# A Review of the integrated WEF nexus modeling platform in the NENA region: Morocco case study

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**ABSTRACT**

Nowadays, the world is recognizing the water-food-energy (WEF) as a conceptual framework that aims to the implementation of the Sustainable Development Goals (SDGs). The WEF Nexus is being developed to support the integrity of national and more importantly local projects in the cross-sectoral partnerships and coordination to enhance the sustainable development outcomes from the different projects as well as avoiding the trade-offs. Most importantly, building a great synergy between the sectors is challenged by sectorial boundaries such as policy decisions, scaling investments, and cross-sectorial consequences, which leads to anticipation biases when it comes to social, economic, and environmental costs. This paper aims to review the latest integrated WEF Nexus modeling platform that has been developed in the NENA region during the project "Implementing the 2030 Agenda for Water Efficiency/Productivity and Water Sustainability in NENA Countries" (WEPS-NENA), led by the Food and Agriculture Organization of the United Nations (FAO) and supported by the Swedish International Development Cooperation Agency.

***Keywords:*** *Water-Energy-Food Nexus, Sustainable development, Modeling, Decision-making.*

## 1. INTRODUCTION

WEF Nexus is considered nowadays a buzzword in the sustainable development communities on national and global levels. From a macro viewpoint, the WEF Nexus, as a conceptual framework, acts on resources, material flows, technical assessments, and infrastructure development. It's recognized by international organizations (IRENA & FAO), policy analysts, academics, and many other stakeholders [1].

The main reason behind developing such a concept is that 1 in 3 people globally does not have access to safe drinkable water [2] which exposes them to water-borne illnesses. 940 million people (13% of the world population) are living without electricity [3]. The State of Food Security and Nutrition in the World (SOFI) revealed that in 2020, between 720 and 811 million people were affected by hunger, which increased due to the Covid19 pandemic. This highlights the fact that major nexus challenges are faced by householders, institutions, local businesses, and communities on a local level.

As a conceptual framework, the WEF Nexus is mainly composed of 3 subsystems that are often treated separately [2]: water, energy, and food. They're often referred to as "the nexus" when taken together. Those three domains are deeply connected and have complex interdependencies, synergies, and also trade-offs. For example, limited access to water and energy can reduce food security, while energy is highly needed in water extraction, distribution, and treatment and water is also a must for energy generation. A small action or a choice in any of these subsystems (or domains) of the Nexus can directly affect positively or negatively the others.

Although it is accepted that those subsystems are interlinked, the WEF Nexus is so far treated separately by most of the development interventions [1]. Few authors have addressed the question "How to operationalize the mainly theoretical WEF Nexus concepts?"

Specifically, this paper aims to enhance the visibility of the WEF Nexus concept and how it helps achieve

Sustainable Development Goals (SDGs) through the WEF Nexus modeling platform that facilitates the scenarios development and sensitivity analysis which is applied to the NENA countries and specifically the Souss-Massa region in Morocco as our case study.

## 2. WEF NEXUS – STATE OF THE ART

### *2.1 Overview of the WEF Nexus*

World leaders committed in September 2015 to collaborate as a part of their 2030 sustainable development agenda, to achieve 17 Sustainable Development Goals (SDGs), each goal has many targets. The water, energy and food goals (2,6 and 7) are highly interconnected. Consequently, the strategy of one of the three goals directly affects the other two. Despite the importance of moving forward to achieve the different goals, their interconnectedness triggers potential competition between the three sectors due to the sectorial boundaries.

