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Integrated Water Resources Management and Climate Change

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Abstract

This paper presents the state of the art of Integrated Water Resources Management (IWRM) by identifying users, their management tools, theory and how their tools should be used in recurring scenarios of water management and analyses the institutional setting and the possibilities for feasible IWRM.. The chapter takes an interdisciplinary approach to IWRMS, which provides a set of tools for policy development, planning and organization, assessment, systems analysis, finance, and regulation The theory provides a unifying framework to foster understanding among disciplines and participants about how IWRM should be applied. It reviews the concept, contemporary research efforts and the implementation of (IWRM). The IWRM concept was established as an international guiding water management paradigm in the early 1990ies and has become a vital approach to solving the problems associated with the topic of water. Owing to the multidisciplinary nature of IWRM, cooperation between different organizations and institutions at different levels is an absolute prerequisite for its successful implementation. Yet, the institutional and governance aspects are usually not well addressed in commitments and recommendations, and subsequently in policy analyses related to river basin management. Some caes of the of Integrated Water Resources Management and Climate changet are presented

Key Words: Integrated Water Resources Management and Climat Change

Gestion intégrée des ressources en eau et changement climatique

Résumé

Cet article présente l'état de l'art de la gestion intégrée des ressources en eau (GIRE) en identifiant les utilisateurs, leurs outils de gestion, la théorie et comment leurs outils devraient être utilisés dans des scénarios récurrents de gestion de l'eau et analyse le cadre institutionnel et les possibilités d'une GIRE réalisable. . Le chapitre adopte une approche interdisciplinaire de la GIRE, qui fournit un ensemble d'outils pour l'élaboration de politiques, la planification et l'organisation, l'évaluation, l'analyse des systèmes, le financement et la réglementation La théorie fournit un cadre unificateur pour favoriser la compréhension entre les disciplines et les participants sur la façon dont la GIRE devrait sois appliqué. Il passe en revue le concept, les efforts de recherche contemporains et la mise en œuvre de (GIRE). Le concept de GIRE a été établi en tant que paradigme international de gestion de l'eau au début des années 1990 et est devenu une approche vitale pour résoudre les problèmes associés au thème de l'eau. En raison de la nature multidisciplinaire de la GIRE, la coopération entre différentes organisations et institutions à différents niveaux est une condition préalable absolue à sa mise en œuvre réussie. Pourtant, les aspects institutionnels et de gouvernance ne sont généralement pas bien traités dans les engagements et les recommandations, puis dans les analyses des politiques liées à la gestion des bassins hydrographiques. Quelques caes de la gestion intégrée des ressources en eau et du changement climatique sont présentés

Mots Cles : Gestion intégrée des ressources en eau et changement climatique

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INTRODUCTION

IWRM has been the accepted paradigm for efficient, equitable, and sustainable management of water resources since the 1990s. It recognizes the dual relationship between the environment and water resources. The environment is both a water using sector and as the resource base a provider of ecological and hydrological services that maintain the water resources in a fit state for all sectors. According to the Global Water Partnership, the water resources are under increasing pressure due to the demographic pressure and improved standard of living. The global population increased by a factor of three during the 20th century and will reach 10 billion people by 2050. Climate change is progressively modifying both plant water demand and the water available from rainfall [103]. The Mediterranean, cradle of our modern civilizations and subject to growing geopolitical issues, is also one of the most sensitive area to pollution of all types and to ongoing climate change. The most recent scientific results should be at the basis of a realistic policy of sustainable development to ensure the stability of the Mediterranean countries. Since the adoption 40 years ago of the Mediterranean Action Plan (MAP) under the United Nations Environment Programme (UNEP), and the creation of the Union for the Mediterranean 10 years ago, scientific research, such as MISTRALS and MedCLIVAR, has been organized to understand the mechanisms involved in the climate and environmental changes in the Mediterranean and to provide answers to the questions of our societies. More recently, in 2015, a synthesis effort was initiated within a network of experts covering the whole of the Mediterranean (MedECC) to make these scientific results accessible and useful to decision-makers.

Threats to watersheds come from direct human activities or indirect transport by air pollutants [72]. Modeling both the natural processes and human demands of the hydrological system requires the use of an integrated approach in order to understand how climate change may impact the entire water system [36]. The demand is not only to detect new groundwater resources but also to protect them. Coastal areas in several countries, mainly those situated in the semi-arid regions (Tunisia, Algeria, Morocco, Egypt …) are characterized by groundwater vulnerable to salinization by seawater [35]. Water resources management has traditionally been done in a sectorial manner and with this fragmented approach it has not been possible to fully address the supply and demand problems for various water uses northe cumulative effects on water quality from different land use activities [81].

Origins and development of the Integrated Water Resources Management (IWRM)

Watershed management has existed for millennia [100]; nevertheless, a holistic and bottom-up approach [56] has only emerged since the 1970s. Darghouth et al. [26] consider that the shift from an “engineering-led” approach to a participatory approach actually occurred during the 1990s. Very few ideas and recommendations have been embraced in the “water world” as quickly, enthusiastically and universally as IWRM. Probably the most prominent among these events was the World Summit on Sustainable Development held in Johannesburg in 2002. The Johannesburg Plan of Implementation (JPoI) [90] stipulates that within five years all countries should have IWRM and water efficiency plans. While this appeal triggered the compilation of national IWRM plans the implementation of this resolution was much less than universal. With this resolution the JPoI placed IWRM at the national level. Other models are also promoted however. The European Water Framework Directive (EC 2000/60/EC) defines the basin and “water body” scale as appropriate for water resources management whereas other sources promote small scale, stakeholder involved IWRM [22]. In this context it is worth mentioning the critical evaluation of IWRM [10 ; 12] highlighting the meager accomplishments in applying IWRM worldwide. More than a decade after this review IWRM still looks like a cherished birthday cake, none of the guests daring to cut and savor. The above-mentioned enthusiasm for IWRM is accompanied by fairly broad interpretations [59].

