The Role of Information and Communication Technology (ICT) in Water Resource Management

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The Role of ICT in Water Resource Management

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Executive Summary

Today, the applications of Information and Communication Technologies (ICTs) have become very essential tools in the water management sectors. Water is a crucial need for human survival. The availability of efficient and clean water is extremely essential to human life and overall national development. Hence, many initiatives that are implemented today are designed to improve water availability, efficiency, accessibility, and sustainability by the application of various ICT tools. Such tools are one of the most effective methods in enhancing scarce land and water resources, which consequently maximize food production and secure human life.

The International Telecommunication Union (ITU) is the United Nations (UN) specialized agency for Information and Communication Technologies (ICTs), which develop internationally recognized standards for defining elements in the global infrastructure of ICTs. ITU, at the very heart of the ICT sector, recognizes the positive influence that ICTs can play in the allocation, distribution, treatment, and management of the available scarce water resources. The ITUs Focus Group on Smart Water management (FG-SWM) provides a platform to tackle the gap between the ICTs and effective water resource management. Hence, ICT tools help water scares countries and even other countries can solve the current water scarcity issue jointly.

Climate change, economic and population growth highly influence the availability of water resources. Hence, the strategic incorporation of different ICT tools in the water management sector mitigates some of the existing and future water issues. ICTs act as a tool, an agent of change, and an alternative method. Currently various websites and helplines exist as a form of delivery means of technical services, which show potential uses of ICT tools as a change to manage water resources. The basic objective of this report is to move further and emphasize how ICT tools can overcome some of the water management challenges faced in agriculture, and water supply and management sectors.

The first section of this publication seeks to highlight the current and future water scarcity, the impact of climate change, and water related issues. The second section reveals some of the various ICT tools applied in integrated water resource management. The intention is to provide an overview of the roles of ICTs in effective and smarter ways of scarce water management for present and future development and sustainability.

1. Introduction

Sustainable water resource management (including provision of safe and adequate water supply for drinking, sanitation, irrigation, flood management, and protection of the aquatic ecosystems) contains enormous challenges in many countries and regions. In spite of the global availability of water, and its renewable character, one-fifth of the world's population lives under conditions of water scarcity (Hering & Ingold, 2012). Clean and reliable fresh water is a very fundamental element to human life, economy, and political stability of regions. Access to clean and safe water for basic services and for drinking and sanitation purposes are still a problem to a large amount of the global population. According to UN estimation, 85% of the population of the world lives in the driest part of the Earth. Hence, around 783 million people do not have access to a clean and adequate water supply. Moreover, more than 2.5 billion people do not have the opportunity for improved sanitation, and about 6 to 8 million people die every year due to water related diseases.

Climate change affects the demand and supply of available water resources, and creates an adverse effect on the quality and consistency of the water supply, agriculture development, hydropower generation, food security, and other activities. According to a UN-Water (2013) report, almost one-fifth of the world population or approximately 1.2 billion people live in areas of physical water scarcity, and about 500 million people are approaching it. In addition, about one-quarter of the world population, or 1.6 billion people experience the economical water scarcity problems.

Water scarcity, climate change, and food security become increasingly important topics in global population growth. Due to a general lack of water resources, water is largely the limiting factor for agricultural production and development. Hence, sustainable water management is critical to a country's existence. In many counties, however, though there are enough fresh water resources for its population, but the management of these resources is less than optimal; economic water scarcity therefore is a major issue challenging some. Overexploitation is another major dilemma causing physical water scarcity in most countries and as some countries push for economic development; their water resources in most times pay a price. Additionally, poor water resources management is a big problem faced by many developing countries as well as emerging nations, as they seek to find the right balance between supply and demand.

Reliable access by citizens to a safe water supply and proper sanitation is another major challenge facing both the developed and developing countries, as they endeavour to obtain sustainable development. Sustainable water management policies are considered a top priority issue on many government agendas.

Reliance on historical hydrologic weather patterns to predict future variables is no longer practicable due to the high weather variability associated with climate change. Instead, employing the capabilities of Information and Communication Technology (ICT) solutions and systems (smart metering technologies, information systems, and Geographical Information Systems (GIS), and remote sensing,…etc.) are now a growing industry that provide individuals, businesses, and water companies with information about water resources management, development, usage, and demand. ICT tools provide a unique opportunity for water stakeholders to obtain reliable and relevant information easily. These tools can then be used for proper decision-making processes, as well as be considered as a catalyst for social change. Accordingly, ICTs have a high capability to improve the current water resource management of many countries. Satellite remote sensing, cloud computing, semantic sensor web, and Geographical Information Systems (GIS) are just a few examples of technologies currently available that can be used innovatively to obtain real time water use information for tracking, forecasting and identifying new sources of fresh water. The accessibility of precise and reliable information is crucial for proper decision-making within a watershed system.

2. Water Scarcity and Access to Basic Water Services

Water scarcity is the lack of available water resources to meet the demands of water usage within a country. This occurs when the amount of water withdrawn from lakes, rivers, groundwater, reservoirs etc., is much greater than the water supply in satisfying the overall (human and ecosystem) demand. This results in an increasing competition between water users and other demands. Water scarcity involves the stress, shortage, deficits, or crisis of the available water resource. Water scarcity is one of the main problems in the 21st century that has risen to the top of the global agenda, and it already affects almost all countries. Approximately 2.8 billion people around the world are suffering from water scarcity at least one month a year. In addition, more than 1.2 billion people lack access to a clean drinking water supply. According to the Water Resources Group, the global fresh water demand will exceed the supply by 40% in 2030 (KPMG, 2012; UNDESA, 2013). Figure 1 shows the fresh water availability and related scarcities of different regions.

Box 1: Water Scarcity

- Approximately 700 million people in 43 countries suffer from water scarcity today.
- In 2025, 1.8 billion people will be living in countries with absolute water scarcity, and 67% of the global population could be living under water stressed situations.
- Under the existing climate change condition, almost 50% the global population will be living in areas of high water stress by 2030, with 75 to 250 million people in Africa.
- In some arid and semi-arid places between 24 and 700 million people will be displaced from their places.
- Sub Saharan Africa has the largest number of water stressed countries of any region (UNDESA, 2013).

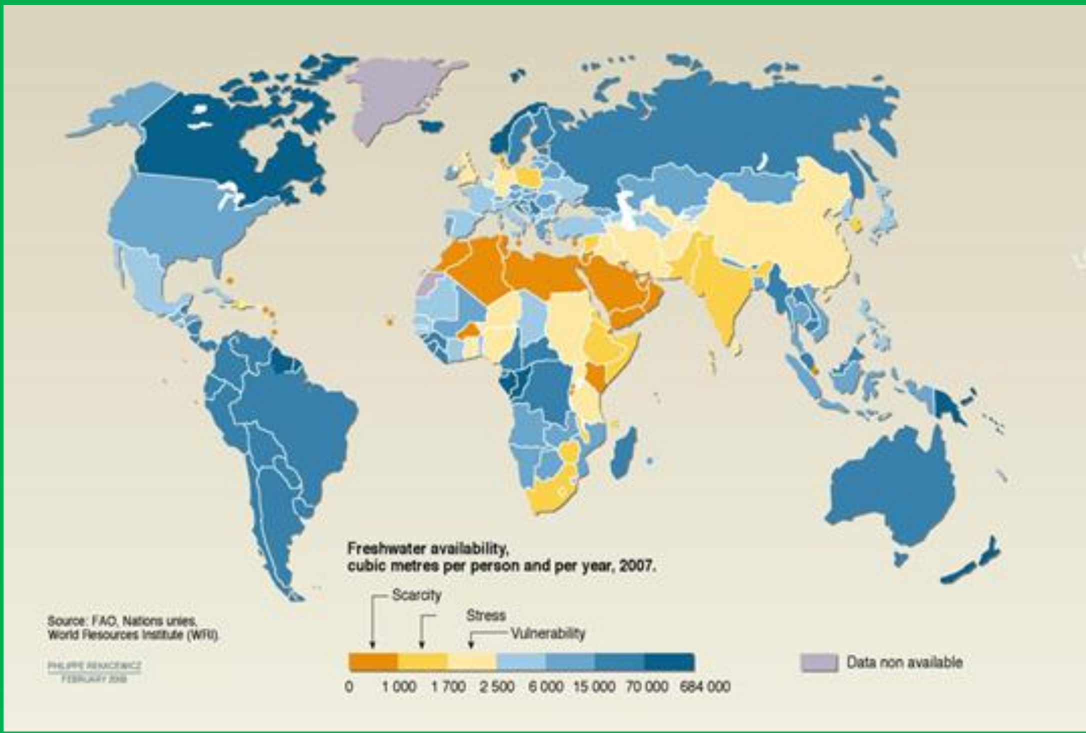

Figure 1: Fresh water availability and country classification

According to the UN medium population projections (UN-MPP, 1998), more than 2.8 billion people from 48 countries will face water scarcity problems by 2025 (Figure 2). Out of the 48 countries, a reported total of 40 countries will be in located in West Asia, North Africa, or sub-Saharan Africa. The population growth and the growing demands of fresh water are projected to push all of the West Asian countries into water scarcity problems within the next two decades. Due to the rapidly increasing population growth, the water scarcity condition could rise to 54 countries by 2050 as shown in Figure 2 (Tom-Gardner & Engleman, 1997).

