Arid Climate Conditions Vs Water Resources Management in Africa Based on the Sustainable Supply Chain Operations

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***Abstract*-The purpose of this paper is to explore the impact of sustainable supply chain operations on economic, environmental and social performance, which are the three dimensions of corporate sustainability. Africa has been subjected to water stress due to its large part in arid and semi-arid geographical areas and its topographical features and uneven temporal and spatial distribution of rainfall. In this research, an attempt was carried out for water resources management in an arid climate area, the area is the central part of Darb El Arbeain. The study area occupies the central area of Darb EL-Arbeain and bounded by long. 30º 15/ and 30º 25/ E and lat. 23º 55/ and 24º 05/ N, it has an area of about 120 Km². In this study four suggested exploitation rates of groundwater have been explored using the three-dimensional finite difference flow model (MODFLOW 2005) to simulate the flow system. These scenarios include running the model with abstraction from the aquifers equal 110 %, 180 %, 280 %, and 370 % of calculated initial recharge. The results indicated that the equilibrium could be reached while pumping out from the aquifer in that arid climate area, and the drawdown could be stable after some time depending on the potentiality and heterogeneity of the aquifer.**

Keywords; *Aquifer, Water Resources Management, Sustainable supply chain operations, Initial Recharge, MODFLOW, Darb El-Arbeain*

1. Introduction

Trends in supply chain management (SCM), such as the globalization of market economies, shorter product life cycles, digitalization, and multifaceted customer expectations, along with developments such as resource scarcity, stricter regulatory requirements, and a more long-term focus, have led to the evolution of highly complex supply chains. The incorporation of environmental and social responsibility issues into the management of supply chains is becoming increasingly relevant to the success of organizations and their supply chains. Organizations are considered accountable for their activities that affect the environment, society, and economy of their own businesses, as well as those of their supply chain participants [1] Climate is attributed to the weather conditions of a geographic region such as temperature, humidity, atmospheric pressure, wind, precipitation and other meteorological characteristics over a relatively long period of time [1-5]. In meteorology, the current climate is usually monitored, while long-term climatic characteristics are considered in climatology. It is obvious that the climate in different parts of the world is determined by latitude and altitude [6].

A region is arid when it is characterized by a severe lack of available water, to the extent of hindering or preventing the growth and development of plant and animal life [7,8]. Environments subject to arid climates tend to lack vegetation and are called xeric or desertic. Most "arid" climates straddle the Equator; these places include parts of Africa, Asia, South America, Central America, and Australia [9].

Africa has been subjected to water stress due to its large part in arid and semi-arid geographical areas and its topographical features and uneven temporal and spatial distribution of rainfall. On the other hand, due to factors such as population growth, the need for more food, the need to improve health and social welfare, industrial development and protection of ecosystems, water demand is increasing day by day [10-13].

In an arid region from Paris town towards the Egypt–Sudan border, the groundwater represents the main resource of water. The annual rainfall is less than 1.1mm [14, 15]. The aquifer thickness in northern parts ranges between 211 m and 294 m [16]. The aquifer thickness increases to the northern part. The Nubian sandstone aquifer in the area of study is capped by a confining bed (Dakhla Formation) and underlain by basement rocks. The initial hydraulic conductivity ranges between 2.76 m/day and 1.99 m/day, initial transmissivity ranges between 233 m2/day and 652 m2/day, initial average hydraulic gradient is 0.00719, and average net flow rate in the aquifer is 0.022 m/day. In the current study, it was tried to Delay the food crisis of the Egypt through reaching the optimum equilibrium of the confined aquifer in arid climate areas, case study [17,18]. The primary goal of this paper was to identify and analyze drivers of sustainable supply chain management that influence or encourage organizations to undertake sustainability initiatives and implement sustainable solutions throughout their supply chains.

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2. Methodology

2.1 Description of the Study Area

Hence, identification of the important sustainability issues emphasized by various internal and external factors to the supply chain (also described in the literature as the drivers of sustainable supply chain management (SSCM)) not only promotes extensive stakeholder engagement, but also contributes to the achievement of overall supply chain sustainability goals. In Darb El Arbeain the ground surface slopes gently from NW to SE with about 5.0 m/Km. The rainfall rarely exceeds 1 mm / year and the maximum temperature exceed 40 °C at summer and 30 °C at winter while, the minimum temperature ranges from 15 to 18 °C at midnight. Darb El- Arbaein is subdivided into three geomorphologic units, the western Atmur peneplain; the southern Naklai-Sheb pene-plain and a plateau surface (Issawi 1971). Geologically, the exposed rocks range from Quaternary sediments to Pre-Cambrian to. Darb El-Arbaein area is related structurally to the Red Sea and south western regions. Issawi (1971) has identified the faults in E-W, NE-SW and NW-SE and three anticlines (Bir Kiseiba, Rage, and Shirshir). The litho-stratigraphic successions from base to top: 1) PreCambrian basement 2) Paleozoic-Mesozoic sandstone; 3) Lower Cretaceous; 4) Upper Cretaceous; 5) Paleocene; 6) Eocene; and 7) Quaternary [19-22].