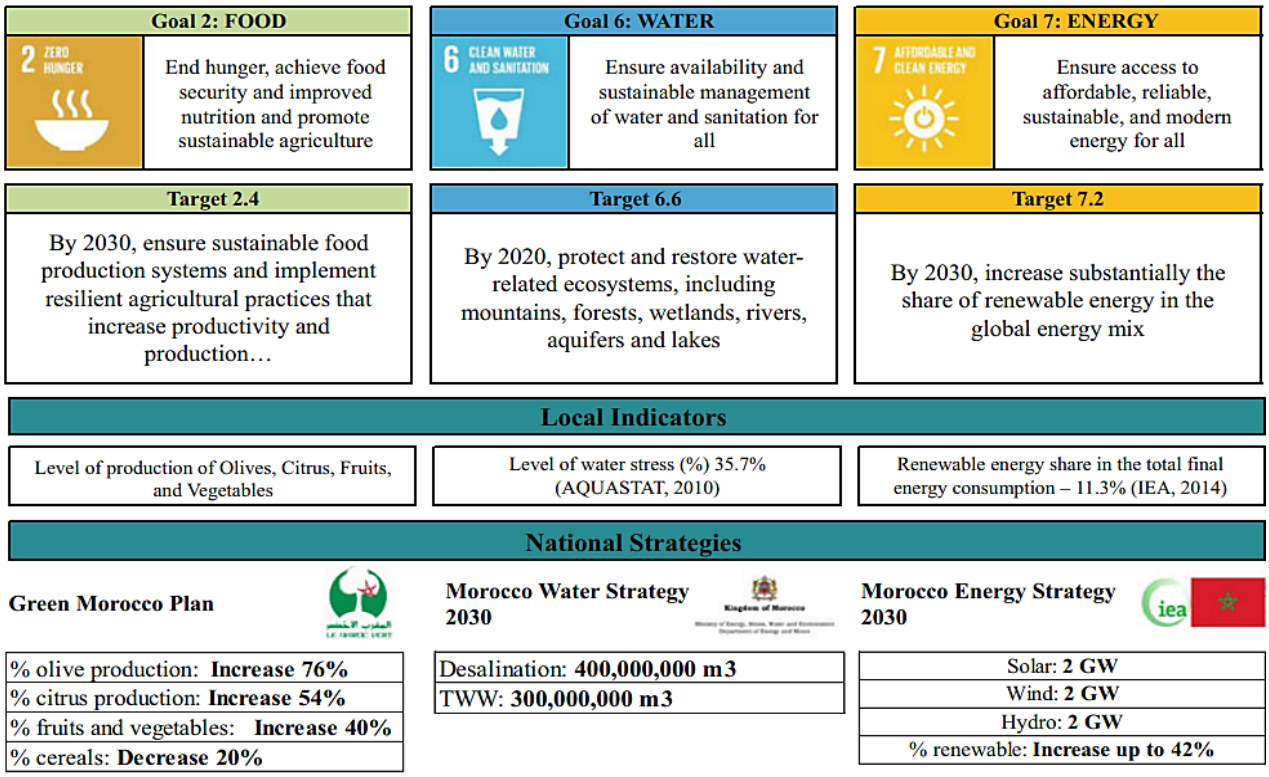
During the project "Implementing the 2030 Agenda for Water Efficiency/Productivity and Water Sustainability in NENA Countries" (WEPS-NENA), led by the Food and Agriculture Organization of the United Nations (FAO) and supported by the Swedish International Development Cooperation Agency (SIDA) was developed to gain visibility and try to highlight the different trade-offs that are associated with achieving the SDGs [4]. Morocco, as our case study, is a great example to put the light on the importance of such quantitative tools in form of an integrated WEF Nexus online platform that has been developed during this project to support the scenarios analysis of the integrated WEF Nexus on NENA countries.

### *2.2 The reason behind developing the WEF nexus in the NENA region*

The most important question to ask is, of course, why developing a WEF Nexus concept in NENA countries and what is going to be the approach and most importantly the outcome. To get a clear vision behind developing the WEF Nexus, there are mainly two big issues.

The first one is the freshwater scarcity, as we can tell, the NENA region is one of the most water-scarce regions in the world [5], with an estimated average annual precipitation being at 150mm. At the same time, the region has one of the lowest renewable water resources per capita due to the fast population growth. With that in mind, the energy and food security are threatened in all the NENA countries since the use of one of the WEF nexus element impacts the other two, and if water is a big issue, then all the nexus system is in danger and thus require an urgent call to action.

