Sustainable Development of Non-renewable Transboundary Groundwater: Strategic planning and strategic alternatives for the Nubian sandstone aquifer system

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ABSTRACT

The sustainable development of a resource that will be surely depleted is an extremely challenging process. The sustainable development in that case refers to prolonging the use of such resource as much as possible by applying relevant management tools and measures. Much complexity is added when the non-renewable aquifer of interest is shared between different countries. The unwritten rule of shared resources will then be applied. The rule entails that what is left today will not necessarily be saved for tomorrow, but will be exploited by other partners.

The Nubian Sandstone Aquifer System (NSAS) is a good example of a transboundary non-renewable aquifer with motivated riparians. Egypt, Libya, Sudan, and Chad have shown much interest in cooperation and have responded positively to many initiatives.

The authors have previously studied different scenarios for the safe future utilization of NSAS in Egypt. This study focuses on the four riparian countries altogether. Scenarios will be drawn based on the developmental needs of all countries. A total management plan can then be proposed. The optimum management plan to achieve the maximum possible sustainability of NSAS could be divided into two main parallel axes, the first is decreasing the consumption, and the second is recharging the aquifer. As for decreasing the consumption, among all water use sectors, the domestic sector in all four countries has the highest priority; it should be the only sector using abstracted fossil groundwater. Other sectors can rely on other water sources such as treated waste water which appears to be the most affordable option to NSAS countries or desalinated water. Using treated waste water in agriculture will make a significant difference towards sustainability, as the agricultural sector is usually the highest consumer.

The future development plan for NSAS will clearly identify its life expectancy and accordingly, the maximum yearly drawdown. Alternative plans on utilizing other water resources such as seawater desalination will be set up and ready for execution before the end of the aquifer's life expectancy.

Keywords: Transboundary, Nubian Aquifer, Fossil Groundwater, Non-Renewable, Sustainable Development.

1. THE AQUIFER AND THE RIPARIANS

1.1. Introduction

The Nubian Sandstone Aquifer System (NSAS) is a transboundary groundwater basin in the North Eastern Sahara of Africa (Fig.1). The international waters of this regional aquifer are non-renewable and shared between Chad, Egypt, Libya and Sudan. The area occupied by the Aquifer System is 2.2 million square km; 828,000 square km in Egypt, 760,000 square km in Libya, 376,000 square km in Sudan, and 235,000 square km in Northern Chad. The volume in storage represents the largest freshwater mass in the whole world. The total recoverable volume of about 15000 cubic kilometers was assessed based on 100m drawdown in the unconfined aquifer and 200m drawdown in the confined aquifer (AbuZeid, 2003).

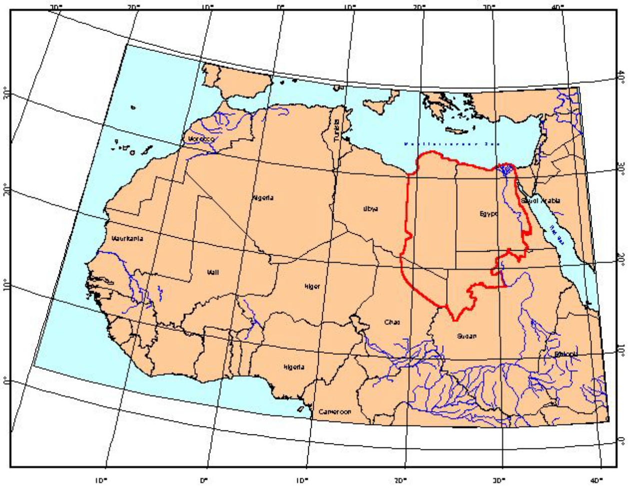

Fig.1 Location of NSAS

The increasing demographic growth and the lack of renewable water resources in this arid region have resulted in an increasing attention to the groundwater potential represented by the NSAS (AbuZeid, 2003)

The four countries sharing the NSAS represented by their National Coordinators adapted a regional information network aiming for cooperation and knowledge exchange in order to achieve the best scenario for sustainable development, and agreed to continue the monitoring of the aquifer through a mechanism specified in two agreements. Regional thematic maps, regional mathematical model, and a regional information system were developed. Also, a regional strategy was developed based on extensive data collection and Numerical Modeling (CEDARE, 2002). Throughout the regional programme as well, the role of the Joint Authority for the Study and Development of the NSAS was revitalized. The countries agreed to update the information by continuous monitoring and sharing of the following information; Yearly extraction in every extraction site, Representative Electrical Conductivity measurements (EC), and water level measurements (AbuZeid, 2002).