This basically unresolved duality of IWRM being interpreted either as a philosophy, or a methodology (tool) can be seen as the main reason for its popularity and frequent endorsement, whereby being simultaneously hampered in becoming a day to day tool in water related institutions. One core dilemma already highlighted by Bogardi [20] is the question of what is to be integrated? This question has been reoccurring in the debate ever since [12, 71, 45].

The Derde Nota Waterhuishouding [77] defines IWRM as “Interrelated water resources policy making and management by government agencies responsible for the strategical and management tasks, executed on the basis of the systems concept under consideration of the internal functional relationships between quality and quantity aspects of both surface- and groundwater, as well as the external interactions between the water resources management and management of other fields like environmental protection, regional planning, nature conservation etc.”

This definition is a clear example of a political/administrative guideline with clear limitations and degrees of consideration of what and how to be integrated. With the reference to systems concept even a hint of methodological prescription is given. Clearly this definition was formulated with IWRM as a practical tool in mind.

While NeWater calls IWRM a “Dublin-Rio principle” the four Dublin principles (the outcome of the Dublin Conference 1992) do not use explicitly the term “IWRM”. Rather Principle 2 “Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels” refers to a participatory approach involving all stakeholders at all levels. Thus, it calls for a kind of vertical integration in the sociopolitical sphere rather than emphasizing the need for the topical (horizontal) integration. It is a substantial addendum (or difference) compared to the definition by Rijkswaterstaat [77].

Within the promulgation of the new water law of the Republic of South Africa in the late 1990s the Department of Water Affairs and Forestry (DWAF) formulated the following definition [42].

"IWRM is a philosophy, a process and a management strategy to achieve sustainable use of the resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits."

Various authors agree to place the birth of Integrated Water Resource Management (IWRM) in 1992 with the Dublin world conference and the World Summit in Rio [39, 56, 23]. Chapter 18 of Agenda 21 [91] states that all states could establish the institutional basis for IWRM by the year 2000 and have completed parts of all freshwater programs by 2025.

IWRM is a process of assignment of functions to water systems, the setting of norms, enforcement (policing) and management. It includes gathering information, analysis of physical and socioeconomic processes, weighing of interests and decision making related to availability, development and use of water resources [46]. IWRM involves the coordinated planning and management of land, water and other environmental resources for their equitable, efficient and sustainable use [24]. IWRM expresses the idea that water resources should be managed in a holistic way, coordinating and integrating all aspects and functions of water extraction, water control and water-related service delivery so as to bring sustainable and equitable benefit to all those dependent on the resource [28].

At the turn of the 21st century, many countries adopted the Agenda 21 guidelines and IWRM " a 2008 survey showed that 22% of the world countries had implemented IWRM plans, while 37% partially implemented it " [89] which has been defined 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" [39].

The definition of the Global Water Partnership [39; 40; 41] "IWRM is 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."

calls IWRM a process and explicitly refers to the necessity of coordinated land and water management, a recommendation which has been repeatedly been called for [19].

The critical evaluation by Biswas from 2004 "The definition of IWRM continues to be amorphous, and there is no agreement on fundamental issues like what aspect should be integrated, how by whom, or even if such integration in a wider sense is possible… in the real world, the concept will be exceedingly difficult to be made operational."

The call for implementation of IWRM on all levels even appears in the recently adopted Sustainable Development Goals (SDGs) of the United Nations (Goal 6, Target 6.5), including transboundary cooperative setups by 2030. Compared to the "deadline" set out in the Johannesburg Plan of Implementation in 2002 (5 years) [90] at least the world gives itself 15 years to comply this time. After the unrealistic resolution in 2002 in Johannesburg the elevation of IWRM to be part of an SDG is an opportunity, but not without risks. The credibility of the professional community, but also that of the concept is at stake. This forthcoming challenge, to be encapsulated in an intergovernmental binding resolution, underlines the importance of this book in providing a broad review of the state-of-the-art of IWRM and its various components.

After almost 30 years of less than satisfactory IWRM implementation the impression is emerging that stakeholder and other non-water professional interest groups increasingly attempt to equate IWRM with the concept of multi-stakeholder involvement [23].

Concept of the Integrated Water Resources Management and Climate chnage Projects

The concept of IWRM is based on the principle: waters should be used to provide Economic wellbeing to the people, without compromising social Equity and Environmental sustainability. Waters should be managed in a basin wide context, with stakeholder participation, and under the prevalence of good governance. Today, it appears that IWRM is supposed to be a framework for any water planning and management. Nevertheless, despite the fine principles of IWRM, the feasibility of the concept in the real world has been questioned. Some scholars suggest that the actual use of the IWRM has been minimal, or even indiscernible in the field [11]. According to these views, the concept is too broad and theoretical to be successfully implemented in the field. In most cases, the real challenge is to orchestrate a system that is formulated from small units –or "bits and pieces" as Mohile [69] articulates– that are focused on a certain category of water use.

One of the main reasons why the IWRM framework was introduced was to move from command and control to a more flexible and adaptive management approach, where water supplies, availability, infrastructure, demand, ecological factors, societal needs, conservation measures and environmental considerations were addressed in a holistic manner. This requires a more participatory and trans-disciplinary approach. This suggests that scientific knowledge should not be independent of cultural, historic and environmental knowledge. These authors state that scientists should take part in a dialogue with society about uncertainties, values and beliefs. To address all these issues, the river basins, or watershed, were chosen as the natural units, which allows for the measurement of processes, helps integrate land use activities and facilitates the assessment of ecosystem health. This is also an effective way to encourage societal interactions between land use activities, water management and scientific assessment within a natural landscape unit that affects all residents.