**Figure 1** WEF SDGs and Moroccan local indicators and strategies
(Source: Water-Energy-Food Sustainable Development Goals in Morocco)



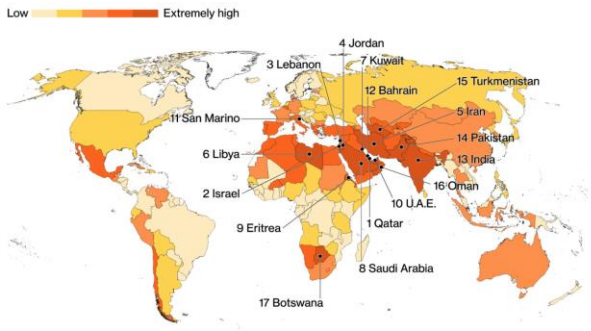



**Figure 2** Water stress (Source: World Resources Institute's Aqueduct Water Risk Atlas)

The second reason behind developing the WEF nexus is the different threats the NENA countries are facing: climate change, the decrease of water availability, the reliance on hydropower and rainfed agriculture, the irrigation demand challenges versus the hydropower capacity, the biofuel plantations, and the infrastructure that has a huge cross-systems impact.

### *2.3 Morocco as a WEF Nexus target*

Morocco's agricultural lands, which include cereal, olive, and livestock farming, have drastically shrunk due to climate change and desertification. In addition, as the population of Morocco grew, the value of total arable land per person (hectares per person) decreased from .3 to .21 between 2000 and 2018. Talking about climate change, Morocco would face a 30 percent decline in precipitation and a nearly 3-degree Celsius increase in yearly temperatures by 2050, according to the Food and Agriculture Organization (FAO) [6]. Given the importance of agriculture in the Moroccan economy, which accounts for roughly 13% of GDP [7], these dynamics will put even more complexity on a national agricultural system that is already under pressure to produce more with fewer resources and in high-variability environments.

Despite the challenging future demands for primary energy that will triple or even quadruple in the next two decades [8], Morocco's government expects renewable energy sources to account for 52 percent of total installed capacity by 2030. Renewable energy projects are aided by the Moroccan Agency for Sustainable Energy (MASEN), which provides a 'one-stop shop' for private project developers, encompassing permits, site acquisition, and finance, as well as providing a state guarantee for the investment [9]. In addition, Morocco has a great natural potential for solar, wind, and hydroelectric generation and has taken major steps to realize this potential, a major example is building the Noor-Ouarzazate complex, the world's largest concentrated solar power plant, an enormous array of curved mirrors spread over 3,000 hectares (11.6 sq miles) [10].

### *2.4 Nexus challenges in the Souss-Massa region*

Souss Massa is considered the 1st early fruit and citrus region of the country with a regional GDP of 17.3% / national of 9%, and a total of 451,165 ha of cultivated land, including 106,664 ha equipped with drip irrigation systems. The figures published by the Agency of the hydraulic basin of Souss-Massa show a considerable decline in the water reserves of the main dams supplying Agadir in drinking water. Thus, the Ibn Tachfine dam has recorded, as of September 25 of 2020, a filling rate of only 12.4%, or 36.9 million cubic meters, instead of 296 million representing its total capacity [11]. Consequently, there is a deficit on the nape of Chtouka which triggers the worries of water shortage. In addition, the energy importations are increasing more and more and the energy efficiency in Sous Massa is still being challenged to reduce carbon footprints and increase awareness of climate change, which leads to higher agricultural costs.

Two WEF Nexus dialogues were held in Souss-Massa: the first Nexus Dialogue, titled "Assessing Water Sustainability Using a Water-Food-Energy-Climate-Ecosystems Nexus Analytic Framework," was held in collaboration with the Stockholm Environment Institute (SEI) and the Royal Institute of Technology (KTH), with 30 participants from various sectors and institutions in April 2019. In partnership with SEI and KTH, the second Nexus Dialogue - Hand-on NEXUS water-food-energy analysis in Souss Massa was held in March 2020 with 30 participants from various industries and institutions. The session provided an opportunity to share preliminary nexus model results that highlight trade-offs and potential synergies in developing policies and infrastructure to improve overall water, energy, and food security [12].

