Effect of Climate Change on Soil and Water Resources in Uganda. A review

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Abstract

An overview of the climate crisis on land and water, as well as techniques for managing water resources to combat climate change and prevent risks, are provided in this paper. Strong scientific consensus exists that the planet's climate has evolved and therefore will continue to shift as anthropogenic impacts raise the atmospheric concentrations of greenhouse gases. The effects of climate change on both soil and water resources in Uganda are very significant, and a more comprehensive understanding of their mitigation measures is needed. The purpose of this study is to evaluate the potential effects of sea level rise on water as well as soils in Uganda, as well as the main effects of global warming on soil characteristics and attributes, choices for water governance to fight climate change, water extraction all through dry seasons, and mitigation measures to lessen the effects of global warming on water and soils. From ResearchGate, online databases, Science Direct, and the Web of Science, a total of 58 peer-reviewed papers from the years 2010 to 2022 that were deemed pertinent for this study were chosen and discussed. While both water and soil supplies are being threatened by the depletion of fossil fuels and climate change, Uganda's population is expanding quickly. According to a number of experts, climate change alters the hydrological cycle, or parts of the water cycle, such as precipitation, evaporation, temperature, stream flow, underground aquifers, and surface runoff. Soils are tightly woven with the carbon, nitrogen, and hydrologic cycles that govern the climate system. This paper demonstrates climate change's impact on water and soil resources, primarily due to fluctuations in temperature and precipitation.

Keywords: Climate change, Ugandan soil and water resources, soil properties, hydrologic cycles and Precipitation

1. Introduction

Climate change refers to long-term changes in the Earth's climate system, including changes in temperature, precipitation, and weather patterns, that are caused by human activity, particularly the burning of fossil fuels and deforestation, which releases greenhouse gases into the atmosphere (Bano & Arshad, 2018). These gases, such as carbon dioxide, methane, and nitrous oxide, trap heat from the sun, leading to global warming and a variety of negative impacts, such as sea-level rise, more frequent and severe weather events, changes in the distribution of plants and animals, and shifts in agricultural productivity. Climate change is considered one of the most significant challenges facing the world today, and it requires immediate and concerted action to mitigate its impacts and adapt to its consequences.

Changes in precipitation patterns and intensity as a result of climate change have increased soil erosion. Heavy rainfall can lead to flash floods that carry away topsoil and nutrients, leaving behind less fertile soil. Hence, climate change is affecting soil quality and health, which could have serious implications for global food security and ecosystem health (Shi *et al*., 2020). Therefore, measures to mitigate climate change must be taken to protect the soil and ensure sustainable agriculture.

Climate change can also impact water quality, with increased temperatures leading to the growth of harmful algae blooms and the spread of waterborne diseases. Changes in precipitation patterns can also lead to changes in water quality, with changes in runoff patterns leading to increased sedimentation and pollution. Changes in precipitation patterns and increased evaporation rates are also affecting water storage. Snowpack, which is an important source of water for many regions, is melting earlier and faster due to higher temperatures, leading to changes in the timing and availability of water (Wan & Roy, 2022).

Worldwide, water, which is frequently the most limiting factor for plant growth, is also the most important factor in soil and land degradation processes, either directly or indirectly (Daba et al., 2018). Floods and droughts are the deadliest natural calamities, claiming lives and wreaking havoc on economies, ecosystems, and property (Shi *et al*., 2020).Weather alteration influence agricultural production and water quality (Diamantini *et al.,* 2018), diversification, and production methods hence, a gap to fill. The agricultural sector is likewise affected by physiography and technology interventions (Singh *et al*., 2020).

According to WHO (2020), 42 percent of people lack basic water supply, 72 percent lack basic sanitation, and only about 57 percent have access to appropriately accomplished consumption water amenities (Thomas *et al*., 2020) in Sub-Saharan Africa. There is currently a lack of information on the climate change's effects on water and soil in East African nations like Uganda, suggesting that more evidence is required to close this gap. In Uganda, soils are particularly important for ensuring food security, and climate consistency's effects on soil could imperil food and nutritional security (Jacob, 2021).

Currently, due to the low sensitivity and limited knowledge of the water and soil quality in the Uganda, the public continues to use water for drinking and cooking, which exposes them to a huge threat of water-borne diseases hence, a need for water quality assessment. Therefore, little effort has been taken to scientifically record smallholder farmers' awareness of the climate change consequences on water and soils. Therefore, the aim of this study is to assess the potential impacts of climate change on water and soils, the key implications of climate change on soil processes and properties, options for water management to combat climate change, water harvesting during dry seasons, and the mitigation measures to reduce on climate change effects on water and soils in Uganda. The study aimed at assessment of the potential impacts of climate change on water and soils resources in Uganda. It was guided by the following specific objectives, namely: assessing the key implications of climate change on soil processes and properties, and finding out the mitigation measures to reduce on climate change effects on water and soil resources in Uganda.

