Sustainable Development of Non-renewable Transboundary Groundwater: Strategic planning for the Nubian Sandstone Aquifer System (NSAS)

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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 focuses mostly on 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. 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 for 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.

Key words: 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 one of the largest freshwater masses 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).

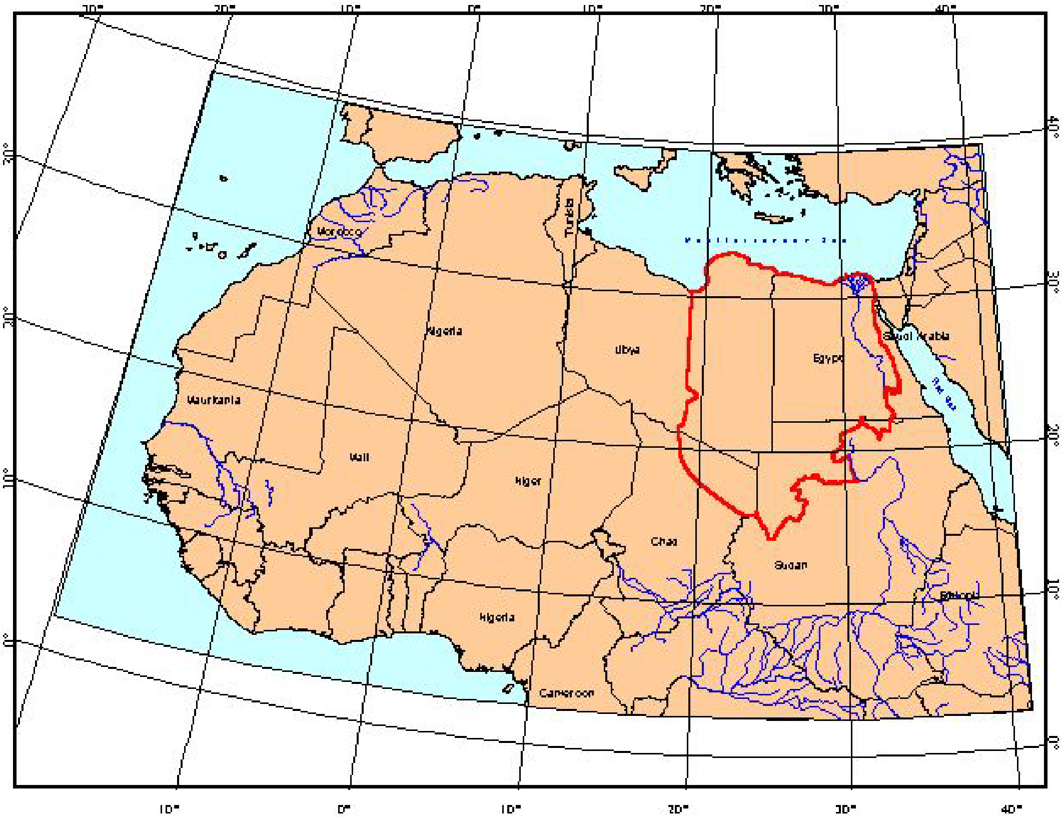

Fig.1: Location of NSAS

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)

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 centres 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 the 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.

Table 1: Basic data and assumptions

Country	Population	Population Growth rate (%)	Total Area (km^2)	Aquifer Area (km^2)	Cultivated area (km^2)	Recoverable Volume (Million CM)	Annual Renewable Water Resources per capita (Cubic Meters(CM))
Chad	11,274,106	2.7	1284000	100000	43300	638,298	3940
Egypt	78,826,000	1.82	1001450	850000	35380	5,425,532	702.8
Libya	6,546,000	2.01	1759540	650000	20500	4,148,936	95.33
Sudan	39,154,490	2.24	2505810	750000	195460	4,787,234	1560

2. UTILIZATION SCENARIOS

The first scenario will work on securing all future population needs in the four riparian countries; the water scarcity limit 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. Therefore, providing each country with 500 cubic meters per capita from NSAS abstractions will be a reasonable compromise, the NSAS sustainability for each country is shown in Table 2 which also shows the increase in agricultural land and the end year population for each country.

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 under the realistic assumption that each acre needs 5000 CM annually. Fig. 3 shows the per capita share in all countries according to scenario 1.

