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Water resources management and climate change in South Sudan

Musa Kose

University of Juba, College of Natural Resources and Environmental Studies, Juba, South Sudan.
Corresponding Author e-mail: musakose053@gmail.com

Abstract

South Sudan, one of the least developed countries, is vulnerable to the socioeconomic losses and damages caused by climate change since its people rely on climate-sensitive natural resources for survival. Given the country's recurring droughts, promoting water collection and storage for varied purposes is a high priority. Water availability may be directly affected by poor water quality. This study focuses on how climate change has altered water supplies to assist South Sudan's future water usage and highlights the potential for future research to make a significant impact. The findings of this study will be necessary for future Nile River research, a field that holds great promise. In South Sudan, the quantity and quality of water have dropped during the last two decades. The article also shows how droughts are becoming more frequent, and rivers and streams are shrinking due to climate change. Several once-permanent rivers now have seasonal flows. South Sudan is especially vulnerable to the effects of climate change due to poor infrastructure, several developmental obstacles caused by the protracted civil war, and the fact that 95% of the population relies on climate-sensitive natural resources, particularly rain-fed subsistence agriculture, and total reliance on forests as a source of energy and other environmental goods and services.

Introduction

The impact of climate change on water resources is a pressing concern for both science and policy, particularly as global warming continues to dominate global concerns. According to a 1997 UN report on global freshwater resources, one-third of the world's population lived in countries facing water stress, using more than 20% of their available water supplies. The report predicted that by 2025, up to two-thirds of the global population would live in areas with water shortages (Jubek et al., 2019). However, the effects of climate change on water resources can vary significantly by region. Some areas may experience water shortages, dramatically increasing the number of people at risk due to rising consumption. Conversely, in coastal areas, rising sea levels threaten the lives and livelihoods of millions. Droughts and floods are expected to become more frequent in many parts of the world, leading to increased poverty and hunger, higher economic costs, and potential crop losses. These impacts must be assessed with precise spatial and temporal data to enable long-term water resource planning in light of climate change, a crucial aspect that this research aims to address (Abbaspour et al., 2009).

Water is one of the nation's most valuable natural resources, essential for agricultural production and human life (Albut et al., 2018; Bağdatlı et al., 2024). Climate and water systems are closely linked: climate change affects water availability and usage. Generally, higher temperatures increase water usage, especially for irrigation, while higher precipitation reduces use. However, there is yet to be a definitive historical link between water usage trends and climate, mainly due to limited data and the influence of non-climatic factors (IPCC, 2007). Regional climate models suggest that rising temperatures and reduced rainfall will cause significant declines in water resources.

In South Sudan, water resources are unevenly distributed geographically and seasonally. The country's water availability is highly variable due to frequent severe floods and droughts. Most of the country lies within the Nile River basin, where water is stored in floodplains, ponds, rivers, and wetlands. With low population density and limited industrial development, current water demand remains low, but it is expected to rise sharply with population growth and economic development. In 2007, the Ministry of Water Resources and Irrigation raised concerns about human activities' growing impact on water availability and quality, noting decreasing water tables, reduced river flows, and increased pollution in urban areas (MWRI, 2007).

Water is a naturally renewable resource, continuously circulating through the environment. Water resource assessments must prioritize water flow, although stored water in natural and artificial reservoirs increases availability for human use. The climate system limits the flow rate of renewable freshwater resources (RFWR). While global water withdrawals are currently well below the upper limit, over two billion people live in regions of extreme water stress due to the uneven distribution of RFWR across time and geography. Climate change is expected to accelerate the water cycle, potentially increasing RFWR. This could reduce the number of people experiencing water stress, but changes in seasonal patterns and the likelihood of extreme events may offset these benefits. Reducing current vulnerabilities will be the first step in preparing for these anticipated changes (Jubek et al., 2019).

While water has historically been a source of conflict, it can also provide opportunities for cooperation and peace. In Sudan, effective management of water resources is seen as a pathway to sustainable development and stability. With proper institutions and legal frameworks, water resources can significantly contribute to the country's economic, social, and environmental progress (UNEP, 2020). Studies on climate change in Sudan and South Sudan have mainly focused on temperature and precipitation, the two key climate variables and extreme events (Nasreldin & Elsheikh, 2022; Elsheikh et al., 2022a). Thus, this study aims to assess the effects of climate change on South Sudan's water resources.

Water Resources and climate change in South Sudan

South Sudan, a landlocked country occupying 96% of the Nile River Basin in East-Central Africa, shares borders with Sudan to the north, Ethiopia and Kenya to the east, Uganda and the Democratic Republic of the Congo to the south, and the Central African Republic to the west. Positioned between latitudes 3.5° and 12° North and longitudes 24° to 36° East, it spans 658,842 km². Vast grasslands, wetlands, and tropical forests dominate the landscape. The country's natural resources include significant agricultural, mineral, water, wildlife, forestry, and energy assets (Jubek et al., 2019). South Sudan has one of the lowest population densities in sub-Saharan Africa, with fewer than 13 people per square kilometre. In the arid northern regions, livelihoods are primarily based on seasonal agriculture, pastoralism, fishing, and hunting, while the wooded savannas in central South Sudan offer diverse livelihood opportunities. The country is divided into three regions—Bahr el Ghazal, Equatoria, and Greater Upper Nile—and was initially organised into ten states, which have since increased to thirty-two (MWRI, 2016).