In the first section, we discuss the impact of climate change on water and soil resources in Uganda (Section 1). Section 2 was about the materials and methods. Section 3 gives a detailed overview on the effect of climate change water and soil resources in Uganda; Section 4 describes the options for water management to combat climate change. Section 5 of the paper highlights the mitigation measures to reduce on the effects of climate change on soil and water resources. In Section 6, we discuss the conclusions and recommendations respectively. The results of the study provided information that increases the awareness and willingness of all stakeholders in water and soil conservation in the unpredictable change error. The understanding of the impact of climate change on water and soil resources in Uganda may underpin the development of measures to protect the water and soil from further deterioration in quality and quantity, thereby protecting the population relying on these resources as well as the biodiversity.

2. **Materials and Methods**

2.1.Study Area

The research was carried out in Uganda (Figure 1). East Africa's Uganda is situated north of Rwanda and Tanzania, north of South Sudan, east of the Democratic Republic of the Congo, and west of Kenya. Uganda is a landlocked nation without access to the sea, however a major portion of its border is lakeside (Griffiths, 1986). Despite this, Uganda is a rich and well-watered nation, consisting of many lakes and rivers, including the largest, Lake Victoria. Since two of the Great Lakes, Lake Edward and Lake Albert, encircle the nation, it is located in the center of the Great Lakes area (Burgis *et al.*, 1973). There are two dry seasons in the tropical climate's two wet seasons (December to February, June to August) (Nimusiima *et al.*, 2013). In addition, the semiarid northeast of the nation. The majority of Uganda is located on a plateau, a broad area with a gentle incline that ranges in height from roughly 5,000 feet in the south to about 3,000 feet in the north (King, 1950). Mountains and valleys delineate the plateau's boundaries in Uganda. The majority of the lateritic soils are fertile in general, and the soils around Lake Victoria are some of the most productive in the world (Krishna, 2013). These are interspersed with the wet clays typical of Lake Victoria's western and northwest coastlines.

Elevation and local lake presence in Uganda both influence its tropical climate. North-easterly and south-westerly air currents dominate (Hills, 1979). The length of daylight is almost consistently 12 hours due to Uganda's equatorial location, where there is little fluctuation in the sun's declination at midday. All of these elements ensure an agreeable climate all year long, along with a reasonably consistent cloud cover. The majority of Uganda receives an appropriate quantity of precipitation, with yearly totals ranging from 20 inches or less in the northeast to 80 inches or more in the Islands of Lake Victoria. Although there are still sporadic tropical thunderstorms in the south, there are two wet seasons (April to May and October to November) that are separated by dry intervals (Wan & Roy, 2022). Climate change is now affecting Uganda. For instance, rivers are drying up and certain lakes, like Lake Bunyonyo, which was once the deepest lake in Uganda but is now small, are drying up. Lake Victoria has overflowed into other areas of the local community. There is a need for this subject topic because nothing has been done.

