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Original Article

### Assessing the Linkages between Energy Poverty and Climate Change in Lakes State of South Sudan

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Energy poverty and climate change are pressing global challenges that adversely affect forest ecosystems, water resources, human health, livelihoods, and environmental resilience. These issues are interlinked and surpass geographical boundaries. The intricate relationship between energy poverty and climate change is encapsulated in the theory of forest transition, highlighting the need for integrated mitigation and adaptation strategies to manage South Sudan's natural resources sustainably. The progressive installation of clean and renewable energy infrastructure, such as solar energy, wind energy, geothermal energy, and hydroelectricity, in the local areas of Lakes State in South Sudan will improve their economic standards and promote sustainable development. The overall objective of this Study was to assess the linkages between energy poverty and climate change impacts in Lakes State of South Sudan. A cross-sectional research design was used to capture the community's perceptions on these linkages. Yamane's Formula was used to calculate the sample size of 80 respondents who were proportionately selected to participate in the study. Face-to-face key informant interviews were conducted with the local government officials in the energy sector, farmers, academicians, NGOs, and traders. Data was presented using bar graphs, charts and narration of participant views. The results indicate that there are linkages between cutting down trees for energy services and deforestation, leading to climate change. The study concludes that energy poverty is a driver of deforestation, which in turn contributes to climate change impacts, especially on agricultural productivity and livestock. This study recommended that the government and other relevant energy stakeholders should implement alternative energy programs, including access to electricity, solar, and wind energy. These interventions are vital adaptation and mitigation strategies in order to stop forest depletion and address climate change.

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## INTRODUCTION

Energy poverty and climate change are pressing global challenges that adversely affect forest ecosystems, water resources, human health, livelihoods, and environmental resilience. These issues are interlinked and surpass geographical boundaries (Intergovernmental Panel on Climate Change (IPCC), 2023; Moraes *et al.*, 2013; Njora & Yilmaz, 2022; Picornell *et al.*, 2024). Energy Poverty is the inability to keep households adequately warm (Day *et al.*, 2016; Kez *et al.*, 2024; Hansgaard, 2023; Raihan, 2022; Belaïd, 2023). Nguyen & Su (2021) define energy poverty as the "absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic development." Our study defines energy poverty as mean of reliable, affordable, and adequate energy sources, which include electricity, oil, coal, natural gas, and other biomass fuels such as wood and charcoal.

This study assesses the overall reliance on polluting and inefficient traditional energy sources, which limit the ability of households to meet basic needs such as cooking, lighting, heating, and supporting livelihoods in Lakes State of South Sudan. Globally, 2.9 billion people have no access to energy services such as electricity in their houses (FAO, 2022; Banjwa, 2016; Batool *et al.*, 2022; Rita, 2020). According to Rita (2020), Portugal had between

20% and 29% of its households living in energy poverty. The article states that access to affordable and efficient use of energy services are important aspects to reduce energy poverty, deforestation, and mitigate the effects of climate change, and improve healthcare, education, and enable higher standards of living among the vulnerable groups in both the developed and developing countries (Rita, 2020).

In the study done by Nguyen & Su (2021), a global sample of 74 developing countries was used from 2002 to 2016. The findings indicate that alleviating energy poverty can protect forests from deforestation, which agrees with A.S. Mather's (1992) theory of forest transitioning. Nguyen & Su's (2021) study shows that energy poverty is linked to deforestation. The author's findings indicate important policy implications that suggest that addressing energy poverty can lead to a significant reduction in deforestation through easing the resilience of forest-based fuels. This emphasises the need for targeted interventions that will reduce the thresholds of deforestation caused by energy poverty. The findings from these authors indicate the crucial linkages between economic vulnerability and energy poverty at a global level, which demand urgent action on appropriate laws and policies to reduce energy poverty and environmental issues. This study argues that energy poverty has lessened human wellbeing, caused health issues, and reduced food productivity, as well as increasing the climate

change issues in the Lakes State of South Sudan due to degraded lands.

Energy poverty remains prevalent in sub-Saharan African countries (Ladu *et al.*, 2021; Okoye, 2020). Every country, like South Sudan, is responsible for providing energy services to its growing population in line with Sustainable Development goals (SDGs) number 7, which calls for universal access to affordable, reliable, and sustainable energy (Ayik *et al.*, 2020; Rita, 2020; Hansgaard, 2023). This study examined energy poverty and its impacts on forest resources and climate change in Lakes State, South Sudan. Energy poverty is closely linked to climate change, as forest cover is often used to provide solid fuels for household needs and socio-economic services. The absence of forests in an area increases global warming on the Earth's surface. Miyamoto (2020), using multinational data from Malaysian and Indonesian household surveys conducted between 1990 and 2014, found that poverty strongly influences forest area change and that agricultural rent accelerates deforestation. Their findings highlighted the relationships between deforestation and poverty. This study explored the linkages between energy poverty and climate change impacts in Lakes State, South Sudan.

