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Original Article

A Review of the Effects of Climate Change on Water Resources in Sub-Saharan Africa

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ABSTRACT

Water provides different goods and services like handcraft and fishing materials, water supply for domestic use, businesses, agriculture, transport, washing, drinking, and eco-tourism. However, few studies have assessed the effects of climate change on water resources in recent years. This study investigated the relationship between water resources and climate change in Sub-Saharan Africa. In the first segment, Vos-Viewer was used to map, study the literature, and identify any gaps in order to evaluate the interdependence between water resources and climate. The study was guided by specific objectives, which include assessing the adaptation and mitigation strategies for the effects of climate on water resources. Searches for the keywords "climate change" and "water resources" were conducted to obtain literature for this study. A total of 125 papers were selected for this study from 1945–2022, from Scopus, Google Scholar, Science Direct, and Web of Science, that were found relevant for this study and were selected and discussed. Thus, the worldwide literature was used to provide a real understanding of the effects of climate change on water resources, adaptation, and mitigation measures. According to the findings of the study, cooperation networks in developing countries were not as prominent as research networks in developed countries. It was shown that irregular rainfall affects water quality and quantity by giving the water a muddy, acidic, and turbid appearance. Therefore, all stakeholders should facilitate prudent water resource usage by 695 million people who still use unimproved water facilities in sub-Saharan Africa.

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INTRODUCTION

Worldwide, water resources form an indispensable component of the Earth's planet that supports all life forms (Phan, Bertone and Stewart, 2021; Falkenmark, 2020). Water delivers handcraft and fishing materials, water supply for domestic use, industries, agriculture, transport, cleaning, drinking, and eco-tourism (Saturday et al., 2022). However, Bayatvarkeshi *et al.* (2021) note that few studies have assessed the effects of climate change on water resources, yet climate change has adversely affected Water (Schilling et al., 2020; Xiang et al., 2021). Changes in development forms and stages have hindered the utilisation of water resources in essential areas like electric power generation (Ahmadzai and McKinna 2018). Cosens *et al.* (2017) note that there is little knowledge about how climate change affects water resources.

According to Turyasingura *et al.* (2022), water resources are susceptible to pollution brought on by complex anthropogenic activities like urbanisation, industrialisation, agricultural operations, and sewage discharge (Ram and Irfan 2021). The greatest risk to human health is rising water contamination (Mensah et al., 2020). According to estimates, harmful characteristics of water are responsible for around 80% of all ailments in humans (Xiang et al. 2021). Furthermore, there is rising concern about how climate change may affect the world's already-vulnerable water resources.

Water stress is a critical concern in Sub-Saharan Africa, where the region faces significant challenges in ensuring access to clean and sufficient water resources (UNEP, 2020). With a combination of factors such as population growth, rapid urbanisation, climate variability, and inadequate water infrastructure, the availability and reliability of water sources are increasingly compromised (UNESCO, 2018). Prolonged droughts, inconsistent rainfall patterns, and limited access to improved water supply and sanitation facilities contribute to the severity of water stress (UNDP, 2021). The consequences of water stress in Sub-Saharan Africa are far-reaching, impacting various sectors including agriculture, food security, public health, and overall socio-economic development (UNEP, 2020). Addressing water stress necessitates a multifaceted approach, encompassing sustainable water management practices, investment in infrastructure, and collaborative efforts between governments, organisations, and local communities to ensure equitable access to water

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resources and build resilience in the face of a changing climate (UNESCO, 2018; UNDP, 2021).

Over 2 billion individuals reside under water stress in 53 nations around the world; for instance, 31 countries have high water stress levels between 25% and 70%, while 22 other countries have serious water stress levels exceeding 70% (Gurera and Bhushan, 2019). Approximately 80 % of about 319 million people in sub-Saharan African countries live in rural areas (Braune and Xu 2010; Machado, Amorim and Bordalo 2022). According to Turyasingura *et al.* (2022), Water resources are vital in Sub-Saharan Africa (SSA) as they provide fishing grounds (Onyena and Sam 2020) and wetlands which provide materials for making handcrafts (Gopal, M. Raghavan and PS 2022) and mulching (Milder et al. 2011; Yahaya et al. 2022).

According to Adeyeri (2020); Turyasingura *et al.* (2022), altering rainfall patterns were noticed in Nigeria, which may affect surface water. Understanding the dynamic linkage between climate change and water resources in Sub-Saharan Africa is crucial for building future water supply and water quality management projects (Muringai, Mafongoya and Lottering 2021). In South Africa and Mozambique, people are fed by surface water or groundwater (Verlicchi and Grillini 2020). However, many natural and human-made factors such as geochemical processes (Akhtar et al. 2021), heavy rain, flooding (Du Plessis 2019), and the release of untreated wastewater, sewage and industrial effluents have the potential to pollute water sources.

Turyasingura *et al.* (2022) note that Ethiopia has surface and underground water sources which feed 12 significant stream bowls, 11 freshwater and 9 saline lakes, 4-hole lakes and more than 12 marshes and wetlands. However, approximately 60 % to 80 % of the populace suffer from waterborne and water-related illnesses (Soboksa *et al.*, 2020). This is in line with the findings of Turyasingura and Ayiga (2022) who revealed that good farming (climate-smart agricultural) practices would combat climate change and its associated problems.

