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Study of Water Issues in Taiz City and it's the Best Solution-Yemen

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Abstract The study area including the City of Taiz, in particular is suffering from an acute shortage of water due to the increase of the growing demand on water for domestic and industrial needs as well as the water needs for agriculture in the region. Therefore, it highlights the importance of water demand management to maintain the quantity and quality of drinking water and domestic use, irrigation and industry. The objectives of this study; is to Develop of Scenarios and analysis of future water balance to find out the best solution to the problem of water in Taiz basin as the study area; Select the appropriate scenario to resolve the water problem. The results of this study will assist decision makers in the field of water resources for better planning and management in the future. Data was used from WEAP model and formulated a simple method to quantify increases in aquifer life for the five aquifer zones. WEAP data has used a simple method to quantify increases in aquifer life of the five sub-catchments in the study area. Develop Scenarios corresponding to parameters changes in each scenario for the period 2013-2050, for the following:

- Improve urban water supply;
- Increase irrigation efficiency;
- Water efficiency in industrial facilities;
- Rainwater harvesting from rooftops, City streets, streams valleys, and construction of dams and water retaining walls;
- Importing desalinated water from Red Sea;
- Re- use treated wastewater.
- Integration of increased irrigation efficiency and rainwater harvesting
- Importing desalinated water from Mocha City and rainwater harvesting

For calculating the amount of water supply in the region and the amount of water deficit, in addition to knowing the amount of needs that must be secured in the future, Water Evaluation and Planning (WEAP) application as Decision Support System (DSS) to manage the supply and demand for water in Taiz basin as the study area. The analysis and results using WEAP program include the following themes: Ground water storage in the aquifers: The usable storage for the base year of the model (2013) has been calculated for the five sub-basins in the study area. The best choice to solve the problem of water supply for Taiz City and to provide an adequate water of the study area is generally during the years 2013- 2050 is the integration of importing desalinated water from Red Sea and rainwater harvesting scenario.

Keywords Aquifer, Taiz basin, Water demand, Water supply, WEAP, Water scarcity

1. Introduction

Taiz City being the third largest City in Yemen has a great socio-economic importance. It is experiencing acute shortage of water as a result of increasing rate of water demand for municipal and industrial use, together with

increasing agricultural demand. Water resources of the Taiz basin are dependent on rainfall, which varies quite a lot from one sub-area to another within the same catchments. While the mean annual precipitation for the whole area is around 568 mm, the highlands receive a significantly greater amount. Heavy rainfall on the highland areas generates run-off that flows into the valleys, causing flooding. The surface water flowing into the valleys is diverted for irrigation by means of natural ditches called" Sawaagi". The Taiz basin has three main aquifer systems, they are: (a) alluvial aquifers, (b) volcanic aquifers, and (c) Tawilah sandstone aquifers [1]**.** For Al Haima zone one of the main sources of water supply, as a whole, the average decline in the groundwater level has been nearly 0.5 meter per year in the alluvial aquifer and more than 3 meters in the volcanic aquifer [2, 3].
Water supply constitutes the most pressing problem in Taiz today due to significant shortage of supply (the average consumption is 23 L/ c/d// [4], caused by the depletion of existing water resources and the lack of a clear direction in dealing with the problem. This forces frequent water supply service interruptions (30-40 days)[5] and the service is rarely extended to new users (only 57% of the population are covered). Sanitation is another daunting problem. The poorly maintained, sewerage network covers only 44% [6] of the population. In Several un-severed areas to the north, east and west of the City, raw sewage is directly disposed to Valleys, which causes a health hazard and threatens to contaminate groundwater resources.

2. Objectives

A. To develop Scenarios and analyze future water balance in order to find out the best solutions to the problem of water in Taiz region;
B. To select the appropriate scenario for resolving the water problem;

3. Study Area

The study area is located in the upper part of Rasyan valley, It is one of the seven major Valleys which form the Red Sea drainage basin [7,8] and which drain the high and mid-land region of the country and flow in a westerly direction towards the Red Sea. The study area which is defined as the catchment area upstream from the point 378 UTM E and 1510 UTM N. This area covers approximately 750 km^2 (Fig. 1).