Table 2: Sustainability ,Population and increase in agricultural land for Scenario 1 (500 CM/Capita/year allocated equally to all countries)

Country	Sustainability(end year)	End year Population	Increase in Agricultural area (Acres)
Egypt	2079	273,623,180	22,800,472
Libya	2174	279,095,643	14,034,441
Chad	2062	45,055,227	3,855,730
Sudan	2093	246,213,215	20,516,455

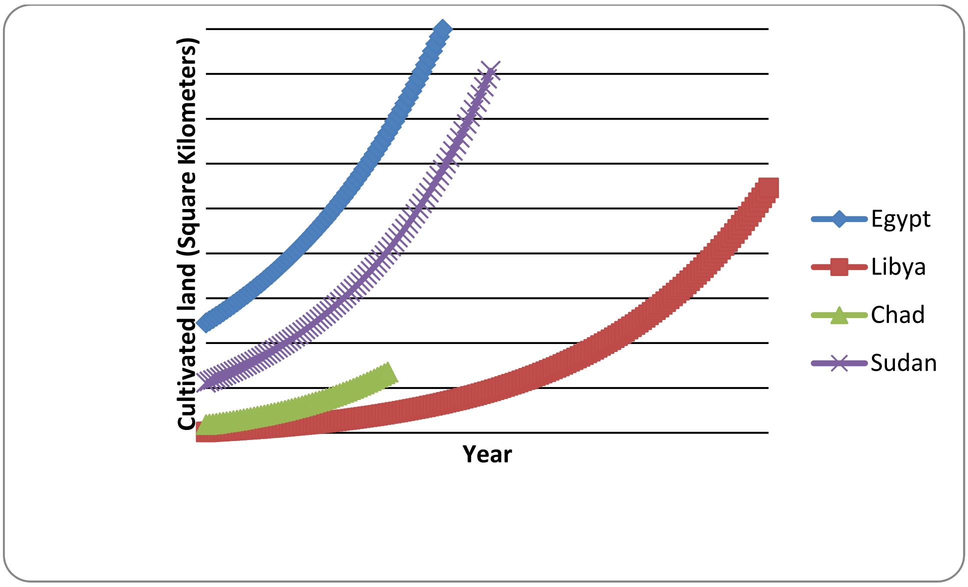

Fig.2: New Cultivated land according to Scenario 1 (500 CM/Capita/year allocated equally to all countries)

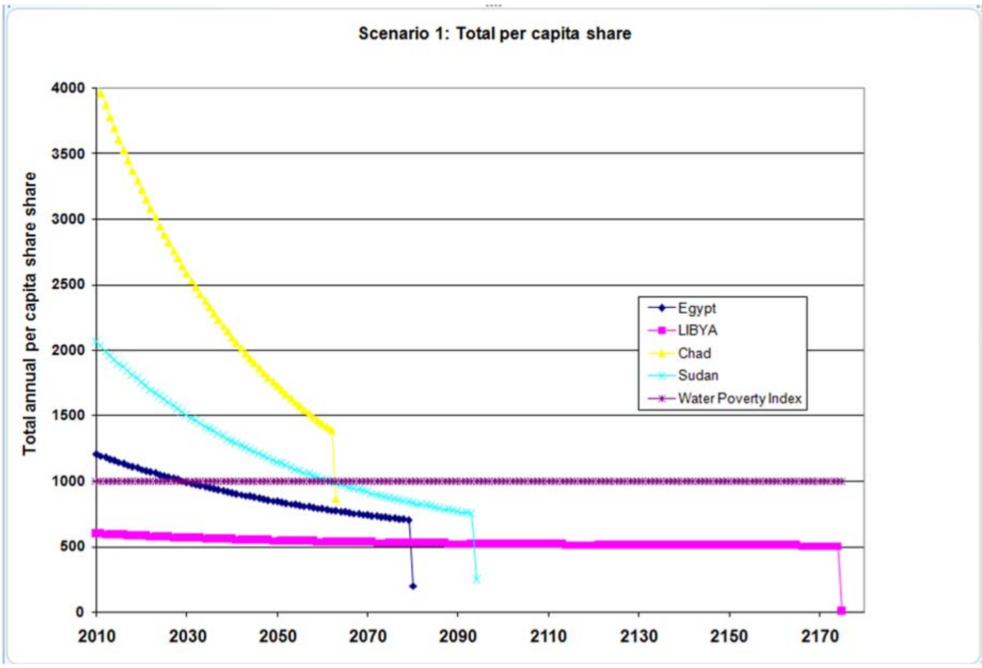

Fig.3: country per capita share according to Scenario 1 (500 CM/Capita/year allocated equally to all countries)

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 and it will be equally allocated to all four countries, 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. It is assumed that 80% of the abstracted water will be treated which amounts to 120 cubic meters per capita. Table 3 shows the sustainability that could be achieved through the second scenario, while Fig.4 shows the new cultivated land in each country during the years in which the NSAS is exploitable.