Interestingly, integration has also been criticised from the standpoint that, judging by themanner in which it is being promoted in the IWRM framework, it is not all embracing. Critics point out that integration within IWRM does not take a truly holistic view of natural resources. They argue that land resources are only included superficially within the framework, and there is need for better integration of land and water resources management. In addition, other natural resources which are critical for rural livelihoods, such as forest resources and biodiversity, appear not to be included in the framework [64]. Furthermore, issues of access to land and markets, and provision of infrastructure such as roads and telephone networks should also be integrated into water resources management and sediment.

IWRM involves many tools (Figure 1) and scenarios of water management, but no single blueprint of it fits every situation. Regardless of this reality, the practice of IWRM has a structure that can be expressed as a theory for how to apply it. The IWRM Thematic Group aims to support the water management and sediment in an efficient and structured way by setting up seven main priorities. These are as follows: (i) IWRM project management and communication, (ii) Growing network and Sharing Knowledge and experiences, (iii) Organize and participate in events and conferences, (iv) IWRM, nexus and Water Security Approach; research and publications, (v) Water governance, advocacy and participation in global processes, (vi) Capacity development and awareness raising, and (vii) Design and implementation of water management and sediment.

Figure 1. Thematic Group of IWRM project

Among the changes which the IWRM paradigm has brought to water resources management, and which has become the tenet of the management approach, is that of managing water resources along hydrological boundaries [98]. This appears to have been strongly influenced by the perception that water is an integral part of the ecosystem, and therefore it is logical that the resource be managed along its natural boundaries than the human-created administrative ones [97]. While this approach has been widely promoted as part of the IWRM framework, it is not entirely new as managing water along hydrological boundaries dates as far back as the 18th century [70]. In practice the management of water along hydrological boundaries has resulted in an institutional re-arrangement, for example, organisations managing water and stakeholder participation are now delineated along river basins rather than the traditional administrative boundaries. However, reality is that operating along hydrological boundaries ignores the administrative boundaries within which water users live, and within which socio-economic development is ordinarily planned for and implemented [97]

Climate Change Impact and Adaptation Strategies

Climate change will affect everyone. Changing temperature and precipitation regimes, sea-level rise, more-frequent extreme weather events, and coastal erosion will be experienced around the world. For analysing the effect of climate change, groundwater resources may be divided into four categories. The first category includes confined aquifers with upper impermeable layers. The recharge of such aquifers is encountered only where the water-bearing formations outcrop at the surface. Renewability of such aquifers depends on the availability of rains at their surface exposure. The second category includes phreatic (unconfined) aquifers in wet regions, where rainfall is high and evaporation is low. Since precipitation exceeds evaporation and evapotranspiration throughout the year, such aquifers are highly renewable and will not be affected under the expected geographical redistribution of rainfall. The third category encompasses unconfined aquifers in dry and arid regions, where there is a shifting annual balance between precipitation and evapotranspiration. Such regions may be subject to drier weather under the expected trend in global warming. Therefore, the available groundwater will be less on one hand and, because of the expected decrease in rainfall and increase in the population, the demand for groundwater will be more on the other. The fourth category includes coastal aquifers, which are generally subject to sea water intrusion [34].

Climate change is one of the significant threats for the society. Water is the primary medium through which climate change influences the Earth's ecosystems and therefore people's livelihoods and well-being. Changes in hydrological cycle due to climate change can lead to diverse impacts and risks [34]. Renewable surface water and groundwater resources in most dry subtropical regions are projected to reduce due to climate change. The fraction of global population that will be affected by water scarcity and riverine floods is projected to increase with the level of warming in current century. Agriculture is directly related to water and therefore, food security will be potentially affected by climate change, including food production, transportation, process, access, use and price stability. Climate change and the associated impacts on water are expected to lead to increases in water-related diseases in many regions and especially in the low-income developing countries. In urban areas, climate change is projected to increase risks for people, assets, economies and ecosystems, including risks from heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surges. Rural areas are expected to experience major impacts on water availability and supply, food security, infrastructure and agricultural incomes, including shifts in the production areas of food and non-food crops around the world. Beside climatic drivers, other non-climatic drivers such as current demographic trends, economic development and related land-use changes have direct impact on social and ecological systems and their processes.

Thomsen (1989) evaluated the effects of climate variability and change on groundwater in Europe in terms of the expected increase or decrease in groundwater recharge depending on the regional distribution of rainfall, which was evaluated by global circulation models (GCMs). A study in Australia by Sharma (1989) revealed that a ±20% change in rainfall would result in a ±30% change in recharge beneath grasslands, while beneath pine plantation the corresponding change in groundwater recharge was ±+80% [34]. The effect of climate change on sea water intrusion in coastal aquifers is very important. Under conditions of climate change, the sea water levels will rise for several reasons, including variations in atmospheric pressures, expansion of warmer occasions and seas and melting of ice sheets and glaciers. The rise in sea water levels will impose additional saline water heads at the sea side and therefore more sea water intrusion is anticipated. A 50 cm rise in the Mediterranean Sea level will cause additional intrusion of 10.0 km in the Korba aquifer. The same rise in water level in the Bay of Bengal will cause an additional intrusion of 0.4 km. Sea level will cause additional intrusion of 9.0 km in the Nile Delta aquifer [34]. The Korba aquifer is more endangered under the conditions of climate change and sea level rise. Additional pumping will cause serious environmental effects in the case of the Korba aquifer [34].