Crentsil *et al.* (2019) employed the multidimensional energy poverty index (MEPI) as a measure of energy poverty. Their findings estimated that the portion of energy for deprived individuals decreased from 88.4% in 2005/2006 to 82.5% in 2012/2013. Although there has been a significant decline in the overall energy poverty in Ghana during the study period, the prevalence of energy poverty remains high. The authors concluded that the prerequisite to integrate energy poverty reduction strategies should be integrated into policies that improve income accessibility and energy affordability strategies (Crentsil *et al.*, 2019). Ghana and South Sudan are among the Sub-Saharan African Countries that experience energy poverty, particularly in terms of dependence on fossil fuels and forest resources for solid fuel

services across Africa. Too much dependence on fossil fuels and forest resources increases the rate of deforestation and emission of greenhouse gases into the atmosphere.

In Lakes State, South Sudan, where few off-grid systems provide modern electricity, many of these installations have been damaged. Urgent repairs are needed, including infrastructure upgrades, maintenance, and increased funding for the operationalisation of power distribution units (PDU) in Rumbek Central County of Lakes State. Increasing the number of off-grid energy systems and connecting them to major institutions and offices while extending power lines through community centres would improve accessibility, reliability, and affordability of modern electricity for the local population of Lakes State. Additionally, this expansion could help boost the socio-economic well-being of the local population of Lakes State. Thereby, reducing the negative effects of energy poverty, deforestation, and climate change by preserving forest resources. Forests played a crucial role by providing energy resources, regulating climate, maintaining ecosystem balance, and improving the soil structures in the environment (Ahmed *et al.*, 2019). Moreover, they contribute to reducing the global temperatures through carbon sinks and sequestration (Azam *et al.*, 2023; Asian Development Bank, 2022; Crentsil *et al.*, 2019). They need regulations and laws to protect and preserve them to continue their functions.

Several studies indicate that forest resources are degraded due to the establishment of energy infrastructure, including oil pipelines, the collection of firewood, charcoal black and the involvement of transportation services (UNDP, 2012; Ibekwe *et al.*, 2024; Morgan, 2012; Raihan *et al.*, 2022). These activities significantly contribute to environmental pollution and the emission of greenhouse gases (GHGs). Addressing energy poverty can improve household healthcare, education, and energy access. It also plays a role in mitigating climate change impacts and social conflicts arising from

inequalities and injustices related to the fragmentation of limited natural resources (Acheampong & Opoku, 2023; Hansgaard, 2023; Wilberforce *et al.*, 2023). However, energy-related pollution and deforestation activities pose significant risks to low-income households, livestock, and overall ecological and ecosystem balance (Azam *et al.*, 2023; Nguyen & Su, 2021; Moraes *et al.*, 2013).

Although proper implementation of forest and energy laws and policies can reduce deforestation and climate change impacts on the environment. Many institutions in the region left the forest and energy regulations implemented, leading to the depletion of energy and forest resources across the globe. Miyamoto (2020) states that effective policies and laws through reduce emissions from deforestation can reduce the negative effects of deforestation, energy poverty, and climate change. Kez *et al.* (2024) state that social inclusion, health, indoor temperatures, psychological stress, death, and poor air quality as the main effects caused by energy poverty. Energy shortage has close links with climate change through the use of dirty energy that contributes to the emission of greenhouse gases (GHGs) into the atmosphere, increasing global warming and rising temperatures on the Earth's surface. The identification of laws and policies that support the REDD+ initiatives in the country's developmental projects will help through the provision of socio-economic services, clean and affordable energy services to the community would halt climate change and energy poverty (Miyamoto, 2020).

The efforts to mitigate and reduce the emission of (GHGs) in the countries, per developmental projects, need to know how people generate energy from the forest resources and how the effects of deforestation and energy services are received by the people, animals, plants, and birds on the environment and other functionalities (Azam *et al.*, 2023; Tiitmamer *et al.*, 2018; Wilberforce *et al.*, 2023). The paucity on laws and policies that

regulate energy services and infrastructure and forest resources as well as the lack of implementation of financial budget in the projects and programmes on the energy infrastructure and forest management sectors has increased the households' energy shortage, hence alleviating the level of poverty and hunger among the vulnerable population of rural and urban population in developing and Island Nations (Ajide & Dada, 2024; Yuan *et al.*, 2021).

Conversely, the progressive installation of clean and renewable energy infrastructure, such as solar energy, wind energy, geothermal energy, and hydroelectricity, in the local areas of Lakes State in South Sudan will improve their economic standards and promote sustainable development. In addition, strong enforcement of environmental, energy, and forest laws and policies in places where people need accessibility, affordability, utilization, and distribution of energy services would allow the poor households to mitigate the adverse effects of energy poverty, climate change, and deforestation on the environment (Ayik, 2020; Sharma *et al.*, 2014).