Figure 1. Darb El Arbeain Map, taken from Google Earth.

2.2 Model Description and Calibration for Northern Area of Drab El Arbeain

The Governing Partial Differential Equation for a confined aquifer used in MODFLOW is [22]:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right)+W = S_s\frac{\partial h}{\partial t} \quad (1)$$

where; K_{xx}, K_{yy} and K_{zz} are the values of hydraulic conductivity along the x, y, and z coordinate axes (L/T), h is the potentiometric head (L), W is a volumetric flux per unit volume representing sources and/or sinks of water, where negative values are extractions, and positive values are injections (L^3T^{-1}), S_S is the specific storage of the porous material (M^{-1}); and t is time (T).

2.3 Initial Model Input (First Assumption)

The hydraulic conductivity; Kx = Ky = 2.1 m/day Kz = 0.21 m/day, no of aquifers; 1 (divided into 4 layers, no of rows = 250, no of columns = 190 (each cell is 50*50 m), Average Specific storativity = 0.0001 m^{-1}, Average total porosity = 0.3, average effective porosity = 0.15 (El-Beih, 2007), Piezometric level; taken from Korany et al. 2002, currently average pumping rate of the 27 wells is around 2000 m3/ day. Boundary conditions (Fig. 2); the western boundary; consist 2 segments, line a-b represent constant head 135 m, mean while line from b-c represents 131 m. the eastern boundary; line g-h represent constant head 123 m, line h-I represent, Constant head 119 m, and line i-j represent Constant head 117 m, the northern boundary; line d-e represent constant head 125 m, line e-f represent Constant head 129 m. the southern parts represent no flow boundary. Area two target is to reclaim around 4000 acres.

As it can be seen in Figure 3, the calibration involved comparison of the model results and observed heads at 24 observation points (taken from pumping wells) from a piezometric head map to run in a steady state simulation, once the model calibrated, the calculated hydraulic heads were used as initial heads for the transient flow scenarios [23,24].