In order to deal with these complex problems, water management issues should generally consider multiple decisional criteria and large numbers of possible alternatives, usually characterized by high uncertainty, complex interactions and conflicting interests of multiple stakeholders, but also of a multiplicity of compartments, such as river, land or coastal ecosystems or different economic sectors. Therefore, the traditional fragmented approach of management has to be replaced by more holistic system view approaches. Integrated water resources management (IWRM) is such an approach that has been widely accepted internationally as the way forward for efficient and equitable management of water and related resources [34].

Climate change adaptation (CCA) is emerging in the policy agenda of policy-makers worldwide. In the field of water resources, one of the challenges for adaptation is to integrate and mainstream it into the paradigmatic IWRM concept. Integrating and mainstreaming adaptation with IWRM increases additional implementation burden on IWRM. However, this also fosters innovative governance arrangements and practices to build adaptive capacity to climate change impacts. Despite the main focus of IWRM is on current and historic issues compared to the long-term focus of adaptation share the same goal of promoting sustainable development and both of them require some identical key elements (e.g. public participation, information sharing and disclosure, and concern for social justice) for their successful implementation. lessons drawing and knowledge exchange on IWRM and CCA, in particular how they may contribute to, or undermine, each other. Moreover, the recent approval of Agenda 2030 by the United Nations (UN 2015) has provided a new framework in which IWRM and CCA are considered as components of the planetary efforts towards sustainable development and, in particular as elements contributing respectively to sustainable development goal (SDG) 6 and 13. Within goal 6 of SDGs, the target (6.5) is focused on the implementation of IWRM at all levels, including through transboundary cooperation as appropriate', to be achieved by 2030 [34].

Global warming is very important phenomenon, the impact of which is being realized by everyone in recent years. It is adversely influencing urban and agricultural water supplies, flora, fauna and aquatic systems, increasing more risk and uncertainties in floods and more challenges to manage these events and water resources as well as provide timely protection against these uncertain events. Temperatures are abruptly changing. At some locations, temperature trends are towards more cooling whereas at other locations trends are towards more warming. Temperature trends are also shifting from location to location i.e., sometimes early cooling and sometimes early warming. Due to changing temperature trends, snowpack melting trends are also changing, resulting in change in extent, duration, and frequencies of flood as well as rise in sea water levels. All these events create more complicated problem of water resources management. In addition to this emission of different type of gases particularly carbon-di-oxide, methane, nitrous oxide, ozone, CFC and other halocarbons from decomposition of agricultural waste or livestock or non-agricultural waste is also a major source of environmental and water pollution. This is also one of the important issues and need to be addressed by joint efforts of concerned national and international organizations [34].

Climate change adaptation is a very complex phenomenon and challenging too. To date, significant effort has been invested in developing tools to assess the links between climate and hydrology. These tools offer insights into how large-scale patterns of runoff might change in the future. Adaptation decisions are not made based on assessments of naturalized runoff but are instead derived from assessments of how human interactions with hydrology produce positive or negative outcomes for the economies and ecosystems upon which human communities depend. These aspects need to be better captured in the available analytical tools. As the formulation phase of planning for water adaptation to climate change requires the use of a participatory and holistic process, efforts towards the adoption of the principles of IWRM should be encouraged. While IWRM does not explicitly integrate climate change considerations into the planning process, the underlying principles of good resource management can facilitate a process whereby information required for adaptation to climate change, including data and records, can be elicited from key actors. As the impacts of individual water management actions can accumulate within a particular water system, basin planning, even if it covers multiple political jurisdictions, should be encouraged as adaptation to climate change is identified and implemented. When planning adaptation across boundaries, riparian countries should focus on preventing adverse impacts, sharing benefits and risks in an equitable and reasonable manner and cooperating on the basis of equality and reciprocity. This will assist in avoiding actions that might be adaptive in one location and maladaptive elsewhere, potentially increasing the conflict over water management and allocation.

Research and implementation of the Integrated Water Resources Management and Climate Chang Projects

The actual permeation of IWRM in the legislative and institutional levels is very heterogeneous between nations. In Europe, the Water Framework Directive (WFD) from 2000 established a general framework for the protection of water resources, in particular to improve aquatic ecosystems and mitigate the effects of floods and droughts. In the southern countries, IWRM implantation is more heterogeneous. For example, Morocco included the principles in the Water Law of 1995, while in Tunisia, water management is still very concentrated into the central state. Integrated Modeling of Water Resource for Decision Support Systems (IMWR-DSSs), by using models and including information management capabilities and involving stakeholders, are generally implemented to simulate the functioning and possible evolution of hydrosystems (surface water, groundwater, reservoirs) under natural and socio-economic drivers, to help decision-makers and end-users in solving complex water resource management problems and selecting the best decisions. The DSSs are targeted according to the role they might play in IWRM processes [103].

IWRM is being promoted by many organizations, implemented in some areas and piloted in others. A huge effort involving the reform of water laws, institutions and capacity building is underway based upon the IWRM 'recipe'. However, in much of the world, it remains business as usual. IWRM is about integrated and 'joined-up' management. It is about promoting integration across sectors, applications, groups in society and time based upon an agreed set of principles. IWRM is a global movement driven by a perception of crisis, both current and future. The so-called global water crisis is underlain by a mixture of largely unavoidable development factors (population growth, increasing wealth and demand). However, it is increasingly realised that the heart of the water crisis is poor management or governance. With careful management and wise selection of priorities there is no reason that even in the driest parts of the world there should not be sufficient water to go around, and viable solutions exist to many of the problems faced. IWRM seeks to tackle some of the root causes of the management crisis, namely the inefficiencies and conflicts that arise from un-coordinated development and use of water resources.