In Tanzania, increasing demand for groundwater has effectively been noted in East Africa especially in Tanzania for individuals living in drier areas (Ligate *et al.*, 2021). As a result, the utilisation and nature of groundwater will continue to be critical for the majority of human advancement efforts. Increased rainfall variability has a significant impact on the quality of drinking water at both local and national levels (Bastiancich et al., 2022). As a result, considerable changes in the water quality parameters in the water resources have taken place, frequently exhibiting a noticeable transition from the state of clear to turbid water.

In Uganda, the water level in Lake Victoria steadily rose from 12 metres to its current level of 13.32 metres as of April 30, 2020. The level has increased by 1.32 metres in just 6 months and it is only 0.08 metres below the greatest level ever observed. This was due to heavy rains that caused rivers and lakes in several parts of Uganda to rise over the limits below which no settlements or development should take place. This had previously occurred between 1961 and 1964, as well as between 1996 and 1998 (Yakubu et al. 2012).

Khalid et al. (2020) note that water shortage increases the concentration of toxins in the water bodies. Drought leads people to use contaminated water themselves due to its scarcity, which affects the productivity of their crops and animals. In addition, Kanungu District faced the problem of drought to the extent that people almost ate spear grass due to food shortage. As a result, farmers in Uganda must be trained on flood management and correct water management methods such as tree planting to limit runoffs where trees being major carbon dioxide sinks form a third pillar of climate-smart agriculture because they reduce greenhouse gas emissions (Zizinga *et al.*, 2022).

Rainfall fluctuation promotes cyanobacteria dominance, exacerbates eutrophication and affects the stability of lake features such as

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physical, chemical and biological parameters as well as nutrient availability. For example, agricultural activities have affected the River Rwizi in Mbarara District due to soil erosion during rainfall, thus affecting aquatic species (Ojok, Wasswa and Ntambi, 2017).

Further, there are growing human activities around water resources including coastal or lake borders and islands, which have affected water quality characteristics putting the overall ecosystem setup in danger. However, there is a strong relationship between climate change and the integrity of water resources worldwide (Bastiancich *et al.*, 2022). Nevertheless, there is vivid evidence of escalating climate change which can be attributed to limited knowledge and information on the inter-dependence between climate and water resources (Zhang et al. 2021); hence, the need for the study.

This essay seeks to give an overview of the knowledge on how rainfall variability affects water quality as well as adaptation and mitigation strategies for SSA. In order to effectively adapt to climate change, the article focuses on crucial components of weather variations. The necessary literature was sourced from journals on water, hydrological, climate change, and weather topics in order to achieve the aforementioned goal. In order to get more information regarding the study, a literature analysis was carried out utilising a variety of search engines, such as Scopus, Scholarly Articles, Science Direct, and the Web of Science. The search was limited to peer-reviewed journals with a worldwide reputation and topics that dealt with climate change mitigation and mitigation. Journal articles were supplemented with data from publications, mostly those published by the International Panel on Climate Change (IPCC).

The findings of the assessment of the connection between the current state of climate change and the availability of Water in Sub-Saharan Africa may offer information that raises the knowledge and motivation of all ways of reducing global warming (Adeyeri *et al.*, 2020). The innovation of measures to prevent the water from even further deteriorating in quantity and quality, thus further protecting the population reliant on these water supplies as well as the environment, may be supported by a knowledge of the effects of hydrology in sub-Saharan Africa.

CLIMATE CHANGE AND WATER RESOURCES IN SUB-SAHARAN AFRICA

Rising temperatures and decreased rainfall all have negative effects, including reduced stream flows in significant water catchments, lower groundwater recharge rates, decreased inflows into water storages, and worsened droughts (Mahmood *et al*. 2016). This has resulted in rising competition for water among sectors (Stoerk, Wagner and Ward, 2020). The reliability of climate and water resources in SSA depends on both natural phenomena such as water availability and ocean acidification which may be influenced by man-made activities directly or indirectly (Banda, 2021). In order to maintain effective governance of water resources in the context of a changing climate, it is crucial for governments, stakeholders, and local populations in Sub-Saharan Africa to put first climate change adaptation and fostering resilience initiatives.

The water quality parameters are dependent on the interactions between the impact of human activities, pollutants and natural phenomena in water resources. These interactions are believed to be responsible for climate change which in turn impacts water resources. For example, cutting down forests for agriculture reduces carbon dioxide sinks leading to global warming and climate change. For the purpose of reducing climate change, deforestation must be stopped, and green land use practices must be promoted. Utilising strategies like forest preservation, reforestation, agroforestry (the integration of trees with cultivation), and sustainable farming methods can assist lower emissions, safeguard carbon sinks, and support efforts to mitigate climate change. A key part in addressing the causes of deforestation and advancing sustainable land management can also be played by laws and programs that encourage the protection of forests and sustainable agriculture practices.

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Furthermore, because the increased water volume in water bodies may be attributable to re-suspended bottom sediments due to high water flow rates, this is critical to this review paper because it is an indicator of the effect of seasonal rainfall variability on water quality.

