

ASSESSMENT OF IMPACTS ON GROUND WATER RESOURCES IN LIBYA AND VULNERABILITY TO CLIMATE CHANGE

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Abstract

This paper is designed to present the likely impact of climate change on groundwater resources in general and Libya in particular. State of the art reviews on recent research studies, and methodology to assess the impact of climate change on groundwater resources shows that climate change poses uncertainties to the supply and management of water resources. It outlines to demonstrate that how climate change impact assessment plays a vital role in forming the sensitive water balance rarely achieved in most area owing to precipitation variability's and seasonality. It demonstrates that how large increases in water demand with very little recharge from precipitation have strained Libya's groundwater resources resulting in declines of groundwater levels and its quality, especially on Libyan coastal areas where most of the agriculture, domestic and industrial activities are concentrated. Based on several research studies it demonstrates that how policy and decision making process using best practices for monitoring, analyzing and forecasting variation of climate is a way forward to cope with the impact of sea level rise, and combat some water supplies in vulnerable areas that are becoming unusable due to the penetration of salt water into coastal aquifers (Jifara Plain, Sirt, Jebal El-Akhdar). Finally, a number of Global Climate Models (GCM) are reviewed to demonstrate that how better understanding of climate and climate change forecasting helps in devising appropriate adaptation strategies due to the impact of climate change.

Keywords: climate change, impact assessment, ground water resources, global climate models, greenhouse gas

1. Introduction

Libya as an arid nation accounts for 94.5% areas as desert with perpetually scarce freshwater. Barely five percent of the country receives more than 100 mm of rain each year. Libya since long relies on groundwater reserves to meet its needs. However, surging demand is stressing supply, and many coastal groundwater aquifers are becoming brackish with an influx of seawater. Thus a major environmental concern in Libya is the depletion of underground water as a result of overuse mainly in agricultural developments, causing salinity and sea-water penetration into the coastal aquifers [9]. As per an essay in “The Arab Spring and Climate Change,” a study recently published by three think-tanks in Washington shows that if the new government does not address the issue of water shortages it may cause great insecurity. The draining of the aquifer isn't

Libya's only problem, if it starts extracting even more groundwater from the Nubian aquifer to deal with drought, it could cause tension with neighbours Egypt, Chad and Sudan, all of which share the aquifer with the potential to destabilize the region [2]. Another significant environmental problem in Libya is water pollution due to the combined impact of sewage, oil byproducts, and industrial waste that threatens its coast and the Mediterranean Sea generally [3]. Libya has 0.8 cu km of renewable water resources with 87% used in farming activity and 4% for industrial purposes. Only about 68% of the people living in rural areas have pure drinking water. The Libyan cities produce about 0.6 million tons of solid waste per year. The desertification of existing fertile areas is being combated by the planting of trees as windbreaks. Endangered species estimates of 2001 shows that 11 of Libya's mammal species and 2 of its

bird species are extinct. About 41 of its plant species are also reported as endangered. Endangered species in Libya include the Mediterranean monk seal, the leopard, and the slender-horned gazelle. The Bubal hartebeest and Sahara oryx are extinct [8].

Ground water resources are due to water held in the spaces between the rocks and in the tiny interconnected spaces between individual grains in a rock like sandstone. These bodies of wet rock known as aquifers contain ground water. It does not sit still in the aquifer but is pushed and pulled by gravity and the weight of water above it. The movement of the water through the aquifer removes many impurities and makes it often cleaner than water on the surface. Now scientists and researchers from the British Geological Survey and University College London recently conducted a continent-wide analysis of the water that is hidden under the surface in aquifers. Findings show greatest ground water storage in northern Africa, in the large sedimentary basins, in Libya, Algeria and Chad [4].

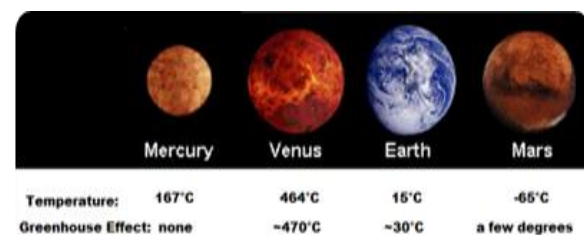
Recent global analysis shows that around 80% of the world's population lives in areas where the fresh water supply is not secure. World over, more people are likely to encounter more severe stress on their water supply in the coming decades, as the climate changes and the human population continues to grow [12].