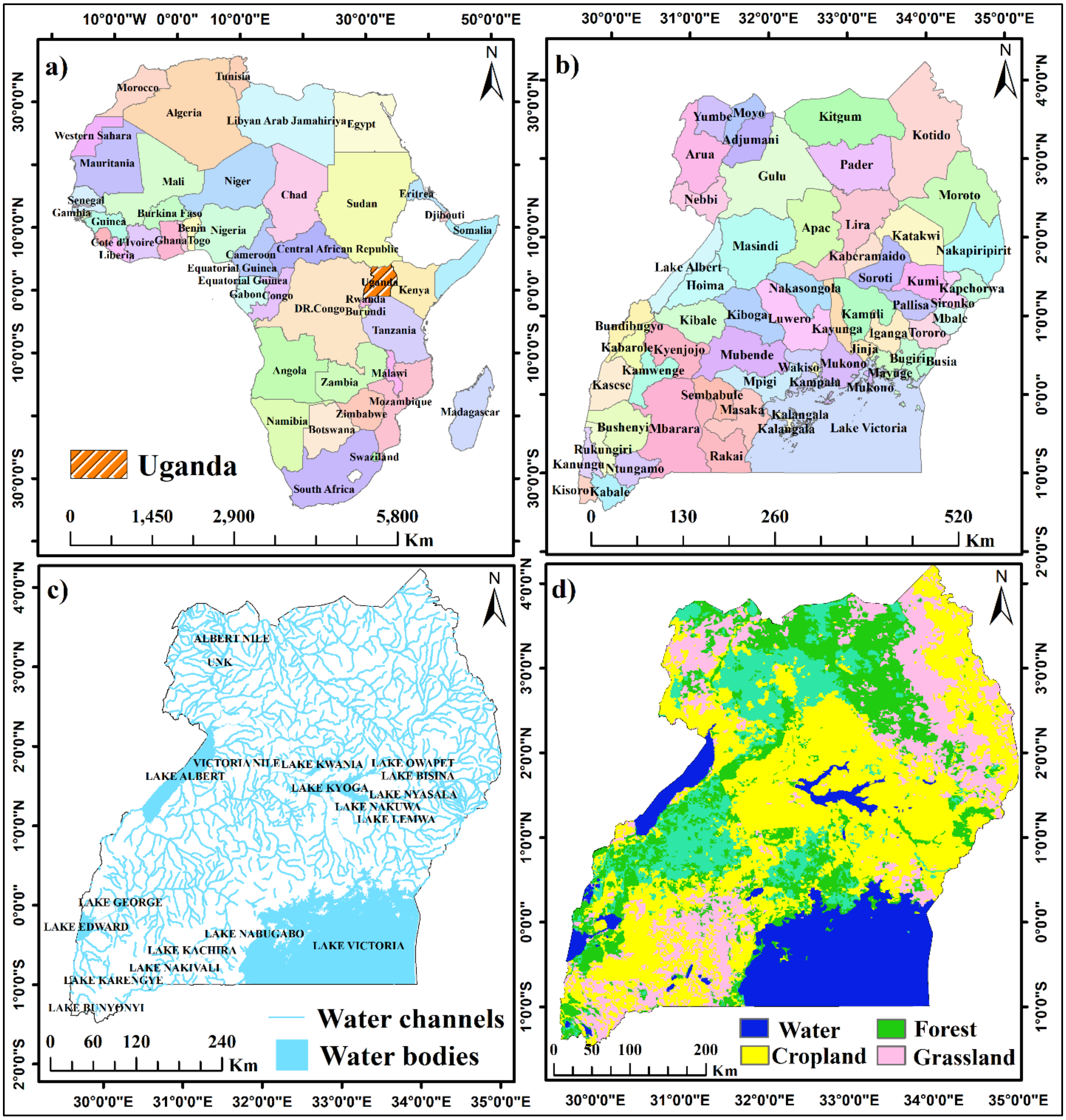

Figure 1: a) Location of Uganda b) administrative divisions of Uganda c) Spatial distribution of major water bodies and channels d) major land use classification of Uganda.

2.2. Literature selection, screening and Extraction

This review is based on literature review of 57 published articles mainly between 2010-2022. To obtain this, an updated perspective on climate change in the general context of soil and water resources. There is no single database which is sufficient to cover all relevant articles and information, and that's why different databases were used (Gray, 2014; Naidoo *et al*., 2018). The reviewed articles where outsourced using three common scientifically cited and indexed databases namely of Web science, Elsevier Scopus and Google Scholar. Search terms included "Soil", "climate change", and "water resources", with a filter of mainly year of publication (i.e. 2010-2022). Additional search terms were included to identify relevant papers that did not directly use the above terms. Selected documents were mainly peer-reviewed journal articles, a limited number of books, reports and online resources, including companies and organization reports and bulletins. From the retrieved papers summaries new graphics and tabulations were made to make the discussions and uncover gaps that need to be addressed. In this study, a methodological approach (Figure 2).

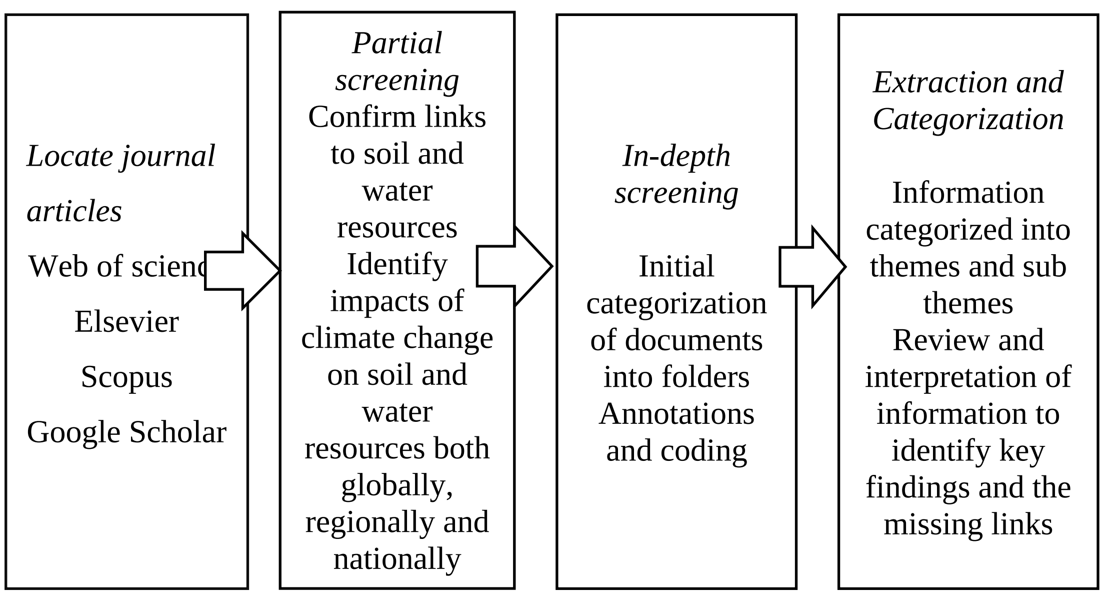

Figure 2. Methodological approach used in this study, (Authors, 2022).

3. Literature Review

3.1.Climate Change and Water Resources in Uganda

Reduced stream flows in important catchments, lower recharging of groundwater, reduced inflows to water storages, or intensified droughts are all consequences of rising temperatures and reduced rainfall (Mahmo od *et al*., 2016), raising competition for water among sectors (Stoerk *et al*., 2020). Changes in surface runoff and groundwater flows in shallow aquifers are examples of hydrological processes linked to climate change, with implications for permanent and seasonal water bodies like lakes and reservoirs hence, affecting its quality for example river Rwizi in Mbarara district have been affected due to agricultural activities which leads to soil erosion during rainfall thus, affecting aquatic species (Ojok *et al*., 2017).