Other studies have tested the Environmental Kuznets Curve (EKC) before in the context of greenhouse gas emissions (Nguyen & Su, 2021; Yuan *et al.*, 2021; Li *et al.*, 2021). But this study tested EKC on the links between economic growth and forest transitioning in how the elements of economic and energy services contributed to deforestation, energy poverty, and climate change impacts. Some studies confirmed the links between deforestation and energy poverty in income generation (Nguyen & Su, 2021; Ritchie, 2021). Nguyen & Su (2021) have tested EKC for deforestation for global samples with different panel data techniques and have refuted it, while other studies found that EKC works for deforestation in countries' specific context of Pakistan and Turkey (Aliyu *et al.*, 2019). This study tests the theory of EKC in the context of the Lakes State of South Sudan, and it agrees on the fact that agriculture and



forest resources are people's main economic activities, leading to deforestation.

In South Sudan, especially in Lakes State, the linkages between climate change and energy services and energy infrastructure, as well as the impacts of deforestation, are not known. The better approaches and methods of examining the linkages between energy poverty, deforestation, and climate change impacts in South Sudan have not yet been explored and researched. This study applied qualitative methods and forest transitioning theory to assess the linkages between energy poverty and climate change impacts in Lakes State of South Sudan. Crensil *et al.* (2019) employed the multidimensional energy poverty index (MEPI) as a measure of energy poverty. Miyamoto (2020), using multinational data analysis of Malaysian and Indonesian household surveys on deforestation, which were conducted between 1990 and 2014, discloses that poverty has a strong impact on forest area change, and agricultural rent speeds up deforestation. The resultant effects of deforestation, which include loss of biodiversity, loss of habitats, and other plant and animal species, are occurring in their daily lives. No one takes note of them to bring such hazards forward for the public to be aware of how these changing social practices are causing natural and human calamities in the environment. This study used a qualitative method to examine the linkages between energy poverty and climate change impacts, as well as identifying the laws and policies that govern the forest and energy resources in the Lakes State of South Sudan.

In Lakes State, there is a significant knowledge gap regarding the linkages between energy poverty and climate change impacts, as well as how to manage and implement off-grid electricity solutions. The lack of capacity to set up solar panels, windmills, and geothermal equipment for clean energy generation is a key issue due to inadequate skills and training. Furthermore, there is a paucity of information on forests and energy resources regulation in Lakes State. This Study is important

because it will help the energy committee and climate change policy-makers in guiding, planning, and conserving the energy resources of Lakes State. It will serve as a policy document to mitigate the ills of deforestation and inappropriate use of biomass fuel energy services in Lakes State. This article aimed to assess the linkages between energy poverty and climate change and to inform the policy of Lakes State in South Sudan. The subsequent section particularises on the literature review, while section three dwells materials and methods.

## LITERATURE REVIEW

### Linkages Between Energy Poverty and Climate Change

According to Churchill *et al.* (2022) define energy poverty is defined as “the inability of small businesses or homes to afford an adequate supply of electricity, heat, and energy services”. The definition has two major categories: First, a very high share of income is spent on energy needs. This category is fitting for developed countries' energy poverty status, while the second category reflects the developing countries' energy poverty status, which means the inability to consume modern energy for various reasons. The definitions of Churchill *et al.* (2022) are in line with the traditional use of biomass energy in rural and urban poor households that increased the emission of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere (Asian Development Bank, 2022; Singh, 2019). This affects the global surface temperatures, leading to the loss of biodiversity, extreme heat waves, and degradation of soil in the environment. Yazdi *et al.* (2024) applied a household survey to assess energy poverty, climate change vulnerability of 335 households using Progress Poverty Index (PPI), Energy Access Index, and Climate Change Vulnerability Index results show agriculture, infrastructure and income as the most significant indicators of energy poverty. The authors also noted that education and awareness were the most effective means of mitigating climate change and reducing energy poverty. This study

using qualitative content and systematic analyses used accessibility and affordability to electricity as variables for measuring energy poverty. Kez *et al.* (2024) stated that climate change impacts caused by energy poverty include health problems, social inclusion, indoor temperatures and psychological stress.

In addition, the increased use of biomass energy for cooking and lighting houses has been linked to a range of health issues for household consumers, especially in the developing regions where biomass fuels such as firewood collection, charcoal, agricultural residue, and animal dung are commonly used (Crentsil *et al.*, 2019; Igeland *et al.*, 2024; Asian Development Bank, 2022; Kez *et al.*, 2024). Energy consumption is a shifting societal practice that disrupts forest ecosystems and contributes to increased emissions of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere (Ladu *et al.*, 2021; Li *et al.*, 2021; Lippert & Sareen, 2023; Moraes *et al.*, 2013). The burning of forests, agricultural residues, household waste, dung, and garbage were the variables for quantifying emissions in Lakes State.

