Water Resources Research in the Souss-Massa Basin, Morocco

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Most recent studies confirm a decreasing trend in water resources availability in the northern African region; the high competition between the sectors that use this vital resource, and the changing climate are considered as the main factors behind this situation. Under such very dynamic interactions between the natural resources, climate and the socioeconomic sectors, scientists from different perspectives have a challenging task to provide up-to-date and reliable insights to guide potential sustainable management strategies. Through the case of the Souss-Massa, the present research provides state of the art scientific research on water resources. The maps of publications analyzed showed that researchers working in the area focus more on the study of the quality, chemical processing and the impacts of climate change on the availability of water resources. The results showed that Souss-Massa is a region where an important amount of research on climate and water has been carried out. Hence, to keep up with the rapid evolution of land use and other anthropogenic actions in the basin there remain several gaps in knowledge and constraints to address.

Souss-Massa climate change water resources research agriculture

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1. Research Gaps and Challenges

Souss-Massa is a region where an important amount of research on climate and water has been carried out. However, there remain several gaps in knowledge and constraints to address. To keep up with the rapid evolution of land use and other anthropogenic actions in the basin, it is necessary to promote research, innovation and technology transfer[1]. Moreover, the quality and availability of data are considered to be insufficient to support local research efforts.

1.1. Data Availability and Quality

Water resources research and watershed modeling studies require observed data collected from stations. However, the data of the Souss-Massa basin reveals gaps and discontinuities; by station and by year on the entire hydro-climatic series. Many existing stations in the basin, hydrological or meteorological, lack reliable data or function badly. Thus, these data are not sufficient to support or reject a given model conceptualization. The ruptures noticed in several periods are most often due to the malfunctioning of some measuring devices, changes in the environment of the station (deposits of debris for the hydrological stations and shadow for the meteorological stations), the change of measuring instrument, or a lack of management of the hydrometric and piezometric data. Although enormous progress has been made in the international data revolution, for example, the use of reanalysis data and satellite data, the data-quality of many existing stations in the basin faces many problems and there has been no progress acquiring high-quality data in the basin.

Numerous floods have occurred between 1960 and 2014, which should serve as a reminder that flooding is a serious risk to those who live and work in the region [2]. In most of the flow measurement stations in the Souss-Massa basin, measurements are taken at a daily time step. However, the daily time step is too coarse to capture the flood events in the headwater catchments due to the rapid characteristics of the rivers [3]. In addition, most of the flow measurement stations have significant gaps in the recorded data. Aside from that, there has been no effort to increase the spatial density and temporal resolution of the hydrometeorological gauging station.

Reliable and complete climate data allow the researchers to trace the history of the station and subsequently the history of the region. This will allow the researchers to better understand the climatic evolution and to capture the non-climatic changes over time in order to make a judicious decision. However, the homogeneity of the data is not regularly assessed for climate analysis. In addition, most climate stations do not have measured temperatures and no action has been taken to increase the spatial density of stations that measure temperature. Modeling exercises generally require historical and high-quality data to perform well.

As it has been shown by this entry, the scientific community in Souss-Massa have tried to give necessary information to decision makers regarding water resources. Nevertheless, the scientific community still face limitations in the availability of detailed historical data on management operations such as irrigation, cropping and other agricultural operations. On the other hand, successful application in a basin that experiences extreme hydrologic events (e.g., droughts) requires the acquisition of more precise GIS datasets, detailed soil, hydrography, land use and geology maps.

1.2. Water Resources Modelling and Multidisciplinary Research Gap

Water contamination and pollution in the Souss-Massa basin has increased significantly due to climate change and anthropogenic activities. Recent water resources research in the basin has been focused on identifying water quality in order to build sustainable management plans. Thus, future research must concentrate on the difficulty of processing water quality data, which are difficult to handle because of their non-linearity, non-stationary nature and vague properties due to unpredictable natural changes [4]. For instance, the coastal region of Souss-Massa has seen a decline in the quality of its groundwater resources because of marine intrusion [5], yet no effort has been made to mathematically represent the models that describe saline intrusion into the coastal aquifer.