Waithaka et al. (2020) found that water quality metrics during the rainy season had a higher mean than their similar values during the dry season. He concluded that temporal precipitation inconsistency significantly affects the pH, turbidity, dissolved oxygen, thermal conductivity, and total dissolved solids of water ecology. Therefore, this research needs to make combined water resource management based on what was found to ease water quality among people. For the sake of maintaining long-term water quality, climate change issues must be incorporated into the management of water resources. The creation and application of climate-smart water management solutions, such as improving water allocation, enhancing infrastructure and storage, and encouraging water-use efficiency behaviours, can benefit from research. These actions can lessen the effects of the changing climate on the quantity and quality of water.

According to Kozisek (2020), many metals are less hazardous to aquatic life when there is enough calcium in the water. As a result, the presence of calcium in water is advantageous and no calcium restrictions have been set to safeguard human or aquatic health (Dinaol, 2015). According to Ahmad et al. (2020), the total hardness of Lake Triveni in Nepal ranged from (69.33 to 193.67) mL. Minimum values reported during the monsoon in the Harsal dam ranged from (83.8 to 178) mL. Sulphates, calcium chlorides and magnesium chlorides are all included in total hardness. The study concluded that the most common ions in natural water are bicarbonates which are primarily related to calcium, to a lesser degree with magnesium and even less with sodium. However, the study never elaborated on how calcium is attributed to climate change thus, there is a gap to be filled.

Magnesium is required for the development of bones and cells in both plants and animals (Ben and Morgan, 2017). According to Mbura (2018), the mean magnesium and calcium ions in groundwater during the dry season were 59.1 mL and 130.1 mL and 67.5 mL and 143.5 mL during the rainy season, respectively. However, the calcium levels determined were greater than the recommended levels for drinking Water (Sila, 2019). The high levels of calcium ions detected were related to the geology of the research area, which consists of limestone with high calcium levels (Schoeman, 1951).

In addition, pH is a parameter to detect whether water is acidic or basic. The pH scale runs from 0 to 14, with 7 indicating neutral, less than 7 acidic, and greater than 7 abase (Tian *et al.*, 2017; Wilbera *et al.*, 2020). Pollution can alter the pH of water, causing harm to aquatic animals and plants. Acid deposition degrades the water quality of lakes and streams by reducing pH levels (raising acidity) and diminishing acid-neutralising capacity as a result of industrial pollutants (Papadaskalopoulou *et al.*, 2015).

According to Alex et al. (2021), electrical conductivity (EC) measurements in Lake Bunyonyi, Uganda, were within the WHO's 2500 Siemens per centimetre maximum permissible limits for international drinking water standards and guidelines. This indicated that Lake Bunyonyi's Water is not strongly ionised and has a low ionic concentration. According to Wilbera et al. (2020), the electrical conductivity of water in river Rwimi in Uganda was the highest with EC (162.831.41 Siemens per cm) compared to the rivers Nyamwamba and Mubuku (146.501.93 Siemens per cm and 103.061.37 Siemens per cm, respectively). Further, Alex et al. (2021) revealed that the nutrient and ammonia readings at Akampene (M2) and Heissesero (L1) stations were 0.070.01 mL and 0.130.07 mL, respectively. The Total Nitrogen concentrations at Nyombe (U1) and Rugarambiro (L2) stations were 1.0 0.7 mL and 2.9 2.1 mL, respectively.

MATERIALS AND METHODS

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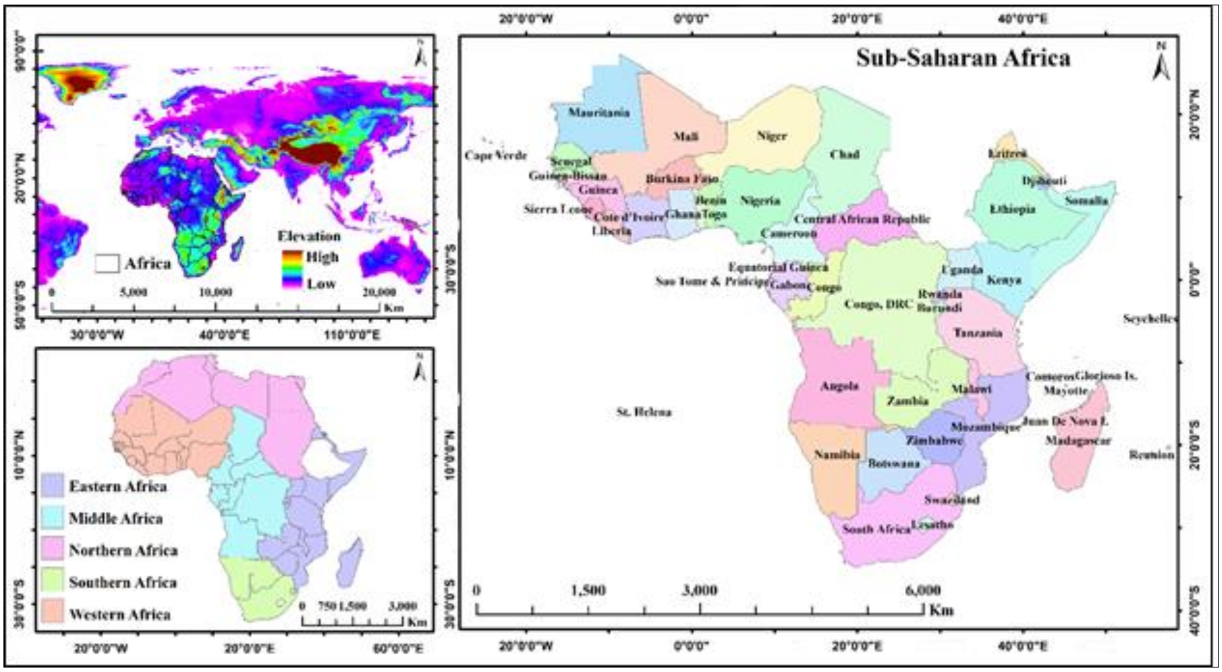
Study Area