The construction and development of energy infrastructure, along with the growing demand for energy services, are key drivers of forest clearance, significantly worsening deforestation and climate change (Ayik *et al.*, 2020; Tiitmamer *et al.*, 2018; Heffronli *et al.*, 2021). Most of the African countries rely on traditional biomass for cooking and lighting (Acheampong & Opoku, 2023; Adusah-Poku & Takeuchi, 2019; Crentsil *et al.*, 2019; Kaygusuz, 2011). According to a study conducted by Hansgaard (2023) in Malawi found that only eleven percent of the population has access to electricity, and the country continues to face severe energy poverty. In addition, the lack of socioeconomic benefits to the people has contributed to energy poverty. Hansgaard concluded that addressing energy poverty requires a complex collaboration between governments, international donors, and private companies through

the implementation of effective regulations and policies (Hansgaard, 2023).

A study by Nguyen & Le (2024) revealed that the traditional use of biomass has impacted the accessibility, affordability, and availability of energy services to the poor rural population in Africa. The inadequate and insufficient use of traditional biomass energy has led many rural African communities to cut down trees to meet household energy needs. Crentsil *et al.* (2019) show that the use of biomass fuel, through the cutting down of various plant and tree species, has contributed to deforestation and climate change. This shift in social practice has not only led to energy poverty but also worsened the negative effects of climate change on human health as well as animals, plants, and birds (Heffron *et al.*, 2024; Ndunguru, 2024). Energy poverty and climate change are closely interconnected, with the burning of forests and the cutting down of trees for biomass fuel being major contributors to carbon dioxide emissions (Nguyen & Su, 2021).

Drawing from the forest transitioning theory and the other previous studies, this study highlights that energy poverty serves as the gateway to deforestation, which in turn exacerbates climate change. Both of these are the key human-driven factors that contribute to the emission of carbon dioxide and other greenhouse gases (GHGs). Which accumulates in the atmosphere, increasing the surface temperatures and driving climate variability and change (IPCC, 2023; Ali *et al.*, 2014). The links between energy poverty and deforestation are strong, as both are significant anthropogenic drivers of climate change. Other research suggests that improving energy efficiency, promoting energy equity, and protecting forest resources through the introduction of alternative renewable energy sources such as solar and wind, along with the establishment of energy and forest programs in the rural areas, could help reduce deforestation and mitigate the impacts of climate change (Kez *et al.*,

2024; Ali *et al.*, 2014; Azam *et al.*, 2023; Iyke, 2024; Cerda *et al.*, 2020).

However, improving the socio-economic activities and lives of the rural population would encourage the restoration of ecosystems in the environment. Therefore, there is a close linkage between energy poverty and climate change, as well as deforestation, based on understanding the causes and effects of deforestation. Energy poverty is linked with climate change due to its impacts on health, socio-economic, ecosystem, and environmental impacts (Miyamoto, 2020; Churchill *et al.*, 2022). Hence, using a qualitative method, this study examined the linkages between energy poverty and climate change, as well as identifying laws and policies governing forest resources in the Lakes State of South Sudan.

### Traditional Biomass Energy Use

Deforestation and energy poverty are linked through the use of traditional biomass energy. The world is experiencing significant effects from the use of traditional biomass fuels, such as charcoal, firewood, and agricultural residue collection. These fuels are widely used in both rural and urban households for cooking, lighting, heating, and other energy services (Ayik *et al.*, 2020; Guliyev, 2024). However, the use of traditional biomass fuel has both advantages and disadvantages. The advantages include lighting households, cooking, and providing energy for industrial purposes, as well as economic benefits (Ahmed *et al.*, 2019). On the other hand, the disadvantages include emission of carbon dioxide (CO<sub>2</sub>) and other greenhouse gases (GHGs), which contribute to global warming and raise temperatures on the earth (Ayik *et al.*, 2020). Additionally, the heavy reliance on traditional biomass fuel in sub-Saharan Africa has exacerbated energy shortage and has led to deforestation as forest resources are cleared to meet the demand for firewood, charcoal, and fossil fuel exploitation.

The diminishing forest cover increases the concentration of carbon dioxide in the atmosphere

through the shrinking of forest areas, which act as carbon sinks and sequestration, thereby exacerbating climate change (Miyamoto, 2020). Energy poverty and deforestation are linked to climate change through emissions of carbon dioxide and other greenhouse gases (GHGs) into the atmosphere. Charcoal production contributes to the loss of biodiversity and tree species, leading to soil erosion in the environment (Bodo *et al.*, 2021). The use of traditional biomass fuel increases the release of carbon dioxide emissions into the atmosphere. Further, the burning of agricultural residues and forest remains is linked to the release of GHGs and contributes to global warming.