In the water resources science, models are essential to understand and predict the spatial and temporal variability of water resources. Hydrological models can be used to understand the hydrological and estimate the catchment water balance. However, little effort has been made in modeling studies in the basin for hydrological forecasting and analysis of agri-hydro-climatological processes. Water resources cover all the areas of activity in the basin, from drinking water supply to irrigation, and contribute to the development of agriculture and industry. Nevertheless, in many places of the basin the good management of water is limited by the lack of reliable and significant hydrological studies. As far as groundwater is concerned, it is necessary to use models to predict the impacts of future scenarios on the quantitative and qualitative parameters of aquifers. For example, the MODFLOW model may be used to simulate these changes and generate numerous outputs such as groundwater piezometric level, recharge and concentration, among others.

The Souss-Massa region is semi-arid with a high demand for agricultural water, considerable concerns have been expressed regarding the water supply's ability to satisfy the demands of all users in the future, especially given the projected increases in demand coupled with climate change. Water resources research in the basin lacks extensive climate change studies, particularly empirical research that helps to understand the potential response of elements of the hydrologic regime to climate stress. This type of scientific research helps in modeling and planning better strategies for sustainable adaptation, conservation and management[6].

2. Recommendations

2.1. Improving Data Quality and Quantity

Potential research paths involve improving databases to provide an accurate decision basis for water resource managers. It would be beneficial to include and fill data gaps with remote sensing products. Temperature and evapotranspiration, for instance, are not very well documented due to the scarcity of in situ measurements and meteorological stations. Furthermore, the implementation and management of instruments over large areas require high financial costs and qualified staff. In this context, remote sensing can help to collect these data by assimilating the results derived from satellite images.

In addition, it is important to extend the studies of homogenization of climatic data at the basin scale; these techniques allow the detection of breaks that are related to natural and artificial phenomena in order to have complete databases facilitating the studies of climate change and water resources processes. For this, the researchers recommend a regular monitoring and maintenance of hydrological and meteorological stations. This monitoring could be included in an annual action program dedicated to adaptation measures to climate variability and change. In addition, it seems that it is very important to sensitize the decision makers and managers of the concerned services on the crucial problem of the availability of complete and reliable data.

By addressing the information gaps indicated above, it is possible to enhance research on climate change and water resources in the Souss-Massa basin. Additionally, adequate funding as well as research instruments in certain areas are required. Consequently, this will contribute to the development of a system that can give a spatially comprehensive dataset that can be utilized by a variety of researchers.

2.2. Multiplication of Studies and Further Research Paths

The interaction between productivity and sustainability of water resources in complex systems, such as the study area, requires a thorough understanding of the complex interactions between different environmental and socioeconomic factors to understand the interactions between productivity and sustainability. The various factors that influence farm management decisions are not always evident, and agricultural production systems are changing at a fast rate in response to shifting production costs, changing consumer demand, growing concerns about food security and concerns about the environmental impact of agricultural production [7]. In particular, it has been shown that the failure to design solutions for water resource management systems is based on a lack of knowledge of the many interconnections and dynamics of the different components within the system[8] [9]. Furthermore, and like all regions of Morocco, Souss-Massa will also benefit from new development plans. First, there is the new Generation Green strategy (2020–2030) which comes to outline the Kingdom's agricultural strategies for the next ten years. The new strategy has been developed based on the evaluation of the Green Morocco Plan (2008–2018). The strategy is based on two fundamentals: the priority of the human element and the sustainability of agricultural development [10]. In addition, and with regard to water, the region will also benefit from the 2020–2027 plan for water saving programs in the agricultural sector with significant portfolio of agri-hydraulic and agri-hydrological projects. Thus, water resources modeling in the Souss-Mass basin can be used to identify development opportunities and to simulate actions to preserve these resources, the researchers recommend the use of models such as the application of system dynamics (SD) modelling [11], utilization of generic simulation models namely MODSIM (Colorado State University) [12], RIBASIM (DEL-TARES) [13] and WEAP (Stockholm Environmental Institute) [14].

Faced with this situation, it is necessary to study and implement policies and management strategies to adapt to the risks associated with the expected changes, by first assessing future scenarios of potential imbalances between water supply and demand. Water system management and planning procedures may be improved by the use of simulation models, which give simplified representations of real-world systems [15]. In the context of extreme events, such as drought, these simulation models enable the reproduction of source–demand interactions and to predict the impacts of different scenarios in time and space. Therefore, it allows the definition of the different appropriate measures to mitigate the economic, social and environmental impacts of the different events. In other words, it is necessary to study and implement policies and management strategies to adapt to the risks associated with the expected changes, by first assessing future scenarios of potential imbalances between water supply and demand.