## 3. THE WEF NEXUS DEVELOPMENT

### *3.1 The proposed solutions to nexus challenges*

As an urgent call to action, the Food and Agriculture Organization of the United Nations (FAO) organized a series of webinars under the WEPS-NENA project to define and give the necessary importance to the WEF nexus, identify its challenges and solutions as well as developing a practical application that supports the WEF nexus decision-making in the NENA region. The solutions to the nexus challenges were categorized into five types and were identified as "The 5Is" [13]: Institutions – Information – International Cooperation – Instruments – Infrastructure. The reason behind this categorization is the need to distinguish the different levels of activity of the WEF nexus stakeholders so that every entity is taken into account in the 5 different layers or levels of implication.

For instance, to challenge water scarcity at the institutional level, cooperation is needed between water

and energy institutions to define a plan of energy efficiency and renewables in a water system. On the informational level, the water system might have operations that could be automated and a high chance of needing training for the operations & maintenance personnel to follow the change accordingly. As instruments, we might consider the enforcement of existing laws against illegal wells and improve collection efficiency through performance-based contracting [13]. As an infrastructural action, there are many recommendations like desalination projects, solar PV water pumping, and the enhancement of the equipment. Finally, the last layer needed is enlarging the scope of international collaboration to establish common goals.

To deal with the water scarcity in the Souss-Massa region that is increasing due to over-pumping of the aquifers, electricity, and butane being the main resources for groundwater pumping and they are subsidized, finally the urgent need to generate more value per cubic meter of water. All of these challenges are putting the necessary pressure on the Souss-Massa region's stakeholders to advance in the nexus analysis and led to 3 main solutions: the first one is the implementation of the biggest project of seawater desalination for irrigation and drinking water supply in the world according to the Minister of Economy and Finance [14]. The second solution is related to the first one, knowing that the desalination project will require a huge amount of energy, which will trigger the need to supply it with solar/wind energy. The third solution is the reuse of treated wastewater to help increase water production [15].

In addition, new scenarios have been proposed for better integration of the WEF Nexus model in the Souss-Massa region. The first one is integrated strategies of the three WEF Nexus solutions combined for a strong synergy. The second scenario is called 'Green Generation', which held the reconversion of 35000 ha of agricultural areas to solar PV panels to accelerate the phase-out of butane to increase the total energy savings.

A review of the WEF nexus model was also investigated during two WEF nexus dialogues that were held in the Souss-Massa case study. This WEF nexus summarized model of Morocco contains two main modules: the supply and the demand of energy and water, as well as the key factors that coordinate between the two modules such as agriculture, desalination, wastewater treatment, etc. In this model, the food sector is