Because of the detrimental consequences of global warming on this region's water supplies, the study (*Figure 1*) was carried out there (Zhu and Wei, 2013; Gökçekuş *et al.*, 2023; Salim *et al.*, 2023). The SSA comprises two-thirds of the land area of the continent, or around 24 million square kilometres and the world's area most susceptible to climate change (Junk *et al.*, 2013). Natural disasters are becoming more frequent and intense, and the geography of the area is dramatically changing, which affects water resources. Nearly 60 % of the population in SSA live in rural regions and rely heavily on water supplies for drinking, industrial usage and agricultural purposes (Fróna, Szenderák and Harangi-Rákos, 2019).

The population of SSA increased from 490 million in 1990 to 1 billion (or around 14 % of the world's population) in 2015 at a growth rate of 2.7 % (Fenta *et al.*, 2020). Although water resources are essential to people's livelihoods, this dependence is most apparent in developing countries like those in SSA, where the majority of the population is impoverished and heavily dependent on natural resources (see *Figure 1*) below showing the study area map.

Figure 1: Map of Africa and regions of SSA



Data Analysis using Vos-Viewer Software

Vos-Viewer software was used to map to investigate the link between climate change water resources and detect current gaps in the literature. (Mbao *et al.*, 2022). Turyasingura et al. (2022) note that using the keywords "Climate-Change" AND "Water resources," searches were conducted in the Web of Science (WOS) and Scopus databases to find the data. Based on the results of the initial search, 125 papers were selected for this study from a total search of 687. In addition, 58 papers from WOS and 67 publications from Scopus were found relevant for this study and were selected and discussed (see *Figure 2*) below showing the flowchart of the selected literature review.

Due to the region's increased susceptibility to rainfall variability, global research was used to provide real knowledge of the impacts of weather on water resources, adaptation, and mitigation strategies from 1945–2022. However, nothing has been done to lessen its consequences on the environment (Turyasingura et al., 2022).

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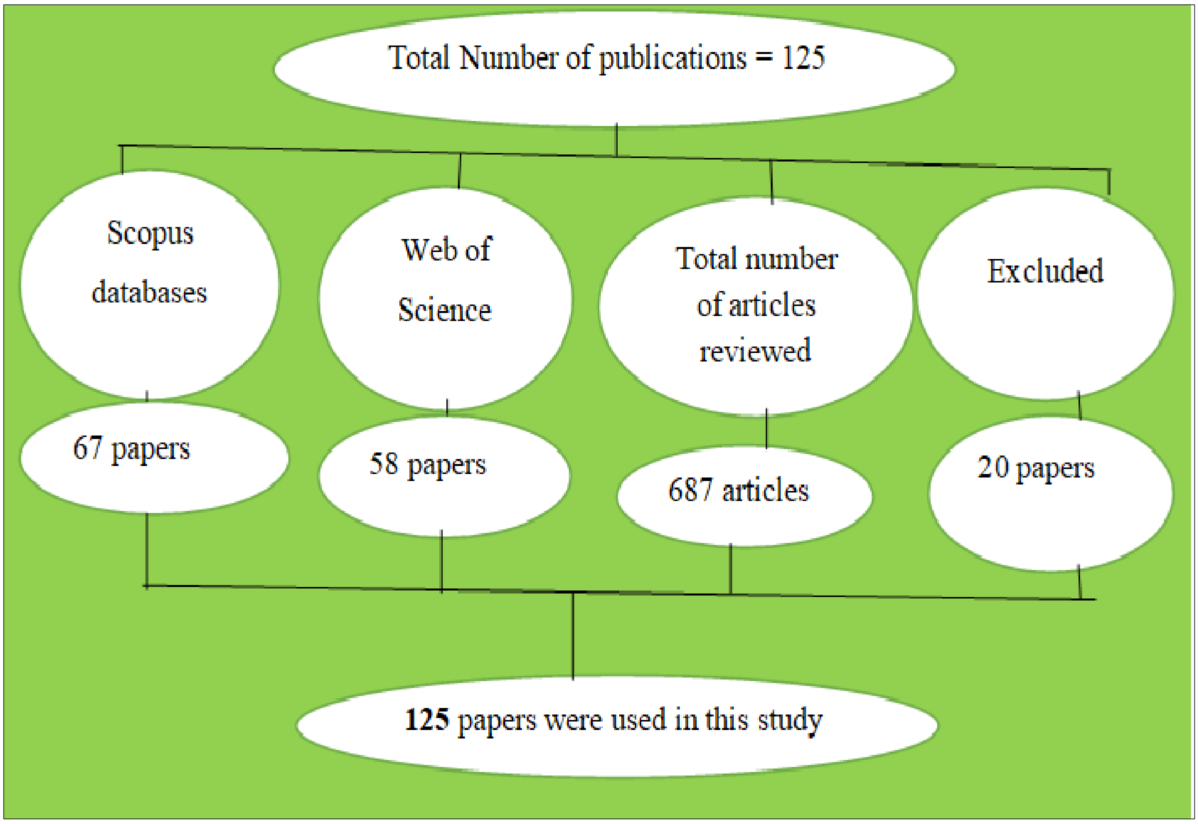
Figure 2: Flowchart for the selection of literature



