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Development a Framework for Assessment of Water Security in Egypt

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Abstract

Water Security is very urgent for sustainable development in Egypt. Growing population needs more food production, water for drinking, hygiene, and to respond to economic activities which rely on access to more water. The objective of this paper is to develop an operational and applicable framework for assessment of water security index for Egypt. The water security index for Egypt was calculated according to the methodology of the Asian Water Development Bank Outlook (AWDO) using 2020 data and it was found that the water security situation is below average and huge efforts are needed to enhance this indicator in order to meet the current water challenges. After applying AWDO methodology for assessment of water security and its five indicators, it was found that some of them are misleading and some are not applicable to Egypt. In this paper, a modification for the indicators will be proposed to be more relevant to Egypt and to be more practical. The modified framework and its new indicators have represented the situation in Egypt with the challenges of an arid and extremely variable climate. The modified water security index evaluation methodology is also used in light of the Egyptian local conditions in predicting the indicator Water security for 2030 based on the assumed expectations of three water shortage scenarios. These future scenarios helped draw a road map for the necessary measures needed to secure the water situation and thus economic growth.

Keywords: Water Security; AWDO; Modified framework; scenarios; WSI.

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1. Introduction

Water is the source of life and a critical input in nearly every socio-economic activity. Egypt located in an arid region, with limited water resources. The Nile River is the main sources of water; it contributes around 97% of renewable water resources of Egypt. Egypt faces great challenges, fixed share of Nile water, limitation of groundwater, limitation of rainfall and desalination water. On the other hand, climate change and its effect on water availability in Egypt. In addition to the mentioned challenges, population rapidly increases and, with the limited water resources the gap between water resources and demand will be increase. It should be noted that we need to have a tool to guide the water security in Egypt, by using this tool we can manage the water uses and improve the water security currently and in the future [1] However, water scarcity, water stress and water poverty and many other terms have been widely used to describe the water situation to any country but it didn't cover all the areas such as economic, social, water quality etc [2]. In the current research, water security index tool will be used to assess the water security for Egypt, enhancement the currently and future situation will be discussed and the good and weakness in the management process will be identified [3]. Water security, which defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies [4] can be good alternative because it includes both physical and economic meanings to water. The current paper will focus on developing a framework using Water security index to evaluate Egyptian water security and to help the decision maker taking the right action for better water management.

2. Different methods for intouducing water security index

2.1 Water Security for Basic Needs

The International Water Management Institute (IWMI) formulated a conceptual framework to estimate the water security for basic needs based on five KDs proposed by [4] namely basic needs , agricultural production, the environment, risk management and independence. Table (1) shows the component and definition and scoring system for the International Water Management Institute framework.

Table 1: Basic needs framework, IWMI, Battaramulla, Sri Lanka, [5]

Overall water security = A + B + C + D + E				
Component	**Definition**	**Scoring system**		**Source**
A = Basic household needs	Proportion of population with sustainable access to an improved water source	High proportion of population with access to improved water source = 5, to low proportion of population with access to improved water source =1		WHO, 2009
B = Food production	The extent to which water is available and harnessed for agricultural production	Water security for agricultural production = (a + b)/2		FAO AQUASTAT, 2007
		a. Water availability (RWR/person)	From low availability = 1 to high availability = 5	
		b. Water use (withdrawal/person)	From low withdrawal = 1 to high withdrawal = 5	
C = Environmental flows	Proportion of renewable water resources (RWR) available in excess of environmental water requirement (EWR). That is, [RWR – (environmental water requirement + withdrawn water)]/RWR×100	High proportion above EWR = 5, to low proportion above EWR = 1		Converted from Smakhtin et al., 2004
D = Risk management	Risk management measures the extent to which countries are buffered from the effects of rainfall variability through large dam storage	Risk management = (a + b)/2		ICOLD, 2003; FAO AQUASTAT, 2007; Mitchell et al., 2002
		a. Inter-annual coefficient of variation (CV)	From low CV = 5, to high CV = 1	
		b. Storage	From high storage = 5, to low storage = 1	
E = Independence	Independence measures the extent to which the country's water and food supplies are safe and secure from external changes or shocks	From low dependence on external waters = 5 to high dependence = 1		WRI, 2009

2.2 Approaches for Framing and Assessment of Water Security

There are two approaches for formulating water security. First one is based on the risk assessment, vulnerability and climate variability and water-related disasters. Canadian experience is an example of risk management approach. Second one, depending on improvement over time and requires inter sectorial multi stakeholder consultation to identify the important key dimensions of water security Asian Water Development Outlook is one example of the development based approach [6].

2.2.1 Water Security Indicators Based on the Canadian Experiences

In 2008, the water governance Canadian Program conducted an inventory of all freshwater-related indicators. The suggested water security assessment is including water quality and water quantity-related variables and their relation to aquatic ecosystems and human health. The suggested assessment included also risk assessment into governance practices" water quality and quantity" risk. They said that by considering the above we can also evaluate the changes in land use, climate change, and water demand changes. The Framework of water security risk assessment framework was based on the hydrological conditions of the watershed including quality and quantity of surface and groundwater beside the risk assessment approach [7]. Water quality risk assessments are based on vulnerability, hazard, and impact on human health consequences. Although the suggested approach is unique as it is based on risk assessment, however it has no methodology for estimation and calculation the water security index.

2.2.2 Asian Water Development Outlook "AWDO "

The Second example is the Asian Water Development Outlook 2013 [8] is a framework for national water security based on household, sanitation needs, water productivity, urban water security, ecosystem and resilience to water related hazards. It has a clear methodology and calculation method used by many countries.