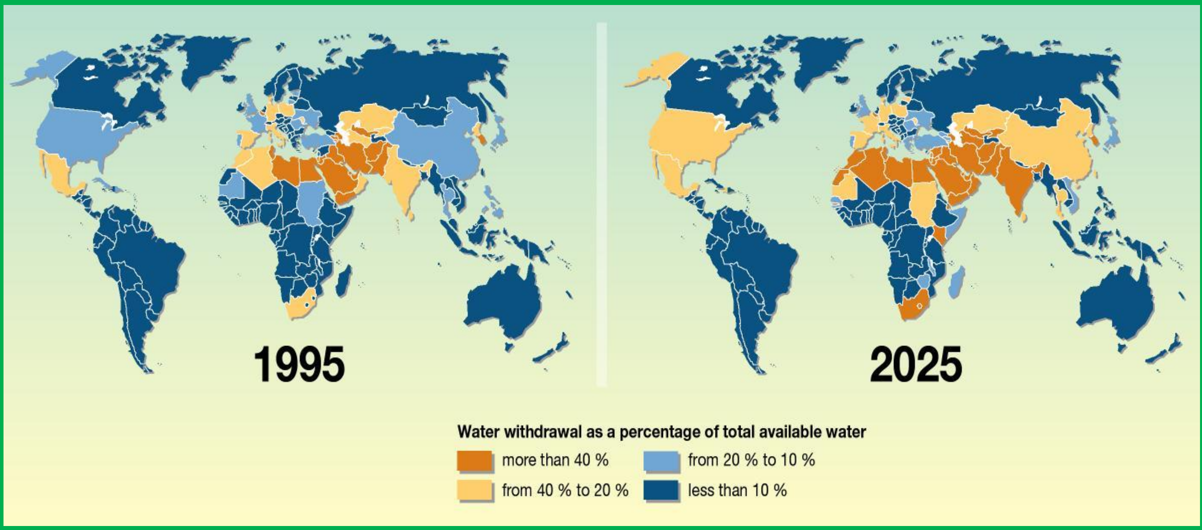

Figure 2: Availability fresh water projection in 2025.

Source: http://www.unep.org/dewa/vitalwater/article69.html

2.1 Physical and Economical Water Scarcity

Physical water scarcity is a condition where there is not enough water to meet demand, including that needed for ecosystem function. Most arid regions often suffer from the lack of physical access to water resources. There are increasing scarcities in some countries of the world, where physical water scarcity is an artificial issue. This occurs when the water is overused and over-managed by the people, a situation that leads to extreme physical water scarcity.

Physical water scarcity can also occur where water seems abundant, but where resources are over-used. High rates of development of hydraulic infrastructure for different water related activities mainly for irrigation is an example of such over-usage. The main indications of physical water scarcity include environmental degradation and the decline in groundwater resources (Water-Project, 2013).

On the other hand, economic water scarcity is mainly induced due to the lack of investment in water resource construction and management to meet the required water demand. This occurs in areas where the population does not have enough monetary means to obtain adequate and clean water. The indicator of economic water scarcity includes the lack of different infrastructures to fetch water from different sources for domestic, agricultural and ecosystem services. The majority of African countries, particularly in sub-Saharan Africa, suffer from economic water scarcity. Figure 3 shows the global classification of physical and economic water scarcity.

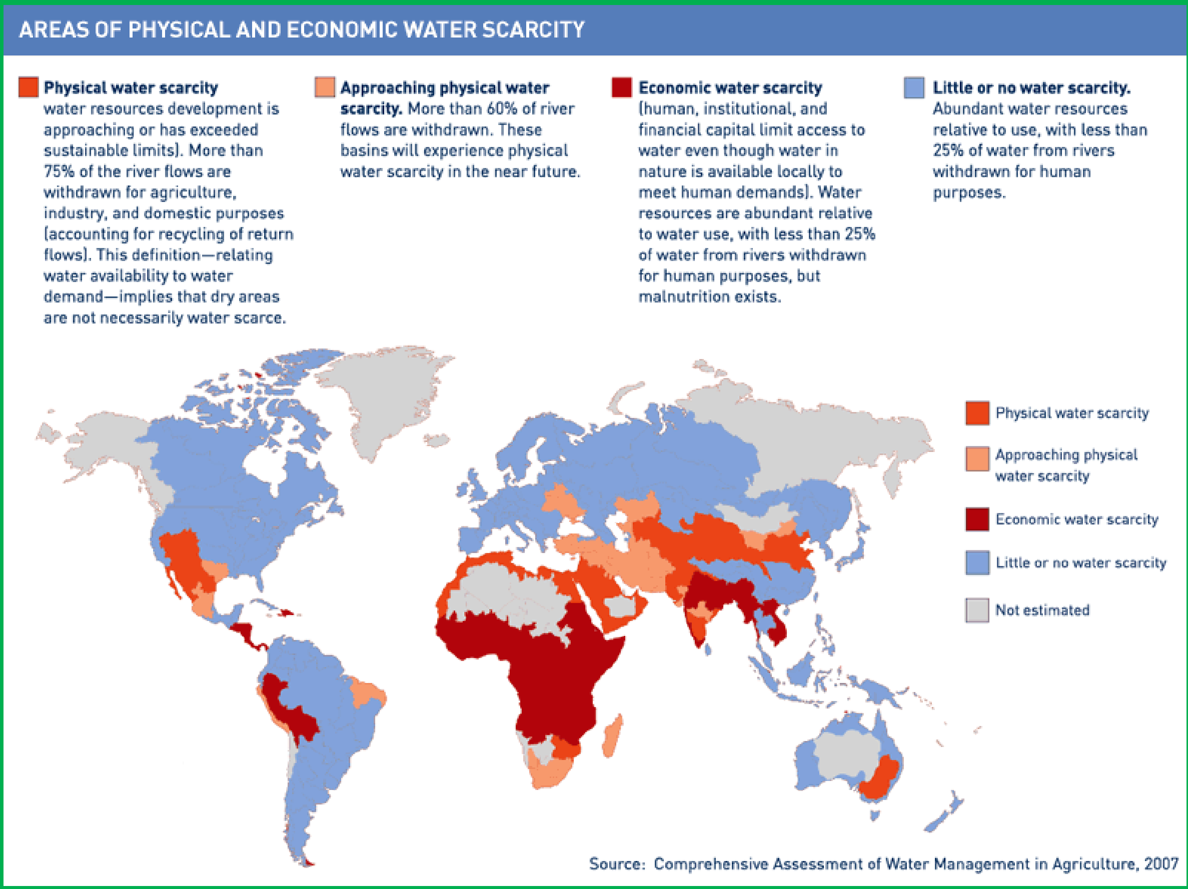

Figure 3: Global classification of physical and economical water scarcity.