Ancient aquifers of Libya store 40,000-year-old reserves of pure drinking water [5]. This groundwater is put in place during ancient eras of dramatically different climates and became encapsulated through geological changes. Like the fossil fuels this “fossil water” is a non-renewable resource with great potential. It is being tapped through Man-Made River Project though a network of pipes and reservoirs that move water from its subterranean desert origins to the heavily-populated coastal region at a total estimated cost in excess of \$20 billion (U.S.). The system with a design life of 50 years is pumping water from some 1,300 desert wells and move 6.5 million cubic meters a day using 4,000 km (2,485 miles) of 4-meter-diameter pipeline. Like elsewhere, Libya too is impacted by climate change in numerous ways, especially in crop production and food security, pastoral lands and livestock production, water resources, human health, population emigration and settlement, natural resources management and biodiversity. As per an estimate annual renewable water resources are 6 km³/year and the annual total fresh water withdrawal is 4.6 km³. The biggest user of water in Libya is agriculture (87 %) followed by domestic use (11 %) and industrial use (2 %) [6]. Climate changes could exacerbate existing problems of water resources and cause a decline in water quality through increasing concentrations of pollutants and sea water intrusion on coastal groundwater aquifers. The changes of precipitation combined with increased evaporation would directly reduce runoff and groundwater levels [7]. The

problem of water resources is expected to be compounded by increases in demand driven by socio-economic factors. Problems of saline intrusion are getting further exacerbated by reductions in runoff and by increased withdrawals in response to higher demands.

2. An Appraisal of Climate Change and Existing Water Resources Using Remote Sensing

Climate change is a long term change in the average weather. Over view shows that climate has always been variable. Glacial periods and warmer periods have occurred throughout Earth's history. This variability is natural and is caused by many things. Global temperature change (between glacial and interglacial periods) occurs normally at a rate of 0.05 – 0.005°C every 100yrs [13]. Global warming is caused by releasing heat-trapping greenhouse gases (GHG) into the atmosphere. The most common greenhouse gas is carbon dioxide. Many of the activities like turn the lights on, cook food, or heat or cool our homes rely on the combustion of fossil fuels like coal, natural gas, and oil, which emit carbon dioxide and other greenhouse gases when burned. Some greenhouse gases are good – they allow our planet to be warm enough to support life. While Venus is closer to the sun than Earth is, cloud-covered Venus absorbs only 25% of incident sunlight, while Earth absorbs 70%. However, Venus is warmer because it has a thick carbon dioxide atmosphere causing a greenhouse effect of several hundred degrees [14, 15]. This atmosphere also causes Venus to be hotter than Mercury on average because Mercury has little atmosphere and does not retain heat, actually making the planet very cold at night as shown below.



For millions of years, huge amounts of carbon, methane, and other contributors to the greenhouse effect are locked up inside of plants, fossil fuels like oil and coal that are made of dead animals and plants, and in frozen pockets underneath the arctic tundra giving the earth a relatively stable climate, to which all current life on earth has adapted. In the last 50yrs the global average temperature has increased by 0.5 degrees. This is between 20 and 200 times the normal rate, and it's accelerating, as seen in figures 1 & 2.

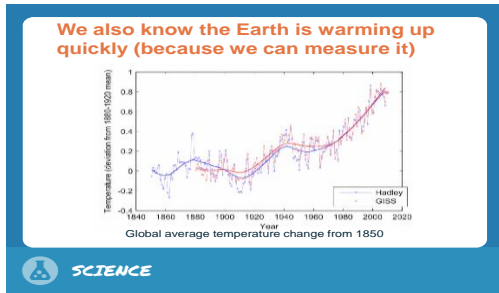


Fig. 1: Warming of earth, source [1]