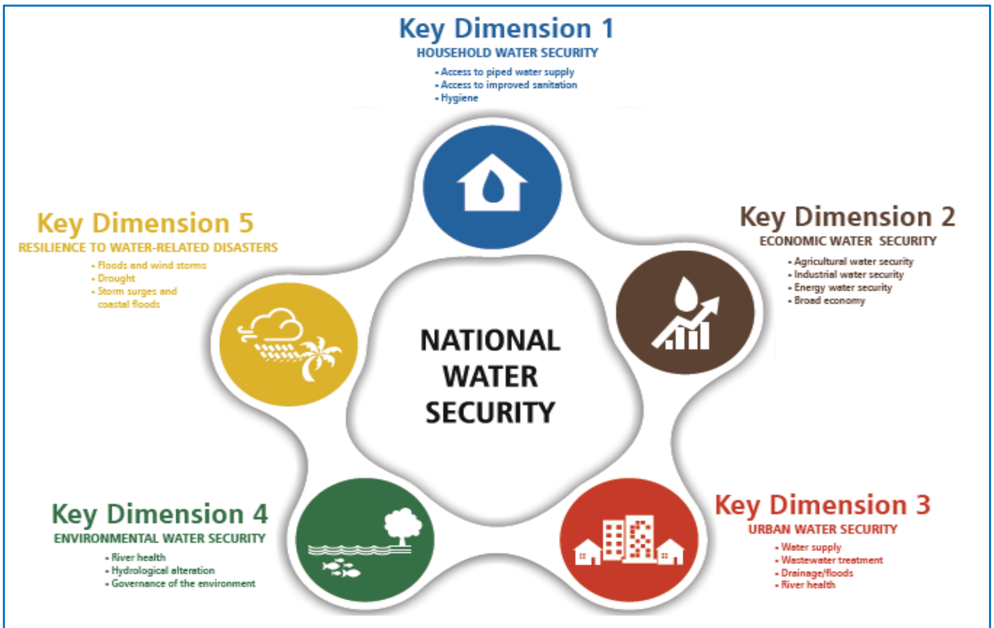
3. The appropriate water security index for egypt

From the above section, a way to find the different dimensions and perspectives of Water Security will be addressed [9]. A multidimensional frame, on which we can assess water security index and identify the different ways to improve it will be developed. In the current paper , the following points will be considered :-

- Reaching a consistency in terminology and agree on a key indicators and sub-indicators.
- Avoid the frameworks which use the weighting factors
- Assessing water security in different scale
- Put indicators which can used to calculate the water security both for the current baseline and Future scenarios

Considering all these aspects, it becomes clear that we are looking for combining, a standard set of indicators that can be consistently applied at all scales and regions, As AWDO is the most clear and international used and has a methodology which has been updated many times, so we are going to use it as a base for WSI calculation for Egypt.

3.1 The Asian Water Development Outlook AWDO 2013-2016



Source: ADB.

Figure 1: ADWO five dimensions, source, ADB 2013 -2016

The Asian Water Development Outlook (AWDO) has been prepared by the Asian Development Bank (ADB) and the Asia-Pacific Water Forum (APWF) in 2007. It introduced a quantitative measurement of water security and provided a baseline against to measure WS based on five key dimensions (KDs): household, economic, urban, environmental, and resilience to water-related disasters Figure (1). The overall national water security of each country was assessed as the composite result of these five key dimensions.

By using the third edition AWDO 2016, Water Security Index "WSI" for Egypt has been calculated; it is 2.46, using the data from [10, 11, 12, 13, and 14]. Figure (2 & 3) show the WSI Key Dimensions and Parameters values based on AWDO methods.

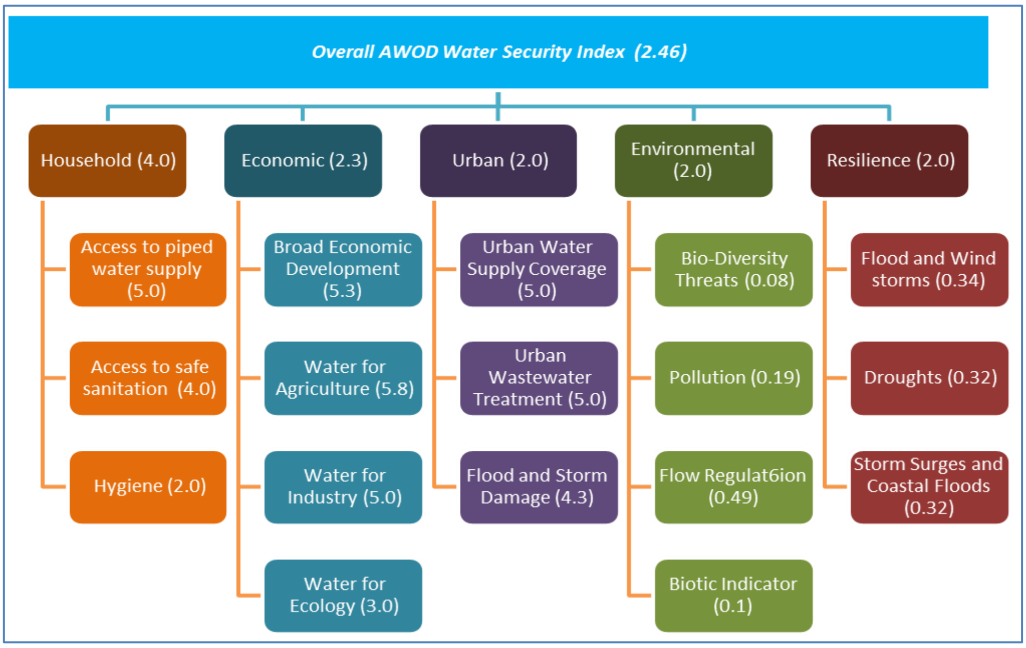


Figure 2: Overall AWDO Water security Index for Egypt

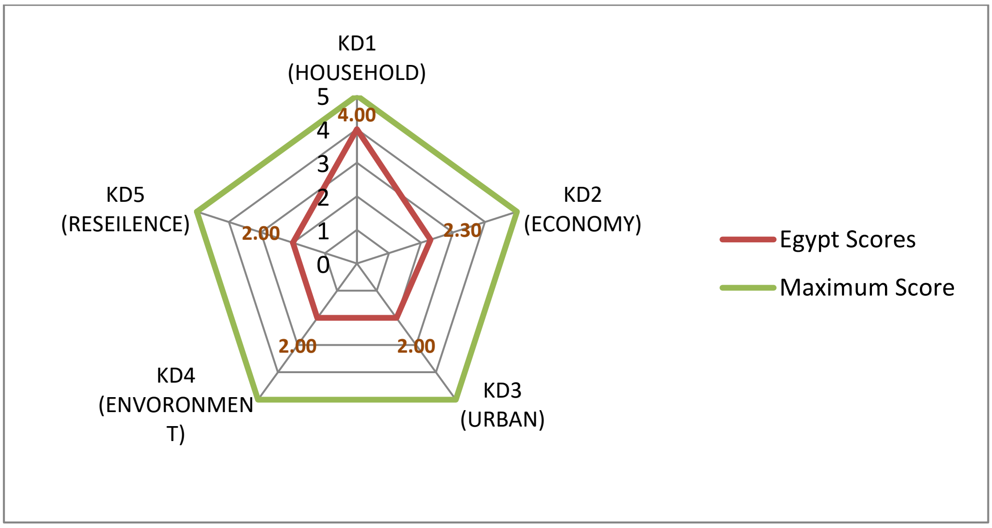


Figure 3: key dimensions of Egypt's water security index

From the Above, WSI is 2.46 this is according to AWDO classification between **Engaged and Capable,** as shown in table (2)

Table 2: National Water Security assessment [8, 15].