In order to limit activities that can contribute to climate change and have an impact on water and soil resources, men and women in farming need to collaborate, according to a study done in Uganda by Benson and Ayiga (2022). For women and men to equally adopt and profit from site-specific climate change strategies, gender analysis and equal participation and engagement of both genders must be carried out from the start of any climate change intervention. However, the study never specified how men and women can main soil and water resources in wet and dry seasons and this leaves unanswered questions to investigate.

Empirical studies on the effects of climate on water resources has been documented as climate change can impact on water supplies by causing greater surface temperatures, melting of snow and glaciers, rising sea levels due to droughts and floods, changes in rainfall frequency and distribution, river drying, water bodies receding, landslides, and cyclones are some of the potential effects of climate change on Uganda's water resources (Yakubu *et al*., 2012). For example, on October 1, 2019, the water level in Lake Victoria steadily rose from 12 meters to its current level of 13.32 meters as of April 30, 2020. The level has increased by 1.32 meters in just 6 months, and it is only 0.08 meters 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.

Drought has an impact on the quality of fresh water, according to Khalid *et al*. (2020), from the shortage of water to the concentration of toxins in the streams. Drought leads people to use contaminated water for themselves, their crops (which affects productivity) and their animals, resulting in crop wilting and low yield rates (Turyasingura *et al.*, 2023).

Rainfall is a seasonal phenomenon with significant inter-annual fluctuation due to climate changes, extreme climate events, changes in the duration of continuous rain or no rain spells, and the overall amount of water supplied during each wet spell (Rani *et al*., 2021). As a result, all of these parameters are dependent on the characteristics of the watershed and its geographic location in Uganda, where rainfall is the norm.

The relationship between precipitation and the microbiological quality of lakes such as Mutanda, Victoria, Kyoga in Uganda is complicated, involving a complex interplay between the type of water supply and its management (Howard *et al.*, 2016). Unfortunately, rapid and unplanned urbanization, poor sanitation, erosion, and a lack of upkeep of water catchment regions all contribute to climate change vulnerability (Maskey *et al.*, 2020). As a result, the infrastructural and environmental changes, the study timeframe (yearly, season, or day to day), and the rainfall patterns are all factors to consider (Ogunsanya *et al*., 2014).

Local weather, climatic change, and hydrologic conditions, according to Vinçon-Leite and Casenave, (2019), are examples of elements that affect water quality in Uganda, nutrient loads, and eutrophication of water bodies. Rainfall fluctuation promotes cyanobacteria dominance, exacerbates eutrophication, and affects the stability of lake features such as physical, chemical, and bacteriological stability, as well as the availability of nutrients.

3.2. Climate Change and Soil Resources in Uganda

Climate change has an impact on soils, and soils also contribute to it especially in parts on Mount Elgon in Uganda (Jiang *et al*., 2014). Plants fix carbon, which is then transported to the soil via dead plant debris such as roots and leaves (Wu *et al*., 2010). This decomposed organic waste serves as a substrate for soil microorganisms to respire carbon dioxide or methane back into the atmosphere, depending on the availability of oxygen in the soil. The bacteria may easily consume and respire some of the carbon molecules, resulting in a short residence time (Davies, 2005). Others stabilize chemically and/or physically in soils, resulting in prolonged residence durations (Medina *et al.*, 2015).

According to Turyasingura and Chavula (2022), agriculture is anticipated to remain the economy’s backbone for the foreseeable future, with agricultural operations employing a large majority of Uganda’s work force (72%), but little has been done to maintain Uganda’s water and soil resources. Thus, there is a need for a strategic plan for the people involved in agriculture to know how soils and water resources are affected by climate change and how to control it through the Ugandan government's parish development model, but nothing has been incorporated into this model at the village level.

Organic matter and soil organic carbon have an approximate connection of 1.724 x percent organic carbon making percent organic matter in mineral soils (Castro Padilha *et al*., 2020). Drought intensification would have the opposite impact, as demonstrated below.

Figure 3: Landslides due to soil erosion. (**Source:** Authors 2022).

3.3. Impacts of Climate Change on Soil Processes and Properties

Climate change is one of the most important elements influencing soil formation, with significant implications for soil development, usage, and management in terms of soil structure, stability, and topsoil water holding capacity, as well as nutrient availability and erosion. Organic carbon content, soil biota features, moisture and temperature regimes, and processes such as erosion, salinization, or physical, chemical, or biological fertility are all soil properties that could be affected by climate change (Bates *et al.*, 2008). Temperature, rainfall (amount, intensity, and temporal distribution), and atmospheric chemistry, particularly carbon dioxide, nitrogen, and Sulphur compounds due to increased temperature and drought, would be the climatic parameters driving these changes.