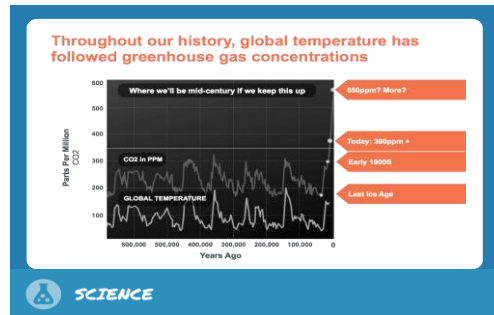


Fig. 2: Greenhouse gas history, source [1]

The top ten hottest years on record have all been in the past 15 years. The Arctic is currently warming at twice the rate of the rest of the world. Between 1979 and 2007, the Arctic lost over 40% of its ice. In a 2005 survey of 442 glaciers, 398 - or 90% - were retreating. World is already seeing an increase in sea levels which is impacting coastal communities across the globe. Houses are literally falling into the sea in some coastal areas of Alaska. Sea level rise is already impacting island nations because it is decreasing their land area. This can be very challenging on smaller islands where moving inland just isn't an option. Many effects of climate change can be seen at the global level such as flooding and drought. Between 1950 and 2000, almost all continents saw a skyrocketing increase in major floods. The fact is 4 percent more water vapour is available both to power individual storms and to produce intense rainfall from them. Climate change is present in every single meteorological event, in that these events are occurring within a baseline atmospheric environment that has shifted in favour of more intense weather events.

Climate change is reported to have turned the Sahara into a desert over centuries. It is found that many of the aquifers underneath were last filled with water over 5,000 years ago. Collated information from existing hydro-geological maps from national governments as well as 283 aquifer studies show that Africa in general and Libya in particular possess enough groundwater to serve as the major source of drinking water. However, its use for irrigation is increasingly on rise to cope with growing food insecurity. Appraisal shows that there is little or no reliable quantitative information on groundwater resources in Africa. Generally groundwater storage estimates are unavailable from assessments of

freshwater availability. The first quantitative continent-wide maps of aquifer storage and potential borehole yields in Africa is based on an extensive review of available maps, publications and data as shown in figure 3. Indicates that the total groundwater storage in Africa is of the order of 0.66 million km^3 (0.36–1.75 million km^3).

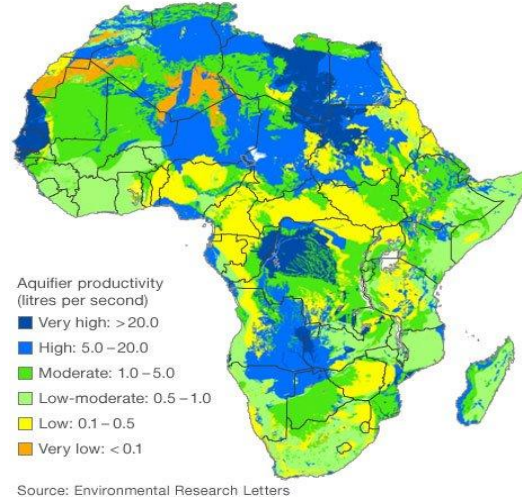


Fig. 3: Ground water storage in Africa

Estimates show that not all of this groundwater storage is available for abstraction. Also, the estimated volume is more than 100 times estimates of annual renewable freshwater resources on Africa. The above figure shows that ground water resources are unevenly distributed. The largest groundwater volumes are found in the large sedimentary aquifers in the North African countries like Libya, Algeria, Egypt and Sudan. Sited and constructed boreholes that support hand pump abstraction (yields of $0.1-0.3 \text{ l s}^{-1}$), show sufficient storage to sustain abstraction through inter-annual variations in recharge. The maps show further that the potential for higher yielding boreholes ($> 5 \text{ l s}^{-1}$) is much more limited. Since groundwater is the largest and most widely distributed store of freshwater in Africa, therefore, the quantitative maps can lead to more realistic assessments of water security and water stress to promote a more quantitative approach to mapping of groundwater resources at national and regional level.