RESULTS AND DISCUSSION

Publication Analysis

Compared to other nations, the USA, Canada, especially Brazil have published more than 100 publications on water and climate change resources. These three countries were responsible for 31.84 per cent, 19.9 per cent, and 18.15 per cent of all publications in this field, respectively. As a result, linkages between nodes are many and intricate, suggesting that various nations frequently engage in cooperative relationships (Almulhim *et al.*, 2021).

The United States is positioned near the leading edge of a few nodes in *Figure 2,* which also suggests that the node holds a significant position within the network structure. This is in line with Grech and Rizk (2018) who notes that publication analysis is very important to increase to measure and evaluate the academic performance of publishers. This analysis helps to understand the effect of climate change on water resources and how authors have tried to come up with scientific research to bridge the gaps. From this study, there is limited information among African countries, evidenced by the low cluster colours compared to the United States where the authors have talked much about the study under the invitation (*Figure 3*).

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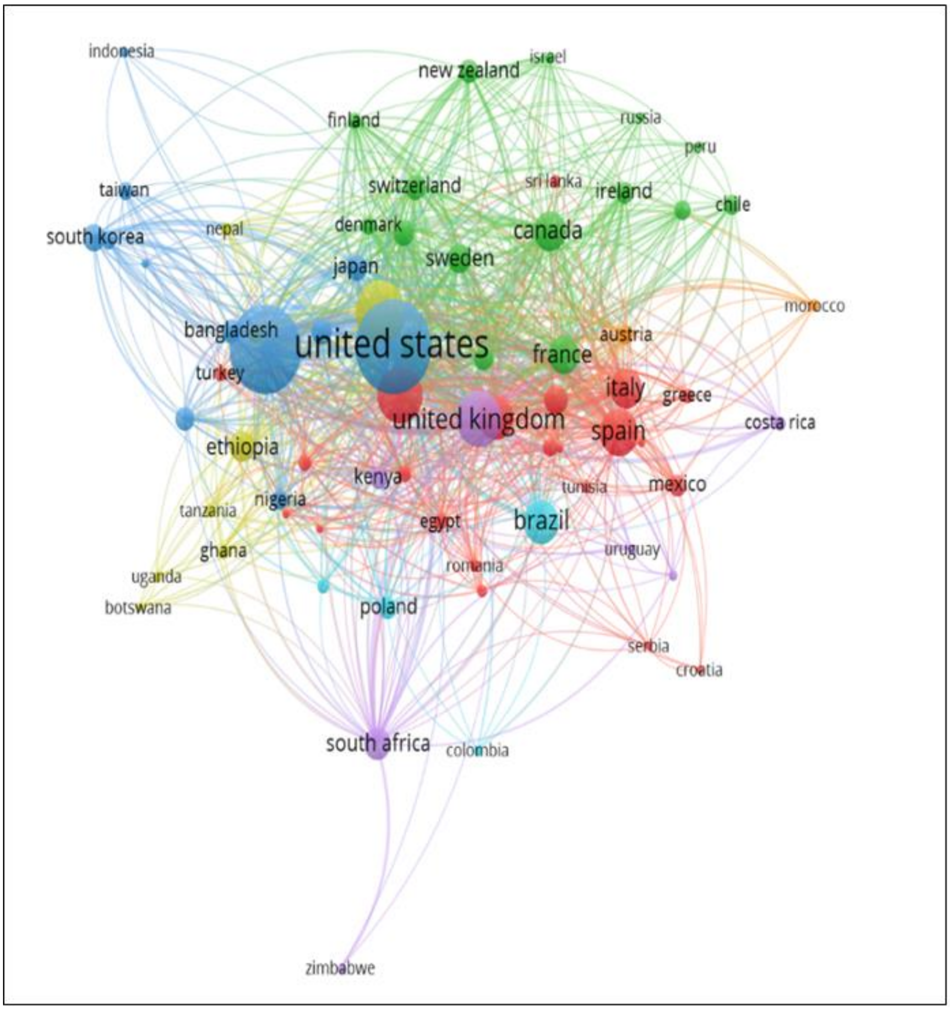
Figure 3: Publication per country



Author Analysis

To categorise the 687 publications that make up the sample, the authors who have been published the most frequently were found and their work was examined. The subjects that come up more frequently in the study area stand out as a result of this analysis. The authors are divided into four distinct clusters on the maps in *Figures 3 & 4*. These maps also show that water resources and climate change appear to be major areas of study that call for in-depth research and development (Eck and Waltman, 2014).

