources (Brazil)
CIFOR	Center for International Forestry Research
COD	Chemical Oxygen Demand
DHI	Danish Hydraulic Institute
DIE	Department and Information Engineering
DO	Dissolved Oxygen
DSC	Development Support Center
DSS	Decision Support Systems
EIA	Environmental Impact Assessment
EMC	Maltese National Utilities for Electricity and Water-Enemalta Corp
ESCO	Energy Service COmpanies
ESD	Education for Sustainable Development
ESPC	Energy-saving Performance Contracts
ESRC	Economic and Social Research (U.K)
ETS	Emissions Trading System
EUR	Euro (EU currency)
EV	Extensive Volunteers
FAO	Food and Agriculture Organization of the United Nations
FC	Fraction of Land Cover
FEFLOW	Finite Element Subsurface Flow System (groundwater flow simulation software)
FONAG	Quito Water Conservation Fund (Ecuador)
FUNAI	National Indian Foundation (Brazil)
GCC	Gulf Cooperation Council
GCF	Green Climate Fund
GGGI	Global Green Growth Institute
GHG	Greenhouse Gases
GI	Geographic Information
GI	Green Infrastructure
GIS	Geographic Information System
GIWEH	Global Institute for Water, Environment, and Health
GPS	Global Positioning System
GTP	Growth and Transformation Plan (Ethiopia)
GWP	Global Water Partnership
HAN	Home Area Network
HGD	Hydropower Generation Dam
HICs	High Income Countries
HLPW	High Level Panel on Water
HTC KL	Humid Tropics Hydrology and Water Resources Centre for Southeast Asia and the Pacific (Malaysia)
IBNET	International Benchmarking Network for Water and Sanitation Utilities
ICC	International Criminal Court
ICCE	International Centre for Coastal Ecohydrology (Portugal)
ICHARM	International Centre for Water Hazard and Risk Management (Japan)
ICIMOD	International Centre for Integrated Mountain Development (Nepal)
ICRC	International Committee of the Red Cross
ICT	Information and Communication Technology
IDE	Interactive Development Environment
IHD	Human Rights Association (Turkey)
IHE-Delft	Institute for Water Education
IHP	UNESCO International Hydrological Programme
IIED	International Institute for Environment and Development
IIWQ	International Initiative on Water Quality
IMM	Istanbul Metropolitan Municipality
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
IS	Information Systems
ISKI	Istanbul Water and Sewerage Administration
IUCN	International Union for Conservation of Nature
IWA	International Water Association
IWRA	International Water Resources Association
IWRM	Integrated Water Resource Management
i-WSSM	International Centre for Water Security and Sustainable Management (Korea)
JICA	Japan International Cooperation Agency
JMP	Joint Monitoring Program
KPI	Key Performance Indicators

LAI	Leaf Area Index
LICs	Low Income Countries
LIPI	Indonesian Institute of Science
LNG	Liquified Nitrogen Gas
LPCD	Litres per Capita Per Day
LRAs	Local and Regional Authorities
LULUCF	Land Use, Land Use Change and Forestry
MDB	Murray Darling Basin (Australia)
MDG	Millennium Development Goal
MDP	Multipurpose Dam
MEMS	Micro Electro-mechanical Systems
MENA	Middle East and North Africa region
MIKE 21	Modeling Software (2D)
MIKE SHE	Modeling Software
MLTM	Ministry of Land, Transport and Maritime Affairs (Korea)
MRV	Measurement, Reporting, Verification
MUWS	Multiple Use Water Systems
NAPA	National Adaption Programmes of Actions
NATO	North Atlantic Treaty Organization
NBS	Nature-based Solutions
NDVI	Normalized Difference Vegetation Index
NGOs	Non-governmental Organizations
NIR	Near Infrared
NORAD	Norwegian Development Agency
NPS	Non-point Source
NRDWP	National Rural Drinking Water Program (India)
NRW	Non-revenue Water
OECD	Organisation for Economic Co-operation and Development
PCGG	Presidential Committee on Green Growth (Korea)
PCJ	Piracicaba Capivari and Jundiai River Basin Committee (Brazil)
PDA	Personal Digital Assistant
PES	Payment for Ecosystem Services
POU	Points of Use
PPP	Public-private Partnership
Prepdata	Preparation for Resilience Preparedness
PRODES	Basin Pollution Control Program
PUB	Public Utilities Board (Singapore)
PWRI	Public Works research Institute (Japan)
RC-IRBM	Regional Centre for Integrated River Basin Management (Nigeria)
RTD	Resistance Temperature Detector
SAIH	Automatic Hydrological Information System
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SDIS	Small Island Developing States
SDSDC	Sihwa District Sustainable Development Council (Korea)
SIDA	Swedish International Development Cooperation Agency
SINGREH	National Water Resources Management System (Brazil)
SMS	Soil Moisture Sensor
SMS	Short Message Service
SNIRH	National System of Hydrologic Information (Brazil)
SP	Special Committee
SRI	System of Rice Intensification
SuDS	Sustainable Drainage Systems
SWAN	Smart Water Assessment Network (Singapore)
SWP	State Water Project (California)
TNC	The Nature Conservancy
TWh	Terawatt-hour
UN	United Nations
UN HABITAT	United Nations Human Settlements Programme
UNCCD	UN Convention to Combat Desertification
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	UN Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Internationals Children's Fund
UNISDR	UN Office for Disaster Risk Reduction
UNITWIN	University Twinning and Networking Programme (UNESCO)
UN-Water	United Nations-Water
USAID	UN Agency for International Development
VI	Vegetation Indices
WBIC	Weather-based Irrigation Controllers
WCC	Water Conflict Chronology
WEF	World Economic Forum
WEF	Water-Energy-Food (NEXUS)
WENDI	Water, Energy and Disaster Management for Sustainable Development
WFD	Water Framework Directive (EU)
WGG	Water and Green Growth
WHO	World Health Organization
WMO	World Meteorological Organization
WPS	Water, Peace, Security Project
WRG	Water Resources Group
WRI	Water Resources Institute
WSP	Water Service Corporation (Malta)
WSUD	Water-sensitive Urban Design
WWAP	World Water Assessment Programme (UN)
WWF	World Wildlife Fund

Introduction

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Water Security : A Dynamic Multidisciplinary Vision from Theory to Practice

Nidal Salim, Morgane Anziani-Vente and Dana Madsen

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Abstract

Water security has emerged as a major theoretical framework in environmental governance and resource management.
An insecure supply of clean water and safe access to freshwater and sanitation raises the dangers of economic disruption, social tension, and even conflict over water resources at both the domestic and international levels. These dangers are highest where water is scarce and governance (at local, national or international levels) is poor.
Water scarcity, aging or inadequate infrastructure, population growth, pollution, more intense and more frequent storms, droughts, and floods—all these pressures are converging to lend urgency to the need to increase global investment in water infrastructures and to develop smart water conservation and management solutions.
Water security is a concept with several aspects and dimensions. In a recent study (Varis *et al.*, 2017), water security is defined in four dimensions, each consisting of two complementary aspects: direct-indirect, macro-micro, technical-political, and peace-conflict.
We will highlight some water challenges in the direct and indirect dimensions, introduce a conceptualization of water security that appreciates its complexity, and present some efforts to secure water development for the future at different scales, with more focus on water and agriculture, water and health, and rural development to show how it could be used to develop a framework for all stakeholders in a community to address their current and future water needs. Such frameworks, developed by communities, should form the basis for a national water policy based on sustainability.

Keywords

Water security, sustainability, peace, innovation and technology, human rights, governance

01
Introduction

The future adequacy of freshwater resources at the global scale is difficult to assess, owing to a complex and rapidly changing geography of water supply, demand and use. Globally, water resources face the greatest pressure to meet rapidly growing needs. Many countries in the Middle East, Asia, Africa and other parts of the world are facing water scarcity, and vulnerability to water shortages.
Water scarcity becomes most acute when one considers demand and supply in the context of future socio-economic and natural changes that may occur. The socio-economic factor with the greatest potential impact is population growth; the natural factor of greatest concern is climate change (Salim, 2006).

While climate change presents formidable challenges to global water systems, water problems are primarily the result of the failure of societal institutions to manage the resource and meet the needs of current residents, the economy and the environment, and future generations.
A single-minded focus on climate change and hydrological responses dominates water science at the expense of research that investigates how to safeguard water systems in the face of inevitable environmental and societal change. Managing climate risk and uncertainty requires better governance and a more integrated and sustainable water resources management approach. Better information, policy, regulation, allocation and cooperation will pave the way for more proactive adaptation and enhanced resilience.

Water is a crucial and highly sensitive political issue. The over-exploitation of groundwater resources and deterioration of water quality caused by pollution as well as the deficiencies of the existing infrastructure require immediate attention. Water resources are becoming vulnerable to four main pollutant sources: domestic wastewater, solid waste leachate, industrial effluents, and runoff from agricultural activities. This highlights the role of markets, urban planning, insurance, policy, technology, governance, cultural attitudes and values, institutions, legal frameworks, and decision-making strategies in mitigating water stress.

The term ‘water security’ and underlying concepts have attracted the attention of governmental and nongovernmental organizations, private sector, and academia in policy and practice. Notwithstanding the palpable rise in its use, a comprehensive understanding of how water security is conceptualized and employed in different contexts around the world is limited.

There is a broad diffusion of water security across geographic regions and scales, expansive framing of water security, and evolving approaches to indicator formulation.

The narratives around future pathways for governance include the promotion of participatory processes, solutions that engage both quantitative and qualitative methods, and a mix of both hard-and soft-path approaches to achieve water security.

Water security is not only a question of the physical scarcity of water; it is deeply rooted in power, poverty and inequality. There is therefore a major difference between these two concepts. On the one hand, one must consider the actual, physical scarcity of water, and on the other, a widespread lack of access to water caused by economic, political, social and environmental factors. Beyond the challenges related to the management of resource scarcity, there are hydro-political and transboundary considerations. The cycling of water exerts important control on climate variability as a result of its complex feedbacks and interactions with other components of the climate system (Salim, 2006).

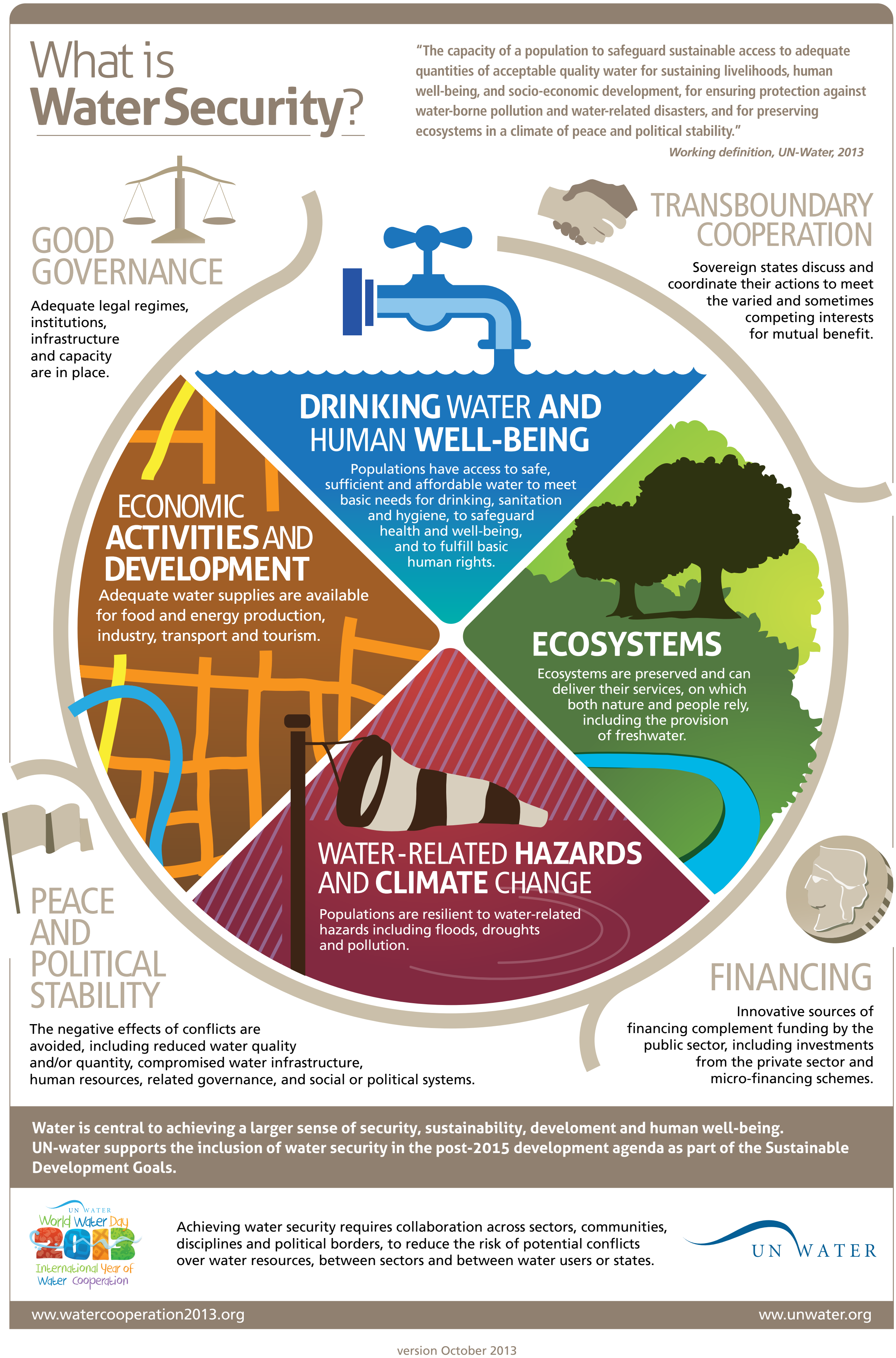


Figure 1-1 *Water security definition and cross sectors (UN-Water, 2013)*

02

Definitions: Water Security

Since the 1990s, the concept of water security has served to articulate concern about issues such as reliability, quality, quantity, safe and equitable access, and environmental provisioning of water supplies. The notion has been increasingly employed in policy circles, from the World Wildlife Fund and the World Economic Forum to the United Nations (UN) (WWF, 2009; UNEP, 2009; WEF, 2011; UN-Water, 2013; UNESCO, 2013).

Historically, water security was defined by different authors and interpretations vary according to the geographic regions they are studying and the aims of their research. This diversity in definitions means that actors are using the concept in widely diverging ways (scholars, planners, managers, and stakeholders, etc.), as normative and instrumental framing elements and as potential benchmarks for reducing insecurity. In most cases, users of the concept are adapting it to fit their own particular contexts (Gerlak *et al.*, 2018).

"In the past few decades, definitions of security have moved beyond a limited focus on military risks and conflicts," says Michel Jarraud, former Chair of UN-Water and Secretary-General of the World Meteorological Organization (WMO). "Security has now come to mean human security and its achievement through development. Water fits within this broader definition of security embracing political, health, economic, personal, food, energy, environmental and other concerns and acts as a central link between them."

UN-Water, the United Nations' inter-agency coordination mechanism for all water-related issues, says water security should be defined as: "The capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water, 2013).

> *"Water, as a crucial and relatively rare resource, plays a key role in the creation and maintenance of human security in relation to the environment."*

A large proportion of water resources are transboundary and final arrangements on water allocation between different countries are not yet in place for "fair and equitable apportionment".

In some areas, like the Middle East, Africa and Asia, natural water is not only threatened, it is also threatening! (Lehmann *et al.*, 2010)

Both water demand and the ensuing gap between water supply and water demand are growing due to population growth, higher living standards, climate change and the need to expand irrigated agriculture and industrial activities, leading to a potential decrease in fresh water availability.

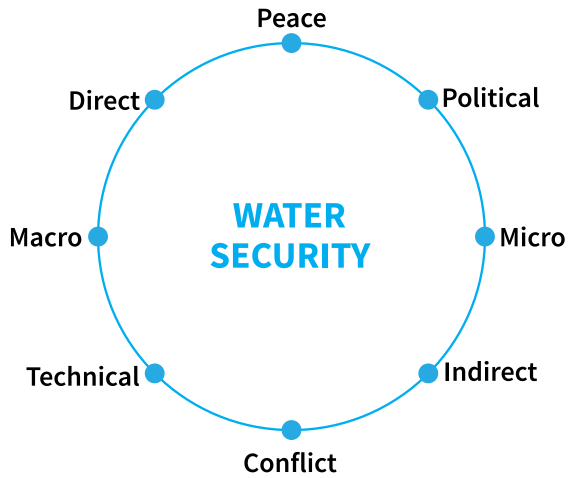


Figure 1-2 Dimensions of water security and sustainability (Varis et al., 2017)

Freshwater sustainability stands out as the most important sustainable development challenge because it deals with the most precious and finite resource on our planet. When water resources in one community become scarce or threatened, the economic, social and environmental risks increase. Thus, a proactive integrated management approach is needed to balance the competing needs for this limited resource. 'Water sustainability' is a collaborative, community-driven initiative, which requires the active participation of all members in the community. It seeks to establish new, creative and coordinated water management strategies based on value addition and security for all stakeholders.

How a community chooses to use its resources to achieve its economic, social and environmental goals implies the elaboration of a unified vision, technology, leadership and goals that are specific and measurable.
A willing and committed private sector should lead this change within the community.

Fortunately, there are innovative strategies that can help communities conserve water and upgrade their existing infrastructure in a pragmatic way, or alternately deploy new infrastructures where there are none and implement conservation and smart management right from the start.

03

The Relationships between Water, the Local Environment, and Human Security

Human security is a paradigm in which security is defined by the needs of individuals rather than those of states.
It takes into account the changing nature of international security, where new threats come from non-state actors and the international economic system is moving toward multipolarity. Increasingly, human security has also come to emphasize the relationships between the environment and society. Water, as a crucial and relatively rare resource, plays a key role in the creation and maintenance of human security in relation to the environment. In fact, “it is the human security aspect of water scarcity which seems likely to cause security threats both nationally and internationally” (Wolf, 1999).
As mentioned above, water scarcity can be defined in two ways: physical scarcity (lack of rainfall; deserts; inequality of geographical water distribution) and economic scarcity (lack of money to pay for water, to create the proper infrastructure for distribution, or to treat water).

One manifestation of the human security dimension of water scarcity is in water’s effect on agriculture. It is a simple reciprocal relationship: when water supply drops, food production does as well. A lack of fresh water leads to poor irrigation practices, the most common of which is the use of salt water and of poorly treated wastewater. Each year, soil salinity destroys nearly a million hectares of arable land in the Middle East and North Africa, the two regions with the lowest percentages of arable land and scarcest water resources in the world (Doble, 2011).

The decrease in food production caused by water scarcity is linked closely with population growth. This combination creates deteriorating living conditions and further environmental problems, especially increased depletion of water supplies, deforestation, and desertification. These environmental changes cause poverty, malnutrition, and famines, and play a significant role in the hunger that affects approximately one billion people worldwide.

For poor countries unable to change their irrigation and agriculture practices, the decline in food production, arable land, and water may cause an increased dependence on foreign food aid. A stable state cannot be dependent on another for such essentials as food and water. Thus, food insecurity, as a consequence of water scarcity, connects water not only with human security but with state insecurity and instability.

04

Objectives

The aims of the present paper are to raise awareness of the importance of water as a means of security at multiple levels and to present good practices to reduce the impact of insecurity. The majority of the world’s water problems are not attributable to an actual shortage, but rather are the result of poor water governance. As such, they are solvable through more effective governance and better management practices.

The main concern of this paper is to highlight water security within cross-cutting issues at different scales and to present good practices to secure water development and peace for the future through different regional cases and different themes. These themes are more precisely: water and agriculture, water and health, and rural development. In so doing, our objective is to demonstrate how these good practices could be used to develop a framework for all stakeholders in a community to address their current and future water needs. Such frameworks elaborated by the concerned communities themselves should form the

Figure 1-3 Sustainable Development Goal 6 (GIWEH, 2015)

Target 6.a By 2030, expand international cooperation and capacity-building support to developing countries in water-and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

Target 6.b Support and strengthen the participation of local communities in improving water and sanitation management.

basis for a national water policy based on sustainability and security for all. Regional and international case studies drawn at different scales and levels can provide useful models to enhance water security. The water cycle itself should link us in a common effort to protect and share equitably, sustainably and peacefully.

Subsidiary project aims: The subsidiary aims of this paper are to highlight some high-quality solutions based on innovation and technology and discuss security in its various dimensions (socio-economic, legal, environmental, technical and political), for example:

- To strengthen the operational capacity, manage the human resources, use technology and perform field work;
- To employ substantial scientific evidence in support of socio-economic water management decisions;
- To build capacity at the national level and at the regional and global scales and benefit from the examples of leading initiatives from different parts of the world;
- To create an environment which enables countries to work toward Goal 6: 'Clean Water and Sanitation' of the 2030 Sustainable Development Goals through a holistic approach, taking into account all the aforementioned complexities of water security as a process.

05

Future Prospective: Integrated Water Resource Management

It is first and foremost important to know 'how' it is done, making an understanding of the role of governance (wherein governance is considered as a process) key to the elaboration of integrated water resource management strategies; rules are brought in and decisions are made. At the same time, governance is a product (*e.g.* good governance, good decision-making, bad governance, etc.).

One of the aims of integrated water resource management (IWRM) is to improve security and sustainability through better water use efficiency and conservation. First, water efficiency can be improved by adopting structural measures, like improving technologies, and non-structural measures such as water pricing, awareness raising, etc. The second level of efficiency is related to the allocation and re-allocation of water resources to specific, higher-value uses and more equitable use by all stakeholders. The third level of efficiency is related to the inter-basin trade of water. As water is quite a bulky item to transport, trading water in its real form is costly. Therefore, the concept of virtual water enters the picture. The economic argument behind virtual water trade is that, according to international trade theory, nations should export products in which they possess a relative or comparative advantage in production, while they should import products in which they possess a comparative disadvantage (Wichelns, 2001). Following this logic, a fourth level of efficiency is water use efficiency for resilient economies and societies.

By adopting Sustainable Development Goal 6, member-states of the United Nations have committed to "ensure availability and sustainable management of water and sanitation for all by 2030". Notably, sustainable water management is also a key precursor to achieving many of the other Sustainable Development Goals. The High Level Panel on Water (HLPW) was convened in 2016 by the United Nations Secretary General and World Bank President to mobilise effective action to accelerate the implementation of SDG6 and its related targets. The Roadmap sets out what needs to be done, why, how, when and by whom. Figure 1-4 provides a schematic representation of this Roadmap (HLPW, 2017).

Water resource management in different regions must meet all needs in a changing socio-economic, political and natural environment. Therefore, strategies must take into account the current gaps in water availability and the need for equity. Effective management also demands international involvement and exchange of information and water for ecosystem.

The theme of water security will be discussed and highlighted in this paper from three different points of view which is completely aligned with the main definition of water security from UN Water. These topics are:

- Water and human rights
- Transboundary water issues
- Knowledge base and dissemination: good practices

5.1. Water and Human Rights

On the 28th July, 2010, through Resolution 64/292 (UN General Assembly, 2010), the United Nations General Assembly explicitly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realisation of all human rights.
The Resolution calls upon States and international organisations to provide financial resources, capacity-building and technology transfers to help countries, in particular developing countries, to provide safe, clean, accessible and affordable drinking water and sanitation for all.

In November 2002, the Committee on Economic, Social and Cultural Rights adopted General Comment No. 15 on the right to water. Article I.1 states that: "The human right to water is indispensable for leading a life in human dignity.
It is a prerequisite for the realization of other human rights". Comment No. 15 also defined the right to water as the right of every person to sufficient, safe, acceptable and physically accessible and affordable water for personal and domestic uses.

According to the World Economic and Social Survey, poor and marginalized groups are likely to experience the worst impacts of water shortages and flood hazards (DIE, 2018), as they tend to live in highly risk-prone areas and lack the funds to prepare for drought or flood scenarios. Thereby, climate change stands to worsen existing inequalities, disproportionately threatening water security and thus the development and well-being of disadvantaged groups.

Today, nearly 700 million people around the world lack basic access to water, and a striking 2.4 billion lack access to sanitation (WHO, 2015). It is not surprising, then, that the water crisis comes as the biggest threat to global prosperity. Yet, a persistent misunderstanding of this challenge is the notion that the poor are in this predicament because they cannot pay for access to water. The truth is, the poor spend an estimated U.S. $200 billion per year on water access (UNDP, 2006).

The high costs are due in part to what the poor have to pay for bottled and well water due to a lack of infrastructure or the means to tap into infrastructure. Many of those without access rely on informal water vendors — known as 'tanker truck mafia' — in slums around the world. The price of water in these informal markets is remarkably high and can reach U.S. $15 per cubic meter (Boccaletti & White, 2015); compare that to the U.S. $1 per cubic meter paid by households in New York City.

The poor also pay in the forms of forgone income and illness. The World Health Organization estimated that the total global economic losses associated with inadequate water supply and sanitation is approximately U.S. $260 billion annually (WHO, 2012). In short, the poor incur huge coping costs because they lack access to safe, efficient piped water networks.

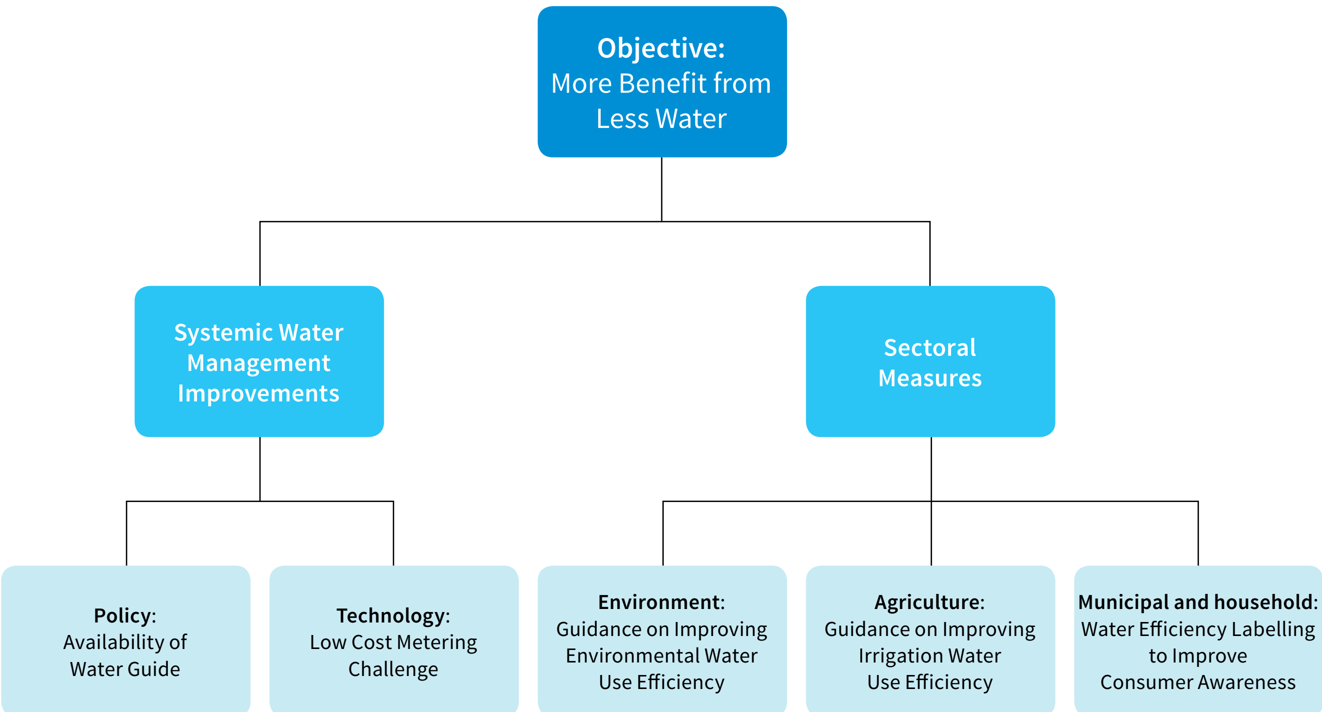
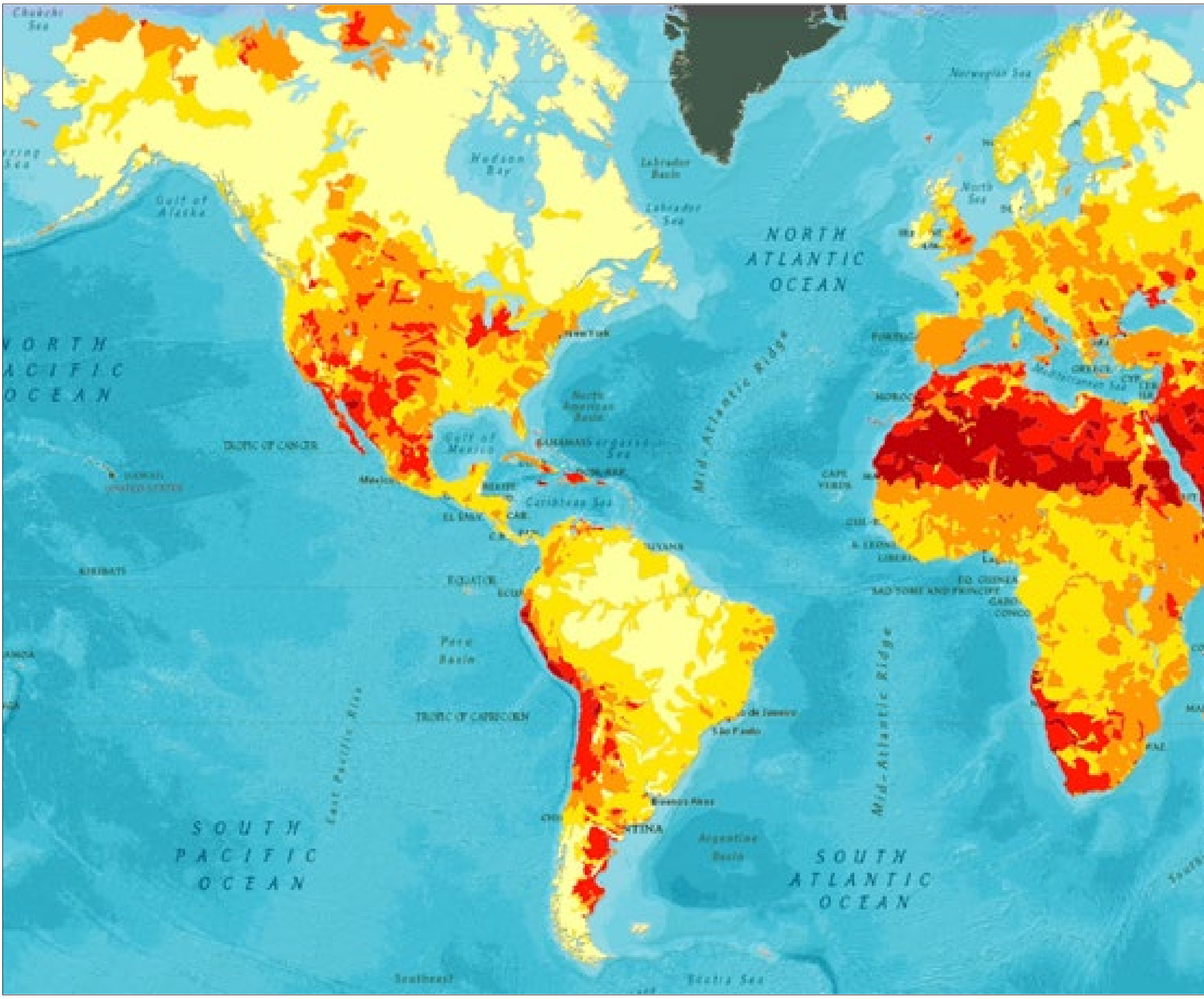


Figure 1-4 HLPW roadmap for enhancing efficiency

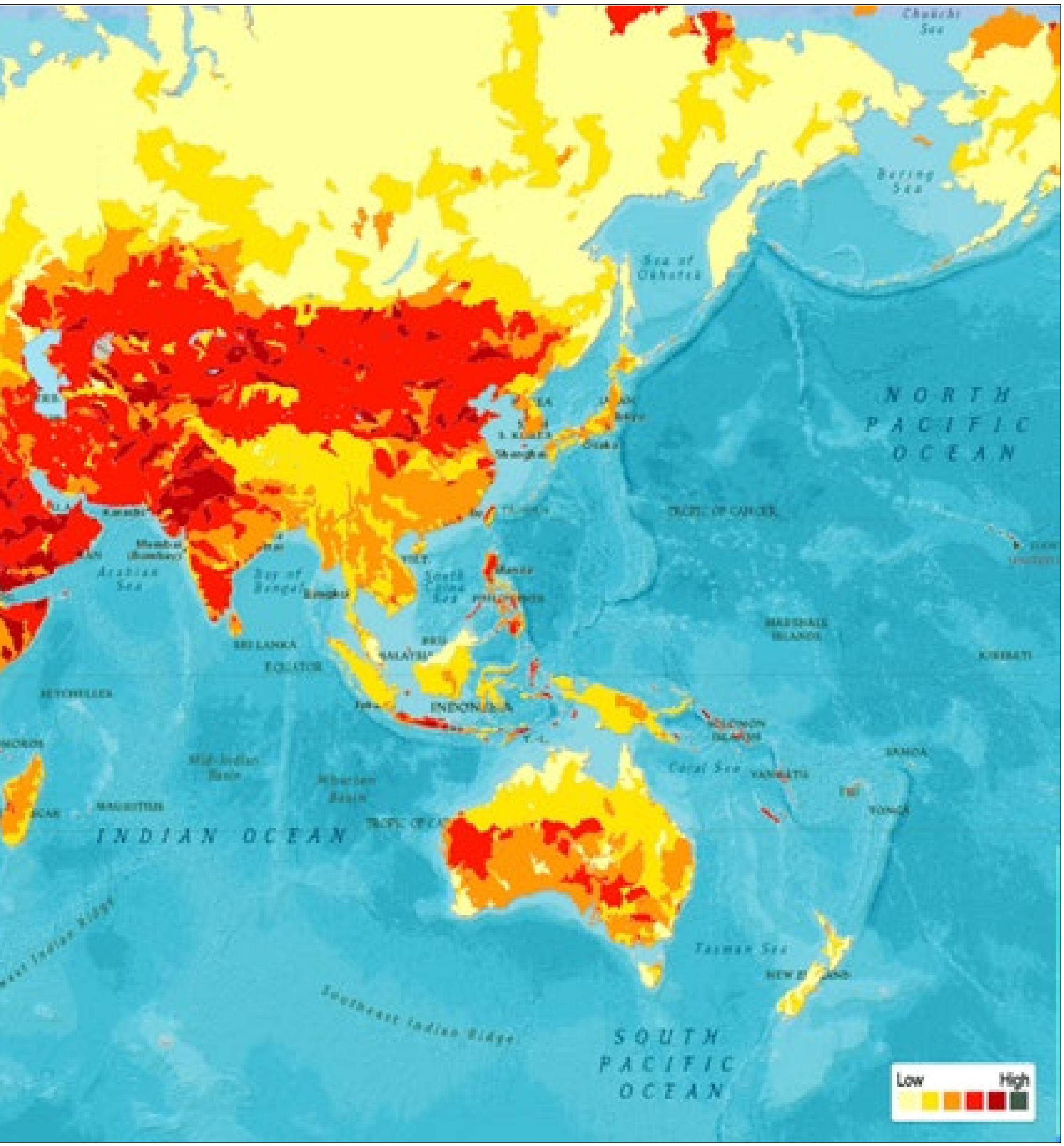


This raises the question of justice and equity, and the affordability in the most vulnerable areas. “Charity alone will not be able to solve the global access to water problem. Conservative estimates of the expenditures required to provide and maintain safe water access is U.S. $1 trillion with only U.S. $8 billion provided in international aid each year” (Boccaletti & White, 2015).

Overcoming these problems requires the elaboration of a comprehensive integrated water resource management scheme, based on a fine understanding of the problem and appropriate solutions. This does not imply inventing new technology, but rather scaling knowledge and proven solutions that we have seen work on the ground.
India and China are home to one-third of those without access to water and more than half of those without access to sanitation. A long trail of countries from Africa, Asia, South America and Middle East like Nigeria, Burundi, Somalia, Indonesia, India, Peru, Yemen and Nepal are among the most affected.

While of the fundraising agencies are concentrated on providing water grids for cities, villages and highly populated areas, we still need to focus on the very local level to extend the network for remote areas. This can be achieved by loans to pay a connection fee, wherein people are able to tap into the water supply or build a toilet, and repay the loan in full with consistent reliability (Boccaletti & White, 2015). Furthermore, for the poor that live close to an existing water grid in a city, extending financing to buy last mile connections and toilets can have a huge impact in increasing access to services.

The growth of off-grid water treatment technologies could present a potential for positive change. The number of rural households without access to water and sanitation is roughly five times higher than that of the urban poor. For these individuals, and some in peri-urban areas, connecting to a public utility is often not an option. Because of falling water treatment costs and the growth of social impact investment capital, there are new possibilities to set-up water kiosks and



“Smarter, more efficient solutions allow the poor to redirect their coping costs to affordable, sustainable and higher quality water and sanitation services.”

Figure 1-5 *Overall water risk*

deliver treated water to dispersed populations. Off-grid solutions, such as those offered by Water Health International, allow rural communities to tap local sources of water and render them potable, at a cost that can greatly undercut their current cost.

Investments in nature-based solutions such as reforestation and riverbank repair can improve the quality of the water supply. This drives economic development while saving on water treatment costs. A recent study conducted by The Nature Conservancy of 500 large cities shows that in at least a quarter of those cities, the savings from reduced treatment costs more than paid for the conservation activity. These interventions disproportionately benefit the rural poor and contribute to a sustainable water management system (Nature Conservatory, 2018).

Social entrepreneurs, armed with smart philanthropy and social impact investing, are spurring this trend to leverage market-based solutions in service of the poor, seeing them not as a ‘problem to be solved’ with traditional charity, but as having intrinsic power as customers. Smarter, more efficient solutions allow the poor to redirect their coping costs to affordable, sustainable and higher quality water and sanitation services.

The refugees and displaced people also face huge challenges in safe access to water. In more than half of the refugee camps in the world, refugees cannot secure the minimum daily water requirement of 20 litres per person (UNHCR, 2018). Both the planning and undertaking of comprehensive research and implementation on water, sanitation and hygiene promotion issues among refugee populations has remained a challenge. Reasons include emergency actions with no sustainable plans, security restrictions, complex operational conditions, scarce resources, understaffing or high staff turn-over, the difficulty of undertaking thorough measurements during emergency situations and the fact that refugee camps are often forcibly located on marginal lands. These very real constraints hinder efforts by water and health professionals to systematically document and build on lessons learnt in order to improve services in these areas in subsequent refugee operations.

For many international agencies and governments however, refugees and displaced people are seen as temporary populations and are consequently provided limited emergency and short-term assistance. In consequence, refugees experience little state support and lack access to existing infrastructure and water services. Instead, the responsibility to provide water to populations living in these camps usually lies with international humanitarian organisations, such as the UN Refugee Agency, UNHCR, and their implementing partners.

Access to water has a knock-on impact on most areas of people's lives, such as health, education and importantly income and livelihoods. This spill-over impact is under-acknowledged by the international community seeking to support refugees and displaced people. Although there is recognition that short-term emergency water systems are not sustainable options for refugee populations, especially those living in protracted crisis for many years, little research has been done to engage with community-based approaches as an alternative or a complimentary solution.

The UN Refugee Agency's annual Global Trends Study found that 65.6 million people (UNHCR, 2016) were forcibly displaced worldwide at the end of 2016 – a total bigger than the population of the United Kingdom and about 300,000 more than last year. This number is higher than we have seen since the Second World War. Given the growing number of refugees, we need not only to focus on solutions for emergency crises, but also how to support sustainable solutions to inclusive water services for those in protracted exile. Research to better understand these grassroots initiatives and systems will be essential for rethinking how we can improve water security for current and future refugees.

Human rights and development are closely interconnected, share a number of characteristics and, thus, present an inseparable topic. The SDGs and human rights provide tools to hold governments accountable and help societies to develop in a better way. There are periodic national and international reporting processes for each. However, the international and national framework for SDG is more extensive and interlink with each other. The 2030 Sustainable Development agenda includes 17 targets with 169 indicators. Although the indicators could potentially relate to the global scale, it is still the national government's responsibility to develop indicators at the national and regional scales, according to their needs and vision. Unfortunately, this side lines issues of transboundary and global environmental challenges that directly impact peace, prosperity, human security, and equity within the borders of states.
Due to the indivisible nature of the SDGs, and because most water-related challenges know no borders, more attention must be paid to transboundary solutions.

5.2. Transboundary Water

There are approximately 276 transboundary river basins on the planet, covering a geographical area corresponding to almost half of the earth's surface and 60% of freshwater supplies. Almost three billion people in 145 countries live in these areas. There are also approximately 600 aquifers shared by 2 or more countries (UNECE & UNESCO, 2015).
These physical realities, together with the need for equitable and sustainable use of these transboundary resources, enhance the need for cooperation between people, groups, and states. However, the challenges of climate change, population growth, economic development and urbanization are straining the world's water resources and are exacerbating existing political tensions over transboundary water management.

Water Diplomacy is very much needed for developing the water resources to build cooperation between sharing countries. This demands political commitment to supporting and advancing technology for the collection and analysis of hydrological data, as well as cooperation on projects with a focus on human security to avoid disputes and conflict and to achieve security.

5.2.1. Water Scarcity and International Security: An Ambiguous Issue

Much of the debate over transboundary water surrounds the use of the word 'war'. This can be defined in multiple ways and each definition influences one's view of history and the future. With a broader definition of war, one can find many historical examples. Between 1948 and 1999 there were 507 conflictive events in which water was the main issue at stake (Giordano *et al.*, 2002).

Others, who employ a much narrower definition of war see no historical precedents for water wars, save for one example 4,500 years ago (Wolf, 1999). Environmental activist Vandana Shiva defines war not only as violent conflicts but as clashes between paradigms, a phenomenon she sees every day and throughout the world (Shiva, 2002).

The debate over water scarcity and conflict goes far beyond this dispute over semantics. Political scientists and experts each view the problem with different definitions of water scarcity, different perspectives on security, and different interpretations of history. For example, an international development expert claimed that we don't have a scarcity problem on the global scale, albeit in direct contradiction with the data supplied by the United Nations and scientific communities.

5.2.2. Are Water Wars the Next Major Challenge to International Security?

As stated above, there is no single definition of 'war' that can be used in discussions of the prevalence of water wars.
This makes it difficult to evaluate their impact on international security in the twenty-first century. As an aid, the idea of

water wars can be broken down into three general categories: international water wars, international water conflicts, and localized water conflicts. For the purposes of this essay, the difference between international water wars and conflicts lies in the size and subject. A war is violence between two established entities on a larger scale than a conflict; a conflict can, but does not have to, include violence. A water war is almost solely based on water, whereas a conflict has many causes (Stafford, 2012).

Those who insist that international water wars will be the oil wars of the next century argue this theory because water is a crucial and dwindling resource, more important to human life than oil. Leaders such as Egypt's Sadat and Jordan's Hussein have reinforced the importance of water by stating that the only reason they would go to war would be over their water resources. From a theoretical perspective, the threat of water wars is clear: as water gains value and becomes increasingly scarce, conflict over the resource will inevitably increase. The problem with this is that water has so many facets. No longer just a natural resource, water is political, social, and economic.

> *"As an aid, the idea of water wars can be broken down into three general categories: international water wars, international water conflicts, and localized water conflicts."*

Another line of reasoning against the threat of water wars lies in the strategies of waging war over water. "War over water seems neither strategically rational, hydrographically effective, nor economically viable" (Wolf, 1999). The aggressive nation would have to be both downstream, thus on the receiving end of any pollution or reduced upstream flow, and the regional hegemon so that they are strong enough to sustain the war.
The upstream response to downstream aggression would likely compromise water quantity or quality for the downstream nation. At this point the downstream nation would have to weigh the costs of waging this war against the benefits: to destroy a dam or water treatment plant would impact the water quality and environment of the downstream nation more than the upstream one, while an invasion would have to include an occupation of the watershed to prevent retribution.
"It is hard to 'win' the water unless you take over territory—usually a costly exercise." To this end, the likelihood of war, an organized and prolonged conflict, over water seems unlikely (Sullivan, 2009).

5.2.3. The Future of International Conflicts over Water

It is well established that the link between water scarcity and international security is hotly debated. The threat of water wars is a bit overstated, but the threat of international conflicts driven in part by water is not a threat, but a reality. There is little or no historical precedent for water wars, but there are many instances of intrastate and interstate conflict and violence. Twenty-eight percent of tensions over water have been conflictive (Coskun, 2007). NATO has found that "water resources is an issue that reflects a link between environmental degradation and the outbreak of conflicts."

As water quantity (and quality) decreases in a region, the stability of the area decreases as well. This is due to the many facets of water: its effects on economics, society, health, and politics. The Gaza Strip is an excellent example of this interconnected relationship. The region was under either Israeli occupation or control for a long period, over which the water quality decreased, wells were contaminated by salt water, and public health suffered from an influx of water-related diseases. Palestine retaliated against Israel in the 1987 Intifada throughout the Gaza Strip and West Bank (Wolf, 1999). This can also be seen in the relationship between India and Bangladesh, two countries with internal instabilities and international upstream-downstream problems. The drying up of Lake Chad can, at least to a certain extent, be linked to the rise of Boko Haram. In Syria, the misuse of the Tigris and Euphrates River was a component of the development of the conflict there. More than 1,400 new dams or water diversion projects are planned or already under construction and many of them are on rivers flowing through multiple nations, fuelling the potential for increased water conflict between some countries (Oregon State University, 2017).

A new analysis commissioned by the United Nations in 2013 uses a comprehensive combination of social, economic, political and environmental factors to identify areas around the world most at-risk for 'hydro-political' strife. This river basins study was part of the UN's Transboundary Waters Assessment Program. Researchers from the United States, Spain and Chile took part in the analysis (De Stefano *et al.*, 2017), which has been recommended by the UN Economic Commission for Europe as an indicator for the UN's Sustainable Development Goals for water cooperation. Results of the study have just been published in the journal Global Environment Change.

The analysis suggests that risks of conflict are projected to increase over the next 15 to 30 years in four hotspot regions: The Middle East, Central Asia, the Ganges-Brahmaputra-Meghna Basin, and the Orange and Limpopo Basins in southern Africa.

Additionally, the Nile River in Africa, much of southern Asia, the Balkans in south-eastern Europe, and upper South America are all areas where new dams are under construction and neighbouring countries face increasing water demand, may lack workable treaties, or worse, haven't even discussed the issue. Indeed, "if two countries have agreed on water flow and distribution when there's a dam upstream, there usually is no conflict," said Eric Sproles, an Oregon State University hydrologist and a co-author of the study.
"Such is the case with the Columbia River Basin between the United States and Canada, whose treaty is recognized as one

"Cooperation over water is up to two times more likely than armed conflict."

of the most resilient and advanced agreements in the world. Unfortunately, that isn't the case with many other river systems, where a variety of factors come into play, including strong nationalism, political contentiousness, and drought or shifting climate conditions."

The conflict over water isn't restricted to human consumption, the researchers say. There is a global threat to biodiversity in many of the world's river systems, and the risk of species extinction is moderate to very high in 70 percent of transboundary river basins.

Asia has the highest number of dams proposed or under construction on transboundary basins of any continent with 807, followed by South America, 354; Europe, 148; Africa, 99; and North America, 8. But Africa has a higher level of hydro-political tension, the researchers say, with more exacerbating factors (De Stefano *et al.*, 2017).

The Nile River, for example, is one of the more contentious areas of the globe. Ethiopia is constructing several dams on tributaries of the Nile in its uplands, which will divert water from countries downstream, including Egypt. Contributing to the tension is drought and a growing population more dependent on a water source that may be diminishing.

"When you look at a region, the first thing you try to identify is whether there is a treaty and, if so, is it one that works for all parties and is flexible enough to withstand change," Sproles said. "It's easy to plan for water if it is the same every year—sometimes even when it's low. When conditions vary—and drought is a key factor—the tension tends to increase and conflict is more likely to occur."

In addition to environmental variability and lack of treaties, other factors leading to conflict include political and economic instability, and armed conflict, the analysis shows.

Sproles said one reason the Columbia River Basin treaty between the U.S. and Canada has worked well is the relative stability of the water supply. In contrast, climate models suggest that the Orinoco River Basin in northern Brazil and the Amazon Basin in upper South America may face drier conditions, which could lead to more strife.

Refugees and forced migrants add another dimension to the question of water-related international conflicts. Refugees fleeing conflicts and climate change move into neighbouring states that generally suffer from the same environmental problems as the home state.

Refugees put additional pressure on the natural resources of their asylum countries and this especially affects water resources. It is a vicious cycle: regional armed conflict results in groups of refugees who create water scarcity in neighbouring asylum states and this water scarcity can lead to further conflict and more refugees. Eritrean refugees in Sudan increased by thirty percent in 2006; there is arguably no state in the world prepared to cope with an annual water demand increase of thirty percent. The refugee element underscores the notion that the mismatch between the population and available water is a key spark for conflict.

Water can also create localized water conflicts through its ability to marginalize and thus its (disputed) potential to attract conflict with radical groups. Anger over water management and marginalization can combine with other volatile issues to provide recruiting tools for extremist groups, a fact recently recognized by the United States Pentagon. Water has the potential to become a commodity throughout the world, but in regions suffering from water scarcity and internal insecurity it can, if commoditized, be used as another recruiting tool for these radical groups (by restricting access or availability) or as "an instrument with which one population group can suppress another" (Arsenault, 2011).

Localized, regional discontent with water scarcity can also create targets for these radical groups. Water infrastructure such as dams, dykes, sewers, and treatment plants are all valid targets for those who wish to show their discontent with the management of their local natural resources.

Disagreements over the use of the word 'war' notwithstanding, water does and will contribute to conflicts and thus pose a challenge to international security. Looking to the future, however, it seems unlikely that water will be a sole driver of conflict. NATO (2007) puts it as such, "Water-related tensions between countries often stem from reasons such as high population density, low per capita income, unfriendly relations, minority groups who internationalize the issue of water scarcity, implementation of large water development projects, and limitations of fresh water treaties."

It cannot be emphasized enough that water is now integrated into all facets of life and so its impact on local, regional, and international security is suitably intertwined with other contentious issues.

5.2.4. Cooperation over Water as a Solution from the Past and for the Future

Yet there is a large contingent of scientists and political researchers who argue that cooperation over water is and will be an even more prevalent phenomenon than conflict. "Water could emerge as a potential source of conflict. But it could also emerge as a potential source of economic growth and co-operation between these countries" (Waslekar, 2012).

History supports this view. Between 1948 and 1999 there were 1,831 water-related events, of which 1,228 (67%) were cooperative (Sullivan, 2009). Cooperation over water is up to two times more likely than armed conflict. India and Pakistan often experience bilateral conflicts, but the two states have "demonstrated a remarkable ability to separate water issues from larger conflicts between the two countries," maintaining stable water relations since the creation of the 1960 Indus Water Treaty. Many of those who argue that water is more likely to foster cooperation than conflict base their arguments on the same fact as those who predict war: water is a vital natural resource.

The same water interdependencies among the world's 263 transboundary rivers that often make water a matter of high politics can also lead states to find ways to avoid conflict and de facto, if not proactively, cooperate with one another. The fact that environmental, economic, political and security systems depend so heavily on this resource, which fluctuates over space and time, emphasizes the need for long-term, iterated coordination or cooperation (Bencala *et al.*, 2008).

States cannot afford to lose access to this resource, and this need to fulfil their self-interests drives their appetite for cooperation. Also, contributing to the growth of water cooperation are non-profits and other organizations that believe "a war for water is easily averted" through mediation, mitigation, and amelioration. The Global Institute for Water, Environment, and Health (GIWEH) uses water along with energy as tools for development and cooperation in Africa's Great Lakes region. GIWEH is so dedicated to the idea of water cooperation that they do not even speak about conflict; they maintain that, "water could be a source of war... but it could also be a source of cooperation and peace." To create this cooperation, organizations like GIWEH are using mitigation to overcome the political, social, and economic factors associated with water. It is difficult to change mindsets about such a staple as water, but this is the only way that cooperation can be created. Mitigation and "water dispute amelioration [are] as important, more effective, and less costly than conflict resolution." Once states or organizations establish cooperative water regimes, they are very resilient. The 1960 Indus Water Treaty is one such example.

The 1960 treaty and historical patterns prove that cooperation over water is a reality that can, will, and should continue into the future. Water scarcity is so intertwined with the most important issues of our day—politics, economics, health, society, geography—that the prevalence and threat of conflicts over it should force us to re-evaluate the interactions between humans and their environment. Dealing with water quantity, quality, availability, and access can improve public health, boost agriculture, potentially decrease the number of climate change refugees, end the proliferation of terrorist and radical groups, provide less incentive for volatile regions and neighbouring states to engage in conflicts, and most of all ensure human security. It still remains difficult to analyse the water and security situation of the present, let alone to project far into the twenty-first century. As the environment continues to change and the world becomes ever more integrated, undoubtedly elements of the analyses presented here will become obsolete. Yet one can hope that cooperation and mitigation begun today will prevent water scarcity from spiralling into future wars.

5.3. Good Practices: Managing Water Security: Putting Best Practices into Action

Given the heterogeneity and urgency of the problem, new multidisciplinary and multi-level approaches are needed to secure water to meet future needs. All stakeholders (include governments, academia, experts, private sector, farmers, women, civil society, NGOs and international organizations) are requested to act immediately by calling for the empowerment of networks between local communities and water actors at the micro and macro levels. An exchange of knowledge and expertise can represent a productive option for the management of the water-food-energy nexus and health. The water-energy-food (WEF) nexus is increasingly recognised as a conceptual framework able to support the efficient implementation of the Sustainable Development Goals (SDGs).

At the same time, it is clear that the role of science and expertise cannot be denied and underestimated. The positive outcomes of the integration of traditional knowledge and practices with recent technology and scientific knowledge are promising and essential.

Good practices in irrigation, drawn from the experience of local farmers, traditional knowledge obtained through a nature-based solutions approach, rural development, and local experiences constitute good models and practices for water security.

5.3.1. The Importance of the Local Level

Local knowledge represents a promising starting point for action. It is difficult to identify a single solution for all problems. We cannot expect to find panacea or a single model applicable and immediately transferable to any situation. However, it is possible to identify some broad areas from which solutions should emanate. It will then be for actors to choose which options are most suitable for their specific contexts. Such areas could involve:

- Increasing resource productivity,
- Using waste as a resource in multi-use systems; stimulating development through economic incentives,
- Governance, institutions and policy,
- Benefiting from productive ecosystems,
- Integrated poverty alleviation and green growth; capacity building and awareness raising,
- Smart Water Management & Open Data,
- Natural Resource Management and the Circular Economy. (Hoff, 2011)

Many organizations, agencies and researchers underline the importance of observing agricultural production and water management through a local lens. "Food scarcity manifests itself locally, so efforts to alleviate it must be tailored to the local circumstances. To do otherwise is akin to doctoring a sick person on the basis of global health statistics" (Daily *et al.*, 1998). It is generally accepted that the correct level of action to reduce the dysfunctions of the food-water nexus is the local one. For instance, the household should receive more recognition as a fundamental centre for decision-making regarding numerous elements, including the management of local natural resources.

At the same time, it is obvious that households cannot be understood as isolated, and when taking them into consideration further contextualization is required. The local level should be seen as a starting point that needs to be up scaled and connected both horizontally with other local bodies and vertically with national, regional and global institutions. "Threats to environmental security very often come allied to institutional failure. Thus, when thinking about environmental security, particular attention needs to be given to the institutions in which individuals, households, firms, and communities go about their business" (ibid.).

This is an approach that is beginning to gain traction. For instance, the contributions of farmers to the irrigation sector have historically been greatly undervalued. But now some organizations have begun to recognize that small farmers have the willingness to invest and ameliorate the irrigation systems of their farms. Most of the irrigated area in South Asia, for instance, depends on privately owned and managed wells. Local farmers in fragile areas have developed and implemented extensive adaptation strategies that have enabled them to reduce vulnerability to climate variability over the years. Without the incorporation of local knowledge, some authors contend that environmental science and planning remain limited (Tomaselli, 2014). Coping with climate variability and managing the water-food nexus thanks to local knowledge and modern science has much potential but currently lacks commitment and caution.

In light of the above, it is important to take action and work for the promotion of irrigation solutions and technologies that are suitable for smallholders. But some of the difficulties here are for instance related to market inefficiencies which would require an intervention from the state in order to regulate the issue. Besides, extremely important in this sense is the transfer of knowledge and the fact that all farmers, men and women should have access to information regarding techniques and practices (Jägerskog & Jønch Clausen, 2012).

> *"Local governments have played, and continue to play, a major role in their achievement—often the primary role."*

5.3.2. New Tools for Local and Regional Authorities

The Daegu-Gyeongbuk Water Action for Sustainable Cities and Regions (2015), is a roadmap which provides concrete tools to guide Local and Regional Authorities (LRAs) in the implementation of sustainable water management strategies at the local level. The LRAs process collaborated in the development of a strategy document for action in cities. Endorsed by 95 Local and Regional Authorities from 26 countries, the document differentiates between two different levels: building strategies for local and regional authorities to improve management, and soliciting national governments to help create enabling environments for the achievement of national and global goals.

Among the many issues raised in the document, it highlights the importance of local authorities' roles in implementing and achieving the Sustainable Development Goals and how best to deliver their share of responsibilities in the most effective and efficient way.

Most of the SDGs depend directly or indirectly on the provision of infrastructure and services with a focus on local communities; most infrastructure and services depend to a greater or lesser degree on local governments doing their job. All development interventions are local in the sense that they play out through the provision of some good or service to individuals and communities in a particular location. Their implementation depends on local institutions—utility companies, solid-waste collection services, schools, day-care centres, health-care centres, public transport systems, police stations, etc. Even where interventions are the responsibility of national ministries, or are delivered through private enterprises or international NGOs, the ease and effectiveness with which they are delivered can be greatly enhanced by local government support. The SDGs are most likely to be met where local governments have the competence and capacity to fulfil their responsibilities, and where their residents are equipped to make demands for accountability and transparency, especially those residents whose MDG needs have not yet been met. This is even more the case if local government is taken to include all sub-national government levels. It is too easy to forget the key roles that local government has played in achieving routinely accepted standards in what are today's high-income nations—often with the support of national governments.

Local governments have played, and continue to play, a major role in their achievement—often the primary role. This can be seen in their wide range of responsibilities for the provision, maintenance—and where needed—expansion of infrastructure and services, usually including the provision of water, sanitation, drainage, streets, emergency services, parks and public spaces. Their responsibilities often extend to health care services and schools (although usually with the national government). Thus, local governments play key roles in ensuring health and safety—for instance through building standards, land-use planning and management and environmental, occupational and public health services. They have good knowledge and experience in dealing with disaster prevention and preparedness as well as contributing to public security issues. Good local governance is also central to democratic participation, civic dialogue, economic success and facilitating outcomes that enrich the quality of life of residents.

5.3.3. Examples of Good Practices: Measures are Taken at Different Levels

Once water risks have been identified, they need to be well managed. There is an urgent demand for managing water effectively and efficiently. Identifying good practices is key to finding solutions to diverse water-related issues around the globe, by learning from others and disseminating the knowledge and information. We consider that good practices are those that have substantially contributed to the improvement of the living environment on a sustainable basis, especially to the living conditions of the poorest and most disadvantaged groups of society, and demonstrate a positive impact. Possible impacts to be considered include, but are not limited to:

- Improvement in health;
- Improvements in disaster prevention, preparedness and mitigation;
- More effective and efficient administrative, management and information systems;
- Social integration and the reduction of exclusion within the community;
- Gender equality and equity in decision-making, resource-allocation and programme design and implementation;
- Community participation in decision-making and resource allocation.

5.3.3.1. Smart Water Management & New Technologies

Drinking water, irrigated agriculture, fisheries, recreation, hydropower, industrial cooling, navigation and more: water serves a myriad of uses in today's society. Managing the trade-offs among these uses and, at the same time, ensuring that sufficient water is available to support the environment requires a steady flow of reliable and accessible data and innovative technologies.

Today, water-related data such as precipitation, river flows, lake and groundwater levels, water quality, and so on, are collected by a multitude of agencies and organizations around the world, at a rate that is unprecedented in human history. These complex data sets allow researchers to track and observe water across scales and timeframes, making it possible to reconstruct and understand environmental processes such as changes in rainfall patterns or surface water temperatures. Data from satellites provide information on groundwater levels, allowing researchers to identify potential challenges for people and ecosystems.
Satellite data are also beginning to be used to assess water quality across large areas, with frequent measurements from space meaning that sudden changes in water quality can be identified more quickly than when relying on on-the-ground sampling.
In developing regions, satellite data is providing increasingly fine readings on water level, water quality and other data. As Hering (2014) notes, "satellite-based data also offers a 'leapfrog' technology for developing countries that lack an established ground-based monitoring network."

In all regions, Open Data plays a critical role in meeting 21st century water challenges. Aggregating this diverse Open Data can provide a "big picture" of competing and interdependent water needs.

From new desalination and wastewater treatment techniques to air-to-water distillation systems, science and technology are driving many of today's innovative new approaches to securing and preserving freshwater resources. One technical innovation in particular, the burgeoning Internet of Things (IoT), has already begun to play an important role in smarter water management. In IoT-enabled smart water systems, a wide array of sensors is deployed throughout the water infrastructure, and connected via wireless networks.
These sensors can measure volume, flow, temperature, pressure, vibrations, humidity levels, and more. Sensors are likewise embedded in networked "smart meters" deployed in homes and businesses. These multi-purpose meters and infrastructure sensors effectively constitute the "nervous system" of water networks. They can send vital information back to central systems for real-time monitoring, analysis and control of water systems. Or, if sensor devices are equipped with advanced computer chips and control systems, they can collect and act on information autonomously, for instance by automatically shutting off water flow and sounding an alert if a leak or burst is detected.

The remote, real-time detection of leaks and bursts is one of the prime benefits of smart water networks. The rapid response it enables reduces water loss and repair costs, and reduces the amount of energy and money wasted purifying lost water. Worldwide, the UN finds that one-third of reporting countries lose more than 40% of the clean water pumped into their distribution systems, with India having the highest non-revenue water (NRW) loss at 60%. In addition to cutting NRW losses, other smart water technology advantages include:

- Reducing labour costs associated with manual meter reading.
- Conserving water and reducing costs by analysing usage and dynamically adapting supply to demand, or providing sufficient awareness and pricing mechanisms to entice consumers to do so on their own.
- Continuously monitoring water quality and responding early to what can become highly damaging and costly problems.

These are all important benefits, but stemming NRW losses through leak detection and accurate metering is the benefit with the largest and most immediate bottom line impact. While all benefits include conserving funds that can be redirected towards pressing infrastructure needs, leak detection and smart metering in particular offer deep cost savings plus a unique way to phase in upgrades.

A. Smart Technology in India

The National Rural Drinking Water Program (NRDWP) in India, which supplements the efforts of the State Governments by providing technical and financial assistance, is looking at rural drinking water from a holistic viewpoint. The Ministry has shifted its focus from hand pumps to piped water supply systems with the aim of providing monitored clean water, with a focus on those States which suffer from low levels of piped water supply. The Water and Sanitation Program has compiled an excellent collection of success stories and best practices from the States of Kerala, Karnataka, Maharashtra, Gujarat, Jharkhand, Punjab and Uttarakhand. Some of these success stories, such as the Asoga village intervention in Karnataka which showcases a unique demand-driven approach to facilitate participatory decision-making leading to community ownership, the Bidholi piped water supply scheme in Uttarakhand which manages and recovers 100 per cent operation and maintenance costs from the community, the Shikayat Nivaran Kendra experiment in Punjab which uses information technology for online web enabled centralised complaint redressal and the Water and Sanitation Management Organisation experiment in Gujarat where the registered body acts as a facilitator in developing water and sanitation facilities owned and managed by communities, are all outstanding examples of how to address various challenges and shortcomings the program is facing (Water and Sanitation Program & Ministry of Drinking Water and Sanitation of India, 2015).

B. Singapore's Robotic Swans Testing Water Quality

Singapore's Public Utilities Board (PUB) has created the Smart Water Assessment Network (SWAN) to monitor water quality in the five reservoirs of Marina, Punggol, Serangoon, Pandan, and Kranji. In the past, water sampling was conducted manually and through stationary online water quality profiler stations that continuously monitored basic water quality.

SWAN complements this process by automating the process of monitoring raw water quality in real-time and in hard-to-reach locations, with each SWAN collecting pH, conductivity, chlorophyll levels, and turbidity. To ensure the robot does not disturb the natural environment while collecting the data, designers from PUB and the National University of Singapore's Environmental Research Institute and Tropical Marine Science Institute came up with the swan design.

Each SWAN is fitted with a water quality sampler and water quality profiler to monitor water in real-time with data sent back to PUB live. The SWANs also have an inbuilt camera to capture photos of the water surface. With this range of technology, the robots can work autonomously, only requiring basic monitoring and operational maintenance, freeing up resources to perform other tasks (Brears, 2017).

5.3.3.2. New Water

The world's population is projected to increase by 2 to 3 billion people over the next 40 years. As a consequence, in many parts of the world, changing demand and supply patterns are contributing to the increasing physical scarcity of water and growing competition over water resources. Historically, new demands have been met by developing additional supplies, with the incremental cost of water remaining relatively constant over time due to the ready availability of water development project sites to meet growing demands. New water alternatives are needed to cover the gap between supply and demand; this could be offered through new technologies of wastewater, or desalination or through very advanced filtration systems designing nanometre-scale water filters that could soon make clean drinking water available and affordable for even the poorest of the poor.

A. Wastewater Treatment in Malta

Water is a limited resource in the European Union (EU), with one-third of the EU's territory experiencing water stress. Over the past 30 years, the frequency and intensity of droughts and their environmental and economic damages in the EU have drastically increased. Between 1976 and 2006 the numbers of areas and people affected by droughts increased by 20% and the total costs of droughts amounted to EUR 100 billion. In 2017, summer droughts resulted in the Italian farming sector alone losing EUR 2 billion. This trend is expected to continue in the future, leaving no part of Europe immune.

Malta, a semi-arid country located in the centre of the Mediterranean Sea, is developing a New Water solution to ensure water security. Traditionally, Malta has been challenged in meeting demand for municipal water supply as well as the needs of the agricultural and commercial sectors. To meet demand, Malta has developed sea-water desalination technology over the past two decades which today accounts for around 60% of the municipal water supply.

To further water security, Malta's Water Services Commission has established the New Water program, which involves treated wastewater going through ultrafiltration to remove bacteria, reverse osmosis to remove chemicals, and advanced oxidation to remove remaining pollutants. Each year the program produces 7 million m^3 of high-quality water suitable for safe crop irrigation. This will potentially meet up to 35% of the current total demand of the agricultural sector. In addition, the high-quality water can be used for landscaping and industry, ensuring New Water is fully utilized during periods of low demand by the agricultural sector.

Currently, New Water is available through hydrants, which are accessed by electronic cards. As of 2018, seven hydrants are available in the Northern region of Malta. Moving forward, the program is developing three additional networks to increase the number of hydrants available for water users (Brears, 2017).

B. Singapore - Developing Alternative Water Supplies

Singapore's Public Utilities Board recycles treated, used water into ultra-clean, high-grade reclaimed water: NEWater. In total, five NEWater plants supply up to 40% of the city-state's current water needs. By 2060, it is projected that NEWater will meet up to 55% of Singapore's future water demand. NEWater is created through a three-step process involving microfiltration, where microscopic particles including bacteria are filtered out through reverse osmosis, in which contaminants are removed to create high-grade water, and ultraviolet disinfection, where water passes through ultraviolet light ensuring any remaining organisms are eradicated. Because of its ultra-clean state, NEWater is used for industrial and air-con cooling purposes at water fabrication plants, on industrial estates, and in commercial buildings.

C. Melbourne's City-West Water's Recycled Water Project

In Melbourne, West Wyndham Recycled Water Project aims to deliver high quality, Class A recycled water to housing estates in the Wyndham area, as well as a number of open spaces managed by the Wyndham City Council (Class A recycled water can only be used for toilet flushing, car washing on grassed areas, garden watering, filling water features, providing drinking water for pets, and washing machines). Currently, recycled water—a mix of drinking water and recycled water—is supplied to around 3,750 homes in the area. The ultimate aim of the West Wyndham Recycled Water Project is to create a supply of 100 percent recycled water (Brears, 2017).

In 2016, the West Wyndham Recycled Water Project started supplying high quality recycled water to housing estates in the Wyndham area, as well as a number of open spaces managed by Wyndham City Council.

5.3.3.3. Nature-based Solutions

In 2018 for the first time, Brazil hosted the world launching of the United Nations World Water Development Report, which publicly stated the importance of nature-based solutions (NBS) for water. According to Stefan Uhlenbrook, the Coordinator and Director of the UN World Water Assessment Programme (WWAP), reservoirs, irrigation canals and water treatment plants are not the only water management instruments at our disposal. "We can't wait for nature to solve all problems by itself, but we can get inspired and use it in favor of the planet."

As the name itself suggests, nature-based solutions are those that use or simulate natural processes to address contemporary challenges, including those associated with water management. Its objectives are, for instance, to increase water availability (soil water retention and groundwater recharge are nature-based solutions), to improve water quality (natural and artificial wetlands, and riparian forest buffers), or to reduce water-related disasters and climate change risks (restoration, flood plains and roof gardens). In other words, nature-based solutions are ecological processes driven by vegetation and soil in forests, pastures, humid areas, as well as in agricultural and urban landscapes, which play an important role in water movement, storage and transformation.

> *"Ecosystem-based adaptation strategies offer an opportunity to enhance water security, climate-resilient livelihoods, and social cohesion simultaneously, while also benefiting natural systems."*

Nature-based solutions offer some of the most effective and sustainable ways to improve water security, and they frequently offer additional benefits for communities where they are implemented, including improved agriculture, job creation and climate resilience. It can also play an important role in improving the supply and quality of water and reducing the impact of natural disasters.

A good example is that of the state of Rajasthan in India, which experienced one of the worst droughts in its history in 1986. Over the following years, Tarun Bharat Sangh, an NGO, worked alongside local communities to set up water harvesting structures and regenerate soils and forests in the region. The initiative, a nature-based solution, led to a 30% increase in forest cover, groundwater levels rose by several meters, and cropland productivity improved.

The main point is that the 2018 edition of the United Nations World Water Development Report recognizes water not only as an isolated element, but as an integral part of a complex natural process involving evaporation, precipitation and absorption of water through the soil. The presence and extent of vegetation cover across grasslands, wetlands and forests influences the water cycle and can be the focus for actions to improve the quantity and quality of available water.

"For too long, the world has turned first to human-built, or 'grey', infrastructure to improve water management. In so doing, it has often brushed aside traditional and Indigenous knowledge that embraces greener approaches. Three years into the 2030 Agenda for Sustainable Development, it is time for us to re-examine nature-based solutions (NBS) to help achieve water management objectives", writes Gilbert Houngbo, Chair of UN-Water and President of the International Fund for Agricultural Development (WWAP & UNESCO, 2018). So-called 'green' infrastructure, as opposed to traditional 'grey' infrastructure, focuses on preserving the functions of ecosystems, both natural and built, and environmental engineering rather than civil engineering to improve the management of water resources.
This has multiple applications in agriculture, the greatest consumer of water by far. Green infrastructure can help reduce pressures on land use while limiting pollution, soil erosion and water requirements by contributing to the development of more effective and economic solutions.