The last few years of the 20th century witnessed an unprecedented level of international discourse involving the world's water users, managers and policy-makers. They engaged in intense consultative activities, reviewed the global water predicament and identified ways to secure regional water environments and the societies and economies which depend on them. The preparatory process produced numerous reports for the Second World Water Forum in the Hague in March 2000 [98, 39, 95].

During the consultations for the report-writing, attention was drawn to the fundamental political nature of the pre-Hague process. Water was a hydrological phenomenon rather than a multi-dimensional resource enmeshed in nested political economies. There was talk of civil society, governance and stakeholders, even of political commitment. But the discourse ducked the challenge of recognizing that innovative outsider scientific information as well as outsider principles of economy, equity and the environment are subordinate to local political milieus into which they would have to be introduced.

IWRM comes out of an attempt to tackle and avert problems or crises. Its conceptual backbone is provided by a set of four core principles, agreed upon by the Dublin Ministerial Conference that preceded the first world summit on sustainable development in Rio de Janeiro in 1992. IWRM is therefore the water community's contribution to the sustainable development dialogue that has been running since Rio (and before).

While the principles have been further refined and added to during subsequent conferences of the water community in the 1990s and 2000s. The Global Water Partnership, the international 'custodian' of the IWRM concept. Three key concepts which in one form or another are present in all definitions of IWRM are: equity, efficiency and sustainability.

The basis of IWRM (Figure 2) is that the many different uses of finite water resources are interdependent.

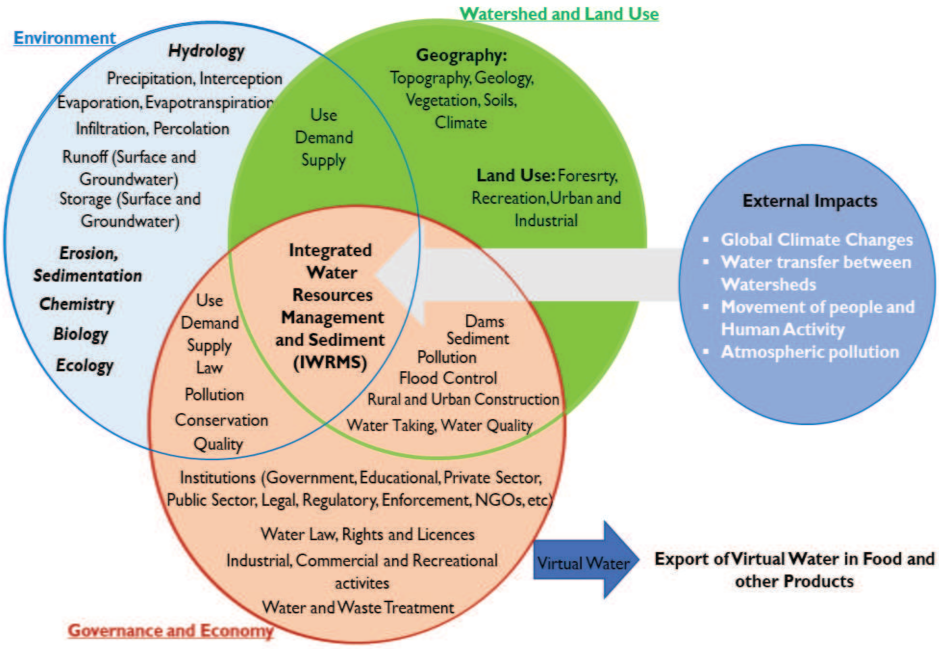

Figure 2. Elements of Integrated Water Resources Management

The diagram (Figure 2) is an attempt to show the factors that impact developing an IWRM plan in a watershed or drainage basin. The five main areas to be considered are:

- Environment: Hydrology, Chemistry, nutrients, Biology, Ecology and Erosion, sedimentation.
- Social concerns: Equity, Empowerment, Polarization, Marginalization and Poverty
- Economy: Traditional livelihoods, Industry, Modern agriculture, Forestry and Fisheries, Services, Tourism and Informal sectors
- Paricipation: Education, capacity buildinbg (Universities, administrations, Public awareness), Local actors (village surveys) , Stakeholder links and Communication, workshops.
- Governance: Linking central government to local level, Links between sectors, International actors , NGOs, Legislation and conventions.

The dimensions of IWRM are considered in Water quantity, Water quality, Water demand, Climate change, Water governance, Public information and participation, Capacity Development, Decision support, Integrated land and water management and Pathways to sustainable water management.

A set up that fulfils the requirements of IWRM can be arranged in several ways. Basically, either all the institutions should cover all three aspects, or they should focus on their main mandates and responsibilities, and by cooperation ensure that all the other aspects are considered. In addition to the institutions themselves, the donors should take care that environmental, social and economic issues are equivalently considered in one way or another.

North Africa Case Study: Integrated Water Resources Management and Climate Change

The assessment of sediment yield has become increasingly important for water resources management by ensuring sustainable land management and securing stable water resources. In Maghreb (North Africa), which has only scarce water resources, most damage is associated with the loss of alluvial sediments from the catchment and subsequent dam siltation [68].

Sediment deposits in North African catchments contribute to around 2%–5% of the yearly loss in the water storage capacity of dams. As in most semi-arid and arid regions, which cover over 40% of the world's land surface, waterr esource management in the Middle East and North Africa is more complex than it is in humid zonesdue to the lack of perennial rivers and other readily available water sources [84]. This alone would lead to a 40% drop in per capita water availability in the region by 2050 [87].