Information about the NSAS in Chad is limited (IAEA, 2010). It is well known that the agricultural sector provides the life blood of almost the entire population with livestock farming being the second most popular activity (WRI, 2009).

Being under severe water pressure, Egypt has realized the importance of expanding development to the desert since the mid seventies. The NSAS is the only source that can replace the Nile River. However, the sustainability of utilising the NSAS is highly questionable as fossil water could not be a reliable water source for new settlers. A scheme that involves conjunctive use of Nile Water and NSAS water would sound more reasonable, especially if other non-conventional water sources are utilised such as treated waste water.

Revenues from oil exploration and abstraction projects greatly helped the Libyan government to invest in water investigations which lead to the establishment of the biggest groundwater conveyance system in the world. The "Great man-made river" has cost Libya no less than 30 billion USD. The Project will eventually convey over six million CM of water per day from the Sahara Desert to coastal population centers including the capital Tripoli. (IAEA, 2010)

The cultivable area in Sudan is estimated at about 105 million hectares which accounts to about 42 percent of the total country area, however, in 2002 the cultivated land was 16.65 million hectares which only accounts to 7 percent of the total country area and 16 percent of the cultivable area (WRI, 2010). As in the case of Egypt, the Nile has also become a strained water resource, in light of the country´s growing human populations and migrations of younger generations from rural to urban areas. To the north of the country, life is confined to the narrow, low areas adjacent to the Nile. Government policy has called for increased wheat production in the two northern states which has further strained limited water resources there. The NSAS area in Sudan is predominantly desert in the north and central parts changing to semi-desert in the south. It has a population size of about 285 000 people with 77% living in North Darfur State and the rest in the Northern State. Development policy has called on increased exploitation of the NSAS which has recently been fuelled by the country´s strong oil revenue base (IAEA, 2010).

1.2. Objectives

The main objective of this paper is to draw variable scenarios for the four riparian countries to utilize NSAS sustainably. The sustainable development of a resource that will be surely depleted is an extremely challenging process. The sustainable development in that case refers to prolonging the use of such resource as much as possible by applying relevant management tools and measures.

All scenarios will have the year 2010 as a base year and a starting point for calculations. Population data for the year 2010 were acquired from the Egyptian population clock, Chadian census, Sudanese census, and the 2008 UN population estimate for the year 2010. Annual growth rates were taken from recent World Bank assessments. Other Water Resources related data were acquired from FAO AQUASTAT database.

The recoverable volume for each country was assumed to correspond to the NSAS area included in each country. Table 1 shows some of the important and assumed data that will influence the scenarios build-up.

Country	Population	Population Growth rate (%)	Total Area (km^2)	Aquifer Area (km^2)	Cultivated area (km^2)	Recoverable Volume (CM)	Annual Renewable Water Resources per capita (CM)
Chad	11,274,106	2.7	1,284,000	100,000	43,300	6.38298E+11	3940
Egypt	78,826,000	1.82	1,001,450	850,000	35,380	5.42553E+12	702.8
Libya	6,546,000	2.01	1,759,540	650,000	20,500	4.14894E+12	95.33
Sudan	39,154,490	2.24	2,505,810	750,000	195,460	4.78723E+12	1560

Table 1 Basic data and assumptions

2. UTILIZATION SCENARIOS

The first scenario will work on securing all future population needs in the four riparian countries; the water poverty index has been set at 1000 cubic meters per capita per year. Table 1 shows that Egypt and Libya are well under the water poverty limit. In an imaginary scenario, fulfilling 1000 cubic meters per capita per year will have different effects on the aquifer's sustainability for the four different countries as countries with highest populations will be affected the most as shown in table 2a. There are so many reasons that make the previous scenario un-realistic, a country like Libya has always accommodated its development plans to 95 CM/ Capita/ year, a sudden increase to 1000 CM/ year will be too drastic. Chad will not benefit from this scenario at all as they are already well over the water poverty index. Also, relying on NSAS alone for securing future needs is not practical, given the fact that it will always be a temporary water source.