Source: http://www.fewresources.org/water-scarcity-issues-were-running-out-of-water.html

2.2 Access to Improved Water Supply and Sanitation

The lack of access to clean and adequate water supply remains a challenge mainly for the poorest countries, preventing them from accelerating their development. The drinking water supply target was one of the first millennium development goal (MDG) targets developed. Hence, almost 89% (6.1 billion people) of the total global population have access to an improved water source in 2010. However, more than 780 million people, or one-tenth of the global population still relied on unimproved drinking water sources (Figure 4) (UNICEF & WHO, 2012).

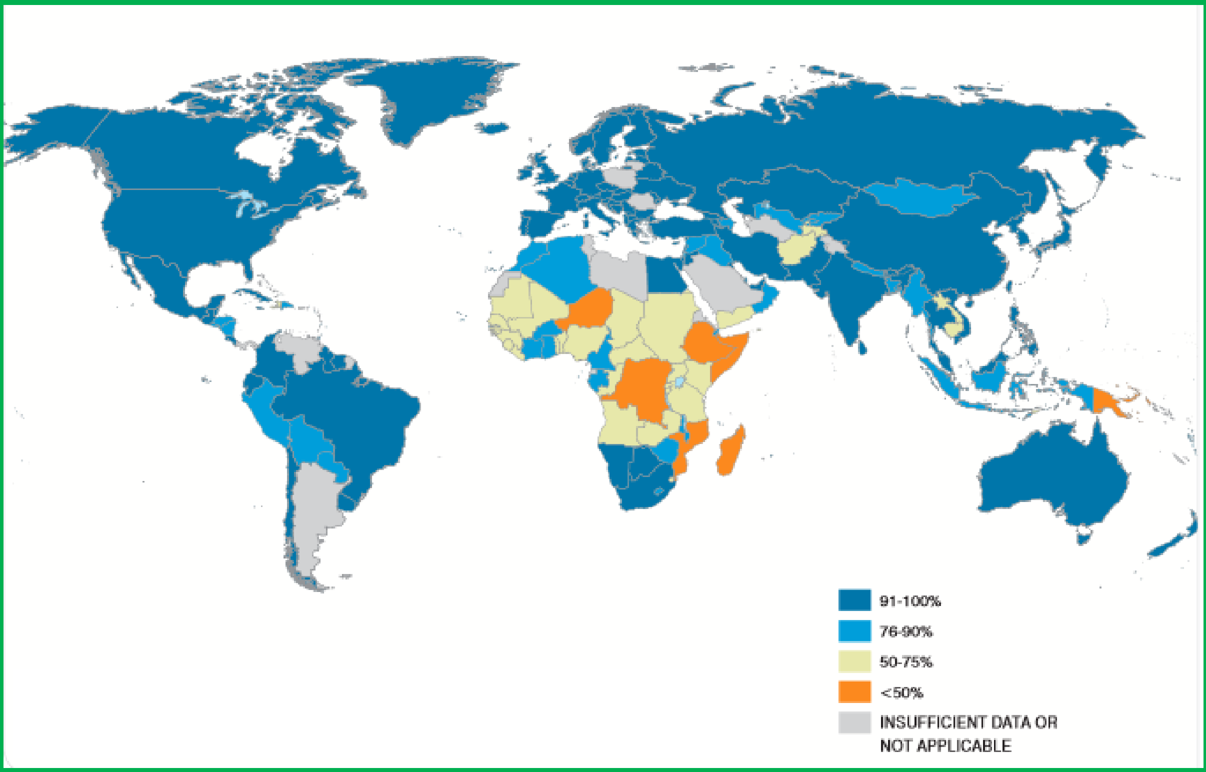

Figure 4: Proportion of the population using improved drinking water supply sources

Source: http://www.unicef.org/media/files/JMPreport2012.pdf

In general, 63% of the global population use improved sanitation facilities, which demonstrates an increase of almost 1.8 billion people since 1990 (Figure 5). The reported figure is estimated to increase to 67% coverage by 2015. However, approximately 2.5 billion people in the world still live without improved sanitation. Access to improved water and sanitation remains below the world average, which causes the wide spread of water related diseases (UNICEF & WHO, 2012).

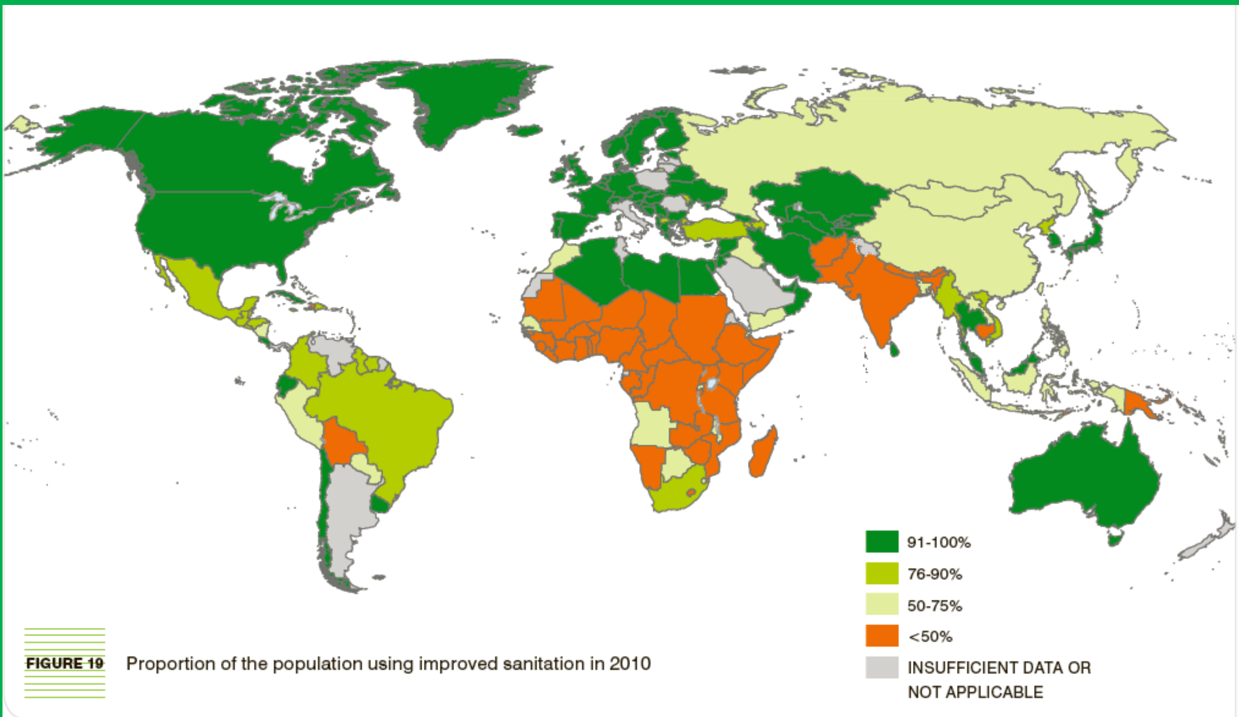

Figure 5: Proportion of the population accesses to improved sanitation in 2010.

Source: http://www.unicef.org/media/files/JMPreport2012.pdf

2.3 Impact of Climate Change on Water Availability

The hydrological cycle is a continuous movement of water through precipitation and evaporation and all of the processes in between above and below the surface of the Earth. The increase in temperatures due to the change in climate increases the rate of evapotranspiration of water into the atmosphere, which subsequently increases the atmosphere's capacity to hold more water. Consequently, the process causes excess precipitation in some areas due to the excess evapotranspiration. The increase in temperature during winter causes more precipitation to fall as rain rather than snow. In addition, the increase in temperature causes snow to melt earlier in the year, leading to changes in water flow of rivers.

The increase in temperature causes people, animals, and plants to consume more water in order to safeguard their lives. Moreover, many social and economic development activities, such as producing energy at power plants, raising livestock, and growing food crops also require more water. However, the amount of fresh water available for all of these activities may reduce as the Earth warms and as competition for water resources increases (USGCRP, 2009).

The real future concern of the change in the rainfall pattern is the decrease of run-off water, which may affect large agricultural areas. Figure 6 shows how climate change is expected to seriously affect the available water resource for arable regions in the next 40 years (e.g., Europe, United

States, parts of Brazil, South Africa). The situation is expected to place millions of people at risks of hunger and poverty (UNEP, 2008).