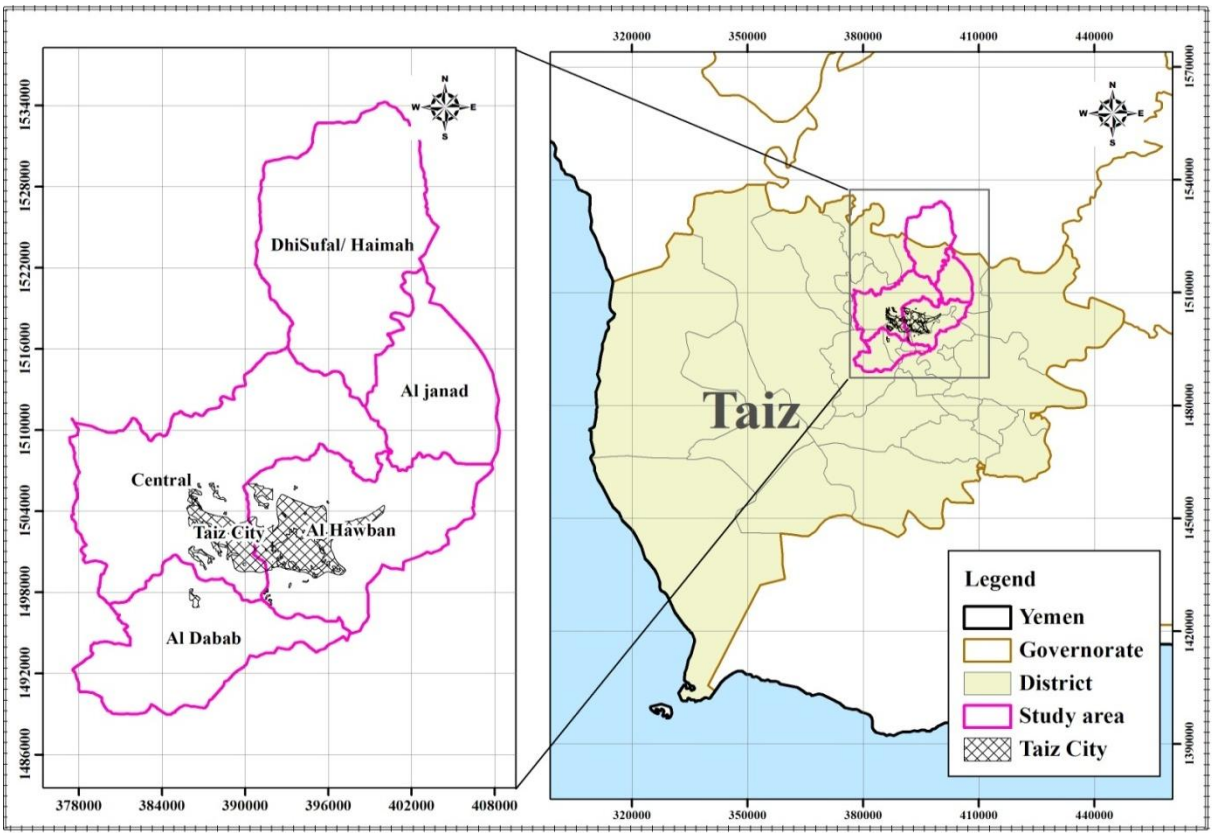

Figure 1: Location of the study area

The five sub-catchments areas are:

1- Al Dabab sub-catchment (Comprising, in addition to Al Dabab, part of Jabal Habashi and part of Jabal Saber),
2- Al Hawban sub-catchment (SE part of the area, comprising Ursum valley , Hawban valley and tributaries),
3- Central sub-catchment (Lower part of Upper Rasyan Valley, downstream of all other sub catchments),
4- Al janad sub-catchment (plateau in eastern part of the area),
5- Thi-Sufal/ Haimah sub-catchment (NE part of the area).

4. Methodology

Data was used from WEAP model and formulated a simple method to quantify increases in aquifer life for the five aquifer zones. WEAP data has used a simple method to quantify increases in aquifer life of the five sub-catchments in the study area.

Develop Scenarios corresponding to parameters changes in each scenario for the period 2013-2050, for the following:

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WEAP Model Application

On the basis of hydrologic and physiographic characteristics, the study area was divided into six main sub-areas or sub-catchments. The boundaries were chosen and plotted to help delineate the quite complex drainage pattern of the area and to provide a framework for discussing various land and water characteristics of the study area, which would facilitate the subsequent use of the data for management planning [9], boundaries of the study area included the following areas within the divisions of the study mentioned above.

WEAP input

- Long term climate data (rainfall, runoff, temp. evaporation, Evaporate. etc…).
- Land use and cropping pattern.
- Groundwater abstraction and use.
- Irrigation area.
- Estimated groundwater storage and spring flow in area.
- Estimated groundwater storage in the three aquifers.
- Annual natural recharge and water use in Taiz Region.

5. Results and Discussions

In the Reference scenario, the climate sequence for future years was developed by repeating historical data for the period 1979 to 2013 and assuming a similar periodiCity through 2050.

The results show WEAP program used for decision support systems in the study area development and Scenarios Options for multiple development and water resources development and management of the multiple uses to solve the water problems in the City of Taiz and the overall study over the years 2013-2050. Table (2) presents a synopsis of our hydrologic for the various Scenarios for the Study area. The following are the implications of the results of our analyses in our proposed priority of implementation.