However, there has been limited input to utilise already available data for a proper understanding of the variations in trends in climate change. According to Eck and Waltman (2014), the study used VOS viewer, a bibliometric tool to enhance knowledge dissemination among different fields on climate change. According to Aria and Cuccurullo (2017), two articles are bibliographically coupled when at least one referenced source appears in both of their reference lists. A co-citation relationship is also created, leading to author analysis. Our type of analysis is crucial to this study since it shows that numerous writers are researching climate change, water resources, and potential adaptation and mitigation strategies, as shown in (*Figures 4* and *5*) below.

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Figure 4: Network Analysis of the author trends

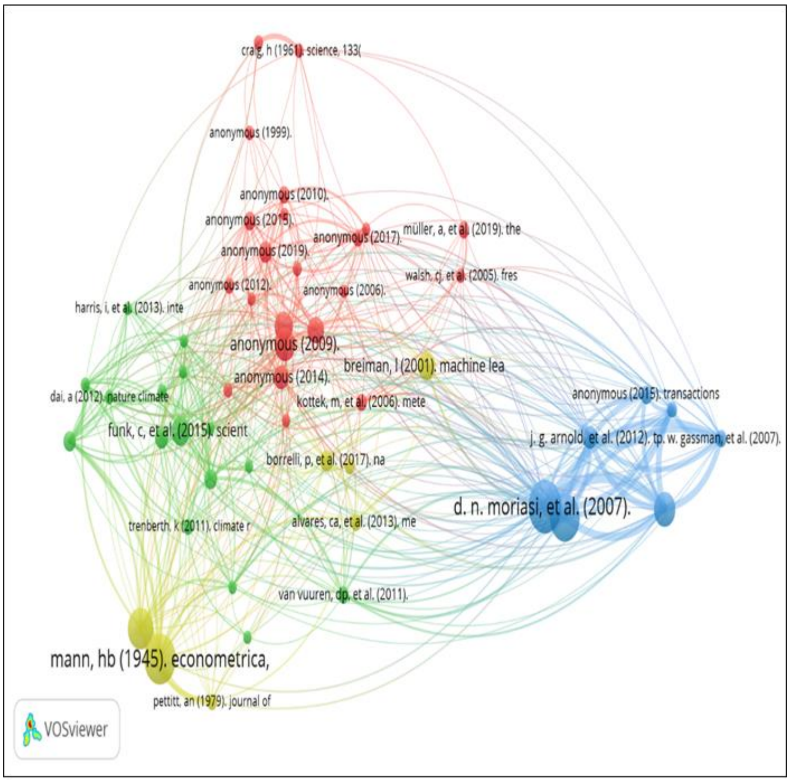

Figure 5: Density visualisation of the author trends

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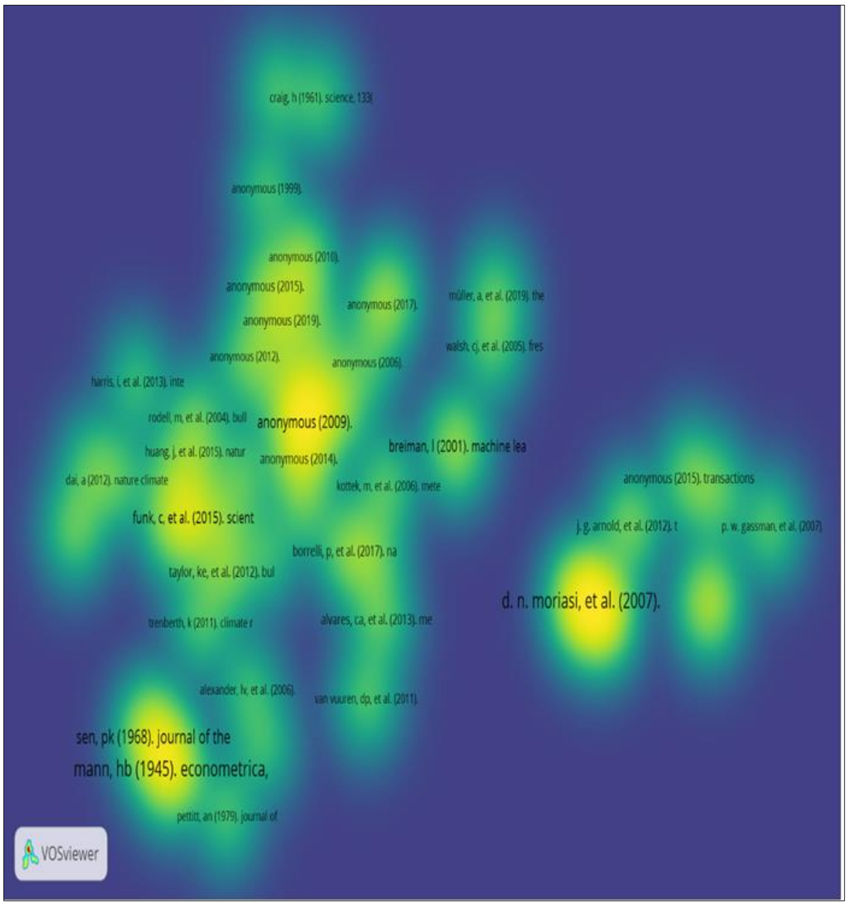

Adaptation and Mitigation Measures for Water Availability

Adaptive Measures

To create practical and effective adaptation and mitigation strategies for SSA, it is necessary to use an interdisciplinary and holistic strategy that involves policymakers, academics, practitioners (Falloon and Betts, 2010), and the community and private subdivisions. The viability of so many African regions is threatened by the multiple short- and long-term impacts of global warming on the river on organisms and communities in those countries. These repercussions range from economic and social ramifications to food and health shortages (Fuso Nerini *et al.*, 2019).