### Modern Energy Sources

Although several alternative energy sources, such as hydroelectric power, solar, wind, and geothermal energy, exist to transition away from traditional biomass fuel, these sources are environmentally reliable, efficient, affordable, and renewable (Ayik *et al.*, 2020; Iyke, 2024; Whiting *et al.*, 2015). However, many developing countries in the Global South continue to depend on traditional biomass energy economies for development due to a lack of skills and knowledge in exploiting and setting up modern renewable energy resources (Wilberforce *et al.*, 2023). South Sudan, for example, receives sunshine for eight hours per day, which could support solar energy services, but due to a lack of skills and knowledge has made it difficult for the local population in Lakes State, South Sudan to embark on traditional biomass fuel energy, which contributes to deforestation and energy poverty (Whiting *et al.*, 2015; Ayik *et al.*, 2020; Ladu *et al.*, 2021). The local population is suffering from the resulting effects of climate change and loss of biodiversity. The availability of renewable energy could significantly contribute to socio-economic, water resources, and infrastructure development in the country's development strategies. But there is a weak implementation of laws and funding of climate change and energy programs (IOM DTM, 2020).

The increasing floods and droughts have contributed to loss of lives, damage to property, health risks, and food insecurity that increase hunger and poverty issues among the rural population in Lakes State of South Sudan (Ladu *et al.*, 2021; Bilali *et al.*, 2021; IPCC, 2014). Lakes State is endowed with many rivers and Lakes that can support its hydroelectric power provision, but insufficient funds and inadequate skills have increased the use of firewood, charcoal, and agricultural residues to be used in the households for cooking and lighting. These traditional biomass fuels increase the health risks and manual labour of local women and girls in the country, as a lot of time is spent in search of firewood and charcoal for cooking.

The availability of sufficient land to support wind energy and geothermal energy services in the State is crucial for this study, to inform the policy makers and other stakeholders on the potential of these renewable energy sources, which could significantly contribute to both the sustainable development of the State and the country's economy (Ayik *et al.*, 2020; Bilali *et al.*, 2021; Ladu *et al.*, 2021). Allocation of Funds and establishment of modern renewable resource facilities would help to improve the economies and standards of living of the local population, especially in the States (IOM DTM, 2020). Understanding the interlinkages between deforestation, climate change, and energy poverty can enable various stakeholders to transition to renewable energy resources in South Sudan.

## **National Policies and Laws on Energy Resources**

### ***National Land Acts of 2009 and 2012***

The South Sudan National Land Policy (NLP) is a vital framework developed to address land-related challenges, promote equitable access, and foster peace and sustainable development across ten states and three administrative areas. Its development has been a long process, finally gaining approval from the Council of Ministers in October 2023, and is

currently awaiting parliamentary approval. A significant focus of the policy is on strengthening women's land rights, ensuring their equal access to ownership and inheritance. The South Sudan National Land Act of 2009 and 2012 provides the regulations for land tenure and details more on how the community protects the rights of land, forest, and energy use in South Sudan. It classifies land as public, community, or private land and provides for the regulation of rights in land (IOM DTM, 2020; Lok, 2013).

The Act pays attention to customary land rights where the local community should manage and use the land, including the forest resources, and others, for the provision and regulation of land use (Lok, 2013). Its implementation is seen as crucial for building climate and energy resilience as well as encouraging long-term socio-economic and infrastructure investments. These regulations and provisions are not well represented and implemented in the protection and management of forest resources, hence leading to the diminishing of forest resources and allowing deforestation to occur, and later on bring more negative effects to community livelihoods, ecology, and exacerbate the extreme weather and events through heat and floods.

### ***National Energy Policy (NEP) of 2015***

The national Energy Policy includes the energy infrastructure such as oil, gas, coal, and petroleum and electricity as well as transportation sectors. These sectors are experiencing the indirect and direct challenges of energy use and distribution, accessibility, and establishment of the energy infrastructure and energy services on the environment, with the animals, birds, plants, water, and human beings at greater risk (IOM DTM, 2020; MoEF, 2022). Despite the grants and donations, as well as plans for energy and agriculture, most people from South Sudan, especially Lakes State, continue to experience severe energy poverty and water shortage and food insecurity. The instability



of these energies and food security are further compounded by climatic shocks, such as floods and droughts in the region. As of 2015, only about 1% of the South Sudan population had access to electricity, with most relying on traditional biomass for cooking, lighting and heating (Whiting, 2015; IOM DTM, 2020).