Many factors influence soil formation, including environmental elements like temperature and precipitation. These climate variables have a direct impact on soil formation by providing biomass and weathering conditions. The sum of active temperatures and the precipitation evaporation ratio are the two main climate elements that have a direct impact on soil formation (Ponting *et al.*, 2021). They calculate energy consumption for soil formation and water balances in soil (Turyasingura and Ayiga, 2022), as well as the mechanisms of organic-mineral interactions, organic and mineral material transformations, and soil solution fluxes (Ramesh *et al.*, 2019).

External factors affecting soil formation (temperatures and precipitation) will cause internal factors to change (energy, hydrological, biological) (Morozov *et al.*, 2018). Climate change will increase the energy required to destroy soil minerals, resulting in the simplicity of the mineral matrix due to the build-up of weather-resistant minerals. It will result in a loss of soil function for maintaining fertility and an increased reliance on mineral fertilizers (Abatenh *et al.*, 2018).

Climate, parent material, and vegetation type all play a role in soil development. Climate change is projected to affect soil growth primarily through changes in soil moisture conditions, as well as increases in soil temperature levels. Climate plays a crucial effect in the weathering of rocks and minerals, which is one of the many elements that control the soil development process. Climate change factors such as temperature and rainfall determine the phases of weathering of rocks and minerals (parent material), resulting in chemical and mineralogical changes in soil-forming rocks (Ugwu *et al*., 2021).

Through the nitrogen, carbon, and hydrologic cycles, soils are inextricably related to the climate system. As a result, climate change will have an impact on soil processes and qualities. The ability of soils to support crop growth will be influenced by how soil organic matter levels react to changes in the carbon and nitrogen cycles, which has substantial implications for food security (Kopittke *et al*., 2019). As a result, more research into the interconnections of soil and climate in a changing world is essential for solving future food security challenges.

Soils play an important role in several global nutrient cycles. The carbon and nitrogen cycles are the most important in terms of soils and climate change interactions since carbon and nitrogen are important components of soil organic matter (Liu *et al*., 2018) and carbon dioxide, methane, and nitrous oxide are the most important long-lived greenhouse gases.

In Uganda, soils with sufficient organic matter are more productive than soils with insufficient organic matter (Camarotto *et al*., 2018). As a result, one of the most pressing questions about climate change and its effects on soil processes and properties is how potential changes in the carbon and nitrogen cycles will affect soils, as shown in the (Figure 4).

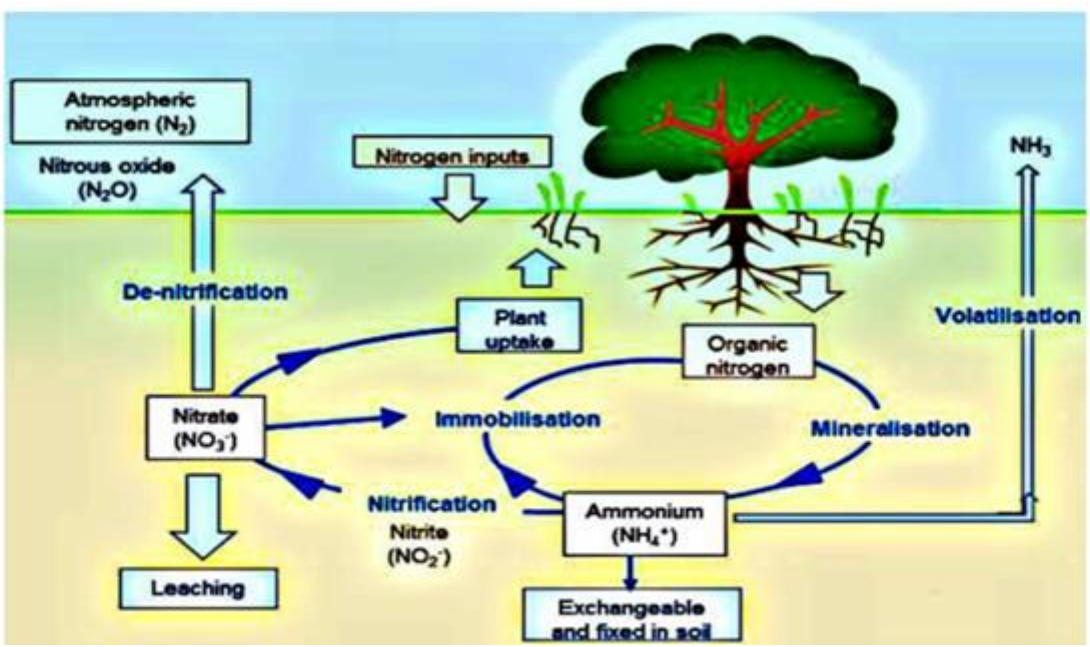

Figure 4: Nitrogen cycle and climate change (Daba *et al*., 2018).

Climate change has an impact on soil qualities such as texture, which is the proportions of different sizes of individual soil particles (Patil & Lamnganbi, 2018) as shown in the (Figure 5).