The table (1) shows the estimated annual natural recharge and water use in study area.

Table 1: Estimated annual natural recharge and water use in the study area

Sub-catchments	Central sub-catchment	Al Hawaban sub-catchment	Thi Sufal Al Haimah sub-catchment	Al Janad sub-catchment	Al Dabab sub-catchment	Total
Natural recharge MCM (NWRA, 2011)	4.28	2.15	4.2	1.54	2.3	14.47
Urban (2013) pop	769940.1	133302.4	0	0	0	903242.5
Rural (2013) pop	0	0	36878.9	108416.6	33927.5	179223
Commercial urban (2013) pop	111272.3	47834.3	0	0	0	159106.6
Commercial rural (2013) pop	0	0	1364	3287.3	4799	9450.3
Industrial Urban (2013) product in Unit	96	96	0	0	0	192
Industrial Rural (2013) product in Unit	0	0	0	0	48	48
Urban use in 2013 MCM	16.86	2.9	0	0	0	19.76
Rural use in 2013 MCM	0	0	0.41	1.2	0.4	2.01
Commercial urban use (2013) MCM	3.2	0.72	0	0	0	3.92
Commercial rural use (2013) MCM	0	0	0.02	0.02	0.02	0.06
Industrial use (MCM in 213)	10.1	10.9	0	0	4.3	25.3
Irrigated area in 2013 (ha)	590.7	450.1	90.9	123.4	392.3	1647.4
Irrigated use in 2013 MCM	47.2	49.8	0.99	1.2	5.3	104.49
Water balance in 2013	-62.72	-45.44	20.88	7.12	1.78	
Available storage	1003.5	196.3	957	291.2	303.8	2751.8

Table 2: Output from WEAP Scenario in the study area

Scenario	Extended life of Taiz basin	Quantity of water available m^3/year	The cost of cubic meter of water $ /year (1.17$)-TWSLC, 2014	Investment Cost $	Priority
Improve urban water supply delivery	-	9808441	11475876	3,900,000	High
Increase irrigation efficiency	11	51942435	60772649	4,250,000	Moderate
Water efficiency in industrial facilities	2	10672011	12486252	NA	Moderate
Rainwater harvesting	6	16450000	19246500	157,000000	High
Importing desalinated water from Red Sea	12	54750000	64057500	280,000000	High
Re- use wastewater from treatment plant	2	10,500,000	12811500	24,500,000	Moderate
Integration of increase irrigation efficiency and rainwater harvesting	17	68392435	80019149	161,250,000	Moderate to high
Importing desalinated water from Mocha City and rainwater harvesting	18	71200000	83304000	437000000	High

*NA: Not Available

Improvement of water distribution system in urban areas such as Taiz City, in order to reduce loses by 20% [10] and management of water demand. The results of this scenario show that the life of aquifers of Taiz region will last for 19 years as before the intervention. However improvement in the distribution network system is required due to loses of water up to 9808441 m3/year with the cost equal 11475876 $ /year that is the cost of a cubic

meter is 1.17 $ [10]. In addition, reducing the losses in the network will ensure the supply of water to Taiz City from other sources such as sea water desalination or rain water harvesting ….etc, with low loss from network.

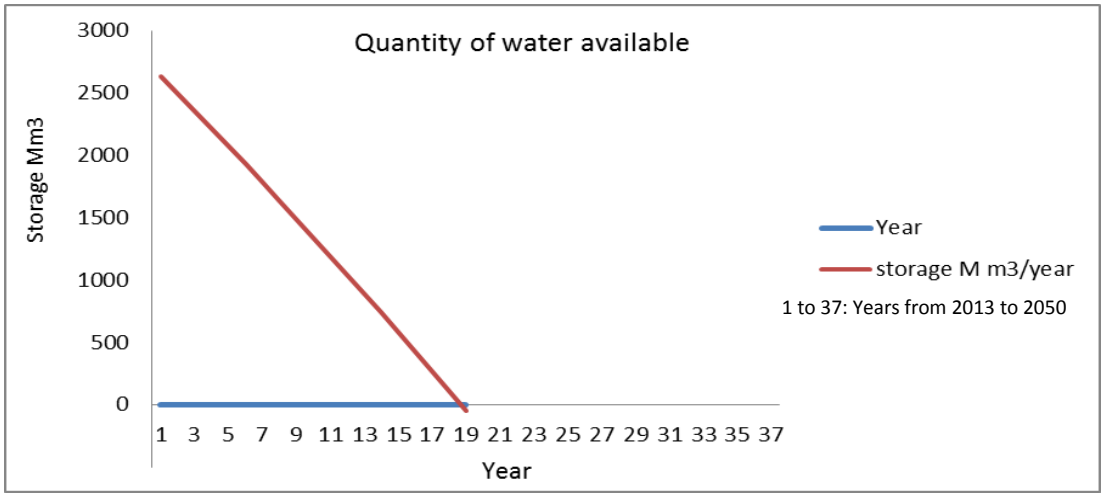

Figure 2: Quantity of water available m^3/year, improve urban water supply scenario.