Water availability in upstream and downstream regions of transboundary river basins is a sensitive issue. South Sudan's location in the middle of the Nile Basin, between downstream countries like Egypt, Ethiopia, and Sudan, and upstream Nile Equatorial countries such as Burundi, Kenya, and Uganda, means that its water quality and quantity are influenced by water retention, withdrawals, and development activities in these neighbouring states (Fernando & Garvey, 2013). Through floods and groundwater flow, lateral water transfers move water between surplus and deficit areas. However, monitoring water flows throughout the Nile Basin is challenging due to variations in how each country and sector measures water data, such as withdrawals, stocks, and wastewater return flows. Earth observation data provide insight into the basin's main water flows and fluxes (Bastiaanssen et al., 2014).

Water usage in the Nile Basin threatens its ability to meet future demand, especially for South Sudan. Over 80% of the water withdrawn from the basin is used for irrigated agriculture. South Sudan's water withdrawal remains low relative to other Nile Basin countries (Jubek et al., 2019). Before 2011, Sudan's total water withdrawal was estimated to be around 27,590 million m³, with agriculture accounting for 26,150 million m³. Post-2011, South Sudan's annual water withdrawal is estimated to be about 658 million m³, or 1.3% of its total renewable water resource, with agriculture still using the majority (FAO, 2016; MWRI, 2016).

As water resources become increasingly strained due to societal demands, understanding climate change's effects on the water cycle is crucial for managing this resource. Water management strategies, such as operational adjustments, demand management, and infrastructural changes, must be considered to adapt to climate change. Resource supply, system demands, and performance requirements will likely shift due to climate impacts, requiring diverse strategies and preferences for adaptation (Levi et al., 2009; Elsheikh et al., 2023; Elsheikh et al., 2024). Cooperation between regions that share water resources is critical for improving management. However, climate change and rising water demand may exacerbate conflicts over water, mainly where unilateral actions to address shortages could increase competition. Changes in land productivity could also result in new agricultural systems, potentially leading to environmental stress, including soil erosion and biodiversity loss (Meier et al., 2007).

In South Sudan, where surface water resources may become increasingly inaccessible, the demand for groundwater will likely rise, particularly as irrigation agriculture expands to meet the growing population's food demands. Although irrigation remains limited, effective water resource management and accurate demand projections ensure the country's stability (Jubek et al., 2019). South Sudan's water resource management strategies aim to improve water resource mapping, evaluation, and monitoring capabilities, enhance the water information system, and promote sustainable management and conflict prevention (MWRI, 2016). National governments, particularly in less developed countries, must implement key water management measures to address the effects of climate change on water resources. This includes identifying areas at risk of shortages, promoting the construction of water harvesting infrastructure, improving water and sanitation facilities in urban areas, and developing supplemental irrigation systems in rural areas to increase food security. Additionally, establishing legal frameworks to penalise water pollution and manage waste effectively is essential (Wada & Bierkens, 2014; Jubek et al., 2019).

Since 1970, global surface air temperatures have significantly increased. Independent research teams have processed data from various sources, showing a consistent warming trend supported by the melting of Arctic sea ice, glacier retreat, and other indicators (Elsheikh et al., 2022b). As climate change continues, droughts and floods are expected to become more frequent, with precipitation patterns increasingly concentrated in heavy events. This

uneven distribution of rainfall, influenced by topography and atmospheric circulation, is already altering precipitation patterns globally, including in South Sudan (Elsheikh, 2021a; Bağdatlı et al., 2023).

In South Sudan, subsistence agriculture, which depends on rain-fed farming and traditional methods, forms the economic backbone for 78% of households. This makes the country highly vulnerable to climate change, particularly irregular rainfall. Droughts and floods threaten livestock, crop production, and natural habitats, while flash floods damage low-lying forests near wetlands and rivers (Jubek et al., 2019). Global action is required to mitigate the effects of climate change, including reducing carbon emissions and preventing global warming (Elsheikh, 2021b). South Sudan's Sudd wetland, vital in regulating regional weather patterns, is particularly vulnerable to these changes. Effective water resource management in South Sudan is crucial to mitigate the impacts of climate change, ensure sustainable development, and prevent conflicts over water.

Conclusion

The Republic of South Sudan needs to strengthen environmental health infrastructure to prevent the spread of water-borne diseases, significantly as climate change worsens water quality and availability. The rising population and increasing demand for water will further strain the country's water resources in the coming years. The pressure on these resources will be unevenly distributed globally, with some regions, including South Sudan, feeling the impact more acutely and urgently. Climate change can either exacerbate or alleviate stress on water resources, depending on various factors such as climate scenarios, water demand, and the quality and quantity of available water.

Water quantity and quality in South Sudan have declined significantly over the past two decades. Rivers that once flowed year-round are now seasonal, and the reduction in water flow has led to increased siltation, particularly in downstream areas where sediment accumulates. Urban water quality has deteriorated due to the direct discharge of municipal wastewater, sewage, and industrial effluents into water bodies. The lack of adequate wastewater and sanitation management has resulted in widespread contamination, contributing to repeated outbreaks of gastrointestinal diseases and posing additional threats to already stressed water resources. To mitigate these issues, South Sudan must prioritise upgrading water and sanitation infrastructure, improving wastewater management, and implementing strategies to adapt to the effects of climate change on water availability and quality. Proper management will be crucial to safeguarding public health and ensuring a sustainable water supply in the face of growing environmental challenges.

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