NWS Index	NWS Score	NWS Stage	Description
5	96 and above	Model	All people have access to safe drinking water and sanitation facilities; economic activities are not constrained by water availability; water quality meets standards for people and ecology; and water-related risks are acceptable and relatively easy to deal with.
4	76<96	Effective	Nearly all people have access to safe drinking water and sanitation facilities; water service delivery is mostly formal and effective to support economic development; water quality is in general acceptable and attention is given to ecological restoration of water bodies; and water-related risks are seriously brought down by infrastructure and warning systems.
3	56<76	Capable	Access to safe drinking water and sanitation facilities is further improving, also in rural and poor areas; water productivity in economic activities has improved; water quality is improving through regulation and wastewater treatment; first measures are taken to restore ecological health of the water bodies; and the most serious water-related risks are being addressed.
2	36<56	Engaged	More than half the people have access to modest drinking water and sanitation facilities; water service delivery is starting to develop, supporting economic activities; first measures are taken to improve water quality; and first attempts are being made to address water-related risks.
1	0<36	Hazardous	Drinking water and sanitation facilities are limited and impose serious health risks; water service delivery is mostly informal and a constraining factor for economic activities and development; water quality is poor and dangerous for people; serious damage to aquatic ecology is present; and droughts and floods drive people into poverty.

NWS = national water security.
Source: ADB.

3.2 The Proposed Framework Methodology for the Egyptian WSI

After applying AWDO to calculate the Water Security index for Egypt, there is a need to use other parameters which are more relevant with the Egyptian case. In the current paper a modified framework with five key dimensions, with parameters related to the Egyptian local conditions will be used. In the following paragraphs, the five key dimensions will be introduced with some clarification. For Key Dimension1 KD1, **Water Availability** instead of household water security in AWDO is used to include not only the access to drinking water and sanitation but also to include water scarcity, water consumption, available water resources, per capita share, water scarcity, inter annual rainfall, intera annual rainfall, proportional of external water resources and reservoir storage. In addition to piped water supply and access to sanitation. All these indicators give a complete picture about the situation of water resources in Egypt and give a clear indication to use in WSI assessment. For Key Dimension2 KD2, **Water Productivity** most of the AWDO indicators are kept, but we used some indicators from it in water availability KD1 such as , water stress, storage (dam capacity), and inter and intra-annual rainfall variability as it is related more to the concept of KD1 . In KD2, food security indicator is introduced as it is very important to get a full indication of water productivity which missed in AWDO methodology. For Key Dimension3 KD3, AWDO includes urban cities only which is misleading indicator as the current paper is about National Water security not urban only. Instead of that the dimension KD1"water availability" takes into consideration the urban and rural areas at the same time. So there is a repetition in some sub-indicators such as access to drinking water and sanitation which we already take it into consideration in

KD1. So in our proposed framework, KD3 is an indicator for **Water Related Disasters** in which we concentrate on the flood and draughts disasters which Egypt can most probably face. For floods, from a long time we have High Aswan Dam which protect the country from river floods, however the probability of GERD dam failure makes HAD at a risk. So to take flood risks into account is very important in addition to expected coastal floods due to sea level rise and climate change. It will also include draught disasters as Egypt is an arid area and rain is very limited, climate change and upstream development projects is a factor also to take draughts as a very important indicator when we study the Water security. KD3 in the proposed framework is replacing the KD5 in AWDO methodology but we exclude Storm and cyclone which is not applicable for the Egyptian case. On the other hand, hard and soft coping sub-indicators were moved to Governance indicator. For Key Dimension4, KD4, **Environmental Water Security,** in AWDO methods there are a lot of drivers which is very difficult to measure and it was taken as a weight which depend on the expert opinion , that is make it not accurate and change from expert to another. On the other hand, the system in Egypt is different as we have the river, irrigation canals, drains, groundwater and coastal Lakes [16] which must be included in water quality index or river health indicators which will be included in the proposed frame work we exclude all the sub-indicators and drivers which is not related to Egyptian situation and include water quality index from canals, lakes and ground water [17]. The biodiversity , habitats and species are also assessed [18]. For Key Dimension5, KD5, **State Capacity**, this is a new key dimension in the proposed framework , which including Water governance which has political stability as a parameter under it, as we know Water governance is the set of social relations, or system, that determines who gets what water/services, when and how. 'Good governance' is thus crucial for improving access to water and sanitation services. It includes establishment of rules, responsibilities, operating mechanisms, policies, and user and official accountability systems. Effective governance is that which provides water for livelihoods and economic growth, yet maintains a sustainable environment. Improving water governance is therefore essential to improve water security for Egypt. We miss this indicator in AWDO that is why we fill the gap by introducing this very important indicator in our proposal framework. Policy, rules, stakeholders participation, regular monitoring and evaluation and financial resources allocation all of these sub-indicators and more we include in our Governance index. On the other hand KD5, Sate capacity includes other parameters as economic growth capacity, social stability, and transboundary water cooperation including tensions and conflicts over transboundary water share. The use of water resources generates political disputes between countries sharing waters within their borders. So it is very important to include transboundary indicator in our water security index frame and some sub-indicators such as hydropolitics, and water diplomacy with upstream countries, SDG 6.5.2 and Status of existing transboundary water treaties and institutions. On the other hand, economic growth capacity with its sub- indicators such as GDP growth rate Share of shadow economy (% of GDP) and others are very important and have a direct impact on water security. Social stability with its very important sub-indicators such as human development index, unemployment and literacy were missed in ADBO, although it has their direct impact in water security. Each indicator is measured with respect to specific variables. The modified framework is presented in figure (4).