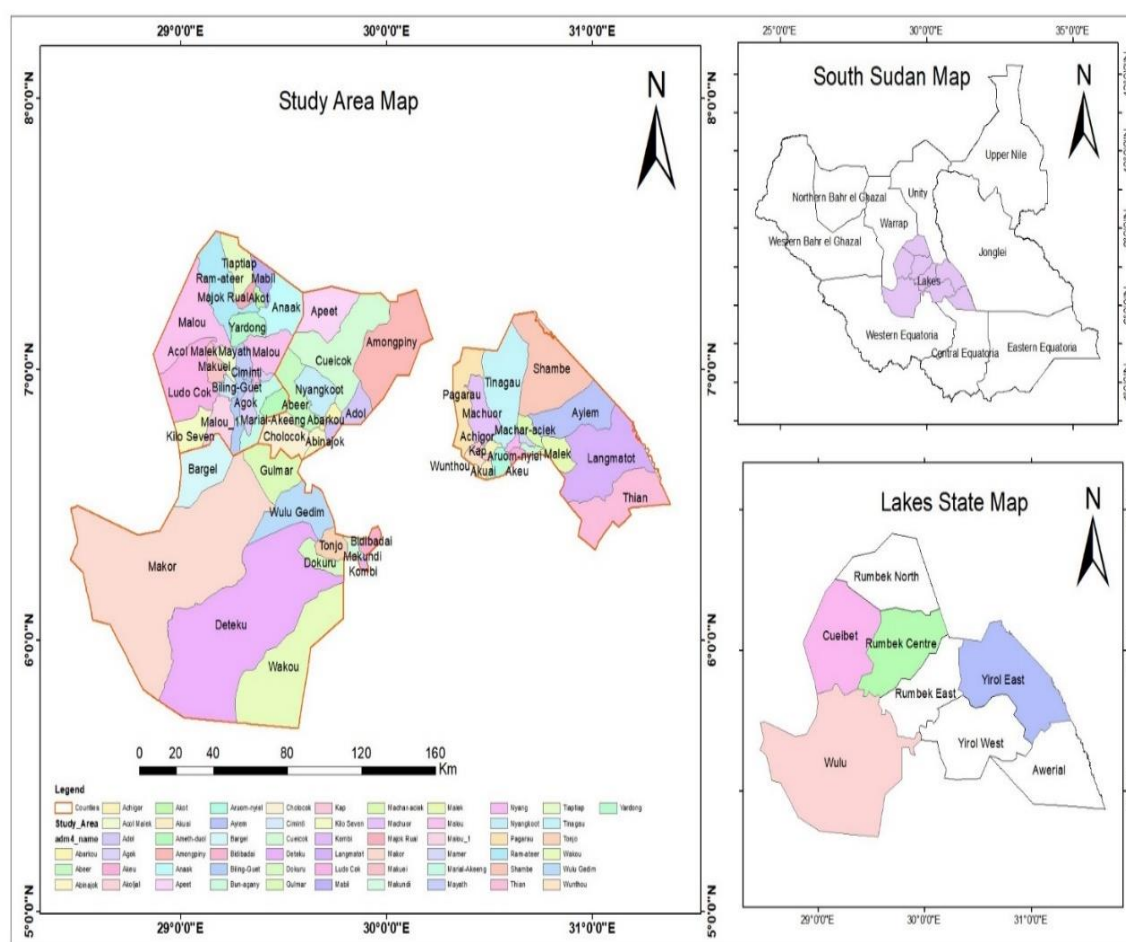
## METHODOLOGY

### Study Area

The study area falls in the coordinates of 29° E – 31° E and 06° and 46° N, and its position falls in the central part of South Sudan. Lakes State, which is one of the ten states of South Sudan, falls in the

central part of the country and is bordered by Western Equatoria to the West, Unity State to the East, Warrap State to the North, Central Equatoria to the South, and Western Bhar El Ghazel to the North-West (Figure 1). Lakes State's total land area is 43,595.08 km<sup>2</sup> and it is confined to eight (8) counties, namely: Yirol East, Yirol West, Awerial, Rumbek East, Rumbek Center, Wulu, and Chueibet Counties, with an estimated population of 695,895 persons, of which 365,869 are males and 347, 786 are females (Lok, 2013; UNDP, 2012). These areas are proportionally selected for their importance of linkages between energy poverty and climate change in Lakes State.

**Figure 1: Shows the Location of Lakes State on the Map of South Sudan**



Source: Author, 2024

## Biophysical Setting

The biophysical setting of Lakes State includes: moderate climate, shrubs and herbaceous woodland vegetation, fertile soil which supports agriculture. The human population is majorly dominating the natural resources depletion and misuse of forest land (FAO, 2022). The population of Lakes State is estimated to be 695,730 in the eight counties of Lakes State (UNDP, 2012; Lok, 2013). This population is composed of Dinka, the majority, and Beli (Jur-Bel), the minority ethnic group, as well as the Atuat ethnic minority in the State. Both the Dinka and Atuat are agropastoralists, as the Beli tribe keep some cattle, bee hives, arable cropping, hunting, and gather some wild fruits as main sources of economic ways of life. The Dinka and Atuat rear large numbers of cattle and grow several crops, including dura ketch, cassava, ground nuts, simsim, makuein-arol, and maize, among other crops (FAO, 2022). These socio-economic activities are sensitive to climate change impacts in the state. Lakes State has several Lakes, rivers, streams and ponds that provide fish and water for the population of Lakes State during the drier months.