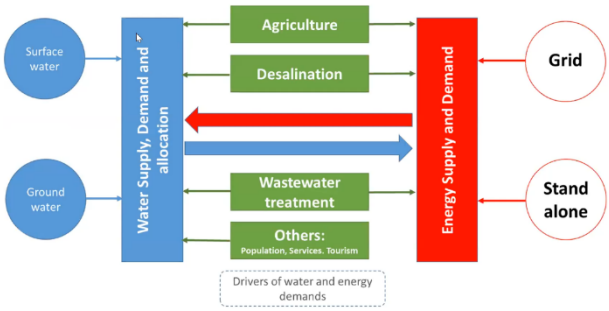


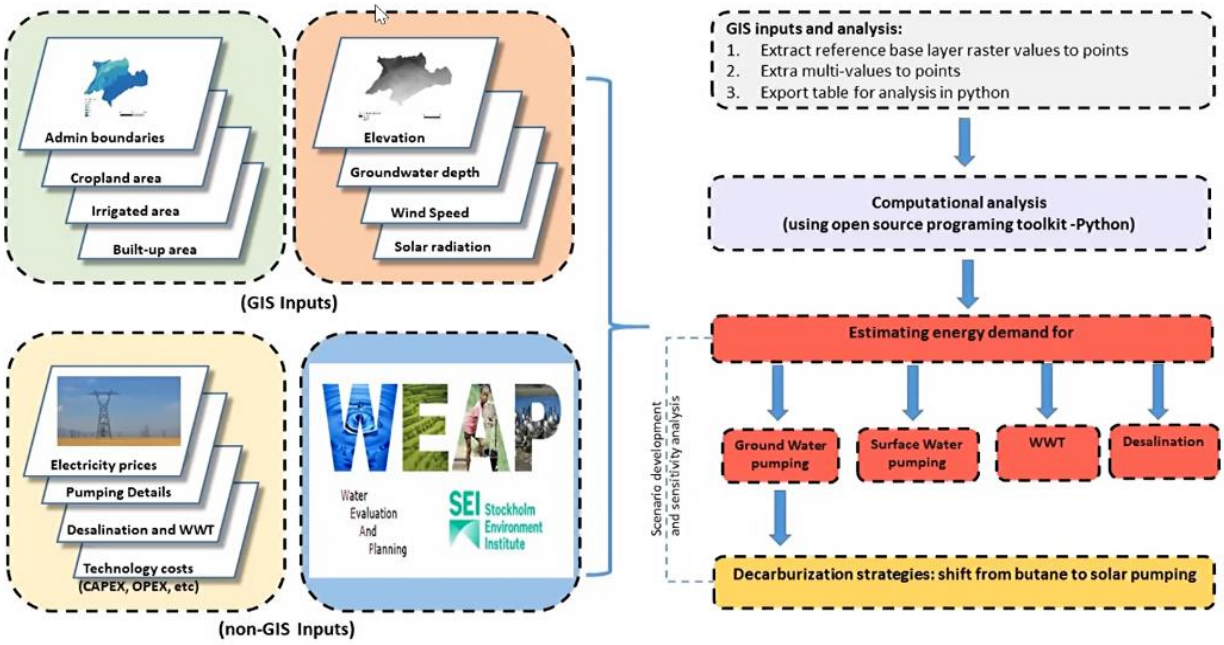

**Figure 3** The Nexus model for Morocco (Source: 2nd Water-Energy- Food Nexus Webinar series – FAO)

represented as an energy and water demand driver, but not as a WEF nexus module or subsystem.

### *3.2 The WEF Nexus online platform*

This integrated WEF Nexus online platform was shared with all participants so that they can learn to

**Figure 4** The Integrated water, energy, agriculture model for Morocco (Source: 2nd Water-Energy- Food Nexus Webinar series – FAO)



explore and interpret results through a hands-on activity in small groups and then report back in plenary on their experiences of the integrated WEF nexus during Morocco's Nexus dialogues. It was meant to explore the modeling results of the project titled "Implementing the 2030 Agenda for water efficiency/productivity and water sustainability in the Souss-Massa River basin in Morocco". This platform is based on two types of input data: geographic information systems (GIS) and non-GIS inputs to generate the mathematical calculations for the different scenarios, it is implemented on the Cloud Application Platform Heroku as a built data-driven web application using python.

GIS inputs are mainly maps of the groundwater depth, elevation difference, cropland area, built-up area, water network, and all the key elements that are present in the study area such as the desalination project. On the first hand, non-GIS inputs are some technical specifications like the costs of energy and technology as well as other details related to technology (CAPEX, OPEX, etc). On the other hand, the Water Evaluation and Planning (WEAP) is a tool that provides generic water resources management modeling as a non-GIS input to the online platform as it also evaluates the scenarios aimed at balancing the water supply and demand, it has been developed by the SEI.

In this platform, WEAP has been used to estimate water supplies based on climate routines that are capable of calculating the rainfall-runoff and groundwater recharge [16]. It calculates water use patterns for the major water sectors, analyses agricultural yield under various climatic scenarios, and assesses the impact on energy and water systems. In addition, the energy component uses GIS-based approaches to predict energy needs for groundwater and surface water pumps, new water desalination projects, and big wastewater treatment plants. Finally, low-cost electricity generation technologies for the water and agricultural sectors are discovered.

Using None of the interventions means that the domestic demands are assumed to increase over time with a growing population of 1.4% per year and the total irrigated area is assumed to stay constant. The wastewater reuse scenario considers the implications of augmenting irrigation water supplies with effluent from existing and planned wastewater treatment plants. To assess the full potential of wastewater reuse to meet water demands within the basin, it is assumed that all of the discharge from these facilities could be used to meet irrigation requirements within irrigation perimeters closest to the treatment plant. Moving to the desalination scenario, it adds 275,000 m3/day of desalination capacity in 2021, of which 150,000 m3/day for Agadir and 125,000 for m3/day for Chtouka agriculture [17], expanding to 450,000 m3/day in 2030 with equal share between both regions. For many of the crops that are grown within the Souss-Massa River basin, improvements in irrigation, fertilizer application, soil tillage, and farming practices have resulted in sustained increases in yields over the past couple of decades. This increased water productivity scenario explores the potential for these advances to mitigate the overuse of water resources within the basin (primarily groundwater overdraft). That is, to what extent can groundwater drawdown and associated pumping costs decrease if less water can be used to maintain the current level of agricultural production within the basin.