Despite all the efforts employed for water management, the water situation in Souss-Massa needs more investigation to support the sustainable decision system[16]. Indeed, in response to the needs of the market, farmers are adopting more and more water-demanding crops (bananas and fodder crops). These crops increase water withdrawals, which in turn will have an impact on agricultural land. With the scarcity of water that the area is witnessing on the one hand, abandonment of cultivated land, such as the citrus area located in the plain of Souss, which met serious difficulties with the decrease in the level of groundwater, has forced farmers to leave their crops dry on the perimeters of Ouled Teima and El Guerdane [17]. On the other hand, and for the smallest farms that do not find another supply solution (collective borehole, agreement with the owners of boreholes, and supply from surface water resources) will have to return to rain-fed agriculture [18].

In the same context, it is known that the availability of water resources in the region, as well as the decline in availability as a result of increased demand, along with a decrease in inflows, would lead to an increase in water stress as the basin's population grows. According to the arguments of Bouchaou et al. [19], the response of water resources to climate change, as well as the agricultural and irrigation practices that arise, may have significant consequences for water resources, particularly groundwater recharge in agricultural regions. Furthermore, variations in the climate of the basin will affect the volume and timing of groundwater pumping in the basin [19]. An in-depth examination of agricultural systems is thus required in order to understand how these systems could adapt in the face of climate change. In addition, the subsistence of rural populations is strongly linked to the availability and security of water to maintain their livelihoods [20]. The abundance of low productivity crops will have tragic results. In order to adapt to climatic conditions, while ensuring a non-declining income for family work, it is important to combine the increase in irrigation needs of crops with an increase in their productivity [21]. Research can be improved by addressing gaps in assessing the impacts and quantifying the socioeconomic costs of climate change, while using econometric approaches to assess the effects on net income and profitability of agricultural activities.

Artificial intelligence (AI) or machine learning methods appear interesting and reassuring for hydrological model modeling and forecasting as well as for processing large amounts of data. For hydrological forecasts, machine learning (ML) models have proven to be very accurate in predicting river flows [22]. Many research tools and techniques of artificial intelligence have been used to solve complex problems, namely mathematical optimization methods, logic-based methods, and statistical learning and probability [23]. Artificial intelligence methods can be successfully used to simulate as well as predict groundwater time series, as well as being easily linked to numerical and conceptual models such as MODFLOW [24]. According to Tiyasha et al. [25], artificial intelligence (AI) models have demonstrated remarkable success and superiority in processing water quality data as well as being perfect tools for river water quality monitoring, management, sustainability and policy development.

Furthermore, the political, social, economic and institutional aspects of the different components of water resources need to be investigated and improved in order to achieve a better allocation and management of water. However, the limitation of the geographic scope of this research has hampered the methodology from analyzing the research on water policy, governance, economics and water management institutions. Studying the social and institutional factors that affect water governance and adaptation decision making is an important way to generate a more comprehensive understanding of the problem of water management and improve adaptation planning for future water security [26]. More effort is needed to strengthen the engagement that brings together the scientific community and civil society together in a research framework.

The climate-smart agriculture (CSA) technologies and approaches, for instance, the introduction of crop varieties that are tolerant of drought, flood and heat/cold stresses are essential to boost adaptive capacity, food security and contribute to climate change mitigation in farming systems in this region [27]. Further innovative research is required, with the primary goal of developing recommendations for the development of high yielding cropping systems by improving soil microbial diversity, as well as for the maximization of beneficial interactions between plants and their root systems and other organisms in the field, in order to reduce chemical inputs while improving ecosystem services and reducing chemical inputs. These research activities will open new potential approaches involving novel biostimulants for the improvement of crop performance through plant microbiome manipulation, as well as the introduction of new cultivars that are stress tolerance and improve plant protection to face problems derived from climate change such as water scarcity and desertification [28][29][30][31]. In order to achieve this goal, scientists from different backgrounds will need to work together closely with farmers, stakeholders, seed producers and water management specialists.

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