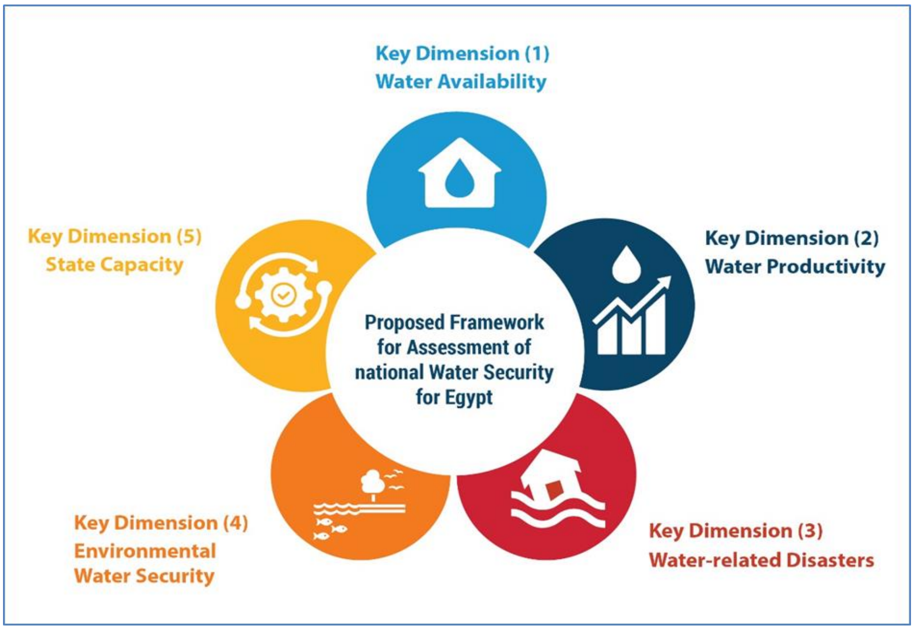


Figure 4: Proposed Framework for Assessment of national Water Security for Egypt

3.2.1 Overall Water Security Index by the Proposed Framework

Table 3: Interpretation of the Water Security Index

Water Security Index Score	Water Security Condition	AWDO National water security stage	Description
1	Very Poor	Hazardous	The basin is highly insecure with respect to most of the dimensions of water security. The basin is affected by server water-related problems. Furthermore, the management and governance in the basin are inefficient.
2	Poor	Engaged	The basin is insecure with respect to most of the dimensions of water security. The basin is affected by some water-related problems. The management instruments are in place but are still to yield the intended results.
3	Average	Capable	The basin has mixed water security with respect to the dimensions of water security. There are patches of water-related problems in the basin, Governance and management instruments are in place but are still to yielding most of intended results.
4	Good	Effective	The basin in quite secure with respect to most of the dimensions of water security. There are hardly any water-related problems in the basin. The governance and management instruments are yielding in the intended results.
5	Very Good	Model	The basin is highly secure with respect to all the dimensions of water Security. There are no water-related problems in the basin. The governance and management instruments are yielding the intended results

Using the aggregation technique described above, the variables are to be aggregated to arrive at an indicator score between 1 and 5; then the indicators are to be aggregated to represent the key dimension score; and finally the aggregation of key dimensions will lead to the overall WSI, which will also have a score between 1 and 5.

Hence, WSI = Sum of (KD1 + KD2 + KD3 + KD4 + KD5) scores / 5, where:

KD1 = Water availability, KD2 = Water productivity, KD3 = Water-related disasters, KD4 = Environmental water Security, and KD5 = State Capacity

According to the modified framework, the overall Water Security Index (WSI) for Egypt scores 2.45, according to the Interpretation of the Water Security Index; this means that the water system in Egypt is classified as between **average and poor,** as shown in Table (3), which has the same range in the original AWDO score “capable and engaged”. Figure (5&6) show key dimensions of Egypt’s water security index.