A. Examples of Nature-based Solutions Presented at the 8th World Water Forum, Brasilia, 2018

The 8th World Water Forum paid special attention to nature-based solutions as one of the main themes to be highlighted. Here are five brief examples:

1) The System of Rice Intensification, originally introduced in Madagascar, helps restore the hydrological and ecological functioning of soils rather than using new crop varieties or chemical products. It enables savings of 25 to 50% in water requirements and 80 to 90% in seeds while raising paddy output by 25 to 50%, depending on the region in which it is implemented.

2) New York City has used green solutions to protect its three largest river basins since the late. While vegetated walls and roof gardens are perhaps the most recognizable examples, others include measures to recycle and harvest water, water retention hollows to recharge groundwater, and the protection of watersheds that supply urban areas. Disposing of the largest unfiltered water supply in the USA, the city now saves more than US$ 300 million yearly on water treatment and maintenance costs.

3) China recently initiated a project entitled “Sponge City” to improve water availability in urban settlements. By 2020, it will build 16 pilot Sponge Cities across the country. Their goal is to recycle 70% of rainwater through greater soil permeation, retention and storage, water purification and the restoration of adjacent wetlands.

4) Over the past few years, Ukraine has been experimenting with artificial wetlands to filter some pharmaceutical products from wastewater. There is evidence that wetlands alone can remove 20 to 60% of metals in water and trap 80 to 90% of sediment from runoff. Wetlands only cover about 2.6% of the planet but play a disproportionately large role in hydrology. They directly impact water quality by filtering toxic substances from pesticides, industrial and mining discharges.

5) Chile announced measures to protect its coastal wetlands after the tsunami of 2010. This is because wetlands also act as natural barriers that soak up and capture rainwater limiting soil erosion and the impacts of certain natural disasters such as floods (WWAP & UNESCO, 2018).

5.3.3.4. Water Security and Ecosystem-Based Adaptation to Climate Change

Ecosystems deliver a variety of water-related benefits to people. Besides recreational opportunities, they provide fish, timber, fruit, and a variety of other products, as well as water for agriculture, industry, drinking and hygiene. Additionally, ecosystems and their services can help people to cope with the impacts of climate change.
For example, Andean highland ecosystems (paramos) capture and retain water, serving as a flood buffer in the rainy season and a balanced source of water in the dry season. Coastal mangroves and wetlands reduce the impact of flooding or gales on human communities. Considering the importance of ecosystem services for human wellbeing, many development and environmental agencies have turned towards promoting ecosystem-based adaptation strategies to confront the threat to water security and to help people adapt to the adverse effects of climate change (Rodriguez de Francisco *et al.*, 2018).

Many ecosystem-based adaptation projects are implemented within local communities on a relatively small or pilot scale. Yet, next to these communities, powerful economic actors (i.e. large-scale cattle ranchers, real estate developers) pursue activities that frequently reduce the adaptive capacities of communities, for example by draining wetlands or cutting down trees, which increase the risk of floods. Most ecosystem-based adaptation projects entail better environmental protection, meaning reduced access by communities to some ecosystem goods and services (*e.g.* less irrigation water, less wood, land use restrictions) and increased time-demand to keep up adaptive measures (*e.g.* living hedgerows, planting mangroves). Meanwhile, powerful economic actors tend to circumvent environmental protection laws with the use of political power, usually carrying on with destructive practices towards ecosystems. In that sense, the success of ecosystem-based adaptation not only depends on efforts made by the communities themselves but also on environmental law enforcement and on the degree of responsibility that powerful economic agents are willing to accept for these shared-ecosystems (Rodriguez de Francisco *et al.*, 2018).

Ecosystem-based adaptation strategies offer an opportunity to enhance water security, climate-resilient livelihoods, and social cohesion simultaneously, while also benefiting natural systems.

A. Water Harvesting

With some modifications to conventional piped water systems in hilly areas, a new system, called Multiple Use Water Systems (MUWS), was introduced in Nepal in 2003 with the aim of addressing water needs for domestic (drinking, washing and bathing) and productive (irrigation and livestock feeding) purposes.

MUWS are a participatory and integrated approach with a focus on poverty reduction. The gravity-fed MUWS configurations are considered the simplest and most-effective system. In this approach, water from a higher elevated spring source is collected in storage tanks and supplied to downstream communities. Where gravity-fed MUWS are not viable, water pumps—powered by electricity, diesel or kerosene or renewable energy—are common. The MUWS consists of a single or double chambered intake to capture water at the source which is then transferred to the reservoir tanks near settlements through pipelines. The reservoir tank, also known as a storage tank, forms the main structural component of the MUWS. The pipelines distribute water from the reservoir tank to the water outlets. Water outlets are designed to deliver water for end-use application such as domestic use or water application technologies such as micro-irrigation.

Low cost water tank technology such as modified Thai jars and ferro-cement lined tanks can be used as storage tanks for regulated MUWS, in which water from highland spring sources and/or rainwater can be stored where water is scarce.

Nepal is a pioneering country in the field of MUWS planning and implementation. While IDE Nepal initiated MUWS concept in Nepal, a number of organisations such as ICIMOD, the Winrock International, Water Aid, Practical Action Nepal, Nepal Water for Health, Biogas Sector Partnership Nepal, Rural Village Water Resource Management Project, Non-Conventional Irrigation Technology Project/Department of Irrigation and other organisations have promoted the MUWS approach in the country. Most of these installed systems are concentrated in the middle hill districts of the western, mid-western and far-western development regions (Raut *et al.*, 2018).

There are multiple benefits to the MUWS, which ensures water availability and accessibility, enhanced economic opportunity and community involvement. MUWS implementation has increased not only water availability but also water usage for all water needs. The effective tapping of small sources in the hills, enabling irrigation with less water through micro-irrigation technologies, has effectively contributed to increased water supply to small hill communities.

MUWS users in Syangja, Surkhet and Palpa districts have increased water use by approximately 50 per cent for household use and 95 per cent for irrigation.
MUWS interventions have enabled households to grow high value crops for commercial purpose both on season and off-season, greatly enhancing the local economy. With better access to water supply at the household level, MUWS has significantly helped in reducing women's workload from water collection.

The multiple services provided by the system allow users—particularly women—to be involved in productive activities such as horticulture, staple food production, poultry and livestock rearing, and fish farming, with potentially significant livelihood benefits. Prior to MUWS implementation, women were typically involved in agriculture by providing labour with little input in marketing, commercialization and financial decisions. With the adoption of MUWS, there has been a visible reduction in labour burdens for women, who had to travel long distances to fetch water for the household.
This leaves them with ample time to get involve in vegetable production and marketing. Women's involvement in such productive activities generates substantial income, which provides them with not only financial independence but also increased participation in financial decision-making.
In addition, men have also started to assist women in household chores, particularly fetching and managing livestock due to the closeness of taps.

However, there are certain challenges when it comes to MUWS implementation. Although water usage increased after the introduction of MUWS, water shortages still persist during the dry season (March to May) due to the decrease in water availability at the source. Such situations can be overcome by improving the system with additional water storage and water taps. Households also need to limit their productive water use during the dry period so that households get sufficient water for their drinking needs. In order to address these complex and interlinked water challenges, a holistic approach encompassing adaptive management practices and mitigating measures is essential (Raut *et al.*, 2018).

06
Conclusion

The UN Sustainable Development Goals explicitly refer to water in Goal 6, Clean Water and Sanitation, but in fact, water security is fundamental to achieving any kind of sustainable economic and human development. But in the economics of water security, water is usually the vehicle of the value, rather than its source. The infrastructure and institutions established to deliver water when and where it is needed determine how economic and social value are created and distributed.

The World Economic Forum believes "water crises" to be among the most likely and the most impactful global risks of the next decade. Similarly, the US Intelligence Community Assessment of Global Water Security considers that water problems will contribute to destabilising key states and, "when combined with poverty, social tensions, environmental degradation, ineffectual leadership and weak political institutions will contribute to social disruptions that can result in state failure" (WEF, 2016).

"Importantly, the intelligence community also anticipates that many water conflicts will not necessarily take the form of overt violence, but rather will see some states use water to exert leverage over their neighbours" (Michel, 2016).

> *"but in fact, water security is fundamental to achieving any kind of sustainable economic and human development."*

Global water crises are not limited solely to drought, but also include flooding, inadequate access to drinking water and sanitation, water-borne diseases and other challenges. Furthermore, the increasing frequency and severity of extreme weather events continues to place additional pressure on water supplies worldwide.

Water resources management and water governance issues vary widely, but most are common challenges faced by a majority of countries. The key issues can be grouped as:

- Insufficient institutional skills in applying the IWRM approach and adaptation to climate change;
- Insufficient understanding of how policy instruments in water management can affect the economy and growth;
- Limited application of a holistic approach in water policy-making, multi-sector involvement and low coordination of roles and responsibilities;
- Hesitant transboundary cooperation in promoting the sustainable and equitable development of a shared watercourse;
- Unsatisfactory cooperation, joint research actions and knowledge sharing;

To encourage better management and conservation, many countries are sharing responsibilities for water management between several ministries, while engaging water stakeholders at various levels of governance. Consequently, improving relationships between competent authorities and stakeholders at all levels of governments, strengthening democracy and combating poverty remain issues of high priority.

Policymakers must strive to improve and extend cooperative institutions to prioritise the sustainability of water resources and increase human security. Water politics are still politics. Thus, like all politics, it is, in the classic formulation of Harold Lasswell, a matter of who gets what, when, and how.

As environmental problems are increasing across different regions and different scales, there is an urgency to take measures for the protection of the water and to improve legislation and public awareness in this field to find the optimum way to manage, protect and serve our limited water resources, and enforce water pollution control and the protection of water by suggesting remediation alternatives to reduce or control the influence of the contamination. Asia Development Bank suggested 4 factors to manage water security and increase efficiencies in water use (ADB, 2016):

1. Expanding wastewater management and reuse.
2. Embedding integrated water resources management.
3. Expanding knowledge and capacity development.
4. Enhancing partnerships with the private sector.

There are other enabling factors which could support and enhance the water security and human security. For instance:

- Developing new technology, water harvesting, desalination and water treatment.
- Raising the profile of water security on the political and developmental agendas of national governments.
- Including water in security policy planning.
- Involving local populations in the development process and running capacity-building programs at different levels.
- Encouraging investment in and increased collaboration on water management technologies.
- Generating better policies through dialogue, knowledge exchange and communication.
- Improving data quality in order to generate better policies.

In response to the various challenges, a multi-sector water resource planning strategy that promotes the sharing of ideas, expertise, and best practices between sectors with a focus on managing water demand and protecting the environment under the framework of integrated water resources management is needed. The priority areas in which we must encourage innovative thinking are:

- Reducing water-energy nexus pressures
- Reuse—Recycling of wastewater and industrial waste
- Support and enhance the natural infrastructure
- Managing demand

This multi-sector strategy will focus on how to effectively engage customers on the need to conserve water, maximizing the potential outcomes of water demand approaches that include water conservation, using grey water, and installation of water-saving equipment.

The strategy is intended to improve water cooperation by increasing the number of agreements and joint management initiatives throughout the world and to place interstate cooperation on transboundary water high on the global agenda, in addition to developing a platform for cooperation and a tool for strengthening the political voice for peaceful and objective debate on water issues.

To this end, some plans, efforts, limits, regulations must be added and put in place. Some countries have a plan to be put into action in case of crisis. But in a lot of places, plans are elaborated after a crisis point has been reached; these are reactions rather than the products of forethought and foresight. Now, it is time to move into implementation and action, the SDG agenda being both a point of reference and an opportunity for countries and communities to take the action. What plans should be put into place, what laws are necessary, what legal infrastructure exists to provide the backbone of resilience to crises? What projects have to be developed immediately as a basic human need? How to overcome the Millennium Development Agenda's gaps and move toward the SDG?

Water resources are of strategic importance and have contributed to conflict in many regions. We consider that the handling of water resources should be a tool for shared prosperity and peace. Hence, we recommend:

- An increase in international involvement and support to regional development, mainly in the fields of water diplomacy, training, research and data exchange. A standardized approach to data management would also facilitate collaboration between communities within regions.
- The production of non-conventional water resources, such as those available through desalination and wastewater treatment, should be considered a strategic industry and could become a major product for export.
- Industry and business leaders should embrace water sustainability as good business. They should lead this effort within their organizations and integrate water sustainability principles and goals into their business plans. Sustainable business growth in Asia, Africa and the MENA region cannot be achieved without the successful implementation of water sustainability.
- Academia and other community leaders should play a leading role in increasing community awareness of water sustainability.
- The media has a critical role to play in raising the awareness of the public at large. A fair, independent media could serve as a watchdog or early-warning system of abuse or misuse of limited freshwater supplies or unsustainable management practices.

International security is not a clean, precise field of study and analysis. It evolves alongside the convolutions of international and regional politics and as new factors become increasingly—or decreasingly—important in the affairs of humanity. Among these, however, one factor remains constant: the importance of water to life means that providing for water needs and demands will never be free of politics. As social and political systems change and evolve, the chronology and categories will change and evolve as well. Water security, as all security issues, is a matter of good leadership and commitment. Leadership plays an important role in performance and productivity. A leader sets a clear vision for the organization, motivates employees, guiding through the work process and builds morale. Without good leadership, security can never be achieved.

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Water Security and Technology

2

Smart Water Solutions for Water Security: From Concept to Operational Implementation

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Abstract

The water security concept encapsulates complex and interconnected challenges and highlights water's centrality for achieving a sense of security, sustainability, development and human well being, from the local to the international level. In the coming years the new technologies from the IT sector will affect the full water cycle and the management of the water related services. This evolution will contribute significantly to support the concept of water security. Technologies will play a pivotal role in achieving the Sustainable Development Goal 6 (SDG). The development of smart water solutions represent an opportunity if the implementation is carried out according the exposed methodology allowing to identified key business processes. The identification of the added value of each smart solution has to be established and validated before operational implementation in order to ensure sustainability and increase efficiency in water management. If this perspective represents a clear benefit both for natural and manmade environments, it requests the development of a coherent vision based on a process allowing to integrate the fragmented activities developed until now in the water sector. The Information and Communications Technology (ICT) solutions will allow this integration process but they have to be coordinated under guidelines and standards that have to be jointly defined by the various actors of the water sectors. The analysis of the domains and of the business processes demonstrates the need for a consistent and standardized water Information System able to integrate within the one of cities that covers all the functions and services like energy, transport, communication and safety.
The Water Information System should provide relevant details in real-time to water professionals and decision makers. The development of Decision Support Systems (DSS) represents a major trend that requests comprehensive data architecture and the possibility to integrate models able to run in real time. The interest of Automated Meter Reading (AMR) technology is today demonstrated globally, for both developing and developed countries. AMR represents a consistent solution to support water security components. In addition, smart water solutions may have a relevant contribution in the agricultural domain with the smart irrigation solutions.
The smart water solutions are based on numerous methods and tools that could, under a consistent vision, contribute to build an efficient water management system targeting the objectives of the water security. However, this approach requests effort in order to properly identified the real added values and the main priorities where smart water solutions can bring major improvements. The suggested approach can be elaborated only within a consensus and collaborative multidisciplinary process that brings together experts, decision makers and users. The capacity to promote this new inclusive approach will drive the spread of the smart water solutions and highly contribute to implement efficient water management matching water security objectives.

Keywords

Smart water, water security, information system, real time, smart metering, smart agriculture, water efficiency, Sustainable Development Goal (SDG) 6, Automated Meter Reading (AMR), Information and Communication Technology (ICT), Decision Support System (DSS)

01

Introduction

The water security concept encapsulates complex and interconnected challenges and highlights water's centrality for achieving a sense of security, sustainability, development and human well being, from the local to the international level. Many factors contribute to water security and range from biophysical to infrastructural, institutional, political, social and financial—many of which lie outside the water realm. Addressing water security requires interdisciplinary collaboration across sectors, communities and political borders in order to manage potential for competition or conflicts.

Obviously, in the coming years the new technologies from the IT sector will affect the full water cycle and the management of the water related services. This evolution will contribute significantly to support the concept of water security. Technologies will play a pivotal role in achieving the Sustainable Development Goal (SDG) 6 dedicated to the availability and sustainable management of water and sanitation for all by 2030.

If the concepts of water security and smart water are more and more frequently mentioned in publications and actions plans, clear definitions are needed in order to ensure a proper implementation. The perimeter of each concept has to be identified as well as the relevant technical solutions able to provide an added value. The smart solutions should be defined in order to bring sustainability in various water uses, ensure protection of the natural environment and mitigate as much as possible natural hazards water related.
This approach requests a clear and robust methodology that could be deployed widely.

"The term water security captures the dynamic dimensions of water and water-related issues and offers a holistic outlook for addressing water challenges."

02

Water Security: Concept Definition

UN Water has published in 2013 a first definition for the water security concept: "Water security is defined here as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."
This definition of water security is based on the one provided in UNESCO's International Hydrological Programme's (IHP) Strategic Plan of the Eighth Phase (UNESCO-IHP, 2012a), endorsed at the 20th Session of the UNESCO-IHP Intergovernmental Council (UNESCO-IHP, 2012b: Resolution XX-5). Within this definition, human well being includes multiple constituents, such as basic material for a good life, freedom of choice and action, health, good social relations, and security (Alcamo, 2003). This proposed definition implies that water is managed sustainably throughout the water cycle and is done so through an inter-disciplinary focus, so that it contributes to socio-economic development and reinforces societal resilience to environmental impacts and water-borne diseases without compromising the present and future health of populations and ecosystems.

Achieving water security requires allocation among users to be fair, efficient and transparent; that water to satisfy basic human needs is accessible to all at an affordable cost to the user; that water throughout the water cycle is collected and treated to prevent pollution and disease; and that fair, accessible and effective mechanisms exist to manage or address disputes or conflicts that may arise. The concept operates at all levels, from individual, household and community, to local, sub-national, national, regional and international settings, and takes into account the variability of water availability over time (UNU-INWEH, 2013).

The discourse on water security in recent years contains a number of common, key elements to water security.
From various published definitions, the core elements necessary to achieving and maintaining water security, can be summarized with the following points:

- Access to safe and sufficient drinking water at an affordable cost in order to meet basic needs, which includes sanitation and hygiene, and the safeguarding of health and well-being;
- Protection of livelihoods, human rights, and cultural and recreational values;
- Preservation and protection of ecosystems in water allocation and management systems in order to maintain their ability to deliver and sustain the functioning of essential ecosystem services;
- Water supplies for socio-economic development and activities (such as energy, transport, industry, tourism);

- Collection and treatment of used water to protect human life and the environment from pollution;
- Collaborative approaches to transboundary water resources management within and between countries to promote freshwater sustainability and cooperation;
- The ability to cope with uncertainties and risks of water-related hazards, such as floods, droughts and pollution, among others; and,
- Good governance and accountability, and the due consideration of the interests of all stakeholders through: appropriate and effective legal regimes; transparent, participatory and accountable institutions; properly planned, operated and maintained infrastructure; and capacity development.

The term water security captures the dynamic dimensions of water and water-related issues and offers a holistic outlook for addressing water challenges. While some definitions of water security have a narrow focus, representing specific interests, many others attempt to capture the various dimensions of the term. Approaching water issues under the umbrella of water security captures most interests in water and offers a means for considering these issues holistically, as many issues are closely interrelated and have multiple causes, impacts, and solutions across sectors.

Water security encapsulates complex and interconnected challenges and highlights water's centrality for achieving a sense of security, sustainability, development and human well-being, from the local to the international level. Many factors contribute to water security and range from biophysical to infrastructural, institutional, political, social and financial—many of which lie outside the water realm. Water security, therefore, lies at the centre of many security areas, each of which is intricately linked to water (Zeitoun, 2011). Addressing water security, therefore, requires interdisciplinary collaboration across sectors, communities and political borders, so that the potential for competition or conflicts over water resources, between sectors and between water users or states, is adequately managed (Wouters *et al.*, 2009).

SDG 6 requests ensuring the availability and sustainable management of water and sanitation for all by 2030 (https://sustainabledevelopment.un.org/sdg6). Technology will play a pivotal role in achieving this ambitious goal, not just in terms of engineering technology in the delivery and maintenance of water and sanitation facilities and systems (such as taps, toilets and pipework), but also in the more extensive use of ICTs in helping to manage water itself—the resource on which sanitation and hygiene depend.

Good governance, based on reliable information gathered by and shared through ICTs, is essential to manage uncertainty and reduce the risks of overexploitation and pollution of water resources and to extend and maintain sanitation systems that are proven to massively reduce the spread of disease. An integrated, data-driven approach to water and sanitation that takes account of the needs of the whole economy and protects the environment is requested in order to achieve the success of the SDGs as a whole.

03

Smart Water Definition

Several projections confirm that 70% of the world's population will live in a city by 2050. Currently, around half of all urban dwellers live in cities with populations between 100,000 and 500,000 people, and almost 10% of urban dwellers live in megacities, which are defined by UN HABITAT as a city with a population of more than 10 million. As cities around the world experience this massive growth, the need to ensure sustainable expansion, efficient operation and development of high quality of life for residents becomes even greater than it is today. Within this context, the smart city concept has emerged. The term "smart cities" is trending amongst governments, urban planners and even the private sector to address the projected demands of cities in the future. Making cities smarter to support growth is emerging as a key area of focus for governments and the private sector alike. This decade, cities around the world will invest US$108 billion in smart city infrastructure, such as smart meters and grids, energy-efficient buildings and data analytics, according to Navigant Research (https://www.navigantresearch.com/reports/smart-water-networks).

Smart cities encompass six important sectors that need to work in unison to achieve a common goal of making a city more liveable, sustainable and efficient for its residents. These sectors are smart energy, smart integration, smart public services, smart mobility, smart buildings, and smart water. Building smart cities upon the six sectors is crucial for sustainable global growth, but the financial, logistical and political challenges are enormous. The conversations about growth of smart cities have historically been dominated by large IT companies that focus on analyzing "big data" taking a top-down, software-centric approach. However, when it comes to the modernization of hundred-year-old systems like water distribution or the power grid, advanced software and networking capabilities are rarely broad enough in scope to make the necessary impact. Conversely, a bottom-up approach to smart city development is based on the belief that the rapid migration to cities will tax municipal infrastructures beyond their breaking points. The cities that succeed in transitioning to "smart" operations will be those that improve their critical systems and infrastructure at a fundamental level as well as integrate their systems through advanced technology. Lastly, smart cities will apply advanced monitoring and analytics to continuously measure and improve performance.

One of a city's most important pieces of critical infrastructure is its water system. With populations in cities growing, it is inevitable that water consumption will grow as well even if the individual use will decrease. The term "smart water" points to water and wastewater infrastructure that ensures this precious resource—and the energy used to transport it—is managed effectively. A smart water system is designed

to gather meaningful and actionable data about the flow, pressure and distribution of a city's water. Further, it is critical that that the consumption and forecasting of water use is accurate. A city's water distribution and management system must be sound and viable in the long term to maintain its growth and should be equipped with the capacity to be monitored and networked with other critical systems to obtain more sophisticated and granular information on how they are performing and affecting each other.
Additional efficiencies are gained when departments are able to share relevant, actionable information. One example is that the watershed management team can automatically share stormwater modelling information which indicates probable flooding zones and times based on predictive precipitation intelligence. The transportation department can then reroute traffic accordingly and pre-emptively alert the population using mass notification.

Water systems are often overlooked yet as critical components of energy management in smart cities, typically comprising 50% of a city's total energy spends. Energy is the largest controllable cost in water/wastewater operations; yet optimizing treatment plants and distribution networks has often been overlooked as a source of freeing up operating funds by cash-strapped municipalities. Once facilities are optimized and designed to gather meaningful and actionable data, municipal leaders can make better and faster decisions about their operations, which can result in up to 30% energy savings and up to 15% reduction of water losses. Water loss management is becoming increasingly important as supplies are stressed by population growth or water scarcity.
Many regions are experiencing record droughts, and others are depleting aquifers faster than they are being replenished. Incorporating smart water technologies allows water providers to minimize non-revenue water (NRW) by finding leaks quickly and even predicatively using real-time SCADA data and comparing that to model network simulations. Reducing NRW also allows municipalities to recover costs incurred in treatment and pumping—this can be significant. A medium-sized city with 450 000 m^3 per day of produced water that loses 25% (not an unusual amount) is incurring over US$13 million per year in non-recoverable labour, chemical and energy expenses.

Obviously, the reduction of NRW contributes to improve the water security of a community. The reduction of NRW is a priority for cities in both developed and developing countries in order to ensure efficient service to population and sustainable use of water resources. In developing context, priority has to be given to SDG 6.

On the wastewater side, there is a move by many water utilities—public and private—to transform wastewater treatment plants into resource recovery facilities, which includes energy. There are several examples of facilities that now produce more energy than required for their operations and sell the excess energy back to the grid. While this is not practical for all treatment plants, it is a worthy ambition for most of the major treatment sites and should be included within the implementation roadmaps or master plans at the national level. However, implementation requests to improve financial capacity of municipalities in order to implement the smart water approach and to contribute to the water security in a global way.

One of the biggest obstacles to any capital-intensive project is access to funding. As cities and municipalities look to achieve smarter water, there are a number of options available to help them get started. One very effective path is through leveraging energy-saving performance contracts (ESPCs). ESPCs are a form of a public-private partnership (PPP), a financial model that capitalizes on the flexibility and resources of the private sector to pay for energy-saving capital upgrades using future energy savings. The private financial community provides the initial investment, and services are delivered by Energy Service COmpanies (ESCOs). The financier is paid from the accrued energy savings, with the ESCO guaranteeing the savings amount. An ESPC starts with an energy audit. After identifying opportunities and quantifying the potential savings, the ESCO recommends any number of energy conservation measures, such as equipment retrofits, pumping optimization, demand monitoring and control, and/or load-shedding and cogeneration which will save energy through more efficient operations.

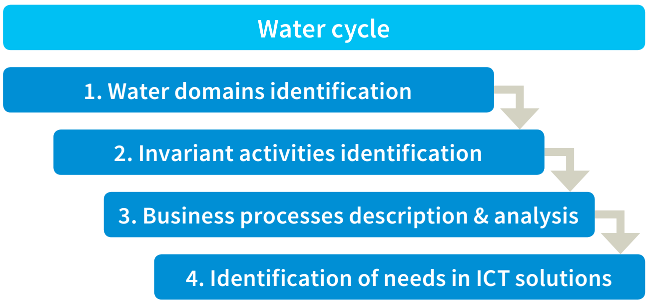

Figure 2-1 General methodology for development of ICT solutions in the water sector (Gourbesville, 2011)

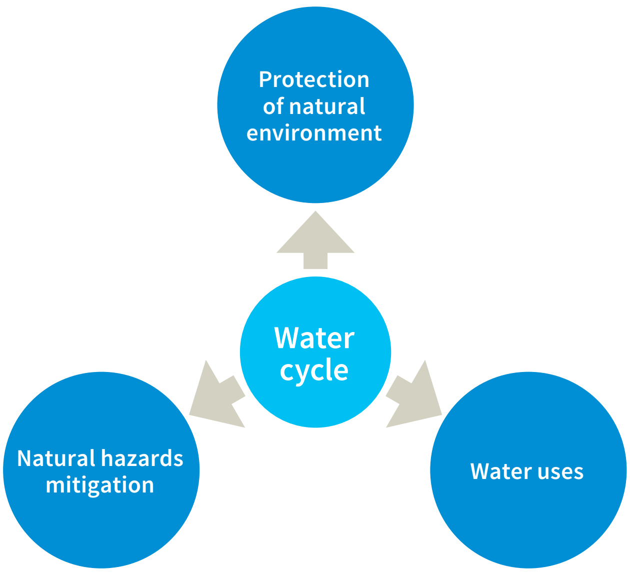

Figure 2-2 Domains of water cycle (Gourbesville, 2011)

04

Methodology for Smart Water Implementation

Obviously, in the coming years the new technologies from the IT sector will affect the full water cycle and the management of the water related services. This evolution will contribute significantly to support the concept of water security. However, the impact of these new technologies—from sensors to Decision Support Systems (DSSs)—could be stronger and really significant if priorities are properly defined and implemented within the R&D strategies. The main driver of the strategy has to be to achieve a comprehensive architecture of an Information System (IS) dedicated to water uses and connected to others systems involved in human activities. This is the operational formulation of the smart water concept.

By definition, Information Systems are implemented within an organization for the purpose of improving the effectiveness and efficiency of that organization (Silver, Markus & Mathis Beath, 1995). Capabilities of the IS and characteristics of the organization, its work systems, its people, and its development and implementation methodologies together determine the extent to which that purpose is achieved. The IS is associated to an architecture which provides a formal definition of the business processes and rules, systems structure, technical framework, and product technologies for a business or organizational information system.

In order to elaborate a specific IS for the management of the water cycle, a methodology is needed for identifying priorities and strategic investments to do in the ICT domain. The requested approach has to investigate all domains and provide a map of the various process taking places in the different domains of the water uses cycle. This formalization exercise, using mainly concepts and processes, is now requested in order to ensure the coherence of technical choices in a holistic approach.

The methodology has to start from the water cycle, to identify the various water domains and the associated activities. The activities can be then defined with business processes that can be analysed regarding the need of ICT solutions. The proposed methodology is summarized on the Figure 2-1.

4.1. Domains of the Water Cycle

The water cycle is frequently defined as the hydrologic cycle that describes the continuous movement of water on, above and below the surface of the Earth. The hydrologic cycle involves the exchange of heat energy, which leads to temperature changes and drives the states of water. The water cycle figures significantly in the maintenance of life and ecosystems.

In order to preserve this essential resource, the concept of Integrated Water Resources Management (IWRM) has been developed (Jønch-Clausen T. & Global Water Partnership (GWP), 2004). The purpose of the approach is to "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." Operationally, IWRM approaches involve applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. As such, IWRM is a comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations. The water security concept complements this initial concept with climate of peace and political stability. In such approach, ICT solutions can play a key role but focus has to be given to the most demanding and relevant domains of the water cycle.

In order to identify which and how ICT solutions can be implemented, it is necessary to look at the water cycle through an approach based on functional domains and business processes. This methodology allows considering each action involved into the resource management and identifying the potential needs of ICT.

The water cycle can be divided into three domains that are associated to specific activities and business processes:

- Protection of natural environment and ecosystems;
- Natural hazards mitigation and disaster prevention;
- Water uses.

The first domain considers all actions needed to assess and advice on the environmental impacts of development proposals and projects related to specific water uses. Results are used by regulatory services. The domain also covers all conservation actions of water related ecosystems.

The second domain is focused on water related natural hazards mitigation actions. Floods, water-borne and vector disease outbreaks, droughts, landslide and avalanche events and famine are the processes covered by this domain. Every year, disasters related to meteorological, hydrological and climate hazards cause significant loss of life, and set back economic and social development by years. The disaster is defined as a serious disruption of the functioning of a community or a society causing widespread human, material, economic and/or environmental losses.

The last domain covers the added influence of human activity on the water cycle. Generally, the water uses refer to use of water by agriculture, industry, energy production and households, including in—stream uses such as fishing, recreation, transportation and waste disposal. All of those uses are directly linked to specific activities and processes that are potential targets for deployment of ICT solutions. In order to stick to the reality of the water management operated by entities in charge of water services, the traditional classification can be reviewed. The main water uses appear then as: agriculture, aquaculture, industry, recreation, transport/navigation, and urban.

4.2. Water Uses, Activities and Business Processes

According to the defined water domains, the water uses represent the largest field where ICT solutions can be developed and implemented. The various uses may be classified and defined as follow.

- **Agriculture**: Irrigation water use is water artificially applied to farm, orchard, pasture, and horticultural crops, as well as water used to irrigate pastures, for frost and freeze protection, chemical application, crop cooling, harvesting, and for the leaching of salts from the crop root zone. In fact, irrigation is the largest category of water use worldwide.
- **Aquaculture**: Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators and so forth. It also implies individual or corporate ownership of the stock being cultivated. This activity uses part of the water bodies in order to develop activities.
- **Industry**: This water use is a valuable resource for such purposes as processing, cleaning, transportation, dilution, and cooling in manufacturing facilities. Major water-using industries include steel, chemical, paper, and petroleum refining. Industries often reuse the same water over and over for more than one purpose.
- **Recreation**: It often involves some degree of exercise as well as visiting areas that contain bodies of water such as parks, wildlife refuges, wilderness areas, public fishing areas, and water parks. Some of the activities that imply the uses of water for this purpose are: fishing, boating, sailing, canoeing, rafting, and swimming, as well as many other recreational activities that depend on water.
  Recreational usage is usually non-consumptive; however recreational irrigation such as gardening or irrigation of golf courses belongs to this category of water use. Besides, recreation and tourism represent a growing sector for industry at the worldwide scale.
- **Energy**: Derived from the force or energy of moving water, which may be harnessed for useful purposes, such as energy production. There are several forms of waterpower currently in use or development. Some are purely mechanical but many primarily generate electricity. Broad categories include: conventional hydroelectric (hydroelectric dams), run-of-the-river hydroelectricity, pumped-storage hydro-electricity and tidal power.
- **Transport/navigation**: It refers to the transport of goods or people using water as a means of transportation. This water use refers only to commercial transport, since recreational transports such as sailing is considered above in Recreation water use.
- **Urban**: Urban water use is generally determined by population, its geographic location, and the percentage of water used in a community by residences, government, and commercial enterprises. It also includes water that cannot be accounted for because of distribution system losses, fire protection, or unauthorized uses. For the past two decades, urban per capita water use has levelled off, or has been increasing. The implementation of local water conservation programs and current housing development trends, have actually lowered per capita water use. However, gross urban water demands continue to grow because of significant population increases and the establishment of urban centres. Even with the implementation of aggressive water conservation programs, urban water demand is expected to grow in conjunction with increases in population. The urban environment is associated to a high dynamic which implies a growing complexity related to number of inhabitants and management of water resources in order to fulfil the needs of population.

> *"The water uses are associated to business processes and are linked to economical and social values."*

The water uses are associated to business processes and are linked to economical and social values. In most of the cases, five major activities are taking place within each water use and appear as invariants. These key activities are: Investigating/surveying, observing/monitoring, designing, building and decommissioning, operating. Each activity could be defined as follow:

- **Investigating/surveying**: Consists in the gathering of information of the previous and actual state and/or working of the domain in study. This assembly of information can be done either by a systematic collection of field data (survey) or a collection of information or data from a methodical research of available documents and/or the production of new ones in order to understand or to improve the actual state of the domain.
- **Observing/monitoring**: From a general point of view, this activity refers to be aware of the state of a system. It describes the processes and activities that need to take place to characterise and monitor the quality and/or state of the domain in study. All monitoring strategies and programmes have reasons and justifications that are often designed to establish the current status of the domain or to establish trends in its parameters. In all cases the results of monitoring will be reviewed and analysed. The design of a monitoring programme must therefore have regard to the final use of the data before monitoring starts.
- **Designing (including risk assessment)**: Refers to the process of devising a system, component, or process to meet desired needs. It is a decision making process (often iterative) in which the basic sciences, risk assessment and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are

the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. In order to obtain a design that achieves the desired needs for the domain in study, the two previous steps should have been accomplished and taken into account.

- **Building & decommissioning**: Consists in carrying out the proposed solution (design) for the domain. In order to execute this design, construction and/or decommission activities may be executed. It is essential a minimal environmental impact when accomplishing these activities. The tolerable environmental impact will be obtained from the risk assessment of the designing step.
- **Operating**: It refers to the action of manoeuvring a system. It may include the combination of all technical and corresponding administrative, managerial, and supervision actions. Operation may also include performing routine actions that keep the system in working order. This latest actions might turn out as response of problems detected during monitoring.

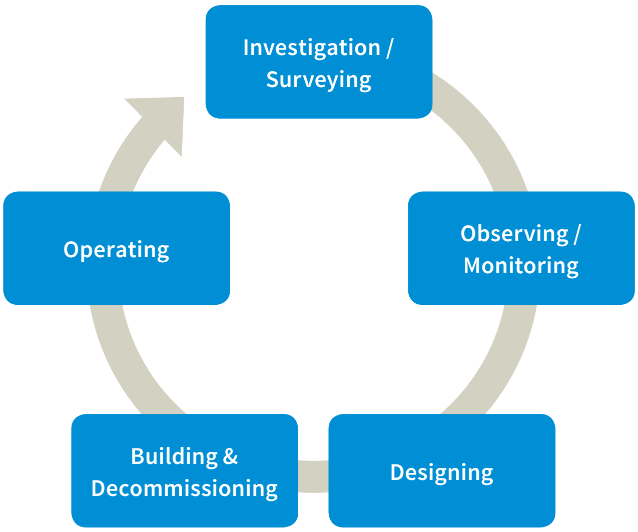

Figure 2-3 Invariant activities taking place in the various domains and water uses (Gourbesville, 2011)

The final step of the approach is dedicated to the identification of the various business processes that are taking place in each activity. A business process is defined as a collection of related, structured activities or tasks that produce a specific service or product (serve a particular goal) for a particular customer or customers. It implies a strong emphasis on how the work is done within an organization, in contrast to a product's focus on what. A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs: a structure for action. Some processes result in a product or service that is received by an organization's external customer. These are called primary processes. Other processes produce products that are invisible to the external customer but essential to the effective management of the business. These ones are called support processes. In keywords, a business process has a goal, has specific inputs and specific outputs, uses resources, has a number of activities that are performed in some order, may affect more than one organizational unit—horizontal organizational impact—and creates value of some kind for the customer. An example of a business process for a water utility can be meter reading. It has to be done in concordance of the billing period. The goal of this process is to give inputs to the billing department, and see the progress of the customer's consumption. Depending on the technology used for the metering (smart or manual metering), different resources (technology, personnel) are used.

The uses in urban environment, carried out by water utilities, can be defined with a limited number of business processes—29 in total—summarized in Table 2-1 and which are covering drinking water, wastewater and storm water management. The final step of the approach is then to identify for each business process how ICT solutions can be implemented and provide added value. This diagnostic has to be shared by professionals and operators in order to ensure a coherent deployment.

No	Process
1	Asset management
2	Crisis management
3	Field intervention management
4	Field works
5	Use of GIS
6	Maintenance of GIS
7	Management of plant maintenance
8	Electro mechanical maintenance
9	Laboratory activity and quality control
10	Illicit trade
11	Real-time network management
12	Planning and design of new assets and plants
13	Water resources management
14	Environment management
15	Drinking water treatment plant management
16	Water primary network management and water balance
17	Water secondary network management
18	Leak detection
19	Meter reading (AMR & MMR)
20	AMR & MMR management
21	Public service contract management
22	Wastewater network management
23	Storm water network management
24	Wastewater treatment plant management
25	Sewer inspection and sewer cleaning
26	Billing
27	Customer care & communication
28	Innovation & pilots
29	Supports

Table 2-1 Business processes for urban uses (Gourbesville, 2013)

05

Identified Priorities for Smart Water Implementation

The water domain—and water stakeholders—is very wide and covers a huge number of business processes especially if all domains and activities are considered. This situation legitimates the mapping process and the prioritization of gaps that need to be bridged. The @qua—Smart solutions for water—association has conducted with the professional representatives from the water sector and utilities an analysis of priorities for the development and implementation of smart solutions (Gourbesville, 2013). Clearly the efforts have to be focused on five major areas directly linked to the urban water use which where both expectations and possibilities are the highest:

A. Real-time Monitoring (major issue for water security improvement)

- Specially real-time networks monitoring including Automated Meter Reading (AMR);
- Installation of leak detectors in the networks;
- Real-time quality management (disinfectant, turbidity, pH, temperature, conductivity, RedOx, etc.);
- Sensors at all Points Of Use (POU);
- Real-time information of customers and stakeholders;
- Related technologies such as Supervisory Control And Data Acquisition (SCADA), GIS, telecommunications, sensors (especially low cost sensors), inverse models, decision support systems.

B. Cities of Tomorrow

- In the current vision, there is an absolute need for generalized and standardized ICT in the operation of the cities of the future, or sustainable cities, or water-sensitive cities;
- Cascading usages of water (incl. re-use and recycling), rainwater harvesting, storm water management, desalination, managed aquifer recharge, micro treatment plants, etc. are the core techniques of the cities of the future. These techniques need a very high level of monitoring and thus, a sophisticated density of ICT;
- Leakage reduction in distribution networks;
- Improving water efficiency in cities.

C. Asset Management and Field Work Management (major issue for water security improvement)

- In-pipe and "through road" condition assessment sensing technologies;
- Continuous performance, condition and risk assessment sensors and prediction models;
- Optimised network operation and "just in time" repairs and investment programmes;
- GIS/GPS information;
- Buried asset electronic identification and tagging devices, wireless communication through road materials;
- "Wearable computers" for field workers, giving access in real-time to all data bases of the company, with interfaces consistent with field conditions.

D. Energy Efficiency (major issue for water security improvement)

- Smart grid in water distribution systems (real-time management of pumping strategy, refined demand forecast, optimization of network management and of operating costs);
- Tools for energy saving in treatment plants;
- Real-time status monitoring (open/closed) of manual valves (cf. above: equipment of field operators);
- Monitoring and control of heat recovery in wastewater;
- Tools for Smart Metering / Smart Pricing (*e.g.* condition-based tariffs).

E. Water Efficiency (major issue for water security improvement)

- Improving water efficiency in cities;
- Improving water efficiency in agriculture, including detection of illegal abstraction;
- Ecosystems and land-use management in perspective of project scope and available resources.

The implementation of smart water solutions according to the five identified priorities will contribute to improve the water security level of the community engaging the approach.
The deployment should be carefully planned according to the legacy of the existing systems and to the technical capacity of the local technical teams. The introduction of the new solutions requests to engage an update of the technical competences and skills of the staff members who will be in charge of the various tasks.

> *"The introduction of the new solutions requests to engage an update of the technical competences and skills of the staff members who will be in charge of the various tasks."*

06

Towards Decision Support Systems for Real-Time Management

The analysis of the domains and of the business processes demonstrates the need for a consistent water information system able to integrate within the general information system of cities that is covering the 6 main sectors including water, energy, transport, communication and safety. The water information system should provide the relevant details in real-time to water professionals and decision makers. In this context, the development of Decision Support Systems (DSSs) represents a major issue as the data architecture and the associated workflows are strongly conditioning the efficiency of the target system.

By definition Decision Support Systems (DSSs) are a specific class of computerized information system that supports business and organizational decision-making activities. In cities, the DSSs are supposed to streamline and integrate rules, procedures and decisions needed for solving complex problems: when relationships between required sets of data are unclear, the data comes in multiple formats and/or pertinent problem-solving methods required to be applied are not straightforward (Gourbesville, 2011). The growing complexity of urban environments requests to develop a holistic approach that integrates the dynamic of the various functions and services under various situations like flooding or lack of drinking water. In the water sector, the services provided to the inhabitants have been gradually integrated in various platforms that provide a real-time overview of the various business processes and also allow to anticipate by using modelling tools running also in real-time. This new approach (Figure 2-4.) combines within a dashboard, a first service that is providing in real-time the display of the collected data (such as water levels, discharges, velocities, pressure, turbidity, etc.) at various locations and a second service that is dedicated to provide forecasts with various modelling tools that are used in real-time.

> *“The water information system should provide the relevant details in real-time to water professionals and decision makers.”*

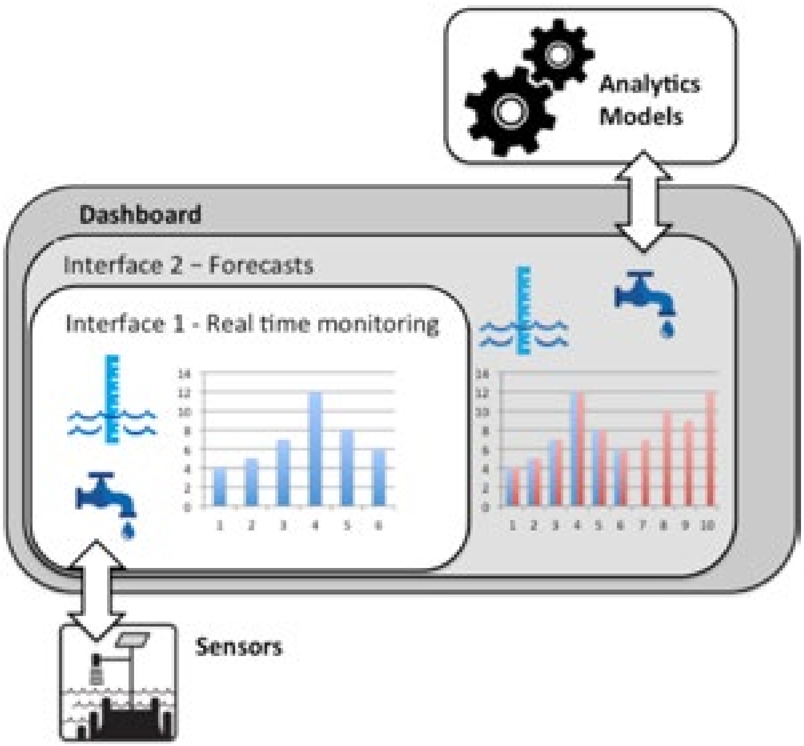

Figure 2-4 Concept of a dashboard integrating the real-time monitoring and the forecasts provided by models

The current demands are in favour of a platform elaborated over a service bus dedicated to collect and integrate field data that are related to various processes including the water services and the natural hazards. Data are formalized through various tools such as Key Performance Indicators (KPIs), predefined alerts and directives. A synthetic dashboard allows visualizing the current situation. In addition, in order to provide real support to the decision process, several tools dedicated to the data analysis and to the simulation are interfaced with the core part of the platform. The models used in this analytics domain start with basic statistical tools and go to complex determinist models such as those commonly used in hydroinformatics. This architecture concept for the urban information system is today commonly shared and appears as a consensus solution (Gourbesville, 2011). However, several serious technical challenges are still there and will request efforts for real integration and functional interoperability. If the concept is now shared, the maturity has to be gained in particular with the definition of the requested standards for managing the workflows among the various applications.

Major water utilities like Suez and Veolia have already produced specific services that are integrated in dashboards promoted by IT providers such as IBM, CISCO, Schneider Electric, etc. In most of the cases, the real-time data on water consumption, potential leakages and quality monitoring are available for the technicians and the decision makers. Several experiments have been conducted successfully in Europe, Asia and USA. One of the most impressive achievements takes place in Malta with the full coverage of the country with an Automated Meters Reader (AMR) solution promoted by Suez and IBM (Sempere-Payá *et al.*, 2013).

In parallel to the urban water uses, DSSs play an important role in many geoscience disciplines, including hydrology and atmospheric science (Demir, 2010; Demir & Krajewski, 2013; Tarboton *et al.*, 2009; Williams *et al.*, 2009). Recent examples of these systems have capabilities for web-based management, visualization, and shared environmental time-series data using web services (Demir & Beck, 2009; Demir *et al.*, 2009). A critical application domain for these systems with real-time information management and sharing capabilities is flood risk management.

The need for reducing the loss of life and property damage is increasing at the worldwide scale (Downton & Pielke Jr, 2001). Key components for reducing the losses from flooding include adequate preparation and lead time, an effective warning system, information communication, and timely public response (Hayden *et al.*, 2007). Researchers suggest that current warning systems are inadequate (Lindell *et al.*, 2004), especially for flash flooding events (Handmer, 2001).

Studies on the simulation of flooding events and communication of flood forecasts with the public (Frick & Hegg, 2011) suggest a need for an integrated approach for communicating flood-related data, information, and modelling results.

6.1. Dashboards and Data Integration for Real-Time Monitoring

With the fast development of sensors and their integration in communication networks (ex: 6LowPAN, IPv4/IPv6, RPL) sharing a common standard protocol such as IoT, data become available (ex: MQTT, CoAP, AMQP, Websocket, Node) and are feeding into management systems. These data are used to monitor and manage urban tasks and operational governance in real-time.

Dashboards act as cognitive tools that improve a user's 'span of control' over voluminous, varied and quickly transitioning data and enable a user to explore the characteristics and structure of datasets and interpret trends. The power and utility of city dashboards is their realist epistemology and instrumental rationality and their claims to show in detail and real-time the state of play of cities. In essence, dashboards enable a user to understand what is happening in a city system at any point in time and to act on that data.

The rise in availability of urban data has encouraged city governments, academia and private companies to invest in ways to analyse, operationalize and communicate the vast amounts of information being created by urban services and operations (Lee *et al.*, 2015). To this extent, there's been a growing trend of cities adopting online urban dashboards as instruments in which both public officials and the general public can interact with city data in order to have a better understanding of the operating dynamics of cities (Kitchin, 2014). These dashboards often coexist with a larger information ecosystem that includes service-oriented apps for mobile devices and online platforms for e-government, among others.

Urban dashboards take this concept out of physical space and make them available from anywhere using personal computer or mobile device screens. This makes it more convenient to share the same information view among a dispersed population, whether they are an expanded group of public officials and technicians, or all residents of the city. These virtual dashboards can help make complex and diverse urban phenomena seem digestible, using raw data visualizations or simplified indicators/benchmarks, but there is an inherent danger of obfuscating or reducing the importance of causes that are not easily sensed or modelled (Kitchin *et al.*, 2015).

The requests formulated by cities are in favour of a platform dedicated (Figure 2-5) to collect and integrate field data that include water services. The produced and collected data are formalized through various tools that produce indicators, and alerts. The synthetic dashboard allows visualizing the current situation.

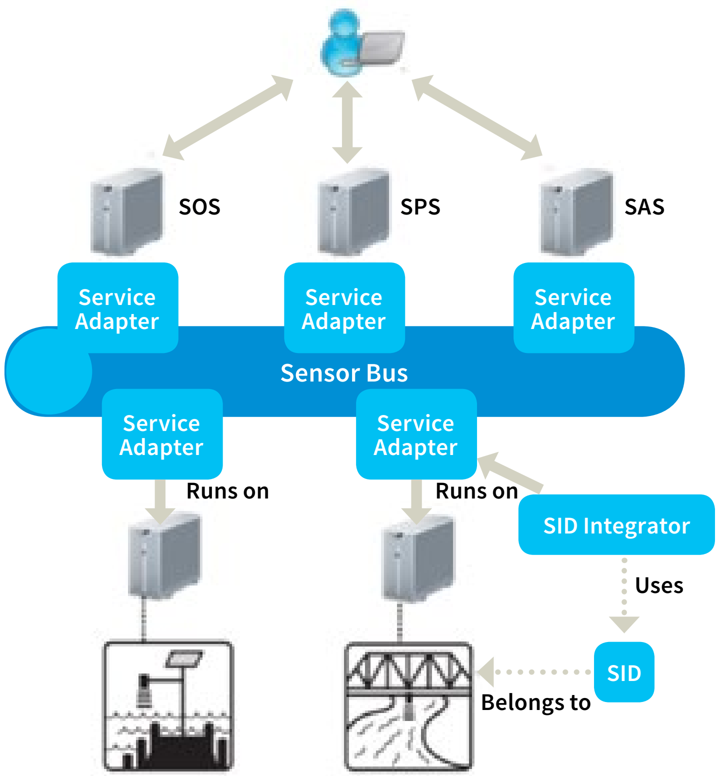

Figure 2-5 Example of service bus platforms' concept (Gourbesville et al., 2018)

6.2. Models and Forecasts

In addition to the analysis of the current situation by visualizing the various information sources, a frequent request is on evolution of the monitored processes in time in order to anticipate reaction and ensure an efficient management. This aspect contributes to improve water security of communities. In order to achieve that stage, the platform can be enriched with several tools focused on data analysis and simulation of physical processes. The models used can be simple as statistical methods or more sophisticated as distributed deterministic systems as frequently used in hydroinformatics. This architecture concept for the urban information system is today commonly shared and appears as a consensus solution (Demir *et al.*, 2009).

If the concept can be easily formulated, some technical challenges remain and request real efforts for integration and interoperability with existing systems that have a strong legacy to take into account. The concept is today commonly accepted and shared. However, the operational implementation should be supported with the standards requested for the various applications' workflows.

6.3. Example of Application: AquaVar DSS

The city of Nice is located on the French Riviera at the mouth of the Var catchment. The recent urban development the fifth largest French city is currently taking in the last available space along the Var low valley and over about 20km of floodplain. Due to the complexity of challenges—water supply security issues from groundwater resources, inundation risk and water resources management under the perspective of climate change—the need for a DSS has been identified since the late 90's. Unfortunately, at such time, both availability of data and technical tools (from communication protocols to modelling tools) have not permitted to engage the development of a DSS. During the last 15 years, systematic data collection on topography, climate and hydrological variables has permitted to gather a significant knowledge on the main hydrological processes within the Var catchment. Since 2014, a new approach has been engaged with the AquaVar project dedicated to the development and implementation of a first DSS able to address a wide diversity of issues: from resources management to emergency situations management.

In the case of the Var low valley, the demands from the local government are targeting the groundwater and flood events management. The requests are both for a real-time information on the current processes and on the possibility to assess a future situation through modelling tools. The models will integrate the Analytics domain in the global Information System (IS) architecture and will be connected through the Service Bus to the various data sources such as water levels, discharges and water quality parameters. The hypervision interface allows to display the measurements and to interact with the modelling tools that produce the simulations.

One of the key questions is obviously on the choice for the modeling tools to integrate within the Analytics domain. In order to provide the requested diagnostics and simulations, the flowing modelling systems have been chosen and interconnected:

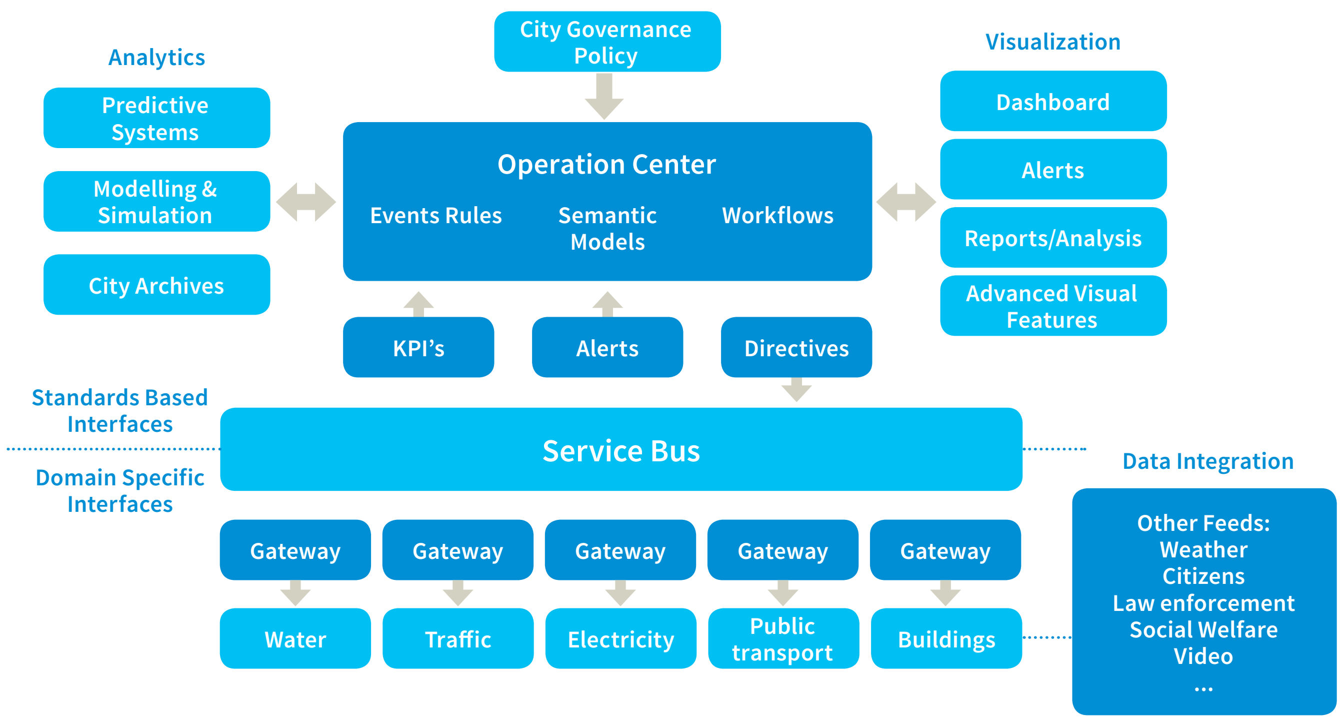

Figure 2-6 Concept of a hypervision platform dedicated to urban monitoring and management (Gourbesville et al., 2018)

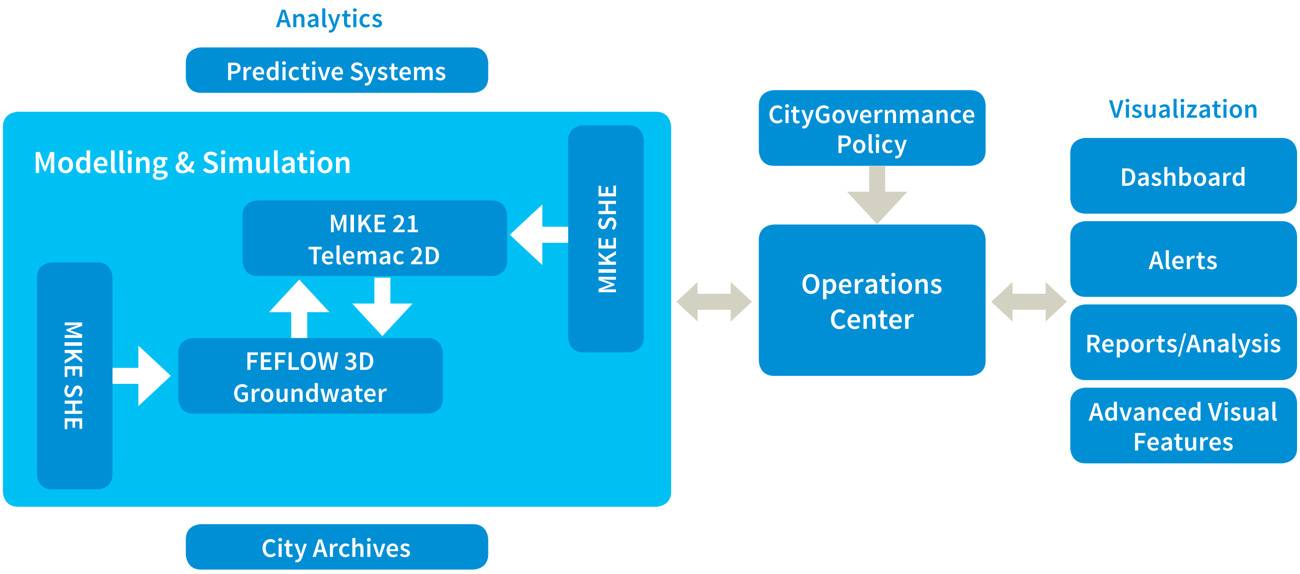

Figure 2-7 Architecture for the AquaVar DSS (Gourbesville et al., 2018)

- The FEFLOW modelling system, developed by DHI, for the 3D simulation of the groundwater resources simulation.
  In order to represent the interactions between the river and the groundwater table, the FEFLOW model is combined with a 2D surface water model;
- The MIKE 21 system from DHI and the Telemac 2D from EDF are used as 2D surface water models and are connected with FEFLOW for the surface/groundwater interaction simulation. In addition, the systems are used for the flood events simulation and for the modelling of the morphological dynamic within the riverbed;
- The MIKE SHE modelling system is used to produce the boundary conditions for FEFLOW and MIKE 21/Telemac systems.

The combination of the 3 modelling systems allows providing a global overview of the hydrological situation in the catchment and in the low valley. After the initial elaboration and validation steps, the models are used for producing simulations that are integrated within the hypervision platform.

In order to ensure an efficient use of the platform, user profiles have been elaborated. The expert profile allows elaborating a simulation scenario that could be launched on the various models and the consultation profile offers only the visualization of the collected data and the results of the forecast procedure produced by the 3 modelling systems. The public profile is also foreseen in order to provide information to the general public and to improve preparedness / resilience (Batica & Gourbesville, 2011; Batica, Hu & Gourbesville, 2012) of the population in case of specific and/or extreme situations (flooding, drought, polluted water, etc.).

The proposed generic operational approach developed in the AquaVar project could be implemented in order to address the management of water uses in a complex urban environment: water supply security issues from groundwater resources, inundation risk and water resources management under the perspective of climate change. The proposed approached is based on a DSS integrating deterministic modelling solutions which allow to have a full simulation of the hydrological cycle at the catchment scale, a 3D simulation of complex underground aquifer and associated relationships with 2D/3D surface flow model including pollutants exchanges. The modelling system integrated with the hypervision platform is based on Feflow, Mike SHE, Mike21 FM and Telemac 2D.

The selected architecture for the DSS AquaVar is based on the interoperability of the various models and is integrated in a platform allowing to organize the workflows of data and the production of real time information's used by the decision makers and different stakeholders. One of the main interests of the approach is to integrate an existing hypervision platform already implemented and used for urban monitoring.

The current approach has been implemented within the AquaVar project, on the Var catchment located in the French Riviera and for an area close to 3,000 km^2. Obviously the developed concept for the DSS can be extended to various catchments and for various objectives such as flood management, groundwater resources management, *etc.* The obtained results demonstrate both the efficiency of the approach and the interest from the management point of view.

The developed DSS is currently a major component of the city information system and contributes to improve the water security for the population. The monitoring of the various water resources—surface and underground—combined with the forecasts elaborated by the deterministic models provides to the decision makers a global view on most of the water issues in the Var catchment and in the Nice metropolis area. The availability of the information opens the door to a more anticipating and inclusive management of water resources.

07

Smart Metering Solutions for Water Efficiency

7.1. The Sensor Revolution

Following the PC revolution in the 1980s and the Internet revolution in the 1990s, the on-going revolution is connecting the Internet back to the physical world, creating the world's first electronic nervous system or Information System (IS). The sensor revolution is based on devices that monitor environment—natural & built—in ways that could barely imagine a few years ago.

A sensor is any device that can take a stimulus, such as heat, light, magnetism, or exposure to a particular chemical, and convert it to a signal. Sensors have certainly been around for a very long time with scales (weight sensors), thermometers (temperature sensors) and barometers (pressure sensors). More recently, scientists and engineers have come up with devices to sense light (photocells), sound (microphones), ground vibrations (seismometers), and force (accelerometers), as well as sensors for magnetic and electric fields, radiation, strain, acidity, and many other phenomena.

While the concept of sensors is nothing new, the technology of sensors is undergoing a rapid transformation. Indeed, the forces that have already revolutionized the computer, electronics, and biotech industries are converging on the world of sensors from at least three different directions:

- Smaller. Rapid advances in fields such as nanotechnology and (micro electro-mechanical systems (MEMS)) have not only led to ultra-compact versions of traditional sensors, but have inspired the creation of sensors based on entirely new principles. The reduced size fits perfectly with the constraints of the water supply and open possibilities into the monitoring and operating activities.
- Smarter. The exponentially increasing power of microelectronics has made it possible to create sensors with built-in "intelligence." In principle, at least, sensors today can store and process data on the spot, selecting only the most relevant and critical items to report.
  One of the emerging concepts in this domain is the ubiquitous computing paradigm. This approach is highly relevant for the water domain especially for all warning and monitoring systems which may avoid the centralized design.
- More Mobile. The rapid proliferation of wireless networking technologies has cut the tether. Today, many sensors send back their data from remote locations, or even while they're in motion.

In the urban water domain, the new sensors are already deeply impacting several business processes with Automated Meter Readers (AMR), water quality control devices and operating supervision. Such trend is following the recent evolution observed in energy distribution sector.
An emblematic evolution is the one taking place with the introduction of the smart metering concept for water consumption monitoring.

The availability of sensors due to mass conduction and reduction of costs allows implementing monitoring actions that directly contribute to improve efficiency of water services: leakages are identified with pressure and water level sensors, contaminants can be detected with multi parameters probes, *etc.* This new environment benefits directly to the improvement of the water security of communities that decide to move for smart water solutions. This approach is particularly relevant for developing countries where very significant improvements in efficiency can be achieved with limited investments concentrated on a monitoring system focused on main infrastructures and pipe/canals. The smart solutions allow improving the efficiency of water utilities by providing to key staff and technicians a better vision on their tasks and associated priorities. In fact, younger water utilities can perform better with limited staff due to the inputs provided in real-time. This perspective should be actively promoted in order to underline the interest of smart solutions towards emerging water utilities in developing countries. This positive evolution contributes to strongly improve their water security and support achievement of SDG 6.

7.2. From Mechanical Meters to Smart Metering

Water meter reading remains one of the core business processes of water utilities or public services in charge of drinking water supply. This activity requests a good level of organization and a good management of the devices.
To date, water meters have been accumulation meters, pulse meters or interval meters which are all mechanical devices. The data are collected by field agents who regularly record the meter readings directly from the field. This process can report about consumption and can detect some leakages in the network. However, reactivity is low due to the limited visits on the field. The past decade has seen an evolution of conceptual design of advanced or smart metering and its terminology. Driven by electricity investment, metering has evolved from accumulation meters to interval meters with simple communications, to advanced or smart metering with an increased range of metering functionality. This increase in electricity meter functionality and complexity has started to be mirrored in the water industry.

Interval metering is comparatively more expensive than pulse metering, as the interval meter is required to constantly monitor the water flows through the meter and record this volume at the expiration of the metering interval. By using a fine pulse quantum and analysing the time stamps of these pulses, pulse metering data can be used to approximate interval water metering data and hence deliver similar benefits. The use of pulse metering where a time stamp is made when a certain quantum of water is used, is more common in the water industry and these pulse meters are available at a reasonable cost.

Smart water metering for the water industry will extend beyond the capability of Automated Meter Reading (AMR). Smart water metering is expected to, as a minimum, establish more granular—within a day—water usage data, two-way communications between the water utility and the water meter, and potentially include communications to the customer. With respect to a customer's household, smart water metering could enable:

- Recording of water consumption within a day;
- Remote meter reading on a scheduled and on-demand basis;
- Notification of abnormal usage to the customer and/or the water utility;
- Control of water consumption devices within a customer's premise;
- Messaging to the customer;
- Customised targeting of segments.

The options to be considered for smart water metering are:

- Choice of communication to the water authority/water utility and the home;
- Choice of consumption data measurement (pulse or interval metering).

Options for the implementation of smart water metering communications arise through choices on:

- Water authority/water utility communications: The method and frequency of data collection through either drive-by collection, leveraging electricity Advanced Metering Infrastructure (AMI) communication networks or standalone water AMI communications networks;
- Customer communications: The method of communicating consumption information to customers: either in real-time across a Home-Area-Network (HAN), or in a historical manner through bills.

Over the last decade, various projects involving several thousands of meters have been engaged worldwide (Korea, USA, Japan, China) and especially in Europe within France, Italy, Spain and Malta. The projects are carried out by the water utilities that are supporting development and implementation in various municipalities and for different situations (type of building, type of cities, *etc.*). Most of the projects are based on wireless devices and very few are deployed on the wire networks. Following the first experiments, the main water utilities have already implemented smart meters at a large scale with for example more than 1,650,000 units for France over the last decade.

The pilot studies and experiments carried out over several years by the water utilities have demonstrated the savings in water consumption due to the use of the smart metering. The savings are taking place at various levels such as:

- Reduction of individual consumption: The details of the consumption are accessible through various media such as a specific website or a small electronic terminal. The information provided to the consumer immediately generates a reduction up to 15%;
- Reduction of water consumption at the macro scale (city to block): Smart metering allows operators and consumers to identify non-conform water consumption and consequently helping to reduce leakages after and before the smart meter itself. Text messages could be sent to consumers when the consumption is initiating a non-coherent pattern with the previous consumption. The water utilities can also detect major leakages on the networks;
- The knowledge in real-time of the water consumption allows to identify seasonal needs of the population and to anticipate the volumes of resources to mobilize. This approach allows a more functional use of resources and contributes globally to reduce the consumption;
- The knowledge in real-time of the water consumption opens the doors to a new approach about pricing, based on seasonal and even hourly values.

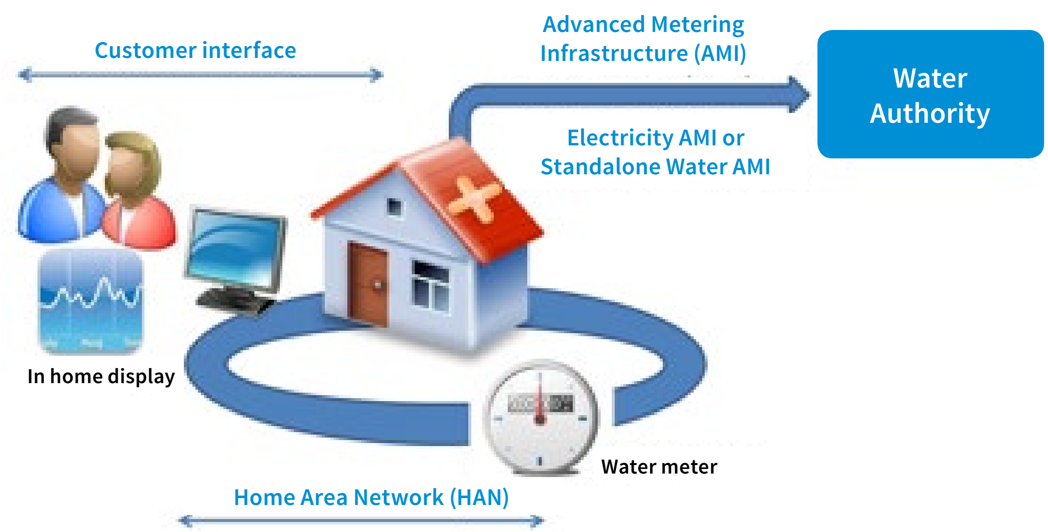

Figure 2-8 Smart water metering logical architecture (Gourbesville, 2011)

Today, according to various publications and sources (Oracle, 2011; 2012), about a third of water utility managers in USA say they are in the early stages of adopting smart meters, despite the fact that 71% of water users say that having more detailed information on their water consumption would promote better water conservation. This figure is representative of the worldwide situation. From the water utilities point of view, the following benefits to adopting smart meters could be identified:

- Enabling early leak detection;
- Supplying customers with tools to monitor/reduce water use;
- Providing more accurate water rates;
- Curbing overall water demand;
- Improving the ability to conduct preventative maintenance.

The financial efficiency of smart metering has been already demonstrated through various study cases and pilots (Marshment Hill Consulting, 2010). In developing countries where development of infrastructures and management of water resources represent a great challenge, the opportunity to invest in the smart metering concept is clearly a key issue which request an integrated effort in the global urban management.

Monitoring water uses is a key aspect for achieving water security for a region or a community. The smart water solutions like AMR associated to the relevant data communication network contribute to have an efficient management of water resources for domestic uses. Obviously, the reduction of leakages and the higher efficiency of water distribution networks allow reducing the pressure on the resources and making available additional volume for hydro-environment preservation. This process supports the global water security development.

7.3. Example of Application: Malta Smart Water Approach

On the Mediterranean island of Malta, with a population of about 400,000 people in an area of just over 300km^2, power, water and the economy are intricately linked. Malta is classified as 'water scarce' with the lowest natural water resource per capita of the Mediterranean countries. The country depends on electrically powered desalination plants for over half of its water supply. In fact, about 75% of the cost of water from these plants on Malta is directly related to energy production. Meanwhile, rising sea levels threaten Malta's underground freshwater source. Additionally, in line with the Lisbon strategy[1] and the other European countries, the government of Malta has set an objective of transforming the island into a competitive knowledge economy to encourage investment by foreign companies. Meeting all of these goals in a relatively short period of time presents a complex interconnected series of challenges that require immediate attention to ensure the country has a sustainable and prosperous future.