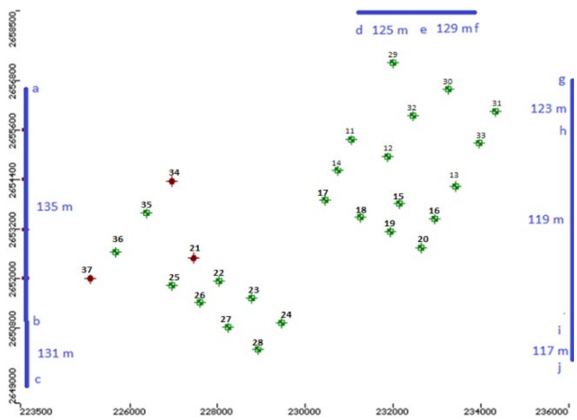

Figure 2. Boundary condition heads in area two, Darb El Arbeain

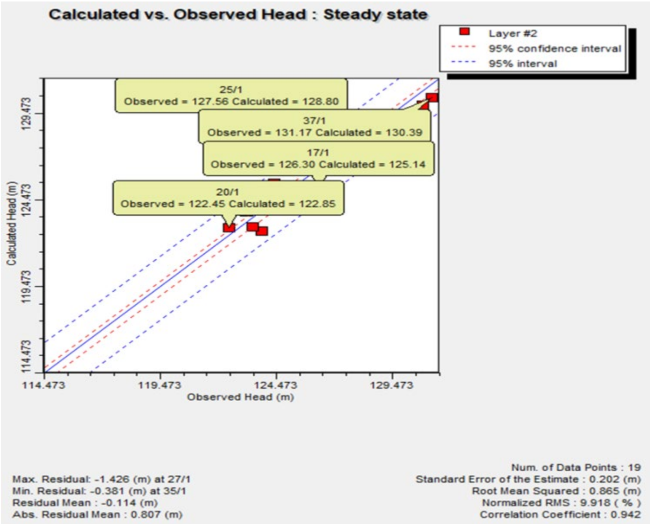

Figure 3. Calibration result to area two, Darb El Arbeain

3. Result and Discussion

3.1 The Equilibrium in The Dynamic State When Pumping out=1.8 of Initial Recharge (Currently, Each Well 2000 m^3/d)

This section describes the results in detail and discusses the findings to provide practical guidance for researchers and practitioners in the field of SSCM. In the specification of categories step, a single categorization scheme was used in which a driver of SSCM could be related to only one category. Collected the field data and interpreted to predict maximum drawdown and maximum time required to achieve the equilibrium (maximum drawdown). In this case the current pumping rate of each well is 2000 cubic meter per day, which equal 1.8 of initial recharge. From the data of 2 observation wells; The maximum average expected (interpolated) drawdown is 13.5 m and expected time for stability is around 25 years. Observed well drawdown are showed in Figure 4. Also, the results of the modelling are showed in Figure 5 [25-28].

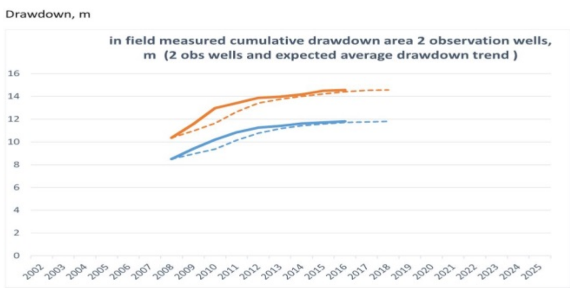

Figure 4. Observed well drawdown m vs years, in area two

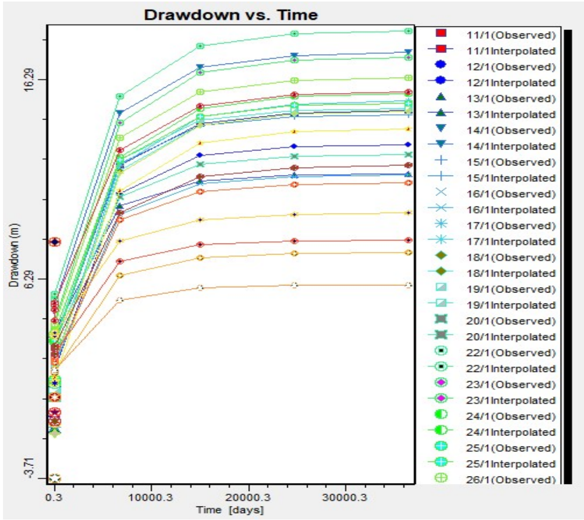

Figure 5. The modelling results; Drawdown Vs time at Q out/Q in = 180 %

Drawdown response overtime under pumping rate equal to 180 % of initial recharge is illustrates in the above figure. Results of managing system when Q $_{out}$ $_{(2000m3/day\ each\ well)}$ =1.8 Q $_{in\ (initial\ recharge)}$ from modelling and after correlation with field measurements;

- The average maximum expected drawdown is around 13.5 m.
- The average years required for equilibrium is around 30 years.

3.2 The Equilibrium in The Dynamic State When Pumping out=1.1 of Initial Recharge (Currently, Each Well 2000 m^3/d)

Drawdown response overtime under pumping rate equal to 110 % of initial recharge is illustrates in the Figure 6.

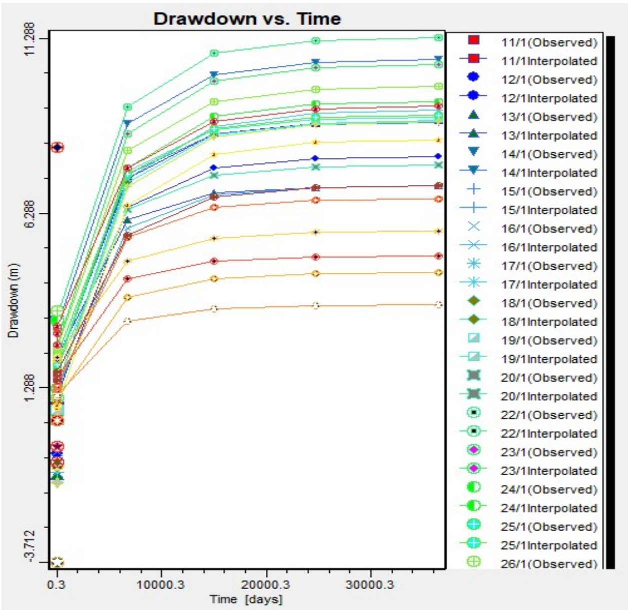

Figure 6. The modelling results; Drawdown Vs time at Q out/Q in = 110 %

Results of managing system when Q out (1200 m^3/day each well) =1.1 Q in When using pumping out = 1.1 of initial recharge;

A- The average maximum expected drawdown is around 6.5 m.

