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# Impacts of Climate Change on Water Resources in Sudan

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## Abstract

The water sources in Sudan vary, as they represent river water, rain water, surface water and groundwater, where the lands of Sudan divide rivers, valleys, and creeks. However, Sudan suffers a variety of issues with regard to water, from a lack of safe drinking water and inadequate sanitation to water pollution and scarcity. Rapid population increase, urbanization, shifting consumption patterns, and competing demands from agriculture, industry, and energy are the main risks to the nation's water supplies. Additionally, with current and projected environmental changes on the horizon there is an urgent need to measure and analyze the impact of these changes. With global warming that has become a reality and the increase in greenhouse gas emissions will have a profound climatic, environmental, and social impact globally. Especially in the field of water sources, where droughts have begun in some areas, so it is necessary to reduce greenhouse gas emissions and switch to clean energy. Urgent and long-term efforts should also be made to conserve water and reduce risks related to climate change. All of these things may threaten life in large areas in Sudan, so through this review we have highlighted some of the problems related to climate change and its impact on water resources in Sudan, Where we focused in some detail on the expected effects on the rate of rainfall on agriculture, as it encapsulates the most significant water supply indirect effects of climate change.

**Keywords:** Climate Change, Water Resources, Sudan.

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## INTRODUCTION

Sudan is a vast country rich in natural resources. The main dependence of Sudan is agriculture, it is 80% of the population's activity, and it also depends on industry, especially agricultural industries. There are two main farming systems used in the Sudan for agriculture. More than 90% of the land used for cultivation (total cultivated land in 2018 was 21.2 million hectares) is covered by the main system, which is rainfed (both mechanically and traditionally), while the secondary system is irrigated (CBoS, 2018; Ministry of Agriculture and Forestry, 2017).

There are numerous agro-ecological zones with a range of climatic conditions, rainfall, soils, and vegetation due to its vastness and extend from south to north. The Nile system's water resources, along with groundwater resources, provide Sudan the possibility of a 30-year growth in the irrigated sub-sector. Additionally, there are chances to improve hydropower production (Abdeen, 2010).

Around 75 per cent of Sudan's land area lies within the Nile River Basin, which represents 44 per cent of the Nile Basin's total area (FAO, 2017). Sudan shares several transboundary aquifers with its neighbors, such as the Nubian Sandstone Aquifer, used by Sudan, Egypt, Libya and Chad, and the Um Ruwaba Aquifer, shared with South Sudan. Seasonal flows, erratic rainfall, siltation, floods, riverbank erosion, and pollution all have an impact on Sudan's inland rivers. The nation's marine and coastal resources are under threat from pollution, unchecked economic development, and climate change, despite the fact that they are becoming more and more essential to the economy and draw a sizable number of tourists (UNEP, 2020).

Sudan's share of the Nile water is about 18.5 billion cubic meters, and yearly rainfall ranges from nearly nothing in the North's hot, dry climate to more than 1600 mm in the South's tropical region (Abdeen, 2010; UNEP, 2020). In accordance with the promotion of basin-wide integrated development of the shared water resources, the national strategy of Sudan aims at the multipurpose use of water resources to achieve water security for achieving food security, drinking-water security, and hydro-energy security, at the regional levels (Abdeen, 2010).

Despite all of this, Sudan is considered a country with a water shortage. Water competition has historically been a source of hostility, but it may also be a chance for cooperation and peace. The careful management of Sudan's water resources is viewed as a means of fostering stability and long-term growth. Water resources could significantly contribute to enhancing the economy, society, and environment with effective institutions and suitable legislation (UNEP, 2020). Numerous research have examined the various aspects of climate change in Sudan. The majority of both the study that was done and the future forecasting work was concentrated on changes in temperature and precipitation, the two most significant climate parameters and extreme occurrences.