In light of this need, the government of Malta has invested massively in smart solutions for major utilities dedicated to electricity and water supply. The Maltese National Utilities for Electricity and Water—Enemalta Corp. (EMC) and Water Services Corp. (WSC)—have established a partnership agreement with IBM and SUEZ to undertake a complete transformation of its distribution networks to improve operational efficiency and customer service levels. IBM and SUEZ have replaced all the electricity and water meters with new devices, and connect these and the existing water meters to advanced information technology applications.

The Automated Meter Management (AMM) in Malta is implemented using a solution from Ondeo Systems-Suez based on a fixed network, 2-layers technology (RF transmitters, receivers), using 169 MHz VHF which is the EU authorized channel for remote reading, long range transmission without repeaters. The system uses 15-years battery life devices that reduce the maintenance activities and costs. Since 2012, more than 225,000 devices have been installed by WSC and an equivalent number of electricity meters by Enemalta. Itron has provided the smart meters for water consumption monitoring.

The strategy being employed by WSC to drive the smart metering for the water network is based on the following:

- Better inter-department coordination to ensure all (old) meter replacements result in smart metering installation,
- Geocoding of all important features of the water network,
- Development of reports and software to analyse data being provided from smart meters,
- Correct monitoring and maintenance of entire AMM solution.

The deployed solution allows for the provision of an early warning to consumer about possible leaks and minimises network water demand. WSC uses all the available AMM data in order to improve its network yield. A system has been designed by which zone balances can be quickly run once a master/zone meter is linked to the consumer meters it is feeding (using Geographic Information—GI). A web portal has been launch and customers can now monitor and manage their own water consumption.

The strategy chosen by Malta demonstrates its efficiency and the interest to implement a smart metering solution based on a consistent Information System defined at the global scale for the full island. The implemented solution has significantly contributed to improve the efficiency of the network and to optimize water resources over the country. The implemented solution has directly contributed to the SDG 6 and obviously improved the water security of the country. The different uses are currently more efficiently managed with the constant monitoring of resources, production and distribution operations. The case of Malta represents a major achievement regarding adaptation and efficient management of scare resources.

08

Smart Water Solutions for Smart and Sustainable Agriculture

Achievement of water security requests to harmonize uses and to successfully balance the water resources without negative impact on the hydro-environments.
Irrigation remains from far the first sector to mobilize fresh water (about 70% of total fresh water resources) and obviously any action that could contribute to improve efficiency of irrigation disposals and reduce water use will contribute to achieve regional water security. The rapid escalation of food demand due to the growing population worldwide is boosting the demand for smart agriculture. Smart agriculture engages advanced technologies such as Big Data, GPS, IoT and connected devices. Smart agriculture helps in automated farming, collection of data from the field and then analyses it so that the farmer can make accurate decision in order to grow high quality crop. The field data are collected with the help of sensors, cameras, micro controllers, and actuators. Then the collected data are transferred via Internet to the operator or the farmer for decision-making.

Agriculture accounts for around 70% of global water withdrawals, so improving the efficiency of this sector will play a major role in the sustainability of the world's water resources. For instance, knowing when to irrigate crops, and how much water to use, is crucial to maximizing yields. Wireless sensors are being used in the fields to monitor humidity levels and soil moisture, and can automatically turn on irrigation systems, based on the specific needs of those crops at that location and at that point in time.
Advanced monitoring also allows for better planning and management, especially during cycles of drought and flooding. For example, the Somalia Water and Land Information Management project (http://www.faoswalim.org) developed by the FAO has developed sophisticated systems for monitoring surface and groundwater to support sustainable development of scarce water resources in Somalia.

8.1. Smart Irrigation

Smart irrigation is today a key component of agriculture. Smart solutions can help farmers to avoid water wastage and improve the quality of crop growth in their fields by irrigating at the correct times, minimizing runoff and determining the soil moisture levels accurately, thereby, finding the irrigation requirements at any place. Replacing manual irrigation with automatic valves and systems also does away with the human error element and is instrumental in saving energy, time, and valuable water resources. The installation and configuration of smart irrigation systems doesn't represent a major challenge and be implemented over a short period of time.

Most of the available and robust solutions are based on an IoT-based architecture. A smart microcontroller that serves as the 'information gateway' lies at the heart of the automated irrigation infrastructure. Soil moisture sensors and temperature sensors, which are placed on the fields, send real-time data to the microcontroller. Generally, a 'moisture/temperature range' is specified, and whenever the actual values are out of this range, the microcontroller automatically switches on the water pump, which is mounted on it with output pins. The microcontroller also has servomotors to make sure that the pipes are actually watering the fields uniformly so that no area gets clogged or is left too dry.
The entire system can be managed by the end-user through a dedicated mobile application. Smart irrigation makes it possible for growers to monitor and irrigate their fields remotely, without any hassles.

The flow of information to and from the centralized gateway has to be supported by stable Internet services.
Wireless low-power networks such as LoRaWAN (www.lora-alliance.org) or Sigfox (www.sigfox.com) can easily be used to power the sensors. These sensors send field information to the local computer of the user or to a cloud network.
The system can combine the information with other inputs from third-party services to arrive at "intelligent irrigation decisions." For example, if some rain is forecasted, water will not be released—even if the real-time data suggests that the field needs irrigation. Recalculations are also completed at regular intervals.

Several types of sensors are used to parlay data to the irrigation multi-controller unit. Each unit is dedicated to capture and transmit specific data. The first of the units is the soil moisture sensor (SMS), which examines the dielectric constant of soil surfaces to estimate the volumetric water content in the surface. This moisture level is directly proportional to the dielectric constant reading.
SMS controllers can either be on-demand with the capability of initiating and terminating irrigation sessions or bypass with the capability to allow irrigation sessions within pre-specified threshold levels. Next are the temperature sensors, which typically use advanced Resistance Temperature Detector components (RTDs) to track soil temperature levels accurately. These relay systems are made responsible for turning on or turning off the pumps, as per the precise soil requirements at any time. Soil moisture sensors offer much more efficient on-field irrigation than traditional, timer-based sprinkler systems. There are no risks of over-spraying or overwatering with the former.

In an automated irrigation infrastructure, the wastage of resource is minimized. As a result, there are cost benefits to be gained as well. By replacing the traditional watering system with a fully self-operating one, the chances of crops dying due to excessive—or insufficient—watering are minimal. Farmers will not have to worry about frequent plant replacement. Also, since smart agriculture, in general, and smart irrigation is all about faster, healthier crop growth, the average crop cycle is shortened. This means that there are chances of increased annual yields.

Even if the smart soil moisture sensors provide a relevant knowledge about the environment, they do not integrate the weather-related factors in any way. This aspect remains an important limitation. Significant amounts of moisture are lost due to evapotranspiration. Hence, crop-growers should ideally think beyond SMS controllers and start using the smarter evapotranspiration controllers or weather-based irrigation controllers (WBICs). These work with weather sensors or weather stations, which receive real-time weather updates and use the same for customizing the irrigation events. WBICs can also work with historical weather information and/or data received from satellites. Other unique characteristics of a particular crop field, right from types of plants and nature of the soil, to the ground slope and the amount of sunlight available, are taken into account. This is done to determine the exact amount of watering a place needs at any specific point in time.

One of the advantages of switching over to a smart irrigation regime is the considerable volume of water savings. These savings can be increased to around 20% by ditching the sprinkler systems and using nozzles that can spray rotating water streams in multiple trajectories instead. These new sprinklers go a long way in ensuring uniform distribution of water to all parts of the field (or a particular section of it) and offer much greater resistance to changes in weather conditions. The water released by these rotating-head sprinklers is mostly soaked in by the soil, thereby minimizing runoffs and other forms of wastage. Rain sensors have found widespread acceptance among crop-growers in many locations. These sensors double up as shutdown devices, sending signals to stop automated sprinklers at the time of (and just afterward) heavy rainfalls.

Small leaks and cracks in traditional irrigation systems (in tanks, reservoirs, *etc.*) can lead to considerable water losses. Manually detecting the source of these problems is often difficult and can be a potentially time-consuming activity. Smart irrigation tools can offer a relevant alternative. With IoT-support, the controllers can detect existing problems—pressure, level, velocity, and temperature—in any irrigation unit in real-time and a first diagnostic can be formulated easily.

While some investment is required to implement smart irrigation solutions on a field, the sensor costs are far from being exorbitant. On average, the price of a soil moisture sensor lies in the US$150–$160 range, while that of the more advanced WBICs is around US$300. The rotating sprinklers are priced on a per-unit basis of around US$6 or US$7.

The adoption of IoT based solution in agriculture has gained interest in recent years. Even so, the concept of smart irrigation remains a relatively new one. Most of the existing smart irrigation controllers have many complex features and capabilities. While these are perfectly suited for large-scale commercial usage or farms, they could be seen as too elaborate for small farm owners who are not familiar with technology. The current need is to raise awareness about and familiarity with these smart irrigation systems among individuals, particularly since user-inputs such as the type of crops, soil, and surface slope are critical for the performance of these systems. For the interested farmers, the smart irrigation systems will help to implement an optimal utilization of water, ensuring the uniform watering of plants. With the help of high-end sensors, climatic parameters can be integrated and make the irrigation routine more efficient.

> *“Achievement of water security requests to harmonize uses and to successfully balance the water resources without negative impact on the hydro-environments.”*

Significant savings are planned to be had, both in terms of much lower water wastages, as well as the diminished need for manual labour. With intelligent ‘irrigation decision-making’ capacities, advanced IoT-supported smart irrigation controllers are changing the face of agriculture. The field is evolving rapidly, and it will be interesting to track further developments in this domain over the foreseeable future.

The development of smart irrigation represents a major issue for achieving water security in many regions and countries. The development and the operation of efficient irrigation disposals combined with the relevant crops according to climate and soil conditions allow reducing in a drastic way the use of water resources. The made available resources can be then mobilized for other uses like drinking water, hydro-environments preservation or industrial production. The approach contributes to the SDG 6 by making extra water resources available and contribute to sustainability of populations.

8.2. Remote Sensing for Irrigation Efficiency

Irrigation systems have a key position within the water uses and can potentially heavily contribute to optimize the agricultural productions combined with an efficient improvement of the natural water environments. As already mentioned, the systems will allow reducing the diverted resources and should ensure a sufficient quantity to preserve ecological quality. Obviously, the initial improvement will come from the choice of agricultural products that could be produced according to local climate conditions. This first step has to be initiated within a consensus process that involves local communities and representatives of distribution networks.

For an optimal and sustainable irrigation management, the crop evapotranspiration (ETc) should be determined as precisely as possible (Toureiro, 2016). The weakest link in this weather-based approach to predict crop water use and irrigation requirement is the difficulty to estimate in a reliable way the crop coefficient (Trout *et al.*, 2007). Crop coefficients are commonly estimated based on days since planting or growing degree days (Allen *et al.*, 1998). For better accuracy, in the place of a single crop coefficient (Kc), dual crop coefficients may be considered (Allen *et al.*, 1998): A basal Kcb, accounting for the dependence of ETc on the genetic characteristics of the crops, through transpiration; and a soil evaporation coefficient, Ke, which accounts for the degree to which the soil is covered by the crop, mainly referring to the evaporative component of ETc. A soil water balance will allow for the determination of the irrigation opportunity and crop water requirement (Allen *et al.*, 1998). The best results with this approach are obtained if on site determinations of soil water status are compared to the estimated values obtained from climatic data (Toureiro, 2016).

Relationships can be defined between these types of data—weather-based and in situ determined—and biophysical parameters derived from vegetation indices (VI) that can be obtained from multispectral images, through convenient empirical equations. These relationships incorporate the eventual influences of local factors such as crop, soil, and topography. If such empirical equations are valid and reliable for a given crop in the region, they may be used for defining the crop water balance parameters from remote sensed data, instead of using the corresponding in situ parameters, which are harder and more expensive to obtain (Toureiro, 2016). Research has shown improvements in irrigation scheduling, due to better water-use estimation and more appropriate timing of irrigations, when Kcb estimates derived from remotely sensed multispectral vegetation indices were incorporated into irrigation-scheduling algorithms (Hunsaker, 2003). Remote sensing can be used to determine biophysical parameters that are incorporated in the crop water balance in an irrigated area.

Multispectral cameras provide images of the earth's surface that can be used to estimate the crop coefficient Kc and other crop parameters such as the fraction of land cover (Fc) and the leaf area index (LAI). These crop parameters can be estimated from vegetation indices defined on the multispectral and thermal images obtained from satellites. Vegetation indices (VI), computed as differences, ratios, or linear combinations of reflected light in the visible (blue, green, or red) and near infrared (NIR) spectra have been found to be closely related to several crop growth parameters (Heilman *et al.*, 1982; Jackson *et al.*, 1991; Moran *et al.*, 1994).

Current in use satellites like Landsat 5, although spatial and temporal resolutions present limitations due to a low rate of image acquisition. However, the launch of a new generation of satellites that can overcome most of such limitations by frequently providing quality images highly suitable for precision agriculture, inclusive the irrigation scheduling (Mulla, 2013). Special relief is due to the NASA Sentinel 2 satellite, with multispectral high-resolution images (up to 10m), with a relatively short recurrence interval (5 days), quite suitable for irrigation management purposes.

The normalized difference vegetation index (NDVI) can be derived from remote sensing data using near-infrared and red bands. The normalized difference vegetation index (NDVI) utilizes reflectance of the canopy in the near-infrared (NIR) and red (R) bands of the spectrum.

The NDVI values are reported to be well correlated with vegetation parameters, like leaf area index, net primary productivity and gross primary productivity. The normalized difference vegetation index (NDVI) has been used extensively for vegetation monitoring, crop yield assessment and drought detection. Higher NDVI indicates a greater level of photosynthetic activity. Increase in crop coefficient caused by higher temperature results in a decrease in soil water and a decline of NDVI, while dense vegetation induces more evapotranspiration and lowers the land surface temperature; or the transpiring canopy is cooler. Several authors (Neale *et al.*, 1989; Choudhury *et al.*, 1994; Bausch, 1995; González-Piqueras, 2006) have observed that NDVI is well related to the water use and transpiration of the plants. Therefore, the definition of reliable relationships between NDVI and Kcb and Kc became of main concern. The implemented approach tries to define the most reliable possible relation between the indices and the crop parameters.

Current developments are focused on the general objective of testing and validating procedures for obtaining information on crop water status and growth stages, estimating crop coefficients, evapotranspiration and crop irrigation requirement using satellite images. This information can be extremely useful to elaborate, over short-term intervals, maps of crop water status and irrigation requirements in any large irrigation area, in order to serve as basis for an irrigation advisory system.

Remote sensing data represent clearly major inputs for smart irrigation systems. With the evaluation of parameters able to characterize various water related variables, the water volume distributed to crops can be optimized.

The availability of remote sensing data allows to address issues and brings knowledge that were not available previously for the farmers and organisations operating irrigation systems. The possibility to optimize the quantity of water for an optimal agricultural production is a big step forward for communities' water security. The use of the right quantity of water is allowing ensuring sustainability of the agricultural activities and conciliating domestic and industrial needs. The remote sensing data and the associated methodologies should be promoted actively to the various professional sectors that could benefit from their inputs.

09

Conclusion

The water security concept is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability. This proposed definition implies that water is managed sustainably throughout the water cycle and is done so through an inter-disciplinary focus, so that it contributes to socio-economic development and reinforces societal resilience to environmental impacts and water-borne diseases without compromising the present and future health of populations and ecosystems.

> *“The smart water solutions are based on numerous methods and tools that could, under a consistent vision, contribute to build an efficiency water management targeting the objectives of the water security and the SDG 6 in priority.”*

The development of smart water solutions represent an opportunity if the implementation is carried out according the exposed methodology allowing to identified key business processes. The identification of the added value of each smart solution has to be established and validated before operational implementation in order to ensure sustainability and increase efficiency in water management. If this perspective represents a clear benefit both for natural and manmade environments, it request the development of a coherent vision based on a process allowing to integrate the fragmented activities developed until now in the water sector. The ICT solutions will allow this integration process but they have to be coordinated under guidelines and standards that have to be jointly defined by the various actors of the water sectors. The suggested approach, based on business processes, represents a solution that has to be extended to all activities and domains of the water sector. It implies a real mobilization of all actors from who have to formalize their processes. Of course this effort requests maturity in the process itself in order to be able to characterize the tasks and their dynamic.

The analysis of the domains and of the business processes demonstrates the need for a consistent water Information System able to integrate within the one of cities: Cities are currently implementing gradually an Information System that aggregates information from utilities (water, energy), transport, communication and safety in order to improve the services provided to the population. The Water Information System should provide relevant details in real-time to water professionals and decision makers. The development of DSSs represents a major trend that requests comprehensive data architecture and the possibility to integrate models able to run in real-time. This new approach represents one of the major axis of development that will allow to monitor and to forecast in real-time the water processes related to uses, natural environment protection and natural hazards mitigation. The new developed tools will contribute to support the water security concept and implement efficient water management for the benefit of populations.

In addition to the request of a consistent IS for water and its various declinations for urban or natural environment, the development of automated meters can strongly improve the management of water supply networks by reducing leakages and improving efficiency in services to customers. The interest of the AMR mature technology is today demonstrated globally, for both developing and developed countries. Millions of meters have been deployed and use various communication protocols according to their availability. The solutions by their agility and adaptability represent an alternative for developing countries that wish to improve significantly the efficiency of their networks. Water meters reading remains one of the core business process of water utilities or public services in charge of drinking water supply. This activity requests a good level of organization and a good management of the devices. AMR represents a consistent solution to support water security components. The example of Malta demonstrates the efficiency of the approach and the added value of the concepts for implementing an efficient water management.

In addition to the major issue of water supply, smart water solutions may have a relevant contribution in the agricultural domain. Irrigation remains a major sector for water uses and requests efficiency for its management. Smart irrigation solutions based on simple sensors can be easily deployed and used for various crops production optimization. The on-going developments in the remote sensing sector allow producing inputs for smart irrigation systems that can integrate climate dimension and de facto gained efficiency. The availability of data and their higher accuracy will contribute to the performance of the water management and to the water security components.

The smart water solutions are based on numerous methods and tools that could, under a consistent vision, contribute to build an efficiency water management targeting the objectives of the water security and the SDG 6 in priority. However, this approach requests effort in order to properly identified the real added values and the main priorities where smart water solutions can bring major improvements. The suggested approach can be elaborated only within a consensus and collaborative multidisciplinary process that brings together experts, decision makers and users.
 The capacity to promote this new inclusive approach will drive the spread of the smart water solutions and highly contribute to implement an efficient water management matching water security objectives.

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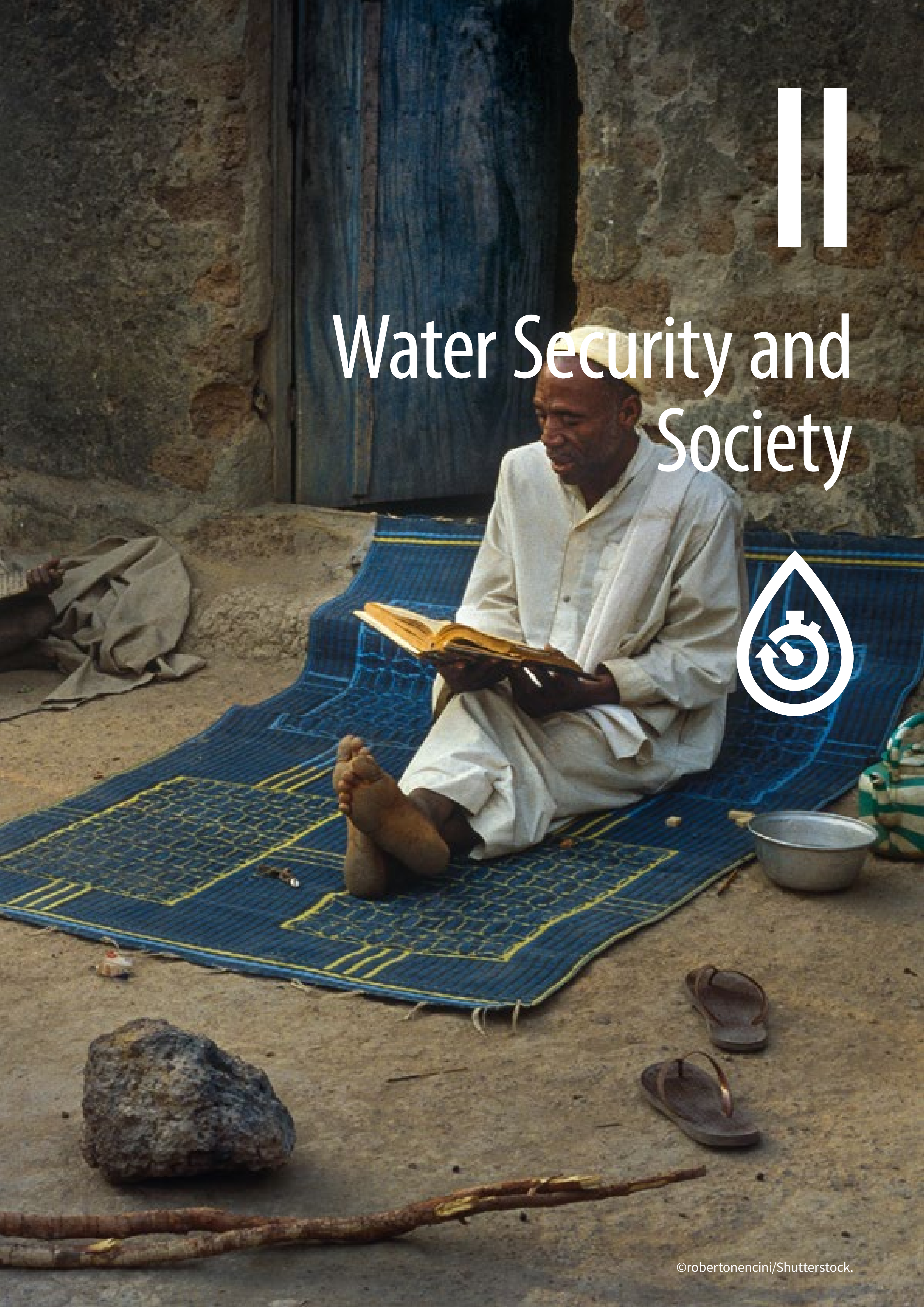
Notes

1. The Lisbon Strategy intended to deal with the low productivity and stagnation of economic growth in the European Union, through the formulation of various policy initiatives to be taken by all EU member states. The broader objectives set out by the Lisbon strategy were to be attained by 2010. It was adopted for a ten-year period in 2000 in Lisbon, Portugal by the European Council. It broadly aimed to "make Europe, by 2010, the most competitive and the most dynamic knowledge-based economy in the world".

II

Water Security and Society



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3

Water Security and Society: Data and Definitions for Water Conflict and Cooperation

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Abstract

This paper presents new findings on the history of water and conflicts internationally, including water as a trigger, weapon and casualty of conflict. The work looks at trends, categories, and causes of water-related violence with case studies from recent history. It offers an improved understanding of the links between water and conflict as well as strategies for improving cooperation over water and reducing the risks of future incidents, with specific recommendations for reducing water security threats for organizations at multiple levels, including the United Nations.

Keywords

Water, freshwater, conflict, environmental security, cooperation, international law, resources, Syria, Yemen, Iraq, Africa, Asia, India, Ukraine, Mali

01

Introduction

There is a long history of conflict over fresh water resources, with water and water systems being used as a target/casualty, weapon, or trigger of violence. Data on water conflicts has been compiled and maintained for three decades by the Pacific Institute in the comprehensive Water Conflict Chronology open-source database; comparable data on a wide range of other water-related issues has been compiled and maintained by the World Resources Institute for their Aqueduct (now Resource Watch) program. This paper will summarize the context, history, data, and some recent case examples related to water, and security and will present an overview of the joint project between the Pacific Institute and the World Resources Institute on linking challenges associated with water scarcity, economics, extreme events, with the risks of water conflicts. Among the case studies we will explore are recent events in western Asia/Middle East, Africa, and southern Asia where water was a trigger, casualty, or weapon of conflict.

“As water stress can heighten social disruption, intensify conflicts, and spark migration, there is an urgent need to better understand the relationship between water and security, and be able to act in a timely and effective way to prevent situations from worsening.”

02

Background

Nearly two billion people currently live in severely water-scarce areas or lack access to safe and affordable water or sanitation, according to the United Nations (United Nations Joint Monitoring Programme, 2017). And millions are affected by water insecurity through loss of income, food shortages, and conflicts over scarce resources. With climate change worsening extreme floods and droughts, increased destruction of ecosystems, and exploding population growth, the situation is only expected to worsen. As water stress can heighten social disruption, intensify conflicts, and spark migration, there is an urgent need to better understand the relationship between water and security, and be able to act in a timely and effective way to prevent situations from worsening.

The links between water resources and violent conflict have been explored for several decades as the field of security studies has shifted from the traditional 20th century focus on realpolitik to a broader view encompassing economic, social, and environmental threats to both international and subnational security. Among the earliest environmental concerns of the security community were access to energy resources, the price of critical goods such as food, large-scale climate change, and freshwater resources (Gleick, 1989a, 1989b; Myers, 1986; Ullman, 1983; Westing, 1986).
More recently, the threats posed by these kinds of challenges have been evaluated and analyzed by the defense and intelligence communities as part of their overall efforts to understand and prepare for nontraditional security threats (for example, see Defense Intelligence Agency, 2012; U.S. Department of Defense, 2104).

The central issue is not “water wars” per se, but the ways in which access to water, or water and water systems themselves contribute to or play a role in violence and conflict.
Wars start for myriad reasons, including ideological competition, economics, culture, religion, border and territorial disputes, and access to resources, and are rarely, if ever, attributable to single drivers. At the same time, combinations of weak institutions, state failures, resource constraints, and historical animosities can all play a role in the breakdown of cooperation and peace. The purpose of the field of security studies is to understand, assess, and analyze these factors to identify trends and ultimately develop and deploy strategies for reducing the risks of conflicts over water.

03

The Use of Data and Analytics to Understand Water and Security Risks

As challenges associated with freshwater grow, a wide range of efforts at academic, non-profit, and international organizations are underway to address them. Two efforts described here—at the Pacific Institute and the World Resources Institute—are focused on understanding and addressing the links between freshwater resources and conflicts. Both organizations are international non-profit research and policy centers using data and analytical tools to understand water and security risks, including historical information on events, demographic information on population and development trends, economic information on poverty and financial resilience, and a wide range of other factors.

3.1. The Water Conflict Chronology: Pacific Institute

The focus of the Pacific Institute in this area has been the creation and management of the open-access, online database: The Water Conflict Chronology (WCC)[1], which tracks violence related to water. Table 3-1 summarizes the categories of water-related violence addressed by the WCC. Three core distinctions are made: the use of water as a weapon in a conflict, targeting of water resources or water systems ("water as casualty of conflict"), and water as a trigger in disputes over access or control of freshwater.

By early-2019, the WCC had over 650 entries from around the world and was being used to help analyze both specific regional case studies and broader trends in the field of water and security. Data from the WCC shows that the number of water conflict events has been on the rise in recent decades (Figure 3-1). The reasons for this increase can include better reporting, growing disputes over scarce resources, economic and political failures, or other factors—ongoing work at the Pacific Institute is exploring these trends and their drivers.

Each entry in the Water Conflict Chronology is coded as one or more of the following actions of states, non-state groups, individuals, or a combination of actors in the context of fresh water resources or managed water systems and infrastructure.

- **"Trigger" Water as a trigger or root cause of conflict: where economic or physical access to water, or scarcity of water, triggers violence.**
- **"Weapon" Water as a weapon of conflict: where water resources, or water systems themselves, are used as a tool or weapon in a violent conflict.**
- **"Casualty" Water resources or water systems as a casualty of conflict: where water resources, or water systems, are intentional or incidental casualties or targets of violence.**

Table 3-1 Water Conflict Chronology categories of conflict

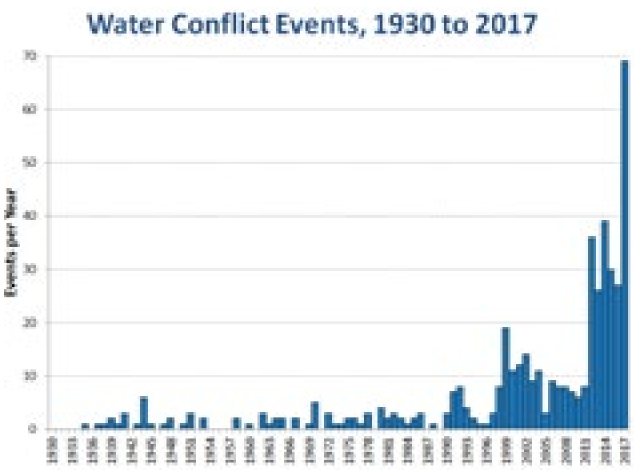

Figure 3-1 Time series of water conflict events, 1930 to 2017. (Data from the Pacific Institute Water Conflict Chronology as of late 2018, www.worldwater.org)

3.2. Aqueduct Risk Mapping: WRI

Aqueduct 1.0, launched in 2009 by the World Resources Institute (WRI), was part of the first generation of WRI global natural resource risk mapping tools, and was designed to help multinational companies and global investors evaluate their exposure water stress worldwide. Aqueduct 2.0—launched in 2013 and referred to as the Water Risk Atlas—introduced additional indicators that help users address water quantity, water quality, and regulatory and reputational risks. Aqueduct Floods—which assesses global river flood risks—was launched in 2015. Aqueduct 3.0 will be launched in early 2019, and will include:

- An updated improved version of the Water Risk Atlas;
- A second version of Aqueduct Floods, which adds global storm surge risks; and
- Aqueduct Food, a tool that cross-references global food production, consumption, and trade with global water risk indicators.

3.3. Resource Watch: WRI

More data are available today than ever before. Yet too often policymakers, business leaders, and analysts cannot access the data they need to make informed decisions about the environment and human well-being. In response to this need, WRI with over 30 partners, built Resource Watch, a dynamic platform that leverages technology, data, and human networks to bring new data transparency about the planet. Launched in April 2018, Resource Watch includes hundreds of data sets on the state of the planet's resources and citizens. Users can visualize challenges facing people and the planet, from climate change to poverty, water risk to state instability, air pollution to human migration, and more. An example shown in Figure 3-2 uses data on water stress and cross-references it with data on conflicts and protests from the ACLED database. Figure 3-3 integrates data on migrant deaths with the index on fragile states.

Pulling from near-real-time satellite data and ground sensors, the system helps users track and visualize fires, floods, landslides, air quality, natural disasters, and other world events as they unfold. Additional real-time-data sets are added each month.

The underlying data infrastructure (API) is open source, meaning that others can build on it to create their own custom, self-branded applications. In this way, Resource Watch is a global public good, enabling any organization to leverage the data revolution for their own causes.

The Partnership for Resilience and Preparedness (PREP data)—powered by Resource Watch—is the first example of a custom interface to improve access to climate data and help communities build climate resilience, and others are being developed.

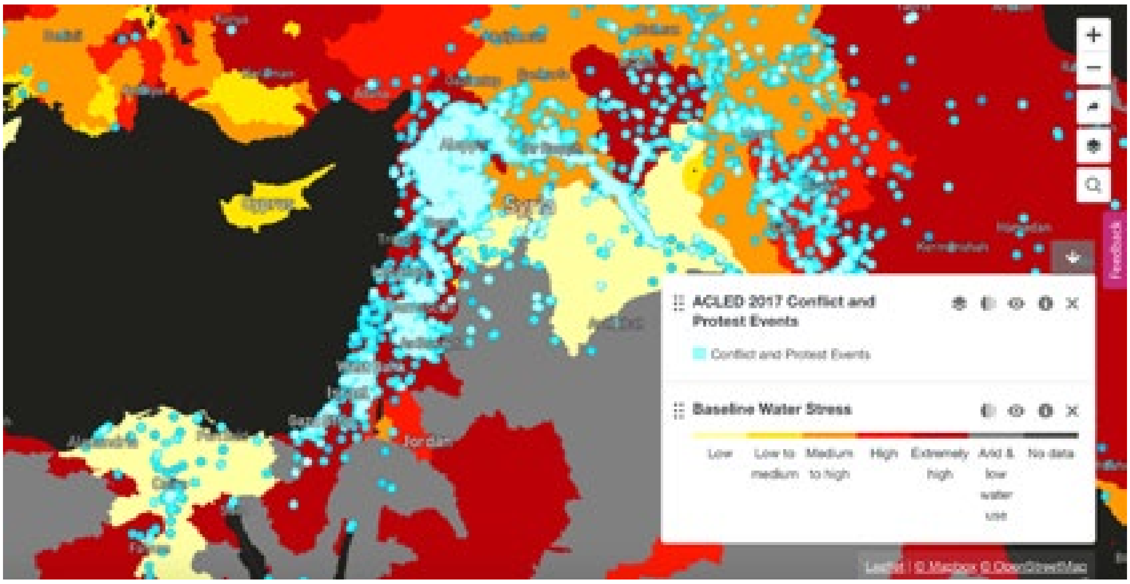

Figure 3-2 *Use of Resource Watch to cross-reference ACLED conflict and protest events with current water stress*

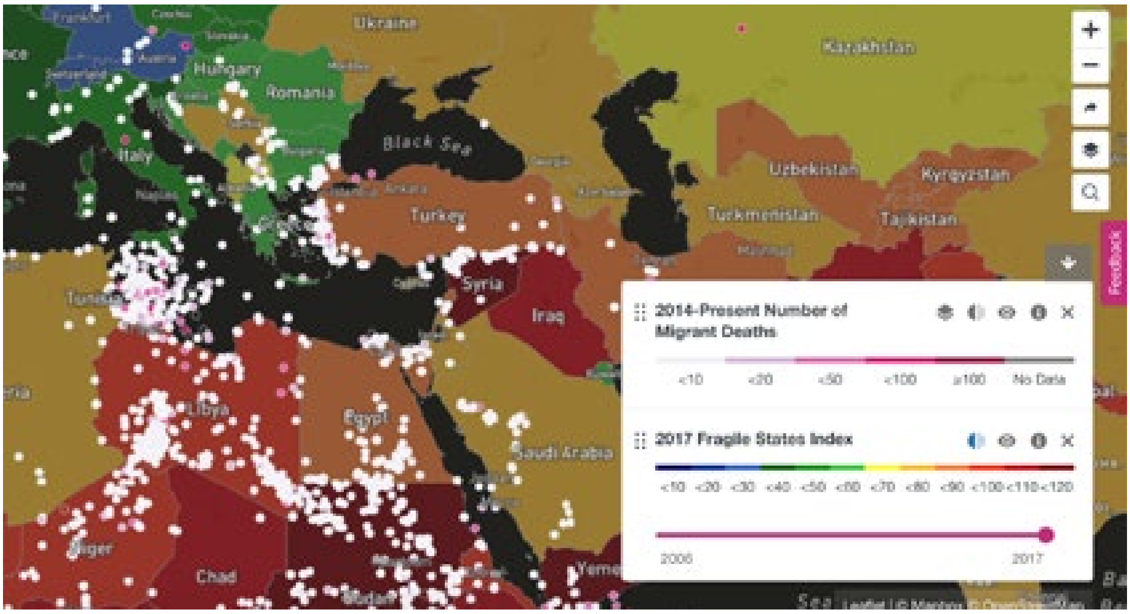

Figure 3-3 *Use of Resource Watch to cross-reference number of migrant deaths with the fragile state index*

3.4. WRI's Water, Peace, and Security (WPS) Project

The WPS project was launched to provide expert guidance on the link between water and security, identify potential "hotspot areas" to prevent the next water-driven security crisis, and support to vulnerable countries.

For example, many European countries are working to address the migration crisis that has sent over a million refugees to the continent. Some of these refugees were driven from their homes, in part, by water, food, and economic threats. As droughts plague major cities and hurt agricultural production from the Middle East to South Asia, concerns are growing about how water scarcity events will threaten economies and livelihoods.

WPS was created as a direct response to growing water crises. The two-year pilot project is being undertaken by WRI, IHE-Delft, Deltares, The Hague Center for Strategic Studies, Wetlands International, International Alert, the Pacific Institute, and Oregon State University, and is supported by the Netherlands Ministry of Foreign Affairs. The project has four components:

3.4.1. Understand

- Develop an online near real-time global early warning system for potential water scarcity-related threats to human security (to be hosted on WRI's new Resource Watch platform).
- Implement on-the-ground rapid assessments to verify and further research the threats and identify possible interventions.

3.4.2. Mobilize

- Conduct outreach to global "3D" audiences (diplomats, defense and development experts), as well as to national governments of developing countries where we identify threats.

3.4.3. Learn

- Provide training and capacity building to help developing countries cope with current and future crises and avert potential destabilizing conflict, migration, or acute food insecurity.

3.4.4. Dialogue

- Convene water dialogues among key stakeholders at international, national, and/or sub-national levels, to try to diffuse tensions and pave the way for solutions.
- International relief agencies, development organizations, governments and civil society need timely, decision-relevant information to take action on water and security. WPS models and data will provide these actors with alerts and information helpful for making proactive decisions on water management in times of water scarcity. Among the relevant actors and their ideal roles are:

- The UN Office for Disaster Risk Reduction (UNISDR) would have sufficient warning of drought or water scarcity conditions to take preventive action, rather than simply taking action after a crisis begins.
- The UN Refugee Agency (UNHCR) would have sufficient warning of drought or water scarcity conditions to provide assistance to farmers and their families before they abandon their farms and migrate.
- UN peacekeeping forces would have sufficient warning of drought or water scarcity conditions to prevent conflict before it starts, and to provide protection to in-country actors working on solutions, such as government agencies, non-profit relief organizations, global development organizations, and others.
- NATO or national defense ministries can support UN peacekeeping forces if needed. Without security and protection from violence, government agencies, international organizations, and non-profits cannot intervene and help.
- World Bank and regional development banks can identify countries or regions facing more long-term risks, and finance resilience-enhancing infrastructure investments.
- National governments can appeal for help from outside organizations before conditions deteriorate too much.
- Research and advocacy groups can monitor conditions on the ground, warn global and national organizations that intervention may be needed, and hold global and national organizations accountable.

> *"Too often policymakers, business leaders, and analysts cannot access the data they need to make informed decisions about the environment and human well-being."*

04

The Role of Extreme Hydrologic Events in Water Security

A new issue for water resources management and the social and political challenges of long-term sustainability is the growing risk of human-caused climate change and its impacts on severe events. Extreme events such as floods and droughts are part of the natural hydrologic cycle, and traditional water systems are designed to be resilient and robust in the face of them. But as the climate is now changing, extreme events are intensifying in some places at some times, putting new and unanticipated pressures on existing water (Bates, 2009; Jiménez Cisneros *et al.*, 2014). When combined with other factors such as population growing, new economic pressures on supplies, and water contamination, these extreme hydrologic events have a growing potential to affect human and military security. Below we describe the recent drought in central India and some of the drivers and consequences of that drought.

4.1. Drought in Central India Leaves Two Provinces in Conflict Over Dwindling Water Supplies

The Narmada River flows east to west through the Indian state of Madhya Pradesh (MP), then through the state of Gujarat before emptying into the Arabian Sea. Poor rains in 2017 have led to a conflict over how much water should be released from the Indira Sagar reservoir in MP to the downstream Sardar Sarovar reservoir in Gujarat (Iceland, Luo, & Donchyts, 2018; Noronha, 2018).

In 2017, Indira Sagar's peak reservoir water level was 33 percent lower than average, as seen below in Figure 3-4. Releasing more water would have further reduced the reservoir's supply during the critical summer period. On the other hand, because the Sardar Sarovar reservoir didn't get its allocated amount of water from Indira Sagar, its level fell at an alarming rate. The Sardar Sarovar reservoir is the drinking water source for about 30 million people, almost half of Gujarat's total population, and the irrigation water source for more than one million farmers (Iceland *et al.*, 2018).

As of March 15, 2018, the government of Gujarat has stopped supplying water for irrigation; the state minister has appealed to farmers not to sow summer crops. The low water level has also curtailed Sardar Sarovar's ability to generate electricity. The minimal water level required for the dam to generate electricity is 110.8 meters. Its current water level stood at 105.5 meters, as of March 15, 2018 (The Indian Express, 2018).

To date, 34 percent of the obligated water has been released from the Indira Sagar reservoir to the Sardar Sarovar reservoir. Reports say there is political pressure on MP's Chief Minister to not release more water, as that could adversely impact the livelihoods of water users, which is a sensitive political issue prior to the assembly elections set for the year's end.

India is a highly water-stressed country and has suffered through many debilitating droughts in recent years (Figure 3-5 shows a snapshot of overall water stress in India in 2010). These dry spells have devastated farmers, even driving some to commit suicide.

Around 45 percent of Indian citizens are employed in agriculture, making water supply essential for the livelihoods of almost 650 million people. As India continues to struggle with water stress and drought, water allocation decisions may become increasingly contentious (Iceland *et al.*, 2018)

Note: blue line shows a moving average, correcting for underestimates of water levels due to cloud cover or sensor errors.

Figure 3-4 *The area of Sagar Dam over time, showing water losses due to drought and water management changes (data from Deltares using monthly JRC water occurrence data for 1999-2015 and NASA/USGS, ESA satellite data for 2015-2018)*

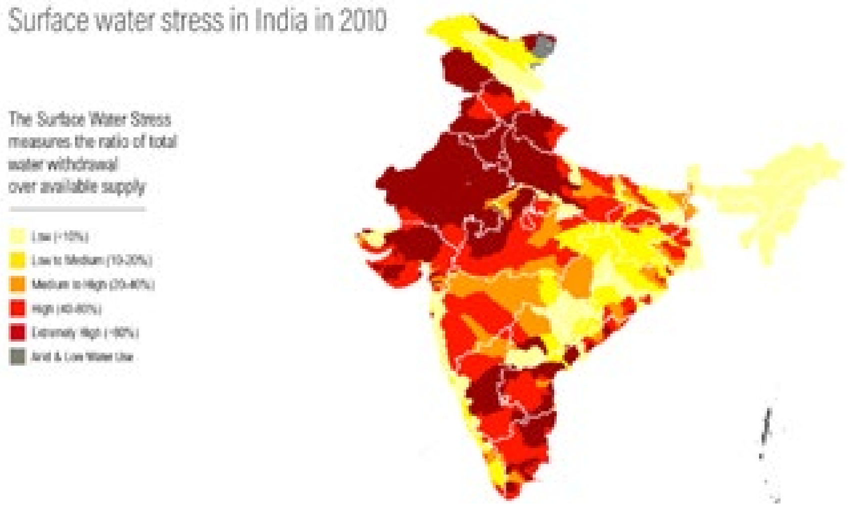

Figure 3-5 *Surface water stress in India in 2010 (graphic from the WRI Aqueduct database)*

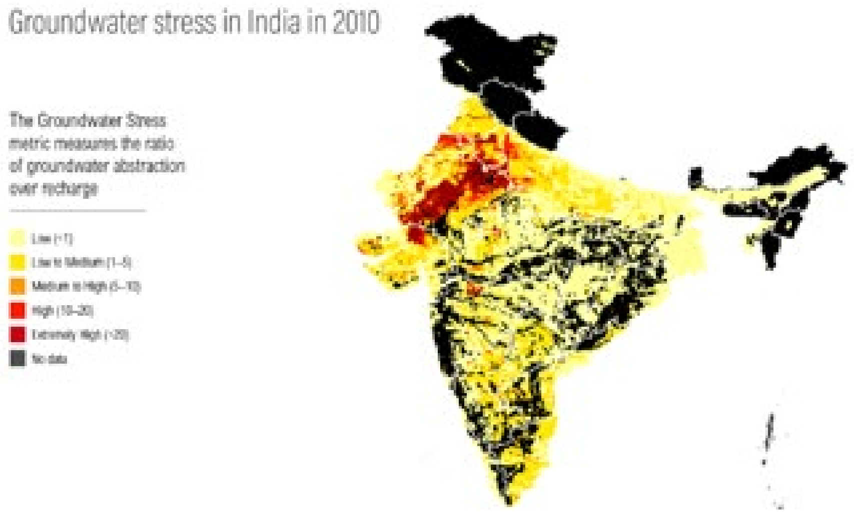

Figure 3-6 *Groundwater stress in India in 2010 (Graphic from the WRI Aqueduct database)*

> *"Without taking measures to ensure sustainable groundwater usage, NASA warned that over 100 million people could face a collapse of agricultural output and severe drinking water shortages."*

4.1.1. What Water Stress Looks Like: India

Nowhere on Earth is groundwater declining faster than in northwestern India. NASA's twin GRACE satellites, which were designed to detect changes in groundwater from space, found that large-scale irrigation caused 108 cubic kilometers of groundwater loss in Haryana, Punjab, Rajasthan and Delhi between 2002 and 2008. Higher resolution data show specific areas of India suffering from severe groundwater overdraft (Figure 3-6). More recent research shows these problems are expanding (Birkenholtz, 2017). Without taking measures to ensure sustainable groundwater usage, NASA warned that over 100 million people could face a collapse of agricultural output and severe drinking water shortages (Jet Propulsion Laboratory, 2009).

In July 2012, roughly half of India's population—about 670 million people, 10 percent of the world's population—temporarily lost power after a massive grid failure. Some experts blamed the severe drought affecting northern India. Low rainfall restricted the amount of power delivered by hydroelectric dams and farmers used more power than usual to run water pumps to irrigate their crops (Harris & Bajaj, 2012). Water shortages in India routinely cause heavily water-dependent thermal power plants to shut down, in part or entirely, for significant amounts of time. A recent WRI study found that between 2013 and 2016 India's thermal power sector lost over 30 TWh of potential electricity due to water shortages (Luo, 2017).

Intermittent water supply can wreak havoc on India's urban and rural populations, with water tanker trucks needed to supply villagers during drought and a high suicide rate among small-holder farmers burdened with heavy debt and unable to eke out an existence from the land. Scarce water supplies have also sparked heated competition among Indian states. For example, when the Indian Supreme Court ordered the state of Karnataka to release water from its reservoirs to relieve drought-stricken farmers in neighboring Tamil Nadu in September 2016, there were protest riots in Karnataka's capital city, Bangalore, until thousands of police were deployed to restore order (Iceland, 2017).

05

Case Studies of Water and Conflict

There are numerous examples of connections between water and conflict. To help illustrate some of the links described above in Section 3, we provide below some short, more detailed case studies.

5.1. Water as a Trigger of Conflict – Mali's Inner Niger Delta

West Africa's largest river, the Niger, fans out across a flat arid landscape to form the Inner Niger Delta, southwest of the ancient city of Timbuktu in Mali. It is one of the largest seasonal floodplains in the world, extending across an area the size of Belgium. It hosts millions of migratory birds, as well as hippos and manatees, has been declared a wetland of international importance under the Ramsar Convention, and is the source of livelihood for 1.5 million farmers, pastoralists (herdsmen), and fishermen. The Inner Niger Delta is also vital for food security in Mali, as it provides an estimated 30% of the country's rice, 80% of national fish production, and dry-season grazing for up to 60% of Mali's cattle (Mitchell, 2017).

Unfortunately, the area's growing population is putting increasing pressure on land and water resources, sparking growing conflict among farmers, pastoralists, and fishermen. Growing populations and increasing farming efficiencies have led to the expansion and intensification of crop production, which is leading to growing soil depletion. Drought is an ever-present concern, with two prolonged and severe droughts occurring in the 1970s and 1980s, and shorter, more frequent drought events since then (Jones-Casey & Knox, 2011). In addition, traditional conflict resolution mechanisms have started to break down, due to the imposition of the modern administrative state, financial challenges, aging infrastructure, and disputes over shared watersheds that cross political boundaries. All of these factors contribute to growing tensions in the region. In early 2018, conflicts between the Fulani and Dogon communities near the town of Koro, sparked by disputes over water and grazing access, killed over 25 people (Agence France-Presse (AFP), 2018).

“Reducing conflict in the region of the Inner Niger Delta and similar regions where pastoralists and farmers compete will require a careful balancing of user interests.”

Growing populations, soil depletion, drought, and the breakdown of traditional conflict resolution mechanisms are not the only threats to local livelihoods. The diversion of upstream river flows by the Office du Niger (a semi-autonomous irrigation agency in Mali) to irrigate water-thirsty crops, such as rice, sugar, and cotton is reducing the size of the Inner Niger Delta's annual inundation. Leo Zwarts, a Dutch hydrologist, has estimated that the diversion of these river flows has cut the annual area of delta flooded by up to 7 percent (Madgwick *et al.*, 2017).

A couple of years ago, the Office du Niger began planning for additional irrigation upstream of the Inner Niger Delta, which would more than triple total irrigated area. These plans hinge on the construction of the Fomi dam upstream in Guinea. In addition to helping the Office du Niger expand irrigated area, the dam would produce electricity (hydropower) and supply water for mining. While the new irrigated area would boost rice production by Office du Niger, annual flows of water into the Inner Niger Delta would fall by almost a quarter, reducing its fish trade by 31%, the surface of pasture by 28%, and the production of non-irrigated floating rice by 37% (Wetlands International, 2016).

Reducing conflict in the region of the Inner Niger Delta and similar regions where pastoralists and farmers compete will require a careful balancing of user interests. This balancing of interests is best done via multi-stakeholder dialogues, in which all user groups have a seat at the table.
Successful solutions will also need to address the other key drivers of risk discussed above, including population growth (Mali has an annual growth rate of 3%), soil depletion, drought, and weakened conflict resolution mechanisms. There are solutions to each of these problems, but the task is formidable.

5.2. Water as a Casualty of Conflict – 2014 to 2018 Donetsk, Ukraine

In 2013, the president of the Ukraine, Viktor Yanukovych, sought closer ties with Russia, moving away from an agreement with the European Union. This decision sparked protests and civil unrest by citizens who favored the EU. By early 2014, the demonstrations and the government's response had become increasingly violent (Traynor & Walker, 2014). During this time, several separatist movements, backed by Russian funding, troops, and arms, expanded. This included growing violence in the southern region of Crimea and the eastern portion of Ukraine referred to as Donbass, which has divided into two territories, the Donetsk People's Republic and the Luhansk People's Republic.

The Donbass has seen substantial violence since 2014. In spite of several attempts to instate a ceasefire, fighting has continued nearly daily and roughly 10,000 have died because of it (Vox Atlas, 2018).

Early in the dispute, water systems became a casualty of the conflict. Starting in July 2014 damage to civilian water systems disrupted water service to the city of Donetsk, a city with a population of nearly 1 million people. At one point, the city only had enough water for 5 days of service. As fighting continued gunman fired at a water filtration plant, killing several employees.[2] In addition, the water utility reported that a reservoir was targeted in the Donetsk region, injuring two people (Naharnet Newsdesk, 2014). In 2015 more violence led to damaged water systems. This time the losses occurred in the Luhansk region (AFP, 2015; National Consortium for the Study of Terrorism and Responses to Terrorism, 2018). Civilian lives were also lost during these events.

A brief respite to attacks on water infrastructure between 2015 and through 2016 ended in February 2017 with multiple additional attacks on water systems, causing disruptions to water service to over 2.9 million civilians. At times, disruptions lasted for 24 hours or more (Reliefweb, 2017). One source reported that in the single month of May 2017 there were 15 separate incidents of shelling of water infrastructure (UN Office for the Coordination of Humanitarian Affairs, 2017). In 2018, the violence and targeting of water systems and the civilians who run them continued. In March of 2018 vehicles carrying water utility employees going to and from the Donetsk Filtration Station were fired upon (Dymkovskyy, 2018).

5.3. Water as a Weapon of Conflict – 2017 Somalia

Somalia is a country of more than 14 million people, sitting at the Horn of Africa. Due to its proximity to the equator, Somalia has a warm climate year-round with monsoon winds and irregular rainfall. It experiences average annual precipitation between 100 and 600 mm, with lower amounts of rainfall in the west and higher amounts of rainfall along the coast in the east. Somalia has experienced drought and flood cycles throughout its history, but recent dry spells, such as the drought in 2011, have led to water and food crisis for millions of people (Maxwell & Fitzpatrick, 2012).

Civil war broke out in the country decades ago after the downfall of General Siad Barre, who gained power in 1969 with a military coup and civil war has been a longstanding challenge, with fighting between different clans and religious groups. One group that has arisen from the ongoing conflict is called Al-Shabab. Al-Shabab is an Islamist militant group that has pledged allegiance with Al-Qaeda. Al-Shabab is considered a terrorist organization by most nations around the globe, using tactics targeted at civilians and civilian infrastructure to wreak havoc on non-aligning communities.

One of Al-Shabab's means of fighting is through the weaponization of water. This has taken several forms. In one event in 2014, Al-Shabab was attributed with an attack on levees along the Shebelle River in Somalia, in an attempt, sources claim, to make the roads unusable by military forces.[3] Another means of weaponization of water is through poisoning of water sources so that their adversary would be unable to drink. This has occurred several times, including a 2017 event that left 32 civilians dead, including children (IOL News, 2017). As noted below, this tactic is a clear violation of international humanitarian law that explicitly protect civilians and water supplies. Work is needed to reduce this kind of tactic and attack on water resources.

06

Legal Strategies to Reduce the Use of Water as a Weapon or Casualty of War

Legal strategies offer one example of an approach for addressing water conflicts by limiting the use of water or water systems as weapons or targets. International laws of war—or international humanitarian laws—have been developed to protect civilians and civilian infrastructure. These laws prohibit intentionally targeting civilians, limit military attacks to military objectives, and requires that harm to civilians not be excessive (Cairo Declaration on Human Rights in Islam (CDHRI), 1990).

Prohibitions on using water as a weapon or intentionally targeting core civilian infrastructure go back thousands of years. Documents and texts from early cultures around the world place limits on the conduct of war. In recent years, these guidelines have been explicitly defined and codified by the international community.

> *"Legal strategies offer one example of an approach for addressing water conflicts by limiting the use of water or water systems as weapons or targets."*

6.1. From the 1863 Lieber Code to the 1949 Geneva Convention

In the modern era, the elaboration of codes of conduct during war began to be developed for international laws and agreements in the late 1800s with the Lieber Code of 1863 and the first formulations of the Geneva Conventions (International Committee of the Red Cross (ICRC), 1864; Lieber, 1863; Schindler & Toman, 1988).

The first Geneva Convention of 1864 defined protections for prisoners of war and wounded soldiers. In the late 1860s and early 1870s, the St. Petersburg Declaration and the Brussels Protocol addressed the illegality of actions lacking a clear military purpose and introduced a limitation on certain destructive military tools or the destruction of property "not imperatively demanded by the necessity of war" (Nijhoff, 1915).

These early declarations led to more comprehensive international laws developed by the 1899 and 1907 Hague Conventions and Declarations, whose purpose was "to diminish the evils of war, as far as military requirements permit" and to protect basic infrastructure such as water systems, towns, dwellings, and facilities not being used for military purposes (Kalshoven, 2016).

Following the Second World War, new efforts were made to develop broader legal protections for civilians and infrastructure and the 1949 Fourth Geneva Convention (United Nations Documents, 1949) prohibits deliberate or indiscriminate destruction of property belonging to individuals or "the State, or to other public authorities" (Article 53) and "extensive destruction and appropriation of property, not justified by military necessity and carried out unlawfully and wantonly" (Article 147). The most explicit protections for water-related infrastructure, however, were put in place with the 1977 Protocols to the Geneva Convention.

6.2. The 1977 Additional Protocols to the Geneva Conventions of 1949

Two Protocols to the 1949 Geneva Conventions were adopted in June 1977 with entry into force in December 1978 (United Nations Documents, 1977). Protocol I provides protection for victims of "international armed conflicts" while Protocol II protects victims of "non-international armed conflicts." Both offer language relevant to the protection of civilian water systems.

Protocol I limits the means and methods of warfare that cause "superfluous injury or unnecessary suffering" or "widespread, long-term and severe damage to the natural environment" (Article 35, paragraphs 1-3). It prohibits indiscriminate attacks on civilians and civilian infrastructure

(Article 51, paragraphs 4-5). And it explicitly protects civilian infrastructure critical to the survival of civilian populations including "…foodstuffs, agricultural areas for the production of foodstuffs, crops, livestock, *drinking water installations and supplies and irrigation works*." Militaries are to avoid attacking such installations so as not "*to leave the civilian population with such inadequate food or water as to cause starvation or force its movement*." The Protocols also prohibit attacks on infrastructure "containing dangerous forces" including explicitly "dams" and "dykes" if such attacks "may cause the release of dangerous forces and consequent severe losses among the civilian population."

These agreements refined protections for civilians even when military objectives are claimed. At the same time, it required that combatants not endanger civilians by locating military targets in or near densely populated areas.

6.3. Additional International Protections for Water and Water Infrastructure

Sowers, Weinthal, and Zawahri (2017) describe additional international agreements and guidelines that also limit attacks on civilian infrastructure like water treatment and delivery systems. For example, the 1990 Cairo Declaration on Human Rights in Islam states it is prohibited "to destroy crops or livestock, to destroy the enemy's civilian buildings and installations by shelling, blasting or any other means" (Cairo Declaration on Human Rights in Islam (CDHRI), 1990). The International Criminal Court (ICC) ruled in 1998 that "[i] ntentionally directing attacks against civilian objects, that is, objects which are not military objectives" constitutes a war crime in international armed conflicts (International Criminal Court (ICC), 1998).

The UN Secretary-General stated in 1999 that "The United Nations [peacekeeping] force is prohibited from attacking, destroying, removing or rendering useless objects indispensable to the survival of the civilian population, such as foodstuff, crops, livestock and drinking-water installations and supplies" (UNSG, 1999, Section 6.7).

The humanitarian justification for these protections is based on the fact that access to safe water and sanitation is critical for human health, and that the destruction of water systems leads to enormous human suffering. The destruction of Yemen's water system between 2016 and 2018 led to cholera outbreaks that as of March 2018 killed more than 2200 people and sickened more than a million (Al Jazeera News, 2018).

07
Discussion

As should be clear from the case examples provided above, and from the long history of water-related conflicts, current international laws and approaches are inadequate for preventing water scarcity or access from triggering violence, the use of water or water systems as weapons of conflict, or attacks on civilian water systems. As we learn more about how such conflicts arise, their nature and drivers, and where to focus international attention, new strategies need to be developed for understanding and preventing water conflicts. Data, tools, and analyses collected and provided by organizations such as the Pacific Institute and World Resources Institute can help mobilize a wide range of responses in the diplomatic, defense, and development communities, including improvements in law and policies, expansion of sustainable water management systems to provide safe and affordable water—also an explicit objective of the Sustainable Development Goals (SDG)6, and reduction in poverty that can help as we build institutions capable of managing and protecting vital freshwater resources worldwide.

> *"Current international laws and approaches are inadequate for preventing water scarcity or access from triggering violence, the use of water or water systems as weapons of conflict, or attacks on civilian water systems."*

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Notes

1. The Water Conflict Chronology is available at https://www.worldwater.org.
2. See the Water Conflict Chronology at https://www.worldwater.org.
3. Global Terrorism Database ID 201409010003.


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4

Ensuring Capacity for Water Security: Water Education in UNESCO's International Hydrological Programme

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Abstract

UNESCO's International Hydrological Programme was established in 1975, and has since then carried out a range of water education activities. The nature and focus of these activities are traced, and a series of examples of current water education activities in Asia and the Pacific are provided. On the basis hereof, a set of current trends and developments are highlighted, with particular reference to the increasing transdisciplinarity and diverse delivery mechanisms employed by the programme and its network of collaborating organizations.

Keywords

Water education, UNESCO, International Hydrological Programme, hydrology transdisciplinarity, sustainable development

01

Water Education in UNESCO's International Hydrological Programme

1.1. IHP: A Brief Introduction

UNESCO's International Hydrological Programme(IHP) was founded in 1975 as an intergovernmental water science programme, and has since then been implemented in a series of multi-year phases according to different areas of focus. For the current 8th phase, the overarching focus is "Water Security: Responses to Local, Regional and Global Challenges".

Divided into six thematic focus areas, IHP's 8th phase advocates an interdisciplinary, integrated approach to water management, drawing on and integrating social dimensions of water resources. The six themes are:

1. Water-related disasters and hydrological change
2. Groundwater in a changing environment
3. Addressing water scarcity and quality
4. Water and human settlements of the future
5. Ecohydrology, engineering harmony for a sustainable world
6. Water education, key for water security

As the theme headings make clear, IHP places the hydrological sciences within a wider, societal context that requires science practitioners, educators, communicators, planners and decision-makers to work across disciplinary and sectoral boundaries in order to advance water security at all levels and in this way make a tangible contribution towards the United Nations 2030 Agenda and the Sustainable Development Goals.

"IHP places the hydrological sciences within a wider, societal context that makes a tangible contribution towards the SDGs."

Water education is recognized as a distinct theme within IHP, while simultaneously underpinning the other six thematic areas. In the context of the present-day IHP, "water education" is considered in a broad sense, beyond formal education aimed at future water scientists. Rather than denoting the teaching of the hydrological sciences per se, water education is understood as multi- and interdisciplinary, supporting the advancement of scientific knowledge through a range of distinct approaches that cut across conventional disciplinary and sectoral boundaries. Water education in this sense includes:

1. The training of scientists, water professionals and decision-makers (within and beyond the water sector);
2. The training of mass and community media professionals to accurately and effectively communicate water issues;
3. The development and implementation of community education strategies in support of community-wide water management and conservation, as well as co-management of water resources;
4. The positioning of water as a significant component of the primary and secondary school curriculum (UNESCO, 2012).

While progress towards enhanced water security through these broad areas of intervention certainly requires a strong contribution from water science professionals, it is clear that significant efforts must also be made by actors within other sectors—including national-level decision-makers, formal and non-formal educators, community organizations and the media, all of whom are beneficiaries of IHP water education activities.

In order to arrive at a better understanding of the role of water education within the current IHP phase, the following sections outline and discuss the trajectory taken by the IHP since its formation in 1975, and the positioning of water education within that trajectory.

1.2. Water Emerges: A Historical Perspective

IHP was launched at the close of the International Hydrological Decade (IHD) 1965–1974. The Decade, in turn, had arisen from cooperation emerging during the early years of the United Nations in the 1950s involving UNESCO, other UN agencies such as FAO and WMO, as well as professional non-governmental organizations in the field of hydrology. While this cooperation had focused on the particular needs of arid and semi-arid areas, issues relating to water science and water management were increasingly recognized as deserving of more explicit and focused attention. This focus was granted with the launch of the IHD in 1964 (UNESCO, 2005).

When comparing the scope of work of IHP today with that of UNESCO's pre-IHP water education work in the 1950s and 1960s, the programme's gradual shift towards an increasingly inter- and multidisciplinary platform quickly becomes evident. While considerable attention today is focused on the interaction between hydrological scientists and actors in other fields of science and other sectors of society, the emphasis during the programme's early years was much more focused on interactions between scientists within the hydrological sciences based in different countries and across political, geographical and economic divides.

However, while IHP retained a clear disciplinary focus on the hydrological sciences during its early phases, the need for water education was recognized from the earliest discussions. During the IHD, focus was placed on ensuring sufficient human resources to sustain the future of hydrology—then relatively recently established as a scientific discipline in its own right—through the training of hydrologists and hydrological technicians, in particular in developing countries, and in particular at the tertiary level.

Michel Batisse describes the situation at the start of the IHD as follows:

> *"[…] in most countries, whether rich or poor, hydrologists were practically inexistent. The field had only been approached at a few universities and engineering schools in industrialized countries and then only as a minor appendix to hydraulics or geology, almost never as a completely separate subject. A few scattered individuals had become competent hydrologists, but they were a relative handful and not many of them had actually been trained as hydrologists."* (Batisse, 2005, p. 139).

Batisse further notes that the very existence of an international hydrological research programme would simply not be achievable without a self-identifying global cadre of hydrologists and hydrological technicians. Mobilizing such a cadre through a focus on water education therefore became a priority already during the Decade, to the extent that

> *"[a]ll kinds of resources were pooled to achieve this objective, ranging from individual scholarships, advanced training programmes and scientific seminars to the creation of regional institutes, teacher exchanges, the writing and distribution of manuals and all the other specialized educational or professional training measures that Unesco was accustomed to organizing."* (Batisse, 2005, p. 139).

UNESCO (2005) notes that

> *"To cope with the lack of adequately trained hydrologists, it was decided to put emphasis on training at the postgraduate level. UNESCO provided financial assistance as seed money for the establishment and functioning of ten postgraduate courses in hydrology in various host countries. More than 1,500 specialists—mostly from developing countries—were trained in such courses. In addition, training courses for hydrology technicians were organized in Africa".*

Water education under the IHD in this sense focused on training the scientists and technicians who would populate the new academic field, with particular emphasis on strengthening hydrology in the developing world. UNESCO provided financial support to assist in the emergence of a new global academic discipline in recognition of the importance of hydrological expertise for the provision of knowledge and data deemed essential for global development. The need in this regard was unquestionable—a necessity that helped ensure that water education during the IHD and the early phases of IHP remained strictly focused.

In spite hereof, discussions at the close of the IHD would already provide an indication of changes to come. While water education and training activities undertaken in the context of the Decade were generally met with approval, it was noted that activities targeted to the general public as well as to decision-makers had not been sufficient (Batisse, 2005, p. 178).

1.3. Water Education under IHP-VIII (2014–2021)

The trajectory of water education within the IHP is clearly evident from the introductory paragraphs to theme 6 under IHP Phase VIII under the heading "Water Education, Key for Water Security". The theme is introduced as follows:

> *"[…] water education must be interpreted in a broader sense than the teaching of hydrological sciences and related scientific disciplines. Water education within the eighth phase of IHP includes a multidisciplinary and interdisciplinary approach aimed to advance scientific knowledge through the training of scientists, as well as to strengthen and enhance the water sector through the formation of water professionals and decision makers. Water education also entails working with mass and community media professionals to improve their capacities to communicate water issues accurately and effectively. In addition, the program includes community education strategies to promote community-wide water conservation, as well as skills in local co-management of water resources. Finally, actions to make water a significant component of the K-12 curriculum are considered an integral and important part of the water education agenda".*
> (UNESCO, 2012, pp. 42–43).

"Water education entails working with mass and community media professionals to improve their capacities to communicate water issues accurately and effectively."

The above excerpt makes a clean break with the objectives of training and education programmes during the early phases of IHP. Hydrology is no longer a nascent discipline in need of international efforts to ensure its survival. The challenge to be addressed now is that of engagement far beyond the hydrological sciences themselves—connecting the water sciences with decision-makers, media, local communities, managers and students of all ages. This shift in focus represents at once a considerable achievement for the IHP and related programmes—documenting the establishment and consolidation of hydrology as a fully-fledged internationally connected scientific discipline in its own right—and at the same time a considerable challenge: While the emergence of hydrology as a scientific discipline with significant potential bearing on the sustainable future of communities, nation states and humanity as a whole is indisputable, the need for reinforced education, training and information at all levels at the same time provides an indication that the potential of hydrology for sustainable development had yet to be fully realized.

In other words, while the hydrological sciences are today fully capable of providing knowledge and data with the potential to significantly enhance the sustainable management of water resources, this potential contribution is not yet being sufficiently delivered upon. When the IHP-VIII Strategy notes that water education is “key for water security”, it is in reference to this unfulfilled potential. If water security is to be attained, it requires the unlocking of broader appreciation, acceptance and internalization of basic water science principles and concepts—for which water education is the key.

This does not imply that training of water scientists and technicians is no longer relevant—in fact, it continues to form a significant part of the IHP-VIII strategy under Focal Area 6.1 “Enhancing tertiary water education and professional capabilities in the water sector” and 6.2 “Addressing vocational education and training of water technicians”. However, even here, the focus is broadened so as to refer to “interdisciplinary and multidisciplinary curricula and research initiatives” and professional development of “water scientists, engineers, managers and policy makers in the water sector”. The remaining three focal areas take IHP-VIII’s definition of water science further beyond its original definition, targeting respectively “Water education for children and youth”, “Promoting awareness of water issues through informal water education”, and “Education for transboundary water cooperation and governance”. As the focal area headings show, the majority of IHP-VIII’s water education objectives target engagement with stakeholders and audiences beyond the hydrological sciences themselves.

A significant implication of the evolving understanding of water education and its broadened application is the need for reinforced human, financial and technical resources with which to deliver education, training and capacity development across large segments of society. Not only does this require the mobilization of a much larger contingent of trainers, instructors and conveners—it requires the development of new teaching and learning approaches, methodologies and curricula that address and effectively reach an intended audience ranging from kindergarten students to high-level decision makers.

It is in this context important to note that IHP-VIII was drafted and came into effect during a period of considerable financial constraints for UNESCO, during which austerity measures placed limitations on the ability of the Organization to provide core funding for new initiatives. However, other processes were underway in parallel that provided opportunities for reinforced engagement with and support for the water science and education community.

02

The UNESCO Water Family

2.1. A Brief Introduction to the Family

A specialized agency of the United Nations, UNESCO engages with its members through National Commissions appointed in each member state. According to UNESCO’s constitution, UNESCO member states *“[…] shall make such arrangements as suit its particular conditions for the purpose of associating its principal bodies interested in educational, scientific and cultural matters with the work of the Organization, preferably by the formation of a National Commission broadly representative of the government and such bodies”*. In this sense, National Commissions were from the founding of the organization intended to represent interests from across UNESCO’s mandate—from education to sciences to the humanities to culture and communication —drawing from both government and civil society entities.

With the gradual deepening of UNESCO’s engagement across this broad range of issues during the first decades of the Organization, intergovernmental programmes such as IHP were established, adding their own governance and national counterpart structures. In the case of IHP, member states were encouraged to establish IHP National Committees, which in turn *“form the backbone of the IHP and are fundamental to ensuring the widest possible participation of Member States in the international programme. These Committees are constituted and run under the authority of national governments and play a critical role in the implementation of the IHP”*[1].

As a result of its focus on and engagement with scientific research, UNESCO—and IHP in particular—evolved in close interplay with academic institutions such as national research councils, laboratories and universities, as well as government ministries and departments. Through the IHP National Committees and UNESCO National Commissions, this interplay eventually led to the establishment of member state-funded and hosted structures formally recognized by UNESCO and dedicated to contributing towards the organization’s objectives and priorities. While these structures have taken several forms over the past decades, two principal modalities are today recognized by UNESCO:

1. UNESCO Institutes and Centres (either category 1 or 2); and
2. UNESCO Chairs and UNITWIN Networks

Though they operate with significant autonomy, Category 1 Centres and Institutes are an integral part of the UNESCO programme, supporting research and institutional capacity in Member States. In contrast, Category 2 Centres and Institutes are established and funded by member states to contribute to the achievement of UNESCO’s objectives. They are not legally part of the Organization, but are associated with it through formal agreements between UNESCO and the member state hosting the institute or centre[2].

UNESCO also associates university chairs and networks with programmes and activities across its mandate through the UNITWIN programme, which grants UNESCO-affiliated status to activities and networks within academic institutions contributing toward UNESCO's objectives in accordance with a specific set of guidelines. While these bodies have been established across all of UNESCO's areas of competence, the field of water science has been particularly prolific. Water-related Category 2 Centres were among the first to be established—the International Research and Training Centre on Sedimentation in Beijing, China was established in 1983—and UNESCO recognizes more water-related Category 2 Centres than any other thematic area.