Irrigation efficiency by new techniques has reduced groundwater extraction and extended aquifer life while at the same time improving farm incomes.

Increase irrigation efficiency by using modern irrigation technology such as drip, bubbler and trickling irrigation systems in order to reduce 50% of amount of water currently used to irrigate crops is up to 51942435 m^3 / year, and the total cost of water is up to 60772649 $. Improvement of irrigation means prolonging the life of the aquifers of Taiz region for 11 years in order to ensure the continued supply of water in the region for all uses until 2043.

Figure (3) indicates an increase in irrigation efficiency scenario. It is worth noting that not adopting modern irrigation technology by farmers is due to lack of awareness, among them of the importance of the use of modern irrigation techniques so as to meet the challenges in implementing this option.

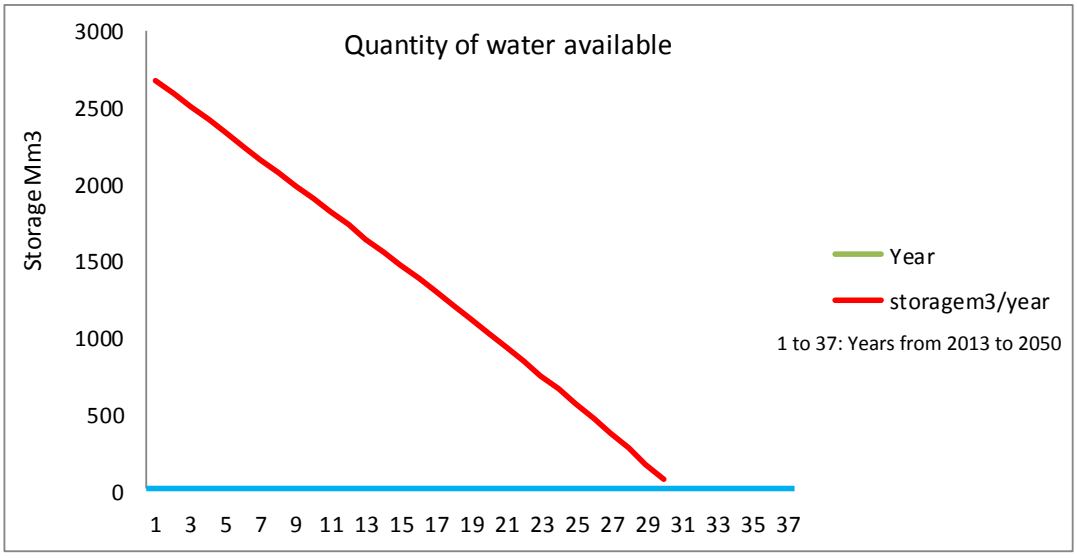

Figure 3: Quantity of water available ^{m3}/year, increase irrigation efficiency Scenario

The approach to reducing the amount of industrial water use in Taiz region. Experience from around the world shows that adopting a systematic approach to water efficiency often results in a reduced water consumption by 20-50 %, and up to 90 % when more advanced measures are implemented, the counter-current rinsing will be 40%, and reuse of wash water will be 50% [11]. Figure (4) indicates that water efficiency in industrial facilities extends the life of aquifers in Taiz region by 2 years and by providing a quantity of water up to 10672010.51 m^3/ year.

This scenario contributes to reducing the cost of industrial products. Knowing that the absence of awareness on pert of the industrial sector resulted in, not adopting the technology of water rationalization at their industries.