The deposits of sediment in Maghreb contribute about 2%–5% of the yearly loss in the dams'water storage capacity. Sedimentation is a complex phenomenon that is widespread in the Mediterranean area, particularly in the North African countries, where it is seriously endangering reservoir management and water quality [18, 48, 96]. As a result, reservoirs' storage capacity is decreasing [80], possibly reaching 43% of their initial storage in 2030.

In Tunisia, rainfall exhibit high spatial and temporal variability, characteristic of the semi-arid and Mediterranean areas, which lead to a high variability of the river discharges. The water in Tunisia is limited and unevenly distributed in the different regions, especially in arid zones. Average annual rainfall ranges from less than 100 millimetres per year (mm/yr) in the south to 1,500 mm/yr in the north-west. Currently, the conventional potential of water resources of the country is estimated about 4.84 billion m^3/year of which 2.7 billion cubic meters / year of surface water and 2.14 billion cubic meters / year of groundwater, characterizing a structural shortage for water safety in Tunisia (under 500 m3/capita/year). With over than 80% of water volumes have been mobilized for agriculture [34].
Many activities related to water resources management are the responsibility of the Ministry of Agriculture, Water Resources and Fisheries (MARHP) and the directorates/institutions under its authority. The MARHP is mainly responsible for public domain management, mobilization and development of water resources, water management projects and agricultural withdrawals as well as providing water resources for domestic and other uses. Through successive decades of water mobilization, Tunisia had acquired a relevant experience in the water resources management. The establishment of an institutional framework to the water policy dates back to 1971 with the institution of the water code. It represented the legal framework that will thereafter define the main milestones of the Tunisia water policy. An assessment of the available water resources allowed the institution of three-director water plan for the north, the center, and the southern country. While the north and the center water plan focused on the development of large dam's facilities and their networking and the multiplication of the collinear lakes in the center, the southern Tunisia observed a tremendous development of the underground resources' exploitation. This mobilization phase allowed satisfying the growing water demand without having to ration water even during periods of acute drought.
The first built dam is on the Mellegue river in 1954, which controls more than 40% of the whole Medjerda watershed, it induces a decrease in the flow coefficient. The sections of the river have also changed since the construction of the dam. Indeed, the water reservoir of the Mellegue dam traps sediments at a rate of 61% between 1954 and 1991. This explains the annual variation of the flow, the erosive effect of flows and thus the morphological changes of the bed of the river and meanders downstream the dams [16].
These large watersheds integrate the hydrological response to climate and environmental change over large spatial and temporal scales, but also changes in the physical environment due to anthropogenic causes, making it very difficult to identify the source of the impact of these changes on the variability of the hydrological regime. These results are part of a larger study of the impact of the reduction of high flows and sediment transports of the Medjerda basin to the gulf of Tunis, as dams trap much of the sediment transport, which now do not reach the sea. These results will help assess how the hydrological changes have impacted the coastal vulnerability, and risk for coastal infrastructures.
The Tunisian example focuses on the pollution mitigation of a lake classified at the UNESCO World Heritage. The emission of pollutants and sediments has been quantified from in situ analysis. The SWAT website lists more than 3500 references during the same period (https://www.card.iastate.edu/swat_articles). Only 6% (225) of the articles concern the Mediterranean area. SWAT is used much more in northern countries (61%) [103]. A hydrological model (SWAT) was used to simulate the transportation of the pollutants and sediments throughout the whole watershed into the lake [53, 73, 101, 65]. An analysis of sensibility was carried out and the model was calibrated. The impact of Best Management Practices (BMPs) was evaluated. The results are expected to raise awareness (with a very extreme scenario of fertilizer reduction) and to suggest possible options to improve the water quality of the lake [25, 83, 102, 47, 32, 2, 3, 63].

In Algeria, Water resources management is the magic key of the national water resources planning and strategy. As a result of social and environmental pressures, the overexploitation of groundwater as a result of population growth, industrial and agricultural emergent activities make the planning efficiency more complicated [75]. Algeria's rivers transporta large quantity of sediments. Algeria is expected to be negatively affected by impacts ranging from increased frequency and intensity of floods and droughts, worse water scarcity, intensified erosion and sedimentation, sea level rise, and damage to water quality and ecosystems. The sediment deposited in Algerian dams is estimated to be 20×106m3·yr−1 [51]. However, the dam capacity has reduced due to sediment transport and lack of surface runoff. Competition for water between agriculture, industry, and

drinking watersupply—accentuated by a drought in Algeria—has shown the need for greater attention to be paid towater and for it to be managed at the large basin scale [21]. Surface water resources in Algeriaare evaluated to be approximately 8376 billion m3 for an average year. These water resourcesin Algeria are characterized by wide variability—the resources for the last nine years have beensignificantly below this average [44]. Several dams were built in Algeria to ensure waterresources for the supply of drinking water to all its cities and allowed approximately 12,350 km2 of irrigated land to be developed [14]. However, dam reservoirs lose about 20×106 to 30×106 m3 of water storage every year [15, 78]. Despite its semi-arid climate, the Tafna catchment plays an important role in water self-sufficiencyin northwest Algeria [13, 66]. The deposits of sediment in Maghreb contribute about 2% – 5% of the yearly loss in the dams'water storage capacity. In Algeria, the intercepted runoff in dams and weirs hold about 5.2 billion m^3, which makes up 42% of total runoff [74]. The construction of dams has raised questions about their hydrological impacts on water resources at basin scale, especially where there are conflicts betweenupstream and downstream water users [6, 55].
Algeria has adopted a demand management strategy given the limited equilibrium between water needs and resources. In addition, this strategy consists of the adoption a new water management strategy based on progressive pricing, integrated and participative management by watersheds, education and awareness of water issues, and large-scale use of wastewater after treatment leaving enough initiative for encouraging water savings [67, 8].