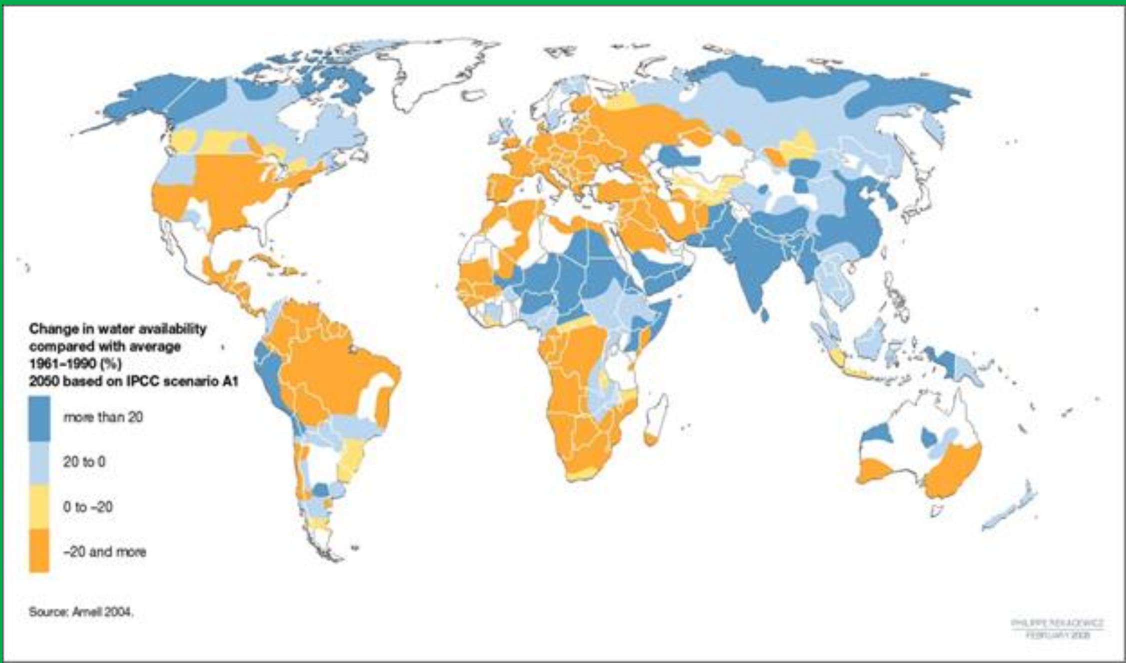

Figure 6: The change in future water availability due to climate change.

Source: http://www.unep.org/dewa/vitalwater/article152.htm

2.4 World Water Stress Index

The index released by Maplecroft, a risk analysis and mapping firm, locates areas of water stress down to 10 square kilometres worldwide by computing the ratio of water consumption (e.g., domestic, industrial and agricultural water), against renewable supplies of water (e.g., precipitation, spring, rivers and groundwater). The index has been developed for companies to identify the risk of water interruptions to supply chains, operations, and investments. According to the index, 17 countries within the Middle East and North Africa, such as a Bahrain, Qatar, Kuwait, Saudi Arabia, Libya, the disputed territory of Western Sahara, Yemen, Israel, Djibouti, and Jordan have been rated to have an extreme water risk level (Maplecroft, 2013).

On the other hand, the Water Resources Institute has illustrated that steady and adequate water supplies are becoming scarce because of the worldwide population growth and global warming. 37 countries in the world already face an extremely high level of water stress with a score greater that 80% stress index (Ferner, 2013) as shown in Figure 7. This coincides with the stress index reported by Maplecroft.

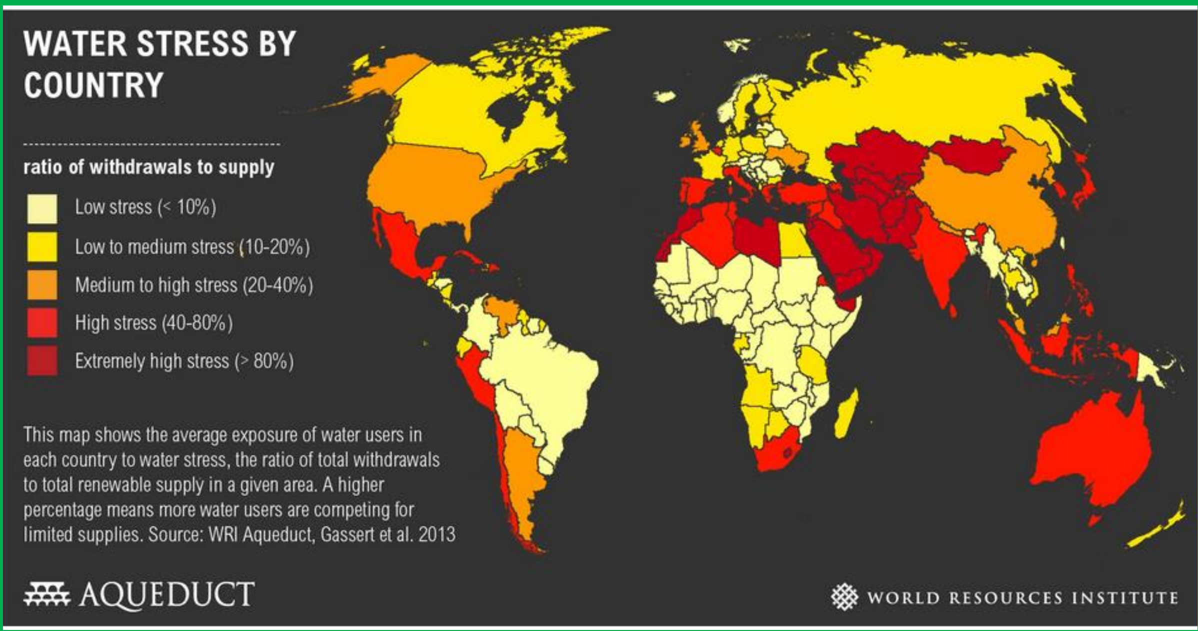

Figure 7: Water Stress index by country

Source: http://www.huffingtonpost.com/2013/12/13/water-stressed-countries_n_4434115.html?utm_hp_ref=green

3. Information and Communication Technology Tools in Water Sector

The previous section illustrated the worldwide water scarcity in different regions of the world. Information and communication technology (ICT) are the convergence and integration of information and communication technologies that enable users to access, store, transmit, process, and manipulate information. The technological evolution of ICT tools and their potential impact and benefit to the water sector has been identified since the last decade.

Both water and ICT experts have begun to explore the vast new ICT applications and their impact on the water sector. Hydro-informatics systems can now investigate the details of the physical hydrodynamic process as well as the complexity of the geometry of continental and marine environments. For example, new types of sensors, multi-beam sonars, and Light Detection and Ranging (LIDAR), have deeply modified the quality and the quantity of the data available on hydro-environments.

Hydro-informatic approaches –data driven and physically based– can now be associated and combined (Gourbesville, 2009). The European Union has defined their priority goals for the next two decades, to include the application of ICTs to realize sustainable growth. Sustainable growth requires a better management of all natural resources, which can be realized through the efficient application of ICTs (Holz, Hildebrandt, & Weber, 2006). In general, studies indicate that the implementation of information systems in different organizations does improve the organization's effectiveness and efficiency in many of its activities (Silver, Markus, & Mathis, 1995).

ICT tools are crucial in improving land and water management, in addition to enhancing food production. Starting from the 20th century, ICT tools have been increasingly used in water supply and irrigation management. The applications of advanced technologies in water resource management provide a remarkably efficient use of water, mainly in countries exposed to severe water scarcity (Sne, 2005).

- 2% Opportunity focusing on ICT direct impact
- 98% Opportunity focusing on ICT enabling impact

Source: (Intel, 2012)

There is an increasing strain on the natural resources pressure of most developing countries, which has worried many regions about achieving environmental sustainability. Harnessing ICTs as a potential instrument is essential for the complete growth of the agricultural sector. ICT tools provide a solution to collect remote data; a process which will otherwise be difficult, expensive and time consuming. Currently, ICT tools are applied to exchange, process and manage data and knowledge (Meena & Singh, 2012).