With the emergence of so many national, regional and global bodies working towards UNESCO's water science objectives—at different levels and through different means—the concept of the UNESCO Water Family has gained prominence in recent years. The UNESCO Water Family refers to a collective comprising the UNESCO Secretariat at the Organization's headquarters and in the field, along with the institutes, centres, chairs, committees, commissions and other bodies contributing to UNESCO's water sciences work. The work of the UNESCO Water Family members is an essential complement to that of the UNESCO Secretariat, as expressed in the documents of the 22nd session of the IHP Council:

> *"UNESCO works to build the scientific knowledge base to help countries in the sustainable management of their water resources. This is done through its UNESCO Water Family comprising the International Hydrological Programme (IHP), the World Water Assessment Programme (WWAP), the UNESCO-IHE Institute for Water Education, water Centres under the auspices of UNESCO and water related Chairs and UNITWIN Networks. UNESCO's Water Family operates as a global network that works together to implement the organization's strategic goals".* (UNESCO, 2016).

The UNESCO Water Family in this sense represents a significant extension of UNESCO's reach and engagement with society through water science research, education and networking. While UNESCO works with similar networks in relation to other programmes and topics, the UNESCO Water Family is unique in terms of the sheer number of institutes, centres and chairs that are formally affiliated with the IHP and its objectives, as well as in terms of its explicit recognition by name.

2.2. Education in the Water Family: Examples from Asia and the Pacific

Water education has over the past decades played a prominent role within IHP as well as its affiliated bodies around the world. In a demonstration of the high importance assigned by UNESCO to water education, the IHE Delft Institute for Water Education was in 2003 recognized as a fully integrated UNESCO Category 1 Centre then known as the *UNESCO-IHE Institute for Water Education*—an arrangement that remained in place until 2017, when a process to convert the IHE into a Category 2 Centre—now under the name *IHE Delft Institute for Water Education*—was initiated following an agreement between the Government of the Netherlands and UNESCO. IHE is the largest international graduate water education facility in the world, conferring fully accredited MSc degrees, and PhD degrees in collaboration with partner universities.

While IHE is perhaps the most prominent example of a global IHP-affiliated organization fully dedicated to water education, other UNESCO Water Family members with broader portfolios also undertake formal, long-term water education programmes in collaboration with degree-conferring institutions, producing master's and PhD graduates in water-related fields—as well as a wide range of shorter-term training and education activities. In the following paragraphs, a few brief examples are provided of such programmes implemented in Asia and the Pacific.

One of the most prolific UNESCO-affiliated contributors to water education at the regional and global water level is the International Centre for Water Hazard and Risk Management (ICHARM), hosted by the Public Works Research Institute (PWRI) in Tsukuba, Japan. ICHARM started operations in 2006, and shortly after its establishment began a Master's degree programme drawing students from water management and research agencies in developing countries in Asia and the Pacific and around the world. With particular emphasis on water hazards and risk, the programme has produced over 130 MSc graduates to date. ICHARM subsequently initiated a PhD programme from which 9 experts have graduated. Delivered in partnership with Japan's National Graduate Institute for Policy Studies as the degree-conferring institution, most ICHARM graduates are supported through scholarships offered by the Government of Japan through the Japan International Cooperation Agency (JICA). Thesis topics are determined collaboratively with each student, and usually reflect a key water-related disaster management challenge faced by the student's home institution. This allows for the application of each candidate's newly acquired skills upon their return home after completing the programme (PWRI, 2017).

ICHARM's Master's and PhD programmes exemplify the process by which the original water education mission of UNESCO—educating the water scientists of the future—has expanded both institutionally (through delivery by a member state-hosted and funded institute) and thematically (through the application of hydrological sciences to address water-related hazard and risk management).

It should be noted that the delivery of full Master's and PhD courses remains relatively rare among UNESCO Water Family member institutions. A more common modality for water education offered by UNESCO-affiliated bodies is the short-term intensive training course. Among the most prolific and long-standing courses of this kind is the series

of *Kyoto-Nagoya IHP Training Courses*, which have been organized annually for more than a quarter of a century by the universities of Kyoto and Nagoya in partnership with UNESCO Office Jakarta and with the support of the Government of Japan through various funding mechanisms. The longevity of this training course series demonstrates both the continuing demand for water education opportunities across the region, and the manner in which topics of the courses offered have evolved with the different phases of the IHP as well as in response to urgent and emerging issues in the region.
The table below highlights course titles across over the past decade in reverse chronological order:

Year	Course	Title
2017	27th course	Integrated Basin Management under Changing Climate
2016	26th course	Coastal Vulnerability and Freshwater Discharge
2015	25th course	Risk Management of Water-related Disasters under Changing Climate
2014	24th course	Forest Hydrology Conservation of Forest, Soil, and Water Resources
2013	23rd course	Ecohydrology for River Basin Management under Climate Change
2012	22nd course	Precipitation Measurement from Space and its Applications
2011	21st course	Introduction to River Basin Environment Assessment under Climate Change
2010	20th course	Groundwater as a key for adaptation to changing climate and society
2009	19th course	Water Resources and Water-Related Disasters under Climate Change-Prediction, Impact Assessment and Adaptation

Table 4-1 Course titles over the past decade

As the titles show, a number of key priorities under IHP as well as other UNESCO science programmes are addressed by the courses in accordance with the prevailing IHP theme priorities—from water-related disasters to groundwater, across space-based technologies to ecohydrology and forest hydrology to climate change, the latter being the most consistently applied theme across the last decade of courses.

The course series also serves to illustrate the continuing development of the manner in which water education is delivered through the network of institutions making up the UNESCO Water Family. While all the courses listed in the table were organized in turn by the two host universities, the course for 2018 is organized in the context of a new UNESCO water-related chair established by Kyoto University under the acronym WENDI—a new, multidisciplinary chair dedicated to "*water, energy and disaster management for sustainable development*". The establishment of a chair on such an integrated platform—placing water in a nexus with energy, disasters and sustainability and drawing on multiple departments across the university—is symptomatic of the increasingly multi- and transdisciplinary nature of IHP, through which the hydrological sciences are applied to address real-world issues in symbiotic interaction with other fields of inquiry. Kyoto University's ambitions in this regard are made clear in WENDI's purpose statement, which reads:

> *"WENDI aims to promote multi-disciplinary and holistic approach for research implementation, knowledge transfer and capacity building in the fields of water, energy, and disaster management and linkages to other sectors (food, forestry, biodiversity, climate change and data science). This is done by developing a comprehensive and trans-disciplinary Education for Sustainable Development (ESD) programme for graduate school level to establish 'KU-Model of ESD' and by providing unique international collaborative research using existing UNESCO-Sites including Geoparks, Biosphere Reserves and Cultural, Natural and Mixed World Heritage Sites as the application field[3]".*

In summary, WENDI was established to promote a multi-disciplinary and holistic approach to research and education, delivered through a transdisciplinary ESD programme focusing on UNESCO-designated sites with both cultural and natural properties. WENDI's water education efforts is in this way delivered through a mechanism that explicitly draws upon UNESCO programmes and capacities from across the organization's mandate—from culture to education to the natural and social sciences—with a focus on sites that have been designated and recognized under UNESCO's global intergovernmental site-based programmes: The World Heritage Convention, the Man and the Biosphere Programme and the UNESCO Global Geosciences and Geoparks programme.

While it would be expected that Japan—as a major global and regional donor, bilaterally as well as directly to UNESCO's science programmes—would take a leading role in advancing international water science cooperation, UNESCO-affiliated centres and chairs have been established across member states in the region. In Southeast Asia, the Asia-Pacific Centre for Ecohydrology (Indonesia) and the Humid Tropics Centre Kuala Lumpur (Malaysia) have both implemented a range of water education activities in recent years.

The Asia-Pacific Centre for Ecohydrology (APCE), hosted by the Indonesian Institute of Science (LIPI) in Cibinong near the capital city of Jakarta, has in the recent past emerged as an organizer of international short-term training courses focusing on the emerging transdisciplinary discipline of ecohydrology—itself a theme under IHP-VIII and a concept promoted through IHP since its inception. Established in 2011 with the mission of becoming an internationally recognized centre for urban and rural ecohydrology by 2021, APCE's mandate includes research, training and knowledge exchange, information system development and public awareness.

APCE's first major international event was the *International Conference of Ecohydrology*. The event, organized in late 2014 in conjunction with a series of thematically linked activities, was undertaken with support from the Government of Indonesia in the context of a UNESCO Office Jakarta project aiming at attaining water security in Indonesia and build the regional capacity in the field of ecohydrology.

During 2018, APCE led the organization of two international training courses. A regional training course for Asia and the Pacific on coastal ecohydrology was held in August in the city of Yogyakarta, organized jointly with Portugal's International Centre for Coastal Ecohydrology (ICCE)—also a UNESCO Category 2 Centre—with financial and logistical support from UNESCO. The event combined lectures, field investigations, laboratory work and presentation sessions. Its organization exemplifies the increasing interaction among UNESCO Category 2 Centres located in different geographical regions but linked thematically through—in this case—their engagement with ecohydrology as an emerging discipline.

Joint organization and close interaction between members of the UNESCO Water Family serve to enhance capacities not only among the direct beneficiaries of the training—the participants—but also among the contributing Category 2 Centres, which are provided the opportunity to exchange both scientific and organizational knowledge and experience. For a relatively young Centre like APCE, such exposure represents a significant growth opportunity, and provides an illustration of the indirect benefits of belonging to the UNESCO Water Family—in this case, the forging of interregional professional exchange and cooperation on the basis of a common thematic purpose (the advancement of ecohydrology), formulated and advanced by the IHP.

In November 2018, APCE hosted a second water education event, this time under the heading of the International Initiative on Water Quality (IIWQ). Part of a series of training events organized in Africa, the Arab States, and Latin America and the Caribbean, the event brought together water managers, government officials, and researchers from countries across the region. By hosting and organizing the event, APCE contributed towards the global objectives of a UNESCO-implemented project funded by the Swedish International Development Cooperation Agency (SIDA). In so doing, APCE was able to demonstrate a growing ability to host and lead international events in its field of competence and to contribute through regional action towards a set of global priorities, an opportunity granted the Centre through its affiliation with UNESCO and IHP.

The Humid Tropics Hydrology and Water Resources Centre for Southeast Asia and the Pacific in Kuala Lumpur, Malaysia, commonly abbreviated HTC KL, was established in 1996 and recognized as a UNESCO Category 2 Centre in 1999. Hosted by the Malaysian Department of Irrigation and Drainage, HTC KL pursues four principal objectives, relating respectively to research, networking, education and publication.

In 2017, HTC KL published a three-volume compendium under the title "*Water Management Curricula using Ecohydrology and Integrated Water Resources Management*" as a contribution towards IHP-VIII and with the purpose of contributing to a deeper understanding of the interfaces and interconnections within the water-energy-food nexus and in turn contribute towards a further improvement of Integrated Water Resources Management (IWRM) practice. In cooperation with UNESCO Office Jakarta and with financial support from the Government of Malaysia, the three volumes examined the application of ecohydrology as a tool for the implementation of IWRM across a wide range of contexts—thereby establishing an operational linkage between two concepts advocated through IHP's water education programmes. The curricula were developed under coordination by HTC KL and UNESCO Office Jakarta in partnership with a range of Malaysian universities.

In this manner, the development of water education curricula allowed HTC KL and its host institution to serve as a bridge, linking national academic networks with UNESCO's global water science priorities. Through a recently-approved UNESCO Office Jakarta initiative supported by the Government of Malaysia, the three volumes will in the coming months be adapted to the African context and published in a new, revised African edition. The adaptation will be undertaken in partnership between UNESCO Office Jakarta, HTC KL and its partners in Malaysia, as well as key African water education partners such as the Regional Centre for Integrated River Basin Management (RC-IRBM) in Nigeria. With the publication of this edition, the curricula will serve as an example of the potential of inter-regional cooperation for water education, in turn further extending the reach and potential of the UNESCO water family.

The establishment by the Republic of Korea of the International Centre for Water Security and Sustainable Management (i-WSSM) in 2017 marked a significant addition to the UNESCO Water Family and its water education potential. Drawing on the accumulated technical and scientific experience of its host institution, the K-Water Institute and the wider Korean water sector, i-WSSM has positioned itself as a bridge through which to leverage Korean knowledge and experience to solve water security problems across a range of different contexts. i-WSSM identifies as an international research and education centre with the purpose of supporting water security strategies *for sustainable development*. i-WSSM's focus on sustainable development explicitly aligns the centre with the 2030 Agenda and the Sustainable Development Goals, adopted in parallel with the Centre's establishment.

Since its inauguration in June 2017, i-WSSM has built an increasingly active profile, providing technical support towards a major UNESCO Africa-Asia water security project supported by the Republic of Korea's Ministry of Land, Infrastructure and Transport, and initiating a dedicated programme aimed at addressing water security concerns in Small Island Developing States (SIDS), a group of countries particularly impacted by climate change and variability with resulting water security challenges. i-WSSM's SIDS activities focus specifically on the development of capacity for solving water security challenges in the field through tailored education and training interventions. The first such field-based activity under i-WSSM's SIDS programme is currently in the planning stage in collaboration with UNESCO Office Jakarta.

03

Future Perspectives for the UNESCO Water Family

The brief examples above comprise an—albeit incomplete—image of the current status of water education implemented in the context of the UNESCO Water Family in Asia and the Pacific. As discussed in chapter 1 above, the positioning of water education within IHP–VIII as trans-disciplinary and multi-directional in nature should result in a broad range of water education activities beyond IHP's original scope both in terms of thematic scope and target audience. The examples cited in Chapter 2 have to a considerable degree lived up to this expectation.

> *"IHP water education stresses trans- and interdisciplinarity, linking scientific disciplines and concepts and applying tools and knowledge across a variety of contexts."*

In terms of thematic focus, the IHP water education activities in Asia and the Pacific outlined in the examples cited above stress trans- and interdisciplinarity, linking scientific disciplines and concepts and seeking the application of tools and knowledge across a variety of contexts in support of global sustainable development targets. Furthermore, they increasingly and explicitly associate water education and sustainable development. It is in this sense possible by example to confirm that the transformation of IHP's water education from an endeavor focused on training the next generation of hydrologists has now evolved in several fundamental ways, notably:

1. **Increasing inter- and trans-disciplinarity**: IHP's water education activities today cut across disciplinary boundaries, integrating disciplines and promoting new and innovative approaches to address real-life challenges, as exemplified by the practical application of ecohydrology to IWRM;
2. **Broadening constituency**: While the training of hydrologists remains an important element in the water education activities outlined above, it is by no means the only area of focus. Education activities target a broad range of beneficiaries, including government planning officers, land and water managers, and researchers and educators from across multiple disciplines;
3. **Decentralized delivery**: IHP water education activities are often implemented in partnership with UNESCO and its network of field offices, however with a member of the UNESCO Water Family in a leading role. The delivery of UNESCO programmes through the growing and diversifying UNESCO Water Family represents a significant transformation, vastly extending the reach of IHP's water education;
4. **Stronger alignment with the global sustainable development agenda**: The adoption of the 2030 Agenda and the Sustainable Development Goals contributed to the alignment of IHP's water education activities with a globally agreed agenda, adding additional focus and clarity of objectives. The establishment of i-WSSM in 2017 represents a very tangible example hereof;
5. **Enhanced focus on social issues**: the trends outlined in points 1–4 above all contribute towards an increasingly visible and overt association between IHP's water education activities and its contributions to a sustainable future for all. Where the coupling of IHP's technical contribution with the wider social impact of water education during the programme's early years was perhaps implicit, IHP today makes an explicit contribution towards fostering sustainable societies and responding to social and environmental needs.

This paper has taken stock of the IHP's engagement in water education through a brief review the programme's history and a cross-section of current activities and trends observed in Asia and the Pacific. In so doing, a trajectory has been traced from the programme's beginnings as an effort focused on the consolidation of hydrology as a scientific discipline into a broad platform designed to deliver "science for society" in pursuit of the 2030 Agenda and the Sustainable Development Goals. The emergence of the UNESCO Water Family has played a role in ensuring the continued growth in scope and reach of the IHP during a period of financial constraints, and has provided an indication of a more diverse, complex and decentralized delivery mechanism likely to play a key role in IHP's future.

While the core direction of the IHP and its water education activities are established and disseminated by the IHP Intergovernmental Council, its Bureau and the IHP Secretariat, the institutions and individuals making up the rest of the IHP Water Family—from Category 2 Centres to Chairs to academic and civil society partners—are likely to increasingly serve as the interface between IHP and its growing, broadening constituency. To ensure that the high scientific and technical standards associated with the IHP are retained, this will require continued reinforcement of communication and networking efforts on the part of the IHP Secretariat.

While this certainly represents a challenge for the programme—in particular during a period of financial constraints—it also represents an opportunity for the IHP to reach a larger audience than at any point in its history—and in this way to make a strong and viable contribution towards the 2030 Agenda and the Sustainable Development Goals.

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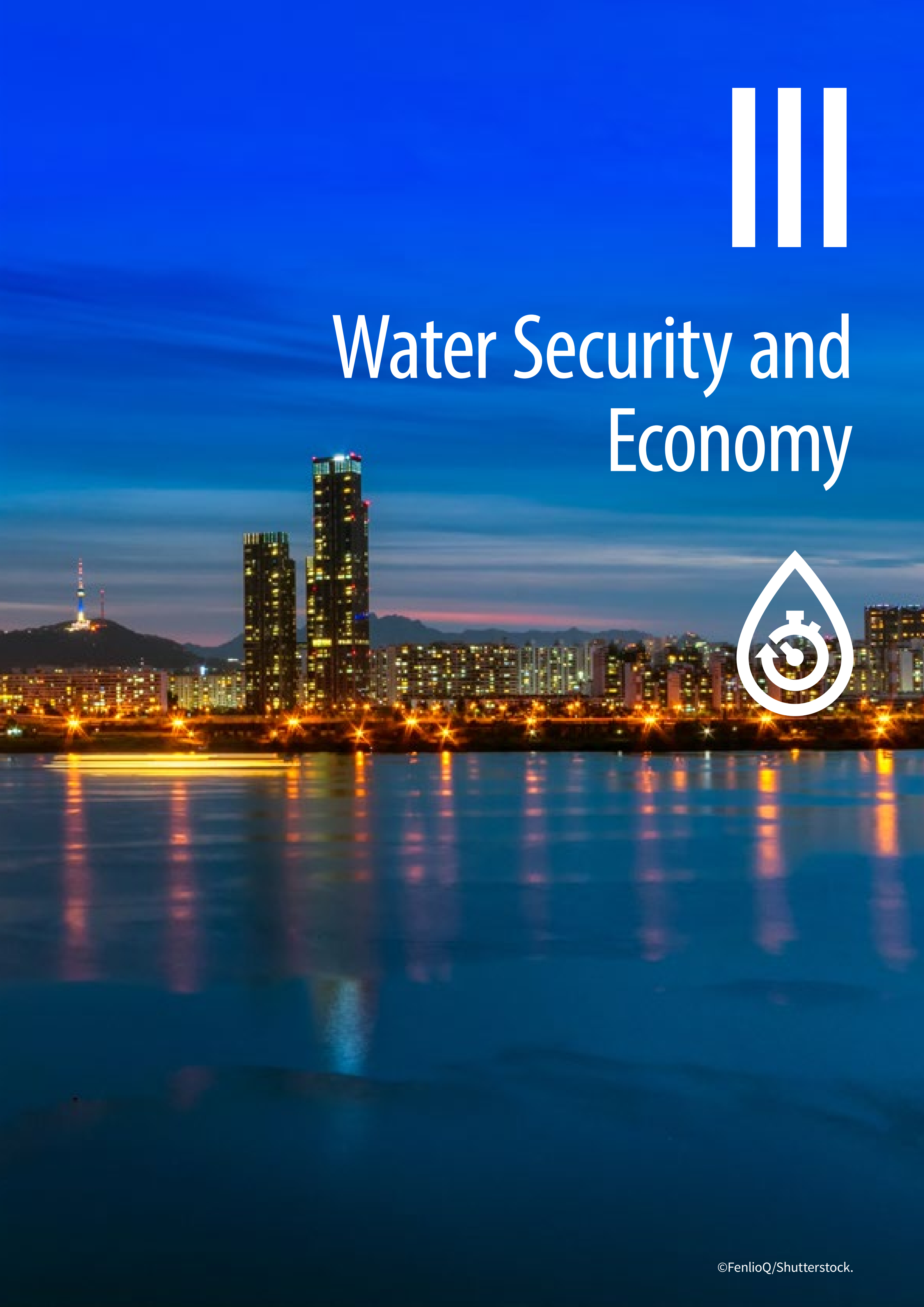
III

Water Security and Economy



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5

Financing Water Security to Support the Sustainable Development Goals

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Abstract

Water security underpins practically all of the Sustainable Development Goals, but it faces difficult financing constraints. While it supports other sectors such as cities, food and health, the water sector confronts many complex issues that require attention. Without realization of the pivotal role of water, supporting governments may weaken attention to other critical sectors. Understanding of this pivotal role faces barriers because the complexity of the water sector leads to general discussions that blur the focus for financing strategies. Examples of valid but general discussions are about confronting risk and return, emphasizing public finance, and improving development finance. The challenge is to pursue these valid goals in nuanced situations involving water supply, sanitation, hydropower and other water sub-sectors. In them, the general situation is that low-income countries need more infrastructure, but are challenged by lack of local capital and capacity, while high-income countries need to renew and get more service from existing capital-intensive systems. Most new large water projects are in developing countries, and financing strategies increasingly involve public-private approaches. At the small-scale watershed level, governance issues are simpler but there is less attraction for investors. Whereas urban systems can often be enterprises, irrigation system finance must align with social issues in communities and lack of capacity for self-finance as enterprises. Urban water infrastructures require large amounts of capital, and the needs will continue to increase as cities grow and expand. At the site level, financing systems for homes or small plots of land will address issues of poverty, including support for local water supplies and smallholder irrigation systems. Ultimately, water organizations serving cities, rural communities and irrigation systems must adopt social missions as well as to provide self-supporting infrastructure systems.

Keywords

Water security, finance, infrastructure, SDGs

01
Introduction

Water security will be an essential element in meeting most of the Sustainable Development Goals (SDGs) by 2030. This is because water is a supporting resource for the urban, food, health, energy and environmental sectors, among others, and its support roles make water unique as a connecting sector as well as a support sector. Among many challenges, the main issue in achieving water security is how to finance it. Water security financing scenarios are determined by the unique attributes of water and the contextual situations in which it is managed. In turn, these are shaped by the multiple jobs that water does and the different types of management systems that it requires.

The congruence between the goals of improving water security and improving water resources management opens up a trove of research about financing water systems. This is evident from a comparison of the definitions of the two concepts. Water security is defined as: *"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"* (UN Water, 2013).

This is one way that water security can be defined. It focuses on the capacity of a population to achieve water-related goals. Capacity is a state variable that measures a level of capability with multiple elements, such as finance, governance, and human resources, among others. Definitions of water management point toward the same goals was water security, but they focus on the process of how you achieve them. For example, the Global Water Partnership (2018) defines Integrated Water Resources Management 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."* Concepts for both water security and water management thus extend across similar goal categories involving water and sanitation, well-being, socio-economic development, protection against pollution and disasters, and ecosystem protection.

> *"Among many challenges, the main issue in achieving water security is how to finance it."*

Although water security has different facets, such as water scarcity and flood damage mitigation, discussions of it tend to generalize. They focus on high-level topics such as policy and international finance, but to understand water security it is necessary to study issues that are unique to local and regional settings and to the specific water issues at hand. Relating to context, there are important differences between developing new infrastructure in low-income countries and addressing renewal needs of aging infrastructure in high-income countries. Context also depends on the water subsector, as for example in the difference between urban water supply and rural irrigation. Governance effectiveness also determines context, which is dependent not only on national income but also on ability to pay, to govern, and to manage. These variables depend on region and culture as well. As elements of institutional capacity, they determine ultimately whether countries can achieve social and economic goals (Graham, 2002).

Regardless of the problem setting, one of the main challenges is to finance water security, which is the focus of this paper in its discussion of strategies for water subsectors and cohorts of problems that occur repetitively in different contexts. Achieving success in financing strategies for water security is formidable, just as it is for the other SDGs (United Nations, 2018), but by explaining the situations in the water subsectors and problem archetypes, the opportunities to make improvements can be clarified to help inform the international dialogue about water security globally.

An important driver affecting water security is demographic change. By 2014 the world's urban population had increased to 3.9 billion from just 746 million in 1950, and about 54 percent of people lived in urban areas. The most urbanized regions are North America (82 percent), Latin America and the Caribbean (80 percent), and Europe (73 percent). Africa and Asia are still mostly rural, with 40 and 48 percent of people living in urban areas. However, Africa and Asia are urbanizing quickly and projected to reach 56 and 64 percent urban by 2050, which will bring huge numbers of people into cities. At the same time, the world's rural population is expected to decline from a peak of 3.4 billion to 3.2 billion by 2050. About half of urban people are in settlements of less than 500,000 and only about one in eight lives in one of the 28 megacities with more than 10 million. The fastest-growing urban areas are medium-sized with less than one million inhabitants in Asia and Africa (United Nations, Department of Economic and Social Affairs, 2014). The implication of these forthcoming changes is that most of the capital investment required for water security will be in urban areas, although many needs will still exist in rural areas. The financing scenarios for the two situations will, of course, be much different.

Although much is known about the gaps in financing water security (World Water Council and OECD, 2015), solutions still seem out of reach. Most studies mention the difficulty in finding a focus (Winpenny, 2003), which is required to illuminate the financing issues of the facets and contexts of water security. The next section reviews the broad picture provided by past studies and addresses institutional capacity for water management across its subsectors. It identifies problem archetypes by aligning types of water scenarios with institutional issues and demographics of the people involved. The goal is to present a comprehensive view of methods, challenges, roles and needed actions to strengthen water security financing across the contextual situations.

02

How the Water Subsectors Support the SDGs

The SDGs aim at sustainable development across multiple sectors and reflect society's aspirations for ending poverty, protecting the planet and ensuring peace and prosperity. As these are interconnected in nexus arrangements, it is difficult to explain how one mission area, such as water security, impacts a particular SDG. While water is mentioned in only one of the SDG goals, it clearly relates to others through its connector attribute. To illustrate the connections, Figure 5-1 shows the 17 SDGs in two groups, one that is impacted directly by water management and another group which supports water security. More details can be explained and there will be exceptions to the display, but it illustrates how sector issues depend on water security.

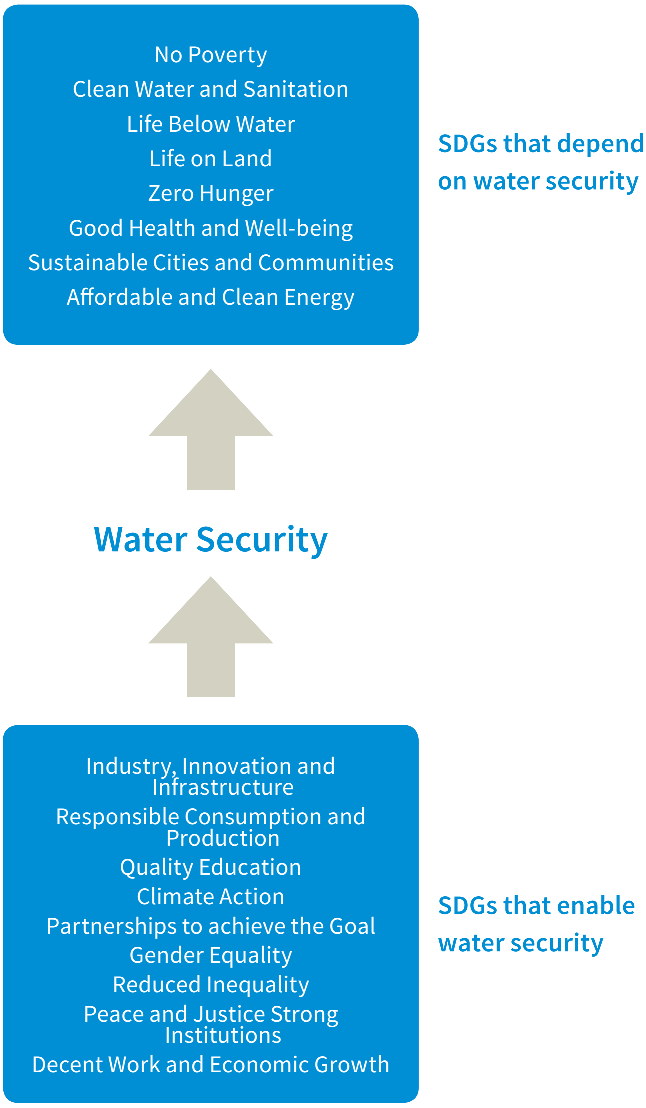

Figure 5-1 SDGs as they enable and depend on water security

03

Review of Water Sector Financing Needs

The first study of water infrastructure finance to support the Millennial Development Goals (MDGs) was the 2003 Camdessus report, sponsored by the World Water Council (WWC). While it focused on water and sanitation, it also addressed the general elements of water security (Winpenny, 2003). The report explained how conditions such as good governance and government commitment to water issues are necessary for successful financing, and it listed good practices such as to use existing financial vehicles and to remove barriers to financing. The roles of main parties were identified, such as central and local governments, water authorities (sub-sovereigns), community organizations and NGOs, and the investment community. The Camdessus report identified a main difficulty that is central to this present discussion, which is that each water subsector has its own issues and by lumping financing issues together for all parts of the water sector, important nuances are missed.

The Camdessus report's recommendations were reviewed in 2006 by a Task Force which focused on financing for new water infrastructure in developing countries and upgrading networks in advanced economies (Gurría, 2014). It recognized that new sources of funding are needed for changed times and that best use should be made of available finance. It noted how water infrastructure is financed by tariffs, taxes, and transfers (3Ts), but each poses challenges. Tariffs are constrained by limited willingness-to-charge for domestic water services and irrigation, as well as affordability issues. Tax revenues are unstable, especially in countries undergoing fiscal consolidation, and water investments compete for public funds with other priorities. Transfers from the international community can help finance water infrastructure in developing countries, but are less effective at financing operation and maintenance.

As a result of the studies and task force work, recommendations converged toward a consensus about needs for reform such as to have water action plans for central and local governments, to use sustainable cost-recovery policies, for central governments to facilitate access to finance for local governments and help develop local financial markets, to use long-term maturities with affordable interest rates and to develop pooling mechanisms for funding (Payen, 2006).

These reports were followed by further studies by the World Water Council (WWC) and the Organization for Economic Cooperation and Development (OECD), which organized a High-Level Panel on Financing Infrastructure for a Water-Secure World (WWC & OECD, 2015). Its report entitled "Fit to Finance" focused on alignment of financing needs with funding sources. The title implies the quest for financing strategies that are up to the job required. This study also confronted the dilemma of many different situations and many different channels of finance. In the report, Benito Braga, the President of the WWC, referred to this dilemma as the "nuanced" status of water sector reform, which is the same as to characterize it as depending on which sector and which context is involved.

Given the focus on aid and multilateral financing, the studies tended to focus on general issues of infrastructure projects rather than sector management issues involving operations and management, along with needs for renewal of legacy infrastructures. Water security involves more than new projects and requires stakeholders to also address issues that fall off of the radar screen of project financing. Projects are a convenient focus for financing because they have beginning and end points and they usually develop infrastructure, which can be used to secure debt.

Water security financing involves many players. To underscore the challenge of explaining the multiple layers of responsibility and resulting financing challenge, the stakeholders are listed here: governments, financial regulators, industrial water users, land and property developers, banks and other commercial financing and investment institutions, water utilities and service providers, individual water users and consumer groups, international, regional or basin agencies, networks and research bodies, international financing institutions, donor agencies, and civil society organizations and educators. While not all stakeholders have central roles in finance, they influence either the sources or uses of the funding.

Given that studies showed many complex situations of water security finance and to clarify the actions needed, the WWC (Money, 2018a) condensed the actions to ten. In the list below, note that the focus is on project finance and does not extend very much to operations, maintenance and programmatic issues:

Develop a Typology of Water Infrastructure Projects.
This should help to align projects with appropriate funding in terms of scale, status, function, and operating environment.

Develop a Typology of Water Infrastructure Investors.
This will help align projects with accessible financing in terms of source, risk and return appetite, and mandate.

Broaden the Attribution of Risk and Return.
This addresses perceived risk and return because return is usually assessed as financial, while not financing infrastructure should also be evaluated.

Renew the Emphasis on Public Finance.
This addresses the need for predictable and dedicated financing from the public sector for safe and affordable drinking water.

Exploit the Opportunities of Purposed Finance.
This relates to financing for issues such as low carbon, climate resiliency, sustainability and regional initiatives, among others.

Optimize the Value of Development Finance.
This would exploit the capability of development finance to convene investors and financiers to increase bankable projects.

Improve Project Selection and Development.
This recognizes that financing gaps can be partially bridged by improving existing practices of project selection, delivery, and asset utilization.

Distinguish between Capex and Opex.
This addresses that in emerging markets and developing economics funding for capital expenditures is often easier to obtain than funding for operating expenditures, but both are needed.

Explore Hybridity and Blended Finance.
This emphasizes that blended finance and hybrid models (such as leveraging traditional sources and mixing sources in multipurpose projects) should be considered.

Revisit Tariffs, Taxes and Transfers (3Ts).
This seeks to unlock funding by innovative approaches such as basing tariffs on user volumes or social issues, by taxing property values enhanced by new infrastructure and by transfers to fund infrastructure that mitigates climate change.

These ten actions are a summary of recommendations from earlier reports, which addressed similar issues but from different perspectives. Generally-speaking, the topics they addressed included governance, strengthening of sub-sovereigns, development financing, new sources of finance, targeted aid, debt, NGOs and financing public-goods, among others.

In conclusion, the earlier reports provide a good framework to guide decisions and actions toward improving water sector finance, but to understand the situations in the water subsectors and in contextual situations, it is necessary to drill deeper and to explore needs other than financing of projects.

04

Financing the Water Subsectors

With the general recommendations from past studies as background, the subsector issues can be examined to reveal their unique and compelling requirements. They can be organized by scenarios through a classification system. This need was expressed by the WWC (Money, 2018b): "*In order for this investment case to be made effectively, we believe that there is the need to develop and use a typological framework of projects that recognises the heterogeneity of water infrastructure as an asset class.*" This approach covers projects (by scope, system, structure, security and sustainability) and investors (by mandate, motivation, materiality, mobility and momentum). However, it does not explain the uniqueness generated by the subsector and contextual issues.

The WWC study identified the importance of including non-financial returns by arguing that it is necessary to "*…re-frame the value proposition around non-financial returns on water infrastructure investment if the SDGs are to have a realistic chance of being met.*" Assessment of non-financial returns is critical to evaluate needs for water infrastructure because benefits such as improved health, access to water for lower-income populations, and environmental improvement are critical societal issues but may not demonstrate high economic and financial returns.

A useful way to classify water infrastructures is by their use in subsectors and by scale (Grigg, 2017). The subsectors align with water management purposes, such as water for cities or for irrigation. Also included as water management purposes are instream flow uses and flood control and drainage services. These purposes use different types of infrastructures at different scales. This separates subsectors by large scale at the river basin level, medium scale at the watershed or city level, and small scale at the site level, which corresponds to an individual home or small plot of land.

The subsectors are grouped as shown in Figure 5-2, with storage and conveyance as infrastructures that normally serve multiple management entities at medium-to-large scales. Major dams and river works, in particular, are found on larger streams and require special attention for their financing. These can be found at smaller scales as well, as in small dams serving local watersheds. At that scale they can be included with infrastructures for water services.

Water and wastewater services normally serve user needs at small or medium scales. These range from large cities, which can be medium scale, to smaller towns down to settlements of only a few dozen people. Irrigation systems are similar, serving from small-to-medium scale, depending on the size of the irrigated areas.

Instream flows represent the water commons and occur at all scales of small-to-large streams, but in different ways. There is a large gap, for example, between recreation on a small local stream and a giant hydropower development on a major river.

Flood and drainage systems occur at all scales, but also in different ways. At larger scales, the infrastructure might comprise major flood control reservoirs, while at smaller scales the services might focus on urban stormwater.

Each column in Figure 5-2 has a water system category that varies by scale and each cell represents a distinct scenario of ownership, responsibility and scale. Financing also varies by context, mainly by income and governance effectiveness.

Each cell shown on Figure 5-2 represents a different financing situation. By categorizing the instances shown, the major financing scenarios for water infrastructure can be organized by water management purposes and by scale (Table 5-1):

	Storage & conveyance	Water services	Instream flows	Flood & drainage
Large scale	Dams and river works		Navigation/Hydropower Water quality/environment	Flood control
Medium scale	Pipelines and canals	Water supply and wastewater Irrigation system		Stormwater systems
Small scale		Household system Site irrigation		Site drainage

Figure 5-2 Classification of water infrastructure systems and instream flows

	Site or household scale	Watershed/urban scale	River basin scale
Storage and conveyance		Watershed level storage and conveyance systems	Large dams, river controls, conveyances
Water and wastewater	Household and on-site water and sanitation	Urban water and wastewater systems	
Irrigation and drainage	Site-level irrigation and drainage systems	Irrigation and drainage systems	
Instream flows		Watershed-level instream flows	Instream flows in rivers
Flood and stormwater	Site-level drainage systems	Urban stormwater systems	Larger flood control systems

Table 5-1 Financing scenarios for water infrastructure by purpose and scale

These categories can be grouped further into five clusters with common approaches for financing:

- **Group 1**: River basin scale infrastructure (large dams, river controls, conveyance channels and pipelines; river basin hydropower, navigation and protection; and larger flood control systems)
- **Group 2**: Watershed level infrastructure (watershed level storage and conveyance systems, watershed-level hydropower, navigation and protection)
- **Group 3**: Irrigation systems (irrigation and drainage systems)
- **Group 4**: Urban water systems (urban water and wastewater systems urban stormwater systems)
- **Group 5**: Site-level water systems (household and on-site water and sanitation systems, site-level irrigation and drainage systems, drainage, including green infrastructure)

Figure 5-2 also showed instream flows, but they depend on actions with other infrastructures and do not normally require additional investments, while they do require effective water management.

The following sections discuss the financing scenarios for each category of water infrastructure from large-to-small scale according to context. From the discussion, financial roles and needed reforms are identified. It is well to remember that in addition to infrastructure, effective planning and regulation must also be provided as enabling factors.

4.1. Large-Scale Multipurpose Projects

In project financing, large-scale multipurpose projects gain the most attention due to their major positive and negative impacts, which have spawns a series of studies in recent years (World Bank, 2004; Bird, 2006; World Commission on Dams, 2000). These include dams, river works, and large-scale water conveyance infrastructures, such as China's South-to-North Water Transfer project or Libya's Great Man-Made River project (WWC & OECD, 2015; Qantara.de, 2017; Water Technology, 2018). They are normally at the river basin scale and beyond the scope of most local and state governments. Sponsors of such large schemes are at the national government level, and may be ministries, departments, or special authorities organized to manage the projects. For example, in the U.S., the agencies in charge for most large projects are the U.S. Army Corps of Engineers and the Bureau of Reclamation. In China, the Three Gorges Project Development Corporation was organized for construction of the dam, and now has become a dam development organization seeking international contracts (China Three Gorges Corporation, 2018).

For the most part, large projects are already built in high income countries (HICs) with most current development activity in the low income countries (LICs). This trend can be seen in new installations of hydropower, where recent growth has been fastest in East Asia and the Pacific, South America, South and Central Asia and Africa. The exception is Europe, where momentum in pumped storage development is evident (International Hydropower Association, 2018).

Hydropower is the driving force for most current projects (International Journal on Hydropower and Dams, 2017) because it can provide marketable benefits, while but benefits such as navigation, flood control, environmental enhancement and recreation will be difficult to finance using market mechanisms. For this reason, governments must retain stakes in multi-purpose project development to support non-market benefits.

Some nations place a major focus on dams, as for example Switzerland with an energy strategy to 2050 that refers to itself as "hydropower country." Several countries in Latin America, such as Brazil, Colombia and Venezuela, depend heavily on hydro for energy production, making them more vulnerable to drought and climate shifts. This vulnerability occurs because a drought will cut generation capacity, whereas a country relying on coal-fired plants can draw down its fuel reserves as needed. The largest growth in generation has been in China and Brazil (BP Global, 2017; World Energy Council, 2017). China's installed hydro capacity is at 320GW, with 16GW of new capacity commissioned in 2015 and plans for a further 60GW of capacity and 120GW more under construction or approved for development by 2020. Nepal has over 100 projects underway and plans to increase its total capacity to 10 gigawatts within a decade (Stacey, 2017).

"In project financing, large-scale multipurpose projects gain the most attention due to their major positive and negative impacts."

In the LICs, financing from multilateral institutions may be required, although financing sources are diversifying beyond these international institutions. As shown by examples that follow, consortia of national and private interests are able to assemble needed support for some projects. Although the World Bank cannot finance many dams, its policies set an international tone for them and other development banks follow similar policy lines. Reengagement of development banks will not be sufficient for needs and greater private investment is required. This is evident from recent projects, where much of the financing is by public-private partnerships.

To illustrate, financing for the Three Gorges Dam involved the China Development Bank as the primary lender, with substantial private sector support and without support from the World Bank. Support was also provided from companies and banks from Canada, France, Germany, Switzerland, Sweden, and Brazil. Export credit agencies were an important source, such as Canada's Export Development Cooperation, Germany's Kreditanstalt für Wiederaufbau and Switzerland's Bundesrat Exportrisikogarantie. Private banks in Germany also helped to finance the project in exchange for contracts directed to its national suppliers (O'Hara, 2005).

As another example of diversified finance, Ethiopia's approach for its Grand Renaissance Dam uses bonds, taxes and local donations. Ethiopians at home and abroad contributed $350 million, with government workers contributing large amounts. The country tracks tax compliance with a computerized system and has explained how taxes are funding the dam and related needs. Some think that this approach could slow progress, but the government believes that sale of electric power will offset the risk (Ighobor & Bafana, 2014).

As still another example, the planned Inga 3 dam in the Democratic Republic of the Congo could eventually involve the African Development Bank, World Bank, French Development Agency, European Investment Bank and Development Bank of South Africa, as well as project developers (Vidal, 2013). World Bank funding was withdrawn in 2016, but the timetable for the project has been pushed back and new financing approaches may emerge.

Large infrastructure systems provide the basis for some flood control, but it is widely-recognized that structural measures do not provide adequate protection and integrated approaches are needed. As a project purpose, flood control does not lend itself to financing by according to benefits, and projects must be supported by public funding, primarily taxes. However, the shift of responsibility to individuals and property owners means that flood insurance has come to dominate the financing picture, at least in high-income countries. For example, in the U.S. the flood insurance program dates back to 1968 and has spawned many studies and projects to improve security against flooding. The insurance is subsidized by federal funding, but attempts to put it on a pay-as-you-go basis continues.

Large water infrastructure projects face future financing challenges, which the OECD summarized as requiring business models to grapple with operation and maintenance, lower-than-expected performance and unforeseen risks and negative externalities (Naughton et. al., 2017). These future challenges will focus on the tension between large economically-viable schemes and social and environmental issues and, with multiple partners, there will be competition for the benefits.

4.2. Irrigation Projects

Irrigation infrastructures support the SDGs through food security, among other contributions. The central issue is that financing for it must confront its social aspects and less-than-market financial returns. This reflects the dilemma of farm policy itself, that a purely market approach does not provide security against the vagaries of crop production and food security, or even for the health of rural communities themselves. As a result, financing for irrigation projects must confront issues ranging across the economic, social and environmental categories.

Regardless of their financing challenges, irrigation projects are important because, in addition to being critical for the SDGs, irrigation water use is dominant where it is practiced as it accounts for about 70% of total water withdrawals to water some 330 million square km globally (World Bank, 2017). Land and water constraints indicate that the potential for new large irrigation systems is limited, and future emphasis will be on systems rehabilitation and implementation of new irrigation technologies to raise productivity of existing irrigated lands. Renewed momentum in irrigation improvement projects is evident and new technologies, such as smart systems, are promising.

The extent of the needs is uncertain because there has been little comprehensive research about irrigation investments to sustain the infrastructure (Ward, 2010). The main issue is whether investments are needed in infrastructure or whether management improvements can offset needs, including for farmers with small plots who are engaged mainly in subsistence agriculture and only limited cash crops (smallholders) (Pittock *et al.*, 2017).

No matter the case for large projects, irrigation infrastructure for smallholders will be a priority for food security, rural stability and poverty alleviation (Makin, 2016).
Irrigation system managers see their jobs as integrated with food security and rural development, including water and sanitation (Avinash, 2017). Smallholder support is more of a local credit/agricultural financial issue. This linkage of irrigation with other sector issues in rural communities means that integrated financial approaches are required.

Whether large or small systems, user fees rarely pay full irrigation system costs, and revenues to maintain and repair systems are scarce. In many cases, irrigation water is free, reflecting the political aims of governments for goals such as rural stabilization and food security. This means that capacity-building among farmers and support for water user associations are critical elements for the SDGs. In terms of project development, by linking irrigation with other water uses, financing schemes for multipurpose projects can be created.

4.3. Urban Water Systems

Among the water infrastructures, urban systems are the most capital-intensive and will require the greatest investments in coming years to support the SDGs. As explained earlier, most people live in urban areas and the percentage will grow. Africa and Asia will experience the greatest number of new urban arrivals. As cities develop and expand, access to safe water and sanitation will depend on development of water and wastewater infrastructure systems. Although most attention is given to these systems, stormwater is a closely-related service, and the three together make up the urban water system.

The financing challenges of these systems vary widely because many types of organizations provide services in different types of cities and contextual situations. This creates multiplexed situations, which is another way to say that they are nuanced and difficult to classify. The highest profile global issues are safe water and sanitation, which are discussed later under site-level water issues. This section is about financing larger-scale water systems with the focus on water supply as the highest-priority of the urban services.

Water supply management organizations range in scale from small community groups to large and sophisticated international corporations. Their financing needs and capabilities vary as widely as the types of organizations do. Examples of large water supply systems are megacities like New York or São Paulo, which serve millions of people. Financing and management capacities in large cities will normally be much greater than in small water supply organizations, which struggle to manage infrastructure and meet standards around the world. Data about the many small systems are diverse and scarce (WHO, 2014).

Financing requirements depend on type of organization, which vary from business-oriented large utilities to small community organizations, which often depend on voluntary help. A view of the types of organizations may be derived from the classification by the International Benchmarking Network for Water and Sanitation Utilities (IBNET, 2017), which is funded by the World Bank and has information on some 4,500 utilities from about 130 countries and territories (Danilenko *et al.*, 2014). These include: local or national government water department (ring-fenced and not ring-fenced); statutory bodies; and providers operating under commercial law, to include joint government and private providers, privately owned providers, and not-for-profit providers.
Whereas government and private business ownership are common, many less-formal water user associations or community water systems are also in operation.

Water supply organizations are businesses with social purposes, but the ideal situation is for them to be operated as enterprises and collect their full-cost revenues from users. In practice, this can be difficult due to stratified incomes in urban areas where affordability is a major issue. The capacity of urban water systems to be financed thus depends on the economics of the service areas. An affluent community with little poverty will not face the same challenges as a city with many low-income citizens. An example of the latter is Flint, Michigan, which has experienced severe problems with its water distribution system.

Given the many types of cities and water supply utilities, national governments or donors will have difficulty in deciding where to support capital or operating costs of water supply utilities. Even if subsidies are provided for capital construction, without adequate operations and maintenance financing, the systems will falter. Ultimately, methods of self-finance must be found.

The preferable way to finance water supply utilities through self-finance is with full-cost rate structures. Many types of rate structures can be designed to provide funding and incentivize management issues such as conservation and support for low-income people. One type of rate structure to meet needs of low-income people is cross-subsidy by higher-income users within a system. This can cause controversy if the higher-income customers resist the charges. Another form of subsidy is a transfer from a different financing entity, whether a higher level of government or external partner. These are attractive to utilities but not sustainable in the long run. Loan programs can be useful, such as in revolving loans managed by infrastructure banks. These are like development bank loans, which can be at market rates or subsidized. They can help utilities with capital expenditures, but they must ultimately be repaid.

Privatization seems appealing to some, but it has pitfalls if social issues are not addressed. It may work well in some situations, but can backfire if the needs of all people are not met, regardless of income. The risk of privatization can be seen from the experience in Cochabamba, Bolivia, where massive protests arose in response to a privatization program.

Ultimately, the success of financial strategies will be a function of the effectiveness of utility management, so the most promising strategy is improvement in utility management and to derive the best performance from the financing that is available. There are global programs to improve effectiveness of utility management (IWA, 2017), but utilities face high hurdles. Concerns they report include inability to raise rates for needed improvements, falling revenues and delinquent customers, customer attitudes that water should be cheap or even free, politically-motivated decision makers reluctant to approve rate increases, access to water supplies, aging infrastructure, water quality, and security from sabotage or other threats.

“Among the water infrastructures, urban systems are the most capital-intensive and will require the greatest investments in coming years to support the SDGs.”

Regulation has proved necessary to oversee performance of water utilities. In addition to water allocation, regulation is needed for health and safety (such as to maintain safe drinking water), rates and charges (such as rates of a private water company), and service access and quality (such as adequate water pressure). The possibility for successful regulatory systems depends on governance arrangements, and no one size fits all.

Water supply utilities are changing from centralized, government-dominated and supply-side models to flexible organizations with new tools such as smart systems, demand management and private sector participation. Competition may increase in the future as people may have more choices, whether to draw drinking water from the tap, purchase bottled water, or install point-of-use treatment devices.

In support of integrated strategies, a trend to watch is the rising use of reclaimed water. This opens new possibilities for utilities where reclaimed water becomes a third water utility to go along with wastewater and potable water. Reclaimed water can be used for non-potable applications such as landscape and agricultural irrigation, toilet flushing, industrial process water, power plant cooling, wetlands and groundwater recharge. In some cases, it can become the raw water supply for drinking water. Examples include Windhoek, Namibia (Espinola, 2017) and Wichita Falls, Texas (Martin, 2014).

Wastewater service is different from water supply. Globally, its availability is highly variable, from functioning systems in some cities to those with no treatment at all. From the time of early human settlements, disposing of wastewater was necessary for sanitary living conditions, but only in recent decades have modern wastewater-handling systems emerged. Wastewater systems evolved slower than drinking water systems because people are less willing to invest in them than they are to invest in water supply. People may support sewers to remove wastewater, but they do not see the need to treat the wastewater for the next community downstream.

To address this problem generally requires government action and regulation. For example, in the U.S., the 1972 Clean Water Act launched a new era in wastewater infrastructure construction with massive subsidies. Today, wastewater management in the nation is as large as the water supply business and facing its own independent financial challenges. Wastewater systems also require monitoring and enforcement for environmental water quality control, which must also be financed.

While residential wastewater customers are the same as those for water supply, commercial and industrial enterprises can have unique needs in factories, office complexes, food and beverage outlets, hospitals and medical facilities, as well as in schools and sports or performance venues. Industrial wastewater systems may be attached to centralized systems or stand alone. Manufacturing and process industries may be connected to networks and be subject to pre-treatment regulations, or they may have their own discharge permits.

Most urban wastewater service is provided by government-owned systems. A wastewater utility may be a division of a city government or a special district that is organized under state laws. Many other types occur in rural areas, including small businesses, associations and auxiliary enterprises connected to other organizations. The service of wastewater collection in sewer systems may be unbundled from treatment operations and operated by separate management units. This unbundling can open the way for private sector participation. Investor ownership of wastewater utilities is less common than water supply utilities, but contract operation of wastewater treatment plants is common.

In the wastewater sector, high-profile issues will have public policy implications such as aging infrastructure and water pollution. The issue of “out of sight, out of mind” looms large, and wastewater may not compete with larger political issues as public concerns. Risk would not seem as large an issue for wastewater as it is for water supply, but infrastructure failures, regulatory violations, pollution, disease outbreaks, and sabotage are still large risks. If you add the overall risk to society from poor environmental water quality, then the risk needle turns to red and indicates rising concerns.

As in the case of water supply, governance and good management will be the most important issues for the future. Self-finance is more challenging for wastewater utilities than it is for water supply utilities. Financing wastewater treatment plants and sewer networks will be a major issue in the future. For example, the U.S. has seen continually-increasing rates as the initially-subsidized systems begin to wear out.

The future of wastewater systems may open new avenues for finance. Wastewater services connect with the issue of point sources in water pollution control, so charges for polluters are a financing avenue. Wastewater infrastructure also enables better access to sanitation, which provides an essential barrier against waterborne diseases. Resource recovery in the Utility of the Future can be another source of finance (Water Environment Federation, 2013).

Stormwater services are an emerging part of urban water systems. They are important not only for quality of life in cities but also linked to public health. The basic service provided is drainage of sites and streets. One aspect is convenience drainage and another is to protect people and property along urban waterways. When stormwater discharges to streets, it drains through systems of gutters, overland flows and underground pipes that discharge to local streams and ditches. When flows increase, they begin to cause damage as urban flooding. Green infrastructure is used increasingly to mitigation stormwater pollution and improve livability in cities.

Stormwater services are more difficult to classify than water supply services are. Organizations with stormwater services range across local (city and county) government departments of public works, utilities, street management and environmental services, state transportation departments and special drainage and flood control districts. Towns and cities have stormwater programs located in different departments and divisions. Their organizational locations range widely. Location with street management and public works programs is common, but stormwater is increasingly located with water and wastewater services as an integrated utility.

As an example of the importance of stormwater systems in emerging cities, China has developed a "Sponge City" program. Beginning in 2014, it includes low impact development and additional urban water management strategies. Sixteen cities were selected as pilot cities in 2015 and the government provides subsidies for three years. The choice of the initial cities reflects the diversity of situations. Public-private partnerships are to be used in construction and operations, and the Chinese central and local governments are seeking ways to sustain financial support (Li *et al.*, 2016).

Financing of stormwater services is similar to wastewater and fees for them can be assessed in many cases. They can also be associated with local floodplain management programs and qualify for tax support. However, the difficulty of measuring stormwater benefits means the facilities are difficult to finance and, as cities developed their stormwater and flood plain management programs, they faced many dilemmas about how to finance them. In the U.S., cities began to realize that the property tax was too limited as a financing mechanism for stormwater and the concept of the stormwater utility was born. The idea of the stormwater utility is that the service provided and its beneficiaries can be identified and measured and that user charges can be levied accordingly. The legal standing of the fees and charges is based on specific benefits, which are mainly found in the drainage of private property.

Financing under the stormwater utility concept has some problems. It is difficult to separate general and specific benefits of stormwater facilities because drainage systems are inter-connected and it is difficult to identify exactly who pays and who benefits for each project. As long as fees are uniform across a city, there seems to be little controversy over their use instead of a general tax.

Recognizing the increasing pressure on water management in urban areas, there is interest in creating more integrated approaches to development and management of urban services. The approach involves measures such as wastewater recycling, stormwater harvesting, dual water systems, and point-of-use treatment systems, instead of centralized distribution. These approaches are in an evolutionary stage, but they have the potential to increase the performance and effectiveness of urban water management and consequently to open new avenues for financial solutions.

4.4. Water Security at the Site Level

The concept of water security at the site-level illuminates the differences between financing formal, organized utility services and financing the last step of access to services. The issue is about the difference between access points, such as in housing, and the delivery of services by utilities. Access is like whether demand is satisfied and service provision is like whether supply is adequate. Supply is the domain of the organized water sector, whereas access also depends on the housing or health sectors. While the nuance may seem slight, it becomes important in the discussion of roles and responsibilities.

The financing issue of access to safe water ranges across scenarios from services offered by utilities in large cities to providing individual systems in urban or rural areas. There is a large difference in water security between water system customers with 24/7 safe water services and those who may live in cities but do not have safe and reliable water connections and, in some cases, no access at all.

Site-level water supply services are highly-variable. Statistics on them are maintained by the Joint Monitoring Program for Water Supply and Sanitation (WHO & UNICEF, 2015). They include urban access and rural domestic self-supply systems. Site level services also apply to commercial and industrial water systems which are self-supplied. Sanitation access is different, and relates less directly to water security, although from a health standpoint it is also related.

The JMP (WHO & UNICEF, 2015) reported that in 2015 some 71 percent of the global population or 5.2 billion people had access to "safely managed" water supplies. Of these, some 4.2 billion people or about 58 percent of the global population had access to piped water on premises. The remaining billion or so people were receiving "safely managed" water on premises from boreholes, protected dug wells, protected springs, rainwater, bottled water and tank truck water.
By lumping the 4.2 billion people with access to piped water on premises together, the status of the infrastructure is not well understood. JMP (WHO & UNICEF, 2017) has plans to study the service levels in more detail, but this will be challenging because global data are not well-organized.

The core financing strategy to serve the most people will support the organizations that supply water, whether they are well-organized utilities or emergent community organizations. While the needs for subsidies will vary among these organizations, the goal should be to move toward the user-pay principle, with provision for cross-subsidies where needed.

The financing of sanitation services differs from water supply because the main issue is to provide adequate access to sanitation at the household level, rather than to deliver a commodity. Sanitation is thus primarily a housing and health issue and only becomes a water issue when wastes enter the water environment. The financing problem bifurcates into the housing and health issue of providing access points and the water issue of establishing wastewater services.
Providing wastewater service enables improved sanitation and without wastewater service, the sanitation options are on-site.

At the site level, stormwater systems comprise the drainage systems from roofs, driveways, small commercial centers and other small areas. The more developed and impervious an area, the more the runoff problem worsens. As the sizes of the sites increase, the stormwater problem takes on larger scales. On small sites, drainage facilities start with small sizes and the industry that provides them tends to involve landscaping more than it does engineering and large-scale construction.

Today, there is much more realization that stormwater is a key component of green development, and might be called "low-impact development," or LID, which is often used in combination with green infrastructure. At the site level, an ideal stormwater design will result in efficient handling of stormwater and minimization of the impact of water releases. The idea fits into the concept of sustainable development and would involve methods such as local detention storage of stormwater, use of pervious pavements and on-site water storage, minimizing stormwater runoff and treating stormwater to remove contaminants.

Irrigation at the site level is a central issue in smallholder systems. Scenarios can vary from rural situations where farmers provide irrigation and domestic water from the same source to cooperative situations, such as small mutual ditch companies.

	Users	Managers	Financiers
River basin scale infrastructure	Multi-sector users, such as local governments, power generators, and irrigators	Sub-sovereigns at the regional, state and national levels	Multi-lateral financing organizations, national governments, public-private partnerships, energy developers
Watershed level infrastructure	Smaller-scale and multi-sector water users	Local governments, water user associations	Local capital markets, intergovernmental transfers
Irrigation systems	Larger farms and irrigation enterprises	Government agencies and water user associations	Government agencies, water users, private interests
Urban water systems	Residents of urban areas	Water utilities, local governments, cooperatives	Customers, debt, national subsidies, development banks
Site-level water systems	Residents and enterprises in urban and rural areas	Self-management, cooperatives	Self-finance, cooperatives

Table 5-2 Financing categories aligned by water users and managers

05

Financing the Cohorts of Water Security

The water subsector issues discussed above can be grouped into problem cohorts with common financing issue. This will help to overcome the problem of generalization in discussion of financial strategies. Table 5-2 shows the five categories introduced earlier aligned with the water system users and managers and with the logical financiers of each system.

The financiers shown in the table form a hierarchy that begins with the international level and extends down through the levels of government to individuals. Private interests are also included. This hierarchy of financiers is:

- Multi-lateral financing institutions
- NGOs (with international scope)
- National governments
- State governments
- National and state development/infrastructure banks
- Local governments
- NGOs and development interests with local scope
- Micro-lending organizations
- Individual water system owners

Each type of financier acts according to its mission and incentives. The major challenge is in the massive amounts of capital and operating funding required globally across all situations. A related challenge is to finance needed infrastructure where financial resources are slim and management capacity is not well-developed. Given the diverse social and environmental agendas of water security, recognizing and financing the non-market attributes rules out investors with profit motives and requires a major reliance on public sources.

06

Conclusion

The call to action for this analysis is: "If business as usual continues at the global financial arena, the public sector will not be able to finance the implementation of the 2030 Agenda" (UN General Assembly, 2018). This is not unexpected because the social agendas in aspirational areas are normally greater than the resources available. So, the operational agenda for water security is to set priorities for the best decisions about available resources, just as it is with the other SDG sectors.

Given their lack of infrastructure, the main need in LICs is to finance capital formation, but the major challenge is lack of local capital and capacity. These needs are nuanced, however, by the types of projects and programs that require funding. Given the mixed public and private purposes of water infrastructure and services, tariffs, taxes and transfers can be used in ways to compensate for lack of local capacity and incremental financing can stimulate cost-sharing. In general, financial transfers are needed more than taxes or tariffs, but management capacity is critical or investments will not pay off. The fact that not all water investments yield attractive financial returns presents a major obstacle to use of private sector funding. The roles of NGOs and even private sources with philanthropic missions are critical to fill the gaps.

The main financing issues in HICs are to innovate in services, renew infrastructure, and get more service from existing capital-intensive systems. Examples of innovation are national revolving funds and private sector involvement in operating and financing water systems. By decomposing water systems into their parts, more opportunity for investors can be provided (Grigg, 2018). Planning for renewal requires date-centric asset management systems and commitments to implementing decisions. Extending the lives of existing facilities is like an infusion of financial resources because the life-extension frees capital to invest in other needs.

The studies that were reviewed made useful general recommendations, which must be tested at a detailed level because water security involves such a broad agenda and extends past often-discussed site-level water and sanitation issues. From its definition, it also includes access to acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, protection against water-borne pollution and water-related disasters, and ecosystems. The reports ranged across many topics, mostly with a focus on increasing the magnitude and effectiveness of project investments in developing countries. This is to be expected because of the development orientation of the organizations preparing the reports. The focus on projects is also appropriate, but financing water security also involves program finance, system operation and maintenance and much-needed system renewal.

From the reports, the general principles are clear, although many issues are involved. This led the WWC to condense recommendations to "ten actions", with the goal to focus the discussion (Money, 2018a). The ten actions are like a menu that includes development of project and investor typologies to focus the discussion, to broaden the concept of risk and return and renew emphasis on public finance, to exploit opportunities of purposed finance, to optimize the value of development finance, to improve project selection and development, to distinguish between capital and operating costs, to explore hybridity and blended finance, and to revisit tariffs, taxes and transfers.

It was not unexpected that the reports contain much discussion about the issues of safe water and sanitation. It was also not surprising to see a conclusion that financing of irrigation is a complex and difficult subject, but that it remains critical, given the intersections of water and food security. The reports acknowledged the importance of finance in other water subsectors, but they devote less discussion to them.

Since the Camdessus report, access to safe water and sanitation has increased substantially (JMP, 2018a), and the never-ending challenge is to sustain progress and improve the quality of services. Irrigation also faces continuing challenges in its social complexity and from competition for water from other sectors, as well as climate change. Adding these challenges to the general problem of managing water resources and infrastructure creates an urgent need for the new thinking called for in the subsequent reports.

"Given their lack of infrastructure, the main need in LICs is to finance capital formation, but the major challenge is lack of local capital and capacity."

To address the many scenarios, financing scenarios were classified to aid in providing a tighter focus on subsector issues and issues in developing countries and high-income countries. This provides an approach to the analysis that considers details of water subsectors and how they are linked to other social and economic sectors, as well as how water security requirements vary among incomes of countries and levels of management capacity.

Most new large projects are in developing countries, and financing strategies involve public-private approaches. Facilitating these while taking care to protect ecosystems and social systems is the main financing need. Given the large scales involved, developing cooperation among stakeholders is also imperative, especially given the potential for conflict in transboundary situations.

At the watershed level, projects involve the same multipurpose issues as in river basins, but the scales are smaller, the governance issues are simpler, and the need for cooperation is normally focused on fewer people and entities. Consequently, multi-national financing authorities may only be involved with demonstration projects, while the need for local capital should be stressed.

The need to finance irrigation projects at small and large scales confronts the strong social linkage of water management with communities and the lack of financial capacity for self-finance. International financing authorities may find a few large projects to support, mainly for rehabilitation and renewal, but there seems to be little prospect to develop new large projects. Meanwhile, the prospects are excellent to improve the efficiency of water management and implement new technologies to increase food security with minimal investments in water infrastructure.

Urban water supply, wastewater, and stormwater systems require large amounts of capital and, given the deficits in the existing urban systems and the rapid rate of urbanization that will require new and expanded systems, they will demand more financial support than the other categories of water infrastructure. Financing urban water systems confronts local governments globally, and each nation faces its own unique situation. In the United States, for example, many studies have been completed to grapple with the problem in its own governance system. There is much need for technical, operational and organizational innovation. One Water strategies, such as China's Sponge City program, offer hope to offset some of the financing requirements.

Financing water security at the site level runs squarely into the issue of poverty and income. If all residents had the capital to invest in effective self-supply systems, they would be able to develop the required water, sanitation, stormwater and irrigation systems for their sites. Lacking the investment capital and management capacity required, how can these needs be met? Logically, the key to meeting them is in management organizations that serve cities, rural communities and irrigation systems. If these organizations will adopt appropriate social missions to go along with their enterprise goals of providing financially self-supporting systems, much of the problem can be solved. In turn, capacitating the organizations so they can deliver effective services while meeting needs is the major challenge.

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6

Water Security and Green Growth: Supporting Development While Safeguarding Water Resources

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Abstract

Water plays a vital role in our future development and security as we face the growing global challenges of population growth, urbanization, economic stresses and climate change. Substantial research and policy analysis on the role of water in achieving development around the world were conducted by a team of experts from 2010 to 2015 and set out the case for water resource strategies, policies, institutions and instruments that stand on the three pillars of sustainable development—environmental protection, economic growth and social development. The project, Water and Green Growth, was undertaken to encourage national, international and other policy-makers to adopt green growth as a policy approach to water management and to provide them with well-documented tools for implementation. The purpose of this paper is to summarize some of the lessons learned, share best practices based on international case studies, and document the interconnections between water, green growth and global water security issues in the context of the United Nations' 2015 Sustainable Development Goals. Water and Green Growth offers an innovative water-centered paradigm for environmentally sustainable and socially inclusive economic growth that safeguards water resources and contributes to water security around the world.

Keywords

Green growth, Water and Green Growth(WGG), water security, Sustainable Development Goals

01
Background

"We all accept that water is important to human well-being. However, the vital role that water plays in national economic development is less clear. Yet, this is changing. Driven by the scale of impact, both positive and negative, water now represents the number one risk in terms of impact on our global society."

Benedito Braga
President, World Water Council [1]

Substantial research and policy analysis on the role of water in achieving development around the world were conducted by a team of experts from 2010 to 2015 and set out the case for water resource strategies, policies, institutions and instruments that stand on the three pillars of sustainable development—environmental protection, economic growth and social development. The project, Water and Green Growth, was undertaken to encourage national, international and other policy-makers to adopt green growth as a policy approach to water management and to provide them with well-documented tools for implementation. Near the end of the project, the Sustainable Development Goals (SDGs) were adopted by the 193 Member States of the United Nations (UN) in September 2015. The purpose of this paper is to summarize some of the lessons learned, share best practices based on international case studies, document the interconnections between water, green growth and global water security issues in the context of the SDGs, and contribute to water security around the world.

1.1. What is "Green Growth?"

"Green Growth" is an idea that evolved in response to the high environmental cost of rapid economic development and urbanization over the past several decades. As defined by the UN Economic and Social Commission for Asia and the Pacific (UNESCAP), green growth means "environmentally sustainable economic progress to foster low-carbon, socially inclusive development." (UNESCAP, 2012). It diverges from traditional unsustainable energy- and carbon-intensive economic models of growth.

The concept of Green Growth as a national policy emerged from the Republic of Korea (South Korea) in 2008 as "a new national development paradigm for job creation and new growth by using green and clean technology," in the words of former President Lee Myung-bak (Republic of Korea, 2008). International organizations that promoted the concept of Green Growth included UNESCAP and the Organization for Economic Cooperation and Development (OECD, 2011). Green Growth is also related to the concepts of Green Economy (UNEP, 2009) and Inclusive Green Growth (World Bank, 2012) that emerged around the same time (UNEP, 2009; World Bank, 2012). As the Green Growth concept evolved in the Republic of Korea and other countries in Asia, it became clear that water was vital both to green growth and to the three pillars of sustainable development.

1.2. Water as a Catalyst for Green Growth

Water plays a crucial role as a catalyst for green growth. The cross-cutting nature of a wide range of water issues places it at the center of the paradigm for green growth. For example, successful investment in water infrastructure and water security fosters economic growth and enhances socially inclusive development while also protecting the environment and the many services it provides. International cooperation around water issues plays a significant role in green growth when countries work together to protect the environment through water agreements, improve efficiency in water use and conservation, and avoid costly climate change adaptation measures. In addition, technology transfers between countries and watersheds can support economic growth, protect water resources, and reduce greenhouse gas emissions.

1.3. Water and Green Growth Research 2010-2015

The Government of the Republic of Korea and the World Water Council established the Water and Green Growth (WGG) concept and launched the project in 2010. The parties signed a Memorandum of Understanding for phase 1 of the project in November 2010 and established an International Steering Committee to oversee the evolution of the project from 2010 to the present. The Government of the Republic of Korea was represented by the Ministry of Land, Transport and Maritime Affairs (MLTM), the Presidential Committee on Green Growth (PCGG) and the Korea Water Resources Corporation (K-water). Nautilus International Development Consulting, the author of this paper, served as consultant to the World Water Council from 2011 to 2015 with responsibility for helping to analyze the role of water in green growth, research and summarize exemplary case studies, prepare reports for international discussion, and develop a policy framework to support implementation.

"Green Growth is an idea that evolved in response to the high environmental cost of rapid economic development and urbanization over the past several decades"

1.3.1. First Edition

A draft policy framework for WGG was presented to the 6th World Water Forum in Marseille in 2012 as both a published document, *Water and Green Growth, Executive Summary—Edition I, and a full report on a CD-ROM entitled Water and Green Growth—Edition I.* It was based on analysis of 26 case studies, and the policy framework was divided into policy directions under the three dimensions of sustainable development: Economic (Water as an Engine for Growth); Environmental (Protection and Conservation of Water Resources); and Social (Water for an Improved Quality of Life). Four policy directions under each of the three dimensions were suggested in the initial framework.

1.3.2. Second Edition

During subsequent phases of the research, the WGG team built on this foundation to develop a policy framework that would also include an institutional analysis and the practical application of WGG policies. The 2015 report, *Water and Green Growth: Beyond the Theory for Sustainable Future*, was published in two documents as Volume 1, 2015 and Volume 2, 2015, Case Studies. A full version of the 2015 study is available at <www.worldwatercouncil.org/en/publications>.

The institutional analysis included an examination of the relationships and interactions among exogenous factors, relevant institutions, and the performance of projects and programs. Exogenous factors relate to external conditions and included economic, social, political, environmental and technical factors. Eleven case studies were evaluated in more depth during 2014. These were selected by the International Steering Committee to supplement the earlier work on 26 case studies, to explore the role of water in green growth and to enhance WGG policies. The 2015 two-volume report discussed the policy implementation mix in relation to state-driven, market-oriented, and community-centered approaches to water management. The results of the analysis provided insight into the types of institutional structures that demonstrated the instrumental role of water in economic development, environmental protection and social progress.

The full report provides guidance on developing WGG policy and implementation approaches. Policy makers can benefit from suggestions on a variety of approaches that combine state-driven, market-oriented and community-centered institutions and policies. An implementation roadmap provides a step-by-step process that interested policy makers could use to systematically develop a WGG program in their own countries.

The contributions of the many partners who were involved in developing the case studies and the WGG concept were invaluable. Many partners continued to contribute by sharing their experience at the 8th World Water Forum which took place in Brasília, Brazil in March 2018. Events there were convened by K-water Institute, United Nations Educational, Scientific and Cultural Organization's (UNESCO) International Centre for Water Security and Sustainable Management (i-WSSM), and the World Water Council. The events included participation by panelists from the International Union for Conservation of Nature (IUCN), Korea Water Forum, K-water, MOLIT, Nautilus International Development Consulting, OECD, the World Bank, and the World Water Council.