In Morrocco, water resources are limited and irregular in time and space. The average rainfall is 140 billion cubic metres per year (BCM/yr), Evapotranspiration is high, amounting to 118 BCM/yr on average. The potential of natural water resources is estimated at 22 BCM/yr, the equivalent of 700 m3/capita/yr, comprising 18 BCM of surface water and 4 BCM of groundwater. The amount of water that is technically and economically exploitable is 80% of current available resources. This reveals the constraints on water resources and the challenges that lie ahead regarding the urgency of an integrated management approach [99, 88]. The elaborated hydraulic balance sheet shows that water deficit situation is already registered at some basins in Morocco [60]. The quality of superficial and groundwater resources are currently affected by: (i) pollution from rejected domestic and industrial wastewater, (ii) leakage of fertilizers and phytosanitary products and (iii) soils erosion and transport of sediments. To meet the challenges posed by the growing water scarcity, Morocco has adopted an integrated approach to water resources management through mutually reinforcing policy and institutional reforms. A new water law has been promulgated in 1995. It provides a comprehensive framework for integrated water management. This new law constitutes an efficient juridical tool to develop more considerable efforts for water use and mobilization in order to make them compatible with aspirations of socio-economic development of Morocco in the 21 centuries [76]. In 1995, the Moroccan government emphasized in its National Environmental Strategy that the priorities in term of environmental management would be on water, air, solid waste and soil-related issues [93]. In Morocco security of water supply has always been an important consideration in the economic and social development of the country. An integrated approach to water resources management is adopted through mutually reinforcing policy and institutional reforms as well as the development of a long-term investment program mobilizing innovative financing mechanisms including public-private-partnerships [9]. Morocco is divided into 9 major river basins (RBA), with long-term water resources development policies written down in Integrated Master Plans. On the whole, the achievements of Morocco to realize speciic objectives in integrated water resources management are considered satisfactory [82].

In the Moroccan example, there has been a rapid depletion of the groundwater table since the end of the 20th century [85, 62, 52]. The WEAP tool, [43] which provides a graphical approach to build a model of the system, facilitates the participation of many stakeholders into the building of the model, even if they have little scientific or technical knowledge [1]. The WEAP website lists more than 500 references (www.weap21.org), among which 16% correspond to the Mediterranean area for the period 2002–2018. Almost 60% of those references were published in peer-reviewed journals. The most common topics are the assessment of water resources (40%) and the impact of climate change (31%) [103]. The model building can be resumed in three phases (54]. At first, institutional representatives of the main sectors (agriculture, city, high-education, forest, etc.) were gathered in a workshop. The modeler acted as a guide for the stakeholders, focusing on questions such as what is important, what complexity is needed, what should be the time step regarding the goals, etc. After a sketch of the watershed functioning was accepted by the stakeholders, the second phase began. This typical technical process involved several bilateral interactions with the different stakeholders: data gathering, calibration and validation, etc. The running version of the model was discussed in a new workshop with stakeholders: conception issues were pinpointed, data and calibration issues were discussed, giving way to new technical rounds. The scenario phase was the last part of the process. In this case, the development of the scenarios took place separately. It appeared that the translation of those narrative scenarios to quantitative and spatialized scenarios would be difficult [61].

In Egypt, about 98% of Egypt's fresh water resources originate outside of its borders, such as the Nile River and groundwater aquifers. Indeed, the Nile River provides the country with some 93% of its water requirements. The Nile River supplies about 93% of Egypt's annual renewable water resources [7]. A share of 55.5 billion cubic metres per year (BCM/yr) is allocated to Egypt according to the Nile Water Agreement (1959). About 10 BCM/yr is lost through evaporation from the Aswan High Dam reservoir (Lake Nasser). Egypt has huge natural mineral water resources. However, most of them have not yet been significantly exploited. The total amount of deep groundwater has been estimated at about 40,000 BCM [27]. Egypt produces about 3.5 billion m^3 /year of municipal wastewater, while current treatment capacity is in the range of 1.6 billion m^3 /year [86].

The Nile River in Africa is the second largest river in the world, with a total river basin of 2.9 million km² and a length of 6 825 km. The Nile flows through nine countries: The Republic of Tanzania, Burundi, the Democratic Republic of the Congo, Rwanda, Kenya, Uganda, Ethiopia, Sudan and Egypt. It has 1 400 km in Egypt, where it empties into the Mediterranean Sea [31].

About 96 percent of the territory of Egypt is desert, with an annual precipitation of only a few centimetres. The population is concentrated along the Nile and the river delta. The annual runoff at the dam site is 84.0 billion m^3, with a yearly fluctuation of 41.3 to 134 billion m^3. If the yearly runoff is more than 130 to 140 billion m^3, a food disaster occurs [29]. However, if it is less than 40 to 50 billion m^3, it causes droughts. The annual sediment load is 316 million tons, with a sediment concentration of 3.764 g/l. Floods like the one in 1878, with a maximum daily runoff of 1.14 billion m^3, and droughts like the one lasting nine years (1979 to 1988) can create disastrous situations for the Egyptian people [31, 33].