## CLIMATE CHANGE and WATER RESOURCES in SUDAN

Global climate change, the industrial revolution of the then mankind atmosphere to release the carbon dioxide, methane, ozone and nitrogen oxides as gases are very quickly heat the earth by the greenhouse effect that occurred as a result of the increase is a result of an increase above normal (Bağdatlı and Bellitürk, 2016a). Increasing or decreasing changes in climatic values affect living things negatively and cause a decrease in productivity, especially in agricultural production (İstanbulluoğlu et al., 2013).

Greenhouse gas emissions are the primary source of both global warming and climate change. There are varied contributions and intensities to the emissions of these gases from all economic activities, which implies diverse policy implications for how to cut emissions and deal with the effects of climate change at the national level (Mohammed, 2022). Climate change, as opposed to short-term weather variations, refers to large and ongoing changes in the average weather conditions over an extended period of time (IPCC, 2014). Increasing world population, changing climate conditions and economic activities are growing with each passing day makes it more important than water (Bağdatlı and Bellitürk, 2016b).

The second most important element for human survival is water. We face numerous problems with water supply, sustainability, and quality on a global scale (Ahuja, 2015). Therefore finding strategies to increase water sustainability is essential (Ahuja, et al., 2014).Most importantly, we need to reuse contaminated water and utilize water sparingly. The water cycle is an integrated and dynamic component of the earth's geophysical system and both affects and is affected by climate conditions. Changes in the earth's radiation balance affect winds, temperatures, atmospheric energy and water transport, cloud dynamics and more. Changes in temperature affect evaporation and transpiration rates, cloud characteristics and extent, soil moisture, and snowfall and snowmelt regimes. Changes in precipitation affect the timing and magnitude of floods and droughts, and shift runoff regimes. Synergistic effects will alter cloud formation, soil and water conditions, vegetation patterns and growth rates (Abdeen, 2010).

Water resources are one of the most important natural wealth of the country. Increasing parallel to the increase of the population's food needs is revealed as the role of water more efficiently. Water in agricultural production as well as significant human life is one of the indispensable inputs (Bağdatlı and Bellitürk, 2015).

Water scarcity is a result of both natural and human-caused factors. Freshwater is plentiful enough to supply the needs of 7 billion people, but it is dispersed unevenly and too much of it is squandered, polluted, and handled in an unsustainable manner. Every continent is impacted by the water crisis. Although there isn't a worldwide water scarcity per se, more and more regions are experiencing chronic water shortages due to the fact that water demand has been increasing at a rate more than twice as fast as population growth over the past century (Mejía, et al., 2012). In addition, sea level rise affects the water cycle under the surface of the coastal areas, which leads to a decrease in the flow of fresh water and a decrease in the proportion of fresh water areas. On the other hand, the rise in sea levels increases the water level in groundwater aquifers, which may increase the percentage of surface runoff, but at the expense of recharging the groundwater aquifers.

World has been threatened by climate change under the effect of increased carbon emission and greenhouse gas. Carbon is one of the basic elements of life and shows search without being fixed. The amount of $CO_2$ reduces the protective use of the bard layer. With this effect, it causes irregular precipitation and excessive temperature increases (Bağdatlı and Arıkan, 2020). Population growth rate along with the climate change phenomenon will cause lots of problems for worldwide food supply and we will face numerous nutritional problems in the near future. By gradually reaching to the 8 billion population on the earth, the mankind is really in challenge to provide the growing population food needs (Bağdatlı et al., 2015)

Sudan experiences mean annual temperatures between 26°C and 32°C, with summer temperatures in the north often exceeding 43°C. Rainfall in Sudan is unreliable and erratic, with great variation experienced between northern and southern regions. Northern regions typically experience virtually no rainfall (less than 50 mm annually), central regions receive between 200 mm and 700 mm per year, and some southern regions experience more than 1,500 mm annually. Most rainfall occurs during the rainy season from March to October, with greatest concentration between June and September (Ali, 2017). The Sudan is vulnerable to climate change because of its hot climate, with mean annual temperatures that range from 26 °C to 32 °C nationwide. From North to South, the nation is ecologically divided into five vegetation zones by rainfall patterns3: (1) desert with 0 to 75 millimetres of precipitation yearly; (2) semi-desert with 75 to 300 mm; (3) low rainfall savannah on clay and sand with 300 to 800 mm; (4) high rainfall savannah with 800 to 1500 mm; and (5) mountain vegetation with 300 to 1000 mm of precipitation (Ministry of Environment, Natural Resources and Physical Development, 2015).