1.4. Key Messages from Case Study Analysis

Water and Green Growth proves to be applicable worldwide and can be especially valuable to developing countries as a pathway to achieve sustainable development in an accelerated way. Several key messages have been extracted from the analysis of the case studies as follows:[2]

- Water is the vector through which green growth can occur.
- Strong political leadership and political commitment from the top and from local government and water basin levels are essential.
- A holistic approach to encompass the three pillars of sustainable development is essential for the implementation of WGG strategies and policies.
- For better coordination, responsibilities among actors should be clearly defined.
- A clear legal framework provides support and continuity to WGG projects.
- Secure and sustainable financial resources for water services yield high economic, environmental and social returns.
- Educational programs and capacity building for communities can increase environmental awareness and lead to participation in and promotion of Water and Green Growth.
- Enhanced water and data information systems can provide essential decision support for effective water management.
- Community participation in design and decision-making is valuable and necessary for reflecting the community's interest, building support and for conserving and protecting water resources.
- Partnerships at all levels are critical for success. This means government policies must be flexible enough to encourage innovation from many sectors—public institutions, non-governmental organizations (NGOs), civil society, academic institutions and the private sector—at many levels.
- There is 'no one-size-fits-all' strategy. WGG strategies need to be context-specific at the initial stage of the project.

1.5. How to Apply the Key Messages

Every WGG case study is specific to its own context at many levels—from the local area, region and water basin to the national and international environment—where it is being implemented. There are, however, factors that are key to water security described in the key messages above that reappear in many of them and can provide guidance for how to adapt the lessons to other locations. Every case study depends on political commitment, a holistic approach, defined responsibilities, legal framework, sustainable funding, educational programs, data systems, stakeholder participation, partnerships at all levels, and other enabling conditions.

In order to replicate results, there is the possibility of scaling up for some of the case studies while scaling back to more manageable projects may work best for others. For the case studies with new technologies and water fund programs, for example, many of them began as small pilot projects. Then, once the schemes were underway and showed credible results, those could be leveraged to encourage others to participate.

Many NGOs and international organizations can help exchange best practices, new approaches and cutting-edge technologies. This happened, for example, with the water funds that started in Quito's watershed and have now spread into other parts of Latin America and the Caribbean.[3] Each fund follows a basic model, but also deals directly with the unique conditions, stakeholders and needs of its own watershed.

Conversely, some of the ambitious large-scale, top-down infrastructure projects may depend on significant investments and carefully coordinated public resources, and require substantial efforts to mobilize communities and negotiate with stakeholders. This was the case in Gujarat and Istanbul. However, in cases where major public investments are not available, it may make more sense to break up the projects into smaller pieces that can be implemented in a defined sequence based on the resources available over time. 'Start small and scale up' may be the best approach. In these cases, programmes can be implemented step-by-step. Results can be measured by agreed-upon benchmarks before moving on to the next step or expanding the geographic area. Because successful watershed management at a large-scale requires a careful balance between economic, environmental and social factors, achievement of water security will not be successful if implementation is imposed unilaterally from the top.

1.6. Interconnections between Water Security & Water and Green Growth

Water security interconnects with the concept of WGG in many complementary ways. This paper focuses on three of those interconnections: Economic, ecological and human security. Water is essential to produce economic goods and services and must be available in affordable, equitable ways to support sustainable growth. This means safeguarding the quantity and quality of water which, in turn, ensures the protection of our natural ecological resources, including biodiversity and water resources for future generations. Underlying these elements of economic and ecological security is the ability of water resources to meet our basic human needs with enough water to keep people healthy and nourish the world's inhabitants in the face of population growth, urbanization and changing climate.

02

Water and Green Growth Strategies, Policies, Institutions and Instruments

Achieving Water and Green Growth (WGG) objectives depends on a solid policy framework. Most international organizations and NGOs emphasize establishing and carrying out appropriate policies and related implementation strategies, which can have a far-reaching impact on economic growth, environmental protection, and social development.

The policy framework for WGG was based on the three pillars of sustainable development, particularly in light of adoption of the Sustainable Development Goals (SDGs) by the United Nations in 2015. These 17 SDGs are the basis for Transforming Our World: The 2030 Agenda on Sustainable Development.[4] Goal 6 is the one that covers water and sanitation: "*Ensure availability and sustainable management of water and sanitation for all.*"[5] Meeting the targets for water and sanitation are crucial to achieving the other SDGs.

Based on the results of the in-depth institutional analysis presented in the 2015 WGG report, this paper includes a fourth strategic component to the WGG policy framework: Strengthening of Water Institutions. This reflects the importance of an institutional approach to water management. Many of the WGG case studies were successful because of their strong institutions.

A summary of the policy framework for WGG that structures the following sections can be found in Table 4-1—Policy Framework for WGG. The policy framework provides suggestions for a variety of policy directions under each strategic component. More detailed policy options and implementation recommendations are provided in the full report. The following sections will examine the policies that contribute to meeting SDG 6 and describe selected international case studies where those policies have been tested.

2.1. Economic Security – Water as an Engine for Growth

Based on the WGG case studies, the research identified key strategies that can be used to promote 'Water as an engine for growth' and ensure economic security. These include: promoting technology transfer and investing in innovative tools to improve water and energy efficiency; revitalizing urban waterways and waterfront areas and working with communities to make them function better; adopting a package of economic instruments, including demand management and incentives for recycling and reuse of water; and balancing green and grey infrastructure among

Strategic components	Policy directions
1 **Water as an engine for growth – Economic Security**	1. Promote technology transfer and invest in innovative tools to improve water and energy efficiency
	2. Revitalize and better use urban waterways and waterfront areas
	3. Adopt a package of economic instruments, including demand management and incentives for recycling and reuse of water
	4. Balance green and grey infrastructure among the competing uses- e.g., energy, industry, municipal, domestic, agriculture
2 **Protection and conservation of water resources – Environmental Security**	5. Adopt river basin management plans using integrated water resources management (IWRM) principles
	6. Value ecosystem services to ensure watershed conservation (e.g. Payment for Ecosystem Services)
	7. Strengthen the capacity of people and communities to adapt to and build resilience to climate change
	8. Ensure environmental integrity of the ecosystem and protect biodiversity
3 **Water for an improved quality of life – Human Security**	9. Empower people, especially women, to better manage their own water resources
	10. Promote access to clean drinking water and sanitation as a key to poverty alleviation, public health and quality of life
	11. Facilitate adoption of Water and Green Growth through education and capacity development policies
	12. Build resilience among watershed communities to cope with water-related disasters
4 **Strengthening of water institutions – Institutional Resources**	13. Develop policy, planning, legislative and information tools • Indicative and river basin planning • Clear legal framework(water policy, legislation and regulations) • Data information systems
	14. Determine the best mix of institutional structures for policy implementation • State-driven • Market-oriented(including public private partnerships) • Community-centered
	15. Mobilize funds to ensure financial sustainability • Central or municipal budget • Consumer tariffs and taxes, removal of inefficient subsidies • Payment for environmental services
	16. Create a workable coordination mechanism among relevant government agencies dealing with water and the environment and other key stakeholders

Table 6-1 Policy framework for Water and Green Growth

competing uses—*e.g.* energy, industry, municipal, domestic, agriculture.

2.1.1. Policy 1 - Promote Technology Transfer and Invest in Innovative Tools to Improve Water and Energy Efficiency

Contributing to structural transformation towards green growth, governments need to facilitate innovation and adoption of greener water and energy technologies. Barriers to adoption of innovative tools and technologies, such as lack of access to finance, knowledge and patents, must be addressed if a country decides to adopt green growth policies.
There are opportunities for developing countries to 'leapfrog' past traditional unsustainable patterns of growth using information technology. Public-private partnerships (PPPs), which are cooperative, long term agreements between government entities and private sector companies, can bring innovative tools and be essential to successful green growth strategies.

Among the case study examples of governments investing in innovative tools that the private sector and communities adopt are Lake Sihwa in the Republic of Korea and the Murray Darling River Basin in Australia.

The Lake Sihwa project in the Republic of Korea[6] demonstrates urban renewal based on recovery of a lake basin. The lake was created by construction of a dyke along the Yellow Sea coast in 1987. However, serious eutrophication (when a body of water contains excessive nutrients that stimulate overgrowth of aquatic plants and algae) of the lake caused protests by the population in the area against the project for many years. Finally, in 2004 the government created the Sihwa District Sustainable Development Council, a consultative group that engaged the population living in the district in drafting a comprehensive long-term development project. The Council has expanded the participation of stakeholders while encouraging active communication with the local community.

The components of the project include a high-tech industrial complex, housing and theme parks, as well as the world's largest tidal power plant. The latter is designed to produce over 500GWh of clean ocean energy per year. The wave energy has improved the water quality of Lake Sihwa through increasing circulation of seawater. In addition, its tidal power reduces greenhouse gases. The Council changed the direction of some of the original plan by insisting upon environmental measures that would reduce the impact of the development. The government accepted the Council's suggestions on low-density housing and restoration of habitats that had been lost.

The Lake Sihwa case study should be very instructive to any government setting out to do a large-scale development project. Such projects require a lot of time for consultation and social mobilization in order to be successful. This case also shows how adoption of innovative technology, such as constructed wetlands and tidal power plants, can improve water quality and provide economic benefits. This can only happen with the full support of the resident community.
The wetland area now hosts a research and education center with a steadily increasing number of visitors, helping to stimulate the local economy. The Sihwa Tidal Power Plant caused no additional harm to the environment, while it produced eco-friendly energy, helping to ease the Republic of Korea's recent close-to-capacity energy usage. The lake also attracts tourists, increasing its regional income.

In a case study from Australia, a new economic instrument was introduced in the Murray Darling Basin (MDB), to improve water use efficiency.[7] The water rights transfer contract (private temporary agreements), was introduced at the same time as the 1999 Water Act reform. The chief innovation was the establishment of well-defined water rights, their separation from land rights and the ability to trade water rights. With the total quantity of water rights capped across the entire basin, the objective was the efficient allocation of water rights within a sustainably managed river basin. Trades have taken place within and between states.
The management of the MDB required more than water rights to be defined and water rights to be tradeable, however. The basin is also sustained by a complicated arrangement of horizontal and vertical institutions which bring together and represent stakeholders across different federal states, across sectors, and across different ministerial departments.
The successes of the management of the MDB are rooted in these institutional arrangements, as well as in the ability to trade water rights. Water trading has proven to be a useful tool in helping water users, particularly irrigators, to respond to changes over the past decade.

2.1.2. Policy 2 - Revitalize and Better Use Urban Waterways and Waterfront Areas

Many of the case studies demonstrated how the revitalization of urban waterways and waterfronts results in positive economic, social and environmental benefits. One of the primary international examples is the Golden Horn in Istanbul, Turkey.[8]

The case study from the Golden Horn estuary, that divides the city of Istanbul, shows how a polluted urban waterway can be restored and become the center of vibrant economic activity. The Golden Horn rehabilitation project is a multi-dimensional plan aimed at improving water quality and navigation in the estuary. By 1985, the extensive industrial zone around the Golden Horn, including active operation of dockyards, factories, and warehouses, had increased pollution of the estuarine waters. The results were devastating, and the estuary turned into a shallow, dead lagoon where the boats could not move, where there were no living species and the smell from anaerobic degradation could be detected from several kilometers away.

The Golden Horn Restoration Project, implemented by the Istanbul Metropolitan Municipality and the Istanbul Water and Sewerage Administration (ISKI) from 1995 to 2003, took a huge amount of government investment and private

sector participation. The project had five phases: Investigation; dredging; construction of wastewater facilities; landscaping; and repurposing the area as a tourism and cultural destination. Much of the initial work was concentrated in dredging the Golden Horn and preventing sewage from entering the estuary by collecting it and sending it to a treatment facility. Then the landscaping and repurposing of this strategic and historic waterway became an engine for economic growth. As a result of the project, water quality in the estuary has improved so that many aquatic species have returned, while tourism and recreational areas have increased. The revitalized waterfront is now used by all levels of society for fishing, boating, biking, walking, visiting cultural destinations, small enterprises, convention centers, hotels and sporting events.
The restoration of this historic waterway has had enormous economic, social and environmental benefits.

“Based on the WGG case studies, the research identified key strategies that can be used to promote ‘Water as an engine for growth’ and ensure economic security.”

Similar examples can be found for urban waterfronts ranging from New York City, USA[9] to Shanghai, China.[10] Restoration of waterways generally requires an agreement with upstream residents and businesses to maintain water quality, reduce erosion along the river banks, and carry out actions to reduce siltation. Such agreements require sustained government commitment and economic resources, but they pay dividends far into the future. As can be seen from the case studies in this category, the value of restoration affects all aspects of life; it cannot be calculated in monetary terms alone.

2.1.3. Policy 3 - Adopt a Package of Economic Instruments, Including Demand Management and Incentives for Recycling and Reuse of Water

Similar to the earlier case studies cited on innovative tools, this category includes other economic instruments, such as public-private partnerships.

The Shanghai Pudong joint venture project in China,[11] established between the Shanghai Chengtou Group and Veolia Water, is a good case using the WGG framework where the role of water has been instrumental in improving economic well-being and social equity coupled with protection and revitalization of ecosystems. The huge city of Shanghai is considered a pollution-induced water-short city that is geographically located in a water-rich region. The key challenge for the Shanghai Pudong authorities was to cater to extremely rapid economic development and ensure that water services would support the pace of growth. The Pudong water authorities had to match the needs of a population that grew from 2.65 million in 2002 to 3.6 million in 2011, and had to increase the area of coverage from 320 to 536 km^2 over the same period. In addition, the level of service had to ensure state-of-the-art water, sanitation and health conditions. The Chinese government did not have the capital, technology or management skills to cope with this pressing demand for water services, and thus it initiated the Shanghai Pudong joint venture as a 50-50 partnership between the Shanghai Chengtou Group and Veolia Water (50% shares for each).

The partners brought depth and international expertise to develop and expand Pudong’s water services to meet the needs of the growing population and booming economy. The company operates under a “system of collective leadership and joint decision-making” with 50-50 representation in Executive Management and the Board of Directors. A well-balanced management team was established with rotation of main positions (General Manager and Chairman) every four years and distribution of key management positions between the two shareholders. The same conditions expected of other water companies in Shanghai are applied to the Joint Venture: standards of water quality, service levels, water tariffs, laws and regulations.
The joint venture received no special subsidy. The Shanghai government transferred the entire Pudong water supply operation to the joint venture company without any profit margin guarantees. The profit margin depends entirely on the efficient operation of the joint venture company and development of the Pudong area.
The government sets water pricing; however, reasonable costs and profits are the government’s long-term principles when establishing water prices. In this context, the results of the partnership have been successful. The objectives of the joint venture were achieved in less than ten years, and there has been an increase of water access and an improvement of water quality that has matched the growth in demand for water services.

2.1.4. Policy 4 - Balance Green and Grey Infrastructure among Competing Uses

Over the years, extensive systems of grey infrastructure have been constructed, such as water distribution networks, waste water treatment plants, dams and other manmade structures. When this older infrastructure needs repair or replacement, there is an opportunity to consider a combination of grey and green infrastructure to reduce its negative environmental effects. This would include the preservation and restoration of natural resources, such as forests, floodplains and wetlands. Not only can water quality can be improved with green infrastructure, but also it helps protect wildlife habitats and create outdoor recreational opportunities.

The case study of the Ebro River Basin in Spain is an example of how to implement integrated water resources management (IWRM) over the long term by blending green and grey infrastructure.[12] Planning and management in the basin reflects Spain’s decades-old water management policy based at the river basin level as modified by the European Union (EU) Water Framework Directive. The Ebro Basin is the biggest one in Spain, covering 85,700km^2.

The management of the Ebro River Basin and construction and operation of hydraulic works, whether self-funded, commissioned by the national government, or agreed upon by Confederación Hidrográfica del Ebro (CHE by its Spanish acronym, or Ebro River Basin Confederation in English), have played a central role in transforming the formerly semi-arid Ebro Valley into a prosperous economic hub of the nation.

To adapt the available water resources to the locations and quantities where they are needed, the Ebro basin has been gradually transformed into one of the most regulated river basins in the world. It has 108 big dams with water storage facilities that support agriculture, manufacturing, energy production and drinking water supply, and thus serve as an engine of growth in the region.

Setting the achievement of a good or fair ecological status of the water bodies as the main objective of river basin management plans in the EU has been an important element in the Ebro River Basin Management Plan and has helped make economic development compatible with environmental objectives. Thus, the plan has created a near-optimal combination of green and gray infrastructure to meet the needs of all the competing uses in the basin, including agriculture, energy, industry, municipal, and domestic water supply and sewerage.

2.2. Environmental Security – Protection and Conservation of Water Resources

To achieve environmental security, protection and conservation of water sources and watershed resources need to be clearly prioritized and recognized. Water basin planning and management are the foundation for designing water policy that reconciles economic growth, the protection of freshwater ecosystems and the creation of jobs linked to the green economy. In consultation with major stakeholders, basin planners examine economic opportunities and address environmental and development challenges simultaneously. The protection of the source of water is the first step in a green growth program.

2.2.1. Policy 5 - Adopt River Basin Management Plans Using Integrated Water Resource Management (IWRM) Principles

The approach in Brazil provides a good example of integrated river basin management (IRBM) in practice with a sophisticated water resources management system.[13]

Brazil has one of the world's largest endowments of freshwater resources (12% of the world's fresh water).

The National Water Resources Management System (SINGREH) has introduced such water management practices as decentralization, the use of economic tools for water management, and public participation in the decision-making process. The National Water Agency (ANA) is the institution responsible for implementing the national policy and coordinating the SINGREH, particularly its technical and institutional instruments. Moreover, ANA is responsible for regulating water uses for rivers under federal jurisdiction by issuing water permits and controlling water uses.

To ensure that water has been an engine of growth and has contributed to both environmental protection and social development, the government of Brazil implemented policies recommended in the WGG policy framework.

- Adopt river basin management plans using IWRM principles;
- Value ecosystem services to ensure conservation and protection of water sources;
- Promote technology transfers and invest in innovative tools to improve water and energy efficiency;
- Adopt a package of economic instruments, including demand management and incentives for cleaning up waterways, recycling and reuse of water; and
- Promote access to clean drinking water supply and sanitation as a key to poverty alleviation, public health and quality of life.

The country has been divided into 12 hydrographical units, each with its own water management plans, agreements, regulations and water fees. The boundaries of these regions are different from the geopolitical boundaries of the Brazilian states. Since the promulgation of the National Water Law in 1997, federal, state and river basin management institutions have grown rapidly, with over 200 river basin organizations created by 2014. However, the policies and institutions that have been responsible for the initial improvements in water management and availability are still evolving, and are adapting to changing circumstances and lessons learned. The broad participation of stakeholders in consultations related to river basin planning and management has had a strong influence on this evolution.

At the sub-basin level, the River Basin Committee includes representatives of the government, users and non-governmental organizations. These committees are responsible for approving the River Basin Plan and for proposing the amounts to be charged for water use. A Management Contract enables collection of water charges by Federal or State organizations and transfer to the River Basin Water Agency. ANA has introduced the 'polluter-pays' and 'user-pays' concepts in Brazil.

The basin authorities in Brazil and the Ebro Basin in Spain (also see Policy 4) ensure that the ecosystem water needs are met, and both use a variety of instruments—economic, regulatory, legal and engineering—to achieve their water management goals. Basin Committees that involve major stakeholders are an essential part of the negotiation process. These two case studies provide excellent examples of integrated water resources and basin management plans.

2.2.2. Policy 6 - Value Ecosystem Services to Ensure Watershed Conservation (*e.g.* Payment for Ecosystem Services)

Payments for ecosystem services (PES) schemes have been identified as a tool used by many sectors—notably agriculture and forestry—to protect watersheds, support rural livelihoods and restore damaged ecosystems. When successfully implemented, they can also help communities adapt to climate change and preserve aquatic ecosystems. PES has been used for income generation in rural areas and, thus, can be a direct means to green growth.

In the cases from Latin America and the Caribbean, Water Trust Funds, some of which were originally established by The Nature Conservancy (TNC), are endowment trusts to support watershed protection and promote green growth. The trusts are set up to compensate for environmental services, such as supplying clean fresh water and providing biodiversity-related benefits. The trust fund is collectively invested in conservation projects that protect the healthy habitat from which environmental services derive. They are based on payment for environmental services (PES) principles, and are a means of mobilizing long-term trust funds. A public-private partnership of water users determines how to invest in conservation activities in priority areas.

PES Funds require involvement of stakeholders upstream and downstream, and spread both benefits and costs among industries, municipalities, communities, utilities and the ecosystem. Financing comes from the users, the government (often including a percentage of the water company's revenues), international development banks and other donors. Although it is difficult to initiate them, these Funds can serve as models for municipalities that are searching for ways to reduce costs of treatment and distribution.

The largest of the PES Fund is in Quito, Ecuador, where about 80% of the water for the city comes from three protected areas and their buffer zones.[14] The Quito Water Conservation Fund (Fondo para la Conservación del Agua—FONAG) was created with the help of TNC in 2000. It receives money from government, public utilities, electric companies, private companies and non-government organizations. An independent financial manager invests the money, and the interest is used to fund activities for watershed protection. These include: control and monitoring of protected areas, restoration of natural vegetation, environmental education, training in watershed management, and a hydrological monitoring program. Local communities that live close to the water sources receive support from FONAG for environmental education and community-based projects. Initial funding for the Quito Water Fund included TNC and UN Agency for International Development (USAID) grants.

The Fund amounted to US $5.4 million at the end of 2008 and is now over US$ 10 million. FONAG has reached sustainability in terms of its funding, with enough funding every year to cover project implementation and administrative costs (average US $1.5 million/year). The FONAG endowment produces a financial return of approximately US $800,000 per year (a value that grows every year, as the endowment grows) to invest in conservation projects.

Other case studies in this category show a wide variety of PES and similar schemes that provide monetary and non-monetary (including provisional land tenure) incentives to residents of the watershed to be stewards of the forest and water resources. Water Stewardship has now become an important model for restoration and protection of watershed resources and has spread internationally into the Alliance for Water Stewardship, spearheaded by The Nature Conservancy.[15]

“Water basin planning and management are the foundation for designing water policy that reconciles economic growth, the protection of freshwater ecosystems and the creation of jobs linked to the green economy.”

2.2.3. Policy 7 - Strengthen the Capacity of People and Communities to Adapt to and Build Resilience to Climate Change

By the mid-20th century, people, corporations, governments and their various activities had produced such serious impacts on the environment that it was beyond the capacity of nature to absorb them, with consequent negative effects on people's livelihoods and health. Thus, it became clear that the benefits of traditional economic growth had come at the expense of a serious deterioration in the environment. Climate change, including increased air and water temperatures, rising sea levels, more frequent storms and extreme weather events, has come about mainly because of mankind's unsustainable use of natural resources and ecosystems.[16] Climate change in turn has resulted in droughts and floods, the spread of infectious diseases and loss of biodiversity, which threaten national security and the very existence of island countries.

Green growth policies are a response to the traditional unsustainable energy and carbon-intensive economic models based on constant growth that have caused climate change and impacted human health and water security. An underpinning assumption of the green growth concept is that, if people were to change how they pursue economic growth, they could solve the environmental problems it has caused. The Republic of Korea initiated its Green Growth policy in 2008 in an effort to achieve environmentally-sound economic growth using new and renewable energy and green technologies. The policy aimed to implement climate change mitigation and adaptation strategies nationally and internationally, and to contribute to green growth and climate change resiliency in developing countries. In 2010 the Republic of Korea established the independent Global Green Growth Institute (GGGI)[17] to share its experience of green growth policies and promote knowledge exchange throughout the world.

In order to move forward on a sustainable development path and in line with the Paris Agreement on Climate Change of 2015, all countries will have to introduce or expand measures to protect the environment and mitigate or adapt to climate change. Many technologically advanced countries have already begun investing in green technologies and industries as part of their efforts to mitigate climate change. They have also started to introduce preferential policies for the purchase of environmentally-friendly products. Accordingly, developing countries would do well to invest in manufacture of products in an environmentally- sound way in their efforts to promote economic growth; otherwise they may be left behind in terms of international competitiveness.

In 2008, the Republic of Ecuador passed a new constitution after a heavily confrontational national assembly. The new constitution was approved by public referendum and became effective in October 2008, replacing the constitution of 1998. Among its many innovations was the inclusion of a concept that nature has inalienable rights, and the recognition of ecosystem rights.[18] In a similar way, the water laws and integrated water resources management plans in the Brazil and Ebro River (Spain) case studies reference satisfactory ecological integrity in the water bodies as one of the main objectives of river basin management plans, making economic development compatible with environmental objectives. Such policies will be necessary to reverse the harmful effects of climate change, create resiliency and ensure water security.

Technological innovations can also have an impact on climate change, increasing water availability from water savings and pollution control. These are considered green growth solutions, as they improve the environment and reduce costs to users. Some of them include: recycling and reuse of water, low water using appliances, efficient irrigation systems, decentralized sewerage systems, rainwater catchments and reclamation of nutrients. With such green growth innovations, energy costs are reduced with savings on fossil fuel consumption in the short term and with reductions in greenhouse gas emissions and climate change impacts in the longer term. Other technological tools that contribute to green growth include information and communications technologies that will assist water managers to encourage conservation and manage demand.

2.2.4. Policy 8 - Ensure Environmental Integrity of the Ecosystem and Protect Biodiversity

As pointed out in the previous section, IWRM plans normally include a requirement to ensure the environmental integrity of the basin ecosystem. In addition, some local municipalities can begin the process of cleaning up their waterways and restoring ecosystem integrity, as discussed in Policy 2.

The Taehwa ecological restoration project is an example of an industrial zone that was restored in line with conscious green growth policies.[19] It is located outside the city of Ulsan in the Republic of Korea. Ulsan was designated as the Republic of Korea's first industrial zone in 1962 because of its advantages of being located by the sea, with a bay and harbor. It is located on the Taehwa River, providing an accessible supply of water for industrial use, and has no high mountains in the coastal area, with room for expansion of land for development. After the designation, population growth and industrialization progressed rapidly with the entry of large-scale heavy and chemical industries, including petrochemicals, automobiles and shipbuilding. However, insufficient attention to environmental facilities led to the discharge of untreated domestic sewage and industrial waste into the Taehwa River. Also, construction of dams for industrial use led to water shortages and an inadequate river flow. As a result, the water quality in Taehwa fell to its lowest point in 1996, with a biochemical oxygen demand (BOD) of 11.3 ppm. In an attempt to address the water quality problem that was reported daily by the press, citizen groups and the local government engaged in scattered and uncoordinated measures to improve the situation. However, these efforts were not enough.

In June 2000, yet another mass fish death occurred along the Taehwa River. The broadcast of this incident on national television gave rise to nationwide recognition of the seriousness of the Taehwa River's pollution, and became the background of the River Revival Campaign. Despite this movement, contaminated water continued to flow into the river, with widespread reports of the problem.

At the beginning of the 2000s, the city of Ulsan began its efforts to improve the environmental pollution problem. Going beyond mere pollution reduction, Ulsan adjusted its development course toward building an ecological city in 2004. As the short-term target year in the Phase 1 project (2004-09) approached, the phase 2 comprehensive plan was adopted to ensure the continuation of the Taehwa River environmental policy. The plan consisted of building treatment facilities for water quality improvement, the development of waterfront space, such as the Taehwa River Grand Park, and projects for cultural value restoration such as transforming the Taehwa River into a safe, ecologically healthy, and culturally enjoyable space.

The Taehwa River Restoration Project was carried out under the leadership of Ulsan Metropolitan City, a municipal-level authority. Within this process, Ulsan built and worked in a close cooperation with the local community.
Thanks to the efforts of Ulsan's environmental groups, local experts, local volunteer projects by K-water and other companies, citizen participation, and the local press, the Taehwa River was reborn from an almost-dead river to one boasting the best quality of all rivers in the Republic of Korea by 2011. This result is considered the fruition of the efforts of the municipal government, local residents, and area businesses, who realized that Ulsan would have no future without a clean river.

2.3. Human Security – Water for an Improved Quality of Life

The social and human dimension of green growth policies is at the heart of implementation of WGG projects. It is essential to have the support and buy-in of communities, non-governmental organizations, the private sector, universities and other stakeholders to have these projects work and to provide human security. With the support of those who are affected by a project, it will have a positive impact on their quality of life and security in terms of a reliable water supply. In the case studies that are part of this research, positive impacts on public health, education and quality of life were documented in depth. When a public waterway that was polluted is cleaned up, people love to stroll along its banks and use its water for recreational and other purposes. When women and girls have ready access to water and sanitation, they can use their time for other purposes, such as education and income generation. Attention to improving quality of life and the social dimension of green growth policies make people enthusiastic about implementation.

> *"It is essential to have the support and buy-in of communities, non-governmental organizations, the private sector, universities and other stakeholders to have these projects work and to provide human security."*

In each case, it is necessary to establish a specific mechanism to promote stakeholder participation in WGG projects prior to their launch. Managers must build in education and training programs for capacity-building aimed at both women and men and strive for gender balance. It is also important to pay attention to the establishment of participatory irrigation management through Water Users Associations and farmer cooperatives.

2.3.1. Policy 9 - Empower People, Especially Women, to Better Manage their own Water Resources

Communities have traditionally respected their water resources and may have a great deal to offer from accumulated know-how on management and knowledge of natural systems. Knowledge-sharing is a two-way street. Many of the case studies show how important it is to understand those traditions, history, and social relationships for effective water management. Empowering local communities, especially women, is needed to derive maximum benefits from water management initiatives.

To gain maximum benefits from water projects especially in rural and peri-urban areas, it is essential to involve women in decision-making related to water management so that the solutions proposed to them correspond to their needs. In most places, women hold primary responsibility for water use and hygiene in the home, and are responsible for caring for both the young and the old. Providing equal access to drinking water and sanitation services for the general public, especially the poor and marginalized, is a means to improve human health, livelihoods, gender equality and economic development. Community participation is essential to ensure that the facilities are taken care of and valued.

In the case study of Gujarat, India we found positive effects on the quality of life for 24 million people in water-short areas of north and central Gujarat.[20] Enhancement in social indicators in Gujarat, such as a decline in the proportion of people falling below the poverty line, improvement in health status and literacy rate, has empowered people and improved their capacity to manage and use resources more efficiently. With better education and awareness, people have begun to recognize the value of obtaining better quality water and power supply, and keeping the environment clean.

While many of these outcomes have resulted from large investments in social welfare and in large-scale water projects, various local level institutions such as Water User Associations and community-based Pani Samitis, have also played an important role in improving water security for both domestic and agricultural purposes. The Pani Samitis community groups were formed to delegate legislative power to local committees to manage village water supply.

Numerous NGOs, social activists, environmental groups, the international donor community, and scientific and academic institutions that are active in Gujarat have played a crucial role in highlighting the issues of water security, environmental protection, water management options, and their linkages with human development.

One example is the "People and Panchayat-led equitable water governance" project implemented in 18 villages of Meghraj Block in 2011 by the Development Support Center (DSC), an EU-IWRM implementing partner in Gujarat. The DSC has been working in Meghraj since 1996 undertaking projects on watershed development, agriculture enhancement and micro-finance. The DSC project focused on three critical areas: Improving access to water supply; improving water demand management through more efficient use of water; and better water governance through a people-led process that builds capacities to manage water resources, addressing the water needs of everyone including the poor and marginalized, with special attention to women.
The communities are mobilized into 'Sujal Committees' with the help of locally-selected women as extension volunteers (EVs). The Sujal Committees include members of already existing self-help groups, farmers' clubs, Panchayats or other groups and have relatively equal numbers of men and women.

In the absence of well-defined water rights, however, the opportunity cost of using water is very small in most situations. In Gujarat, water is not used efficiently in agriculture, as water is appropriated by those who pay more rather than people who need it more. When access to groundwater is attached to land ownership rights, the resource-rich farmers are likely to benefit more. To address this inequity of access to water, a well-defined water right system is needed, especially for the resource-poor small and marginal farmers in semi-arid areas of the state. To address equity and sustainability, water rights need to be established for groundwater resources.

2.3.2. Policy 10 - Promote Access to Clean Drinking Water and Sanitation as a Key to Poverty Alleviation, Public Health and Quality of Life

Access to clean drinking water was among the major achievements of the Millennium Development Goals (2000-15). The top four countries who led improvements in access to water and sanitation were China, India, Indonesia and Brazil. Among the achievements in water and sanitation in Brazil was an increase in access to water piped on premises from 78% to 96% between 1990 and 2015; an increase in access to improved sanitation from 68% to 86% in the same period;[21] a functioning national system to finance water and sanitation infrastructure; a high level of cost recovery compared to most other developing countries; as well as a number of notable technical and financial innovations, such as small-scale condominial sewerage and the output-based subsidy for treated wastewater called PRODES.[22]

Among the remaining challenges is the still high number of poor Brazilians living in urban slums (favelas) and rural areas without access to piped water or sanitation; water scarcity in the Northeast of Brazil; water pollution, especially in the Southeast of the country; the low share of collected wastewater that is being treated; and long-standing tensions between the federal, state, and municipal governments about their respective roles in the sector. Only 39% of sanitation facilities were considered safely managed in 2015, and only 27% of wastewater was being treated according to the World Health Organization/ United Nations International Children's Fund (WHO/UNICEF) Joint Management Program (JMP).[23]

Access to water and sanitation is essential for health, education, gender equality and personal security. In the coming years a renewed focus needs to be brought to bear to ensure that sanitary facilities are adequate, hygiene education is available and wastewater is properly treated in order to increase the availability of clean water.

2.3.3. Policy 11 - Facilitate adoption of Water and Green Growth through Education and Capacity Development Policies

As described in the previous two sections, skills required to maintain and manage local systems are needed at the community level. To ensure that installed facilities are used effectively and maintained, services should be provided to follow up after new technologies have been adopted. Local community members need to be trained in operation, maintenance, and repair of facilities. Women, in particular, need to understand the connection between clean water, sanitation and disease. Similarly, farmers who install drip and sprinkler irrigation systems on their farms need to be trained in irrigation scheduling.

Sustainable and equitable water management is possible only if local community institutions are capacitated and sufficiently empowered to play an effective role in governance at local level. Also, it is important that gender balance is considered in local water committees, as women are able to take responsibility for domestic water and sanitation facilities and care about them the most. Skills required for operation and maintenance at the local level, such as hand pump repair, can be taught to relatively uneducated people. Technologically driven solutions such as micro-harvesting should consider the needs of poor farmers.

Village water committees require capacity-building in operation and maintenance, and populations need to understand their rights and responsibilities. Capacity-building could increase understanding of impacts of a project and assist local water committees to make wise decisions about water management and environmental protection.

2.3.4. Policy 12 - Build Resilience among Watershed Communities to Cope with Water-Related Disasters

Protection of the watershed is needed to preserve ecosystem services and build resilience to climate change. It requires a broad framework that incorporates integrated planning and management of land use and water use at the river basin level, within a broader ecosystem context. Small-scale local projects can also provide resilience, particularly to isolated communities, such as in Nepal.

The Andhikhola Hydel and Rural Electrification Project (AHREP) in Nepal show that a small-scale multipurpose hydropower project can transform a local community and significantly improve its level of prosperity.[24] The project took a decade in preparation before it came into commercial operation in 1991, with technical and financial assistance from the Norwegian Development Agency (NORAD).
The long gestation period provided its owner, the Butwal Power Company Limited (BPC), time to develop innovative, sustainable rural electrification approaches and to develop local capacity, all of which has influenced Nepal's hydropower sector. This case study shows how the protection and management of a watershed area by a poor community can be used as the basis for green growth. As a result of a small-scale dam for hydropower and irrigation, both the quality of life in the community and levels of prosperity have risen significantly. This has been achieved through community engagement, capacity development and ownership of the project. Where local geography favors such a scheme, elements of this project could be transferred to other regions.

Within integrated water management, all sectors—governments, private sector and civil society—have to assume their responsibility, and all stakeholders need to be involved.

2.4. Institutional Resources - Strengthening Water Institutions

Strong institutional resources lie at the core of the ability to support green growth while safeguarding water resources. Traditionally the water sector has been led by an underlying assumption that, as a public good, water should be governed by the public sector. This view, however, has been shifting over the last several decades as non-state actors have also contributed to the sector through a variety of private sector and civil institutions. On the one hand, the state and its administrative agencies generally create public policies related to water, draft legal instruments and take responsibility for their implementation. On the other hand, water-related programs and services are increasingly undertaken by companies and consumers acting in their economic interests along with community-centered stakeholders. In order to strengthen institutional resources and tackle our complex water challenges, it is important to develop a variety of tools, align different institutions for policy implementation, mobilize funds, and coordinate multiple organizational structures.

2.4.1. Policy 13 - Develop Policy, Planning, Legislative and Information Tools

A variety of tools can be developed to strengthen water institutions ranging from instituting public policies at many levels, to insuring comprehensive planning, establishing a clear legal framework of legislation and regulations, and providing information through reliable data systems. Being able to apply different tools as needed helps support water institutions to manage river basins or watersheds in a holistic way, balancing economic growth with environmental protection and social development for green growth.

The Ebro River Basin provides an example based on Spain's decades-old water management policy at the river basin level. The Ebro basin has been managed since 1926 by the Confederación Hidrográfica del Ebro (CHE) as a partnership of private users and public authorities. CHE was the first water authority created to coordinate water policy in a river basin in Spain and one of the earliest river basin authorities in the world. It is an autonomous organization under the Ministry for Environment (currently named Ministry of Agriculture, Food and Environment) of the Kingdom of Spain.

During CHE's early period, the main objective was to promote and coordinate the construction and operations of infrastructure to support agricultural development and economic growth. More recently, the main functions of the Confederation have been:

“In order to strengthen institutional resources and tackle our complex water challenges, it is important to develop a variety of tools, align different institutions for policy implementation, mobilize funds, and coordinate multiple organizational structures.”

- To implement and enforce the Ebro River Basin Management Plan (or Hydrological Plan), 2010–2015, which was required by the Spanish Water Act. The Plan also responded to the EU Water Framework Directive (WFD) by increasing public participation and demanding higher water quality levels.
- To administer and control allocation of public waters. This includes water licensing to private users, quality control and environment protection.
- To manage public dams (over 100), canals and hydraulic works affecting more than one region within the river basin.

One of the top achievements of the Ebro planning process has been the creation of the Automatic Hydrological Information System (SAIH), a technological advance. SAIH uses flood zone mapping and flood risk management systems to minimize risks to people and property with high quality and real time information. The data also enables stakeholders to prepare in advance for floods, droughts and other emergencies. (Also see Policy 4.)

In Brazil, the National Water Agency (ANA) has primary responsibility for implementing the National Water Resources Management System (SINGREH) that governs the planning, regulation and control of the use, preservation and reclamation of the country's water resources. In addition, The Brazilian Water Law provides the legal framework for a series of water institutions and agencies allowing water management to be decentralized using the watershed as its geographical unit. The law established five management instruments for implementation: river basin plans, classification of water bodies, water permits, water use charges and information systems. (Also see Policies 5 and 10.)

While the National Council of Water Resources (CHRH) holds responsibility for national water policy, as part of the decentralization, all states and municipalities are mandated to prepare sanitation plans. However, it is the water basin committees that bring together different levels of government and types of water users. A total of eight river basin agencies had been installed by 2013 and over 200 river basin committees have been formed with a concentration in the southeast. The Piracicaba, Capivari and Jundiaí River Basins (PCJ) committee, for example, includes 50 members from both the federal and local governments, water users, stakeholders and NGOs. The PCJ committee undertakes numerous activities including hydrologic monitoring, basin conservation, water quality improvement, and capacity building.

Another key element of Brazil's water management is a total of 6,500 river gauging stations throughout the country where water quantity and quality are monitored by the National System of Hydrologic Information (SNIRH).

Together the Ebro River Basin and Brazilian case studies illustrate how water institutions can be strengthened when a wide variety of instruments are available to them—and when all major stakeholders are represented.

2.4.2. Policy 14 - Determine the Best Mix of Institutional Structures for Policy Implementation

Water-related challenges and water management cannot be addressed with a single policy instrument because of the different socio-economic contexts in each country and situation. Therefore, the WGG team analyzed the relationships and interactions among exogenous factors (*e.g.* economic, social, political, environmental and technical factors), institutions, and performance of the project in each case study. The team categorized water-related policy instruments into state-driven, market-oriented, and community-centered options based on relevant principles and drivers of change. Different types of options should be selected and tailored to the context and development objectives. The WGG project developed a policy mix framework focusing on three types of policy mixes based on the results of the analyses. These are:

SM (State-driven + Market-oriented Policy) Mix;

MC (Market-oriented + Community-centered Policy) Mix;

SC (State-driven + Community-centered Policy) Mix.

The State-driven plus Market-oriented Policy Mix (SM Mix) is the most common among to the 11 WGG in-depth case studies. This policy mix has been effective in four of 11 case studies: in China (Pudong Shanghai), Brazil, Turkey (Golden Horn), and Egypt. According to the results, the levels of economic, environmental, and social performances achieved were relatively high compared to other policy mixes. The strong leadership of the state and effective market-oriented instruments created synergies for sustainable development. Therefore, the State-driven and Market-oriented Policy Mix (SM Mix) showed a positive impact on the institutional effectiveness towards Water and Green Growth.

The Market-oriented plus Community-centered Policy Mix (MC Mix) combines market-oriented policy instruments and community-centered governance mechanisms. Among the case studies, Australia, Ecuador, and Nepal have deployed the MC Mix and found it to be effective. However, the performance of the MC Mix as measured in the analysis came out relatively low compared to other policy mixes. The low performance of the MC Mix may be a result of two factors: lack of political leadership for enforcement of plans and policies; and/or its use in the countries that already have achieved an advanced level of development goals (*e.g.* Australia). Commonly, stable political and economic environments were identified as pre-conditions for effective implementation of market-oriented instruments and stakeholder participation.

The State-driven plus Community-centered Policy Mix (SC Mix) combines a top-down approach by the central government with decentralized institutions and policy instruments. Four case studies fall under this category: India (Gujarat); the two case studies from the Republic of Korea (Sihwa and Taehwa); and Spain (Ebro Basin). The performance of the SC Mix is found most outstanding on the environmental dimension. To implement the SC Mix effectively, a coordination mechanism is necessary to resolve conflicts. As key enablers and implementers, the government and stakeholders can embrace different points of view on development plans. To harmonize the different opinions on all sides, regular meetings, with access to transparent and adequate information, and clear divisions of roles are required. Since the coordination process can be a lengthy one, a time frame should be carefully established. To implement a long-term Water and Green Growth Project, the government should provide financial support for the negotiating process. However, there might be financial constraints to continuing the projects. Since ensuring financing will be one of the key issues to facilitating the SC Mix, the private sector may also be encouraged to mobilize financing.

Details of the above policy mixes and suggested options for policy makers as part of a 'policy implementation roadmap' can be found in the 2015 WGG report.[25] The roadmap is a step-by-step tool to help policy makers achieve sustainable development and water security.

2.4.3. Policy 15 - Mobilize Funds to Ensure Financial Sustainability

Financial sustainability is essential for water institutions to be able to support green growth and provide water security over time. Stable funding streams can be secured in a number of ways: through central or local budgets; consumer tariffs and taxes; payments for environmental services (PES); water trading rights; and contributions from private firms and public-private partnerships.

A. Local Funds

The restoration of the Golden Horn estuary in Istanbul, Turkey provides an example of dedicated funding by the Greater Istanbul Municipality which was driven by the extent of pollution caused by heavy industry, overpopulation and lack of treatment facilities. (Also see Policy 2.) The Istanbul Water and Sewerage Administration (ISKI) contributed substantially to the project with around US $480 million in collaboration with the Istanbul Metropolitan Municipality (IMM), which added approximately US $173 million.

B. Consumer Tariffs

Water tariffs also played an important role in the Golden Horn project. (Also see Policy 2.)

ISKI based tariffs on a 'full capital and service cost recovery' principle as directed by the EU WFD and included water treatment costs in line with their 'polluter-pays' principle. As an autonomous municipal administration, the ISKI's ability to collect fees became the main source for project development and implementation. This allowed for well-planned financing and sustainable mobilization of monetary resources.

Brazil's federal government has a sustainable funding stream from water use and sewage charges, allowing them to allocate a dedicated part of their budget to water resources management. In turn that work contributes to green growth with environment management and sanitation improvements. This funding source is substantial: In 2011 values over US $10 billion were dedicated to water management.

C. Payments for Environmental Services (PES)

With large parts of Brazil facing water insecurity from climate variability, the country has also introduced two PES programs. (Also see Policies 5 and 10.) First, the Basin Pollution Control Program (PRODES), designed in 2001, offers financial support for construction and improvement of sewage treatment plants. Payments are only made after the project is complete and are based on the biochemical oxygen demand (BOD) abatement performance and population served. This avoids the risks of incomplete projects absorbing federal funds as well as increasing the efficiency of sewage treatment within river basins. From 2001 to 2013, 66 PRODES River Basin Restoration Program projects (sewerage and treatment stations) had been contracted by ANA in six different states of Brazil. This amounted to a total federal investment of US $152 million plus US $630 million of counterpart funding by local institutions and US $6 million from water charges. Although the Northeast region is the one with the most critical sanitation problems in Brazil, the large majority of PRODES projects have been implemented in the South and Southeast regions of the country. As far as the project's social performance is concerned, more than 7 million people in six states benefited from improved water quality from PRODES projects by the end of 2013, based on the population served by the wastewater treatment plants built.

The second program, the Water Provider Program, compensates farmers for effective erosion and sedimentation abatement with appropriate best management practices. Downstream water user and local governments who benefit provide the funds for the program which vary from US $25 to $150 per hectare per year depending on the level of economic development of the affected region.

D. Water Trading Rights

Water trading rights in the Murray-Darling River Basin, Australia provide another financial model. (Also see Policy 1.) The major challenge in the basin was balancing supply and demand for water in the face of population growth in its cities and climate change. Water rights have been distinguished legally from land rights and a market was established that allows water rights to be traded among different water users within a cap across the river basin. This cap allows the trading of water rights to the most valuable users and inherently redistributes water use to the most efficient allocation. The flexibility of the market system responds to changes over time with programs to stimulate inter- and intra-state trading within the basin. Since 2007, there has also been a mechanism for the Commonwealth to buy back water for the environment and restore it to the river basin when needed.

E. Public-Private Partnerships (PPPs)

Attracting private investments played an important role in the success of the Shanghai Pudong public-private partnership. (Also see Policy 3.) Starting in the mid-1980s, the Chinese central government prioritized development of Shanghai as one of the world's leading financial hubs. In order to attract more foreign direct investment, they decided, along with the local government, to invite private companies to bring investment, cutting-edge technologies and advanced management skills to the urban water services sector for the Pudong New Development Area. To provide an enabling environment for foreign investors, the 21st Century Urban Water Management Pilot Scheme of 1997 increased water tariffs to allow for favorable rates of return. Decisions on tariffs remained with the government under the Price Law. This reliable legal and regulatory framework strengthened business opportunities for private companies to invest. In this case, private sector participation was encouraged in areas such as the commercialization of public utilities, management contracts, concessions and joint ventures. The Shanghai Pudong Veolia Water Corporation Limited was China's first public-private partnership for the management of drinking water services. The municipal government represented by the Shanghai Chengou Group owns 50% with Veolia Water awarded a contract in 2002 for the remaining 50% stake for 50 years with an investment of about US $240 million.

A key achievement of the joint venture has been technological advances that reduce costs and water wastage. For example, a new customer service system optimized meter-reading with PDA and GPS locations and improved the quality of services. Smart technologies help bring more efficient water resources management via networking systems. In addition, real-time monitoring devices, state-of-the-art technologies at waste water treatment plants and independent laboratories have improved water quality to a level that meets European standards. While private sector financing in the water sector here helped the government to surmount financial constraints, the public sector provides the institutional framework to effectively regulate the business activities of private players and allows them to operate without unexpected market risks.

Together, these case studies demonstrate that there are numerous ways to mobilize funds that can ensure financial sustainability and strengthen water institutions to deliver green growth and water security.

2.4.4. Policy 16 - Create a Workable Coordination Mechanism

When there are competing demands for water resources across different levels of government operating in different policy areas—such as agriculture, water, climate change and regional development—there can be barriers to coordinating and collaborating across institutions within the state as well as with other non-state organizations. Disconnects can occur due to vertical fragmentation from one level of government to another, and horizontal fragmentation among agencies on the same level. Finding workable coordination mechanisms among relevant government agencies dealing with water and the environment and other key stakeholders can be crucial to the outcomes and green growth. Two examples of effective coordination mechanisms can be found in the Lake Sihwa and Ebro River Basin case studies.

During the long-term development of the Lake Sihwa urban renewal and lake basin recovery project in the Republic of Korea, formal government bodies, such as the Office of Government Policy Coordinator, took the lead in coordinating between the ministries involved. (Also see Policy 1.) Playing a mediating role were also informal groups, such as the Sihwa District Sustainable Development Council (SDSDC), whose discussions are open to the public and provide a platform for the local population to debate the issues and for the government to communicate ongoing progress of the project. The SDSDC was established after 10 years of opposition and protests against the eutrophication of the lake that had resulted from previous government actions. In addition to the Council's suggestions on restoration of lost habitat, the government has also accepted proposals on other issues, such as low-density housing. On any large-scale development project, meaningful public consultation and social mobilization along with the needed time commitments for them to take root can contribute significantly to their success. Green growth needs public support.

For almost 90 years, the Ebro River Basin Confederation (CHE) in Spain has provided a coordinating mechanism for their growing region as one of the earliest river basin authorities in the world. (Also see Policies 4 and 13.) Their Ebro River Basin Management Plan sets the overall framework for water management and has evolved under the EU's Water Framework Directive (WFD) to include greater public participation and higher water quality objectives. CHE engages not only government organizations but also communities, local authorities, representatives of civil society and the private sector, such as energy producers and agro-businesses. The result has been an extensive participation network that reaches all the sub-basins, acts as a forum for sharing information, allows consultation and feedback on proposals, and helps foster a shared understanding of the basin's complex water challenges and the tools available to surmount them.

These examples and other best practices demonstrate that effective coordination mechanisms work well when they are based within independent organizations with the resources to promote multi-agency cooperation. A key is to employ task forces, working groups or committees to engage with existing institutions across the public, private and civil landscape, to accommodate voices from many levels of society, and to remain flexible and transparent towards the public.

03

SDGs, Policy Guidelines and Next Steps

The magnitude of water-related issues in sustainable development has been widely recognized since the adoption of the Millennium Development Goals (MDGs) by the United Nation's Heads of State in 2000 to guide policy to 2015. In the context of the Sustainable Development Goals (SDGs) set forth in Transforming Our World: The 2030 Agenda for Sustainable Development,[26] adopted by the UN General Assembly in September 2015, the Water and Green Growth (WGG) project can provide practical approaches to using water as a vector through which green growth can occur in both developed and developing countries. Most countries need to rethink their approaches to water management. Policy makers would benefit from examining the recommendations in the Water and Green Growth: Beyond the Theory for Sustainable Future, Volumes 1 and 2, 2015 to set their countries on a more sustainable economic growth path.

Water security is among the top global risks in terms of development impact. It is also an integral part of achieving the SDGs. The world will not be able to meet the sustainable development challenges of the 21st century—human development, livable cities, food security, environmental protection and energy security—without improving management of water resources and ensuring access to reliable water and sanitation services. Water security remains a challenge for many countries currently coping with complex water issues that cut across multiple sectors. Population growth, urbanization, economic stresses and climate change have placed unprecedented pressures on water resources.

The SDGs, in particular Goal 6 on Clean Water and Sanitation, are to be universally applied to both developing and developed countries and have specific targets for water and sanitation from 2016 to 2030. As countries were far off track to meet the MDG sanitation target, they will need a renewed focus on the important role of sanitation and wastewater treatment in protecting our water resources and making more water available for productive use post-2015. International organizations, governments, the private sector and civil society organizations will need to work together to set realistic priorities for achieving the SDGs. WGG is one approach to addressing these targets simultaneously. The concept presents a new paradigm for understanding the formidable challenges of water management in the course of socio-economic development. The practical WGG policy options can make a major contribution to achievement of the SDGs over the next 12 years.

The policy guidelines for WGG provide policy makers options on how to establish a sustainable development process for water management, pursuing green growth in both developed and developing countries. The guidelines are related to the three pillars of sustainable development, as discussed above: Water as an Engine for Growth; Protection and Conservation of Water Resources; and Water for an Improved Quality of Life. Suggested policy options can be adapted to the circumstances specific to the area and incorporated into larger national development policies and plans for achieving green growth in the future. They should be pursued in line with strengthening water institutions, and can be supported by such instruments as: indicative basin and river planning; clear legal frameworks (*e.g.* water legislation); water management regulations; data management systems; mobilization of funds to ensure financial sustainability through the public budget; and coordination mechanisms. They can also employ an array of economic instruments such as private sector participation, payments for environmental services (PES), incentives for conservation, and stakeholder participation.

“Policy makers would benefit from examining the recommendations in the Water and Green Growth: Beyond the Theory for Sustainable Future, Volumes 1 and 2, 2015 to set their countries on a more sustainable economic growth path.”

Some of the major international initiatives in support of SDG 6 are highlighted below.

A. International Decade for Action on Water

Among the major initiatives underway now, an International Decade for Action on Water for Sustainable Development was launched on World Water Day, 22 March 2018 at the UN General Assembly, to run through 2028.[27]

B. Global Water Initiative

In recognition of the essential role of water in economic growth, the World Economic Forum (WEF) has established the Global Water Initiative that is currently working on accelerating implementation of SDG 6 with a new generation of technological solutions based on the 4th Industrial Revolution.

C. 2030 Water Resources Group

Another current initiative is the World Bank’s 2030 Water Resources Group (2030 WRG),[28] a global public-private partnership to help countries achieve water security by 2030, with a mission to facilitate collective action on water among governments, the private sector and civil society.

D. International Conferences

Annual conferences, such as the Stockholm International Water Week and Korea International Water Week, as well as periodic meetings among water professionals and policy makers, such as the triennial International World Water Association (IWRA) World Water Congress[29] and World Water Forums,[30] bring together water and sanitation practitioners representing all aspects of water management. In particular, the 9th World Water Forum will focus on “Water Security for Peace and Development,” in Dakar, Senegal in 2021. These gatherings provide excellent forums in which public and private sector actors, academic institutions and NGOs can coordinate their efforts to reach water and sanitation goals and targets.

All of these international efforts must be harmonized and coordinated to reduce the risk of serious global water crises in the near future. Attention to climate change, protection of water sources and ecosystems, and participation of all stakeholders will be needed to achieve sustainable economic growth. International cooperation is a driving goal of the WGG project and is critical to addressing environmental issues, such as climate change and integrated river basin management, as well as economic issues, including trade agreements, watershed and resource protection, water transportation and navigation. It is also essential for technology transfers, development cooperation, capacity-building and disaster preparedness.
As a result, it is worth paying special attention to the WGG project in the context of the increased attention being paid to water resources in the 2030 Agenda for Sustainable Development.

In conclusion, water plays a vital role in our future development and security as we face the growing global challenges of population growth, urbanization, economic stresses and climate change. Water and Green Growth offers an innovative water-centered paradigm for environmentally sustainable and socially inclusive economic growth that safeguards water resources and supports water security. This overview of the Water and Green Growth research and policy analysis, which were developed by a team of water resources specialists over five years, summarizes realistic and flexible policy options along with examples of best practices from extensively documented international case studies. It also draws the interconnections between global water security and green growth in the larger context of the United Nation’s Sustainable Development Goals. We encourage policy-makers at all levels to look into the opportunities for valuable economic, environmental and social benefits and increased water security that can be gained from embracing and implementing the approach put forward by Water and Green Growth.

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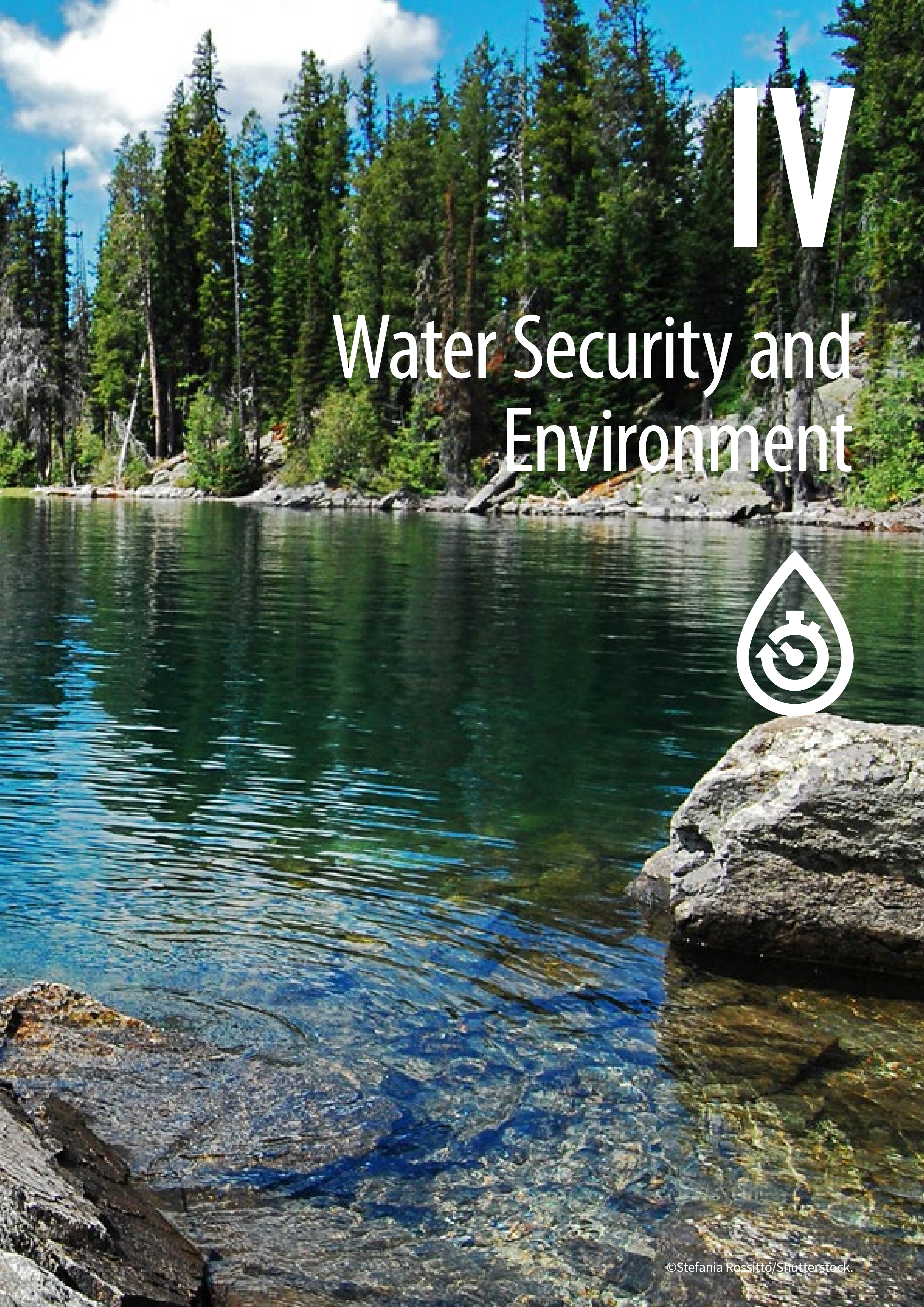
IV

Water Security and Environment



7

Integrated Climate Action in the Context of the Water-Land Nexus: Centrifugal Force vs. Centripetal Force

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Abstract

This paper aims to promote integrated climate action in the context of the water-land nexus by highlighting the interrelations between mitigation and adaptation interventions as well as the interlinkage of water and land sectors. Due to growing concerns on water security associated with climate change, more innovative tools to address water security are needed.
The water-land nexus is useful to promote the efficient resources management, effective risks management, and sustainable development as well as to address water security. Key centrifugal force and centripetal force for integrated climate action in the water-land nexus are identified, which are reflected in the following policy recommendations:

1) a holistic assessment of climate action;
2) a precautionary approach;
3) integrated development planning processes in the context of the water-land nexus; and
4) balanced approach to empower key actors in both water and land sectors.

Keywords

Integrated climate action, water-land nexus, centrifugal force, centripetal force, water security

01

Introduction

One of the most significant UN initiatives is the 2030 Agenda for Sustainable Development, which are specified within the internationally agreed 17 Sustainable Development Goals (SDGs) and 169 targets. Based on the lessons learned from the 'Water for Life' decade,[1] a comprehensive water goal (SDG 6) was developed, aiming to 'ensure availability and sustainable management of water and sanitation for all'. According to UN-Water, the water goal is highly linked with other SDGs, so it is central in achieving the SDGs (refer to Figure 7-1).[2] Due to the key role of water in economic, social, and environmental aspects of the SDGs framework, there are growing interests in ensuring water security.

Water security is very complicated, so it is often considered beyond the traditional water sector. By applying a nexus approach, cross-sectoral issues can be more efficiently addressed and some interlinked sectors can make collective efforts to explore co-beneficial solutions. The water-land nexus has been primarily promoted by the agricultural sector and food security, coupled with water security, becomes the core issue in this nexus. Although food security is still an urgent issue particularly in the developing countries, the water-land nexus should also focus on other important issues such as competing goals and unsustainable uses of the limited water and land resources in support of rapid urbanization and industrialization. Since climate change is considered as one of the common challenges to water security and food security, climate change should be addressed in the water-land nexus.

> *"Since climate change is considered as one of the common challenges to water security and food security, climate change should be addressed in the water-land nexus."*

The Paris Agreement, the new global climate deal, finally entered into force on 4 November 2016, which requires more robust climate action towards a climate neutral world. In the climate negotiations, the collective mitigation goal (*e.g.* 2°C or 1.5°C temperature limit) had been always highlighted, so the political agenda and investment focused on national or sectoral emissions reduction targets and mitigation interventions that reduce the sources or enhance the sinks of greenhouse gases (GHG). As climate-related risks had been noticeably increased, however, the significant need for adaptation was recognized by international and national decision makers as well as local communities and governments. In the Paris Agreement, countries agreed to further promote adaptation interventions to reduce vulnerability and build resilience to the impacts of climate change and also apply a balanced approach to climate finance and international support for between mitigation and adaptation.[3]

Although the UN Framework Convention on Climate Change (UNFCCC) is the primary forum for global negotiations on climate change, SDG 13 also provides a basic framework to promote and track climate action by focusing on the importance of 'urgent action to combat climate change and its impacts'. Integration is particularly highlighted in SDG 13 targets and indicators, which do not include only mitigation and adaption, but also disaster risks reduction/impact reduction/early warning, technology transfer and development action in the context of policy/strategy/plan or education.[4]

While the importance of integrated climate action has been widely recognized in the international frameworks for climate change, climate action has been rarely integrated in the national context of climate policy or development plan as well as in the context of the water-land nexus. This paper aims to promote integrated climate action in the context of the water-land nexus. Through literature review, it explains what integrated climate action means in the context of the water-land nexus and why this nexus context is proposed to combat climate change. And then, it explores how to nurture climate action by identifying centrifugal force or centripetal force for its integration.

Figure 7-1 SDG 6 infographic on the linkages between the water targets and other SDGs (Source UN Water. http://www.unwater.org/app/uploads/2017/05/SDG6-Interlinkages-1and2.pdf/)

02

Literature Review: Interlinkages between Mitigation and Adaptation

Mitigation and adaptation measures have been separately implemented until recently. Mitigation interventions can proactively reduce climate risks, but it is impossible to completely avoid climate risks, which requires reactive adaptation interventions to deal with negative and often irreversible effects caused by unavoidable climate risks. It is recognized that mitigation and adaptation are complimentary to deal with climate change and that the climate neutral world can be achieved by incorporating both mitigation and adaptation measures into the development pathway towards low GHG emissions and climate-resilience.

Climate expert groups such as the Intergovernmental Panel on Climate Change (IPCC) identified co-benefits and synergies as well as common enabling factors and constraints for mitigation and adaptation e (IPCC, 2014c). In order to ensure the effectiveness of the integration, it is fundamental to understand the differences, commonalities, and interlinkages between mitigation and adaptation measures.

2.1. Differences between Mitigation and Adaptation

a) **Objective**: Mitigation is to limit anthropogenic GHG emissions in the atmosphere by reducing the causes of climate change, while adaptation is to deal with the impacts of climate change by enhancing resilience to climate risks and impacts.

b) **Key parameters**: Mitigation focuses on emission factors or total emissions, while adaptation focuses on vulnerability and resilience.

c) **Priority**: The priority groups (locations or sectors) for mitigation have the high levels of GHG emissions, sufficient financial resources, or cost-effective mitigation measures, while adaptation prioritizes the most vulnerable groups to climate risks.

d) **Approach**: The primary approach for mitigation is command-and-control, market-based, or technical, while adaptation often relies on a process-based or community-based approach. By establishing standards for GHG emissions or energy efficiency, many countries apply a command-and-control approach. The typical policy instruments of a market-based approach are carbon taxes, GHG emissions trading system (ETS), and the Clean Development Mechanism (CDM).[5] A one-off adaptation intervention cannot cope with the long-lasting and irregular impacts of climate change over time, so adaptation requires a process-based approach for socio-institutional learning and iterative climate action.[6] Due to the importance of inclusive and participatory climate action, community-based approach (CBA) to climate change adaptation has been promoted by many organizations such as CARE, United Nations Development Programme (UNDP), and International Institute for Environment and Development (IIED).[7]

e) **Spatial and time scale of impacts (Tol, 2005)**: Benefits from mitigation interventions are not directly associated with those who bear the mitigation costs but distributed to global communities and future generations. Adaptation interventions generally benefit local communities immediately or in a relatively short period.

f) **Driver of climate action**: Mitigation has been historically driven by international agreements, while adaptation has been often driven by the needs of local communities or governments. Climate actions can be taken at all different governance levels.

g) **Boundary of projects**: Mitigation requires a relatively specific and smaller boundary (*e.g.* one plant) for projects, while adaptation requires a broader project boundary by considering community-based situation or natural and human systems.

h) **Uncertainty level (IPCC, 2014b)**: Climate change is complex so it is important to understand the uncertainty level. Uncertainties associated with climate interventions may vary widely across different measures, sectors or operational conditions. Many factors (such as economic development, natural system, policies, financial capital, technological innovation, social characteristics and cultural norms/values) unevenly influence the effectiveness of mitigation or adaptation, so it is not easy to determine the level of uncertainty ex ante. Compared with adaptation, however, mitigation seems to face a lower level of uncertainty because measurement, reporting, and verification (MRV) technique for mitigation interventions is advanced, accumulated experience and knowledge (data/information) of mitigation activities are well recorded, and global attention and obligations are quite intensive.

2.2. Commonalities between Mitigation and Adaptation

a) **Complementary risk management**: Proactive mitigation interventions that reduce climate risks and reactive adaptation interventions that cope with unavoidable climate risks are complementary rather than substitutive. To effectively manage climate risks, therefore, a portfolio of diverse mitigation and adaptation interventions is required for climate policy. It is noted that many of current adaptation interventions can be more proactively (*e.g.* before the real impacts are observed) employed due to the ongoing development of technologies in modeling, analysis and evaluation on climate sensitivity and adaptive capacity, (IPCC, 2014a).

b) **Sustainable development**: Mitigation and adaptation both have implications for sustainable development since they share common goals such as efficient resource management and equal access to resources. Climate action in the developing countries can be more effectively implemented by addressing development challenges such as poverty, food security, water security, and education. Therefore, the conceptual framework of sustainable development is required for the effective integration between mitigation and adaptation (Harry and Morad, 2013). Many development agencies such as UNDP, Green Climate Fund (GCF), and World Bank have already prioritized development projects relevant to both mitigation and adaptation.

c) **Implications for other policies**: Mitigation and adaptation also have implications for environmental policy because climate action results in ancillary benefits[8] such as reduced air pollution or reinforced biodiversity. According to the IPCC (IPCC, 2014a), environmentally sound technologies can be beneficial to combat climate change in terms of both mitigation and adaptation. So, technological development paths are often determined for both climate action and environmental sustainability.

2.3. Examples of the Interlinkage between Mitigation and Adaptation

a) The IPCC report (IPCC, 2007) provides various examples and implications for the interrelationships between mitigation and adaptation:

- Four types of interrelationships between adaptation and mitigation are identified. The first type is adaptation actions that have consequences for mitigation. The second type is mitigation actions that have consequences for adaptation. The third type is decisions that include trade-offs or synergies between adaptation and mitigation. And the last type is processes that have consequences for both adaptation and mitigation.
- There will be significant benefits from integrated (mitigation & adaptation) interventions, especially for high climate sensitivities and in sectors/regions that are already showing signs of being vulnerable. National vulnerability index analysis (with and without mitigation) implies that mitigation can reduce vulnerability in terms of exposure and sensitivity to climate change.
- The impacts of adaptation on mitigation can be both positive and negative and vice versa. On the operational scale of most projects, however, the impacts of adaptation interventions are unlikely to be significant to mitigation.
- Short-term mitigation interventions (*e.g.* hybrid forest plantations) may pose a threat to adaptation (*e.g.* low biodiversity and ecosystem resilience).

b) The latest IPCC report (IPCC, 2014a) highlights the positive interrelationship between mitigation and adaptation:

- Mitigation will reduce the rate and magnitude of future climate change, which can minimize the likelihood of exceeding critical threshold of adaptation. However, it should be noted that the impacts of mitigation interventions on adaptation will appear in the future so the current interlinkage between mitigation and adaption is less noticeable and that the threshold of adaptation is relative and site specific. That is, the possible impacts of climate action will vary over space and time.
- Knowledge about adaptation can be used to determine the level and timing of mitigation. However, much knowledge about adaptation is dominated by community-based case studies, which may limit general applications of the knowledge.

c) Dang *et al.* (2003) illustrate how to incorporate adaptation benefits in a mitigation project by conducting a case study of Vietnam:

- By linking both adaptation benefits and sustainable development criteria in the analysis of potential Clean Development Mechanism (CDM) projects, they identify mitigation projects can have ancillary benefits of adaptation.
- They insist that an integration framework for adaptation and mitigation should be established and incorporated in a development policy by demonstrating potential interlinkage between adaptation and mitigation.

d) Based on review of 112 adaptation and 123 mitigation projects in different portfolios that include CDM and Community and Biodiversity Standard (CCB) projects, the Center for International Forestry Research (CIFOR) study[9] shows that mitigation projects have higher potential for adaptation:

- 78% of the adaptation projects had the potential co-benefits of mitigation.
- 100% of the mitigation projects had the co-benefits of adaptation, which doesn't mean that mitigation projects will automatically generate adaptation benefits. The study implies that the potential of mitigation projects for adaptation will be promoted through coordinated project design for the effective integration.

e) The CDM has been designed and implemented to connect mitigation interventions with adaptation potential as well as sustainable development:

- The Adaptation Fund is financed with a share of proceeds (2% of CERs) from issued CDM project activities. Adaptation can be further promoted by this Fund when the scalability of the CDM is facilitated.