The North West Sahara aquifer system (NWSAS) as shown in figure 4 is comprised of multilayered hydro geological system. It accounts for an area of over 1 million km^2 between Algeria, Libya, and Tunisia. This is the most important water resource in the desert and semi-desert area of North Western Sahara with the estimated water reserves of around ($\sim 30,000 \text{ km}^3$). Most of the reserves are non-renewable and not fully exploitable (Abid et al., 2012). As per findings of a recent survey of the basin it shows withdrawals of $2.2 \times 10^9 \text{ m}^3/\text{y}$ with an upward increasing trend due to increasing population and enhanced domestic, industrial, and especially farming needs. This is evident from widespread spatial

concentration of withdrawal points in small areas and new large well fields and adduction works by Libya and Algeria. This is reflected from aquifer pressure loss, salinization, soil degradation, natural oases disappearance, natural discharge depletion and water level drawdown affecting the aquifer.



Fig. 4: North West Sahara aquifer system (NWSAS)

Studies indicate that growing water demand is having a marked impact in terms of both depletions and quality deterioration on the water resources in Libya too. The common benchmark for water scarcity is reported to be 1000 m³/year/person. In Libya like elsewhere in Middle East and North Africa, 53 % of the people live with less 100m³/year/person. Renewable resources per person that are estimated to be down from 538 in 1960 to 154m³/year/person in 1990, respectively, and are expected to shrink to only 55 m³/year/person in 2025.

In Libya, like in most arid and semi-arid lands high evaporation rate is of the order of up to 100 % poses an additional challenge facing water resources similar to the one from a combination of salt water intrusion due to sea level rise and increased soil salinity due to increased evaporation. The result is reduced quality of shallow groundwater supply and saline intrusion as reported in many parts in northern Libya. There is widespread water deficit as evident from declination in water level and quality deterioration especially around agricultural lands and urban areas where excessive use of groundwater has given way to seawater intrusion. The estimates show that decline in water level is over 1 m/year and total dissolved solids exceeded 9,000 milligram/liter over the last four decades. The consequence of water supplies becoming unusable due to the penetration of salt water into coastal aquifers in (Jifara Plain, Sirt, Jebal El-Akhdar) is recently observed by authors. A recent report by Busby et al. at the University of Texas, Austin [10], notes that between now and the middle of the century, some of the wettest and most populated areas of Libya, along the Mediterranean coast, are likely to experience increases in drought days — meaning no rainfall — from a current 101, to a whopping 224. This highlights the need for monitoring, analyzing and forecasting variation of climate that are direly needed for policy making and rational decision making process. In addition, changing temperature and precipitation regimes is causing frequent changes in the water budget vital for monitoring and control of irrigation and flood control system, water storage, and hydroelectric installations as well as for production systems.

3. Climate Change and Water Availability Scenarios.

Recent estimates of results in the form of water availability with change in climate from increased temperature, increased GHG due to industrialization and increased population, for the years 1990, 2020, 2050 & 2070 are shown in figure 5 through figure 8.

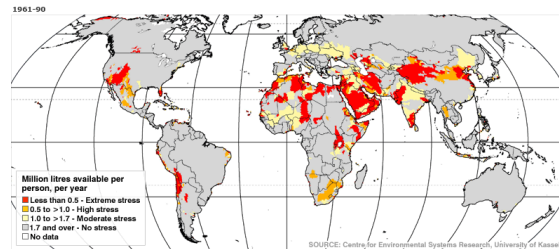


Fig. 5: Water availability in 1990, source [11]

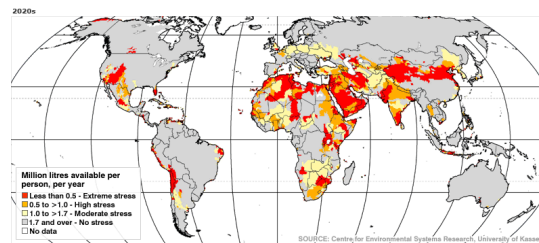


Fig. 6: How water availability may change, as temperatures, population and industrialization increase - year 2020, source [11]

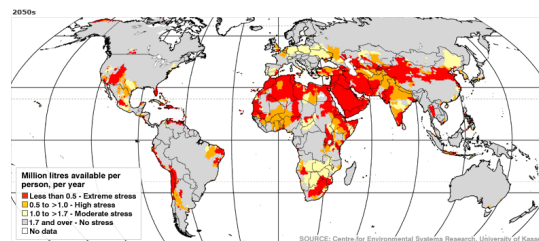


Fig. 5: How water availability may change, as temperatures, population and industrialization increase - year 2050, source [11]