Therefore, reducing the annual per capita share to 500 will be a reasonable compromise to the first scenario, the NSAS sustainability for each country is shown in Table 2b.

Under the assumption that 80% of the abstracted water will be used for new agricultural development, Fig.2 shows the new cultivated land in each country during the years in which the NSAS is exploitable.

Country	Sustainability(end year)
Egypt	2054
Libya	2141
Chad	2044
Sudan	2068

Table 2a Scenario 1 (1000 CM/Capita/year)

Country	Sustainability(end year)
Egypt	2079
Libya	2174
Chad	2062
Sudan	2093

Table 2b Scenario 2 (500 CM/Capita/year)

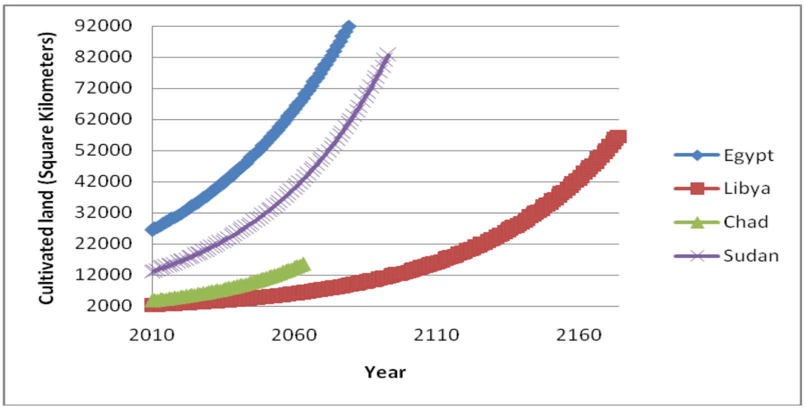

Fig.2 New Cultivated land according to Scenario 1

While the first scenario honoured agriculture as the main activity in the four NSAS countries, the second scenario will assume that industry will be the main activity of future generations in these countries. Therefore, the per capita share of water to be exploited from NSAS is 150 CM in the second scenario, which covers the municipal needs as well as the industrial needs. Agriculture will be a secondary activity that will depend on treated wastewater, in other words, NSAS water will be used by the municipal and industrial sector and then reused by the agricultural sector. Table 3 shows the sustainability that could be achieved through the second scenario, while Fig.3 shows the new cultivated land in each country during the years in which the NSAS is exploitable

Country	Sustainability(end year)
Egypt	2132
Libya	2233
Chad	2099
Sudan	2142

Table 3 Scenario 2 (150 CM/Capita/year)

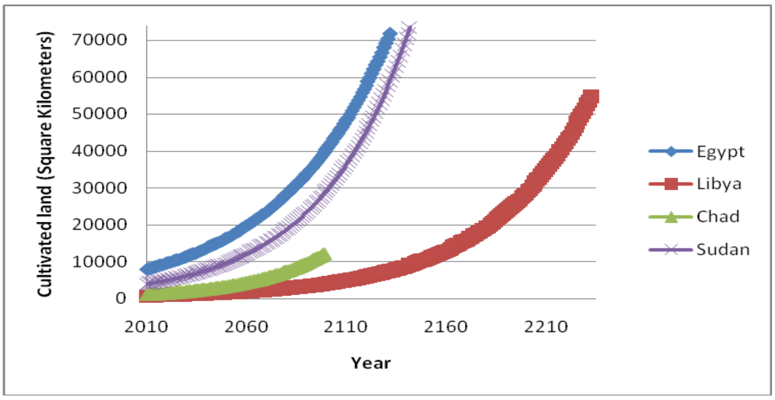

Fig.3 New Cultivated land according to Scenario 2

The third and last scenario will follow the same concept of the second scenario which is prioritizing municipal and industrial water needs; however, it will not be utilized for the sake of the whole country population as in the previous two scenarios, it will rather be exploited for a target population. As commonly practiced by transboundary water resources law experts, dependency will be the main criterion for selecting the target population in each country.