- The UNFCCC secretariat develops the 'Sustainable Development co-Benefits Tool' that enables project participants to voluntarily report the sustainable development co-benefits of their CDM projects. So far, not many CDM project participants use the SD tool, but the published reports demonstrate that their projects contribute to sustainable development.[10]

Although there are various practical research and assessments to confirm the interrelationships between mitigation and adaptation, many national climate action plans do not seem to take their interrelationships and synergies into account. According to a synthesis report[11] from the UN secretariat that supports global climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), most countries announced their mitigation and adaptation commitments but only several countries specified sectors and some example measures that could generate synergies between mitigation and adaptation and a few countries (*e.g.* Burkina Faso and Chile) reported that they would apply an integrated approach. This synthesis report confirmed that most countries identified key sectors and sector-specific work programmes and policies separately for mitigation or adaptation, while some countries highlighted a cross-sectoral approach or the nexus of key sectors such as energy and of interest here, water and land (focusing on agriculture and forestry).

"Climate neutral world can be achieved by incorporating both mitigation and adaptation measures into the development pathway towards low GHG emissions and climate-resilience."

03

Key Sectors and Sectoral Approach to Combat Climate Change

In the context of climate change, mitigation or adaptation interventions have been implemented primarily by key sectors. The key sectors for mitigation include energy, building, transport, industry, waste, and land use sectors that have high emissions or high potential for emissions reduction, while the key sectors for adaptation include water, agriculture, human settlement, health, and ecosystem sectors that are most vulnerable to the impacts of climate change (IPCC, 2007). The IPCC and other international expert groups identify the key sectors for mitigation and also those for adaptation, but the key sectors are varied depending on country-specific situations in terms of the economic, social and environmental aspects.

Since mitigation interventions will generate global benefits for later generations rather than direct benefits for those who implement mitigation interventions or bear mitigation costs, it is necessary to establish regulatory or incentive frameworks to promote mitigation interventions in the key sectors. Mitigation measures such as energy-efficient technologies or efficient resources management can somehow compensate the increased investment costs, but costs of most mitigation measures overweigh direct benefits for the implementers. So, regulatory or incentive frameworks are developed to remove market barriers, increase market opportunities, promote technology development, and provide financial supports. Some key sectors, particularly the industry sector, apply a global sector-based approach and promote international collaborations to reduce GHG emissions through voluntary Agreements and actions (*e.g.* cement sustainability initiative).[12]

Through sectoral vulnerability assessments, countries can identify and manage future threats and implement sector-specific adaptation measures, which can produce local benefits directly for the target groups. As climate-related stresses and risks are increasing, incentives of the vulnerable sectors become stronger to implement adaptation interventions. However, vulnerable sectors and groups often do not have sufficient resources and knowledge for the implementation, so sectoral adaptation measures can be implemented more cost-effectively by integrating into relevant socio-economic and environmental policies and projects. Since traditional knowledge and practices of local communities, specific landscape scopes of local ecosystems, and broad participation are important in successful adaptation interventions, community-based approaches are highly recommended.

Water sector and land use sector are very important in the context of climate change because both are the key vulnerable sectors and also their contributions to climate mitigation can be significant. Adaptation interventions to cope with climate-related risks in the water sector and measures to ensure water security are often similar or produce co-benefits. For example, the water sector has expanded and improved water systems ranging from water sources to end users and adopted innovative technologies for rainwater harvesting, groundwater recharging, desalination, water recycling/reuse, and water conservation, resulting in contributions to both climate change and water security. Adaptation interventions such as coastal protection infrastructure and stabilization of river can also help ensuring water security. By utilizing the advanced information & communication technology (ICT) and monitoring techniques, flood control and water systems can be more effectively managed.

Nicol & Kaur (2009) identify that most of adaptation plans found in the National Adaptation Programmes of Actions (NAPAs)[13] are supply-side interventions. Since the NAPAs are prepared by Least Developing Countries (LDCs) and most LDCs are suffering from water scarcity, their priority needs are to explore and secure water resources. In many other countries, supply-side interventions are still dominant. In South Korea, for example, the 'Four Major Rivers Restoration Project (4MRRP)' was proposed as one of the key adaptation interventions and performed multiple tasks such as water security, flood control, and community development, but it was highly associated with supply-side interventions. However, remaining or emerging challenges and problems in the water sector cannot be fully addressed by supply-side interventions, and they may be rather intensified due to competing objectives and inconsistent strategies of water security and climate action.

The water sector is one of the largest energy consumers, so the sectoral emissions can be reduced through energy efficiency (*e.g.* efficient pumping), fuel switch (*e.g.* from coal to LNG), water saving (*e.g.* water-loss control) and system monitoring including metering of water consumption. The water sector makes a significant contribution to GHG emissions reduction directly by developing renewable energy plants using hydropower. Wastewater treatment plants can be climate neutral by establishing systems for heat recovery, biogas electricity generation from anaerobic treatment, and sludge recycling/incineration.[14] Table 7-1 summarizes key adaptation and mitigation interventions in the water sector and also includes some interventions for both adaptation and mitigation.

Climate change intensifies water scarcity and flooding, so the causal relationship between climate change and water becomes more noticeable and the impacts of climate change on water resources have attracted more attention than their reciprocal relationship. Therefore, the mitigation potential is not fully considered in the water sector and some counter-productive outcomes of adaptation measures on GHG emissions associated with the land sector are sometimes overlooked.

Land is the key resource that has been used for various purposes such as human settlement, agriculture, forestry, and water. In the context of climate change, 'Land Use, Land-Use Change and Forestry' (LULUCF) sector had been developed, which was replaced by 'Agriculture, Forestry and

Adaptation interventions	Mitigation interventions
Augmentation & Improvement of water supply system	Hydropower
Groundwater recharge	Energy efficient pumping
Rainwater harvesting	Fuel switch (to low carbon intensity)
Water recycling and reuse	Heat recovery
Desalination	Biogas electricity generation
Coastal protection infrastructure	Sludge recycling/incineration
Stabilization of river/ Flood control	CH_4 recovery/reduction
Water conservation and saving	
System monitoring	
Integrated Water Resource Management (IWRM)/ Water governance	
Public awareness and Education	

Table 7-1 Adaptation and mitigation interventions in the water sector

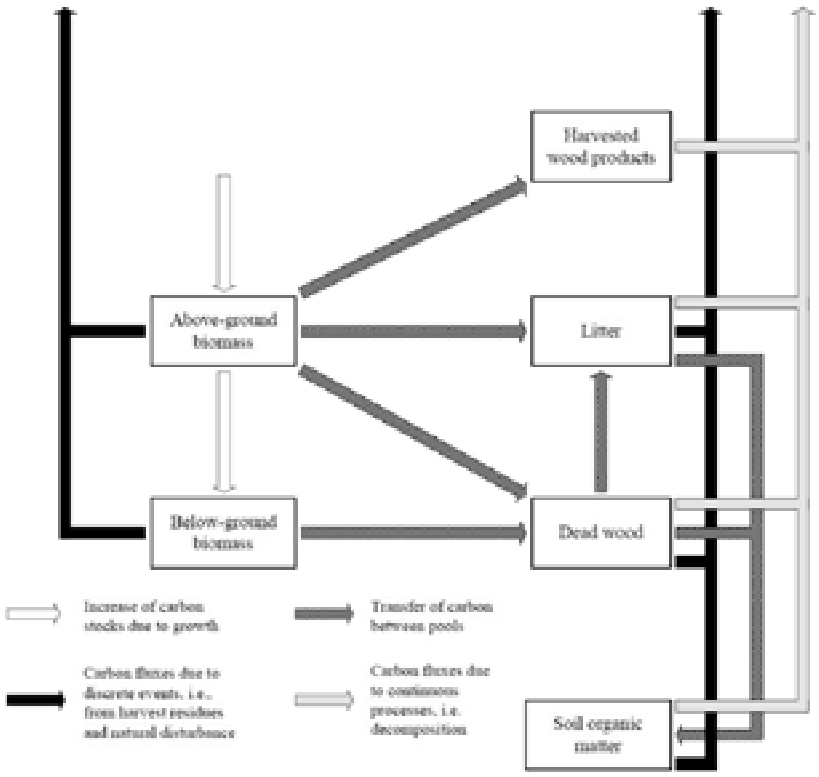

Figure 7-2 Generalized carbon cycle of terrestrial AFOLU ecosystems
(Source 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol 4, Chap 2.)

Other Land Use' (AFOLU) sector.[15] However, instead of AFOLU, the term of LULUCF is widely used because the LULUCF sector still remains in the GHG inventories. In accordance with the Good Practice Guidance for LULUCF developed by the IPCC, the changes in carbon stocks and GHG emissions caused by land-use change can be estimated and monitored, so mitigation interventions in the land sector focuses on land-use change in order to understand the reciprocal relationship between climate change and land change. Figure 7-2 shows carbon cycle of ecosystem in the LULUCF sector.

According to United Nations Convention to Combat Desertification (UNCCD), one fourth of total global emissions come from the land-use sector.[16]
The land development, mainly the land conversion to agricultural land, is responsible for deforestation and the loss of carbon storage. The land sector has contributed to enhance the sinks of GHG by implementing afforestation and reforestation (A/R)[17] and by avoiding deforestation. The land sector has also contributed to reduce the sources of GHG emissions by generating bioenergy or applying effective wetland restoration (*e.g.* peatland rewetting).

Land is also vulnerable to climate change, so various adaptation measures are implemented to increase the resilience and improve the adaptive capacity, which includes adjustment of planting practices, crop variety, crop relocation, erosion control, soil conservation and disturbance control. The land sector generally serves both mitigation and adaptation functions, but the integration between mitigation and adaptation are not based on synergy but on co-benefits (Duguma *et al.*, 2014).[18]
That is, when climate action either for mitigation or adaptation is implemented in the land sector, the co-benefits are intentionally considered or unintentionally delivered, but synergy is not systematically considered to generate more beneficial outcomes. Table 7-2 summarizes key adaptation and mitigation interventions in the land sector, which shows that many interventions in the land sector can be implemented for both adaptation and mitigation.

Adaptation interventions	Mitigation interventions
Sustainable crop and soil management	Low emissions agriculture
Erosion control	Agro-forestry
Disturbance control	Bioenergy generation
Ecosystem conservation and restoration	
Afforestation and reforestation (A/R)	
Water & Energy efficient irrigation techniques	
Integrated land use planning	
Public awareness and Education	

Table 7-2 Adaptation and mitigation interventions in the land sector

04

Climate Action in The Context of the Water-Land Nexus

The water-land nexus is driven by pollution, scarcity and economics (Nkonya *et al.*, 2011).[19] Since water and land can be a pollution source for each other, integrated water-land management is called for to promote the co-benefit of reducing pollution loads in water and soil. Particularly, non-point source (NPS) pollution that is widely distributed through rainfall or snowmelt can be effectively controlled only in the context of the water-land nexus. Due to the overuse/exploitation of water resources and drought, water scarcity becomes a major constraint for land development. Water development (*e.g.* dam development) requires land-use changes, which often reinforce social conflicts and competing interests over limited land resources. For sustainable development, access to and productivity of water and land should be further improved as well as coordinated conservation strategies and integrated development planning processes of water and land should be promoted.

Due to the interdependencies and interactions of water and land resources, each sector recognizes the need for cooperation in order to manage negative consequences or restricted conditions caused by the other sector. Based on cooperation experience and successful achievements in risks reduction and resource use efficiency, the water-land nexus has been widely applied. The water-land nexus has been further enhanced through integrated planning processes that intensify development opportunities and potentials. That is, the water-land nexus is useful to promote the efficient resources management, the effective risks management, and sustainable development. A nexus approach focuses on synergies, trade-offs, and cross-sectoral governance and management, which can promote sustainable development (Hoff, 2011).

Climate change is one of the core challenges in both water and land sectors. Since water security and food security are significantly influenced by climate change, climate change is considered as a risk factor and strong efforts are put on adaptation in the context of the water-land nexus. Climate action (for mitigation and/or adaptation) may result in synergies between the water and land sectors or may result in counter-productive outcomes across the sectors. By applying the integrated assessment of climate action and using empirical evidences in the IPCC's technical paper (IPCC, 2008),[20] three types of integration are identified in the water-land nexus.

The first type of integration in the water-land nexus is adaptation measures in one sector that have consequences for adaptation and/or mitigation in the other sector.
For example, irrigation efficiency, one of the main adaptation measures in the land sector, will contribute to water-saving and energy-saving and consequentially deliver co-benefits for adaptation and mitigation in the water sector. Rainwater harvesting is one of the adaptation measures in the water sector, which reduces the needs of water development and the likelihood of land-use changes that may cause deforestation. Dam and reservoirs, adaptation measures in the water sector, require land-use changes, so such adaptation measures can have negative impacts on mitigation in the land sector.

The second type of integration in the water-land nexus is mitigation measures in one sector that have consequences for adaptation and/or mitigation in the other sector.
For example, wetland restoration is implemented to reduce the sources of GHG emissions in the land sector by rewetting drained peatlands, which can contribute to improve the adaptive capacity in the water sector through enhanced flooding control. In order to replace petroleum fuels, it is often promoted to generate bioenergy, which may increase competition for limited land and water resources (Hoff, 2011). Hydropower considered as one of the effective mitigation measures in the water sector will change land-use and land-cover types and intensify competitions over water resources, which may have negative impacts on mitigation in the land sector as well as adaptation in the water sector.

The third type of integration in the water-land nexus is climate action that have both mitigation and adaptation functions across sectors. Afforestation and reforestation (A/R) will enhance the carbon sinks and adaptive capacity of ecosystems, so this intervention has integral mitigation and adaptation functions. However, A/R projects demand more water, so A/R can reduce water resources, resulting in negative impacts on adaptation in the water sector. When fast-growing alien species are selected to improve the efficiency of A/R, biodiversity can be reduced, which results in negative impacts on adaptation in the land sector. If no trade-offs are considered between mitigation and adaptation in the water-land nexus, the negative impacts can be significant (IPCC, 2007).

Figure 7-3 demonstrates an approach to understand integrated climate action in the water-land nexus, which includes key drivers (*e.g.* sustainable development and cross-sectoral governance/management) and challenges (*e.g.* competing objectives, limited resources, and growing risks).

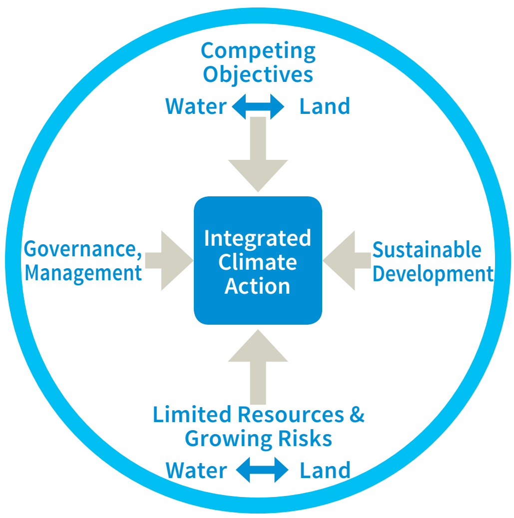

Figure 7-3 Approach on integrated climate action in the water-land nexus

05

Centrifugal vs. Centripetal Force of the Effective Integration

Four sections (*e.g.* adaptation in water, mitigation in water, adaptation in land, and mitigation in land) are introduced for the integration between mitigation and adaptation within the water-land nexus as specified in Figure 7-4. Each section has its distinct scope and specific objective, and its independence can be further enhanced by the following centrifugal forces:

- Complexity and Uncertainty: A high level of uncertainty persistently remains in this complex nexus area of climate change, so current knowledge of the integration between mitigation and adaptation is limited. Due to the lack of empirical data, robust evidences derived from quantitative assessments of their relationships are insufficient.
  The knowledge gap in assessing the opportunities and risks associated with the four sections is the key cause for the lack of awareness and actions on their effective integration. Diverse socio-economical and political settings reinforce complexity and uncertainty in addressing climate change in the water-land nexus.
- Sectoral approach: As described above, a sectoral approach is widely applied to combat climate change. That is, most mitigation and adaptation interventions have been implemented by each sector, which can result in unintended negative consequences to other sectors, particularly when they are not coordinated. Cross-cutting issues are mainly associated with risks and problems, which can be effectively addressed by coordinated governance and management. However, a sectoral approach makes it difficult to sustain coordination across sectors, which often fails to identify and ensure potential synergies.
  The lack of knowledge communication across sectors and expert-dominant governance reinforce the sector approach. Kim *et al.* (2017) identify that knowledge flows across water and agriculture sectors in Korea are very limited and problematic at the community, local, provincial, and ministerial levels. Recently the nexus approach has been applied, but knowledge-sharing and collaboration among sectoral experts rarely go beyond the sectoral scope.
- Institutional fragmentation: Since climate change becomes the top priority of political agenda in many countries, most governing bodies (including centralized and polycentric) are involved in addressing climate change.
  However, the institutional arrangements are rather diverse and fragmented. Also, coordinated governance is a token effort (tokenism) or difficult, particularly at the planning stage. Due to the broad scopes of water and land, the participations of multiple stakeholders and decision-makers are required. Governing bodies organized along hierarchical lines are often unfamiliar with horizontal communications across segmented water and land authorities, so it is difficult to apply a coherent approach to climate change and take conflicting interests and goals of participants into account.
- Trade-offs without synergies: Due to the limited resources, trade-offs between competitive mitigation and adaptation measures are often needed. If mutually aligned, mitigation and adaptation can deliver synergies. Through simple checklists, positive lists, or negative lists, synergies can be enhanced and/or negative consequences can be minimized. In fact, the integration can be effective when trade-offs and synergies are assessed coherently and comprehensively. However, there are few reliable assessment tools available to quantify both synergies and trade-offs.
  Therefore, synergies are rarely considered and trade-offs are made primarily based on political priorities and dynamics. In the nexus context, there are more opportunities for synergies and less needs for trade-offs, which should be further explored.

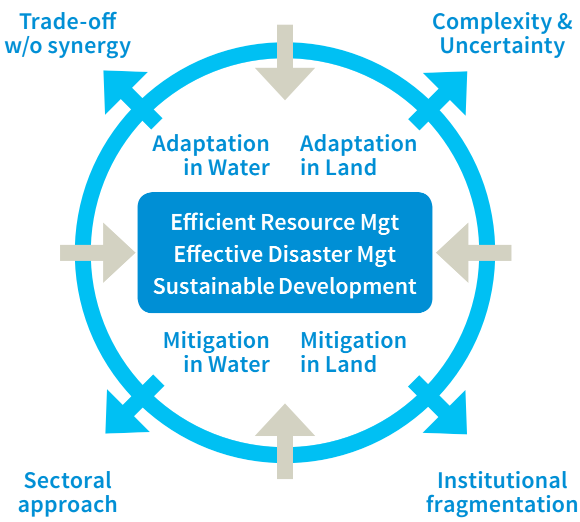

Figure 7-4 Centrifugal vs. centripetal forces of the integration

While the centrifugal forces can enhance the independence of each segment, the centripetal forces can promote their integrations. It should be noted that each segment cannot be completely independent and they are inherently overlapped or linked. The core functions of all the four segments are highly associated with resources management, disaster management, and sustainable development. Therefore, the four segments can be effectively integrated in achieving the common goals of resource efficiency, disaster risks reduction, and sustainable development, which can deliver joint mitigation and adaptation outcomes in the water-land nexus. Coordinated governance and enhanced capacities are needed to ensure the centripetal forces working for the integration. Above all, sustainable development is critical to promote the integration.

06

Conclusion: Policy Recommendations

Although water security is a more comprehensive and inclusive issue compared to water scarcity, water scarcity is the most prominent and common threat, which has been addressed mainly by the top-down, supply-oriented approach. Physical and socio-economic water scarcity is not yet fully addressed. Increasing transparency issues and conflicts associated with water scarcity exacerbate water security, so the importance of water governance[21] has been widely recognized. Water governance consists of complex systems for dynamic decision-making related to water resources and public-private cooperation, and political element is particularly important (Batchelor, 2007). Due to the interdependences between water and other sectors, water governance also calls for cross-sectoral collaboration, and communicative governance should be further enhanced. In order to address climate change challenges in the context of the water-land nexus, good water governance is essential.

To promote the effective integration between mitigation and adaptation in the context of the water-land nexus, policy options can be considered to weaken the centrifugal forces or strengthen the centripetal forces, which include efforts to fill the knowledge gaps, systematic data collection and assessment, institutional reform, enhanced coordination, and cross-sectoral collaboration. Here, some feasible recommendations are proposed.

> *“Efforts to fill the knowledge gaps, systematic data collection and assessment, institutional reform, enhanced coordination, and cross-sectoral collaboration are needed for integrated climate action.”*

- **A holistic assessment of climate action** should be enhanced at the preparation, planning and evaluation stages. For example, environmental impact assessment (EIA) can be improved by incorporating both adaptation and mitigation components into the assessment requirements of programmes and projects. The assessment should be quantitative and integrated, based on systematic monitoring schemes and data collection. It is also important to identify and evaluate context-specific conditions, driving factors and enabling environments for synergies and negative outcomes.
- **A precautionary approach** should be applied to reduce counter-productive consequences of climate action. A comprehensive checklist can be useful to identify risks of negative outcomes of climate actions. If robust evidences are accumulated at the local and project level, a negative list (associated with counter-productive consequences) or a positive list (associated with synergies and co-benefits) of mitigation interventions and adaptation interventions can be developed within specific application conditions.
- **Integrated development plans** should be developed in the water-land nexus and climate action should be mainstreamed. In many countries, national development plans generally incorporate long-term perspectives of multiple sectors but rarely consider cross-cutting strategies, effects or impacts. Since water and land are key sectors in national development plans, the water-land nexus approach can be applied to develop national development plans or water resources development plan and land development plan can be combined in a coherent manner. Given that spatial and time scale of impacts from mitigation or adaptation interventions are different, a long-term comprehensive plan should be developed to maximize cost-effectiveness, increase co-benefits, minimize counter-productive consequences, avoid inefficient duplications, and reduce inconsistencies.
- **Balanced approach** to empower key actors in both water and land sectors is needed. Particularly, the participation and capacity of local institutions should be enhanced. Expert-produced knowledge is important but not enough to fully understand the complicated local contexts, so local knowledge should be further identified and accumulated.

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Notes

1. In 2003, the resolution on the 'Water for Life' decade was adopted and promoted by the United Nations General Assembly in order to achieve the environmental sustainability goal (Millennium Development Goal 7) focusing on safe drinking water and basic sanitation (A/RES/58/217). In 2015, the 'Water for Life' decade was closed with some remaining challenges and problems.
2. http://www.unwater.org/publications/sdg-6-infographics/.
3. Authentic texts of the Paris Agreement are available in six languages (Arabic, Chinese, English, French, Russian and Spanish) at http://unfccc.int/paris_agreement/items/9485.php.
4. The UN develops the 'Sustainable Development Knowledge Platform', where all SDGs' progress and relevant information have been communicated. Specific progress of SDG 13 in 2016 and 2017 is available at https://sustainabledevelopment.un.org/sdg13.
5. At the national level, carbon taxes can be set for GHG-intensive goods such as coals. ETS can be established for countries or companies at the regional or national level by setting an emission target for each participant and allowing them to buy and sell emission allowances or reductions credits. CDM established under the Kyoto protocol is a project-based market mechanism. Project participants can earn certified emission reductions (CERs) when their projects implement mitigation measures and reduce GHG emissions below the baselines of their emissions. More information is available at https://unfccc.int/index.php/topics/market-and-non-market-mechanisms/the-big-picture/what-are-market-and-non-market-mechanisms.
6. http://www.sdgfund.org/sites/default/files/ENV_CASE%20STUDY_Philipines_community%20based%20adaptation%20in%20agriculture.pdf.
7. In 2010, the Global Initiative on Community-Based Adaptation (GICBA) was launched by IIED.
8. Bollen *et al.* (2009) provide a variety of evidences on the co-benefits of mitigation interventions, particularly focusing on the reduction of local pollutants
9. https://www.forest-trends.org/ecosystem_marketplace/forest-ag-projects-can-combine-adaptation-and-mitigation-cifor-study/
10. http://cdmcobenefits.unfccc.int/Pages/SD-Reports.aspx
11. 'UNFCCC synthesis report on the aggregate effect of the Intended Nationally Determined Contributions (INDCs)' summarized the 189 INDCs submitted as of 4 April 2016, which is available at http://unfccc.int/focus/indc_portal/items/9240.php.
12. https://www.wbcsd.org/Sector-Projects/Cement-Sustainability-Initiative.
13. In 2001, the NAPAs, a Least Developed Countries Fund (LDCF), and an LDC Expert Group (LEG) were established to support LDCs in addressing their vulnerability. More information is available at https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/introduction.
14. Germany federal agency (BMZ) introduces several effective mitigation measures in the water sector, and provides calculated potential CO_2 reductions of each measure. More information is available at https://wocatpedia.net/images/9/9e/00_GIZ_Climate_Change_Mitigation_in_the_Water_Sector.pdf.
15. In 2003, the IPCC developed the Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG-LULUCF) in order to provide guidance for the calculation of carbon stock changes and GHG emissions in the LULUCF sector.
    The 2006 IPCC Guidelines for National Greenhouse Gas Inventories improved the GPG-LULUCF, which included the introduction of AFOLU. available at https://wocatpedia.net/images/9/9e/00_GIZ_Climate_Change_Mitigation_in_the_Water_Sector.pdf.
16. https://www.unccd.int/issues/land-and-climate-change.
17. Afforestation and Reforestation (AR) is highlighted as one of the key sectors for mitigation projects, particularly under the Clean Development Mechanism (CDM). Reducing emissions from deforestation and forest degradation (REDD) is another initiative offering financial incentives to increase carbon stocks through forest conservation.
18. Duguma, L. A. and his colleagues explored complementarity (co-benefits) and synergy between mitigation and adaptation in the land sector, based on Tanzania's ecosystem.
19. FAO's report on sustainable land and water management addressed the key issues in the land-water nexus, which is available at http://www.fao.org/fileadmin/templates/solaw/files/thematic_reports/TR_16_web.pdf.
20. In chapter 6, IPCC's technical paper VI (2008) provided several empirical evidences on the interrelationship between climate change mitigation measures and water, which is available at https://www.ipcc.ch/site/assets/uploads/2018/03/climate-change-water-en.pdf.
21. There are many reports and organizations that connect water crisis with governance crisis.
    For example, "Water: A Crisis of Governance Says Second UN World Water Development Report", which is available at http://portal.unesco.org/en/ev.php-URL_ID=32057&URL_DO=DO_TOPIC&URL_SECTION=201.html.

8

Strategies for Sustainable Water Security: Diversification, Decentralization, and Integration

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Abstract

Among various global risks, water crises, failure of climate change mitigation and adaptation, and biodiversity loss and ecosystem collapse are very important factors affecting human life. Since water security is essential to people and the ecosystem, a climate change adaption strategy and an active response to land use and land use changes (LULUC) is required. It is necessary to introduce policies and programs to expand ecosystem services for climate change adaptation and reduction of urbanization problems. A solution to efficiently solve water problems to ensure water safety is Nature-Based Solutions (NBS) for Water. NBS for water is a technical approach to deliver more ecosystem services to people. Integrated water resources management for water safety can reduce water-related disasters including flooding, contribute to water quality, and secure various water resources. Water-wise cities use NBS to solve urban problems caused by climate change and urbanization. Water security and sustainable development require the development of new water resources and a decentralized treatment plant strategy. Agricultural LULUC causes algal blooms and fish kill on surface water and causes groundwater pollution. Surface water and groundwater are very important water resources and must be qualitatively and quantitatively protected. Water security requires the introduction of a fee system to reduce the usage of agricultural water and application of NBS to manage agricultural nonpoint sources.

Keywords

Ecosystem services, Green Infrastructure (GI), Integrated Water Resources Management (IWRM),
Low Impact Development (LID), Nature-based Solution (NBS), water security, water-wise cities, algal blooms, fish kill

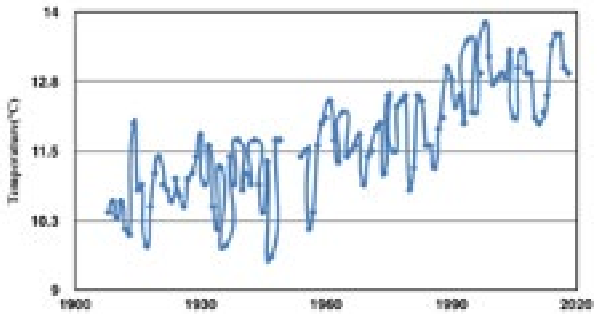
01

Introduction

1.1. Urbanization and Climate Changes

According to The Global Risks Report 2016 (11th Edition) of the World Economic Forum (2016), involuntary migration, extreme weather events, failure of climate change mitigation and adaptation are included in the top 3 out of 10 risks affecting human survival. Among the 10 risks in terms of likelihood, water-related items such as extreme weather events, failure of climate-change mitigation and adaptation and the water crisis are ranked second, third and ninth, respectively. Considering the risks in terms of impact, failure of climate change mitigation and adaptation is ranked first, while water crises, and biodiversity loss and ecosystem collapse are ranked third and sixth, respectively. As a result, water, climate change, and ecosystem were found to be the most influential factors in human life.

As seen in the long history of the Earth, climate change occurs periodically with a variety of natural causes such as the movement of the earth mantle, volcanic activity, changes in geological structure, changes in solar activity and changes in air composition. However, artificial causes of climate change such as urbanization, CO_2 emission, etc. which are due to economic development and population growth, further accelerate climate change. Since 1905, Seoul's normal yearly temperature has been steadily increasing and has increased by more than 2°C over the past century. Normal yearly precipitation also shows a tendency to increase continuously. Climate change affects the frequency and intensity of rainfall, which increases the occurrence of flooding and drought. The regional, annual and monthly variation in precipitation and precipitation ratio of Korea from 2015 to 2017 demonstrated in Figure 8-1 clearly shows the effects of



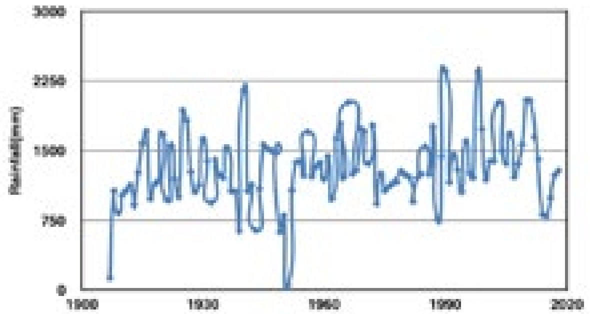


Figure 8-1 *Air temperature and precipitation in Seoul, Korea (Korea Meteorological Administration, 2018)*

climate change at present. Spatial and temporal variations of water due to climate change affect water resources and water pollution, making water management difficult and causing various water disputes.

The world population is expected to increase from 7.7 billion in 2017 to between 9.4 and 10.2 billion by 2050, with two-thirds of the population living in cities (UN DESA, 2017). Korea has undergone rapid urbanization process since 1960, and the population living in urban centers now exceeds 80%. About 45% of Korea's population lives in the Seoul metropolitan, causing various environmental problems related to water. Rapid urbanization causes changes in natural water circulation by changing the natural cover to an impervious surface, instigating problems such as urban flooding, drought, water pollution, and urban heat islands (Figure 8-2). The imperviousness rate of the provinces in Korea

	Likelihood	Impact
1	Large-scale involuntary migration	Failure of climate-change mitigation and adaptation
2	Extreme weather events	Cause of mass destruction
3	Failure of climate-change mitigation and adaptation	Water crises
4	Interstate conflict	Large-scale involuntary migration
5	Natural catastrophes	Energy price shock
6	Failure of national governance	Biodiversity loss and ecosystem collapse
7	Unemployment or underemployment	Fiscal crises
8	Data fraud or theft	Spread of infectious diseases
9	Water crises	Asset bubble
10	Illicit trade	Profound social instability

Table 8-1 *Top 10 risks in terms of likelihood and impact (World Economic Forum, 2016)*

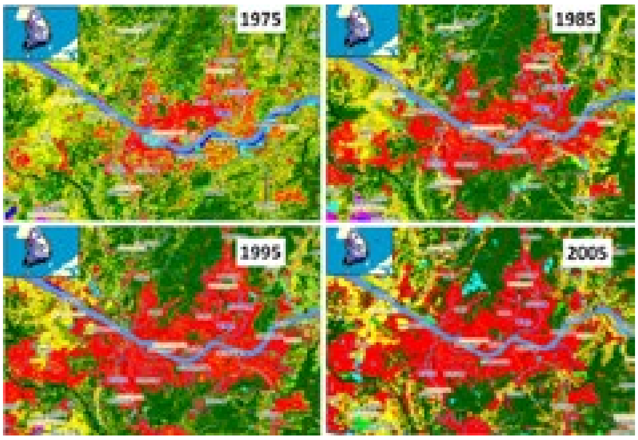


Figure 8-2 *Urbanization process in the Seoul Metropolitan area, Korea (Kim, 2017)*

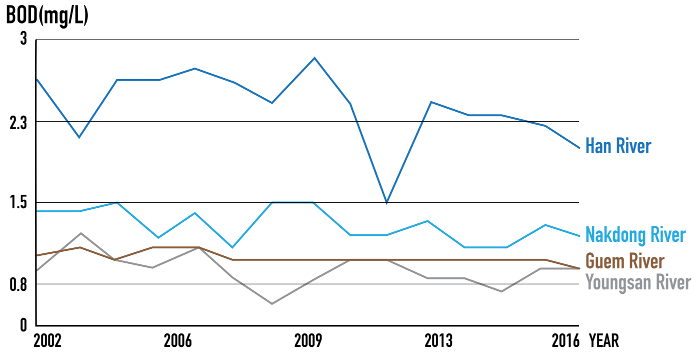


Figure 8-3 *Changes of water quality in the major rivers in Korea*

and the Seoul metropolitan area has reached about 54.4%, and the Busan metropolitan area exceeds 30.3%.
The imperviousness rate of major cities located in each province is very high, and many cities have rates of more than 40%, causing many problems related to water (Ministry of Environment, 2013).

Climate change and urbanization have large impacts on the quantity and quality of water. In particular, water quality is an important part of water problems because it requires high cost and a long period of time for treatment when polluted. Since 1970, Korea has been improving its water quality in the major rivers with its continuous investment on environmental management. Biochemical oxygen demand (BOD)[1] in the major rivers has been decreasing continuously due to the installation of a municipal wastewater treatment plant in the city area to treat the pollutants, but chemical oxygen demand (COD),[2] originated from diffuse pollution (nonpoint source pollution) emitted by various land uses, is increasing. Land Use and Land Use Changes (LULUC) resulted in various types of pollutants, and these pollutants have a great impact on the security of water resources. Therefore, climate change adaptation strategies and active countermeasures for the effects of LULUC are needed for enhancing water security since people and ecosystems are being affected.

1.2. Water Use

The growing population affects the use of water qualitatively and quantitatively. Generally, in most countries, the classification of water depends on its purpose such as for living, industrial water, agricultural water, and river maintenance. Given this trend, clean and adequate water issues will be recognized as being important in terms of water safety in the future for all countries. Water safety requires strategies such as reducing national water use, finding various types of water resources, and maintaining clean water.

As shown on Figure 8-4, country-specific water consumption per capita per day (LPCD)[3] depends on factors including but are not limited to water availability, population and economics. US showed about 450L / capita-day, while Korea used about 330L / capita-day, showing very high water use rates like Italy or Japan (Ministry of Land, Transport and Maritime Affairs, 2010). However, countries such as Somalia, Mali, and Zambia have very low water use rates, which is not reaching the health-influenced water usage rate of 50-100 L / capita-day as suggested by the World Health Organization (WHO). In countries and regions where water is used heavily, it is necessary to reduce water use. In countries and regions where water is scarce, new water resources with good accessibility should be sought.

Korea's water use for agricultural, river maintenance, living and industrial purposes were about 41%, 33%, 20%, and 6%, respectively (Statistical portal of Ministry of Environment, 2018). Comparing Korea's LPCD with water use for purposes, strategies are required to reduce agricultural water use and pollution management for water resources by farming drainage water in the agricultural area.

Since 2001, the average rainfall in Korea has been in the range of 980-1,800mm, showing high deviation, and the drought frequency also shows an increase. Generally, groundwater is an important water resource in all countries because of its good water quality, but it should be used with caution. Use of groundwater should consider the long period of time needed for recharge, and the high cost and long treatment periods for water quality improvement if groundwater contamination occurred. Korea's groundwater level has been steadily declining since 2009, lowering the water level by about total 1m since 2009. This is due to reduced rainfall and the provision of agricultural water use which is free of charge. Considering the variability of rainfall due to climate change in the future, it is necessary to change the agricultural structure such as conversion of the crops and introduce a fee system for agricultural water. Total available water amount by the country depends on precipitation, and precipitation is affected by climate change. Climate change and urbanization increase water bias and vulnerability and affect the available water amount and accessibility. For sustainable water use, it is necessary to reduce LPCD, change water use policies and structure, find new water resources, and introduce a new water management system.

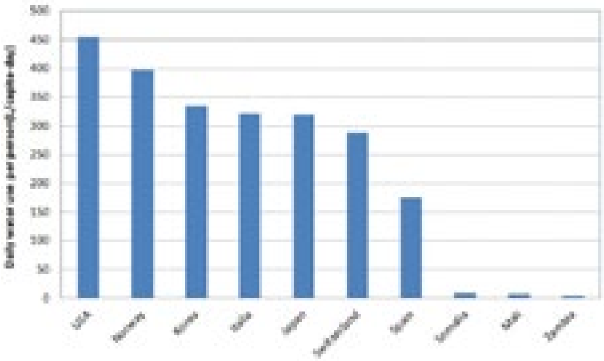


Figure 8-4 *Global water use per capita per day (Ministry of Land, Transport and Maritime Affairs, 2010)*

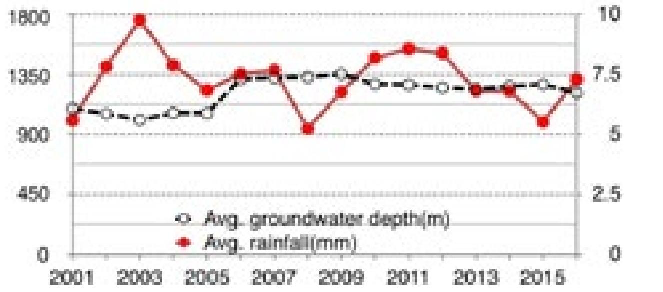


Figure 8-6 *Changes of average rainfall and average groundwater level in Korea (National Groundwater Information Center, 2018)*

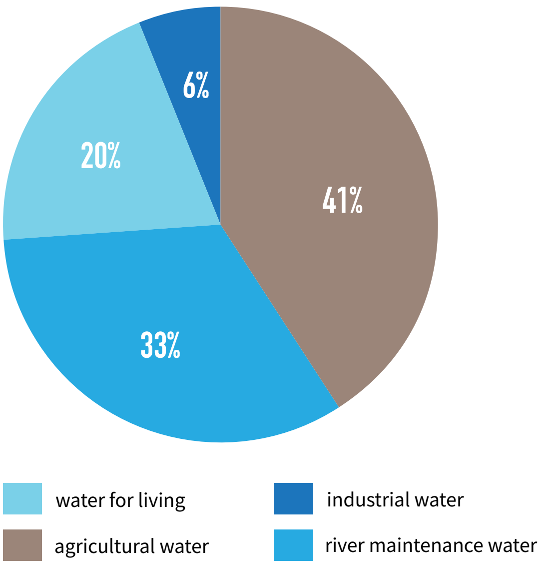
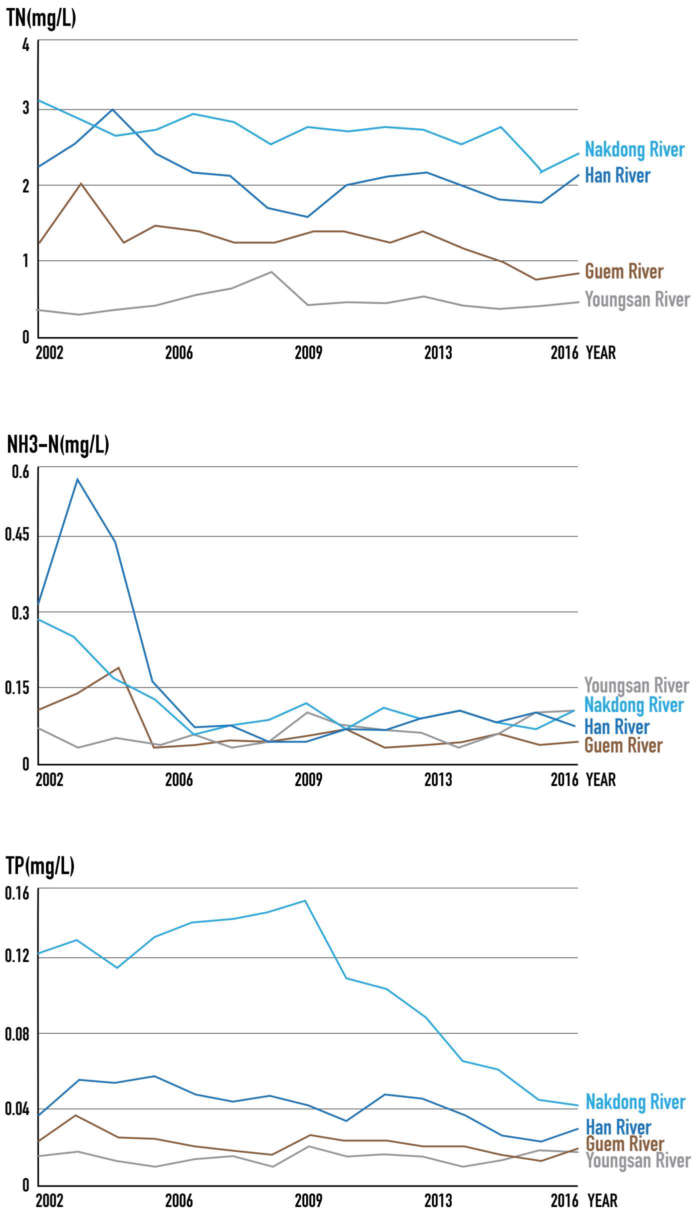


Figure 8-5 *Water use in Korea (Ministry of Environment, 2016)*



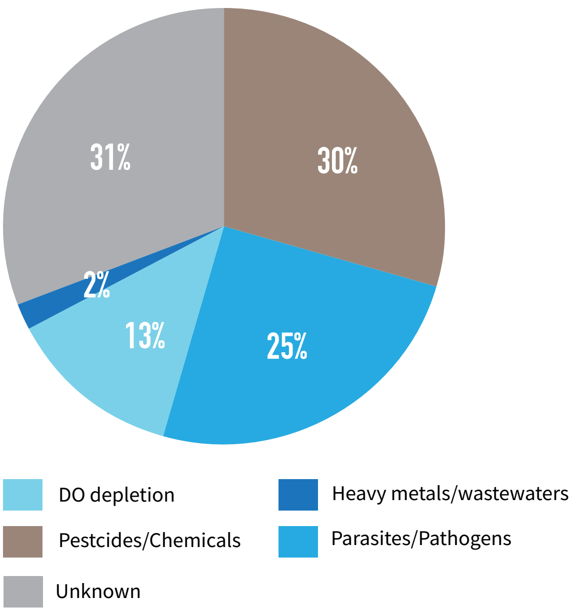


Figure 8-8 *Causes of fish mortality from 2000-2016 in Korea (Korea Environment Corporation, 2018)*

Figure 8-7 *Water quality in the 4 major rivers in Korea (Kim, 2018)*

1.3. Water Quality

Water quality of water resources is very important for sustainable water use and water safety. In Korea, water quality in the 4 major rivers has been greatly improved by continuous point source management. As of 2015, Korea's waterworks supply is about 98.8%, and drinking water is supplied to most people. The number of water treatment plants is 499, and the rate of plants with an advanced water treatment system is about 45.8%. Water usage in LPCD, which is calculated based on the water supplied to the waterworks, is continuously increasing at about 282L/capita-day, while protected areas with water resources is continuously decreasing implying the need for a new strategy for water management. The number of wastewater treatment plants in Korea is 3,879, which treats about 92.9% of the effluent in Korea. Water and infrastructures contributed greatly to the improvement of people's quality of life and water quality improvement, but high water use and water quality in water sources are still a problem.

The well-managed wastewater management system in Korea is estimated to have significantly improved BOD, TP and NH3-N concentrations in the major 4 rivers. However, water pollution, algal bloom and fish mortality still occur due to various causes. Therefore, effective watershed management is needed. Livestock wastewater is transformed into organic fertilizers, as it has high nitrogen and phosphorus contents, and is widely used in the farming process in agricultural areas. Nutrients caused by these fertilizers are amplifying algal blooms in lakes and rivers. The total number of days in which algal bloom warnings occurred in the major 4 rivers has been increasing every summer annually.
Algal bloom in the Nakdong River occurs in April and continues until September, and sometimes, it also occurs in winter. In the Guem River, the occurrence frequency of algal bloom from Daecheong Lake to late autumn is high. Fish mortality occurs predominantly during the summer when rainfall is concentrated and temperature increases. Frequency of fish mortality is increasing every year in Korea. The main causes of fish mortality are dissolved oxygen (DO) depletion due to the input of excess nutrients, toxic chemical compounds, and metals. However, 30% of fish mortality's cause still remains unidentified. As a result, the financial operations of water pollution management must be changed from river-based pollution management to watershed-based pollution sources management.

Non-point pollution sources, toxic chemical emission, fertilizers of livestock wastewater, etc., caused by climate change and LULUC, are threatening water quality management of water resources. In particular, climate change and LULUC require a new paradigm for pollutant management and investment systems because they increase emissions of non-biodegradable organic matters, NO3-N, toxic chemicals, etc., thus affecting water quality and aqua-ecosystem.

Year		2011	2012	2013	2014	2015
Waterworks	Waterworks supply (%)	97.9	98.1	98.5	98.6	98.8
	No. of water treatment plants	531	518	515	508	499
	Rate of advanced water treatment system (%)	23	28.5	32.3	42.4	45.8
	Water use per capita per day (LPCD)	279	278	282	280	282
	Protection area of water resources (No.)	320	313	309	297	291
Sewerage systems	Sewer supply (%)	90.9	91.6	92.1	92.5	92.9
	Sewerage system supply (%)	73.4	75.8	76.5	77.8	79.9
	No. of wastewater treatment plants (above 500m³/d)	505	546	569	597	597
	No. of wastewater treatment plants (less than 500m³/d)	2,858	3,067	3,205	3,160	3,282
	Water reuse rate (%)	11	12.2	12.8	13.5	14.7

Table 8-2 Status of the water and sewerage system in Korea (Ministry of Environment, 2016)

Year	2013 (25 stations)	2014 (25 stations)	2015 (25 stations)	2016 (28 stations)
Han River	35	47	245	0
Nakdong River	185	325	375	313
Guem River	47	0	54	91
Youngsan River	0	0	0	0

Table 8-3 Total number of days in which algal bloom warnings occurred in the4 major rivers in Korea (Ministry of Environment, 2016)

02

Nature-Based Solutions and Integrated Resources Water Management for Water Security

2.1. Ecosystem Services and Nature-based Solutions (NBS) for Water

The ecosystem consists of components such as biotics (animals, plants, microorganisms) and abiotics (water, temperature, soil, air, etc.) and gives various benefits through energy flow and mass circulation. The various benefits that we can get from our ecosystem are called ecosystem services, which are classified into four categories including supporting services, provisioning services, cultural services, and regulating services (Notte *et al.*, 2017). Most of the services in ecosystem services are benefits related to the quantity and quality of water resources, which are important for water safety.

Climate change and urbanization have caused many problems including flooding, drought, and water pollution by altering our ecosystem, thereby greatly reducing ecosystem services. Recently in many countries, policy and programs have been introduced to expand ecosystem services for climate change adaptation and reduction of urbanization problems.

To effectively solve water problems to ensure water safety, UN-Water proposed the used of nature-based solutions (NBS) for water in the World Water Development Report 2018.

The main mechanisms of NBS for water are ecohydrology, which occurs in relation to biotics and abiotics that make up the ecosystem. Ecohydrology is an integrative science focusing on the interaction between hydrology and biota. Human life requires various kinds of infrastructures such as building, roads, water and wastewater treatment plants, and drainage systems. Because all of the infrastructures affect water flow, it is necessary to apply ecosystem-based management and ecosystem-based adaptation or mitigation techniques in planning, design and construction. NBS for water is a technical approach to deliver more ecosystem services to people.

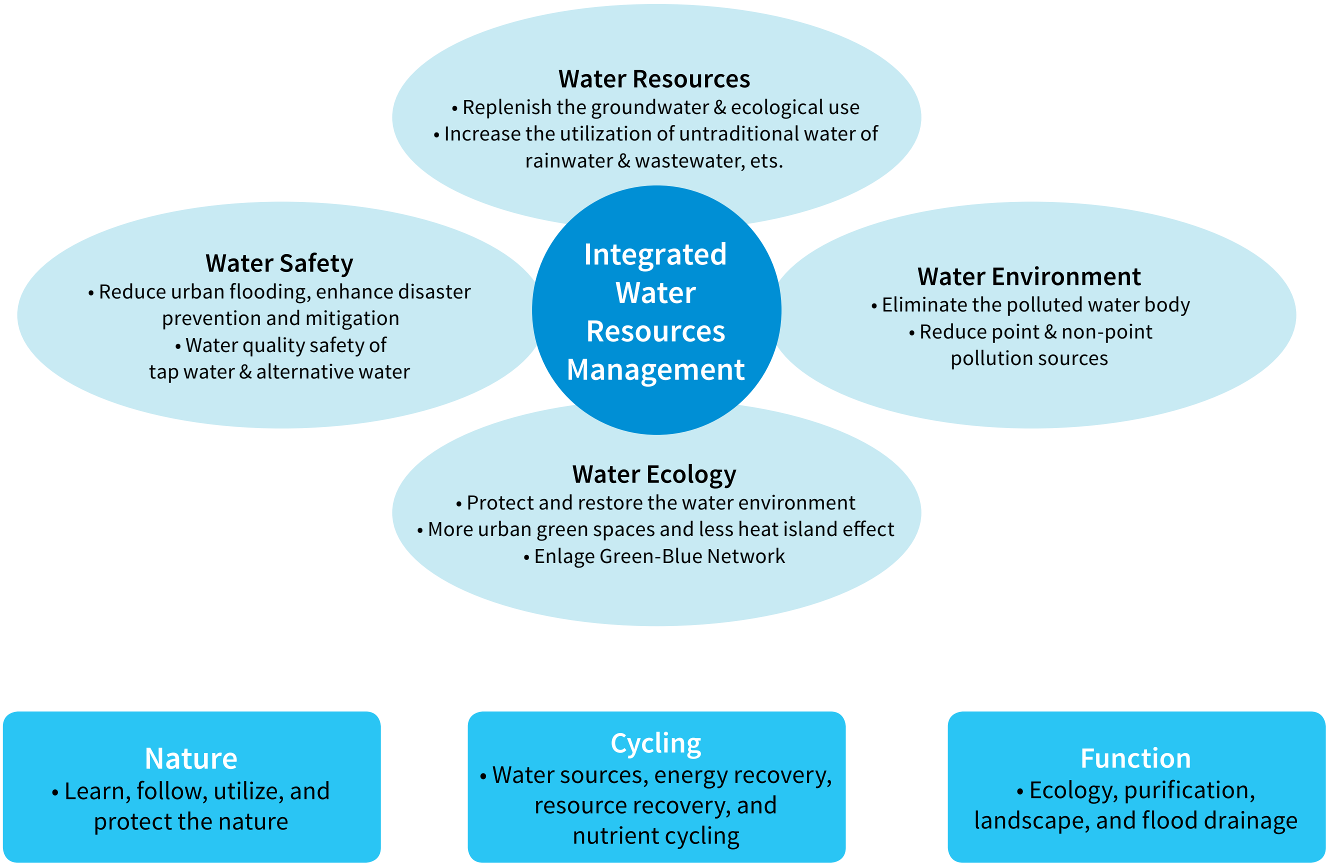


Figure 8-9 Integrated water resources management (Kim, 2017)

2.2. Integrated Water Resouces Management (IWRM)

NBS for water is a technical approach to deliver more ecosystem services to people. By transforming all grey infrastructure[4] into a green infrastructure, more ecosystem services can be delivered to people. Integrated water resources management (IWRM) can be utilized using mechanisms of nature, cycling (water, energy, mass circulation), and various functions. IWRM with NBS can have various positive effects on water resources, water safety, water environment and water ecology. IWRM for water safety can reduce water-related disasters including flooding, contribute to water quality improvement, and provide various water resources. IWRM can be applied to various technical approaches including green infrastructure (GI),[5] low impact development (LID),[6] rainwater harvesting, water reuse, water-wise cities, blue-green networks,[7] constructed wetlands and groundwater recharge system. The IWRM should be constructed as a water loop in the watershed, where all water, such as saltwater, wastewater, rainwater, stream water, and groundwater, must be connected. The integrated water loop is completed when the artificial water loop from the tap water to the wastewater and the natural water loop to the rainwater-groundwater-runoff-surface water are interlinked. These water loops are very important for water security because they can actively cope with flooding and drought, secure more clean water resources, and have accessible water resources for people. In particular, re-treatment of discharged effluent with advanced treatment technology in wastewater treatment plants can become new water resources.
In addition, rainfall can become new water resources by retention, detention, and infiltration through low impact development (LID) techniques.

03

Water Management Strategy for Enhancing Water Security

About 80% of Korea's annual precipitation is concentrated in summer, and about 70% of the national land area is mountainous, making Korea's water management difficult. Major water resources in Korea are surface water and groundwater in the agricultural area including lake water and river water. However, water pollution due to the emission of various pollutants is a problem due to the proximity of many industrial complexes, cities, and agricultural areas to water resources. The high population density of Korea causes serious water security problems by generating water bias, flooding, drought, water pollution, and ecosystem deterioration. LULUCs highly impact on the water quality and water quantity of water resources in Korea. More than 60% of the BOD pollutant loading mass entering the 4 major rivers was reported as nonpoint sources due to LULUC. Therefore, securing water security in Korea requires effective management strategy and climate change adaptation strategy for LULUC. There are various strategies that are useful in Korea for water security including integrated water and watershed management using NBS for water, water-wise cities using LID and GI, decentralized wastewater treatment and water reuse, and management of agricultural areas using NBS.

3.1. Water-wise Cities with Low Impact Development and Green Infrastructure

An urban area is composed of buildings, roads, parking lots, and landscaping. LULUC is actively occurring in urban areas and adversely impacts on the ecosystem. The infrastructure that is constructed on urban areas and giving harmful impact on the environment is considered as a grey infrastructure. GI is considered as an example of NBS. GI refers to the natural or semi-natural systems providing water resources management options with benefits. The benefits of GI are equivalent or similar to conventional grey water infrastructure. Typically, green infrastructure solutions involve deliberate and conscious effort to utilize ecosystem services to provide primary water management benefits as well as a wide range of co-benefits. LID is a term to describe a land planning and engineering design approach to manage stormwater runoff as part of the green infrastructure. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source. There are more broadly equivalent terms, which includes sustainable drainage systems (SuDS)[8] in the United Kingdom and water-sensitive urban design (WSUD)[9] in Australia. Generally, the

Parameters	Conventional approach	LID and GI approach
Water quantity	Exported the runoff as quickly as possible from the urban area	Retain runoff, infiltrate to aquifer, and drain slowly to waterbodies
Water quality	Discharge stormwater runoff after treating in wastewater treatment plants or without treating to waterbodies	Treat runoff through system of nature such as soil, vegetation, and retention pond
Recreation & amenity	Not considered	Designed storm-related facilities to provide opportunities for recreation and improve the urban landscape
Biodiversity	Not considered	Protect the natural habitat by using the rain water and by protecting the urban ecosystem
Resources	Not considered	Utilize the collected rainwater as water resources and retain runoff in watershed or aquifer to protect streams and vegetation

Table 8-4 Paradigm shift of water management (Kim, 2017)

Figure 8-10 LID implementation in university campus in Korea

conventional approach of water management is only focused on water quantity and quality. However, LID and GI approaches are considering more parameters on conventional approach such as recreation & amenity, biodiversity, and resources to provide ecosystem services.

LID and GI are the tools or techniques used in water-wise cities[10] of USA and Europe, water circulation city of Korea, or sponge city of China. Water-wise cities utilize NBS to solve urban problems caused by climate change and urbanization such as flooding, drought, water pollution, and urban heat islands. Generally, urban areas were consisting of various land uses such as residential areas, industrial complexes, commercial areas, public areas, parks, etc. Almost all of urban land uses are made of impermeable pavements of roads, roofs, and parking lots. The impermeable pavement accumulates various pollutants (particulate matters, organic matters, heavy metals, nutrients, etc.) during the dry season and is discharging during a rainy day. The type and concentration of pollutants in rainfall runoff depend on land use (roads, parking lots, roofs). Roads discharge very high pollutant concentrations of particulate matters, heavy metals and organic matter due to vehicle activities. The parking lot discharges low pollutant concentrations compared to roads because the speed and frequency of vehicles are lower than the road, respectively. Roof runoff is very clean compared to roads and parking lots because dry deposition is an only pollution source. Therefore, when the pollutants are properly treated and removed by using LID technologies in consideration of the characteristics of pollutant concentrations, the runoff can be the new water resources in urban areas (refer to Figure 8-10, 8-11 and 8-12).

(The LID facilities were constructed since 2008 using government funding from the Korean Ministry of Environment. The LIDs constructed in the campus are infiltration trench, bioretention, infiltration garden, infiltration planter, HSSF wetland, hybrid wetland, tree box filter, planter, rain garden, and permeable pavement. The monitoring about water quality, hydrological characteristics, sediments, and plant growing were performed since the facility construction.)

(The water samples have been collected from 5 roads, 2 parking lots, and 2 roofs in Cheonan city since 2008 as shown on Figure 8-10. The discharged runoff is managed by LID facilities to remove the pollutants and to reduce runoff volume.)

There are many LID technologies such as a rain garden,[11] bioretention,[12] infiltration trench,[13] constructed wetland, permeable pavement, green roof,[14] tree box filter,[15] etc. Roof runoff can be used as an important water resource for various purposes such as gardening, road cleaning, toilet waters through rainwater harvesting after cleansing through the green roof. Developed countries, including US, Canada, and Korea, are installing LID facilities for various purposes such as securing water resources, improving water quality, reducing urban flooding, and reducing heat island effect. Stormwater LID technologies uses mechanisms related to material circulation and energy flow of nature.
Figure 8-12 shows volume reduction in rain garden, tree box tilter, infiltration trench, and hybrid wetland, which is also reduced the pollutants from stormwater runoff. LID technologies allow cost-effective runoff management by restoring natural water circulation.

(The rain garden is treating roof runoff while other LID technologies are treating road runoff. The hybrid wetland is connected with free water surface wetland and horizontal sub-surface wetland in series for effective multiple purpose pollutant reduction mechanisms.)

The infiltration trench is an LID technology that contributes to the acquisition of clean groundwater by infiltration

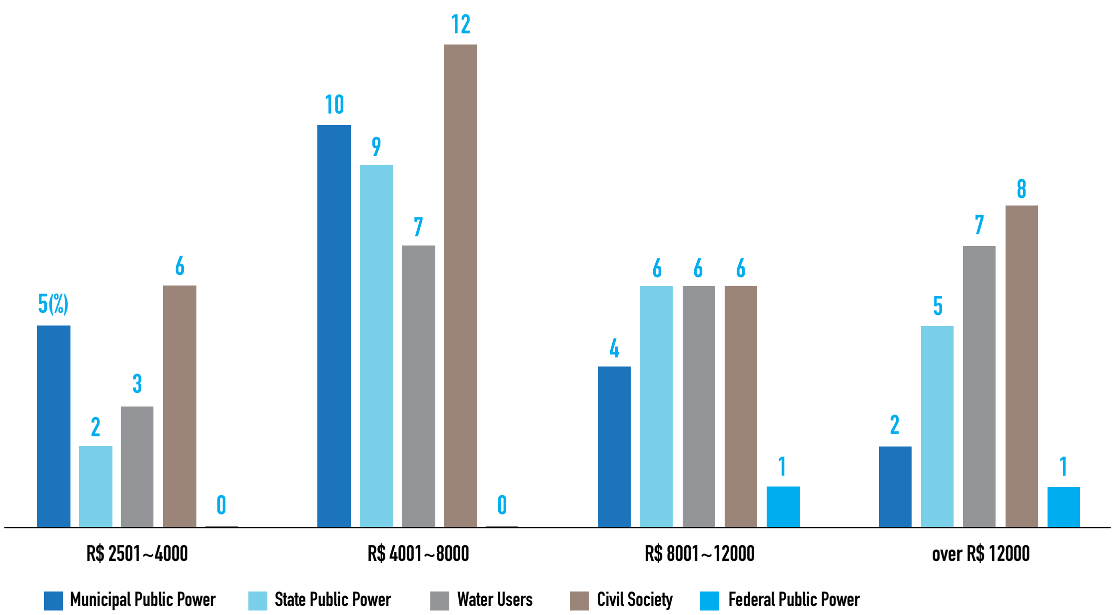


Figure 8-11 *Water quality of stormwater runoff from roads, parking lots, roofs of grey infrastructures (Maniquiz et al., 2012)*

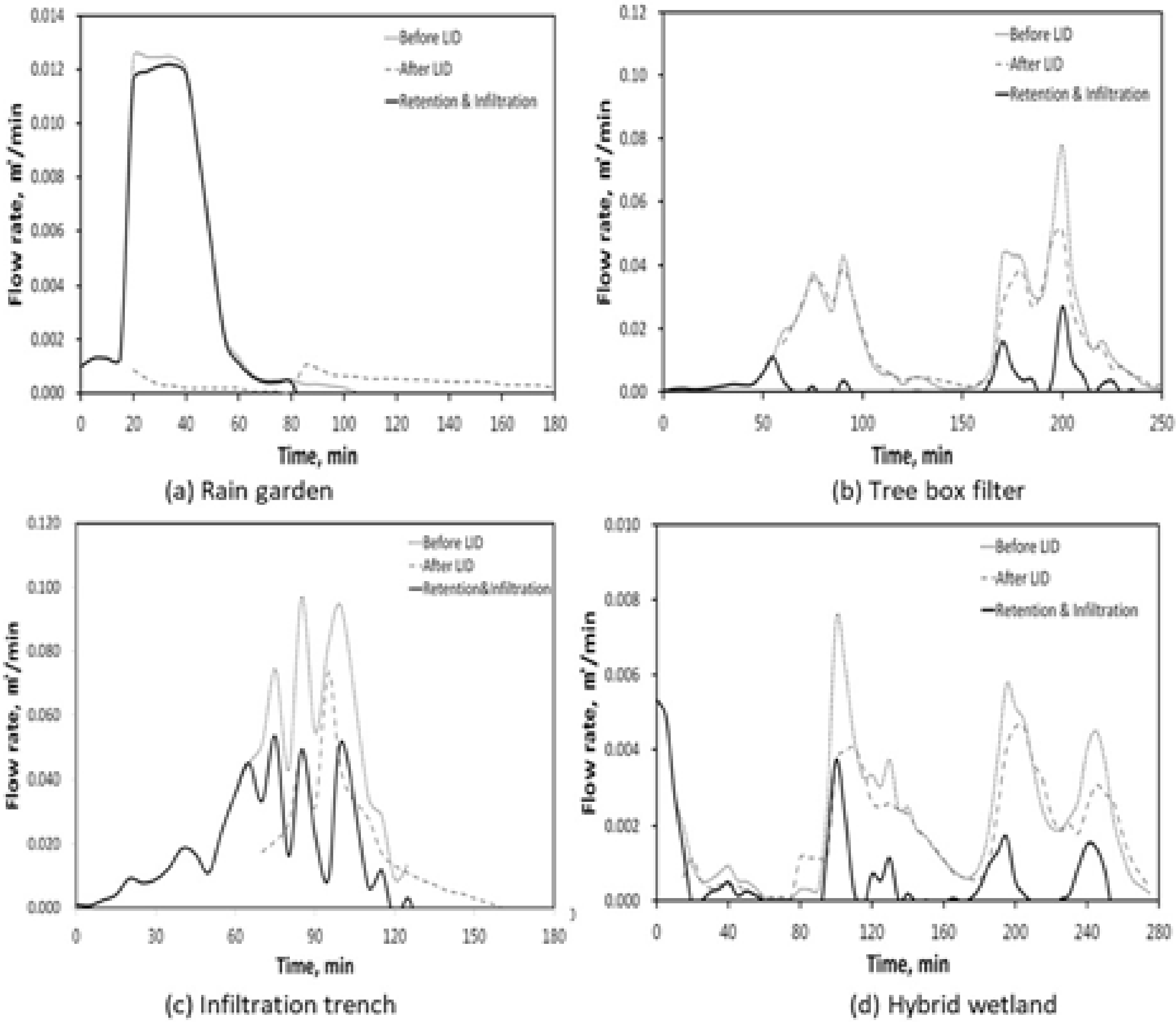


Figure 8-12 *Examples of flow reduction by LID facilities in Korea*

LID	Infiltration trench	HSSF wetland	Rain garden	Tree box filter
Runoff sources	Road	Parking lot	Roof	Parking lot
TSS (%)	87	90	97	98
BOD (%)	60	48	91	83
COD (%)	83	60	96	85
DOC (%)	69	69	93	83
TN (%)	72	54	87	96
TP (%)	80	72	51	91

Table 8-5 *Pollutant removal efficiency in different LID facilities (Kim, 2017)*

and retention mechanisms. The constructed wetland can contribute on water circulation through the mechanisms of evapo-transpiration through plants and the water retention mechanism through the soil medium.
The constructed wetland effectively removes nitrogen and phosphorus contained in stormwater runoff by interaction of microorganisms and plants, thereby contributing to the improvement of water quality and providing new water resources. Tree box filter is a technique applicable to road sidewalks. The runoff stored in the tree box filter is used for landscaping (Table 8-5).

The International Water Association (IWA) Principles for Water- wise Cities aim to provide the necessary frameworks and principles to assist urban leaders in developing and implementing their vision for sustainable urban water, and resilient planning and design in their cities. The ultimate goal of these Principles is to encourage collaborative action, underpinned by a shared vision, of local governments, urban professionals, and individuals actively engage in addressing and finding solutions on urban water management challenges. IWA presented 4 categories and 17 principles to create water-wise cities based on many research results concerning water. The 4 categories include regeneration water services, water sensitive urban design, basin connected cities, and water wise communities. LID is an NBS technology that efficiently manages rainfall runoff in urban areas.
LID can also be installed as decentralized systems with various sizes to have more benefits. Flood reduction can be expected by reducing the peak flow and delaying the occurrence time by installing various LID facilities in urban areas (Figure 8-13). Small scale LID techniques such as small ponds, land management, land cover can be effective for managing small flood magnitude. Floodplain storage and floodplain roughness are manage well for medium and large flood magnitudes.

The LID and decentralized stormwater management techniques are widely applied on urban renovation projects in developed countries to manage stormwater and to increase green spaces. The city of Munchen implemented decentralized LID techniques on the renovation of Riem area (Figure 8-14). Many LID technologies such as constructed wetlands, bioretentions, tree box filters, cisterns, permeable pavements, infiltration trenches, green roofs, rainwater harvesting, etc, are constructed to enlarge the green spaces. The LID application in Riem area reduce nonpoint sources pollution, restore water circulation, secure water resources, manage urban flooding and drought, etc.

Impervious surfaces interrupt the natural water cycle by preventing the infiltration of runoff. Fast-moving runoff flows over impervious surfaces, carrying loads of pollutants into waterways. Downstream water are impacted by polluted stormwater runoff. Conventional methods of stormwater management methods, such as detention ponds and pipe-and-pavement systems, do not address, prevent or remove pollutants from stormwater runoff. However, LID uses a system of decentralized stormwater techniques distributed throughout a site to capture and filter stormwater runoff at the source, reducing the total volume and the amount of pollutants entering waterways. LID meets its goal of reducing development impacts on watersheds by applying the following 5 tools: *preserve natural hydrology and environmentally-sensitive areas, design a system of distributed LID practices, control stormwater at the source, apply non-structural approaches first, and create a multifunctional landscape.* The purpose of LID is to promote an environmentally friendly and cost-effective development (Houston-Galvestin Area Council, 2016). The City of Houston has implemented many LID techniques in road sides with green road project (Figure 8-15).