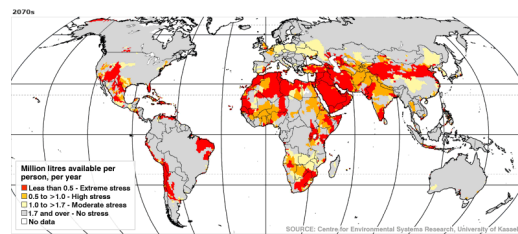


Fig. 5: How water availability may change, as temperatures, population and industrialization increase - year 2070, source [11]

The above findings by Florke et al. at University of Kassel in Germany show that as climate change progresses it is likely to have dramatic effects on the supply of water [11]. In some areas at higher latitudes it may increase, but water-stressed areas in the mid-

latitudes are expected to face a reduction in available water.

A computer model of climate change by the UK Met Office Hadley Centre generates projections of future temperature and rainfall. The Intergovernmental Panel on Climate Change (IPCC) produces “scenarios” suggesting how society may develop economically and socially over time [20]. The Kassel researchers used these scenarios to project water use by various sectors of the economy. Having forecast the availability of water and the demand from industry, it is possible to calculate how much water would be available per person at different points in the future [21].

In coastal regions especially in low-lying areas, are likely to see sea level rise that will change the shape of coastlines around the globe. Industrialized nations are able to spend billions on flood protection schemes. Many small island nations are at risk of disappearing beneath the waves. UN in figure 9 shows that in a century the factors driving the increase? Glaciers: if the world’s mountain glaciers and icecaps melt, sea levels will rise by an estimated 0.5 m. Thermal expansion: the expansion of warming oceans was the main factor contributing to the sea level rise in the 20th Century, and currently accounts for more than half of the observed rise in sea levels. Ice sheets: these vast reserves contain billions of tones of frozen water – if the largest them (the East Antarctic Ice Sheet) melts, the global sea level will rise by an estimated 64 m [16].

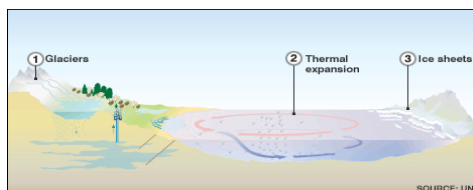


Fig. 9: Factors Driving Climate Change in Coastal Areas, source [16]

As per IPCC, the majority of the current global average sea level rise of about 3 mm each year is from the thermal expansion of the oceans. As greenhouse gases become more concentrated, more heat energy is trapped in the atmosphere. This energy is absorbed by the world oceans, causing it to warm and expand. The IPCC estimates are shown in figure 10.

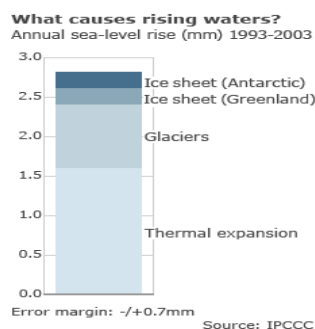


Fig. 10: The main factors after sea level rises, source [16]

Melting water from mountain glaciers is another factor that contributes to sea level rise. UN Data based on observations shows that, on average, snow and ice cover in the world’s mountain ranges have declined. The run-off increases the volume of water flowing into rivers and lakes, which in turn ends up in the seas. However, there are big question marks over how much the vast polar ice sheets, which have the potential to have a catastrophic impact, will contribute to future sea level rise. Estimates show that the world’s three ice sheets - Greenland, West Antarctic and East Antarctic - are vast bodies of ice, containing billions of tones of frozen water. At present, their contribution to average sea level rise is relatively small but is projected to become key drivers. In Fourth Assessment Report (AR4), the Intergovernmental Panel on Climate Change (IPCC) projected a sea level rise of up to 43 cm by 2100 [17]. It did not predict how the ice sheets respond to a warming world. The AR4, researchers of glaciers in Greenland and parts of the Antarctic show flowing more quickly, is feeding more ice into the oceans, leading into faster sea level rise. Since 2007, there is more research into the dynamics of the ice sheets, resulting in a number of updated projections [18].