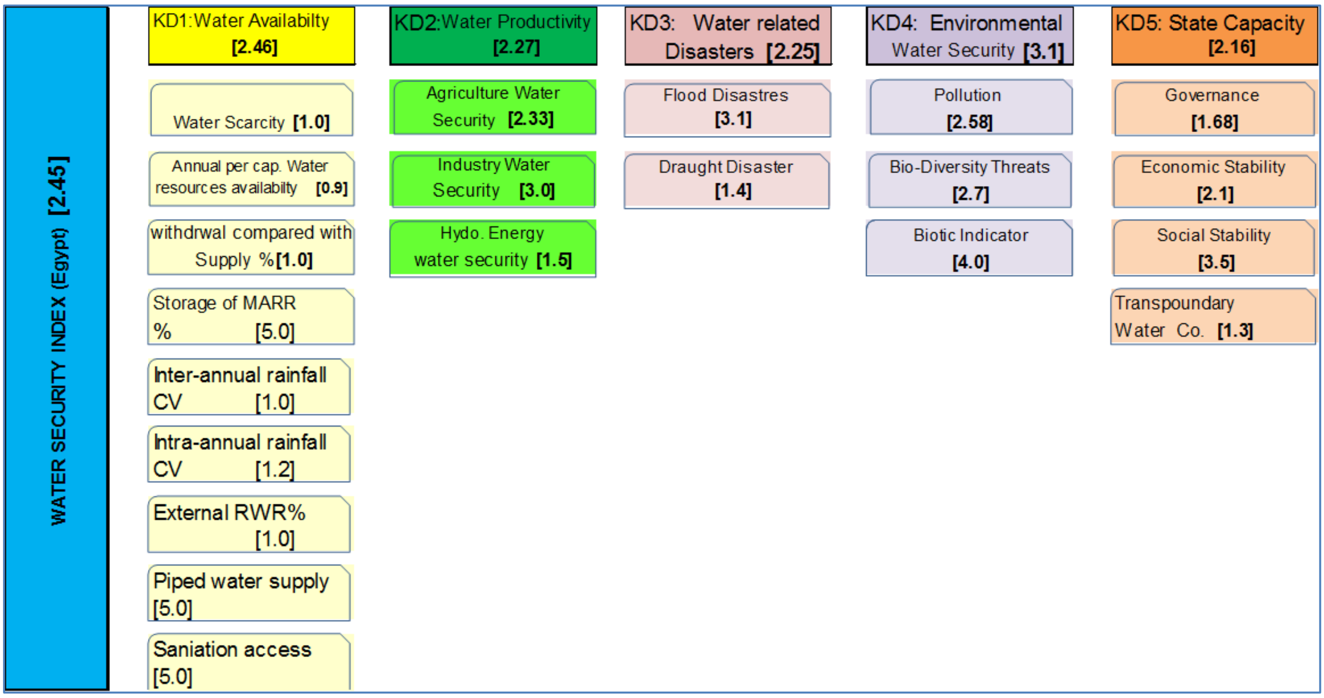


Figure 5: key dimensions of Egypt’s water security index

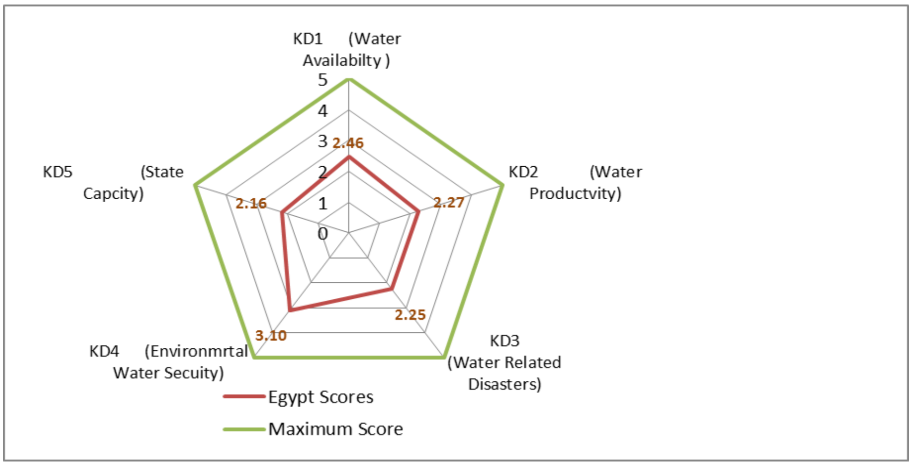


Figure 6: key dimensions of Egypt’s water security index

3.2.2 Recommended Measures to Improve WSI

To Improve WSI, some measures need to be applied which enabling the environment for the better use and treat of water as following:

1. KD1, Water Availability can be improved through implementing measures to protect public health such as launch public awareness campaign, allow sufficient finance to protect public health, reducing the access to polluted water in rural area.
2. KD 2, Water Productivity, can be improved by enhancing agricultural efficiency and Productivity through raising water conveyance and distribution efficiencies of the irrigation system. This could be achieved by applying canal lining, applying continues flow regime, improving *mesqas* with single point lifting, and through increase investments to improve / rehabilitate the old irrigation structures. On the other hand, replacing high water consumptive crops by high value crops, improving Industrial water use efficiency through applying modern cooling systems.
3. KD3, Resilience to Water-Related disasters, can be improved by enhance the strategic planning to face the flood and draught risk , to implement some measures to be adopted with the coming drought such as , enhance cultivation crop pattern which consumed less water , salt tolerant crops , Integrated Coastal Zone management to protect delta from climate change impact. There is a need to take necessary mitigating measures to ensure the minimum possible damage to the coastal areas and consequently guarantee the index would not negatively influenced. Putting high investments to protect the cities vulnerable to flash flood in Red Sea and Sinai areas is expected to enhance the index.
4. Key Dimension (KD 4), Environmental Water Security, can be improved by increase investments in water sector and reduce water pollution in the waterways. By increase the WWTP, By Avoid throwing solid waste in water ways , applying polluter pay principle, protect the North lakes, etc.
5. Key Dimension 5 KD5, State Capacity , can be improved by improving Human development Index, by enhancement the cooperation with Nile Basin countries, strengthen the political stability and economic to enhance KD5. Improving the governance in the country , by reducing the corruption index, strengthen laws and legislation that is will affect positively in WSI.

4. Future water scenarios by the year 2030

4.1 WSI for the Year 2030

By using the proposed framework, we assumed three water shortage scenarios in which we will only reduce one variable, which is the Nile water share, and we fixed the other water resources parameters to see the impact on the water demand and the WSI parameters (NWRP, 2030). We started by calculating the WSI for the year 2030 with the Normal Nile Share 55.5 BCM, Figure (7) the WSI Key Dimensions scores in the Normal Case .

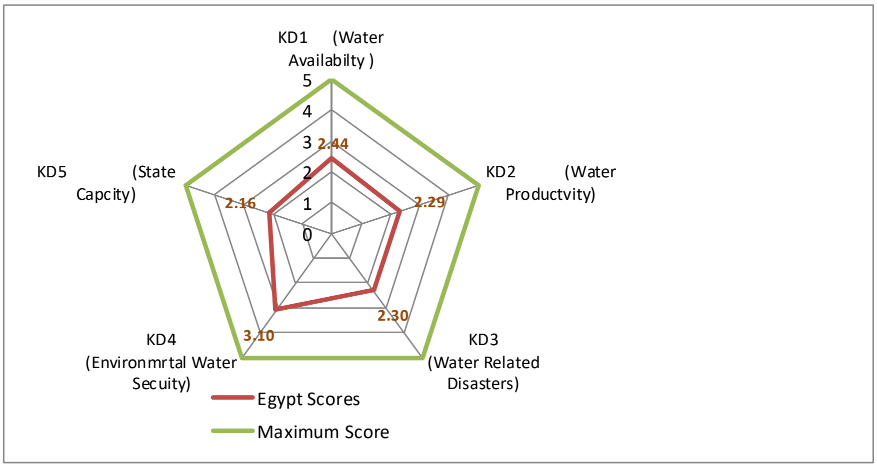


Figure 7: WS Key Dimension for the year 2030 with water Nile 55.5 BCM

4.2 First Water Shortage Scenario

In this scenario the Nile water discharge at Aswan will be reduced to 50.5 BCM, to face this situation, the allocated water for agriculture will be reduced by 5 BCM to be 58.76 instead of 63.76BCM. The rice cultivation area will be reduced to 700,000 feddan from 1.1 million feddan, sugar cane cultivation will be panned in 320000 feddan, and water melon cultivation will be panned in 163000 feddan. Accordingly, the agricultural production loss will be 38 Billion LE, while the total economic loss including import alternative agricultural products will be 5 Billion US$, Figure (8) shows the WSI KDs for the first scenario