The integrated strategies as a scenario combine strategies of augmenting water supplies through seawater desalination and wastewater reuse and mitigating irrigation water demand through increased water productivity. Finally, the green generation extends the integrated scenario by considering the expansion of

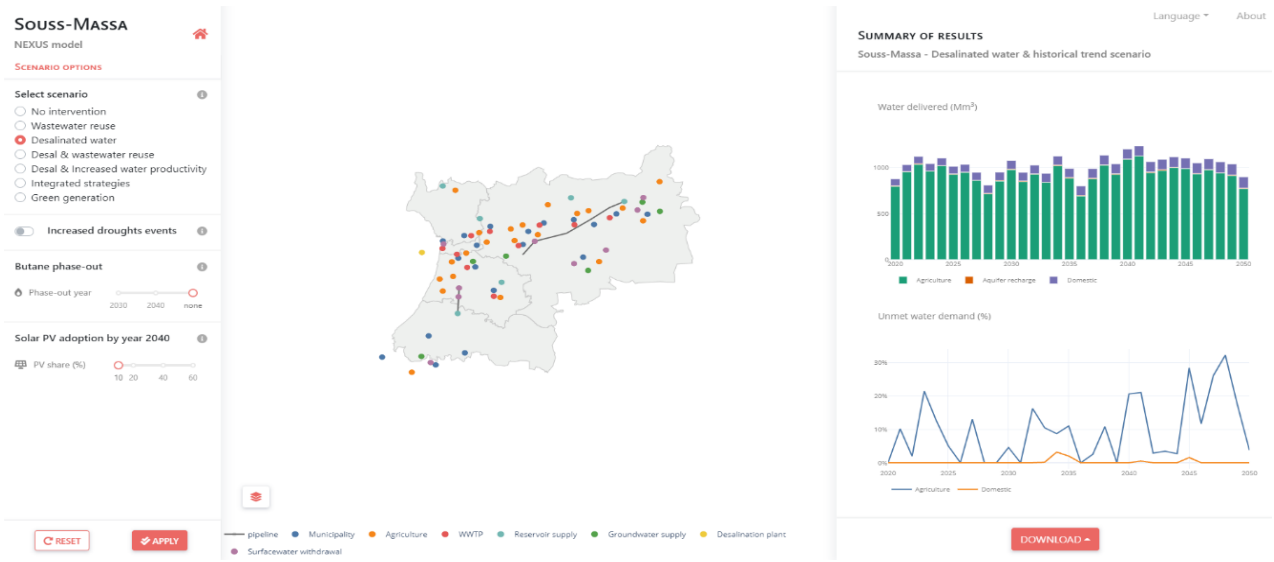



**Figure 5** The Souss-Massa online WEF Nexus scenario-based modeling platform (Source: Souss-Massa nexus platform)

reservoir storage (at Mohktar-Soussi) by 167 million m3 and reconversion of 35,000 ha of agricultural areas to solar PV.

Climate changes are also taken into consideration: either it is the current temperature trend and historical precipitation (from 1980 to 2010) or it is a higher rate of temperature increase and a repeat of the historical dry period (from 1980 to 1987). Additionally, three butane phase-out scenarios can be explored: an early phase-out, which assumes a complete phase-out of butane by 2030, a late phase-out, which assumes a complete phase-out of butane by 2040, or business as a usual scenario, which assumes the current share of butane use to continue. Similarly, for the solar PV adoption, a high PV share assumes an increase of PV share from 10% to 50% by the year 2040, a moderate PV share assumes an increase of PV share from 10% to 20% by the year 2040 and the low