Country	Sustainability (end year)	End Year Population
Egypt	2132	711,716,114
Libya	2233	541,769,191
Chad	2099	120,740,117
Sudan	2142	729,008,444

Table 3a: Scenario 2 (150 CM/Capita/year allocated equally to all countries)

Country	Increase in Agricultural area (acres)
Egypt	17,791,764
Libya	13,543,363
Chad	3,018,310
Sudan	18,224,045

Table 3b: Increase in Agricultural area for Scenario 2 (150 CM/Capita/year allocated equally to all countries)

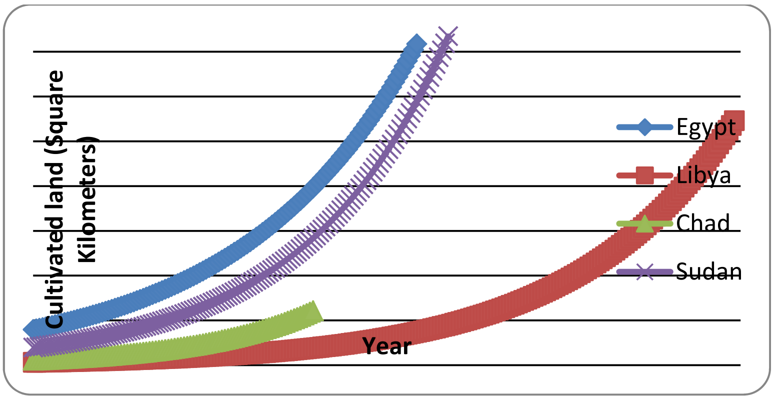

Fig.4: New Cultivated land for Scenario 2 (150 CM/Capita/year allocated equally to all countries)

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 annual population increase will be the target population as the existing population totally depends on the Nile, also, in Sudan and Chad the target population will be the annual population increase as the existing population depends on the Nile and rainwater. The target population in Libya will be half the total future population as half the existing population already depends on the NSAS and the other half depends on the North Western Sahara Aquifer.

As in the previous scenario, 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 4a shows the sustainability achieved under scenario 3 while Fig. 4 shows the new cultivated land under the same scenario.

Country	Sustainability (end year)	End Year Population
Egypt	2348	637,274,014
Libya	2268	541,739,272
Chad	2231	109,777,645
Sudan	2311	690,085,139

Table 4a: Scenario 3 (150 CM/Capita/year for target population)

Country	Increase in Agricultural area (acres)
Egypt	15,930,831
Libya	13,542,615
Chad	2,744,266
Sudan	17,251,024

Table 4b: Increase in Agricultural area for Scenario 3 (150 CM/Capita/year for target population)

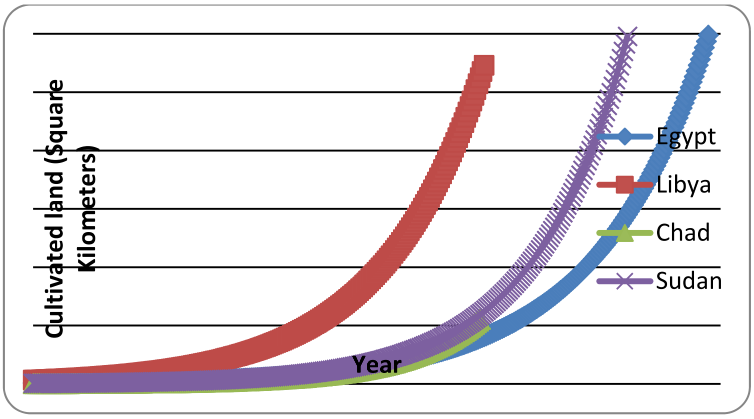

Fig.4: New Cultivated land according to Scenario 3 (target population) (150 CM/Capita/year)

3. CONCLUSIONS AND RECOMMENDATIONS

Three scenarios have been presented in this study the first two scenarios considered the whole population of the four NSAS riparian countries with the main activity being agriculture and industry respectively. Sudan and Chad may not be in need to benefit from the first two scenarios until later years as they are already well over the water scarcity limit.

The third scenario suggests directing NSAS to support the municipal and industrial sectors among all other sectors, for the use of populations above existing levels. Scenario 3 is favoured and recommended as it has the highest sustainability and can be modified to start at different years depending on countries falling below water scarcity limit.

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 and 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. Desalination of deep brackish groundwater is an option for all countries beyond depletion of fresh groundwater as well as treated wastewater which may be considered the renewable resource of the future.

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