Moreover, ICT tools have great capacity to;

- Save texts, audio, photographs, drawings, descriptions and videos;
- Collect and save information in a digital format and produce precise copies of such information at a lower cost;
- Transfer information and knowledge quickly through a wide range of communication networks;
- Speedily improve the standardized procedures for huge quantities of information;
- Attain greater activity in producing, sharing, communicating, and evaluating useful knowledge and information;
- Design well-structured information systems from a raw data and;
- Inter personal discussion and communication (Kappor, 2006; Meena & Singh, 2012).

The following sub-sections will illustrate possible ICTs that may mitigate some of the challenges by either providing a means to better measure, control, model, or predict water resources supply and demand.

3.1 Meters and Sensors

Meters and sensors are currently being intensively applied to regulate different activities of water distribution systems such as hydraulic pressure and flow, water quality, head losses, and water and energy consumptions. The major aim of water utilities is to convey water from one place to another without any losses, saving water and avoiding any damages caused by leaking water. Figure 8 shows some of the different types of meters and sensors that have been developed for effective and sustainable water resource management.

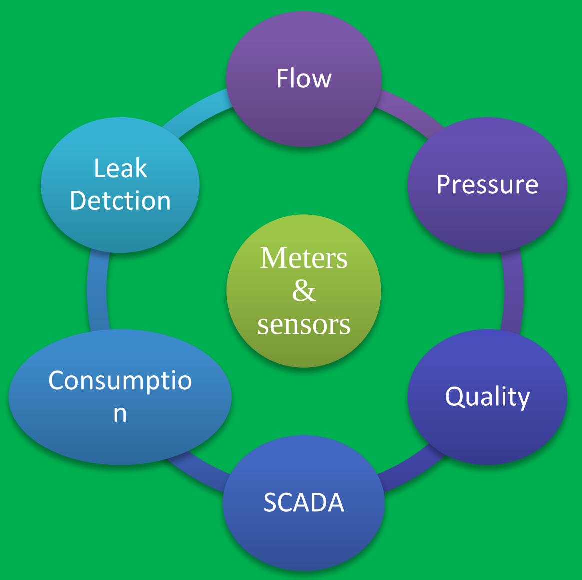

Figure 8: Types of Meters and sensors used in water management

Detecting and localizing leakages help in effectively and easily managing water loss. Leakages are detected mainly by measuring and controlling hydraulic pressures and water flows inside and within the piping network. Sensors are used as a basic tool for monitoring the pressure and flow of water, which enable advanced management.

3.1.1 Pressure Management Sensor

The pressure management sensor is an efficient and cost-effective method to lower real water losses and operational costs in water distribution networks. Different types of pressure sensors applied for the measurement of water in pipes to detect storage water levels and other activities are shown in Table 1 (ICeWater, 2012).

Table 1: A sample of pressure sensors

Producer	**Type and Code**	**Communication means**

Siemens AG	Sitrans P DS III, IP65/IP68	Profibus, RS 485, HART
SAE IT Systems	net-line FW-5, IP20	Ethernet, RS 485
WIKA	S-10, IP65/IP67/IP68	Analog
Ifm electronic	PI2793, IP 67/IP68/IP69K	Analog

3.1.2 Flow Sensors

Flow sensors help to regulate volume of water flow inside the production and distribution system. Flow sensors usually employ the principles of electromagnetics, which are considered as adequate assessment methods for water flow rates and environmental conditions. Table 2 shows different types of flow sensors currently available in the market.

Table 2: A sample of flow sensors

Producer	Type	Technology	Communication
Siemens	SITRANS F M	Electrodynamics	Profibus, RS485, HART, etc.
Endress & Hauser	Promag	Electrodynamics	Ethernet port
Flexim	Fluxus® ADM	Ultrasonic	HART, ModBus, Profibus, BACNET
Isoil Industria	ISOMAG Flowiz Next	Magmeter	GSM, GPRS Wireless
ABB	AquaMaster3	Electrodynamics	GSM
Krohne	Optiflux Waterflux 3070	Electrodynamics	Profibus, RS485, HART,GSM

3.1.3 Energy Consumption Sensors

Energy or power consumption sensors are mainly applied for the optimal power management of pumps inside the waterworks. Power or energy measurement and monitoring systems often rely on a large amount of information from the electric motors that need to be communicated back and forth to the control and monitoring system. Sensors provide a reasonable use of electrical energy during the production and distribution of the water system. Table 3 demonstrates a sample of energy consumption sensors used in the industry.

Table 3: A sample of energy consumption sensors

Producer	Type	Communication means
Siemens AG	Sentron Pac 3200	Profibus, Rs 485
Grundfos	CIM and CIU	Profibus

3.1.4 Supervisory Control and Data Acquisition (SCADA)

Supervisory control and data acquisition (SCADA) technology has evolved over the past 30 years as a method of monitoring and controlling large processes. SCADA includes, but is not limited to, software packages that can be incorporated into a system of hardware and software to improve the safety and efficiency of the operation of these large processes. In general, SCADA systems perform main functions like the acquisition of data through the sensors, the transmission of the acquired data between a number of remote sites, the data presentation through the central host computer and the control of the data at the operator terminal or workstations (ICeWater, 2012). These systems usually consist of the following subsystems (Bentley, 2004):

- Remote terminal units (RTUs) or programmable logic controllers (PLCs) which interface with the sensors in the process;
- A communication infrastructure connecting the remote terminal units with the supervisory system or central host computer;
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the process, sometimes called a SCADA centre, master station, master terminal unit, or MTU;
- A communication system to support the use of operator workstations;
- Standard human machine interface (HMI) software or man machine interface (MMI) software system, which is used to provide the central host and operation terminal application of SCADA, support the communication system and monitor and control remotely located field data interfaces devices.

3.1.5 Water Quality Sensor

Water quality sensors help to detect and address problems related to the quality of water before affecting consumers. Water quality monitoring inside the distribution or the network system helps in addressing problems and providing related operational management activities. An application of different water quality sensors provides verified information that leads to informed decisions related to the observed water quality change. An advanced water quality sensor measures the water pH, dissolved Oxygen, temperature, turbidity, salinity, and conductivity (Analyticon, 2014).

3.1.6 Water Consumption Meter

Water consumption meters measure and record the amount of water used over time by different methods. The water meters not only measure the consumption, but also improve management and help to detects leakages. The consumption measurement methods can be broadly classified as velocity or volume types. The velocity types of meters measure the flow of water from single or multiple jets that pass through well-designed hydraulic structures. The different kinds of velocity meters compute consumption of water by integrating the discharge rate measured over time. The velocity meters work by using a sensor that is either, mechanical, ultrasonic, electromagnetic, pressure, optical, or fluid oscillation based. Volume types of meters uses a mechanical sensor gauge of designed volume that directly prevent the flow of water to measure the water volume over time (ICeWater, 2012; Kamstrup, 2014).

3.2 Communication Infrastructure

The traditional water management system mainly depends on protocols, industrial control systems, and adopted registered structures. Therefore, it is difficult to follow emerging communication trends very quickly. Currently, the water utility networks provide an opportunity to adopt an existing infrastructure into a more flexible IP-based monitoring system: alarm gathering, leakage detection and prevention, demand prediction, energy reduction, water quality monitoring, and billing activities.

SCADA systems, advantageous for being highly distributed, are applied to control geographically distributed resources where centralized data acquisition and control are important to the system operation. It is the most common method currently applied in distribution systems, like water distribution and wastewater collection systems. The system control unit performs centralized monitoring, and control long distance communication network; including monitoring the status of data processing and alarms. The method works using the combination of radio and direct-wired connection systems (Keith, Joe, & KarenK, 2006).

The general packet radio services (GPRS) and global system for mobile communication (GSM) are the common wireless technologies applied to cellular networks to be used as water metering infrastructure. This is because they are widely available and supported by many telecom operators and vendors. GPRS is a packet-data tool that allows GSM users to apply wireless data services, e.g., e-mails (4G-Americas, 2014).

3.3 Information System

Information systems play a role in managing companies or industry activities by providing the required information and data for effective management of different project activities. In the water sector, information system and knowledge management are recognized as important attributes for efficient and effective water works.