Water resources through an integrated model based on African countries' cooperation; state water sustainability through effective management (Abbas et al. 2018); the establishment of a new supportive network; and a strong African motion of young people and women to support throughout the implementation of responsive activities to improve diversification are just a few of the ways that climate change adjustment on Africa's water supplies needs to be rethought (Turyasingura, Mwanjalolo and Ayiga 2022). Mitigation actions focused on the reinforcement of strong institutions and infrastructure in Africa should also be encouraged (Fuso Nerini et al., 2019).

Integrative Approach to Adapt to Continental Water Resources Crisis

A bilateral and global partnership between nations, particularly African nations, to handle the issue of shared water is a comprehensive plan for the crisis in water supplies (Fan et al., 2020). This entails not just cooperation but also legally enforceable agreements, the creation of an African-wide network for exchanging data on water and climate, the use of science, and effective communication. This enables nations to cooperate and take into account each other's demands, advantages, and disadvantages in order to address and benefit from the results of water use (Stead 2014).

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Collaboration, depending on the degree of negotiation of every country sharing the same rivers. Cooperation between countries could provide several benefits (Pathak, 2023), including the prevention of water pollution (Grech-Madin et al., 2018). The usage of dirty water, on the other hand, has all the negative repercussions on public health. For example, because of a lack of bilateral cooperation between the two nations, the river Kasai in the Democratic Republic of the Congo (DRC) is receiving filthy Water from Angola's river (Blessing, 2018).

However, based on the experience of shared rivers polluted by mining companies, the platform would face numerous challenges, including structural corruption, impunity culture, influence peddling, and conflicts of interests (Dandison, 2021), all of which would require the involvement of impartial international courts to effectively combat.

As a result, international cooperation would improve not just the quality but also the availability of water for everyone (Shah et al., 2018). It would improve Africa's economy and development by facilitating trade and prudent management of water resources. Non-binding agreements are one of the most difficult aspects of the integrated approach to getting African countries to collaborate based on transboundary rivers or lakes. Africa has 94 international water agreements for cooperation and management of shared water resources (Kelly, Foster and Schultz, 2023), but none of them is in use (Hirwa et al., 2022). As a result, legally enforceable agreements are useful for enforcing cooperation between transboundary countries (Schmeier and Vogel 2018).

Thanks to technical improvements, African countries may now operate more successfully both inside and outside of their borders. It has been possible to include options such as increased water reuse and reuse, flood control and preservation, and both conventional and modern water cultivation techniques (Bolt 2019).

Infrastructure and Sustainable Water Resources Management

In order to effectively and efficiently manage groundwater resources (in both the current and future climates), it is important to understand the concepts of integrated resource management (IWRM), which need to be accompanied by the appropriate institutional and regulatory frameworks (Al-Jawad et al. 2019).

According to Bertule *et al.* (2018) over 68% of all Nationally Determined Contributions (NDCs) list the construction of new or upgraded water infrastructure, including freshwater resources, versatile dams, soil moisture conservation methods, natural wetlands, and rainwater collecting for storage, as a priority for adaptation action (NDCs) (Wang, Davies and Liu 2019).

Water Harvesting

Water harvesting is the process of collecting rainfall directly from the sky (Tu et al., 2018). Since humans first became aware of rain as a kind of liquid in the water cycle, rain has become a crucial source of water for people (Igbinosa and Osemwengie, 2016). Rainwater harvesting entails absorbing runoff from rooftops, catchment runoff, seasonal floodwaters from local streams, and watershed management (Bennett and Barton, 2018). Therefore, there is a need for rainwater harvesting in Uganda, especially in Kigezi and Northern regions, to keep water during dry seasons for both domestic use and irrigation to increase productivity. Examples of water harvesting in Uganda include; Roof Rainwater Harvesting (RRH): Many households in Uganda collect rainwater from their rooftops using gutters and downspouts like in Kanungu District and Rubanda, as shown in *Plate 1* below.

Plate 1: Roof rainwater harvesting

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Source: Authors, 2023

Other examples of water harvesting include small-scale ponds as well as tanks, and percolation pits. For the purpose of storing rainwater for irrigation, small- to medium ponds and tanks have been established in agricultural areas. In order to irrigate crops throughout dry spells, such reservoirs and tanks can be employed, minimising reliance on unpredictable rainfall patterns.

Other Adaptive Measures for Water Availability

Wetland ecosystems should be conserved, maintained, or rehabilitated (Turyasingura et al., 2022). According to United Nations (2019), Wetlands are crucial for adaptability because they serve as a barrier against floodwaters and other severe weather conditions and also serve to cleanse freshwater. Drought resistance and water scarcity can both be improved by co-management, which allows a region's overall water storage capacity to be increased (Zarei, Karami and Keshavarz 2020).