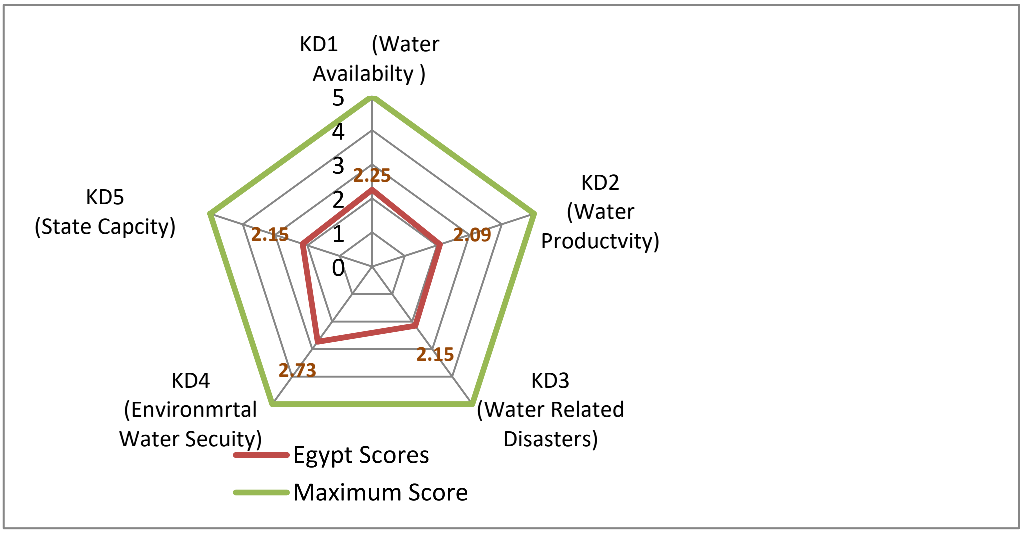


Figure 8: WS Key Dimensions for the year 2030(reduction with 5 BCM from Nile Share)

4.3 Second Water Shortage Scenario

In the second scenario the Nile water discharge at Aswan will be reduced to 45.5 BCM, to face this situation, the allocated water for agriculture will be reduced by 10 BCM to be 53.76 instead of 63.76BCM. The rice cultivation area will be reduced to 700,000 feddan from 1.1 million feddan, the sugar cane cultivation will be banned in 320,000 feddan, the banana cultivation will be banned in 85000 feddan, water melon cultivation will be banned in 163,000 feddan, and reduce the maize cultivation area by 50%. The agricultural production loss will be 66 Billion LE, while the total economic loss including import of alternative agricultural products will be 8.4 Billion US$. Figure (9) shows the WSI KDs for the second scenario

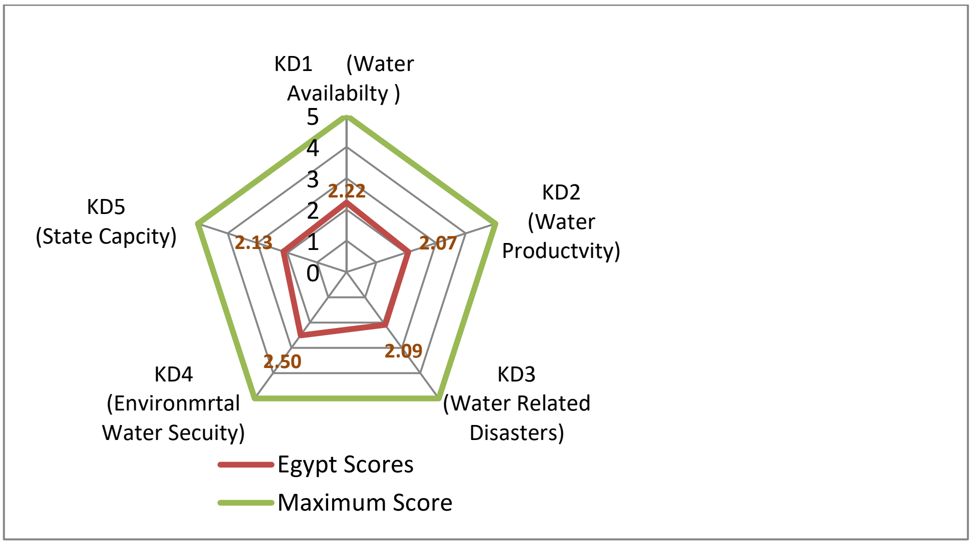


Figure 9: WS Key Dimensions for the year 2030(reduction with 10 BCM from Nile Share)

4.4 Third Water Shortage Scenario

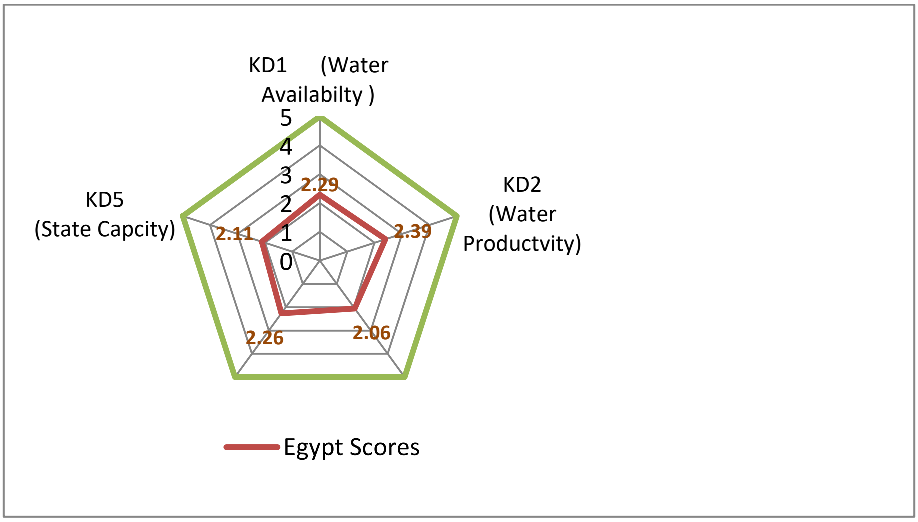


Figure 10: WS Key Dimensions for the year 2030 (reduction with 15 BCM from Nile Share)

In the third scenario, the Nile water discharge at Aswan will be reduced to 40.5 BCM, to face this situation, the allocated water for agriculture will be reduced by 15 BCM to be 48.76 instead of 63.76 BCM. The rice cultivation area will be reduced to 700,000 feddan from 1.1 million feddan, the sugar cane cultivation will be banned in 320,000 feddan, the banana cultivation will be banned in 70,000 feddan, water melon cultivation will be banned in 163,000 feddan, and the maize cultivation area by 80% to cope with the available water resources. The agricultural production will be 95 billion LE, while the total economic loss will be 12 billion US$ including the loss of the poultry and livestock sectors. Figure (10), shows the WSI KDs for the third scenario.