3.3.1 Geographic Information System (GIS)

GIS is a technology that integrates hardware, software, and data required to capture, manage, analyse, and display all forms of geographically referenced information. GIS allows the user to view, visualize, question, interpret, and understand data in different circumstances that clarify patterns, trends, and relationships in the form of reports, maps, and charts.

Box 2: Top 5 benefits of GIS

- Cost Savings and Increased Efficiency
- Better Decision Making
- Improved Communication
- Better Recordkeeping
- Managing Geographically

GIS system helps in answering questions and solves problems easily by looking at the generated data. For example, the ESRI Arc-GIS tool for water utilities helps in the implementation of GIS for water, wastewater, and storm-water services.

The GIS system includes a sequence of maps and applications structured on a common information model, which is designed to work across several disciplines and help water professionals to support daily utilities, in addition to a wide range of operations and workflows (ESRI, 2014). Figure 9 shows different visualisations of future areas in ESRI’s Arc-GIS.

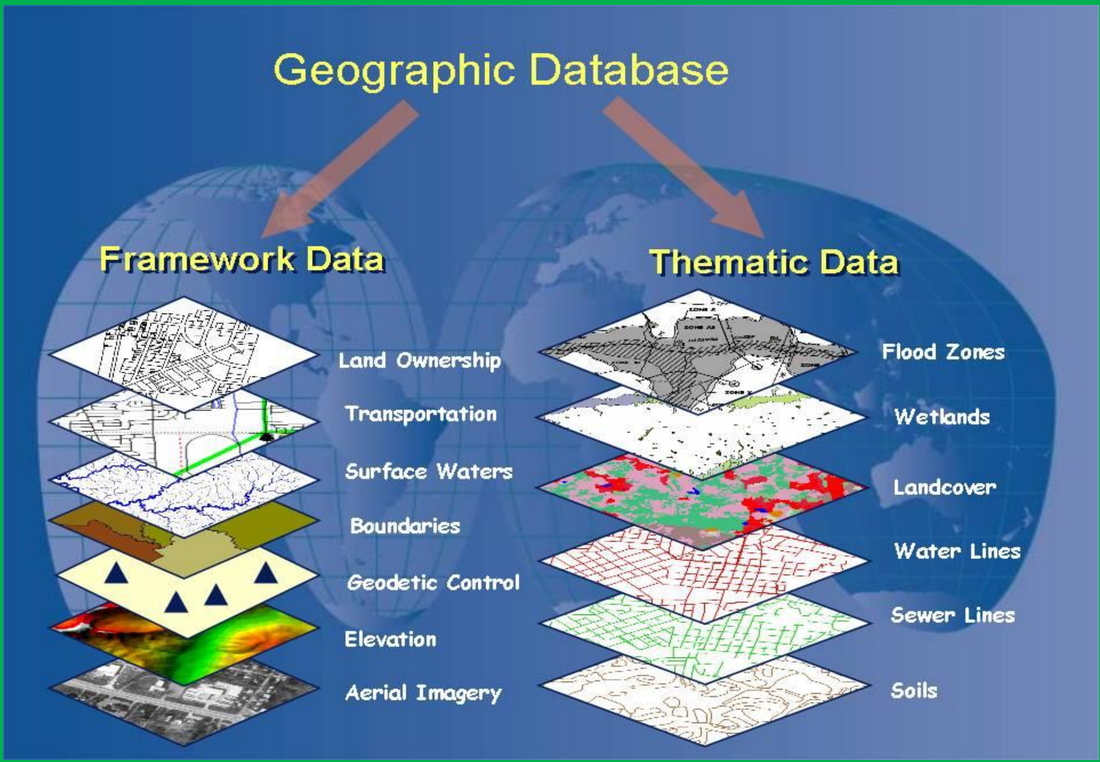

Figure 9: Visualisation of different futures in Arc-GIS.

Source: http://www.onslowcountync.gov/assets/18981.jpg?langType=1033

BENTLEY Water is a geo-spatial engineering solution for municipal water network design and management activities. An integrated GIS and design environment coupled with an intelligent network model allow municipalities and utilities to address all operations of a typical water supply network. The system generates the water network information from graphics and scanned maps, and uses GIS for thematic mapping and other tools to publish data on the web (Bentley, Water and Waste water , 2014).

Another example, the CIVICA GIS - Community Map is a web based GIS community map that supplies GIS, gazetteer management solution, and related back office software applications. The CIVICA GIS method helps users to reduce operational costs and related risks, which are available for web, desktop and mobile phones. Service companies improve their management and assurance of information on millions of underground assets, such as pipes and sewers by using a web-GIS redlining tool that gathers suggested correction from employees and contractors. It also captures field data and delivers real time information to decision makers for easy management through an easy access to the observed data (Civica, 2014).

3.3.2 Enterprise Resource Planning (ERP) Systems

Enterprise resource planning (ERP) systems integrate internal and external management information across an entire organization, embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc. ERP systems are automated through an integrated software application. The purpose of ERP is to facilitate the flow of information between all business functions within the organization and to manage the connections to external stakeholders. The potential of ERP systems in smart water management is tremendous. ERP packages help many companies to reduce operational cost, improve customer service, and increase productivity. (Beor & Mendal, 2000; ERP, 2008)

3.3.3 AQUAkNOW Information System

AquaKnow is an active web-based platform for sharing knowledge related to water issues. It is a collaborative workstation and data management system committed to scientific and technical knowledge for sustainable water resource development. The platform is intended for practitioners and experts of different institutions involved in the water sector as a space for gathering and providing productive tools to manage technical and scientific information. It also enables to share documents, data and information (such as, news and events), ideas, experiences and to find help and work with other members involved in the water sector (AquaKnow, 2014). Figure 10 displays the AquaKnow community webpage.