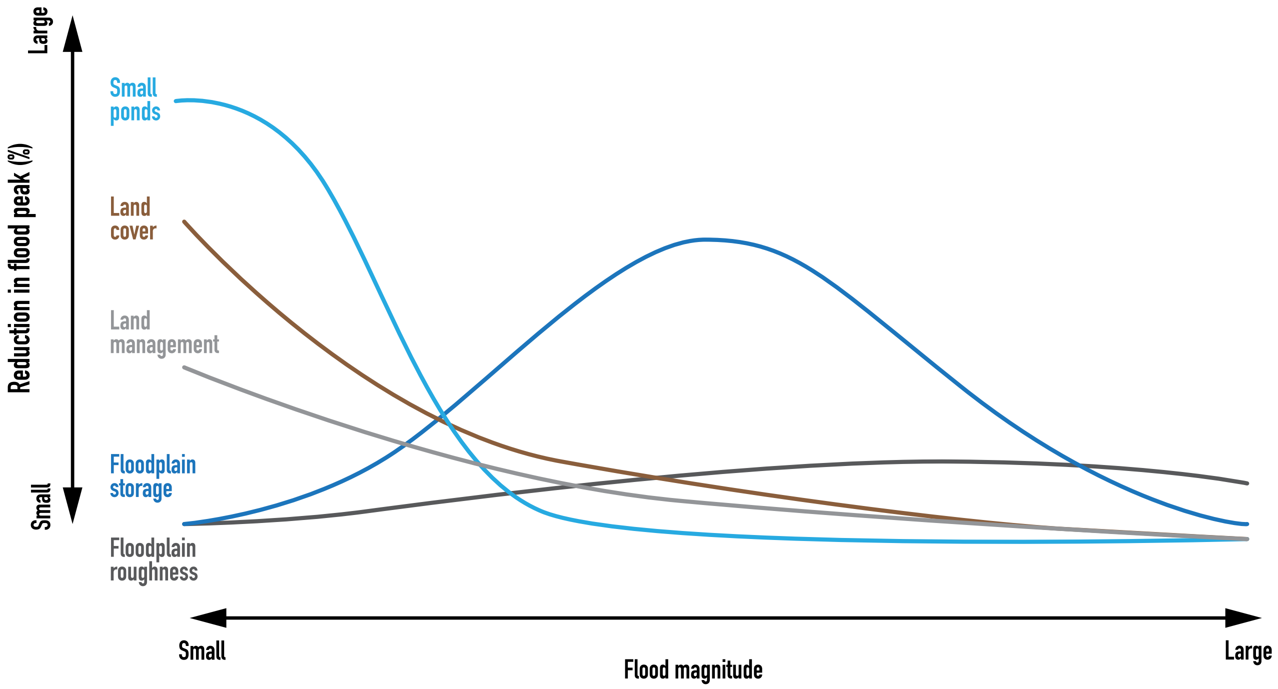


Figure 8-13 *Effect of different NBS on flood peak reduction with flood magnitude (Dadson et al., 2017)*

Background	• The Ministry of the Environment is promoting a water-cycle-leading city project with the aim of reducing heat island effect, reducing non-point pollution, and expanding green space through reduction of stormwater runoff. • In 2016, 5 local cities (Daejeon, Gwangju, Gimhae, Ulsan and Andong) were selected as the water circulation leading cities. • The 5 cities will construct LID on city area and make LID ordinance to enlarge LID on private fields
Characteristics of stormwater runoff from urban areas (Kim, 2017)	**Road**   **Roof top**   **Parking lot**  
LID application in a water circulation city (MOE, 2016)	

Table 8-6 Water circulation city in Korea

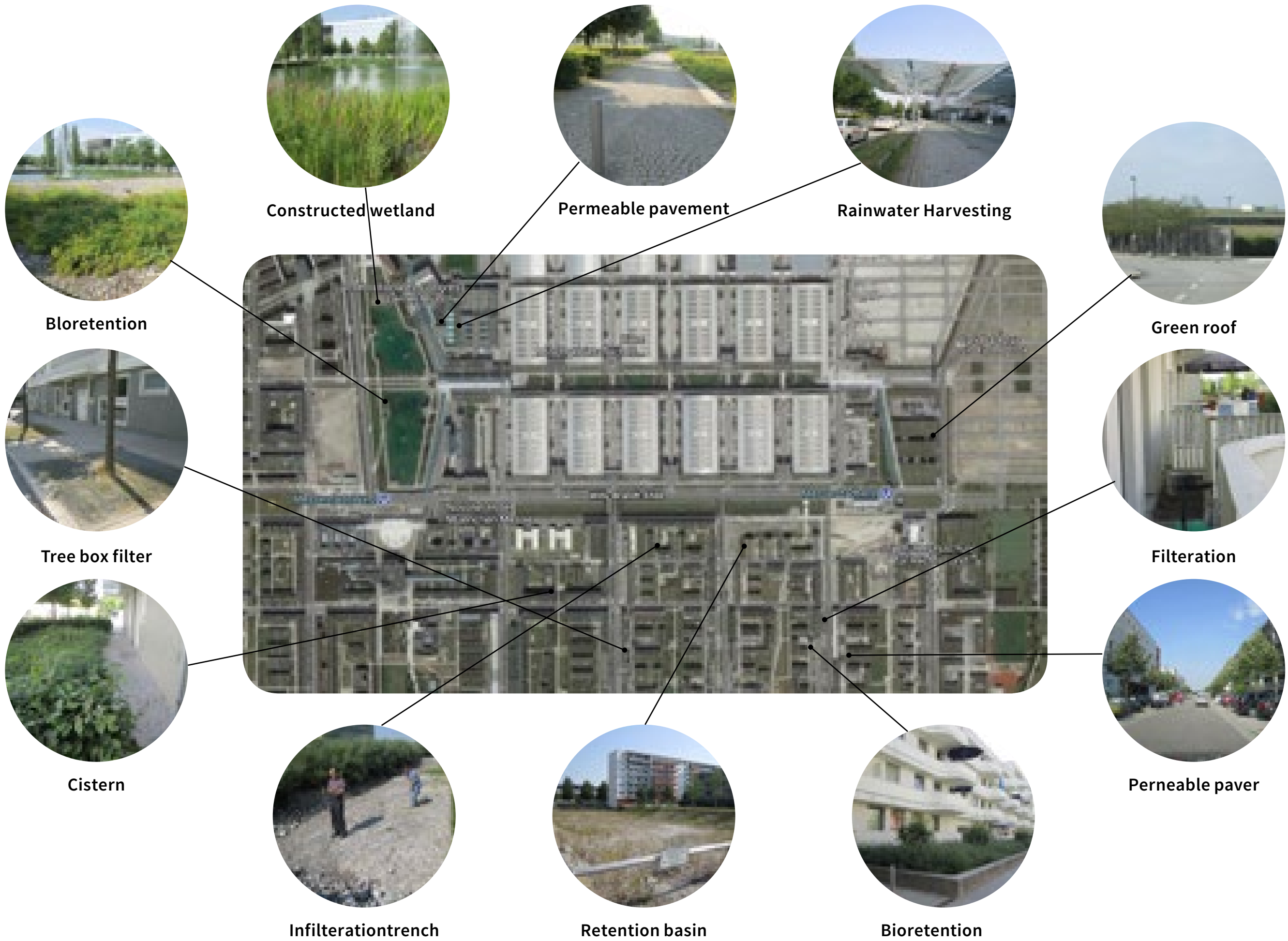


Figure 8-14 LID application in Munchen, Germany (Kim, 2017)

Figure 8-15 Example of LID application on green road project in Houston, Texas

3.2. Water Reuse with a Decentralized Water Management System

Advance treatment processes in wastewater treatment plants have significantly improved the water quality of effluent. The treated effluent reaches a technical evolution that can achieve water quality at the portable water level with the addition of some more treatment processes. Many countries such as USA, Singapore, and Japan have already developed policies and programs for reuse of secondary effluent and have reached the stage of direct reuse as well as indirect use.

Water reuse is the process of transforming used water into new water resources, which can reduce water intake from rivers or lakes. This reuse process can improve the water quality and aqua-ecosystem by reducing the pollutant mass that is discharged to waterbodies. Water reuse in Korea reaches only 14.7% (as of 2015), and most reuse purposes are limited to the cleaning water of treatment plants (Ministry of Environment, 2016). The reason for low water reuse and limited reuse purpose is that wastewater treatment plants are located in the downstream of cities and cannot supply water to urban areas where water is needed. In developed countries, a decentralized wastewater treatment plant was introduced to increase water reuse.

Water security and sustainable development require the development of new water resources and a decentralized treatment plant strategy. Also, integrated management of decentralized facilities using information & communication technology (ICT) is needed. In addition, multiple functions of the treatment facility are required. Sustainability can be ensured when treatment plants are associated with various functions such as energy, recreation, resilience, water culture, water resources, ecological green spaces and parks, and landscaping.

Rapid urbanization and population growth increases the impervious layer and undermine the ecological function of the city. The Ministry of Environment introduced 'the ecological area rate system' to reduce urban pollution, reduce heat island, adapt to climate change, enhance biodiversity, improve ecological soundness and create a comfortable living environment.

Ecological area rate= (Natural ground green area + Σ (Artificial area × Weight))/Total land area

The suggested goals of ecological area rate are 30 to 40% for urban development, 20% for industrial complex development, 60% for tourist complex development, 50 to 80% for installation of physical education facilities, and 40 to 50% for installation of waste and sewage treatment facilities. The weight of ecological area rate is 1.0 for natural ground greenery and water space, 0.5 to 0.7 for artificial ground greenery and green roof, 0.5 for partial pavement, 0.3 to 0.4 for permeable pavement, 0 for non-permeable pavement. However, if the water is not supplied on the green spaces during dry season, the plants existing in green spaces might dry out or eventually die. In addition, due to citizens' recreation and desire for water culture, ecological areas are increasing in the city by river restoration projects and waterfront development projects. Failure to provide enough water in these ecological areas can result to ecological problems, including fish kill. Therefore, water resources that can be supplied to green space or ecological area can be the strategy of water reuse.

Background	The Ministry of the Environment and Water Resources in Singapore established the Public Utilities Board (PUB) to provide integrated water and watershed management for water security ensuring the achievement of the following: • Integration of artificial water circulation and natural water circulation • Development of new water resources • Efficient water and wastewater management • Disaster prevention • Water industry expansion • Ecosystem service provision
Water resources in Singapore	• NEWater: NEWater was first introduced in 2003. Advanced technologies are used to treat high grade used water which is converted and made suitable for drinking and industrial use. The effluent quality is so good that it is used in place of potable water (drinking water). There are currently five NEWater plants which meet about 30% of the country's water demand, a significant breakthrough of how Singapore addresses its water supply in an innovative manner. The Public Utilities Board (PUB), Singapore's national water agency plans to meet up to 55% of Singapore's water demand by 2060, by increasing the production of NEWater by threefold. • Local Catchment: PUB has also improved local water catchment facilities by inventing technology which processes brackish rainwater and then shift to seawater desalination. It is estimated that this new technology will increase water catchment by up to 90% in the long term. Singapore has 17 reservoirs and through its drains, canals, rivers and reservoirs, is one of the few countries to harvest urban storm water on a large scale for its water supply. The country's water catchment area will increase from two-thirds to 90% of Singapore's land area by 2060. • Desalinated water (treated seawater): Singapore's first desalination plant produces 30 million gallons of water daily and meets about 10% of the country's water needs. Combined with its second plant, 25% of the current water needs is now met. PUB plans to build two more desalination plants to meet up to 30% of Singapore's water demand by 2060.

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<td>Water loop in Singapore for water security</td>
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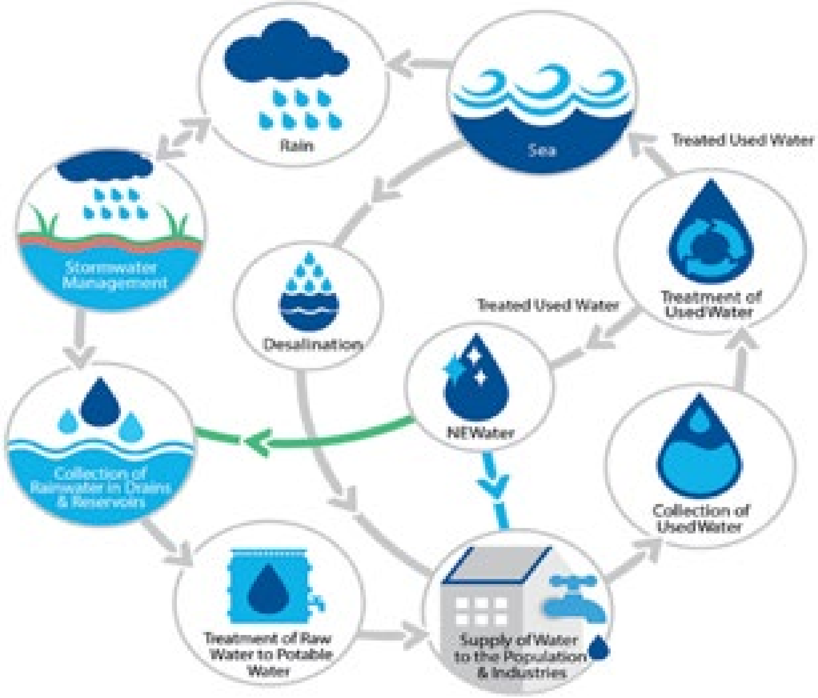

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<td>NEWater in Singapore with 3-Step Treatment</td>
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- Microfiltration: Microscopic particles including some bacteria are filtered out at this stage.
- Reverse Osmosis: Undesirable contaminants are removed here. The water at this stage is high-grade water.
- Ultraviolet Disinfection: The water passes through ultraviolet light to ensure any remaining organisms are eradicated. Chemicals are added to restore the pH balance.

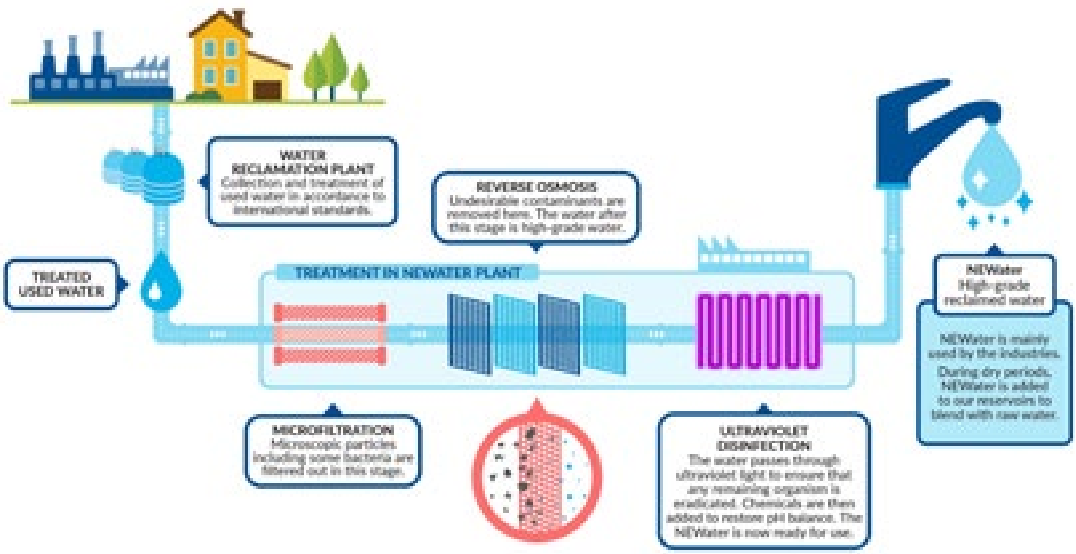

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Table 8-7 Water reuse in Singapore (Singapore PUB, 2018)

Background

- The United States is seeking new water resources to respond to urbanization and climate change and is reusing effluent from wastewater treatment plants as water reuse.
- Water reuse is widely used for groundwater recharge, irrigation water, and industrial water, and efficiency is improved by introducing a decentralized wastewater plant.
- United States' water reuse began in 1975 at Orange County Water District Factory 21 where indirect reuse was initiated by replenishing groundwater using re-treated effluent of wastewater treatment plant, and currently, reuse facilities are being formed for various purposes.

Indirect potable reuse systems in USA (US EPA, 2018)

Name of Project	Location	Start-Up Date
Orange County Water District Factory 21	Fountain Valley, CA	1975
Orange County Water District Groundwater Replenishment System	Fountain Valley, CA	2004
Leo J. Vander Lans Advanced Treatment Facility	Long Beach, CA	2003
West Basin Water Recycling Facility	Los Angeles, CA	2006
Bundamba Advanced Water Purification Facility	Brisbane, AUS	2007
Luggage Point Advanced Water Purification Facility	Brisbane, AUS	2008
Gibson Island Advanced Water Purification Facility	Brisbane, AUS	2008
Joint Water Purification Project	Cottonwood, CO	2010
San Diego Water Purification Demonstration Project	San Diego, CA	2011
Big Spring Water Reclamation Facility	Big Spring, TX	2012
Oxnard Advanced Water Purification Facility	Oxnard, CA	2012

Willingness to use recycled water in California (Hui and Cain, 2017)

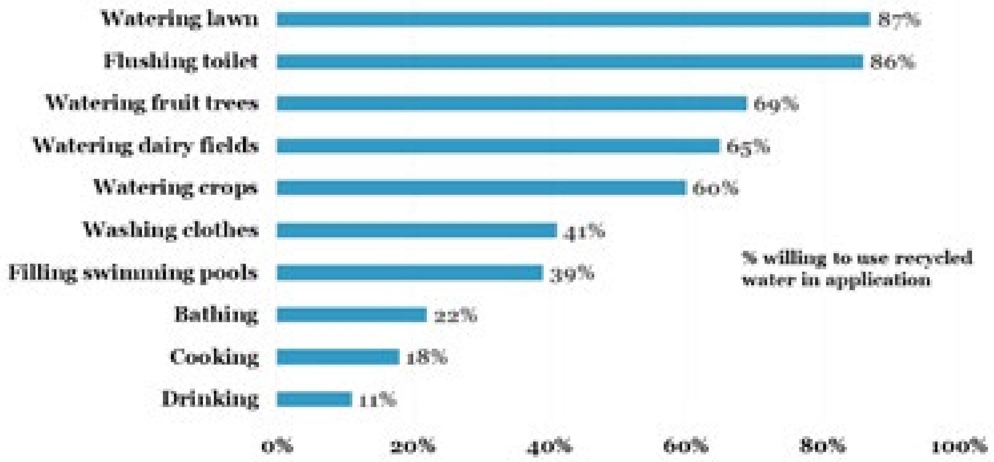

Table 8-8 Examples of water reuse in USA

3.3. Protection of Water Resources in Agricultural Areas

Agricultural activities are the LULUC with the highest water usage and uses various fertilizers, herbicides, and pesticides that discharge various pollutants into surface water or groundwater. Agricultural LULUC produces algal blooms by discharging nutrients into the surface water, releasing toxic chemicals and causing fish kill. Groundwater in many agricultural areas is contaminated with NO3-N due to fertilizers and requires high cost and a long time for water purification. In all countries, including Korea, surface and groundwater are very important water resources and must be qualitatively and quantitatively protected.

According to the OECD (2013), until the early 2000s, the agricultural areas of Netherlands had the highest nutrient contents (nitrogen and phosphorus) in the soil, but nutrient contents decreased with continuous management effort. However, due to excess use of fertilizers made from livestock wastewater, the soil in agricultural areas in Korea is the highest in the world (Figure 8-16). Excess nutrients are caused by surface runoff or sub-surface flow when the rain event occurs, causing waterbodies to discharge, resulting in algal blooms. In Korea, more than 90% of the livestock wastewater is made into fertilizers in 2016 and used in the agricultural area. Therefore, agricultural nonpoint sources should be managed using NBS for water quality and algae control of the 4 major rivers, which are main water sources. Applicable NBS to agricultural areas includes retention facilities such as wetlands, ponds, reservoirs, and detention facilities such as buffer zones, buffer strips, and contour cultivation.

About 41% of Korea's water usage (including stream maintenance water) is used for agricultural purposes and is provided free of charge. For this reason, farmers use agricultural water indiscreetly while performing cultivation activities. Indiscreet agricultural water usage is consistently lowering the groundwater level and reducing the flow rate in streams. Therefore, for improving water security in Korea, it is necessary to introduce a fee system to reduce the usage of agricultural water, and it is necessary to apply NBS to manage agricultural nonpoint sources.

04
Conclusion

Among various global risks, water crises, failure of climate change mitigation and adaptation, and biodiversity loss and ecosystem collapse are very important factors in human life. Spatial and temporal variations of water due to climate change affect water resources and water pollution, making water management difficult. Rapid urbanization causes changes in natural water circulation by changing the natural cover to an impervious surface, causing problems such as urban flooding, drought, water pollution, and heat islands. Land use and land use changes (LULUC) generates various types of pollutants, and these pollutants have a significant impact on water security. Water security, which is essential to people and the ecosystem, requires a climate change adaption strategy and an active response to LULUC. Recently in many countries, policy and programs have been introduced to expand ecosystem services for climate change adaptation and reduction of urbanization problems. A solution to efficiently solve water problems to ensure water safety are the nature-based solutions (NBS) for water. Because infrastructures for human life affects water flow, it is necessary to apply ecosystem-based management and ecosystem-based adaptation or mitigation techniques in planning, design, and construction. NBS for water is a technical approach to deliver more ecosystem services to people.

Integrated water resources management (IWRM) for water safety can reduce water-related disasters including flooding, contribute to water quality, and provide various water resources. IWRM can be applied to various technical approaches including green infrastructure (GI), low impact development (LID), rainwater harvesting, water reuse, water-wise cities, blue-green networks, constructed wetlands, groundwater recharge system. IWRM should be constructed as a water loop in the watershed, where all water, such as sea water, wastewater, rainwater, stream water, and groundwater, must be connected. LID and GI approaches consider more conventional approaches such as recreation & amenity, bio-diversity, and resources to provide ecosystem services. Water-wise cities mean using NBS to solve urban problems caused by climate change and urbanization.

Water security and sustainable development require the development of new water resources and a decentralized treatment plant strategy. Also, integrated management of decentralized facility using Information & Communication Technology (ICT) is needed. Sustainability can be ensured when this treatment plant is associated with various functions such as energy, recreation, resilience, water culture, water resources, ecological green spaces and parks, and landscaping.

Agricultural activities are the LULUC with the highest water usage and use various fertilizers, herbicides, and pesticides that discharge various pollutants into surface water or groundwater. Agricultural LULUC causes algal blooms and fish kill of surface water and cause groundwater contamination. In all countries, surface water and groundwater are very important water resources and must be qualitatively and quantitatively protected. Indiscreet agricultural water usage is consistently lowering the groundwater level and reducing the flow rate in the stream. Therefore, for water security in Korea, a fee system should be introduced on agricultural water, which can reduce the use of water. Also the NBS is necessary to manage agricultural nonpoint sources.

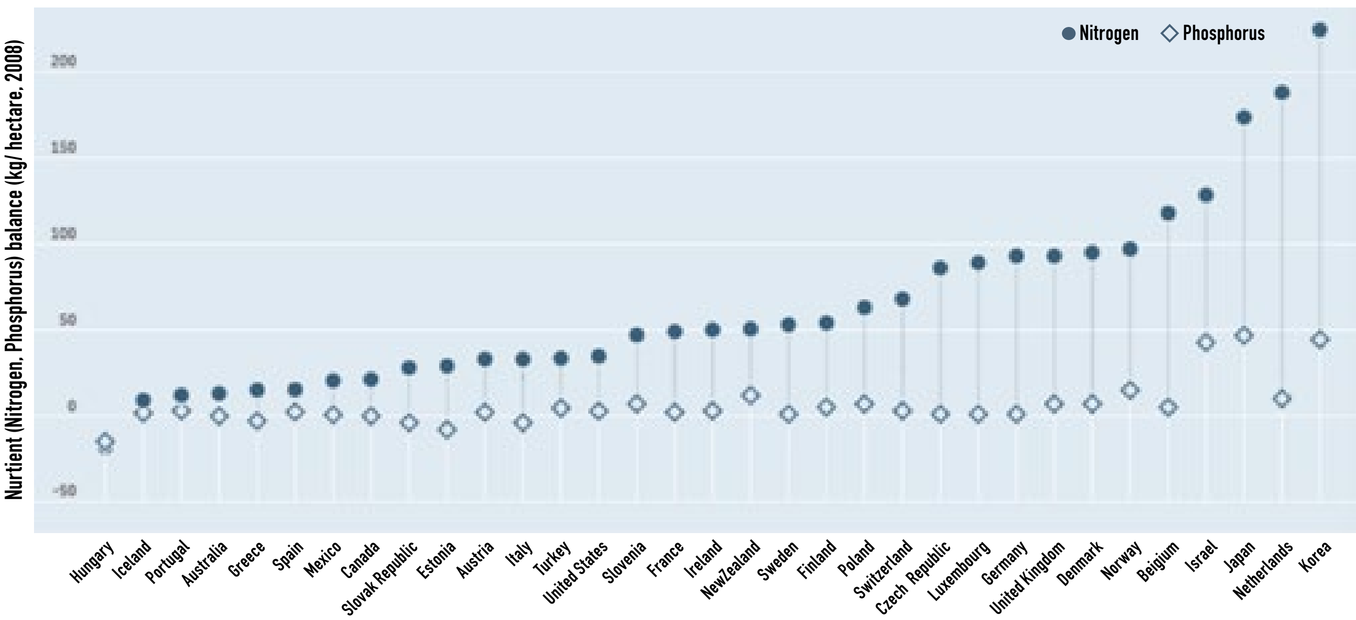

Figure 8-16 Nutrient (Nitrogen and Phosphorus) contents in agricultural soil (OECD, 2013)

Vocabulary section

Integrated water resources management (IWRM): Integrated water resource management (IWRM) is a holistic water management approach where all pertinent factors are considered including supply management, demand management, water quality management, recycling and reuse of water, economics, conflict resolution, public involvement, public health, environmental and ecological aspects, socio-cultural aspects, water storage, conjunctive use of surface water and groundwater, water pollution control, flexibility, regional approaches, weather modification, sustainability and others.

Green infrastructure (GI): Green infrastructure (GI) is defined as an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations.

Low impact development (LID): Low impact development (LID) is a comprehensive technology-based approach to managing urban stormwater. LID technologies mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff.

Rainwater harvesting: Rainwater harvesting is a technique used for collecting and storing rainwater from rooftops, land surfaces or rock catchments using simple techniques such as natural and/or artificial ponds and reservoirs. One millimeter of harvested rainwater is equivalent to one litre water per square metre. After collecting and storing the rainwater is a source in households for drinking, cooking, sanitation, etc., as well as for productive use in agriculture.

Water reuse: Water reuse refers to the recycling, reclaiming and treatment of municipal and industrial wastewater effluent, brackish water, poor quality groundwater, agriculture return flows, stormwater and the oceans for the purpose of same or other beneficial use.

Water-wise cities: Water wise cities refers to cities that are resilient to floods, droughts and the challenges of growing water scarcity despite increasing pressure to water resources due to urbanization.

Blue-green networks: Blue/green networks are an innovative holistic way of planning based around waterways (blue), planting and parks (green). These are managed together through a combination of infrastructure, ecological restoration and urban design to connect people and nature across the city.

Constructed wetlands: Constructed wetlands are man-made systems, designed and constructed to treat municipal or industrial wastewater, greywater or stormwater runoff using the natural processes typical of natural wetlands.

Groundwater recharge system: Groundwater recharge system is a technology that enhances the hydrologic process where water enters the aquifer usually done naturally through infiltration and percolation through unsaturated zones after rainfall events.

Ecosystem services: Ecosystem Services as the benefits people derive from ecosystem which was grouped into four categories such as provisioning services, regulating services, supporting services and cultural services.

Nature-based solutions (NBS): Nature-based solutions (NBS) are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water. An NBS can involve conserving or rehabilitating natural ecosystems and/or the enhancement or creation of natural processes in modified or artificial ecosystems. They can be applied at micro-scales or macro-scales (UN Water, 2018).

Climate change: Climate change in Intergovernmental Panel on Climate Change (IPCC) usage refers to a change in the state of the climate that can be identified (*e.g.* using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Urbanization: Urbanization or urban transition refers to the shift in a population from one that is dispersed across small rural settlements in which agriculture is the dominant economic activity towards one where the population is concentrated in larger, dense urban settlements characterised by industrial and service activities (UN, 2014).

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Notes

1. Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a water sample at 20°C temperature over a specific time period. The BOD value is most commonly expressed in mg/L of sample during 5 days of incubation at 20°C and is often used as a surrogate of the degree of organic pollution of water.
2. Chemical oxygen demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution. It is commonly expressed in mass of oxygen consumed over volume of solution which in SI units is mg/L. A COD test can be used to easily quantify the amount of organics in water. The most common application of COD is in quantifying the amount of oxidizable pollutants found in surface water (e.g. lakes and rivers) or wastewater. COD is useful in terms of water quality by providing a metric to determine the effect an effluent will have on the receiving body, much like biochemical oxygen demand (BOD).
3. The concept of per capita water use is often used for comparing water use over time or among groups of people (cities, counties, etc.) that use public water supplies (e.g., city water). Generally, per capita water use means the average amount of water each person in a particular area uses on a daily basis, expressed as "liters per capita per day." But, water use can be calculated many different ways, which makes fair comparisons of water use among populations difficult. Water managers use per capita measurements for a number of purposes to assess water demand and identifying use patterns, to set goals and establishing use thresholds in permitting, to evaluate conservation program effectiveness, and to have public communication. Calculating per capita water use seems as simple as dividing the amount of water withdrawn or used by the number of people using it. However, it is sometimes necessary to use more sophisticated calculation methods. The Florida Department and districts developed two standardized per capita measures:
   Uniform Gross Per Capita = (Utility Service Area Finished Water Use) / (Utility Service Area Residential Population)
   Uniform Residential Per Capita = (Utility Service Area Finished Water Used by Dwelling Units) / (Utility Service Area Residential Population)
   Where, Utility Service Area Finished Water Use is the sum of finished water used by all sectors (residential, industrial, commercial, etc.) served by a utility. Utility Service Area Finished Water Use by Dwelling Units is the sum of finished water used by all dwelling units served by a utility. Utility Service Area Residential Population is the number of dwelling units served, multiplied by an estimate of persons per household.
   The first measure considers all water users in a service area, including large quantity users, such as industrial, commercial or institutional users. The second measure evaluates household water use only. These measures improve the ability to understand statewide water use data, and compare water use among different populations (Florida Department of Environmental Protection, 2014).
4. Grey infrastructure refers to the human-engineered infrastructure for roads, buildings, bridges, parking lots, and others. In water fields, grey infrastructure typically refers to components of a centralized approach to water management (Benedict *et al.,* 2006).
5. Green infrastructure is the strategic use of networks of natural lands, working landscapes, and other open spaces to conserve ecosystem values and functions and provide associated benefits to human populations (Benedict *et al.,* 2006).
6. Low-impact development (LID) is a term to describe a land planning and engineering design approach to manage stormwater runoff as part of green infrastructure. It emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source (US EPA, 2006).
7. Blue-green infrastructure is also a term used interchangeably with green infrastructure to describe things like rain gardens or reed beds that treat wastewater. Green infrastructure is generally decentralized; water is captured and treated where it falls, rather than being transported to a treatment facility (Benedict *et al.*, 2006).
8. A sustainable drainage system (SuDs, SuDS, SUDS) is the term managing the stormwater runoff, which is reducing the potential impact of new and existing developments with respect to surface water drainage discharges. The term sustainable urban drainage system is not the accepted name the 'Urban' reference having been removed so as to accommodate rural sustainable water management practices (Scottish Government, Planning Services, 2001).
9. Water-sensitive urban design (WSUD) is a land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation and improve aesthetic and recreational appeal. WSUD is a term used in Australia. It is similar to low-impact development (LID), a term used in the United States; and Sustainable Drainage System (SuDS), a term used in the United Kingdom (BMT WBM, 2009).
10. The IWA Principles for Water Wise Cities aim to provide the necessary frameworks and principles to assist urban leaders to develop and implement their vision for sustainable urban water, and resilient planning and design in their cities. The ultimate goal of these Principles is to encourage collaborative action, underpinned by a shared vision, so that local governments, urban professionals, and individuals actively engage in addressing and finding solutions on urban water management challenges, driven by three paradigm shifts: (1) Resources are limited, (2) City densification is both an opportunity for economic growth and a threat to livability. (3) An uncertain future underlies the planning of our cities (IWA, 2018).

11. A rain garden is a designed depression storage or a planted hole that allows rainwater runoff from impervious urban areas, like roofs, driveways, walkways, parking lots, and compacted lawn areas, the opportunity to be absorbed. The primary purpose of a rain garden is to improve water quality in nearby bodies of water and to ensure that rainwater becomes available for plants as groundwater rather than being sent through stormwater drains straight out to sea. It can reduce rain runoff by allowing stormwater to soak into the ground and cut down on the amount of pollution reaching creeks and streams.
12. A bioretention cell is called a rain garden in the United States. It is designed to treat polluted stormwater runoff. Bioretention is the process in which contaminants and sedimentation are removed from stormwater runoff. Stormwater is collected into the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants.
13. An infiltration trench, is a type of best management practice (BMP) that is used to manage stormwater runoff, prevent flooding and downstream erosion, and improve water quality in an adjacent river, stream, lake or bay. It is a shallow excavated trench filled with gravel or crushed stone that is designed to infiltrate stormwater though permeable soils into the groundwater aquifer.
14. A green roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems.
15. Tree box filters are typically filtration systems installed under a street or sidewalk which have trees planted in them. The systems collect stormwater runoff through methods such as permeable pavers or curb cuts. The runoff is then filtered by soil, microbes and vegetation before either being utilized by the tree or discharged into a storm drain system.

V

Water Security and Governance

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9

Exploration of the Water-Energy-Food Nexus for Policy Making and Implementation

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Abstract

The research aims to evaluate the concept and policy framework of the Water-Energy-Food (WEF) Nexus in the Korean and international context for achieving water security and make suggestions for relevant policy-making and implementation. The study introduces practices of the WEF Nexus in Saudi Arabia, Ethiopia, USA and South Korea. The WEF Nexus can be defined as 'a way of thinking about the interdependencies, tensions and trade-offs between water, energy and food security in the wider context of environmental change with a focus on the impact on social systems (Houses of Parliament, 2016)'. There are three essential elements for the nexus approach, the interdependencies, trade-offs and synergies. Saudi Arabia has managed to export livestock and dairy products by consuming water produced through desalination plants. Such energy-intensive practices need to be avoided. Ethiopia has striven to achieve socio-economic development through the nexus approach which can be found from its Growth and Transformation Plan. The state of California, US, has coped with serious droughts via the introduction of brackish desalination plants. Floating solar power plants in South Korea indicates another attempt to apply the nexus approach to the existent infrastructure for efficiency and environmental conservation. Nexus-based policy-making and implementation should reflect the urgency to minimize trade-offs and optimize synergies between water, energy and food, which serves as a backbone to support the enhancement of water security. Mobilizing public and private funding will be necessary, and the socio-economic and environmental systems should be revised and adjusted to reflect nexus-based policies and frameworks.

Keywords

Water-Energy-Food Nexus, water security, interdependencies, trade-offs, nexus-based policy-making and implementation

01

Introduction

Challenges triggered by the depletion, overuse and unsustainable management of resources for human development have been compounded by population growth, industrialization, and urbanization together with adverse impacts of climate change. The Global Risk 2014 indicates that four out of the most influential and possible risks are indirectly or directly related to water and food security. In addition, energy security is increasingly becoming one of the top policy agendas in many regions, which cannot afford to be jeopardized. The security of water, energy, and food can guarantee sound economic growth and an adequate level of living standards (World Economic Forum, 2014). In this context, water security of a society or region is fundamentally in line with food and energy security for safeguarding sustainable development.

There is a growing recognition of the need to prepare an innovative and holistic approach for resolving the complexity of these challenges, and the nexus approach for tackling natural resources, i.e. water, energy and food is needed. The urgency for the nexus between water, energy, and food is imminent considering socio-economic and environmental challenges the global society is confronted with at the moment, including water shortage and stress, an upsurge of energy demand and supply constraint, and food shortage and waste.

“The urgency for the nexus between water, energy, and food is imminent considering socio-economic and environmental challenges the global society is confronted with at the moment.”

Such problems are often exacerbated by climate change which has led to the intensification of unpredictable natural phenomena regardless of geographical locations. The Water-Energy-Food (WEF) Nexus approach is becoming a ‘necessity’ in policy-making and implementation at the local, national, and regional levels. A lack of a good understanding of the WEF Nexus can entail unsustainable management of invaluable resources and necessities for human survival and development, and eventually spawn the downward spiral of socio-environmental conditions.

The purpose of this study is to explore the background and research trend of the WEF Nexus and conceptualize the approach for giving recommendations for policy making and implementation in the course of achieving water security. Discussions of the primary purpose of the approach are geared towards an emphasis of three significant characteristics considering an integrated approach to the three resources, such as interdependencies, trade-off and synergies. On the basis of a good understanding of the concept, the study sheds light on various cases, i.e. Saudi Arabia, Ethiopia, the state of California, USA, and South Korea.

Particular attention will also be paid to policy prerequisites for the WEF nexus approach as enabling environments, relevant policy agendas and implementation issues, and the role of national governments on how to promote the nexus approach for policy making and implementation. The discussion of these elements will pave the way for decision makers to step forward the adoption and implementation of the WEF Nexus in an integrated way and put relevant policies and programs into practice for achieving water security, eventually.

The first part of the study is to discuss the research trend of the WEF Nexus and to conceptualize the approach. In the second section, the study takes a closer look at the applicability of the theory by exploring a variety of cases not only in the Middle East and Northern Africa (MENA) but also the state of California, USA, and South Korea. The third section analyzes various policy matters, including necessary institutional arrangements for the adoption and application of the nexus approach, adequate means of policy-making and implementation, and the roles of national and local governments to promote the nexus approach.

02

Research Trend and Conceptualization

2.1. Research Trend

Previous research outcomes on the WEF Nexus have delineated how water, energy, and food sectors are interconnected and which issues are relevant. Achieving sustainable development requires an integrated and holistic approach considering a complexity of interconnectedness between various sectors, i.e. water, energy, and food sectors. Numerous theoretical and practical approaches have been suggested as platforms with which international communities can realize sustainable development, such as green growth, green economy, inclusive growth and eco-efficiency, to name a few. Nevertheless, an array of tools and theories for sustainable development have proved to be ineffective thanks to continuous silo-based approaches, inappropriate technologies, and governance structures.

The Sustainable Development Goals (SDGs) were established in 2015 on the basis of reflection of what had been done in order to overcome challenges embedded in the Millennium Development Goals (MDGs). Even though the SDGs have put more emphasis on the magnitude of invaluable resources through a setup of individual targets, i.e. water (SDG-6), energy (SDG-7), and food (SDG-2), the 2030 agendas seem to have failed to accommodate interdependencies, trade-offs and synergies via interactions in the WEF Nexus (Houses of Parliament, 2016; Mohtar, 2016; Sullivan, 2017).

Early attention to the WEF Nexus was placed on the consideration of alternatives that can help achieve sustainable development and provide practical solutions to resolve challenges caused by the rapid socio-economic development, industrialization, and technology development since the 1970s. One of the first world-wide efforts to promote the WEF Nexus was the 2011 report on water security and the WEF Nexus, which was published by the World Economic Forum (2011). Whilst discussing various elements to influence the degree of water security for society, the report points out several areas with high risk, including an imbalance of macro-economy, illegal economic behaviors and the WEF Nexus.

In particular, the WEF security can be compromised due to economic crisis, economic imbalance, and the failure of global governance. In order to overcome these barriers, a series of institutional rearrangements and new policy making are necessary, i.e. resource use planning accommodating diverse views from stakeholders, and the implementation mandate given to local authorities. In addition, governments should make the decision of prices of water, energy and food services based on market mechanisms and pursue innovation in the fields of nexus management technologies and related financing (Liu, 2017; World Economic Forum, 2011).

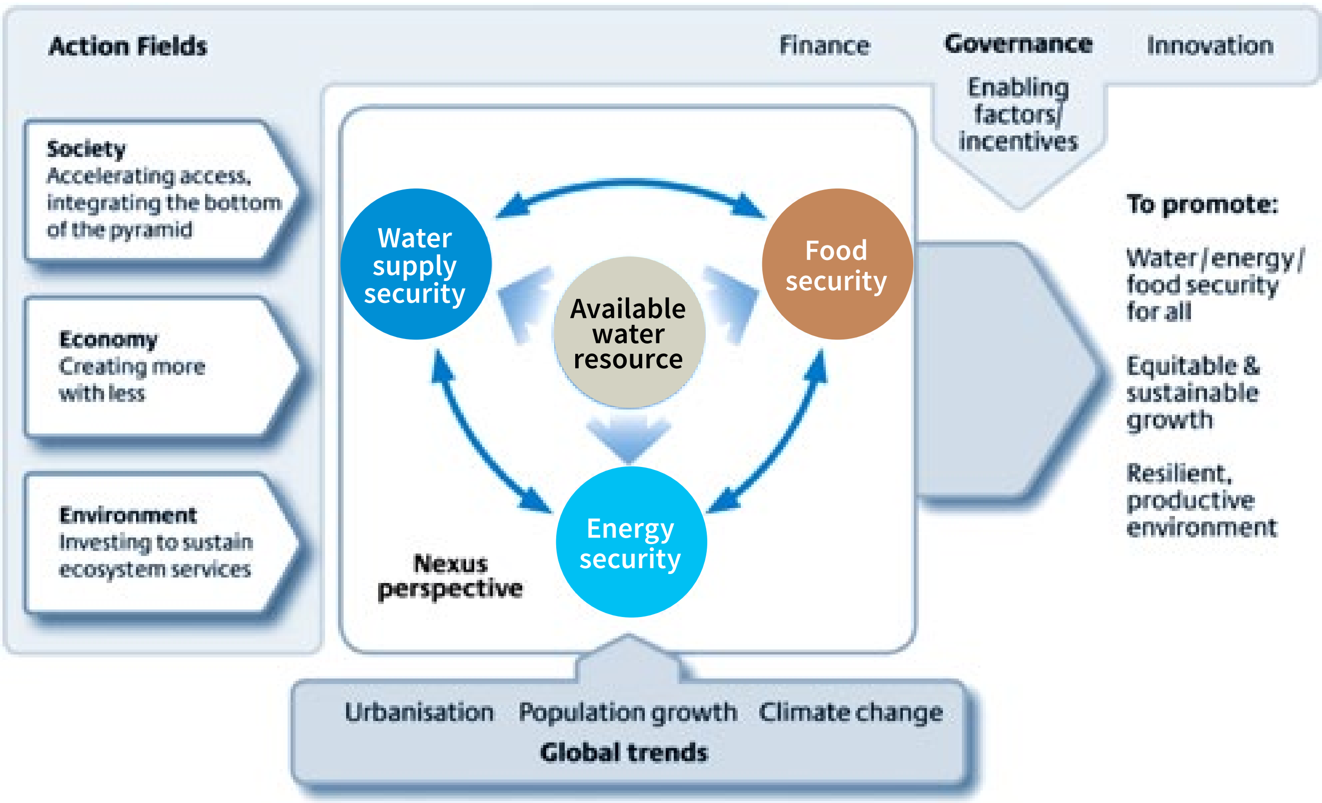

Figure 9-1 The Water-Energy-Food (WEF) Nexus Security Framework of the Bonn Nexus Conference (Source Hoff, 2011)

Together with the WEF report, the Water, Energy, and Food Nexus- Solutions for the Green Economy Conference in Bonn, Germany in 2011 was instrumental in terms of proliferation of the approach to the world. This conference put an emphasis on the need of decision making and interconnectedness through interactions between the sectors of water, energy and food confronted with urbanization, population growth, and climate change. More detailed suggestions included financing for water, energy and food security, an establishment of financing, economic incentives, and governance, and consistent institutions and policy making alongside the improvement of resource production and multiple uses of used resources. The conference also highlighted the magnitude of the reduction of transaction costs related to the integrated management of the three resources and suggested the urgency of policies to maximize synergistic effects of the nexus approach (Hoff, 2011; Lee, 2015; Martin-Nagle *et al.*, 2012) (See Figure 9-1).

Food challenges at the global level have been a major concern of the Food Agriculture Organization (FAO), and the organization underpins the significance of food security in the discourse of the WEF Nexus. The bottom-line principles of FAO for the WEF Nexus demonstrate its commitment to reducing trade-offs and seeking for the most efficient options to maximize synergistic effects.

More specifically, FAO takes into serious consideration the upsurge of resource development demands, population growth, the change of diet patterns, the evolving faith and behaviors of society and culture, technology development, urbanization, international trade, market, food prices, and industrialization for the implementation of nexus-based policies. In lieu of the implementation of nexus-oriented policies, it is imperative to introduce an integrated approach to considering land, capital, knowledge, and labor and call for dialogues and negotiations between diverse stakeholders from different sectors and fields. To support these initiatives, governments should be dedicated to developing and implementing a list of different scenarios and response policies based on the thorough assessment of relevant information (FAO, 2014). Figure 9-2 delineates the process of the WEF Nexus from the perspective of FAO.

A myriad of international conferences on water in recent few years has included sessions on the WEF Nexus, including the 7th World Water Forum, held in South Korea. The programs of the WEF Nexus contributed to increasing the recognition of the nexus approach for resolving not only water challenges but also its impacts on other resources (Lee *et al.*, 2015). In the 8th World Water Forum, held in Brazil, 2018, the discourse on the nexus approach continued, and it seems that the WEF Nexus will become one of the most pressing topics to be discussed and considered at the global level in the foreseeable future.

2.2. Conceptualization

The discussion of the WEF Nexus indicates the growing consensus that silo-based policy making and implementation, R&D, and operation and maintenance will not be able to help manage limited resources in an efficient and sustainable fashion. Those who are interested in research on the nexus approach strive to seek for plausible options related to

"The WEF Nexus is an approach to evaluate political, economic, social and environmental impacts of the exploitation of water, energy, and food with special reference to interactions between the three sectors."

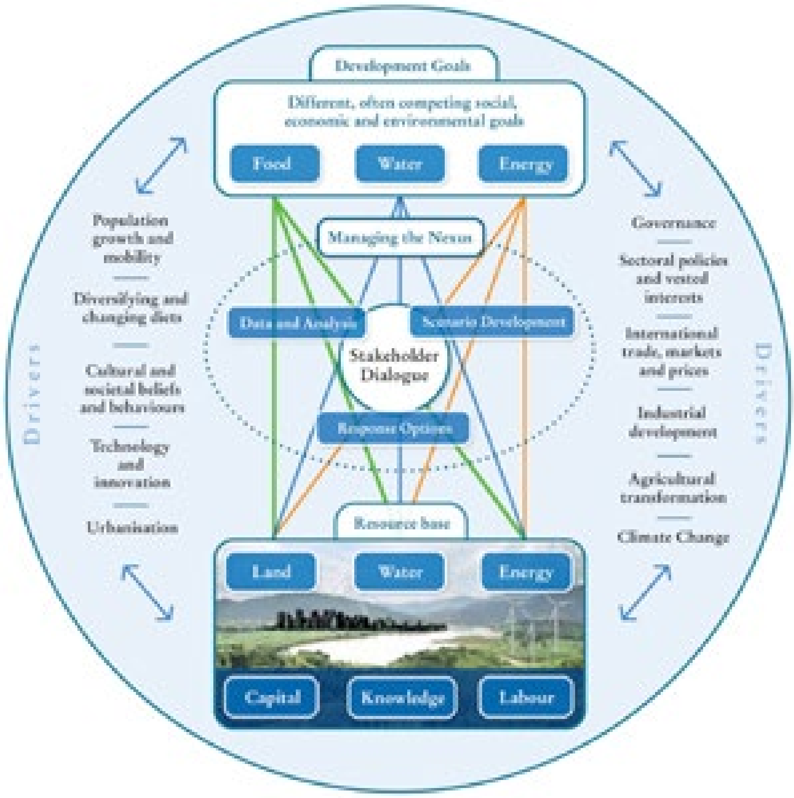

Figure 9-2 FAO's approach to the WEF Nexus (Source FAO, 2014)

efficient and sustainable policy making and implementation, related projects, R&D, a setup and operation of relevant governance structure.

The SDGs were established in 2015 so as to accomplish 17 goals by 2030 and can serve as a useful media that confirms the significance of the nexus approach. Although each of the SDG goals is imperative, many goals are inter-related and cross-cutting, including water (SDG 6), energy (SDG 7), and food (SDG 2). Therefore, it is necessary to take into serious account interdependencies between these goals, and the international communities will be able to witness positive outcomes based on the interconnectivity and synergistic effects between water, energy, and food towards 2030.
Weitz *et al.* (2014) visualizes the WEF nexus especially focusing on the interconnectivity between water, energy, and food as seen from Figure 9-3.

However, one of the fundamental challenges embedded in the SDGs is that the goals do not accommodate inter-connected issues such as the WEF nexus and are not committed to creating relevant targets. In order to effectively achieve the SDGs, the nexus approach should play a key role (KICT, 2017; Houses of Parliament, 2016; Mohtar, 2016; Sullivan, 2017; Weitz *et al.*, 2014).

It is useful to discuss the significance of challenges in the fields of water, energy and food prior to the exploration of the concept and definition of the nexus approach. Over 70% of the total amount of freshwater resources at the global level is exploited for food production, and the energy sector requires more than 15% of the total freshwater resources in the world for resource development and cooling water for power generation. The level of global energy demand in 2025 will be likely to increase 1.6 times than in 2005, and as a result, the water demand of the energy sector will soar to 11%.

Globally, the amount of water intake for energy generation will increase by over 20%, and the level of water consumption for this use is expected to grow by 85% until 2035.
For instance, an extreme drought in 2015 badly hit the western part of Chungnam Province in South Korea, which led to the emergency operation of a coal-based power plant due to the lack of cooling water. Power plants are becoming more efficient, cutting-edge cooling systems will be installed that require less water but demand more energy, and there will be an increase of biofuel production (Jung, 2015; Lee *et al.*, 2015; Liu, 2017; UNESCO, 2014).

More production of corn, wheat, and sugarcane for biofuel can entail a decrease of food supply, which indicates an example of trade-off between energy and food. Many developing countries in Southeast Asia, Africa, and South America lack electricity, which hampers an increase of food production. A speedy desertification, obsolete water supply systems, a dearth of sanitation facilities, and inefficient water resources management have exacerbated water availability and agricultural productivity. The population growth of the world, which is primarily led by developing countries, is expected to demand more water for the agricultural sector, which triggers more water demands by at least 19% until 2050 (Jung, 2015).

More than 3.5% of the total amount of energy consumption in the OECD countries have been attributed to food production whilst developing countries often demand 4.8% on average, and the food processing and transport sectors in rich

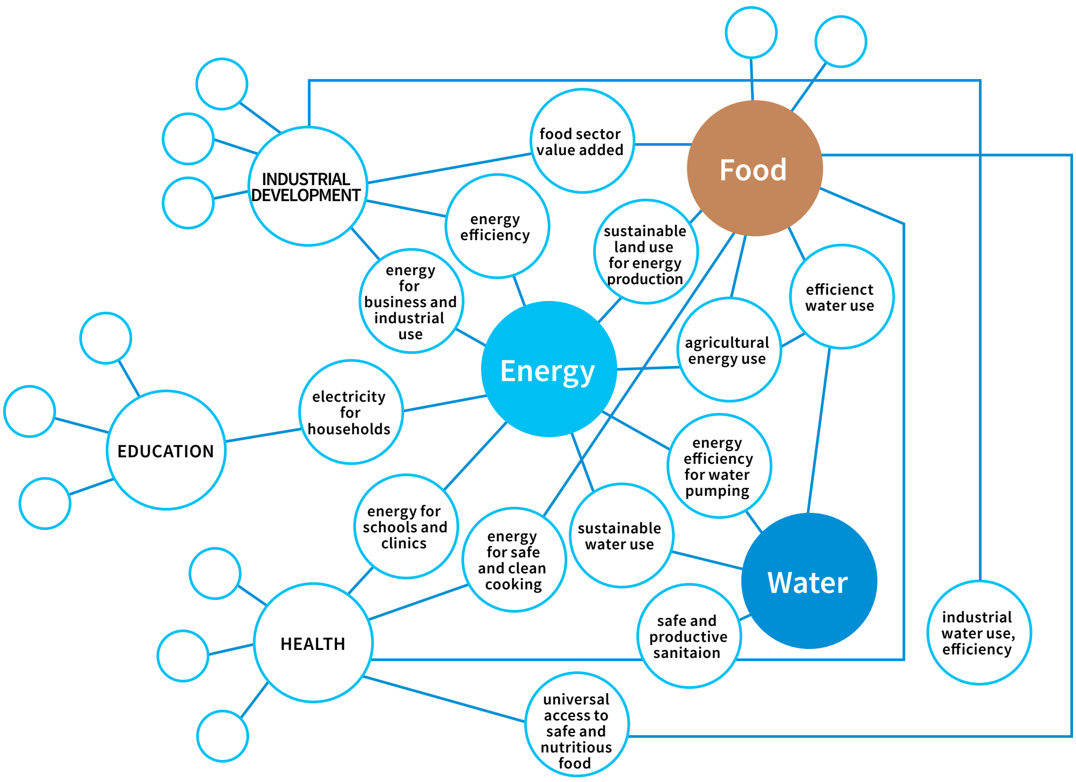

Figure 9-3 Interactions between water (SDG 6), energy (SDG 7), and food (SDG 2) (Source Weitz et al.,2014)

countries consume twice as much energy compared with the agricultural sector. In 2007, the food production system in USA required almost 16% of the total energy consumption at the national level, and Figure 9-4 vividly indicates the causal relationship between the food sector and the oil price indicator at the global level. The blue line shows the trajectory of food price changes and the red line the pattern of oil price changes from January 2002 to July 2015. The significance of oil supply for food production is confirmed from Figure 9-4 since the input of oil, for instance, in the fields of logistics and cooling facilities, gives influences on the production of relevant products, i.e. fertilizers (Laurentiis *et al.*, 2016).

Figure 9-4 *Food and oil price changes from January 2002 to July 2015 in the world (Source Laurentiis et al., 2016)*

One of the essential steps on the study of the Water-Energy-Food (WEF) nexus is to explore the definition of the nexus approach. Simply speaking, the WEF nexus approach explores water, energy and food systems that interact with each other and the environment as a whole. For instance, food crops need energy for fertilizers and pesticides, water for irrigation, and depend upon environmental processes for cycling of nutrients and pollinating crops (Houses of Parliament, 2016).

Discussions on the nexus between these elements are not totally new, and the term, 'nexus' has been used for analyzing the interactions between water, energy and food since the 1980s. It was the Food-Energy Nexus Programme of the United Nations University that first began to adopt the concept on the relationship between food and energy. The programme focused on the introduction of technical solutions and relevant policies for the interconnectivity between food and energy for developing countries (Kim *et al.*, 2015).

The WEF Nexus is an approach to evaluate political, economic, social and environmental impacts of the exploitation of water, energy, and food with special reference to interactions between the three sectors. The nexus accommodates a myriad of principles, such as universal access of all the people including the poor and the weak in society to water, energy and food in development, an increase of resource efficiency, and safeguarding sustainability for sustaining productive ecosystems (Weitz *et al.*, 2014).

In a similar vein, according to the Economic and Social Research Council (ESRC) in the UK, the definition of the WEF Nexus is referred to as 'a way of thinking about the interdependencies, tensions and trade-offs between food, water, and energy security in the wider context of environmental change with a focus on the impact on social systems' (Houses of Parliament, 2016). It is important to note that there are three important interactions in the nexus circle: 1) interdependencies; 2) constraints; and 3) synergies.

The first interaction is neatly explained related to fossil fuel electricity generation which requires water abstraction. Also, energy is needed to extract, treat and distribute drinking water. Constraints in the nexus occur related to trade-offs between systems. If an abstraction of water is increased for irrigating more food crops, water availability for other uses should be reduced, i.e. drinking water consumption, and hydropower, thermal power or nuclear power generation. Synergistic effects can be found in the nexus. Nexus-aware policy-making and implementation can reduce pressure on whole WEF systems, which leads to achievement of sustainable development in the long term (Houses of Parliament, 2016) (See Figure 9-5).

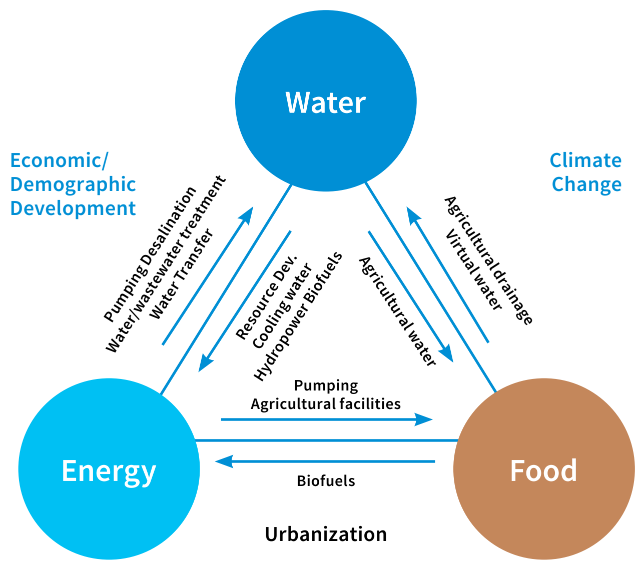

Figure 9-5 *Interaction between water, energy, and food in the WEF Nexus (Source Author)*

On the basis of the discussions above, the WEF nexus is also regarded as a policy platform with which public authorities are able to develop an assessment system, a development mechanism, and implementation measures for implementing policies, programs and projects for the sectors of water, energy, and food in an integrated fashion. Policy approaches related to the nexus play a pivotal role in consolidating water, energy, and food security. In a broader sense, the nexus framework can advocate harmonious management and use of natural resources regardless of scales (Liu, 2017).

03
Case Studies

3.1. Saudi Arabia and Ethiopia

The MENA countries are energy rich (fossil and solar energy), water scarce, food deficit and economically and environmentally vulnerable to climate change and constitute the primary case study areas in which the complexity of impacts derived from WEF interactions has already been prevalent (Mohtar, 2016). Although the Gulf Cooperation Council (GCC) states are referred to as the main cases, the countries endowed with less oil and natural-gas are worth looking into.[1] The study highlights the period since the new millennium (about 15 years) in order to closely scrutinize the changes and influences of WEF interactions in the region.

The case of Saudi Arabia explicitly shows how imperative the WEF Nexus approach is. A large number of dairy farms and cattle farms in the country have been developed coupled with a good degree of export industry of food for the region, which is possible thanks to subsidized water. This water has been 'produced' based on desalination plants, subsidized land, subsidized labor, and in a tax-free environment.
Not to mention, the country's oil export revenues have played a key role. Around 70% of the country's total water use have stemmed from desalinated water, which means that Saudi Arabia is the world's largest producer of desalinated water. Desalination plants in the country need over half of domestic oil production, which implies that a stable and reliable supply of oil can only guarantee water security for the country (Rambo *et al.*, 2017; Sullivan, 2016).

What if there would be a revolutionary change of global energy market, and the primary energy source for transport and Saudi Arabia would be green options, not oil or natural gas? The country would face real economic difficulties and political uncertainties. The World Bank (2012) predicts that Saudi Arabia could burn 8 million barrels a day to produce freshwater by 2040 whilst they are already consuming about 1.5 million barrels a day to desalinate. Possible ramifications of burning 8 million barrels a day for desalination could be tremendous to the global oil market.

These encompass a rapid depletion of precious fossil fuel sources such as oil, a destruction of the ozone layer because of the increase of greenhouse gases, an acceleration of climate change, and an increase of occurrence and scale of damage caused by water-related disasters.
Nexus-considered policies, programs and projects can help reduce anthropogenic and human-induced disasters and establish society with a good degree of sustainable development. Similar pictures could be applied to Kuwait and other oil export countries in the GCC (Sullivan, 2017).

Mohtar and Daher (2016) suggest a WEF Nexus 'hotspot' in which a vulnerable sector, country or region is confronted with stresses in one or more of its resource systems triggered from the interconnectedness of water, energy, and food resources. Such hotspots are often found in the MENA region where some countries like Saudi Arabia, Qatar, and Kuwait are endowed with large amounts of fossil fuels (oil and natural gas). Many countries in the region face water scarcity, and massive amounts of food should be imported to the region. In addition, climate change-induced socio-economic and environmental risks are particularly high in the region.

A good practice of the application of the nexus approach to policies is found in Ethiopia, Africa. The Growth and Transformation Plan (GTP) I (2010–2015) of Ethiopia, which envisaged the socio-economic development in next five years, stressed the urgency to accelerate the development of the agricultural and energy sectors for export. The GTP embraced the plan to scale up the agricultural productivity by 30%, the amount of energy production at 300%, sugar production by 600%, and meat production by 1,000%. In addition, the plan aims to boost food production, advocate energy generation through biofuels, and increase the amount of hydroelectricity via the Grand Ethiopian Renaissance Dam which is under construction on the Blue Nile (International Rivers, 2014; Weitz *et al.*, 2014).

Close attention is paid to individual targets included in detailed development plans of Ethiopia, which are directly associated with food production, bioenergy generation, hydropower development and irrigation projects.
An evaluation of inter-connected challenges between the Blue Nile and Tana Lake indicates that the commercialization and scale-up of the agricultural sector can result in an increase of agricultural productivity but may spawn negative influences on aquaculture downstream and livelihoods near the Tana Lake. Whereas policies for invigorating the agricultural sector can produce positive results in the short term, such policies might hinder food security in the region.

By analogy, the increase of biofuel production can lead to an increase of profits through an export of biofuels to other countries, a decrease of greenhouse gas emission by replacing them with fossil fuel sources, and universal access to energy supply. However, a rise of biofuel production can also require large amounts of water resources for irrigation and vast areas of plots of land. Consequently, these procedures can engender fierce competitions between food production and ecosystem services (Weitz *et al.*, 2014).

3.2. California, USA

The State of California boasts the largest population in the USA and produces vast amounts of vegetables, fruits, and nut products, which accounts for almost half of the total production of these items. Therefore, water security is one of the most urgent and imperative agendas for the state government. Most of the agricultural products in California

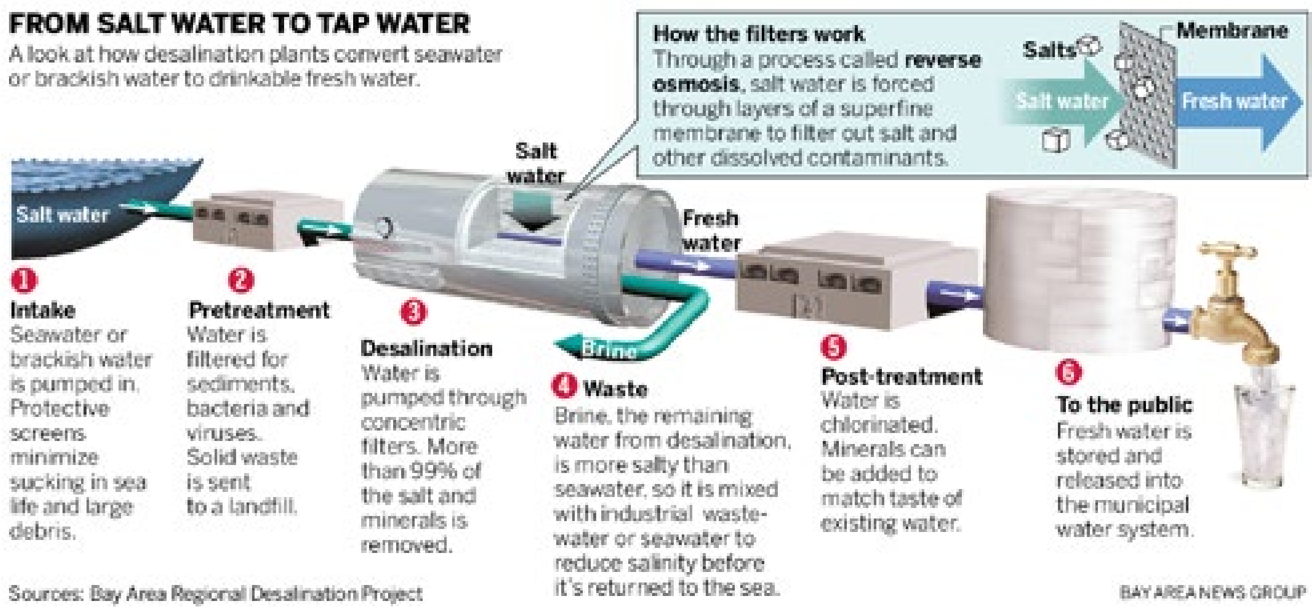

Figure 9-6 *Desalination process in desalinization plants of Southern California (Source Rogers, 2018)Remarks: MPD indicates multipurpose dam, and HGD hydropower generation dam. Modified based on the Han River Flood Control Office Website http://www.hrfco.go.kr/eng/service.do (accessed 15 June 2018)*

are grown based on irrigation projects that require heavy amounts of water resources, and apart from Northern California where water is relatively abundant, the other areas of the state, especially agricultural fields, receive water through large-scale and long-distance aqueducts.

The most renowned water transfer project is called, 'the State Water Project – SWP', which purposes to supply sufficient amounts of water to 75 million locals and 3,000 km^2 irrigated fields in Northern California, the San Francisco Bay area, the San Joaquin Valley, the Central Coast, and Southern California. This gigantic water transfer scheme had effectively been in operation, however, in January 2014, severe droughts in successive years brought about the first suspension of water supply in 54 years owing to a critically low level of water storage in reservoirs within the scheme. More than 25 million residents were affected, and as large as 750,000 acres of farmland had to rely on some other water resources instead (Pickert, 2014).

Aware of adverse impacts of climate change, the California state government has paid close attention to the linkage between climate change and water resources, which displays that the speed of water consumption has been faster than that of water recharge through the hydrological cycle. Large amounts of surface water in California stem from winter rainfall and glacier melting, and over the last three decades, the Californian winter has become warmer, which results in reducing the amount of melted snow and altering the time of snow melting. Such phenomena have consequently caused much less water available for California.

One of the coping strategies considered in Southern California is to introduce ocean desalination plants along the seashores and brackish desalination plants for enhancing water security.[2] In January 2018, the California state government gave a green light for the construction of eight desalination plants with a budget of US$ 34.4 million, and six of them are for brackish desalination. The reason why more brackish desalination plants are preferred is that the plants are less costly compared with ocean desalination plants. Ocean water is often three time saltier and more expensive to be converted into freshwater (Rogers, 2018) (See Figure 9-6).

A major concern about this option is that desalination plants require vast amounts of electricity. The water sector claims approximately 19% of the total amount of electricity supply in California, which are required for water pumping, water transfer, water treatment and the allocation and operation of water for domestic, agricultural, and industrial purposes. If desalination plants were introduced and in operation, the level of electricity consumption for water services would soar up. The option of desalination plants in California would contribute to a reduction of water import from other states, which was estimated at 3 million m^3 per annum on average. But a different side of the coin for this option is that California would need additionally tremendous amounts of electricity at around 3 TWh (Weitz *et al.*, 2014).

3.3. South Korea

Attention is placed on the amount of electricity consumption by the water sector in South Korea. Approximately 7% of the total amount of electricity consumption in the country is allocated for operating and maintaining tap water supply facilities, which demonstrates low degrees of trade-off impacts between water and energy. More specifically, the total amount of annual electricity consumption of water intake points reach 1.35 billion kWh, water treatment plants 1.18 billion kWh, industrial water treatment plants, 32 million kWh, and wastewater treatment plants 2.53 billion kWh (Lee *et al.*, 2015).

Desalination plants of the country are much smaller than those of the MENA in terms of capacity, of which size ranges from 10 m³/day to 1,000 m³/day. In 2014, there were 109 desalination plants with the total capacity of 8,333 m³/day. These plants are situated in small islands and do not consume large amounts of energy (Ministry of Land, Infrastructure and Transport, 2016). In addition, South Korea does not produce much in terms of agricultural products, such as sugarcane, corn, and wheat, for biofuel production, and therefore, there is a weak connectivity between energy and food.

The agricultural sector in South Korea has been the largest water user and claimed around 49% of the total amount of water resources as of 2011. Systematic maintenance works and the continuous construction of agricultural reservoirs have paved the way for farmers to have good access to sufficient amounts of agricultural water although sequential droughts pose a serious threat to water security. 39% of water resources are allocated for domestic uses and 12% for industrial uses. Among the industrial uses, the level of water consumption of fossil-fuel power plants for cooling is 167 m³, and the amount of ocean water accounts for 166 m³ (Kim, 2016; Jung, 2015).

Large-scale infrastructure projects or national-level programs related to the WEF nexus are not necessarily common at the national and global levels but South Korea has witnessed a myriad of new attempts to apply the WEF nexus approach to practical cases through several pilot projects. The first case is linked to the Integrated Operation and Management of Dams in a river basin reflecting the nexus between water and energy. This project aims to increase the efficiency of operation and management of existent hydropower and multi-purpose dams. In particular, the government plans to upgrade single-purpose dams (hydropower generation) which are taken care of by Korea Hydro and Nuclear Power into multi-purpose ones that are operated by K-water, which can result in securing an additional flood control capacity of 240 million m³ and an additional water supply capacity of 540~880 million m³. Consequently, the new scheme will not only optimize the operation and management of hydropower dams but also utilize extra amounts of water for hydropower generation (Lee & Choi, 2018) (See Figure 9-7).

Figure 9-7 Dams along the Han River (Source Lee, 2018) Remarks: MPD indicates multipurpose dam, and HGD hydropower generation dam Modified based on the Han River Flood Control Office Website http://www.hrfco.go.kr/eng/service.do (accessed 15 June 2018)

Figure 9-8 Floating solar power plant on the surface of the reservoir at Chungju Dam (Source Jecheon City Hall, January 2018)

The second case demonstrates an innovative approach to the generation of electricity through photovoltaic plants installed on the surface of freshwater, often dubbed as 'floating solar power plants'. A floating solar power plant embraces several advantages compared with the one installed on land. First, relevant facilities are installed on the surface of freshwater lakes or reservoirs, which eventually requires less land areas and gives less strain on land-short countries or regions. Second, installed facilities on the surface serve as a canopy to prevent heavy sunlight, which results in ameliorating a phenomenon of green algae and providing favorable conditions for fish spawning. Third, floating solar power plants can produce more electricity than the plants installed on land, since the water of lakes or reservoirs cools the panels of the plant that has a better efficiency of electricity generation at 10% compared with land-based solar power plants (Lee & Choi, 2018).

In recent few years, floating solar power plants have become popular in South Korea, particularly both in agricultural and multipurpose dam reservoirs. For instance, K-water has installed floating solar power plants in the Habcheon Dam, 2012 with a generating capacity of 500 kW, the Boryung Dam with a capacity of 2MW, 2016, and the Chungju Dam with a capacity of 3MW, 2017 (See Figure 9-8). In addition, the Korea Rural Community Corporation has spearheaded a boom of floating solar power plants in agricultural reservoirs and plans to build three large-scale floating solar plants in Dangjin (100 MW) and Daeho Lake (100 MW) in the Chungnam Province and in Goheung Lake (80MW), the Jeonnam Province until 2020 (Lee, 2017; Shim, 2017).

“The government should appraise the interconnectivity between water, energy and food and consider appropriate measures to ensure water, energy and food security alongside least trade-offs.”

The Water-Food Nexus has long been recognized for rural communities in Korea, and relevant cases are found in irrigation projects of the country. In order to save water and increase the efficiency of water use, farmers and government authorities have taken into serious consideration various methods on how to improve food productivity with less water and better output. An attempt is the introduction of the System of Rice Intensification (SRI) for paddy rice fields. The SRI technique can help reduce the amount of water for the growth of paddy rice through the introduction of drip irrigation which allows water to be directly supplied to roots and stems of paddy rice. As a consequence, less water is required for rice production by 44%, rice yield is increased per hectare at 52%, and a net income per hectare increases at around 128% based on the SRI technique. These explicitly show synergistic effects of the water-food nexus as well as the case of sustainable agricultural production (Lee & Choi, 2018; Selvaraju, 2013).

04

Water-Energy-Food Nexus Policy

4.1. Enabling Environments

Policy making and implementation of the WEF Nexus approach encompasses several features that are unique and distinguishable from sectoral approaches. Relevant policies are balanced considering the interconnectivity between the three sectors and can be implemented based on appropriate legal settings and systematic governance structures for the achievement of sustainable development. The approach facilitates an increase of resource use and a conservation of resources for future generations, which should be reflected in policy making and implementation with the recognition of interconnectedness between the three sectors. These efforts will culminate in accelerating synergistic effects (Lee *et al.*, 2015).

There are policy actions for the WEF Nexus policy making and implementation. First, it is necessary to set up macro-scale and comprehensive planning for the WEF Nexus that should be spearheaded by governments and embrace integrate systems to accommodate diverse demands and requests from the three sectors. In the long-term, governments are committed to achieving resource-independent policies on the basis of the WEF Nexus approach. Attention should be paid to the reduction of trade-offs in the course of ensuring water, energy and food security. In addition, flexible measures are taken into account faced with mega trends at the global level, including climate change, population growth, land use change, urbanization and industrialization.

Second, strategies for the management of resource consumption and supply are necessary in order to evaluate the evolving patterns of resource consumption due to the change of industrial structure and living patterns of ordinary people and to respond to these changes. In particular, it is critical to consider brand-new policies and cutting-edge technologies such as a smart water grid in order to cope with an unstable water supply, an increase of water-related disasters and deteriorating circumstances of water quality compounded by climate change (Lee *et al.*, 2015).

Third, it is imperative to establish a forum where unique and special features related to the WEF nexus approach are freely discussed and explored through diverse dialogues and discussions between different stakeholders. This forum can be called as 'the Water-Energy-Food Nexus Committee', and should invite various kinds of stakeholders in a society, such as the central and local governments, private companies, social associations/NGOs, and expert groups. Such a governance-based structure will be able to guarantee the soundness of policies and least trade-offs.

Fourth, a maximization of resource use efficiency between the three resources is one of the most significant purposes in the WEF nexus policy making and implementation.
The government has to adequately appraise the interconnectivity between water, energy and food and take into consideration appropriate measures to ensure water, energy and food security together with least trade-offs. In the course of that, the government should focus on the principle of sustainability, which echoes with the principles of eco-efficiency and green growth, 'more value with less impact' (Lee *et al.*, 2015; Min *et al.*, 2013). Table 9-1 summarizes detailed measures for maximizing the efficiency between two resources, water-energy, energy-food, and food-water.