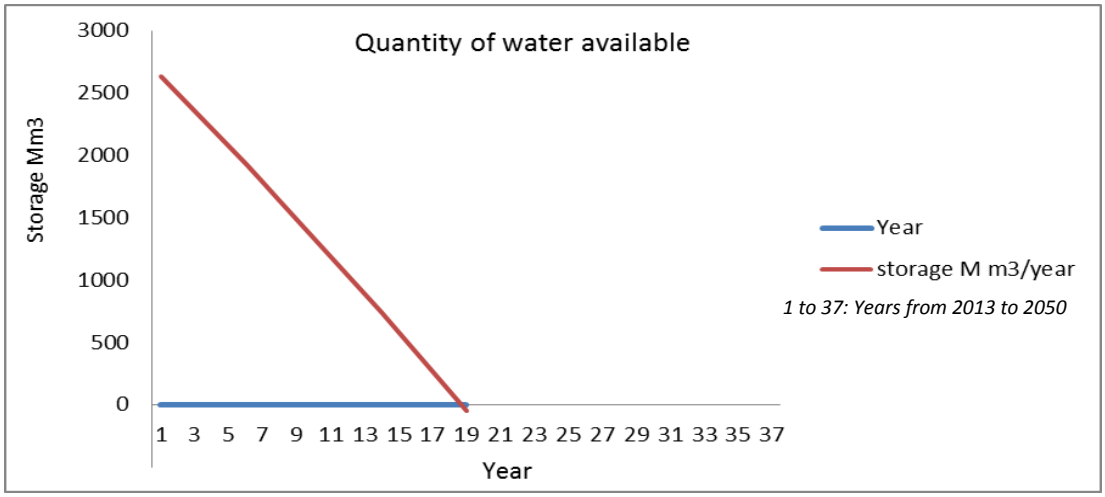

Figure 4: Quantity of water available m3/year, water efficiency in industrial facilities Scenario

The approach water demand the amount for domestic, commercial, industrial and irrigated farms in Taiz region by adopting the use of rainwater harvesting. Providing sustainable water for Taiz City is the main objectives of the study. However, users of water for irrigated agriculture cannot be deprived of their established water rights. To achieve the above objective, surface water is proposed to be primarily used for irrigation and groundwater for domestic and industrial use. Surface water should be stored in underground aquifers by constructions dams because the groundwater is not subject to loss by evaporation. According to Ghayth Aquatic LTD and Associated Consulting Engineers, 2006, the amount of water harvesting in Taiz region has a value of 16,450,000 m^3/year. Rainwater harvesting scenario is a practical solution to meet agricultural, domestic and industrial needs at the level of rural and urban areas. This scenario contributes to the recovery of water resources in the study area that is equivalent to 16450000 m^3 / year at a cost of up to 19246500$ and extend the life of aquifers of Taiz water region in the study area for 6years until the year 2038 .The implementation of this option will save the right amount of water to Taiz City, this including droughts, sub-surface storage of the water, will have a positive effect on water quality in central and Al Hawban sub-catchments, which suffer from high salinity, and will greatly reduce the evaporation rate, recharging aquifers. Adopting of these measures reduce the flash floods will effect on the soil in valleys and, therefore, drains towards the sea without benefitting from water. This will reduce the amount of sediment carried by the flood to Al-Amerah dam at central sub-catchment, maintaining the cleanliness of channels and beds valleys from pollutants associated with floods (Fig. 5) presents the results from WEAP model due to the assumed rainwater harvesting.