The construction of the Aswan High Dam (AHD) has provided Egypt with comprehensive benefits. The water discharge in a year ranged from 1 000 to 10 000 $m^3\ s^{-1}$ before the dam was constructed. After the dam was completed, the maximum water discharge was limited to 2 500 $m^3\ s^{-1}$ and the sediment concentration was reduced to between 0.03 and 0.1 g/l. Before the AHD, the river supplied 4 billion m^3 and 48 billion m^3 of water to Sudan and Egypt, respectively. The water benefit from reservoir regulation is 22 billion m^3, shared by Egypt and Sudan according to the 1959 Nile Waters Agreement. The Delta (particularly along the Mediterranean coast) is also subsiding (and becoming less fertile), because it is no longer replenished each year by 100 million tons of flood sediments from the Nile. Instead, those sediments now drop out where the Nile enters the reservoir created by the AHD [58].

Egypt's agricultural production increased 20-fold from 1960 to 1987, and the wheat yield rose from 1.1 million tons in 1952 to 4.5 million tons in 1991. The AHD has also created other benefits for both Sudan and Egypt, such as power generation of about 10 billion kWh per year (53 per cent of the total electric power of Egypt in 1977), improvement in the navigation conditions upstream and downstream, development of tourism, and 10 000 tons of fish annually [50].

Egypt is approaching the point where water demands are exceeding supplies. This situation will necessitate improved decision making for water resources planning. Integrated management represents a unique approach, incorporating both temporal and spatial variations of the problem. To achieve an integrated procedure, efforts are being made to resolve numerous issues ranging from loss of agricultural lands to farmer involvement in the decision-making process. In spite of the powerful programme of population control, Egypt's population is still growing at nearly 2%. This increase, together with the consistent improvement in living standards, affects the use of water. It creates new aspects of demand, increasing the water requirements to levels that necessitate careful water resources planning. There is some potential for the Egyptian water balance to produce a surplus that fulfils the essential water needs of the vital development plans and projects. Although a considerable portion of the water which flows to the drainage system or groundwater shallow aquifers is reused, the fact that it is impossible to use the whole amount reduces the entire system efficiency. Better water distribution was achieved through the structure rehabilitation programme [30]. Erosion at the river mouth is found and the delta area is threatened because the reduced incoming sediment cannot fully supply the amount carried away by tidal flow. The coast line at the mouth of the Rosetta draws back about 150 m per year. Sand losses are in the order of 200 000 tons per year west of the Rosetta mouth and 400 000 tons per year west of the Damietta mouth. The aquifer beneath the northern reach of the delta 15 to 35 km inland from the sea has the same salinity as the sea [79].

In libya, there's no rivers, and its surface run-off is limited to short floods following extreme rainstorms in the winter. Estimation was done in 2008 for future consumption in Libya including agricultural, domestic and industrial uses during 2006 to 2020. The future evaluation of water utilization for all potential purposes specified the total water consumption rising from 6,293.89 million m3 in 2006 to 12,473.20 million m3 in 2020 with an average of compound annual rate of 4.97% [57]. In 2020, it is expected that the increase would be 98% of the water consumption in 2006. The main water sources in Libya come from four sources which are groundwater supplies almost 95% of Libya's needs; surface water only with 2% comprising rainwater and dam constructions; desalinated from sea water provides 2% and wastewater recycling 1% [49]. To control these intermittent resources in the wadis, 18 dams were constructed to collect around 61million cubic metres (MCM) of run-off water. Natural springs in Jabal al-Akhdar, Jabal Nafusa and several places in central Libya are another source of surface run-off. Their discharge varies from 1litre per second (L/s) to over 10L/s, supplying different uses [37].

The current state of water institutional, infrastructure and water management policies in Libya permit the recognitions and evaluation of a range of options for improving water use capacity in agriculture and the potential role of water pricing in accomplishing sustainability of water sources [5]. The condition of water supply has turned into more problematic with quickly increasing population and minimum rainfall. Consequently, soon after the discovery of fresh groundwater in the deserts of southern Libya, the local authority has made massive efforts to address its water shortfall problems, fundamentally through the enforcement of The Great Manmade River Project to sustain its economy, however, it does not solve the water scarcity in Libya [99].

Libya based academies, universities, high institutes and Research Centers have launched initiative to reduce, reuse and recycle resources product and services (Institute Industry Interaction) for rebuilding the country to combat climate change impacts [4] induced by 2011 Libyan crisis. The country is engaged in preparing actions, accords, ideas and best practices to mitigate the impact of projected extreme events and weather by considering low carbon, resource efficient measures and enhanced use of renewable to tackle impending climate change [17].

CONCLUSIONS

Water's role in the nature is very fundamental. As it circulates in the atmosphere, in the rivers, lakes, soil, rock, and in the oceans, it is the major conveyer of various chemical substances and of energy, and it can also be called as the blood of the ecosystems of this planet. But at the same time water is interwoven in the various functions of the nature and the human of water. But it is only great if it is actually being implemented and improving matters. Concerned the discharges of watercourses, waste management, fishing, tourism and recreational use, off-road traffic, reindeer husbandry and air pollution, the IWRM plans cover the whole river basin in which each country is responsible for the plan relating to its own area.

While IWRM can seem complex, a theory of it and examples through common problem scenarios show its major attributes and uses. The theory explains how it involves three focal points of managing water, services, and infrastructure. Its major variables explain why there are so many dimensions to it; these dimensions can be represented mostly by scales and management functions in situations. The scenarios involve combinations of variables in contextual situations and range across issues such as policy planning, operations assessment, and confl ict management. By identifying the scale and the management function, scenarios can be discussed across different contextual situations so that productive management practices and solution paths can be identified.

The IWRM concept addresses the long term prospects for water management in the world. The approach is designed to develop realistic projections of water availability and demands, and identify infrastructural and procedural development with the aim of meeting demand and optimising resource allocation.

The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking account of social, economic, environmental interests. collecting hydrological and other data, land management, river restoration, preventing invasive vegetation and pollution, sediment management that must be done to keep the basin healthy.

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