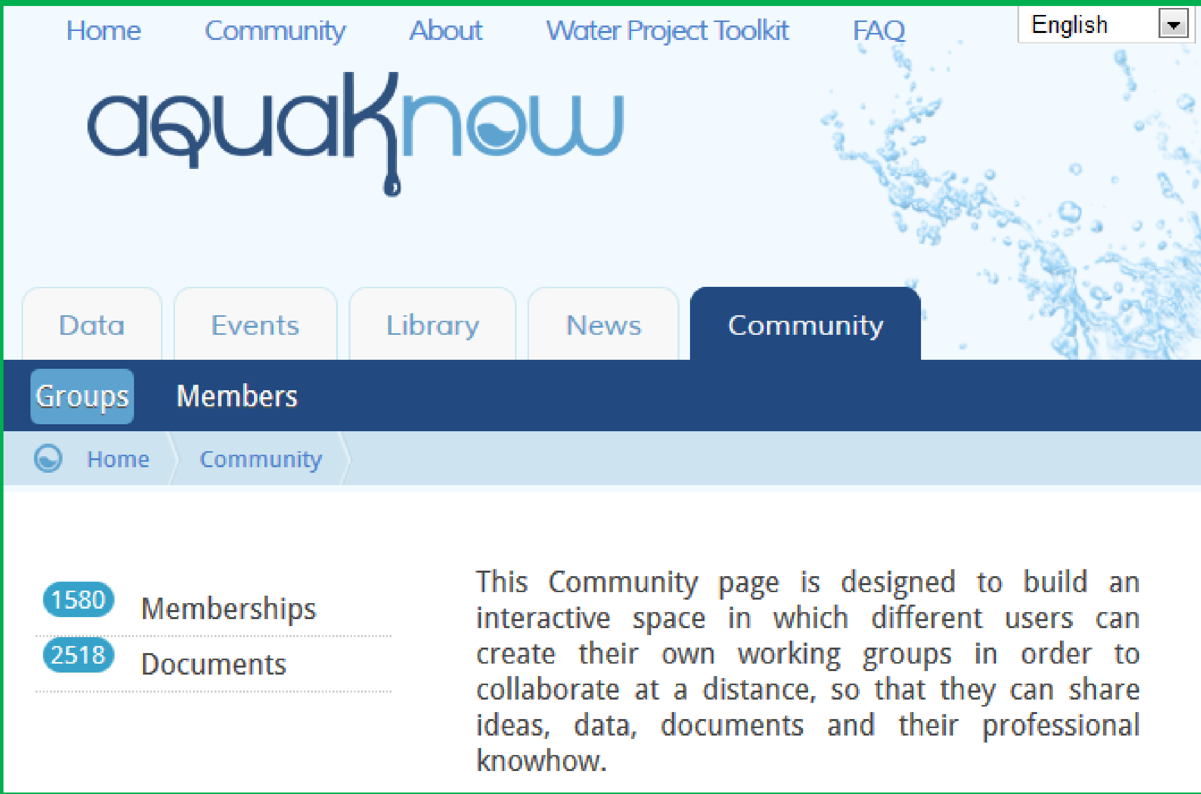

Figure 10: AquaKnow community web page

Source: http://www.aquaknow.net/en/community/groups

3.3.4 EUWI Communication and Information System

The European Union water initiative (EUWI) communication and information system (CIS) is a web-based communication and information system that contains comprehensive information about the water initiative activities. CIS enables efficient communication through internet based tools and services to all the EUWI members ranging from the international organization to non-governmental organizations. The general objective of the EUWI-CIS is to disseminate knowledge and information on water through effective networks and to affirm both transparency toward the public and exchange among its members (Dondeynaz, Mainardi, Carmona, & Leone, 2009).

3.4 Hydraulic Models

Hydrological models help water resource professionals, companies, and universities, local, regional, and governmental authorities, meteorological agencies, and other water sectors to effectively manage, predict, and make proper decisions on the available water resource. Hydraulic model based simulation and optimization of water distribution network (WDN) was a trend of research during the last decades. The ICe-Water decision support system component incorporates simulation models with a network of sensors and forecasting models for practical management of the water distribution system. The new simulation and optimization linkage approach developed based on the innovative use of traditional and global simulation and optimization algorithms. Different companies provide models, simulation and optimization products to the water network managers to design, optimization of energy and costs, lowering the water loss, and effective controlling strategies.

Box 3: *Benefits offered by SIWA*

- Optimize operating processes
- Simulate operating forms, fault states, and structural options to optimize system operation
- Asses automation function and interaction between system components without risk
- Demonstrate complex relations and procedure for planning and training.
- Increase system operating and supply reliability with realistic, and training.

The SIWA technology developed by Siemens AG is a computer-based system used to compute the hydraulic behaviour in the water supply and helps to optimize related operations. The SIWA water management technology consists of SIWA OPTIM modules used to optimize water supply operations, and SIWA LEAK control used for leak management that lower the operation costs and brings higher reliability through dynamic simulation and optimization of network and pipeline distribution systems (Siemens, 2012).

3.5 Decision Support System

The decision support system helps decision-making problems in the management of water distribution network and related methodologies and technical solutions more simple. Moreover, the system applied in water resource and network management, aids the energy consumption optimisation, water quality, and demand management. For instance, division of the water distribution network (district metering areas) is an important activity that significantly simplifies the management of very large and highly complicated structures in the water distribution systems. In addition, the method helps leakage detection and management, reduce energy consumption, water quality management, business intelligence and analytics, asset management and maintenance, and demand management. Currently, several business intelligence based tools developed to analyse data related to the water resource management. Companies like Oracle, Peer Water eXchange, VENTIX, NETBASE, and IBM provide utilities with more or less integrated solutions (ICeWater, 2012).

Box 4: Benefits VENTIX,

- Improve asset and resource utilization
- Improve equipment readiness and strategic plan
- Increase safety and mitigating risk
- Reduce asset lifecycle costs
- Optimize complex maintenance tasks
- Apply lean practice and improvement strategies
- Enhance compliance with regulatory standards
- Confirm supply chain availability and visibility
- Allocate skilled resources appropriately
- Improve productivity and parts management

3.6 Water Supply and Irrigation Design and Management

Mechanization and ICT tools in water supply and network facilities have been adopted since the early fifties the modern and advanced water supply plants in the developed countries are currently fully automatic. Utilizing different ICT tools to synchronize water supply with demand, regulate pump operations to save energy, manage the withdrawal of water from different sources and reservoirs, and control the purification processes in sewage recovery structures.

Improving water use in agriculture meets the acute freshwater challenges facing humankind over the next 50 years. This help achieving the triple goal of ensuring food security, reducing poverty, and conserving ecosystems (Earthscan, 2007). The different ICT tools applied in agricultural development activities helps to improve the network and hydraulic design of irrigation systems. Different elementary software applications were developed to calculate the water head losses during flowing water in pipes. In addition, the new and advanced software applications simulate the water flow in a complicated loop of water network and facilitate optimization of pressure flow in irrigation systems. Designing of irrigation networks requires comprehensive software development using topography, aerial photography, and GIS data. This helps to facilitate computerized designs of irrigation network systems for a better water resource management. Advancement of the systems helps enabling incorporation of irrigation systems design and monitoring as a part of a comprehensive agriculture (Moshe, 2005).

ICT tools help to facilitate computerized irrigation water budgeting system based on soil type and its water retention capacity, climatic condition, crop water requirements, soil moisture, and the plant water potential measurements. The designed water budget helps to programme solid scheduling of irrigation schemes. In addition, more advanced software also facilitates optimization of water distribution under the existing topography and the pressure regimes. In a more advanced irrigation structure, fertilizers applied together with the irrigation water by Fertigation technologies as shown in Figure 11.

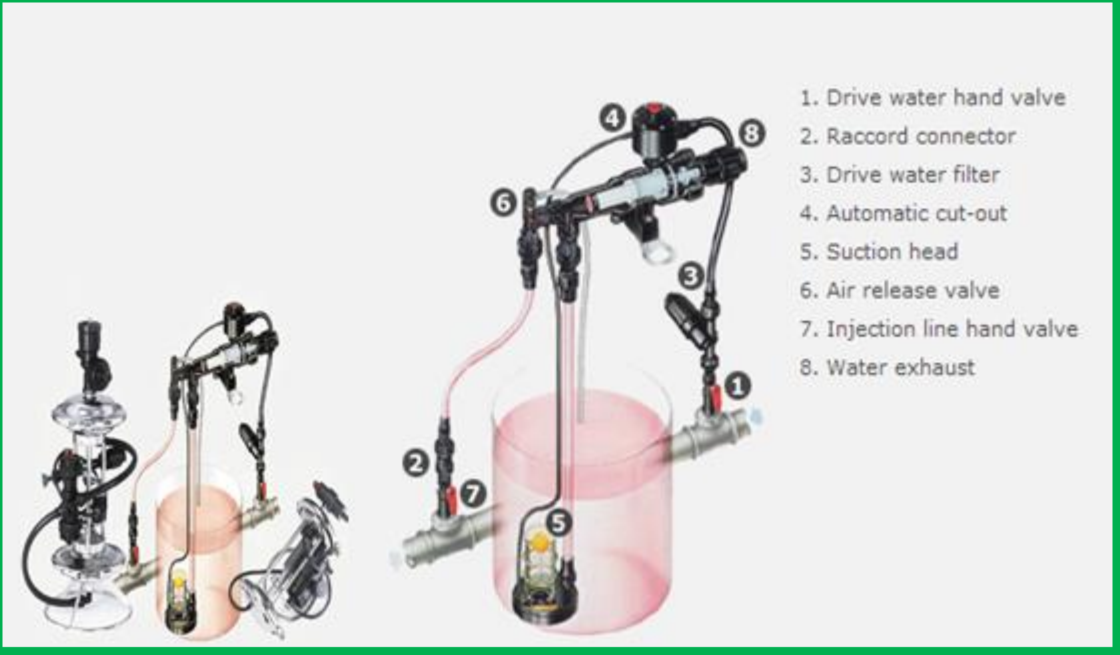

Figure 11: Automated fertilizer and chemical injector

Source: http://www.amiad.com/filters/fertigation_2.asp

The various types of fertilizer injector work based on the amount of water supplied, which help control a precise dosing of fertilizer to water ratios. The amount of water flow measured by flow meters and the fertilizer quantity measured by counting the pulses of the fertilizer pump or flow meter provide proper proportions. Hence, different associated controllers regulate the ratio between the amount of water and fertilizer solution applied in the agriculture area. Comprehensive integration of the ICT and automation control tools in agriculture system shows a substantial increase in water use efficiency and proper water management (Moshe, 2005).