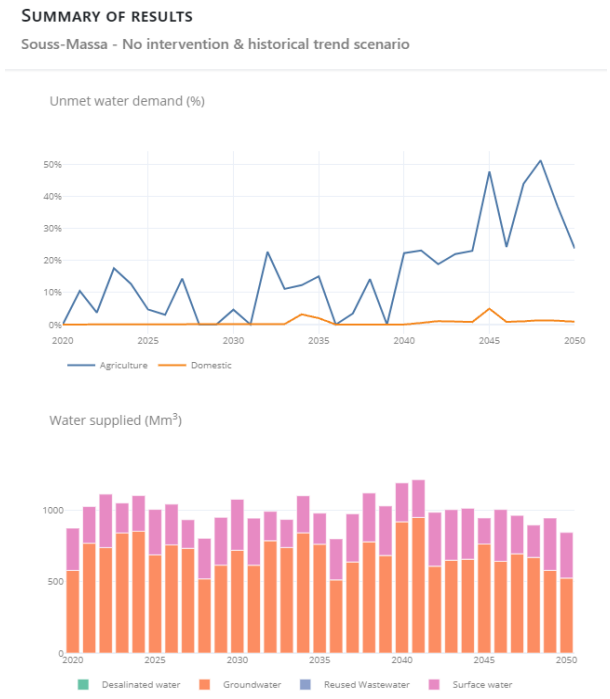



**Figure 6** Example of the displayed results of the "No Intervention" scenario with 10% share of Solar PV adopted in 2040 (Source: Souss-Massa nexus platform)

PV share which assumes the current level of PV share of 10% to continue in the future.

With all these scenarios in hand, we can easily analyze the historical trend scenarios through the different displayed graphs in the platform: water delivery per mm cube, unmet water demand (%), water supplied per mm cube, energy demand per gigawatt hours (Gwh), depth to groundwater per meters-below ground level (Mbgl), crop production per ton, energy for agriculture water pumping per Gwh, PV installed capacity per megawatt (MW), Yearly emission in agriculture per metric tons of carbon dioxide equivalent (MtCO2) and at last the total annual system cost per million Moroccan dirhams (mMAD).

## 4. RECOMMENDATION

A great way to revolutionize the decision-making concerning the different scenarios of the WEF Nexus in the NENA region is to implement an intelligent decision support system (IDSS) which is a decision support system (DSS) that has similar functionalities to the platform we have studied but with much more powerful use that comes from the integration of artificial intelligence (AI) and its techniques to support the decision-makers by acquiring and analyzing facts, identifying and diagnosing problems, suggesting and assessing potential lines of action. The majority of AI research about the WEF nexus management has taken a technological approach, ignoring the importance of management tools and the business model concept. The majority of the publications lacked a theoretical framework; however, experts understand the importance of a multi-stakeholder approach and the relevance of AI and other digital technologies in addressing the WEF nexus dilemma. As an example of the use of the AI in a WEF nexus DSS, determining the quality of desalinated/extracted water and assuring its efficient distribution for diverse

uses (home, industry, and agriculture) [18], as well as the use of wastewater for energy, fertilizer, and irrigation. An integrated IDSS in the WEF Nexus planning and management approach promises increased resource efficiency, new business opportunities, more consistent resource and environmental policies, and economies of scale for data and information services, all of which support better decision-making [19].

## 5. CONCLUSION

This preliminary study highlights the interactions between the three subsystems of the WEF Nexus in Morocco as a country and Souss-Massa as a major exporting region. It also reveals the different scenarios that are built-in functionalities of the WEF Nexus platform. With this online platform on hand, the cross-sectorial impact analysis is ready with some simple clicks. This quantitative tool will improve the decision-making concerning the WEF Nexus projects and scenarios in the Souss-Massa region with the data-driven intelligence and computational analysis facilitated using open-source programming with python. A major upgrade of this platform could be the cross-regional scenarios studies such as the possibilities of transferring energy and water between regions to create an equilibrium and a better synergy between the major WEF Nexus actors in the country.

## AUTHORS' CONTRIBUTIONS

Mohamed Zakaria Hazig: Original draft preparation, study conception, and design, data collection analysis, interpretation of results, and manuscript preparation.

Afaf Dadda: Supervision, data collection, reviewing, and validation.

Brahim Ouhbi: Supervision.

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