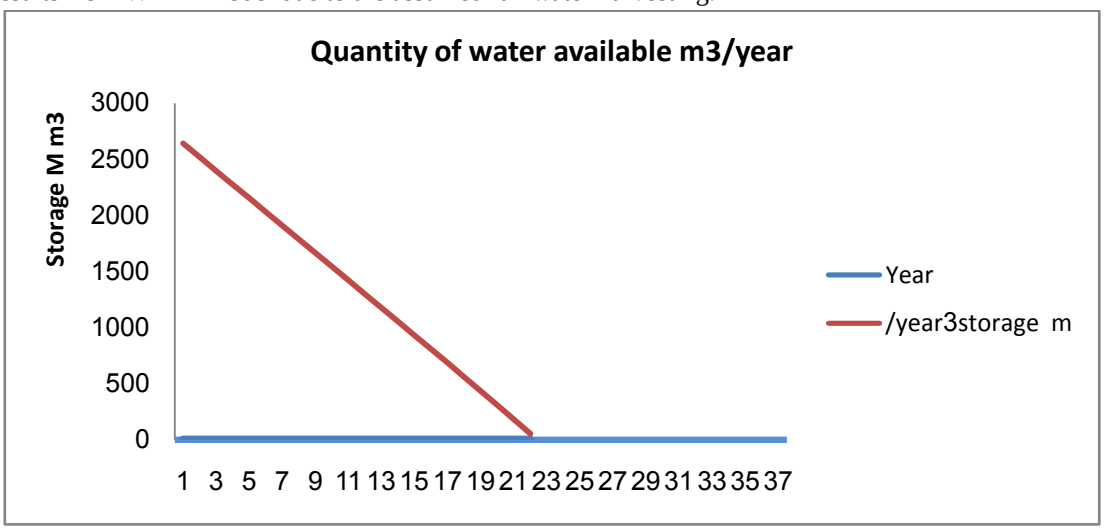

Figure 5: Quantity of water available m^3/year, rainwater harvesting Scenario

Desalination from sea water from Red Sea are necessary to meet the needs of water in Taiz City, according to Hayel Saeed Anam Group, 2009 [12], the amount of imported water value from Red Sea is estimated by 54750000 m3/year. The proposed a scenario of importing desalinated water from Red Sea to meet daily needs for domestic and industrial uses in Taiz region. Any imported water will have to be accompanied by improvements of the urban water systems in order to avoid large water and financial losses. Importing desalinated water from Red Sea is necessary to meet the needs of Taiz City and the areas extending from Red Sea to Taiz and to conserve water resources in Taiz region up to 54750000 m^3 / year at a cost of 64057500 $, and extend the life of aquifers of Taiz water basin in the study area for 12 years until the year 2044. This scenario ensures attracting local and foreign investment to the City in order to ensure the standard of living style and social stability of population. The development of towns and villages stretching from Red Sea and even Taiz City is to ensure the improvement of living style of these communities by providing them with their water needs through improving the technical, administrative, and professional efficiency during and after the implementation of project. Figure (6) presents the results of importing desalinated water from Red Sea.

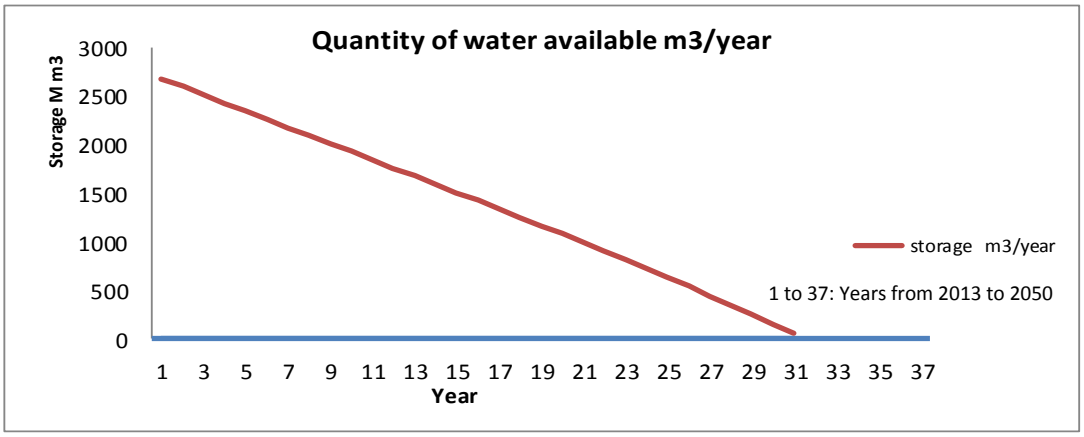

Figure 6: Quantity of water available m^3/year, importing desalinated water from Red Sea Scenario

Scenario of wastewater re-use from treatment plant to reduce the depletion of fresh water at a cost of 12811500 $ and to conserve water resources in Taiz region by using an additional resource of 10,500,000 m^3/year. It will extend the life of aquifers of Taiz water region in the study area for 2 years until the year 2034. Thus it provides alternative water sources and less expensive that can be used in agriculture especially after treatment. Treatment water contains nitrogen, phosphorus and other nutrients leads to the growth of nutritious component. This scenario reduces and prevents pollution which costs deal of financial load for re-contaminated water body rehabilitation. This option needs the rehabilitation of parts of the sewerage networks and the existing treatment plant [13]. Expansion of the sewerage network and construction of new treatment plant is necessary [14], Figure (7) indicates improved wastewater re-use Scenario.

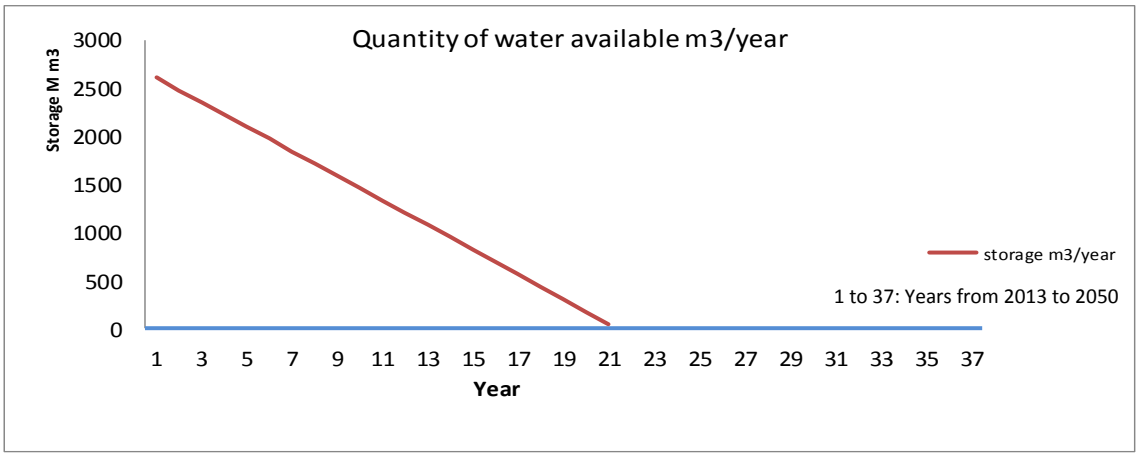

Figure 7: Quantity of water available m^3/year, improved wastewater re- use from treatment plant Scenario