4.5 Overall WSI in the future scenarios

By using the proposed Water Security Index framework we calculate the WSI for the three water shortage scenarios. The expected water security index for 2030 scenarios is between engaged and capable. The WSI is 2.44 in case of optimistic scenario of 2030 where The Nile annual water Budget is 55.5 BCM, while it slightly decreases to 2.28 during the first pessimistic scenario at which only 5 BCM of Nile water will be decreased from Egypt's quota. The coping capacity and mitigation measures against drought will be effective to keep WSI in 2.28. On the other hand, the coping capacity and mitigation measures cannot withstand a decrease of 10, and 15 BCM in the Egypt's quota resulting in a water security index WSI of 2.2 and 2.14 respectively. Figure (11) shows the Overall Water security for the three water shortage scenarios.

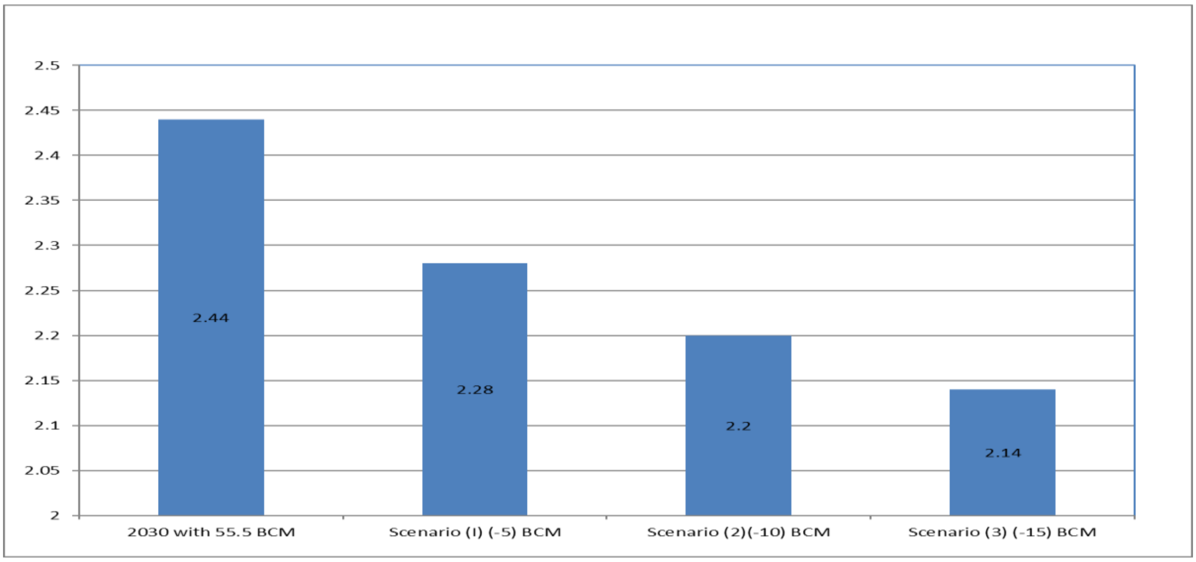


Figure 11: Overall Water security for the three water shortage scenarios

As shown in Figure (12), the reduction of water share will affect mainly in KD1 Water Availability as it depends on the water share, on the other hand, KD4 affected by the shortage of water , because the reuse will be increased to fill the gap between demand and supply and that is mean the water quality will reduced. Drainage to the sea will reduce as the reuse of water will be increase to fill the water gap, that is will increase the water salinity, and affect the eco system as well. To improve the WSI for future we need to invest on KD4 by applying measures which reduce the pollution and improve the water quality. It is also recommended to invest in KD5, to improve the governance which will improve the WSI.

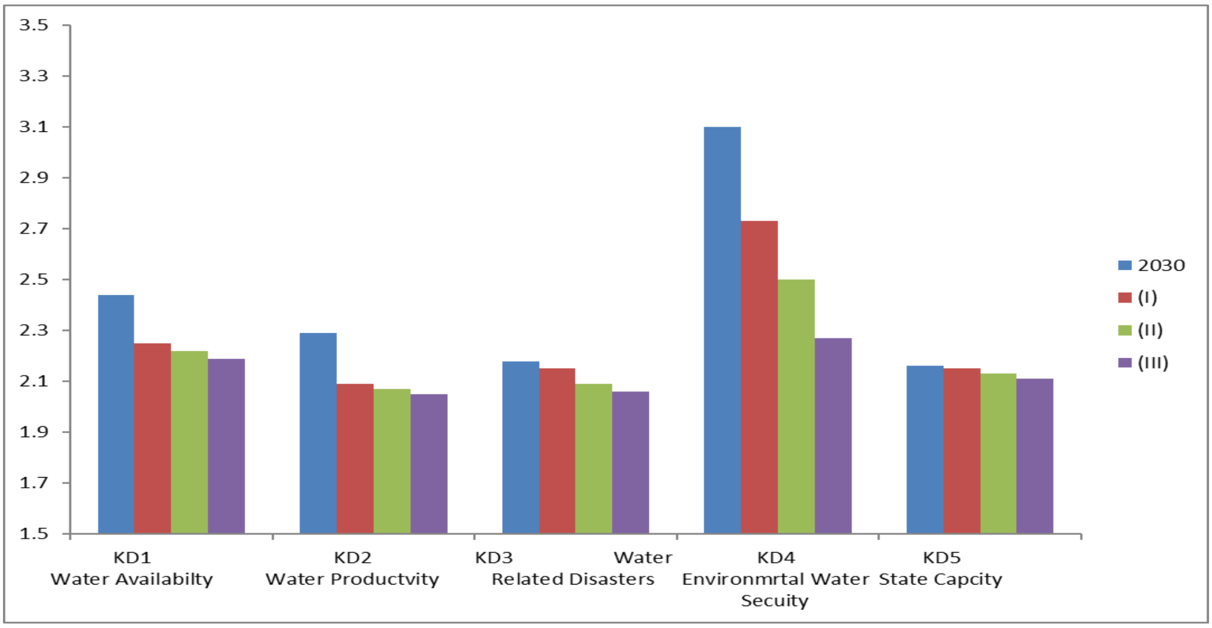


Figure 12: key dimensions indicators of WSI for 2030 optimistic and pessimistic scenarios