Demand management and protection of water efficiency are two challenges that must be addressed. According to Bertule *et al.* (2018), progressive pricing, hydro planning, water permits and licenses shifting usage beyond peak to off-peak hours, and flood control requirements in construction codes are a few examples of conservation methods (Stip et al. 2019). Seawater desalination, solar water distillation, fog harvesting, inter-basin transfers, groundwater prospecting and extraction, boreholes and tube wells, and water recycling and reuse are examples of alternative water sources (Conca, 2021).

Many environmental and natural resource management decisions are being predicated on watershed management concepts to increase diversity resilience, as it is becoming increasingly clear that land management decisions cannot be undertaken in isolation (Turyasingura, Mwanjalolo, & Ayiga 2022).

Mitigation Measures for Water Availability

Water availability is a difficult issue in Africa that necessitates strong institutions, infrastructure, and technology for successful water management, whether transboundary or within the country (Ngene et al., 2021). Most technology-driven climate change mitigation strategies necessitate investing in reducing emissions from water infrastructures, such as drinking water supply, waste and stormwater treatment, and Water pumping for agriculture and other purposes (Otingi 2019).

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Infrastructure is one of the most significant problems, as are strong institutions to address the issue of water availability, a specific program to fund and change the mindset of leaders, and the battle against other concerns such as corruption and impunity for this approach to succeed. Infrastructure, for example, will help to distribute water in the Sud-Sahara region using new technologies such as irrigation systems for large rivers such as the Congo River and other rivers, as well as manage water that falls into the sea internally to avoid waste and maximise water availability for African people, lands, and local communities (Baylouny and Klingseis 2018).

The greatest way to prepare for climate change in the extraction, delivery, and treatment of water is to invest more across Africa in water infrastructure to boost the positive functions and decrease the negative impacts of water. According to United Nations (2019), Nature-based solutions (NBS) are a critical way to go beyond business as usual to address many of the world's water concerns while also providing additional advantages that are critical to all elements of sustainable development (Alpízar *et al.,* 2020). United Nations (2019) adds that they imitate natural methods to enhance water quality (for instance, natural and artificial wetlands), increase water availability (for instance, soil moisture storage or groundwater recharge), and lower the risks associated with solvent catastrophes and climate change.

Implications for the Future Research

This paper recommends that country governments create a strategic plan for managing contaminated water. It is necessary to develop specific methods for offering potable water monitoring capabilities at the community level.

It is necessary to have a regulatory framework that combines goals for acceptable water quality with wastewater control. For the 2.1 million individuals without access to clean drinking water and over 884 million people who lack basic drinking water amenities and depend on surface water for survival—this will be essential. The continent's ability to adapt to the changing climate will be increased by embracing both conventional and modern know-how, such as water harvesting methods, rainwater harvesting and storage, and better water reuse and recycling.

It is important to improve the governance of water bodies, irrigation facilities, the universe system of liquid storage reservoirs, water transportation infrastructure, efficient supply chains for agriculture and drinkable water, and assuredness of availability of water, sanitation, access, and utilisation. The ideal adaptation option is to increase capital investment in resource management across Africa in order to create both tiny and large-scale water infrastructure.

CONCLUSION AND RECOMMENDATIONS

Researchers, decision-makers, the corporate sector, national and international governments, the World Bank, the FAO, funders, the World Food Program, and men, women, and children are some of these stakeholders. Because climate change affects water, the food system, and the ecosystem that produces food, it is a multifaceted problem that requires a diverse approach to developing and putting into practice potential solutions. To expand publications and enhance the SSA's water resources, co-authorship is required.

The following are recommendations to African policymakers and NGOs based on the study's findings. Strategies are required, which necessitate various resources such as financial and human resources, as well as political support for the projects. Local and national governments should consider policies and programs to address the local government's lack of financial and human resources.

In the face of climate change, African planners should seriously consider integrating and institutionalising adaptation with development initiatives. It should not be an afterthought or an add-on. Based on the background and literature assessment, there is currently minimal proof of this, leaving a gap to fill. Long-term policies that satisfy local developmental goals and handle

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water resource management problems should be implemented, with the government and NGOs playing a key role. This will ensure that, despite the uncertainty of future climate projections, local governments have the necessary adaptive resilience in place to ensure that the communities they serve have adequate clean water to meet their developmental needs.

Encourage regional collaboration and cooperation in the management of water resources. This includes exchanging best practices, managing transboundary water resources jointly, and coordinating policies and strategies to tackle common problems. This may help in Investing in the construction of water storage infrastructure, such as dams, reservoirs, and systems for supplying water. This can lessen the effects of water fluctuation and provide a steady supply of water during times of scarcity.

Enhance ecosystem-based techniques by preserving and restoring natural ecosystems, like wetlands including forests, which are essential for controlling water flow, reducing floods, and enhancing water quality. Ecosystem-based methods can offer affordable and long-lasting solutions for managing water resources.

CONFLICT OF INTEREST

The authors state that they have no competing interests in the publication of this research.

Data Availability

Data is available at the request of the author.

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