3.7 Urban Water Management

The very wide water domain and its stakeholder involvements cover an enormous number of all business domains and activities. This describes the mapping process and prioritization of the gaps needed to be bridged. Therefore, the development of ICTs focuses on five major areas that connect directly to the urban water supply and management activities.

3.7.1 Real Time Monitoring

Real time monitoring and measuring the environmental condition using an advanced technologies and communications system provides time-relevant information to users in an easily understood manner, which users can use in their daily decision-making process. In addition, it also provides the following advantages,

- Special real time network monitoring, including the automated meter reading
- Help installation of leak detection sensors in the water network
- Real time quality management of different properties, like quantities of disinfectant, pH level, turbidity, conductivity, temperature, etc.,
- Monitoring of sensors at all points of use in the network
- Real time information about the stakeholders and customers and
- Other related technologies such as sensors, GIS application, supervisory control and data acquisition system, telecommunications, inverse models, and decision support systems that help overall system management.

Figure 12 shows an example of a real time monitoring of stream flow in the United States of America. The application result helps also to compare the result with recorded data of the past events.

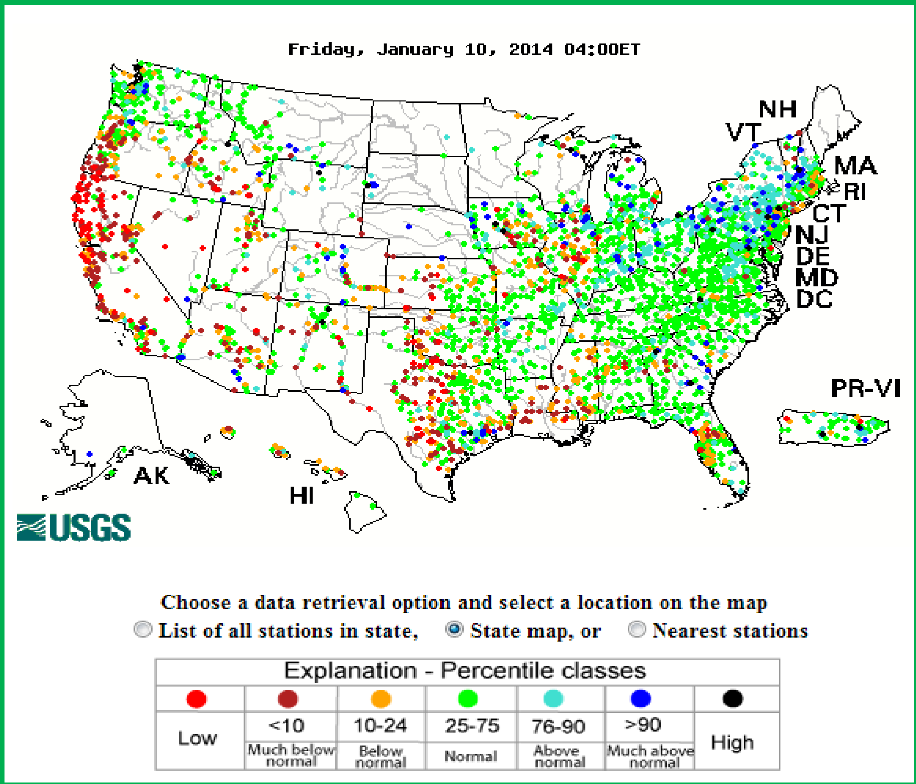

Figure 12: Real time stream flow in the United States compared to the historical flow.

Source : http://waterwatch.usgs.gov/index.php?r=us&id=ww_current

3.7.2 Water Efficiency

Water efficiency is the process of reducing water losses or wastage by measuring the amount of water required for a defined activity in a given period. Efficiency differs from conservation, which mainly focuses on reducing the amount of water losses or waste without restricting the use of water. In addition, this emphasises on the influence of users on water conservation through a behavioural change to lower water losses or to encourage users to apply water efficient products. Hence, ICT tools help to improve water efficiency in cities, improve water efficiency in agriculture areas including detection of illegal water abstraction, and improve ecosystems and land use management according to the available resources (Aqua, 2014).

Box 5: Opportunities to Tap water

- Water entrepreneurship
- Waste water treatment
- Smart water use in Food and agriculture sector
- World purification technology
- Smart grids and dashboards
- Desalination
- Water quality awareness
- Water infrastructure (Intel, 2012)

3.7.3 Energy Efficiency

Energy efficiency is the easiest and the most cost effective method to combat the climate change issue, this method cleans the air we breathe, improves the competitiveness of businesses, and mainly reduces energy costs to consumers. Currently, different ICT tools help to minimize the energy losses in the water sector as discussed below (Gourbesville P. , 2011; U.S-Energy, 2014):

- Controlling and monitoring of heat recovery in wastewater
- Smart grid systems in the water distribution network helps a real time management of pumping strategy, optimization of network management, refined demand forecast, and operational costs
- Different tools installed to save energy in waste water treatment plants
- Different tools for smart metering and smart pricing, like condition based water tariffs and
- Real time status monitoring of valves (opening and closing systems).

3.7.4 Asset Management and Field Work Management

ICT tools help effective management of assets and improve fieldwork management activities that lead to the effective management of available water resource as shown in the following activities:

- Assessment of sensing technologies in pipe and through road condition
- Constant performance, risk and condition assessment sensors and forecasting models
- Optimisation of network operations, and investment programmes and real-time repairs
- Geographical information system (GIS) and geographical positioning system (GPS)
- Electronic identification and tagging devices of buried assets, and wireless communication through road materials
- Special computers for field workers, that gives access in real time condition to all databases of the company (Gourbesville P. , 2011).

3.7.5 Cities of Tomorrow

Well organized and advanced ICT tools helps current cities to provide sustainable operations to meet the demand of the future water-sensitive cities or sustainable cities. Some of the core techniques of the cities of tomorrow are to decrease the amount of water usages through (including re-use and recycling), storm water management, rainwater harvesting, desalination, aquifer recharge management, and water treatment plants. These technologies and techniques demands very high level of monitoring and advanced density of ICT applications. In addition, the technologies help leakage reduction in distribution networks and improve the water use efficiency in cities. This shows core advantages of the applications of advanced ICT tools in creating future sustainable cities or smart sustainable cities through water resource management (EC, 2014).

3.8 ICT Policies and Possible Actions

Fundamental ICT policies and strategies are required for various water resource management and related issues. For effective and efficient water resource management and applications of various ICT tools in the water sector, countries should develop and prioritize their policy actions accordingly. The governments should support the development and deployment of technologies, which will contribute to managing the water demand, alleviating water pollution, facilitating water allocation, and stimulating investment in water infrastructures. Therefore, countries should develop integrated water resource management plans and a road map and financing strategy for the implementation of their plans.

4. Conclusion

In the upcoming years, new ICTs will affect the entire water cycle and the management of the water resource related activities. The overall process of bringing ICT into the water resource sector represents a major task in present and coming years. The integration and implementation of new ICT into the existing implemented water management systems remains one of the most challenging tasks facing technology and water experts. Developing an integrated comprehensive smart water management solution that uses ICT for the measurement, automation, control, monitoring of water supply and demand has a definite positive impact on the entire economy. The saved water uses for expansion of the irrigated areas, urban and industrial water supply; affects food production and industrial development in a way that pushes economic development and long term sustainability of nations all over the globe.

5. Glossary

CIS	**Communication and Information System**
ERP	Enterprise Resource Planning
EUWI	European Union Water Initiative
GIS	Geographic Information System
GPRS	General Packet Radio Services and
GPS	Geographical Positioning System
GSM	Global System for Mobile Communication
HMI	Human Machine Interface
ICT	Information and Communication Technologies
ICTs	Information and Communication Technologies
ITU	International Telecommunication Union
MDG	Millennium Development Goal
MMI	Man Machine Interface
MTU	Master Terminal Unit
PLC	Programmable Logic Controllers
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
UN	United Nations
UNESCO	United Nations Organization for Education, Science and Cultural organization

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