4.6 Estimated Investments for the Proposed Measures

The future scenarios which have been introduced in this paper helped in drawing a road map for necessary measure needed to secure the water situation and consequently the economic growth. Some measures and technological solutions that can contribute to decoupling for different sectors and improve WSI as well are introduced; The Required investments to implement these measures are estimated to be 912 Billion LE, in 2030 scenario. However, the investments increase to 1072, 1232 Billion LE in the pessimistic scenario no. #1, and no.#2 respectively. Figure (13) shows the proposed measures and its estimate cost for each scenario.

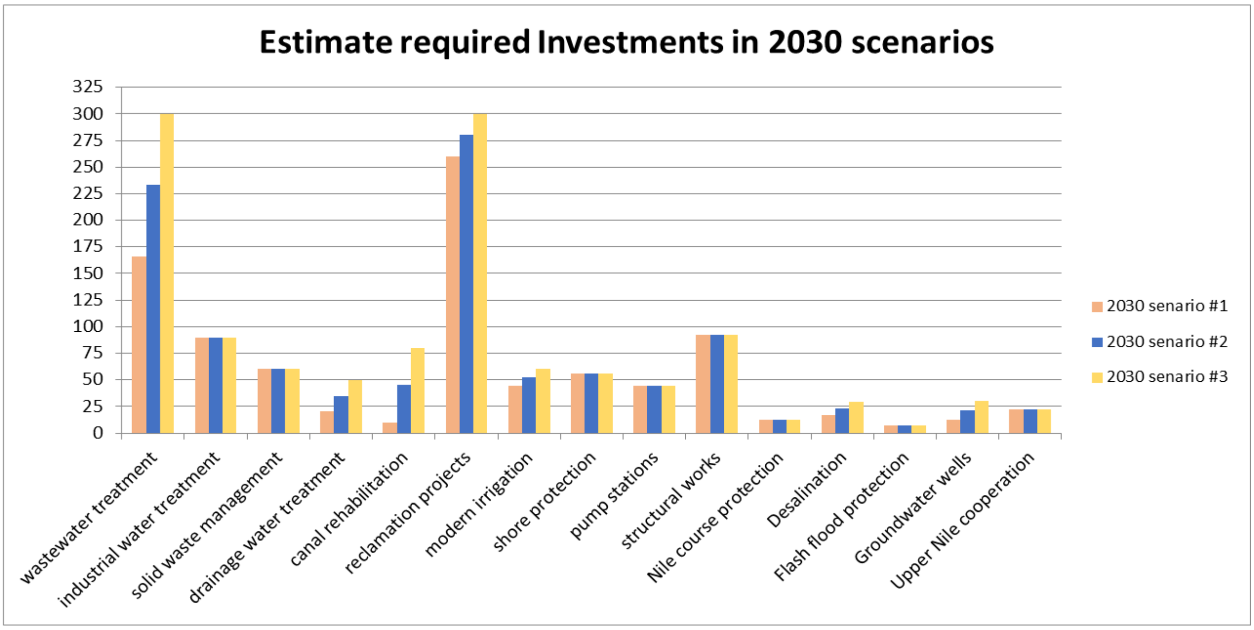


Figure 13: Estimated required investment in 2030 scenarios

5. Conclusion and recommendations

5.1 Conclusion

In the current paper, the Egyptian local conditions are identified based on that the suitable measures which we can take to enhance the WSI for Egypt are suggested. By using the modified framework and knowing the weakness points in our system, the field in which we need to invest is identified as well, in our case 2020, we found that we need to put more investment in Environmental and governance field. From the above water shortage scenarios, we can see conclude that , depending on desalination as a source to fill the water gap will increase but with the high cost we will face financial constraints, studying the impact on the national economy is much recommended. On the other hand using desalination will be mainly to provide the necessary quantity only to fill the deficit in drinking water. For Ground Water as a non-renewable and very sensitive source, increasing abstract from it is affecting the suitability of it as will have negative impact for the coming generations. Reducing water for agricultural sector will negatively effect on productivity that will be a big challenge beside climatic changes and its impact on temperature which will lead to dramatic change in crop and increase the agricultural water consumption. By reducing the water Budget, we can notice from the above three scenarios that the Drainage to the sea will reduce as the reuse of water will be increase to fill the water gap , that is will increase the water salinity , and affect the eco system as well. Improving water security is about capacity building for all actors - water managers and users, regularly risks assessment through planning It depends on reducing pollution and wasteful practices. Water infrastructure is essential, it cannot deliver its expected benefits without a solid complement of watershed management, social behavior change, and policy/institutional/management fixes/ Improved operation and maintenance of existing infrastructure, awareness raising, policy and institutional improvements (better data and better-informed decision-making)

5.2 Recommendations

From the current paper results, it is recommended to do the following

- Using the modified framework to assess the water security index annually.
- Improving WS by applying a combination of technical, economic, operational, legal, and institutional interventions. The choice of the effective measures depends on the local conditions and country goals. According to the WSI results, it is possible to say that Egypt is exposed to high water stress. The expected water stress issues are water demands increasing, water availability decreasing to critical level, groundwater abstraction increasing, low efficiency of irrigation and vulnerability to droughts.
- It is recommended to include some actions and measures to improve water security. These measures can be optimal manage between water supply and demand, strengthening the institutional framework and capacities, effective water allocation mechanism for inter-sectorial and decouple the economic Development from the water resources development.
- It is recommended that government of Egypt, decision-makers and researchers to invest more in research and development concerning improved and additional technological tools for water-use efficiency gains.

- It is recommended to apply the proposed framework in regional scales to get feedback about regional WSI.

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