With the escalation of climate change, The Sudan as a whole will be affected by a rise in local temperatures. The sectors most vulnerable to rises in temperature are rainfed agriculture, aquaculture, natural ecology systems and biodiversity and water resources (Siddig et al., 2020; Elsheikh, 2021).

Sudan may reportedly consume 26 $km^3$ of surface water annually. This includes the water that Sudan is allowed to take from the Nile, which is specified in the 1959 Nile Water Agreement and amounts to 18.5 km3 annually as measured at Aswan in southern Egypt (equivalent to 20.5 $km^3$ in the center of Sudan before the transportation loss due to evaporation and seepage). Flow from streams not connected to the Nile is also included (5.5 km3) (Adam and Abdo, 2017). Sudan depends heavily on the Nile for drinking water, irrigation, hydropower generation, river transport and recreation. Other major sources of drinking water include groundwater reserves and wadis or khors, which are exploited for both people and livestock (UNEP, 2020).

Sudan suffers a variety of issues with regard to water, from a lack of safe drinking water and inadequate sanitation to water pollution and scarcity. Rapid population increase, urbanization, shifting consumption patterns, and competing demands from agriculture, industry, and energy are the main risks to the nation's water supplies. Additionally, there are unforeseen hazards associated with environmental degradation and climate change, as well as rising conflict over the limited water resources that span administrative lines (UNEP, 2020).
The International Fund for Agricultural Development carried out an evaluation study of Sudan's environment and climate change in 2011. Data for various starting years (1900-1937) up to 2011 were obtained from nine meteorological stations (Abdelaty and Babiker 2013). According to the study, Sudan's average temperatures have been rising overall, from 0.6 °C in El Obeid to 2.1 °C in Khartoum (Abdelaty and Babiker 2013).

By 2050, it is anticipated that the average annual temperature will have risen by 1.5°C to 2.5°C. Rainfall decreased by between 10% and 20% over the western and southern states from 1970 to 2011. According to predictions, rainfall will fluctuate from 9 percent less to 9 percent more between now and 2050. (Abdelaty and Babiker 2013). Extreme climatic events are anticipated to occur more frequently (Abdelaty and Babiker 2013). The entire Nile basin is predicted to experience increases in precipitation early in the century (period 2010-2039) (Beyene et al. 2010). Some native flora, insects, and small animals may vanish forever in the northern states if temperatures increase more. Plants from the subtropics that need moisture may go further south (Abdelaty and Babiker 2013). With a considerable decline in the long-term average, crop yields are expected to fluctuate significantly. According to the World Bank, a 1°C rise in temperature might result in a 10% decline in agricultural output (Abdelaty and Babiker 2013). By 2050, this might result in an output decline of up to 25% in the northern states. Currently, the southern, southeastern, and mountainous northeast of the country are all affected by floods, flash floods, and possibly landslides, whilst the northern regions and those in the centre and middle west of the country are more affected by droughts. Pastoralists, impoverished farmers, and usually poor households with elderly members, children, and women make up the groups that are most vulnerable to droughts and floods (Sayed and Abdala, 2013).

Sudan is a poor country with 58% of rural households living below the national poverty line of USD 1.25 per day in 2012 (Ministry of Human Resources Development and Labor, 2013). The economy is mainly dependent on agriculture, which also provides 65% of inhabitants' livelihoods and one-third of foreign exchange profits (CBoS, 2016). Since more than 90% of the land is used for agriculture, the Sudanese population is subject to variations in rainfall as well as more general climate change and variability. Therefore, it is crucial to comprehend the many impact routes as the effects of climate change on agriculture are anticipated to have an impact on the entire economy, either directly or indirectly.