B- The years required for equilibrium is around 30 years.

3.3 The Equilibrium in The Dynamic State When Pumping Out=2.8 of Initial Recharge (Each Well 3000 m^3/d)

Drawdown response overtime under pumping rate equal to 280 % of initial recharge is illustrates in the Figure 7.

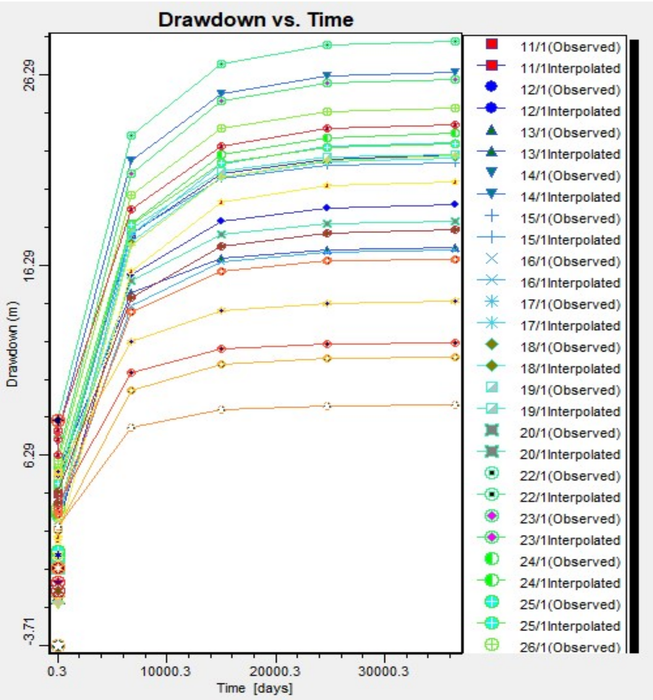

Figure 7. Drawdown Vs time at Q out/Q in = 280 %

Results from modelling of managing system when Q out (4300 m^3/day each well) =2.8 Q in When using pumping out = 2.8 of initial recharge;

- The maximum average drawdown is 17 m.
- The average maximum time for equilibrium is 40 years.

3.4 The Equilibrium in The Dynamic State When Pumping Out = 3.7 of Initial Recharge (Run All wells 4000m^3/day)

Drawdown response overtime under exploitation rate equal to 370 % of initial recharge is illustrates in the Figure 8.

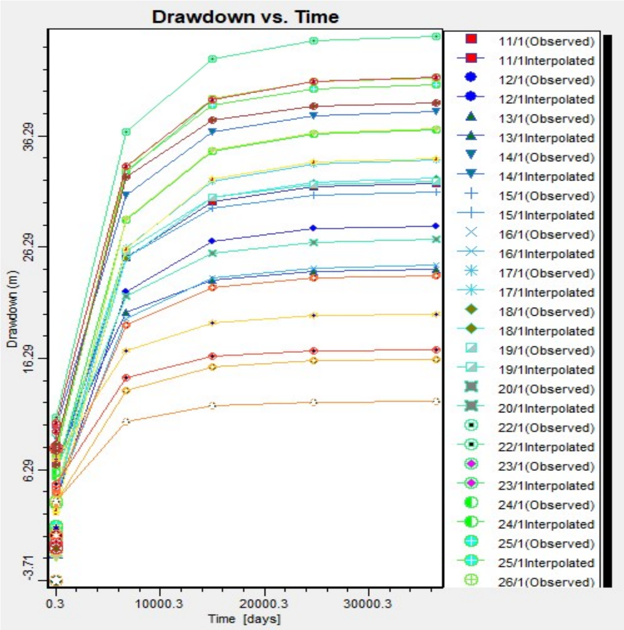

Figure 8. Drawdown Vs time at Q out/Q in = 370 %

Results of managing system when Q out (5700 m3/day each well) =3.7 Q in When using pumping out = 3.7 of initial recharge;

- The maximum average drawdown is 35 m.
- The average maximum time for equilibrium is 50 years.