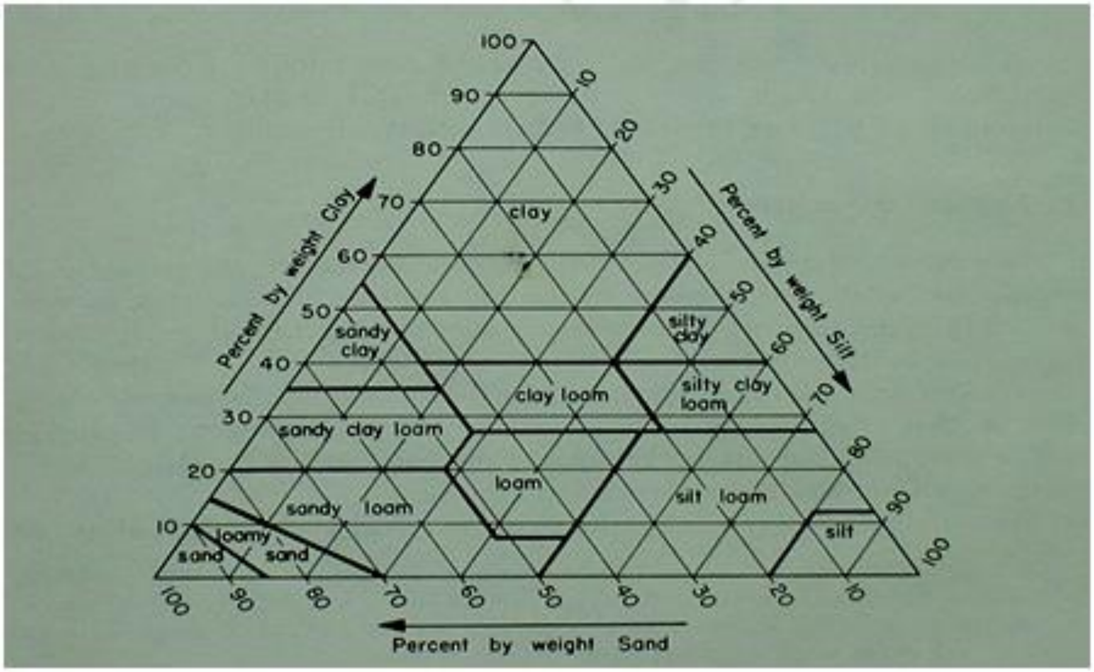

Figure 5: Climate change also affects Soil properties (Patil & Lamnganbi, 2018).

4. Options for Water Management to Combat Climate Change in Uganda

Integrated watershed management: Watersheds are natural environmental and land management units that influence a country's overall health. Poor ecosystem management in watersheds has resulted in and will continue to result in reduced watershed functioning, which in sensitive areas can lead to ecosystem collapse (Pourghasemi *et al*., 2020).

If appropriate policies are enacted, watershed management is often successful. Watershed management necessitates the use of the three "Ps": planning, partnership, and stakeholder participation (Karambelkar & Gerlak, 2020). Public-private partnerships are becoming a more typical strategy to increase management success. This bring these two sectors together to work toward a common goal, allowing each to benefit from the skills and resources of the other to more effectively fulfil management goals.

Watershed management is mainly based on the study of watersheds, which is a branch of hydrology that analyses the effects of vegetation and land management on water quality, erosion, and sedimentation (Ranjan *et al*., 2020). 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).

Water harvesting is also an option used by the local people during drier seasons to store water especially among institutions and agricultural farms. In other words, water harvesting is the process of collecting rainfall directly from the sky (Tu et al., 2018). Rainwater can be collected and stored for immediate consumption or returned into the groundwater system. Rain is the first form of water in the hydrological cycle that humans are aware of, making it a key supply of water for humanity. Rainwater harvesting entails absorbing runoff from rooftops, catchment runoff, seasonal floodwaters from local streams, and watershed management (Bennett & Barton, 2018). Therefore, there is need for rain water harvesting in Uganda especially in Kabale District to keep water during dry seasons for domestic use like at Kabale University, Uganda. Kabale University has a lot of water collecting points to enable students get water during dry seasons. This have enabled students and the local communities neighbouring this Institution get water for their personal activities. Figure 6 Rainwater harvesting (Source: Author 2022).