Despite its significance, the effects of climate change in the Sudan have not received significant scientific attention. According to the research that are now available, climate change will increase rainfall, which will increase agricultural productivity.

For instance, Basheer et al. (2016) used a hydrological model, two statistical downscaling methodologies, and five GCMs to assess how climate change may affect the streamflow in the Dinder River Basin and, ultimately, Dinder National Park. According to their findings, most scenarios' increased rainfall will cause the climate in the Dinder River Basin to become wetter and the river's streamflow to increase (Siddig et al., 2020).

In 2016, Sudan published its climate change National Adaptation Plan (NAP), which was produced by a large number of institutions headed by the Higher Council for Environment and Natural Resources (Ministry of Environment, Natural Resources and Physical Development, 2015). The NAP's main proposals center on enhancing human resource, institutional, methodological, technological, and informational capabilities. The importance of reducing sensitivity, enhancing resilience to variability and extremes, and enhancing heat tolerance and water efficiency in agricultural production are underlined in a recent review of climate change adaptation strategies for the Sudan (World Food Program, 2017).

This suggests that in addition to expected mean climate changes, changes in climate variability and an increase in the frequency of extreme weather events also require preparation. The suggested interventions include creating programs and initiatives for reducing and adapting to the effects of climate change, addressing water shortages by promoting water harvesting and making full use of seasonal streams and rainfall outside the Nile Basin, using groundwater, and creating drought-resistant crop varieties; and treating water as a scarce resource and improving its efficient use, especially in irrigated agriculture, to best utilize the available water resources (Siddig et al., 2020). The increase in the impact of global climate change will cause global water crises between countries. Necessary measures and measures should be taken in advance to reduce the impact of global climate change (Bağdatlı and Arslan, 2019).

Despite the fact that the Sudan is particularly susceptible to the effects of climate change on water resources, however, the political authorities are not focusing on strengthening adaptive governance measures to deal with the this increasing risks, which may exacerbate the situation.

## CONCLUSION

There are changes in the water surface in the world due to global warming. This is the effect of evaporation in water resources and irregularity in the current precipitation regime due to climate change (Albut et al., 2018). Climate change and global warming are reducing the available water resources almost everywhere in the world (Uçak and Bağdatlı, 2017). Excessive increase and decrease of temperatures negatively affect the life of living things. It will be difficult to find clean water in the future as the increase of temperatures will increase the evaporation level. Increasing or falling temperatures will cause climate change (Bağdatlı and Can, 2020). As a result of the effect of global climate change, an increasing trend is observed in temperatures. Rainfall, on the other hand, is gradually decreasing and endangering habitats. In order to minimize the effects of global warming, it is necessary to take measures to prevent the greenhouse effect and global warming. Reducing carbon dioxide in the air may be a solution (Bağdatlı and Can, 2019).

Sudan is characterized by a diversity of water sources. Numerous elements, such as the seasonality of rainfall, siltation, floods, riverbank erosion, and pollution, have an impact on Sudan's inland waters. Despite that, Sudan is considered to be a water-stressed nation, and pollution, unchecked economic growth, and climate change are all posing an increasing threat to the country's water supplies. A serious challenge to global and Sudanese economic progress is the lack of fresh water.

In addition, Sudan suffers from a critical situation with regard to low rainfall and severe variation in its rainfall. Increasing shortage of water resources will lead governments to resort to severe economic projects such as desalination plants, pipelines and dams. For all that, urgent and long-term plans must be made to conserve water by reducing requirements and consumption, by improving water infrastructure to reduce leakage, and by improving water technologies and management. In addition, Sudan should implement an ecosystem-based strategy to manage its inland and marine water resources and integrate the principles of sustainable development into all its institutional practices.

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