In Egypt, the western desert is the place that will most likely depend on NSAS in the near future as it is isolated from other water sources. In Sudan and Chad, picking a target population is an easier task as the aquifer only bounds the Northern part of both countries as shown in Fig.1. The aquifer occupies the areas of least population density in Sudan which gets as low as 1 capita per square kilometre. Whereas in Chad, the aquifer occupies a troubled area, the northern Borkou-Ennedi-Tibesti region is characterized by the presence of un-cleared minefields and significant rebel activities. Even though the Chad/Sudan border is open to overland traffic, it is not currently advisable to travel on the main route from Chad into Western Sudan, which is a huge obstacle to development. The unstable security situation in Darfur is has significantly added its toll to the problem. However, the third scenario assumes that future conditions will be more suitable for development in the NSAS area.

Libya will be the only exception in this scenario, as the dependency criterion set above entails that the whole population is the target population. In the other three countries, it will be assumed that the annual population increase will immigrate to the new communities, 150 cubic meters per capita will be exploited for the municipal and industrial sectors, and the resulting waste water will be treated and used for agriculture. Table 4 shows the sustainability achieved under scenario 3 while Fig. 4 shows the new cultivated land under the same scenario.

Country	Sustainability(end year)
Egypt	2348
Libya	2233
Chad	2231
Sudan	2311

Table 4 Scenario 3(new communities) (150 CM/Capita/year)

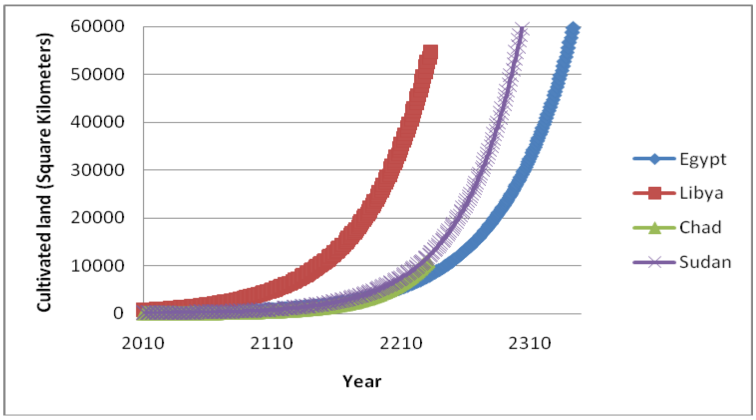

Fig.4 New Cultivated land according to Scenario 3

3. CONCLUSIONS AND RECOMMENDATIONS

Three scenarios have been presented in this study, the main difference between the first two scenarios considered the whole population of the four NSAS riparian countries with the main activity being agriculture and industry respectively. The third scenario supports the formation of new communities in all countries; it also supports prioritizing the municipal and industrial sectors among all other sectors.

Scenario 3 is favoured and recommended as it has the highest sustainability as shown in tables 2 through 4. It seems to be the best optimized solution for the four NSAS country as each country will gain at least one benefit. The Libyans will get 150 CM/capita/year which is a reasonable amount for a country that gets as low as 95 CM/ capita/ year of renewable water resources, Libya was also given an advantage over other countries due their existing dependence on NSAS. This scenario will also help a large area in Egypt in refraining from relying on the Nile River water for a considerable amount of time that is long enough to think of future alternatives after NSAS ceases to exist. Sudan and Chad will revitalize their northern parts in a manner that can possibly enhance trade and other bilateral activities.

An important question that needs to be answered is what will happen after the end years of scenario 3. For Libya and Egypt, expansion in sea-water desalination seems to be the immediate solution, however, it takes huge funds to convey desalinated water from the northern Mediterranean shore to the South of both countries, and therefore, revenues from the new industrial community should be allocated for such future plans. The problem of "What happens next?" is less complicated in Sudan and Chad as they are not water stressed countries, however, expanding in waste water treatment may do both countries good as a water scarcity shelter.

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