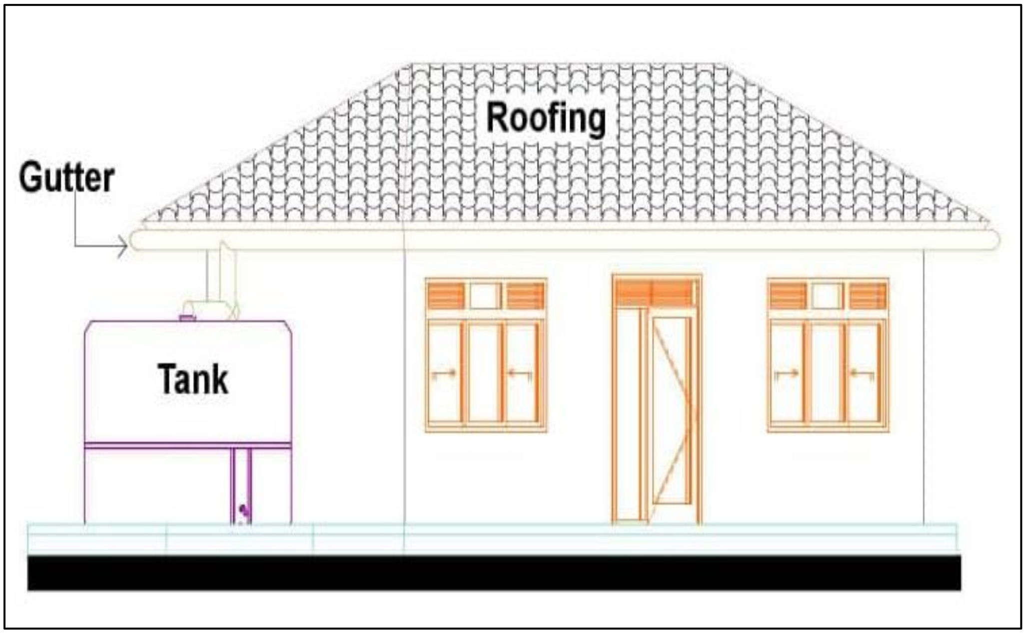

Figure 6: Rainwater harvesting (Source: Author 2022).

5. Mitigation Measures to reduce on the effects of climate change on soil and water resources in Uganda

1. Afforestation, like forests, is typically expected to require more water than crops, grass, or other naturally occurring short vegetation (the total of transpiration and evaporation of water intercepted by tree canopies) (Schwärzel *et al.*, 2020). In lands that have undergone afforestation or reforestation, this effect may be related to increased interception loss, particularly where the canopy is wet for a significant portion of the year, or, in drier regions, to the development of more massive root systems, which allow water extraction and use during prolonged dry seasons (Yang *et al.*, 2021). Landscape variety is crucial for sustaining resilient livelihoods as a way to enhance the health and functionality of socio-ecological systems and as a method of maintaining food security, according to the research done by Turyasingura, Mwanjalolo, and Ayiga (2022), because diversity gives local people's access to a larger choice of food, feed, and job possibilities, which is particularly important during times of climate change, diversity is essential for resilience because it lessens the risk of production losses due to climatic pressures. The novelty from the study is that trees absorb carbon dioxide from the atmosphere during photosynthesis and store it in their tissues, including in the soil as organic matter. This process is known as carbon sequestration, and it helps to reduce the amount of carbon dioxide in the atmosphere, thus mitigating the effects of climate change. Trees planted through afforestation can help conserve water resources by reducing evaporation from soil surfaces, increasing infiltration, and regulating water flow in rivers and streams and this helps rural farmers to increase on their agricultural productivity hence, reduced poverty.

2. In many Ugandan communities that are already at risk, the effects of rising climate unpredictability, such as crop failure and livestock mortality (Abrahams, 2021), are starting to show. Agroforestry systems have been mentioned in numerous studies as a solution to this issue. This is due to the fact that agroforestry increases household food security while simultaneously lowering vulnerability to seasonal food and fodder shortages (Charnley *et al.*, 2022). Thus, the local population in Uganda must follow this technique to lessen the consequences of climate change on soil and water resources (Waaswa & Satognon, 2020).

3. Despite the fact that many households engage in agroforestry activities, there is little information about how these activities affect the preservation and management of soil and water resources (Piemontese *et al.,* 2021). The majority of the data is found in annual publications from the organization that only include a few case studies of specific households experiencing the effects of agroforestry (Gabiri *et al.,* 2020). With such widespread household participation, further research is needed to determine how much agroforestry contributes to lowering the vulnerability of soil and water resources to climate change. This study would serve as an impartial assessment of the study, providing additional verifiable proof of these effects (Sutherland *et al.,* 2019).

4. Forests with extensive leaf coverage throughout the year experience the biggest interception losses. As a result, such losses are often higher in evergreen forests compared to deciduous forests, and they may also be anticipated to be higher in fast-growing, highly carbon-stoked forests compared to slow-growing forests. As a result, afforestation with rapidly expanding conifers on non-forested land frequently reduces the flow of water from catchments and may result in water shortages during droughts.

5. Similar to forest conservation, regeneration can have advantageous hydrological benefits (van Meerveld et al., 2021). In wet areas after afforestation, baseflow increases slowly as stand age increases toward maturity, while the amount of direct runoff initially decreases quickly before gradually becoming constant. This suggests that reforestation and afforestation help to reduce flooding and improve water conservation. Aquifer recharge and streamflow in the Kigezi regions of Uganda can be significantly impacted by afforestation, particularly plantations of species with high water demands, which affects the wildlife living in rivers like the River Rwizi in Mbarara and reduces water flow to other ecosystems and rivers (Nseka et al., 2019). Additionally, modifications in hydrology may have a significant role in some potential changes in soil characteristics.

6. The majority of Uganda currently receives additional water through irrigation, such as in Kasese, Northern Uganda, to preserve soil fertility and crop development, which further lowers water loss. This lessens Uganda's starvation and poverty. Although this effect has not been well studied, some of these benefits might be countered by carbon dioxide

produced by the energy necessary to transport the water. Increased methane emissions from soils could result from the expansion of wetland rice areas, which requires attention to preserve soil quality.