Given the many Scenarios discussed above that do not meet the desired goals of an adequate water supply by 2050, some Scenarios need to be integrated with each other so as to reach the target water supply to Taiz City and the study area, generally, until 2050.

Integrations of Scenarios increased irrigation efficiency and rainwater harvesting. Will conserve water resources in Taiz region by having an additional resource of 68392435 m^3/year. With a total cost of 80019149 $. And it will prolong the life of aquifers in Taiz region until 2049 for a period up to 17 years. See (Fig. 8).

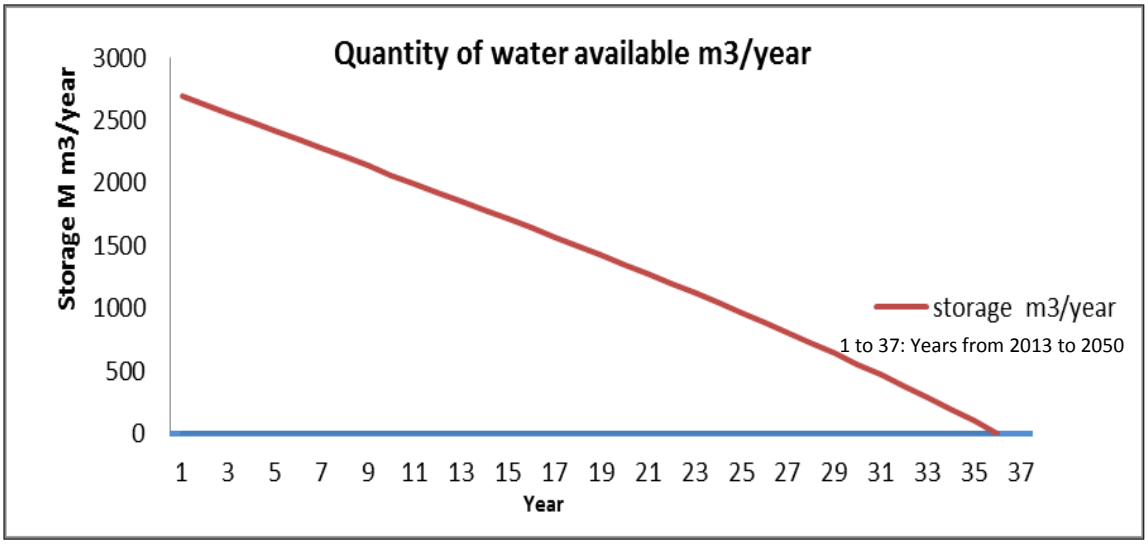

Figure 8: Quantity of water available m^3/year, integration of the increased irrigation efficiency and rainwater harvesting

The Scenarios of merging importing desalinated water from Red Sea and rainwater harvesting. This scenario will conserve water resources in Taiz region by using an additional resource of 71200000 m^3 at an estimated cost of 83304000 $ and it will extends the life of the aquifers in the water basin of Taiz until 2050 for a period of up to 18 years (Fig. 9).