3.5 The Stability or the equilibrium of Confined Aquifer (Where Drawdown Stay Same), and Choosing Managing Plans in Area Two

The average drawdown under different exploitation rate is illustrated in the below Table 1. For confined aquifers under previous assumptions, can choose for managing plan from the Table 1;

Table 1. The average drawdown under different exploitation rate

Q out/Q in(initial)	Average drawdown, m	Time for equilibrium, years
1.1	6.5	30
1.8	13.5	35
2.8	17	40
3.7	35	50

Average drawdown response to exploitation rate when pumping 110 % of initial recharge rate varies between 6.5 meter to 30 meters, meanwhile when pumping 370 % of initial recharge rate varies between 35 meter to 50 meters.

Managing pumping rates from current confined aquifer is vital for extending life time of the project under economical consideration, from different pumping rates we can recommend managing plans of the second (Q out/Q initial recharge =1.8), and third (Q out/Q initial recharge =2.8) scenarios where;

- a- drawdown is not too much
- b- not too much changes to ground water quality
- c- extend life time of the well itself
- d- economically in running

It is not recommended at all to pump more than 3 times of initial recharge to avoid any drastic change to the exploited water and to avoid damage or shorten the life time of the wells.

3.6 Setting Equation between ($Q_{out}/Q_{initial\ recharge}$) and average Max-Drawdown $_{in}$ Area Two in Drab El Arbeain

The relation between average maximum drawdown in meter and the rate of pumping percentage of the initial recharge is best illustrated in the below figure. It is observed that the line is not straight, where the heterogeneity of the aquifer plays important role in the equation, for moderate aquifer potentiality with average hydraulic conductivity of 3.07 meter per day, the governing equation for anticipating drawdown is illustrated through below introduced equation;

For moderate aquifer potentiality (K = 2.5 M/Day)

Average maximum drawdown, m = (Q_{out} / $Q_{initial\ recharge}$) * constant

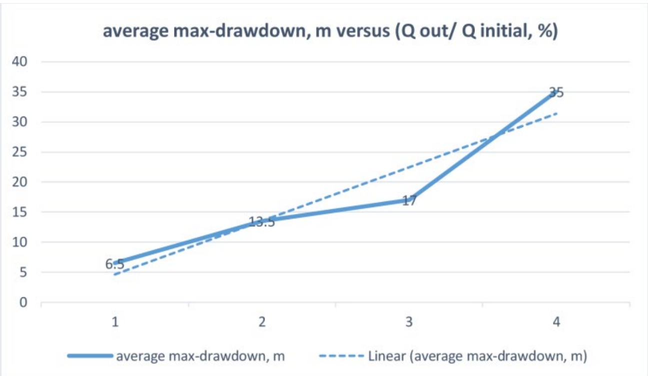

Figure 9. Average max- drawdown, m VS (Q_{out}/ $Q_{recharge}$)

1. When (Q_{out} / $Q_{initial\ recharge}$) = (120 % -220 %); constant equal 6.5

Average maximum drawdown, m = (Q_{out} / $Q_{initial\ recharge}$) * 6.

2. When (Q_{out} / $Q_{initial\ recharge}$) = (220 % -400 %); constant equal 7.7

Average maximum drawdown, m = (Q_{out} / $Q_{initial\ recharge}$) * 7.7

4 Conclusions

In this research, an attempt was made for water resources management in an arid conditions area, only groundwater is the sole economical water resources in the middle part of Drab El Arbeain area fo SSCM. Through applying visual modflow simulation program and applying different exploitation scenarios, the results indicated that the equilibrium in the aquifer or the stability of drawdown could be achieved under different pumping out rates which one of them should be chosen carefully for optimum management of water resources in an arid area. Average drawdown in the area is 35 m and occur in 50 years which happen when pump water water quantity equal to 3.7 of the initial recharges to the aquifer, meanwhile average drawdown of in 30 years could be achieved when exploit water equal to 1.1 of initial recharge. Less pumping out is recommended for the aquifer optimum managing but also economical use should be considered in such an arid area. Future research to identify industry-specific drivers of SSCM, as well as geographically significant drivers of SSCM, is also required. The current list of drivers of SSCM developed in this research may be upgraded after successful research and development of new drivers of SSCM. Since the groundwater is the sole source for water resources in the middle part of Drab El Arbeain arid area Therefore, it is highly recommended to Discuss the results with the local people and developers, and continue appropriate monitoring of the confined aquifer performance. More studies are required for the arid climate conditions, type of agricultural and irrigation methods is optimum for proper managing of the water sources.

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