7. Utilizing bioenergy crops Bioenergy reduces greenhouse gas emissions by replacing the usage of fossil fuels (Yang & Tilman, 2020). Bioenergy crops can be converted into biofuels, which can be used as a substitute for fossil fuels. This can help reduce greenhouse gas emissions because biofuels are generally less carbon-intensive than fossil fuels. However, it is important to note that the utilization of bioenergy crops must be done in a sustainable manner to ensure that they do not have negative impacts on the environment or compete with food production. The crops must also be grown and processed using sustainable practices to ensure that the benefits of reduced greenhouse gas emissions are not outweighed by negative environmental impacts. Large-scale biofuel production, however, raises concerns about a number of issues, including the need for fertilizers and pesticides, the cycling of nutrients, energy balances, impacts on biodiversity, hydrology and erosion, conflicts with the production of food, and the number of financial subsidies needed. Dedicated energy crops' capability to produce energy and reduce greenhouse gas emissions are dependent on the availability of land, which must also be suitable for food production, environmental protection, the sustainable management of soil and water resources, and other sustainability standards (Venkatramanan *et al.,* 2021).

8. Another important factor in reducing the detrimental impact of droughts on crop yields is drainage (Li *et al.,* 2019). The purpose of draining is to lower the ground water table in the spring so that field work may begin earlier and plant growth and root development can occur sooner, and manage excess water in the soil to improve soil structure, fertility, and crop yields, and to reduce soil erosion and disease and pest pressure. This enables the root systems to absorb water from the deeper layers of soil when there is a drought (Elahi *et al.,* 2022). On the other hand, one must be mindful that if water is removed from the soil, less water is left in the soil, which increases the likelihood that drought may develop sooner (Jorda *et al.,* 2022). Proper drainage can help to ensure timely planting and harvesting, reduce disease and pest pressure, and increase crop yields and quality. In

summary, the purpose of draining in agricultural fields is to manage excess water in the soil to improve soil structure, fertility, and crop yields, and to reduce soil erosion and disease and pest pressure.

9. According to Turyasingura et al. (2022), the monitoring, assessment, and reporting activities should be logically linked to support long-term conservation, and the management control function, which is essential to good soil and water resources, should be reformed and repositioned. For the soil and water resources to be protected, specific changes in governance should be made to reduce inefficiencies from wetland conservation control procedures. Monitoring and assessment activities can help to identify areas that are particularly important for conservation based on their ecological significance, biodiversity value, or vulnerability to threats such as habitat loss, climate change, or invasive species.

6. Conclusion and Recommendations

Net water supply would be reduced if precipitation remained constant or decreased. Net water supply would be reduced if precipitation remained constant or decreased because the amount of water available for use by humans, animals, and plants would decrease. Net water supply refers to the amount of water available for use after accounting for losses due to evaporation, transpiration, and other natural processes. Hence through the carbon, nitrogen, and hydrologic cycles, soils are inextricably related to the atmospheric/climate system. As a result, changes in climate will have an impact on soil processes and qualities in Uganda and this needs much attention. Soil organic matter was influenced by changes in average temperatures and precipitation patterns.

Recommendations

- To alleviate water shortages at the village level, local leaders should raise community knowledge of future climate change in the watershed area, as well as the development of ground water and effective rainfall harvesting systems. This knowledge can be used to develop adaptation plans that are tailored to the specific needs of the community. Implementation of adaptation measures: Local leaders are often responsible for implementing adaptation measures, such as the construction of flood barriers or the implementation of water conservation practices. Community knowledge can inform the selection of appropriate measures and ensure that they are implemented effectively.

- Water conservation and efficiency measures should be implemented by the Ugandan government to minimize the amount of water required for agriculture, municipal, and industrial users, as well as to improve water delivery through National Water and Sewerage Cooperation. Uganda is facing water scarcity in many parts of the country, particularly in the dry season. Water conservation measures can help to reduce water consumption and ensure that water is available for essential uses such as drinking and agriculture. Climate change is expected to cause changes in rainfall patterns in Uganda, leading to more frequent droughts and floods. Water conservation measures can help to reduce the impact of these changes by ensuring that water resources are used efficiently.
- Groundwater development, such as rainfall harvesting, watershed management, and rainwater harvesting, should be undertaken in all vulnerable locations on a broad scale. The study recommends the local leaders to create awareness among the community of the future climate change in the watershed area and development of ground water and effective rainwater harvesting technologies to reduce on water shortages at village level. groundwater development is important for many communities around the world, including in Uganda. It provides a reliable source of water, is often of high quality, and can be used for a range of purposes, including irrigation and drinking water. However, it is important to ensure that groundwater resources are used sustainably to avoid overexploitation and depletion.
- In conclusion, rainfall harvesting is an important practice in dry areas of Uganda where water scarcity is a common problem. It provides a reliable source of water, is cost-effective, and can be used for a range of purposes, including drinking water, agriculture, and environmental conservation. However, it is important to ensure that rainfall harvesting is done in a sustainable way to avoid overexploitation of water resources and other negative impacts on the environment.

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Conflict of Interest

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

Conflict of Interest

Not applicable.

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