Pairing Resources	Measures for Maximizing Efficiency
Water-Energy	• Reduction of the significance of water for power generation • Technology development in bioenergy • Improvement of water use for power generation • Measures for the enhancement of stable water supply • Efficient use of multipurpose dams • Energy recycle in the course of desalination
Energy-Food	• Separate policy making for the agriculture products, i.e. wheat, sugarcane, and corn, for food production and biofuels • Reduction of unnecessary energy loss after the harvesting period • Adoption and proliferation of green agricultural technologies
Food-Energy	• Amelioration of water shortage between nations and regions through the promotion of virtual water trade • Ensuring water supply for food production • Reduction of the amount of garbage in the fields of food production and consumption

Table 9-1 Measures for maximizing the efficiency between water, energy, and food (Source Modified based on Lee et al., 2015)

Severe droughts in consecutive years often occur in many parts of the world, and coping with this kind of water-related disaster would be a formidable challenge to international communities. Policies of the WEF nexus approach will be instrumental for ameliorating and resolving challenges brought by droughts. Amongst various kinds of droughts, the study highlights agricultural droughts. Agricultural droughts are directly linked to the nexus between water and food and gives indirect impacts on the energy sector. Once an agricultural drought takes place, the first fatal impact will be given on the agricultural water supply sector, which results in reducing water availability and the decrease of food production. As a chain effect, the prices of different food items will surge, and the food import from other areas will increase. More water can increasingly be allocated for the agricultural sector, which means less water available for domestic use,

> “It is necessary to establish comprehensive planning for the WEF Nexus that should embrace integrated systems to accommodate diverse demands from the three sectors.”

environmental flow, cooling for power generation or hydropower generation. The nexus approach paves the way for authorities to assess possible trade-offs between overall water supply policies and drought-driven emergency water supply policies for the agricultural sector, which eventually leads to efficient and sustainable policy decisions.

Agricultural droughts are closely connected to the water sector and deeply associated with the energy sector. The occurrence of agricultural droughts engenders a rising demand of water not only for agricultural reservoirs but also for other water sources. For instance, more pumps can be required for fetching water from underground, and water for hydropower generation can be reallocated to the agricultural. As droughts become severer, a rapid increase of energy consumption can be followed. Nexus-based policies can serve as a new policy framework to tackle such complicated challenges caused by agricultural droughts (Lee, 2015) (See Figure 9-9).

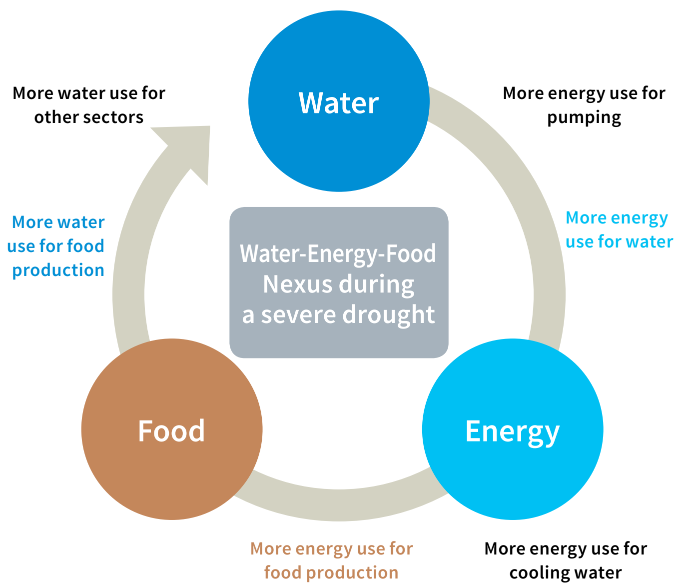

Figure 9-9 *WEF Nexus-based responses to agricultural droughts (Source odified based on Lee, 2015)*

4.2. Role of Government

The roles of governments for the WEF Nexus approach are significant because the water, energy, and food sectors are often the sole responsibility of the public sector although private sector participation has been increasing in the sectors in recent few decades. To begin with, the role of the government should be linked to its encouragement of investment and commitment of relevant bureaus and private players from small-scale technology advancement to a large-scale and national-level establishment of an integrated system for the nexus approach.

Small-scale technology development and relevant policies and programs of the nexus approach appear to have given little impacts on the overall policies and industries of water, energy and food so far. The gradual effects will come into being, which brings about substantial synergies between the three sectors and spawns good benefits to society. The benefits thanks to the nexus policies will encompass better quality compared with the ones created by each sector, separately. Furthermore, these benefits will have a positive impact on society from socio-economic and environmental perspectives.

It will be difficult to create an independent bureau or agency dealing with the nexus issues, because the complexity of vested interests and heterogeneous problems from the water, energy and food sectors is virtually impossible to be tackled by a single agency. An entity in charge of the WEF Nexus policies should play a coordinating role in accommodating various views, opinions, and problems from the three sectors and therefore, a council or committee should be established in which all the concerned stakeholders are invited and discuss related issues on the basis of good governance. The temporarily named, ‘Water-Energy-Food Nexus Council’, will serve as a medium where potential benefits thanks to the nexus policies are adequately distributed and shared between different stakeholders.

Prior to detailed policies and projects for the WEF Nexus approach, it is critical to identify and eliminate pervert subsidies and institutional bottlenecks that hamper nexus-friendly and integrated approaches to water, energy, and food. Socio-economic effects can be optimized through WEF Nexus technologies that facilitate synergistic outcomes on the basis of such enabling environments.

Detailed tasks for institutional frameworks of the WEF Nexus approach are as follows. First, the government should provide opportunities for the public and private sectors to maximize water use efficiency in the process of production and consumption of energy. Second, energy efficiency should be scaled up in the process of water resources management, water treatment, and water allocation. Third, the water and energy system should be enhanced based on principles and mechanisms of eco-resilience. Fourth, non-traditional ways of securing water resources should be promoted, including water reuse and recycle, and rainwater harvesting. Fifth, a tailored management of energy is necessary for coping with challenges caused by water shortage, water pollution, ecosystem damage, droughts, floods and earthquakes. Sixth, various measures and methods should be considered in order to create productive and synergistic effects between the water, energy and food sectors (Kim *et al.*, 2015).

4.3. Steps for Policy Making

Policy making regarding the WEF Nexus encompasses specific stages. At the first step, the government has to undertake thorough studies and research on the current circumstances of the nexus approach. This assessment exercise will unveil the interconnectivity between water, energy and food security and various elements that have an impact on the current and future scenarios of the nexus approach. In the course of this exercise, the interconnectedness of water, energy and food with other sectors have to be simultaneously considered and discussed, such as land ownership and land use, and an array of institutional instruments can be explored, including incentives and penalties.

Second, it is useful to envisage WEF nexus scenarios for the future. At this stage, a myriad of distinguishable and creative ideas should be introduced for promoting the WEF nexus approach in policy making and implementation. Future scenarios include policy implementation measures for providing solid foundations for nexus policies, diverse incentives for attracting investors, and relevant institutional settings.

At the third stage, investment for the WEF nexus should be promoted. Investment strategies are proposed for countries or regions, and the most efficient strategies for the nexus approach are geared towards the benefits of the people living in a country or region and should accommodate their opinions and perspectives.

Fourth, the entire systems for water, energy and food need to be transformed for the nexus approach. Major stakeholders are given the mandate to implement the strategies that have been proposed. One of the prerequisites for the successful implementation of relevant policies will be clear institutional instruments and frameworks. In addition, the process of policy implementation should be transparent so that stakeholders can double-check the soundness of progress and give feedback on the whole process. It is necessary to have the process of double-checking and giving feedback for an adequate level of risk management and effective implementation of policies (Bizikova *et al.*, 2014; Kim *et al.*, 2016).

An adequate regime of water, energy, and food pricing should be imperative for resource use efficiency under the transformation of sectoral policies into nexus-based policies. For example, pervert subsidies that have distorted the level of prices for water and food have to be removed, which have been created and kept in status quo due to political considerations. An introduction of carbon taxes can be an option to be considered as well for the two sectors. Also, the government can rectify the market failure in the water and energy sectors through the introduction of integrated management of water and energy resources and create a new regime of property ownership for water and energy (Kim *et al.*, 2016; UNESCAP, 2013).

05

Conclusion

The study has examined the concept and definition of the WEF Nexus with reference to several case studies, including Saudi Arabia, Ethiopia, USA, and South Korea. In-depth analyses have been made in order to explore how to introduce nexus friendly policies, programs and project by having a closer look at enabling environments, roles of government, and various steps to reach the stage where plausible conditions for nexus policies are available. Whereas an equilibrium between water, energy, and food security is necessary, guaranteeing water security is a basic foundation for the nexus-related policies and projects to be established and implemented as discussed in the case studies.

Numerous research institutes and national government agencies seem to have been busy promoting the significance of the WEF nexus approach for enhancing resource use efficiency, achieving sustainable resource consumption and saving limited amounts of invaluable resources in the world. Nevertheless, as the study has indicated, a plethora of research papers and reports only focuses on a 'possible' application of the nexus approach to policy making and implementation in practice. As potential is much explored, tangible outcomes are not necessarily visible related to the nexus approach. The case studies of Saudi Arabia, Ethiopia, USA and South Korea sketch large potential of how this approach can be developed at least on a small scale but it would be plausible to argue that the nexus approach is critical in achieving the SDGs by 2030.

An array of institutional and political barriers needs to be dismantled for giving more impetus on the viability of the WEF nexus approach for policy making and implementation. Silo-based approaches should be de-emphasized and integrated approaches are advocated for reflecting uniqueness of each sector and seeking for best options that accommodate a variety of benefits and challenges from the water, energy, and food sectors.

> *"Silo-based approaches should be demolished and integrated approaches are advocated with the best options that accommodate benefits and challenges from the water, energy, and food sectors."*

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Notes

1. The Gulf Cooperation Council (GCC) states are Bahrain, Kuwait, Oman, Saudi Arabia and the United Arab Emirates.
2. Brackish desalination plants filter salty water not from ocean but from a river, bay or underground aquifer for drinking water, and this option is often regarded as energy efficient and ocean life friendly (Rogers, 2018).

10

Governance and Water Security: Analysis of The Profile of Representatives of River Basin Organizations in Brazil

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Abstract

This paper aims to contribute to the studies about governance by presenting the profile of the representatives of state river basin committees in Brazil and to provide information that may highlight important aspects of their inclusive capacity, based on the premise that good governance is key to achieving water security. It starts from the perspective that it is possible to analyze basin organizations as governance arrangements made up of different actors that have attributions to mediate, articulate, approve and follow the actions for the management of the water resources of their jurisdiction. These initiatives are characterized by management proposals that are imbued with aspects of decentralization, participation and integration. They imply a relationship between the state (at its different levels) and society (or with entrepreneurs, communities, NGOs) in the management of river basins. The governance arrangements for basin management aim, among other aspects, to guarantee access to water and establish standards for the protection of the quality of territorial waters, seeking water security. Between November/2017 and July/2018, a broad survey was carried out with the representatives of committees in order to identify who are the actors who participate in the processes of formulation and deliberation of water resources management policies, and how the representatives perceive their involvement in the decision-making process. The analysis was carried out based on a sample of 30%, out of a total of 11,197 representatives, between representatives and deputies, who are part of 205 of the 210 state river basin committees in Brazil.

Keywords

Basin Committees, governance, management of water resources, Brazil

01

Basin Committees; Governance; Management of Water Resources; Brazil

The importance of water for maintaining life, protecting human health, and improving quality of life is indisputable and widely recognized. It is noted that the first international discussions that calls attention to the modernization of water resources management occurred at the United Nations Water Conference held in 1977. Among other decisions, its Action Plan recognized the water as a right declaring that "all peoples, whatever their stage of development and social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs."

Water is used for consumption, cultivation and production of food and energy, transportation, as a political and cultural symbol (religious and cultural values), as well as being a place and source of entertainment (recreation and tourism), among others applications. For these benefits to be achieved, various natures are necessary, mainly because the water resources do not always obey the limits of the man-made political structures.

> *"Water security is the result of good water governance, allowing better access to water, sanitation and preservation of water resources."*

The changes that have occurred in the last century, such as population increase, growing and disorganized urbanization, deforestation, food production and industrial activities, among others, have led to a greater demand for the multiple uses of water, which generate competition and conflicts for this limited natural resource. The availability of water resources—in terms of sufficient quantity and quality—has become an object of concern for society as a whole, especially since Rio 1992. When considering these changes and increasing water demand, there may be situations of tension between social, political and economic agents, often expressed through land use and occupation, increasing the need to seek cooperative ways of resolving the use of resources and drawing attention to water security.

In this sense, water security is the result of good water governance, which may allow better access to water, sanitation and preservation of the quantity conditions and the quality of water resources. In general, the objectives are to reduce absolute poverty, develop the health of the population and preserve natural resources. However, it is necessary to adopt policies and strategies that help improve manage and use water resources through the participation and interrelations between different actors and sectors that use water resources, including the environment itself.

It should be stressed that the participation of all actors involved—from all sectors of society—is an important element that can promote equity in water management.
Another point to be considered is that transparency and institutional development are elementary to enable and facilitate participation that can lead to effective governance and better possibilities for action against climate variability and all associated impacts.

According to Greya and Sadoff (2007), water security is determined by numerous physical factors, including the absolute amount of water available, its annual variability and spatial distribution. The socioeconomic factors emphasize the structure of the economy and the behavior of its actors, which reflect cultural legacies and political choices determined by different historical, social, and political conditions.
These factors, along with climate change, influence the institutions and organizations of management and governance in addition to the type and scale of infrastructure needed to achieve water security.

Climate change is the physical element that can impact the availability of water in the semiarid regions of the world, including South America, which can lead to frequent and prolonged periods of droughts and lack of water within the next 50 to 100 years (Bates *et al.*, 2008). The variability and decrease of precipitation in arid and semiarid areas of Argentina, Chile and Brazil will be extreme. In Bolivia, Colombia, Ecuador and Peru, the reduction of glaciers will generate smaller volumes of water to satisfy the most basic needs of the population.

Thus, problems of governance and management of water resources may result in strong impasses related to the availability of water, food, and possible social and political conflicts arising from this situation. For this reason, it is important to look at the water security problem through the perspective of governance. That is to look at the urgency of the theme of water and everything related to it: Food, energy, right to water, gender and social participation. This perspective is in line with what is advocated by the United Nations 2030 Agenda and the Sustainable Development Goals (SDGs), especially with regard to water resources (Goal 6), which aims to ensure universal and equitable access to safe drinking water and safe for all.

Thinking about the concept of water security in terms of governance can be a tool for establishing policies and assisting decision-making on issues related to the private/public and individual/collective use of water.
For Kooiman (2003), governance is the structure that arises in a sociopolitical system as the joint result of the interaction efforts of all the actors involved, which conforms the rules of the game in a specific system. As an example, it is possible to mention the basin committees and management councils of water resources. Therefore, governance occurs when actors can perform and try to use these rules in accordance with the interests and goals of the groups they represent

in these arrangements. Therefore, Integrated Water Resources Management should consider water security as a multidimensional element to be considered as a reference in decision making and as a guide in the elaboration of public management and governance policies, but should be based on technical and scientific knowledge.

Integrated water resources management is associated with the concept of "participatory management", that is, a management model that provides for the participation of representatives of various segments of society in the decision making. This management model can be aligned with goals 6.5 and 6.b of the Sustainable Development Goals. In Brazil, the current regulations require that the Water Basin Committees be composed of representatives of the executive branch, water users and civil society of the geographical area covered by the Committee for the management of water resources in its region of operation, in order to support and strengthen the participation of local communities, to improve water management. Thus, the Committees are collegiate bodies with normative, consultative and deliberative attributions; being the main forum for knowledge, problem-solving, planning and decision-making on the multiple uses of water resources within the river basin within its jurisdiction.

As noted by Chhotray and Stoker (2009, p. 191), concerns posed by environmental changes have led to a serious consideration of how the environment should be governed. The environment encompasses issues that are simultaneously local and global in character, and its governance continues to pose both theoretical and practical challenges in a variety of disciplines.

"Governance can be understood as the way in which individuals and institutions, public and private, manage their common problems."

Governance can be understood as the way in which individuals and institutions, public and private, manage their common problems, among which it is possible to cite access to water. It is a continuous process through which it is possible to accommodate conflicting or different interests that must be adjusted in cooperation actions (Our Global Community, 1996, Chhotray and Stoker, 2009).

For Hollanda (2009 p. 16), the adoption of governance proposes methodologies for strengthening communities in order to qualify them for participation in local decision-making processes with the purpose of better influencing the construction of more environmentally sustainable processes, evaluating and proposing solutions to the problems of basins. In this sense, water governance emerges as an opportunity to build new models, or models of institutional articulation, for the management of the territory that the basin covers in front of the priorities that are presented related to water, such as the recovery of rivers and aquifers and their protection, food and water security, sanitation services to the entire population, reduction of risk conditions in drought or flood events, and assurance of water supply in countless and increasingly large urban areas. In summary, to achieve water security, cooperation and joint work of the different water users are necessary, within a context of management and public policies that protect the environment and ecosystems in the face of changes in the concentration of urban centers (migration), the climatic and economic changes with the purpose of having and maintaining the natural basis for the sustenance and development of the population.

In "The Future of Democracy", Norberto Bobbio (1986) warned that a democratic process is characterized by a set of rules that establish who is authorized to make collective decisions and with what procedures. The author also points out that even group decisions are made by individuals (the group as such does not decide). Thus, the diversity of actors in the process of formulating public policies—with different capacities, with different interests and incentives, and interacting in several arenas—requires the understanding of the following questions: Who are the actors involved in the water policy-making processes at the river basin level? Who are the social subjects that participate in the processes of formulation and deliberation of water resources management policies? What are the characteristics of the participants (training and professional area)? With these questions, it is discussed who are the social subjects that act in these spheres, presenting the profile of the participants.

From this characterization, one can analyze and discuss if the basin organisms are able to include subjects that are traditionally underinserted in spaces of decision. In the first questions proposed in the survey sent to the representatives of basin committees, it was sought to identify who are the social subjects that act in these spaces, presenting the profile of the participants.

The objectives established for this research were to understand who the social subjects are, the practices and interconnection of the organizations responsible for the management of water resources in the exercise of their normative and deliberative function in the scope of the hydrographic basins, and the profiles of the representatives of the River Basin Committees. The full functioning of the committees and the active exercise of representatives of the different segments should contribute to ensuring sustainable access to quality water in an adequate quantity for maintaining livelihoods, human well-being, and socio-economic development. In other words, promoting water security should be the main focus of those who manage water resources.

02

Water Basin Committees in Brazil

Brazil has about 12% of the world's fresh water. However, this availability varies considerably, both geographically and seasonally, with several records of supply problems at various uses. One of the major challenges of water resources management in the country, as Cardoso (2008) points out, is related to the expansion of water supply in regions with low availability of river basins and need to improve quality through the reduction of domestic and industrial pollution. It should also be noted that the lack of water and sewage services threatens the quality of life of the people, the environment and water. In addition to these challenges, another complicating factor for the management of water resource is climate change, as pointed out earlier.

According to ANA (2017), droughts and floods represent about 84% of the natural disasters that occurred in Brazil from 1991 to 2012. During that period, almost 39,000 natural disasters affected about 127 million people. A total of 47.5% (2,641) of the Brazilian municipalities decreed Emergency Situation or State of Public Calamity due to floods at least once from 2003 to 2016. About 55% (1,435) of these municipalities are in the South and Southeast regions. As for drought, about 50% (2,783) of the Brazilian municipalities decreed emergency or calamity situation in the same period.

The basin committees are state organizations, within which state river basins are created by means of Decree of the state governor. The decision to create a basin committee is a political act and the creation of these collegiate bodies is closely related to the state of water policy in the national and state spheres.

As established by the National Water Resources Policy, the main competencies of the Water Basin Committees within their area of action are highlighted as follows:

i) Promote the debate on issues related to water resources and articulate the actions of the intervening entities;
ii) arbitrate, in the first administrative instance, conflicts related to water resources;
iii) approve the basin water resources plan;
iv) monitor the implementation of the basin's water resources plan and suggest measures to meet its goals;
v) propose to the national council and to the state councils of water resources the accumulations, derivations, abstractions, and launches of little expression for the purpose of exemption from the granting rights of water resources use according to their domains;
vi) establish the mechanisms for charging for the use of water resources and suggest the amounts to be charged;
ix) establish criteria and promote the sharing of the work costs of multiple, common or collective interest.

Observing the responsibilities of the Basin Committees as potential spaces for innovation in the management of water resources, it is noticed that the main attributions are related to the planning, articulation and the management of conflicts due to the lack or excess of water. Thus, the approval of the river basin water resources plan is carried out by the Committee, defining rules for the use of water as concession priorities, reservoir operating conditions, guidelines and criteria for charging for water use, among others. In this sense, it is imperative that the management of water resources consider the risks associated with climate change more frequently. However, it is observed, low effectiveness in the implementation of the actions proposed in these plans, as well as committees that have not yet approved their plans. In some river basins, even after the charge for water use has been approved, few interventions are effectively implemented, among those planned. In addition, there is very

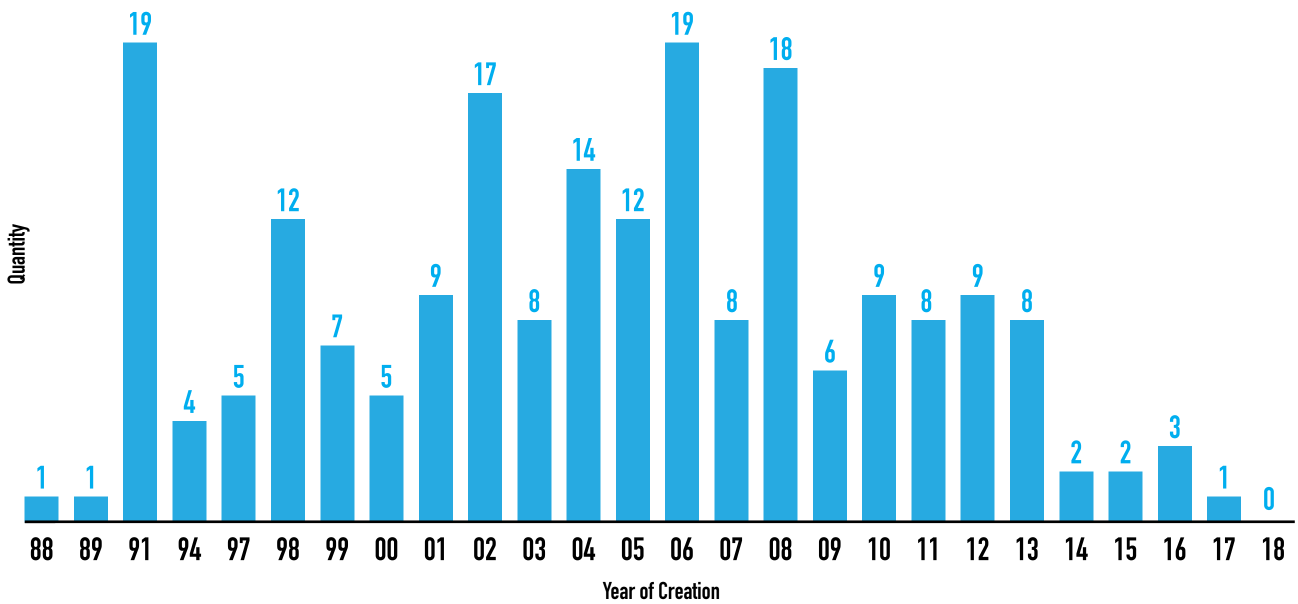

Figure 10-1 Creation of basin committees in the country (Source Prepared by the authors)

low alignment of the basin plans in the programming and budget of the state water resources management bodies, as observed by the OECD (2015).

The Committees are composed of representatives and deputies and their joint structure is constituted by the state public authority of where the territories are located, even partially, in their respective areas of activity. The municipal public government, the water users of its area of action and the representatives of civil entities of water resources with proven performance in the basin are part of this Committee. In the Hydrographic Basin Committees whose territories cover indigenous lands, representatives of the National Indian Foundation (FUNAI) should be included as part of the representation of the Union, in addition to the indigenous communities that are residents or have interests in the basin.

The proportion of these representatives was defined by the National Council of Water Resources, through Resolution No. 5 of April 10th, 2000 (modified by Resolution No. 18 of December 20th, 2001 and Resolution No. 24 of May 24th, 2002) that established the guidelines for the formation and functioning of the Water Basin Committees. It also established that in the rivers at the national territory, the number of representatives of civil entities should be proportional to the population residing in the territory of each State and the Federal District by at least 20%. Furthermore, the number of representatives of the users should be 40% of the total votes, and the votes of the representative of the executive branches of the Union, the States, the Federal District and the Municipalities, should obbey the 40% limit (CNRH, 2000).

The electoral process of these members, according to the National Water Agency (2011b), should be conducted in such a way as to guarantee the participation of all players in the basin. The members of the collegiate are chosen among their peers, considering the various sectors of water users, civil society organizations or public authorities.

From 2010 to 2017, 50 new basin committees were installed and others are still being implemented and installed. According to research conducted in Brazil, there are eight Interstate Basin Committees and 210 State Committees. In addition to these, other committees have been created, but have not yet been implemented, as well as other river basins that do not yet have plans for committees. It can be observed that the National Policy of Water Resources advanced more in the Southeast and South regions of the country, where all the committees were constituted and have more resources to contribute to the installation of the committees and the

> *“In Brazil, the main atributions of the Basin Committes are related to planning, articulation and management of conflicts.”*

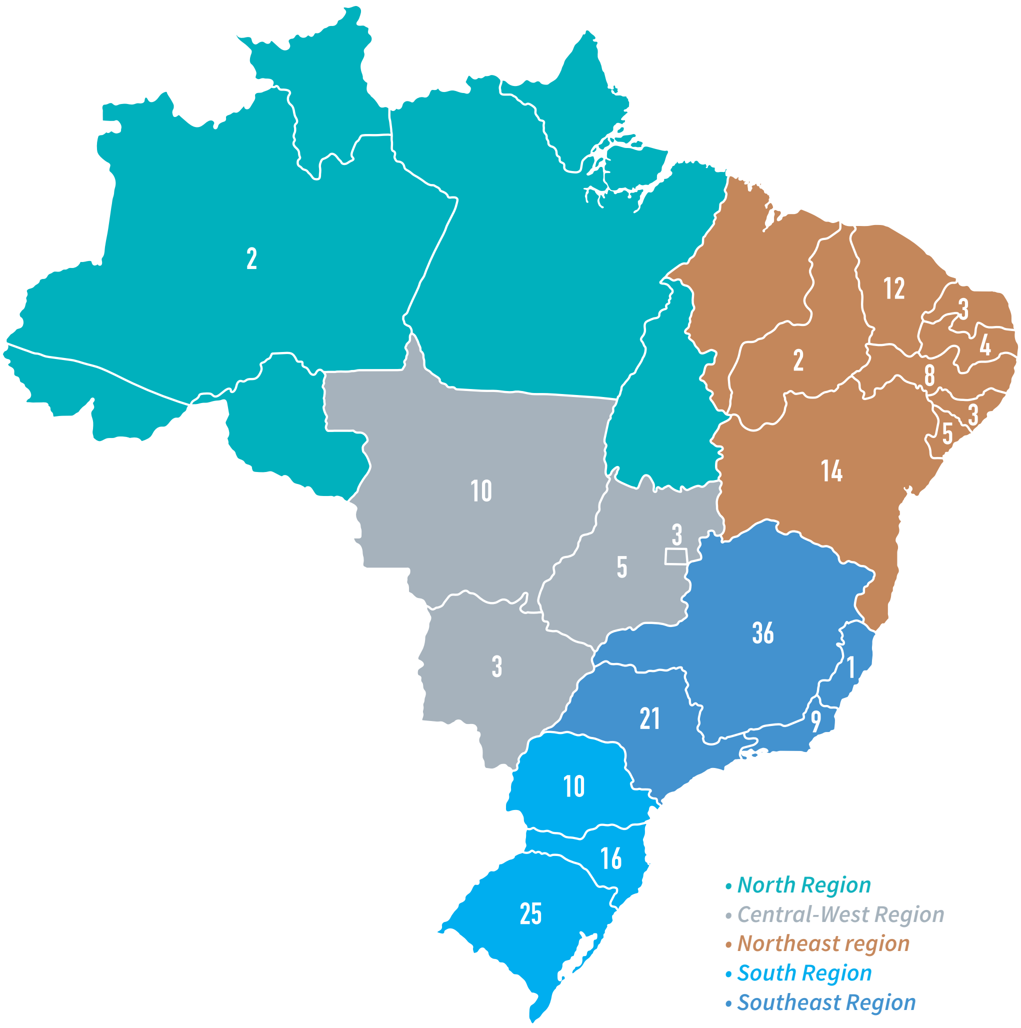

Figure 10-2 *Distribution of State Committees by state*

development of their actions. However, the same is not observed in the Northeast region (semiarid with most of its intermittent rivers), and mainly in the North with large basins. Figure 10-1 organizes information on the implementation of state committees between 1988 and 2017.

There are seven in the North region: Two in the state of Amazonas (founded in 2009 and 2016, but the latter is inactive) and five in the State of Tocantins (founded between 2011 and 2014).

The Central-West Region has 21 Watershed Committees: 10 in the State of Mato Grosso, five in Goiás (founded in 1997, 2003 and 2011), three in the Federal District (founded in 2005 and 2010), and three in the State of Mato Grosso do Sul (instituted in 2005, 2010 and 2016).

The Northeast region has 48 committees of which two are in Piauí (founded in 2009 and 2014). The State of Ceará has 12 committees (the oldest constituted in 1997, two in 1999, seven in 2002 and 2006, and two in 2013), Rio Grande do Norte has three (created in 2004 and 2010) and Paraíba has three (constituted in 2006). The State of Pernambuco has seven basin committees (seven founded between 2001 and 2007, 2012 and 2015), Alagoas has five (constituted between 2003 and 2006), and Sergipe has three (created in 2002, 2005, and 2007). Moreover, the State of Bahia has 14 basin committees (six were created in 2006, four were created in 2008, three in 2013 and another in 2014).

The South region has 51 Committees, of which 10 are in Paraná (the oldest one has a 2002 creation date), 17 committees are in the State of Santa Catarina (the oldest one, basin committee of Rio Cubatão do Sul, was created in 1993), and 25 committees are in Rio Grande do Sul (nine of these were created between 1998 and 2000, the oldest of which was created in 1994, but the Rio Tramandaí committee is inactive).

The Southeast region includes the majority of the committees created. Out of a total of 80, nine are in the State of Rio de Janeiro (eight of them created between 2002 and 2008, and 2011) and 14 committees in Espírito Santo (the oldest two being created in 2001, eight in 2003 and 2007, 2010, and the most recent in 2015). There are 21 basin committees in the State of São Paulo (13 of which were established on 12/30/1991, the last one being created in 2001). Furthermore, in a total of 36 committees, the State of Minas Gerais has the largest number of committees in the country (the oldest was constituted in 1997, seven more were constituted in the subsequent year, one in 1999—Rio Paraopeba committee, and the three most recent were created on 11/20/2008).

03

Materials and methods

The epistemological stance adopted for the development of the project is interpretative in nature. In the first phase of the research, it was sought to quantify River Basin Committees in all States of the Country and the Federal District in addition to the number of members in each organism.
At the collection of these data, the representatives of the State Hydrographic Basin Committees were contacted and sent the questionnaires. The structured research questionnaire (guided by the study questions) was composed of a set of questions with preset answers and the possibility of comments by the respondent, as well as some open questions. This data collection was performed entirely by electronic means.
After the collection, the data was tabulated with the aid of statistical software. In order to analyze the responses received, duplicate and incongruent ones were excluded.
This resulted in a sample of 30% of the seats, including holders and substitutes, in 205 Watershed Committees. Watershed Committees from the states of Amazonas (2) and Piauí (2) were not considered, because they did not obtain the minimum percentages for the study. A Watershed Committees of the State of Rio Grande do Sul, is deactivated due to lack of resources. Data collection was performed between November 2017 and July 2018. In the process of analyzing the open questions, we use the Content Analysis method from the data.

Basin Committees Place	**Number** (Water Basin Committees)	**Members** (representatives and deputies)
Alagoas	5	138
Bahia	14	769
Ceará	12	1263
Distrito Federal	3	120
Espírito Santo	14	405
Goiás	5	290
Maranhão	2	200
Mato Grosso	10	286
Mato Grosso do Sul	3	214
Minas Gerais	36	2120
Paraíba	3	242
Paraná	10	718
Pernambuco	7	245
Rio de Janeiro	9	612
Rio Grande do Norte	3	136
Rio Grande do Sul	24	1072
Santa Catarina	16	677
São Paulo	21	1694
Sergipe	3	140
Tocantins	5	216
	205	**11153**

Table 10-1 List of Water Basin Committees considered in the survey (Source Research Data)

04
Data Analysis

The water sector has intrinsic characteristics that make it highly sensitive and dependent on a multilevel governance system. Water is connected transversally to multiple sectors, places, people and also to different geographic and temporal scales. In most cases, hydrographic boundaries and administrative perimeters do not coincide.

The composition of a basin committee should reflect the multiple interests with respect to basin waters. It is hoped that this plurality of composition is reflected in the diversity of perspectives represented in the discussions and decision-making of the committees. In general, there are three interests expressed in the basins: From the direct users of water resources (whether or not subject to the granting of right of use), of the public branches constituted (municipalities, states, and Union) in the implementation of the different public policies, and civil organizations in the defense of collective interests and with the view of diffuse interests. It should be noted that participation within these arrangements is voluntary and may be a central indicator in the difficulties of establishing more demanding accountability mechanisms. Another point is that the occurence of meetings, in most committees, is every two months and extraordinary meetings may be called. There are those who hold monthly and quarterly meetings. The frequency of the meetings is defined by the plenary of the committees and is part of the internal bylaws. It has not yet been possible to identify a correlation of possible factors for the frequency of encounters.

This paper provides information that can point to important aspects of the inclusive capacity of the researched representatives, presenting as a premise that good governance is fundamental to achieve water security, considering that a democratic participation is necessary in the choice of what measures can be adopted to mitigate the impact of climate change and combat impacts and water preservation.

The committees are composed of a limited number of representatives, as defined in their bylaws approved by the committee plenary, which is the highest decision-making body. The plenary is composed of all the representatives and presided over by one of them. Its operation is based on open and public meetings.

In general terms, it can be said that the definition of the characteristics that qualify the representative as the most adequate to defend the interests of a certain segment is carried out among its peers in sectoral assemblies, convened by publishing a notice of the committees to choose the representatives. These representatives are generally accredited by an internal electoral commission and, after completing the stage of presentation of the supporting documents established by the committee, they are able to participate in the process of choosing the committee members.

Of the respondents to the research questionnaire, 74% are titular representatives and the remaining 26% are deputies. With regard to the representation sector, 22% of respondents belong to the segment of water users, 21% to the municipal public government, 34% to civil society, 20% to the state public government, and 2% to the federal public government. In the case of civil society and water users, this representation is related to constituted entities and there is no space for individual participation.

It should be noted that the term civil society shelter a very different set of organizations, entities, and interest groups: NGOs, philanthropic entities, trade unions, and business organizations, among others. In addition, water users, groups, public and private entities, and collectivities in their own name or in the name of third parties use water resources or even capture water, discharge effluents, or perform uses that are not for consumption directly on bodies (river or watercourse, reservoir, dam, well, spring, etc.).

Thus, in what constitutes representation, an entity represents a set of its peers and an individual is appointed representative of that entity in the committee. In other words, an agent is empowered to make decisions on behalf of an organization and a segment of representation in presenting the perspectives and anxieties of a group that are thinking about the collective interest that is the rational use of water resources. The author Norberto Bobbio (1986) reminds us that the fundamental rule of democracy is the rule of the majority, that is to say that the rule on the basis of which collective decisions are considered, and thus binding for the whole group, are the decisions approved by the majority of those who are responsible for making the decision.

4.1. Socioeconomic Profile

From the research carried out, when the profile of the representatives according to gender is observed, we initially noticed that the Water Basin Committees in Brazil have a predominantly male composition. That is, the percentage of men (69%) more than doubles that of women (31%).
Thus, the data indicates that there is no parity between men and women in these spheres. Gender roles not only determine how men and women are affected by the way water resources are developed and managed. Another point, the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, recognized women as one of the nine major groups in society whose participation in decision-making is essential to achieving sustainable development, and reaffirmed in SDG 5, which is about achieving gender equality, including at the political decisions (5.5).

Figure 10-3 below shows how the representatives are

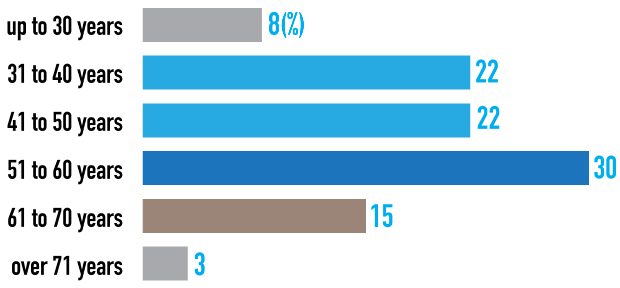

Figure 10-3 *Distribution of representatives by age (Source Research Data)*

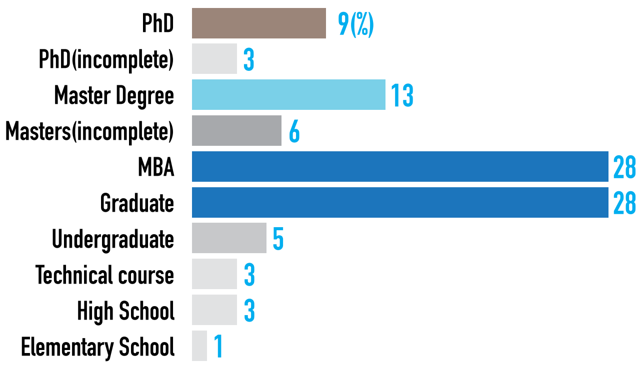

Figure 10-4 *Representatives' education (Source Research Data)*

distributed in the basin committees in Brazil, according to age groups. The data allows us to point out that the distribution of the actors in the committees concentrates the largest proportions in the representatives between the ages of 51 and 60, which are about 30%.

However, considering that slightly less than half, or 47% of the representatives, are more than 51 years old, there is a reflection on the importance of investing in the formation of representatives in order to give continuity to the renewal process of representation and social participation of water management, because it will be necessary to train them for this process.

Considering that the elected member must be prepared to defend the interests of the segment he represents, we also question the representatives about the level of education, training area, and the experience in other collegial organisms in the area of water resources, as in other areas.

When analyzing the level of education of the respondents who work in these spaces, as shown in Figure 10-4 it is noteworthy that 28% of the members of the Committees have completed a higher degree, which is a proportion that is similar to the representatives who also have some MBA/Specialization training. The data also shows that in terms of schooling, the extremes are situated at the fundamental level in which the number of representatives with this full degree reaches 1% while it is 9% of representatives at the doctoral level.

We can see that the education of the representatives of the Committees is diversely distributed and in an unbalanced way between the different levels of education. However, interesting data have to do with the fact that 87.8% of the representatives who answered the question concluded a course of higher education, and almost 60% also entered postgraduate courses.

In addition, basin committees are spaces in which the concentration of respondents predominates in certain training areas, as can be seen in Figure 10-5, especially Engineering courses (38.9%) that are more than double (Public Administration and Business, Accounting and Tourism Architecture, Urbanism and Design, Communication and Information, Law, Economics, Urban and Regional Planning, Demography, Social Work) with 19% of the indications. In the sequence, the Agricultural Sciences (Food Sciences, Agricultural Sciences, Veterinary, Zootechnics) with 16.9% were indicated, the Biological Sciences with 13.3%, and the other areas received less than 8% of respondents' indications.

The existence the rivers favored urban and agricultural development, but this growth causes the "death" of several of them, transforming them into a means of sewage disposal. Urban rivers suffer from pollution, silting, smelling (Pampulha Lagoon in Belo Horizonte, for example), diversion of their courses, destruction of riparian forests, change of color, inability to use their resources (the Tietê River in São Paulo and the Iguaçu River in the South region). Evidence of the urgent need to implement the sustainable development agenda (6.3), which concerns improving water quality and reducing pollution. Thus, it possible to say that the planning and management of water resources bring with it the complex relationship of intersectoral, interdisciplinary and transdisciplinary nature.

Sommerman (2005, p. 7) explains the etymology of complexus, "what is woven together", citing Morin (2001: 33), and explains that this concept "articulates polarities and contradictory, competing, and antagonistic elements of 'fabric'" and adds asking what is the breadth of this articulation? These remarks reinforce the complexity underlying the field of water resources management, considering the influence of technical, political, economic and cultural factors, as well as the involvement of different spheres of government, as well as other actors grouped in the water and civil society.

Transdisciplinarity, according to Bignardi (2011, p. 22) is:

… the contemporary scientific attitude that, recognizing the complexity of phenomena as well as the multidimensionality of

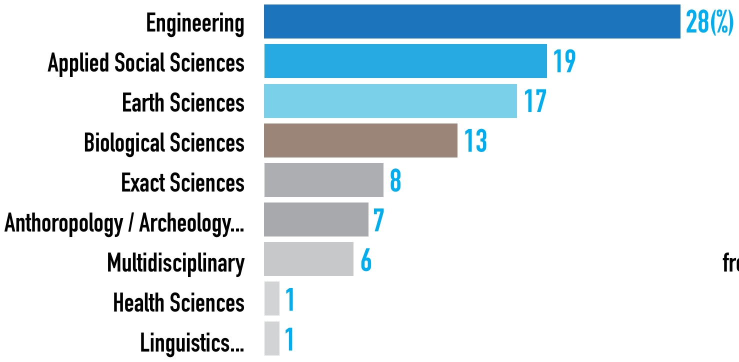

Figure 10-5 *Distribution of representatives by area of training (in%) (Source Research Data)*

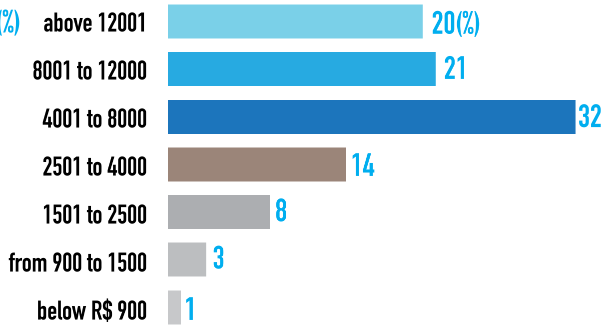

Figure 10-6 *Average family income (Brazilian Reals) of the representatives (in%)(Source Research Data)*

reality, are willing to seek sustainable solutions in the subtler (informational) strata of reality which makes it possible to find situations of genuine collective consensus, through inclusion and respect for diversifying the use of disciplinary knowledge in a synergistic and transformative way.

Sehume (2013, p. 4) explains that this approach "emphasizes the interconnectivity of the branches of knowledge, aiming at improving the human condition." Water is a resource that man can not do without, it is a vital and irreplaceable good. We can also say that the management's view on the water theme, which departs from the definition of this as well as fundamental right and essential to the maintenance of life. The transdiciplinarity approach, according to the author, "encourages the synthesis of knowledge experiences involving actors in academia, government, industry, civil society," which is advocated in water resource management and water governance studies. In other words, the need for greater involvement in the model of articulation of the different sectors of society.

In this sense, we can consider collective decision-making requires a strong type of interdiciplinarity as pointed out by Sommerman (2005, p. 5) that will occur when the predominant one is not the transfer of methods, but of concepts, and when each not only seek to "instruct others but also receive instruction" and "instead of a series of juxtaposed monologues", as in the case of multidisciplinary interdisciplinarity, there is "a true dialogue". The author explains that the term "strong" is related to the "emphasis given to the subject and intersubjective exchanges" and does not even indicate value aspects. For Sommerman this requires "favoring intersubjective exchanges" of the different social subjects which, in this study, is related to the representatives of the river basin committees, "where each one recognizes in himself and in others not only the theoretical knowledge, but the practical knowledge and existential knowledge."

Given the scenario of the representativeness and level of education of the actors involved in these instances and considering that the representations in the committees should reflect the multiple interests in their jurisdiction, we can ask if high qualification of a great part of the representatives with respect to the formation, especially engineering would not be reducing the perspective of interests and demands of groups and social sectors whose voices do not reach expression and recognition in the common spaces of political representation, thus generating socially and environmentally unjust. In other words, for whatever reason, governance arrangements would be leaving out groups with a capacity to influence the policies adopted in them and representing other languages, knowledges, and formations, which are representative in the basin, such as fishermen, the quilombolas, indigenous communities, and other sectors.

Regarding the distribution of resources, the results of the study show that in family income the majority of the members—about 33%—earn R$ 4,001 to R$ 8,000. It is also possible to observe that 73.6% earn over R$ 4,001. In this group, 20% have income above R$ 12,000, as shown below in Figure 10-6.

Of the representatives with the highest incomes, (41% of them earn more than R$ 8,001 a month), it was observed that only 9.8% are women. In a comparative analysis, it is noticed that not only are women still a minority in the basin organisms, but belong to the groups with the lowest family incomes. This seems to reflect the challenge for the country as a whole on gender equality in relation to women receiving the same salary as men. On the other hand, this fact may be positive, because women belonging to the groups with lower family incomes may be representing another voice and language on the committee which could otherwise be neglected.

The results indicate a profile with income above the national average when compared to the value of the minimum wage established (R$ 954) or with the national nominal per capita monthly household income of R$ 2,112 (IBGE, 2018), thus indicating the groups that control the decisions about water management. These data corroborate with the notes of Santos Junior *et al.* (2004) on which the profile of the representatives constitute a kind of elite of reference, or of a civic community (p.37) bearing an associative culture, characterized by a superior socioeconomic profile and by a greater degree of information and technical and political training when compared to the average of the population in general. When data are separated by the representation sector, it is observed that the representatives of the Federal Public Sector segment are concentrated in the two highest income categories (above R$ 8,001).

It is observed that of the 26% of the representatives who are included in the category of those who have family income up to R$ 4,000—a total of 5%—come from the municipal public government and 6% come from civil society.

Joint, participatory and deliberative management within the basin committees should seek to improve the sustainability of supply, demand and the collective security of the population in relation to the availability of water resources, that is, restrictions on consumption can affect water security. So, we can question: does this really happen if we consider income and the major social-economic group?

On the one hand, considering that the participatory experience of both the individual representatives and the civil organizations represented in the Basin Committees represents an important differential in ensuring the potential of the governance arrangements referring to the decision-making process of the public water policies, the results of the research showed a weak insertion of the representatives of the basin committees in other collegiate bodies related to the management of water resources. When questioning whether representatives of the basin committees also participate in other collegial bodies related to water resources management, 25% of the respondents said they participate and 75% said that they only participate in the Basin Committee.

These data show that 25% of the respondents, besides participating in Basin Committees, also participate in the National Water Resources Council (2%), State Water Resources Council (9.5%), National Forum of Basin Committees (6%), and State Forum of Basin Committees (1.5%), in addition to other instances of discussion (1%). Although participation in other forums related to water management issues is still low, this can be a good thing because, by participating in other collegial bodies that also discuss water resources, representatives of basin committees can increase integration and articulation to exchange experiences and learning with other spheres of participation.

On the other hand, given that the political dynamics that characterize the establishment of governance arrangements play an important role in the action of representatives in the decision-making of water policies, the research data shows that in addition to participating in the basin committee 39% of the representatives indicated that they also participate or are members of other collegiate bodies, such as education and health councils.

In particular, the other collegiate mentioned were: Municipal Council of Environment, Municipal Council of Urban Development / Urban Policies, Municipal Council for Economic Development, Environment Committee of the City Council, Climate Change Forum, Council on Environmental Protection Area, Basic Sanitation Council, Development Council of the Metropolitan Region, Municipal Council of Culture, Community Public Security Council, National Council for the

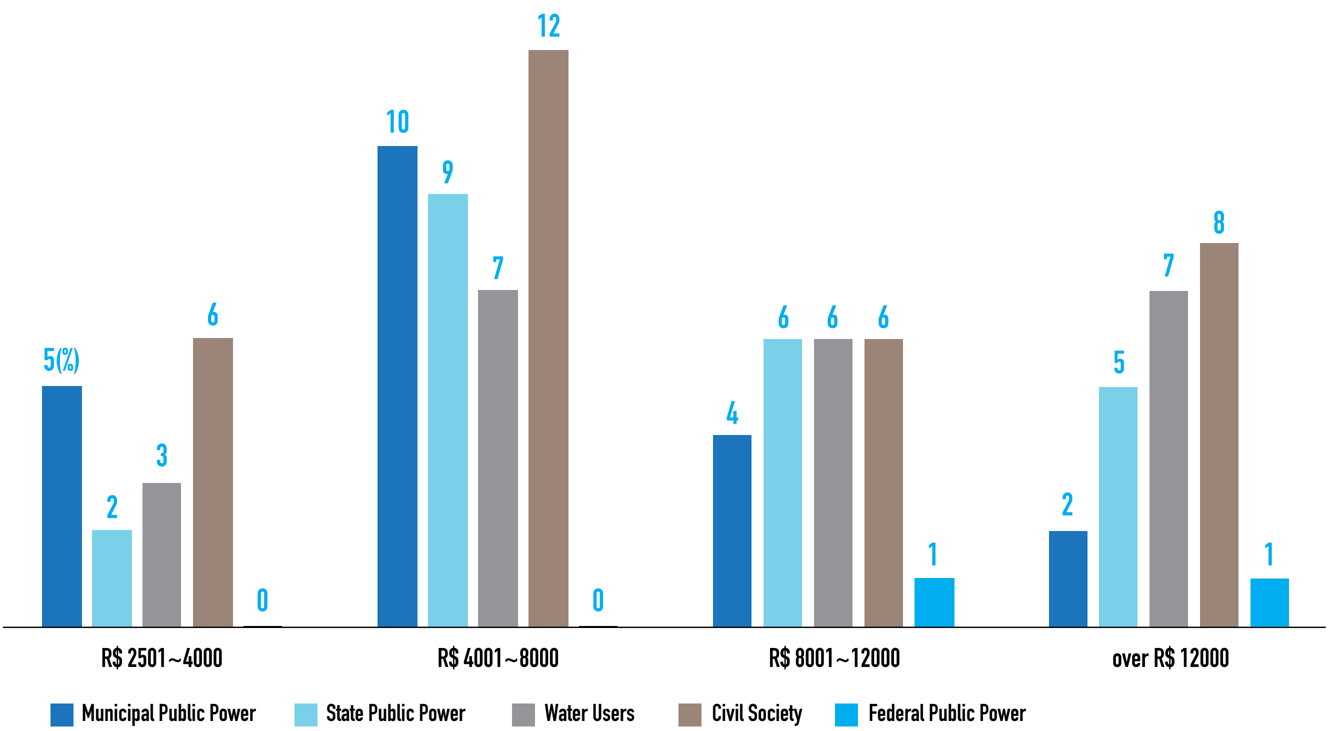

Figure 10-7 *Monthly family income by representation sector (in%) (Source Research Data)*

Environment, and Council of the Federation of Industry and Agriculture. The participation of the representatives in basin committees in other collegiate bodies can be something positive since it can help in the articulation and integration of water resources in other public policies.

The representatives were also asked about the time of participation and representation in basin committees and it was observed that 15% participated for less than one year in the composition of the committee, 49% from 1 to 5 years, 18% from 6 to 10 years, 10% from 10 to 15 years, 5% from 16 to 20 years, and 3% have been participating for more than 20 years. When the data is separeted by the representation sector, the representatives of the segment of the Federal and Municipal Public Authorities are the ones with the highest percentage of representatives with the shortest participation time (28% and 27%, respectively). At the other extreme, those who participate for more than 11 years have the highest percentages of water users (21%) and State Public Authorities (20%).

We sought to identify, among the respondents, representatives who also serve on the Board of the Committee (20%) and those who are members of a Technical Chamber (31%). The technical chambers have the attribution to subsidize the decision making of the committee, as it seeks to develop and deepen the necessary thematic discussions before being submitted to the plenary. The Chambers shall preferably consist of the members, representatives or deputies of the committee, or may be composed of representatives formally appointed by those members. In general, the composition should seek to reflect the proportionality between the segments represented. In these discussion forums, it is common for technical experts to be invited to collaborate with the discussions and to enrich the analyses carried out.

The various forms of participation are important for building a democratic society. Some forms of participation are only consultative, while basin committees differ from other forms of participation foreseen in other public policies since they have as legal attribution to deliberate on water management doing this in a shared way with representatives of civil society and users as well as public government.

4.2. Decision-making Process in Water Basin Committees

According to legislation, water basin committees should define the rules to be followed in relation to water use. Furthemore, the composition of the committees should reflect, as already mentioned, the multiple interests with respect to waters of the basin. Thus, in the exercise of their functions, the representatives reflect the interests of the organization they represent and the segment in which they are a part. In this sense, the indicated representative is subject to what Bobbio calls a bound mandate.
However, there is always the danger that self-representation is an elected representative among his peers who will defend self or private interests and not share the issues discussed with the group. In this way, this member would not be adequately representing the interests for which he was elected.

Considering these notes, the committee members were asked how often, in the exercise of their mandate as a

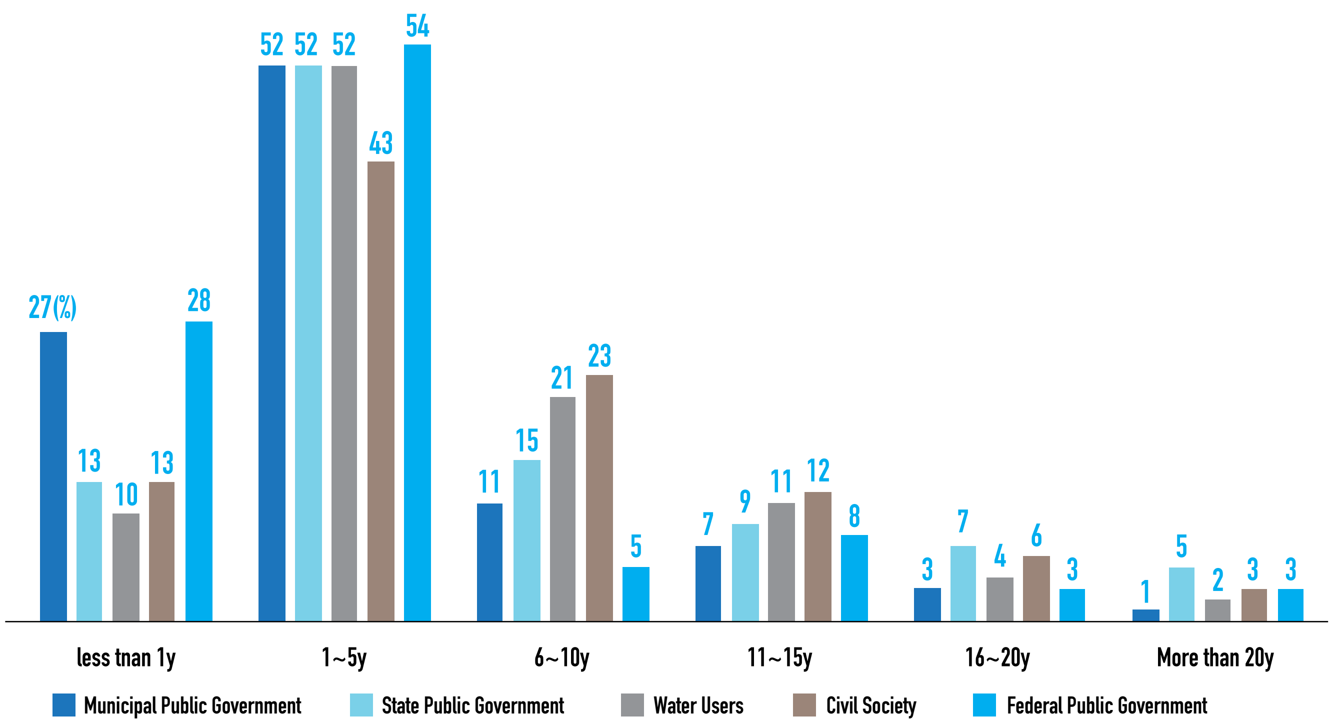

Figure 10-8 *Time of representation in basin committees by segment (Source Research Data)*

representative, they maintain contact with their support base/organization which they represent. After analyzing the data, it is noticed that 66% of the representatives maintain contact frequently or always, 28% make contact sometimes or rarely, and 6% of respondents do not have a support base. The fact that 28% of the representatives do not make regular contact with the organizations they represent is a cause for concern, and even greater, considering that the representation in the committees is by segment, that about 6% report that they do not have a support base.

Based on the data, 34% may have no significant participation in decision making, or defend individual interests, and if they are actors with political power and influence they can impose their own interests.

In a formalist view of representation, the representative must be made accountable. So, in the sequence, we ask how often they consulted their base to build and/or strengthen articulations with their segment representation, account for the performance, report on discussions and deliberations, and define or sustain a position in committee meetings. As can be seen in Figure 10-9, only about 50% (average) of the representatives have more frequent contact with their support base, in essence, the organization they represent in the Committee.

These results show not only the frequency of contact but also the main reasons for contact. However, it is observed that the representatives do not do it regularly; in this sense, it is important to discuss how this should be done by communication. The National Water Agency, in Brazil, recommends that procedures be established to ensure that these representatives perform their representation functions well. It is also necessary to define how this representative should inform and consult the represented base and thus have the exercise of his mandate legitimized to each debate and decision to be made within the basin committee (ANA, 2011).

The terms of representation, once it is clear who (person) represents what (organization), brings along the question: "How does is this representation?" Since they are called to represent the specific interests of a segment, it usually belongs to the same professional category as those represented.

Another issue in terms of the relationship between representatives and represented organization was the most used forms of contact to make contact with the organization that represents the basin committee. In this question, the respondents could indicate more than one option, which were face-to-face meetings (21.9%), personal conversations (20.1%), e-mail and mailing list (19.6%), SMS or WhatsApp messages (19.8%), telephone calls (13.6%), Facebook, Twitter and other social networks (3.9%), institutional site / Intranet (3.7%), letter (3.2%) and others (0.5%).

It was also asked about the perception on the performance of the other representatives of the segment with the following

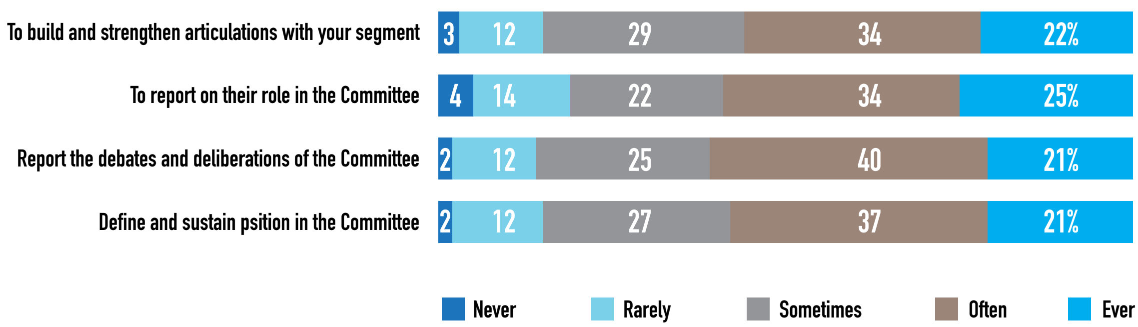

Figure 10-9 Consultation with support (organization representing) (Source Research Data)

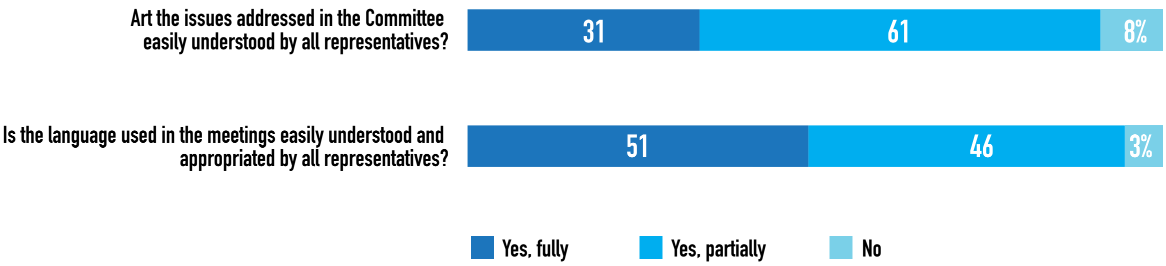

Figure 10-10 Perception about the communication and understanding of the representatives(Source Research Data)

question: "For you, how often does the performance of the representatives correspond to the interests of the respective segments?" For 14% of the respondents, the performance of the representatives always corresponds to the interests of the respective representation segment. For 50% of the respondents, this often corresponds to the interests of the segment. The other percentages were 28% with sometimes, 7% with rarely and 1% with never, corresponding to the interests of the representation segment. As can be observed in the data in the perception of the representatives, the performance of the other members does not always correspond to the interests of the respective segments.

"Perception of representatives seems to have an important weight on qualifying and interpreting other members interests."

Considering that the committee's decision-making process must follow a broad process of articulation and negotiation, and should be based on technical studies to support political decisions, the representatives were questioned on their perception whether the matters dealt with in the Committee are easily understood by all representatives and if language used in meetings is easily understood and appropriated by all representatives.

Considering that most of the participants have a high level of education, the result is worrisome, even more if we consider the need to expand the social base in the management of water resources. In the perception of the representatives, they partially understand the subjects (61%) and also partially understand the language used (46%), which seems to demonstrate the need to rethink the presentation of the themes in the meetings of the members. All attributions of the committee presuppose wide discussion and agreement between the parties involved. Based on these data, we can say that if most do not end up with what they are, they also do not have effective decision-making power. However, the discussions can not be an end in itself, and the committee only makes sense when it manages to fully exercise its legal attributions.

We also ask the representatives how many hours on average per month they dedicate themselves to the activities related to the Basin Committee. The results show that nearly half of the representatives (47%) spend less than five hours per month on activities related to basin committees.
Following that, 30% of the representatives indicated that they dedicate from six to ten hours a month, 8% devote between 11 and 15 hours, 6% from 16 to 20 hours, and 9% dedicate more than 21 hours per month to committee activities.
This data, in isolation, does not seem to be significant, but when it is observed along with the information about the understanding of the subjects approached in the committee's scope, one can suggest that more hours of dedication could broaden the understanding of the representatives on the themes recurrent to the be representative.

With regard to the issues addressed, some of the respondents indicated the need for greater understanding of water legislation; technical capacity for conducting the discussions, and also on the responsibilities of a basin committee (i.e. the role of the collegiate body and the manner in which it, as a representative, falls within this area) as functions or the depth of the topics are being discussed. According to respondents, the renewal of the member organizations, especially of the representatives, is seen as a problem since the new participants "arrive without any instruction and sometimes the issues that have already been overcome are taken over", and there is "high turnover of members mainly in the municipal public sector, when the representative begins to familiarize with affairs, changes management and most of the time representatives of technical and plenary chamber." There was also a lack of commitment regarding attendance at meetings; the prior reading of the topics to be debated; as one representative reports, "there is insufficient reading of the materials available, causing dispersion and lack of control".

The respondents also highlighted there was "lack of an effective agenda", as well as previously unsettled discussions and issues pertaining to the committee. Regarding the participation of the municipal public power, there are reports of "low presence" in the meetings; high turnover; and the indication of non-decision-making representatives.
With regard to the state public government, the complaints are of the pressure of the approval of guidelines, mainly of topics of interest; the "representatives of the public government often act defending the slowness of the process, implying that public power is against the charge for the use of water." "Large users influence public administrations in the sense that charging [for water use] does not happen", "pro-government representatives defend the interests of the current administration."

Other points, the positioning of representatives, mainly of water users is often strictly tied to the specific interest of the organization representing or by personal interests, "disregarding the collective interest", was also reported the lack of transparency and information mainly data relative "to the actual situation of both the conditions of quality and quantity of water, their uses and consequences; as well as on management tools", and on "environmental licensing processes". According to one representative, "the committee is an arena of political dispute, sometimes leaving the other uninformed is a strategy adopted by representatives little fond of democratic debate!". River basin committees are state institutions with clear legal attributions. With its strengthening, it strengthens the implementation of the National Water Resources Policy as a whole, legitimizing the regulatory action by the water resources management bodies.

05

Final Considerations

The importance of thinking about water basin organizations from the point of view of governance lies in the fact that the collective decision process is the structuring basis of the proposal of this type of organization, something that characterizes and differentiates it from others. And in a scenario where water security is threatened, planning and adopting prevention, adaptation and mitigation measures to this new climate reality is a collective action problem that raises institutional responses from states, markets and communities. This Dilemma, strongly related to SDG 6, which aims to ensure the availability and sustainable management of water and sanitation for all, aims, among other goals, to strengthen the participation of local communities in improving water and sanitation management.

The adaptation to water-related changes should be an integral part of water resources plans and vice versa, meaning that no climate change adaptation plan should be developed without explicit consideration of water issues, especially in a scenario on which the global challenges related to water are increasing. Studies indicate that 16 out of the 17 warmest years recorded around the world have occurred since the beginning of this century. Global data show that 2017 was the warmest year ever recorded, surpassing 2016, which by itself surpassed 2015, and so on.
Climate change, one of the greatest challenges of our era, is accelerating catastrophic water-related events at a pace never seen before. In this scenario, droughts and floods are spreading devastation. While population growth, economic development, and changes in consumption patterns, among other factors, demand for water, food and energy increases, rivers dry up and many of them pour into the sea in an intermittent way, if they are able to reach the ocean. Global demand for water has grown and will continue to increase significantly over the next two decades. In this worrying panorama, it is necessary to discuss what the role of water should be in our future. The discussion about how we understand, value and manage water to contribute to policy decisions about our water resources should be encouraged. This challenge involves the consolidation of three fundamental components of a democratic process: participation, citizenship and politicies that are deeply intertwined. The full exercise of citizenship presupposes political participation in decision-making. Politics should be integrated in the sense of dialogue, exchange of opinions and respect for the contradictory against the background of the search for the common good.

The right to access drinking water is essential for a decent human life and is recognized as universal and vital for the realization of human rights. And for management of this finite resource, cooperation and participation are key elements, and that brings us back to the concept of Governance.
The term can be understood as the way on which individuals and organizations, public and private, manage their common problems, like access to water. It is a continuous process through which it is possible to accommodate conflicting or different interests that must be adjusted in cooperation actions. Thus, governance can contribute to developing, implementing, and enforcing sustainable solutions for water allocation and provision problems. This may include notions of demand response and anticipation, based on consensus, to mitigate the effects of extreme events. Water is the link that connects all aspects of human development. Water security is therefore vital to all social and economic sectors, as well as the basis of the natural resources on which the world depends.

> *“The importance of governance within water basin organizations is because the collective decision process is the structuring basis of this type of organization.”*

To contribute to the dicussion, this study presents the profile of the member representatives and providing information that may point out important aspects of the inclusive capacity of the researched representatives with the premise that good governance is key to achieving water security.

For a comprehensive view on adaptation to climate change related to water and water security, water management plans need to consider the needs of all sectors that use water. This means to promote dialogue through their differences in order to arrive at a better understanding of a given problem and its solution. However, this set of agents from the different sectors should seek to bring together the antagonisms of interests over water since the use of water resources must be sustainable in order to ensure conditions not only for the present generations, but also for the future.

However, with the development of the research, it has been observed that in many river basins of the country (state and federal) the committees have not yet been implemented. Moreover, even in the case of active committees, there are still limitations related to integration, communication and return to society; adequate investment of resources; and the implementation of management tools (such as basin management plans), scarce financial resources where there is still no charge for water use.

The data presented allow to outline the profile of the representatives of state river basin committees in Brazil. Most of the representatives are male, middle and upper classes, have high education and are over 41 years old. It is hoped that these governance arrangements should be able to include all individuals in deliberative and decision-making processes regardless of the positions of power they occupy in social relations. This shows the need for a more balanced participation of women and young people in the basin committees and consequently in the management of water resources.

When it comes to the participatory profile, it is noted that although the majority of representatives are members between 1 and 5 years of basin organizations (49%), but a percentage has experience in other deliberative processes as members of other national, state, and municipal collegiate bodies (on average 32%); thus, indicating some experience in this type of activity.

The formation of the representative, as a member of a collegial arrangement, and establishment in the field are significantly related to the trajectory that accompanies, either as a researcher or professional in the area (and even before). The representative's insertion in the field is to deliberate as a member of the committee. The trajectory is influenced by processes of socialization and identification, in which the agent continually builds up as a member, changing over time. In his interaction with others (in the organization in which he works and represents, and also with other members of the collegiate body in which he is a part) in his identification process or not with these others, the representative becomes constituted.

This process of formation, according to Bourdieu (1989), is also influenced by the interests and the taking of political positions in the space of deliberation. Individuals, therefore, assume specific positions that are determined by the action of certain capitals. In this respect, it should be noted that he does not act naively since the representative is a political being. Thus, assuming a position within a field also implies assuming a political position. For Bourdieu, all social fields are immersed in fields of power. Thus, individuals are builders of social reality with the purpose of imposing their vision, but always guided by points of view, interests, and references determined by the position they occupy in the same world that they intend to transform or conserve.

However, collaboration among members of the basin committees in Brazil presents serious challenges. As it has been put, the interests of a particular group (36%), or even individuals (34%), can intervene in decision-making. The misinformation or lack of knowledge (59%) of several aspects of legislation related to water management, on the part of some representatives is also a weak point in the process of exchanging ideas and a fair balance in the participation of members in the Basin Committees, modifying the reference frameworks for water resources and these are affected by different factors—climate change, financing and infrastructure, sanitation, irrigation, quality, quantity, etc.—for each committee, according to their location and geographic conditions, and hindering the capacity for governance, which can only benefit certain group interests.

Based on the analyzes, the need is perceived by the management bodies to create conditions that foster the population's interest in the management of the country's water resources, awareness of the problems of water use and its strong relationship with water and food security, the possible solutions or different scenarios in the future and, in this way, give popular support to the performance of the basin committees.

This proposal should focus on the young population through education and participation in schools and communities, farming groups and fishing, as well as the industry that has manufacturing processes where water intervenes.
In addition, special emphasis should be placed on promoting the participation of women, with the dissemination of messages highlighting the importance of the role of women in the management of resources, specifically water at the household level.

There should be a government effort to invest in education and empowerment of the population at different levels and sectors to gain a comprehensive understanding of the management not only of water but of natural resources and environmental services. However, it is not only a question of knowledge, but of empowering all individuals to use such knowledge and to take part in the processes of consultation or participation in management.

Transdisciplinarity in water issues can facilitate the approach from different perspectives allowing a situation of benefit for all the groups and actors involved, creating new ways of approaching problems and generating good practices, both participation and decision making, creating an environment fair and equitable governance that will facilitate the measures to be taken to achieve water security at the local, regional and federal level.

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Subject Index

Location Index

The 'Global Water Security Issues (GWSI) series' is the product of synergy within the UNESCO system, in particular the International Water Security and Sustainable Management (i-WSSM).

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

While this publication is factual, containing the most current information available concerning the state of knowledge on water security in the perspective of sustainable development and covering the most recent developments that affect it, this publication also provides decision-makers with concrete examples of approaches and potential responses for addressing water security-related challenges from the perspectives of both the sustainable development goals (SDGs) and a broader political and sectoral scope, which covers development, financing, capacity-building, institutional reform and technology.

It is hoped that this publication will be a reference source on water security as it covers all aspects of human development and the cases and solutions introduced in the GWSI series can be invaluable for decision-makers, their advisors and anyone interested in – and concerned about – water security, and that this first edition will reach an ever-widening audience that includes actors outside the 'water box' who make or influence broad socio-economic policies that can affect water security.

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