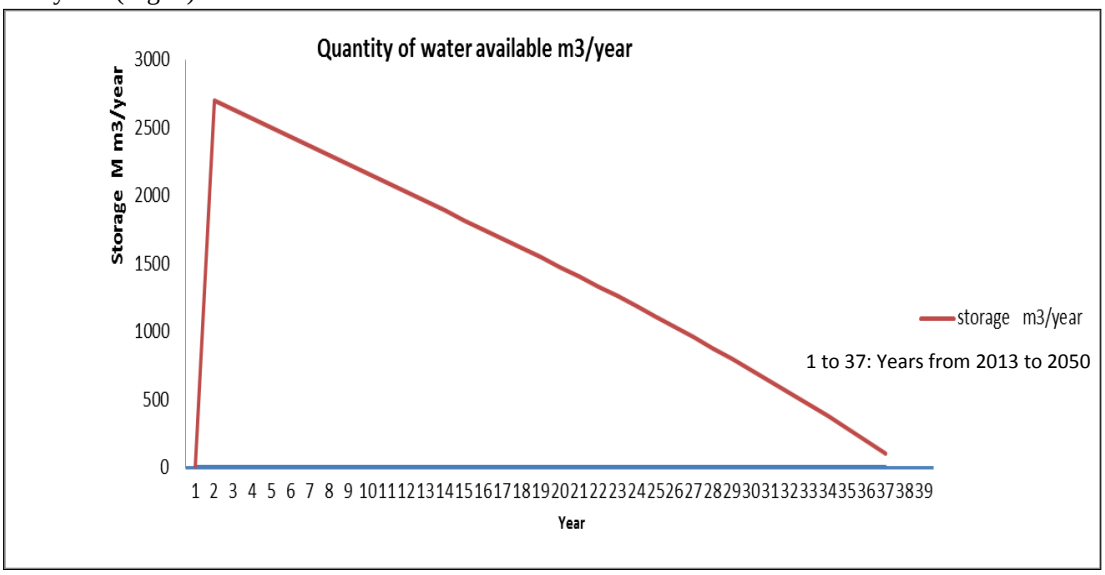

Figure 9: Quantity of water available m^3/year, importing desalinated water from Red Sea and rainwater harvesting

Creating an attractive environment for investments in all fields (Fig.10).

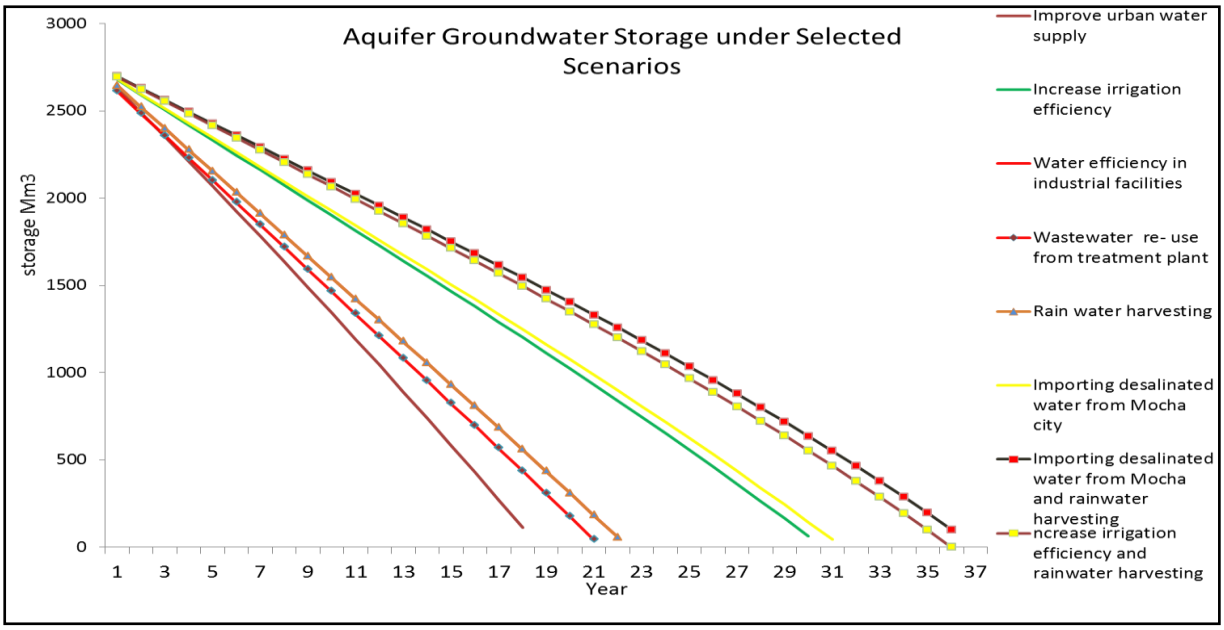

Figure 10: Aquifer groundwater storage under selected Scenarios

The best choice to solve the problem of water supply for Taiz City and to provide an adequate water of the study area is generally during the years 2013 - 2050 is the integration of importing desalinated water from Red Sea and rainwater harvesting scenario.

In selecting the intervention in order to integrate the seawater desalination option from the Red Sea with the option of rain water harvesting, we found that the amount available through this combination of the two options will cover the needs of the areas extending from Red Sea City to Taiz City with water to until 2050, that is to say for 37 years and at a cost of $ 83,304,000.

5. Recommendations

1. Improve urban water supply;
2. Increase irrigation efficiency;
3. Water efficiency in industrial facilities;
4. Rainwater harvesting.
5. Importing desalinated water from Red Sea;
6. Re-use treated wastewater.
7. Integration of increase irrigation efficiency and rainwater harvesting. and Importing desalinated water from Red Sea and rainwater harvesting.

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