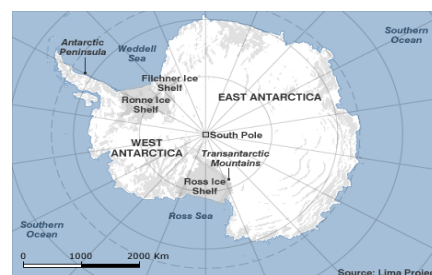


Fig.11: Climate Change in East Antarctica, source [16]

One of the latest assessments suggests that sea levels are likely to rise by about 1.4 m (4 ft 6 in) globally by 2100 as polar ice melts. A major review of climate change in Antarctica by international team of researchers shown in figure 11 warming seas are accelerating melting in the west of the continent.

By the end of the century, it is projected, that the sheet may lose enough ice alone to raise sea levels globally by "tens of centimetres". It added that the Antarctic Peninsula - the strip of land that points towards the southern tip of South America - has warmed by about 3C over the last 50 years, the fastest rise seen anywhere in the southern hemisphere. Other observers project a global average sea level increase of about one metre by 2100. There is a scientific consensus that the IPCC's 2007 projection of 43cm was too conservative. Small Island nations are at risk due to even a small increase resulting in the small islands disappearing beneath the waves.

4. Concluding Remarks

The state of the art on climate change shows that planet in general and Libya in particular is already in

the danger zone. So far, rich countries have emitted by far the most, while experiencing the least impacts from climate change. In order to develop an international, equitable solution to climate change all the Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. If Libya wishes to preserve a country with adequate water resources similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO₂ will need to be reduced from its current 387 ppm to at most 350 ppm [18]. GHGs remain in the atmosphere for a long time, so even if we stop emitting the impacts are there from what we have emitted already. Given our current emissions trajectory, world is headed for a 3-4 degree C rise in temperature, which scientists predict would cause crop yields to fall by up to 30 per cent. By the 2050s, 50% of agricultural lands are very likely to be subjected to desertification and salinization. 1.5-2.5 billion more people worldwide exposed to Dengue fever. 50% decrease in water flowing through rivers in the Mediterranean, Southern Africa, and parts of South America would, produce water shortages for millions.

The Palmer Drought Severity Index, which assigns positive numbers when conditions are unusually wet for a particular region and negative numbers when conditions are unusually dry. A reading of -4 or below is considered extreme drought. As per this Libya falls in a regions that could face more unusually extreme drought conditions. Scientists estimate climate change could wipe out 20-30% of species worldwide by the end of the century. Libya would face sea level rise, ocean acidification, sea surface temperature increase and change or halting of sea currents. Climate change could force 1 billion from their homes by 2050. The most comprehensive review ever carried out on the economics of climate change warns that global warming could inflict worldwide disruption as great as that caused by the two World Wars and the Great Depression. Water development projects established in Libya include steps for the utilization of surface water; in addition to the construction of thousands of reservoirs and tanks. Sixteen major dams with an estimated annual storage capacity of 300 mill. m³ were constructed and over 100 mill/m³ are treated annually for agricultural purposes. The Man-Made River project alleviates the pressure on water resources in northern parts of Libya such as Jifara Plain. Successfully adapting to climate change for ground water resources management using global climate change model (GCM) at the national level in Libya requires a set of conditions and elements at the national level. National level strategy must include: adequate institutional arrangements, including, systematic planning capacity in a cooperative

institutional, setting consistent policies and measures and regulatory frameworks.

Finally the paper concludes that the consequences of inaction are serious and advocates need for an integrated water management, where the needs of all users are taken into account and where natural features are integrated with human engineering. Discharges from the groundwater aquifer e.g. in Jifara Plain should be properly managed and the rate of the sea water intrusion could also be reduced by investigation and new management policies for optimal use of the freshwater in the aquifer. New technology has the capacity to answer challenges, and also to provide new tools and possibilities to the imagination of designers, engineers and architects. There are new solutions, and there are improvements to existing systems which can improve efficiency. One of the priorities in this respect is better use of underground aquifers. 70% of water use in the world for agriculture must use greater efficiency.

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