## Climate

Lakes State is located at an elevation of 389 meters above sea level with yearly temperatures that rise to 36.3 degrees Celsius. Lakes State has a subtropical steppe climate with minimum and maximum rainfall of 900- 1200 millilitres. This is because it falls in the region of Sub-tropical region. The region has a variety of wetlands with a lot of Lakes, Rivers, Streams, Ponds, and aquifers, making it a beautiful place for biodiversity (MoEF, 2018). This influences the wind speed and direction systems during the drier and wet months. January is the driest month, and August is the wettest month. This climate supports the existence of many trees and long grasses that moderate the weather and climate in the region (Strandberg & Kjellström, 2019). These forests provide direct and indirect benefits to the people of Lakes State in the form of income and living standards through fruit and vegetable selling,

as well as for wood fuel energy and construction activities (MoEF, 2018).

## Vegetation

According to FAO (2011) Land Cover Mapping, Lakes State occupied the fourth position of greatest wetland vegetation land cover which is 10 455.1 square kilometer making it to be fourth largest in Wetland Vegetation Land Cover after Jonglei which is 35, 383.1 km<sup>2</sup>, Western Bar el Ghazel with 14,481.5 km<sup>2</sup>, Upper Nile with 14,419.3km<sup>2</sup> and Unity with 12,160.8km<sup>2</sup> respectively. Lakes State vegetation is characterised by herbaceous vegetation with some mahogany, teaks, and shrub trees in the State. It also experiences savannah woodland and long elephant grassland that quickly dries up during drier seasons and causes animal and human being mosquitoes during the rainy seasons (FAO, 2011). This State is susceptible to climate change hazards such as droughts and wildfire outbreaks during the drier seasons, especially when the pastoralists and hunters set fire to the forest for easy regeneration of pasture for their cattle, and allow visibility of animals to hunters as well as honey harvesters use fire to harvest the honey, to set fire to forest species. These burning of bush with fires and other anthropogenic causes on the environment interrupted the forest ecosystem and the microclimate system, and the albedo of the state socio-economic activities in Lakes State (Ndebele & Zenda, 2023).

## Land Uses and Resources

Lakes State land covers mainly consist of shrubs 38.5%, trees 35.5%, herbaceous vegetation 20.9%, and agricultural land 42% (Rhoades *et al.*, 2011; FAO, 2011). Beekeeping is mainly practised in Wulu, Yirol West, and Rumbek East counties, as well as in other counties of Lakes State. This increases the chances of honey harvesters setting fires on forest resources during the drier seasons in the State (Lok, 2013). The charcoal burners also leave some fire in the forest. When the strong wind comes, it blows the fire and sets it on forest areas

this killing the living organisms and subjecting the land to weathering and erosion activities (MoEF, 2019). The rising concerns to understand the impacts of climate change on the environment and livelihoods across the Lakes State have led to this study.

### ***Biophysical Vulnerability***

The economy of the Lakes State is vulnerable to natural and anthropogenic causes of hazards due to its sensitivity to climate change and variability, which includes floods and droughts. Agriculture itself is susceptible to weather and climate change and variability. Bee farming and forest resources are vulnerable to fire outbreaks and droughts during the drier months. The large grassland covers, which are sensitive to weather and climate change and variability, have made the biophysical setting of Lakes State vulnerable (FAO, 2022; UNEP, 2020; UNDP, 2012).

### ***Socio-Economic Setting***

#### ***Social Setting***

Lakes State's huge population depends on agro-pastoral activities (Lok, 2013). The Dinka community, who are the majority, keep a large number of cattle as a source of income and pride. The Beli (Jur-Bel) do keep some cattle but largely depend on crop farming and host several beehives as sources of income and living. The population of Lakes State practices different activities of agro-pastoral, fishing, beekeeping, and some hunting activities in the forest lands (UNDP, 2012; Lok, 2013).

#### ***Economic Setting***

The population of Lakes State is engaged in mixed agro-pastoral activities, fishing, and bee farming activities support the lives of the Lakes State population (Lok, 2013). The State also suffers inefficient energy use due to the changing social practices of heavy production of charcoal, firewood collection, and burning of agricultural residues.

Several rivers, such as the White Nile, and lakes, such as Lake. Yirol, Lake. Nyibior, Lake. Shambe are good for fishing grounds as well, and many ponds and streams are good places for grazing cattle and goats.

### ***Socio-Economic Vulnerabilities***

Lakes State's population is susceptible to natural hazards such as floods and droughts, but climate change is exacerbating their intensity, frequency, and duration (IPCC, 2023; Tiitmamer, 2018). Multiple socioeconomic stressors, such as the ongoing poverty, economic and famine, create a state of extreme vulnerability of the State's young population to the impacts of these natural hazards. The population of Lakes State depends on seasonal rains to support their livelihoods, and the environment (UNDP, 2012). The severe disruption of rainfall patterns and frequent droughts, combined with other health problems, increase the vulnerability of the huge population of the eight counties of Lakes State to climate change impacts. The State government lacks awareness strategies and communication services, leading women, children, and the elderly to suffer during the occurrence (Adkins, 2015).

### ***Political and Administrative Context***

Lakes State is subdivided into eight counties, namely Rumbek East, Rumbek Center, Yirol East, Yirol West, Awerial, Wulu, and Chueibet Counties respectively. Each county is subdivided into several Payams, and each Payam is subdivided into Bomas, and each Boma is subdivided into a number of Villages (UNDP, 2012). Lakes State's population is estimated to be 695,595 based on the 2008 population census for the South Sudan Center for Census Statistics and Evaluation (Lok, 2013). Boma is the lower administrative unit. Lakes State is governed by the State Governor, Deputy Governor, State Ministers, State Legislature, State Judiciary, and Local Government, where County Commissioners, Payam administrators, Boma

administrators, Chiefs, and Sub-chiefs fall under its State local government.

### **National/Regional/Local Economic Setting**

South Sudan gained its independence on 9<sup>th</sup> July 2011 from Sudan after having fought several decades of wars within the Khartoum military government. South Sudan started to base its economy on oil, minerals, and some subsistence rain-fed agriculture, which are impacted badly by the dollar rates in the international market. Hence, leaving the country to a poor economy that does not sustain its population (Tiitmamer, 2018; World Bank, 2015). The newly independent country has ten states and three administrative areas. It fell into an economic crisis due to the political instability that the country has led to subsequent civil wars in 2013 and 2016. All these wars have created negative effects on the country's economy, making it unable to sustain its national and state economies in the world (World Bank, 2013). Lakes State, which is one of the ten states of South Sudan, has one time suffered from political, economic, and social insecurities for years. Lakes State's economy is based on a mixed agro-pastoral economy, which uses the forest land cover as one way of generating income for the state's local government and the people. Food products from cattle and goats, as well as charcoal making and timber production, all add value to its state's economy. Fishing and Honey harvesting are part of the state's sources of income and revenue generation for the State (Lok, 2013). These changing social practices leave the environment to suffer from deforestation and climate change effects, as well as alleviating the energy poverty issues for the population living in Lakes State.

### **Health Setting**

The changes in rainfall and temperature are having direct and indirect effects on human health, particularly the Dinka, Atuot, and Beli (Jur Bel) communities living in Lakes State experienced the floods and drought events throughout the year.

These communities of Lakes State have limited access to clean and safe energy, clean drinking water, sanitation, and health services (Adkins, 2016). The use of traditional biomass which alleviates the households' diseases and the rising water volume from the rivers, lakes and streams of Lakes State which are the inhabited places of mosquitoes and other reptiles have increased the incidents of water borne diseases such as Malaria and air borne diseases such as tuberculosis (T.B.) (UN-OCHA, 2022; Whittings, 2015; USAID, 2019). Extreme heat waves, flooding, and droughts cause numerous negative health effects in human and animal bodies. Health is crucial for both human beings and animals, as well as plants and birds. Hence, this study aims at understanding how energy poverty, deforestation, and climate change contributed to the increase of household diseases through assessing the linkages between energy poverty and climate change impacts in Lakes State of South Sudan.

### **Research Design**

The study used a cross-sectional research design in which four (4) counties of Lakes State were proportionately sampled. The selection of participants was based on easy accessibility to the Office of State Government, the presence of partners, academicians, and other key informants on the ground, which allowed the collection of rich data. Lakes State was chosen as an outlier from the ten States of South Sudan because of its relative peace among the communities. This study employed a qualitative approach whereby eighty semi-structured questionnaires were administered and key informant interviews were conducted (Oranga & Matere, 2023). Additionally, observational notes taking and field visits were carried out across the four selected counties in Lakes State. The criteria of selecting participants were purposively based on locations adjacent to forest areas and markets of forest products. Participants aged 20 years and above were purposively selected. Level of education was



considered as one of the criteria of choosing participants, because of their knowledge base about energy poverty and climate change. The participants who obtained senior four and above were also considered to be well informed about the knowledge of energy poverty and climate change.

In this study, a cross-sectional study design was selected based on the rationale that the data collected would contain information from about people's views, opinions, and attitudes on the linkages between energy poverty and climate change in Lakes State of South Sudan. The State also suffers from inefficient energy use due to the changing social practices of heavy charcoal production, firewood collection, and burning of bushes and agricultural residues. The logging, forest burning, and charcoal production activities in these areas were observed to be dominant in Lakes State. This study aims to quantify the emissions through the bush, garbage, agricultural residues, and dung burning as indicators for measuring emissions and deforestation in the areas selected for study. Indicators such as accessibility and affordability of electricity to households were used to measure energy poverty.

### Target Population

The population of Lakes State in the four selected counties was 358,597; these include Wulu with a population of 40,550 people, Rumbek Center with 157,882, Chueibet with a total population of 117,755 people, and Yirol East with a population of

67,410 people, respectively (UNDP, 2012). The target population was traders, academicians, NGOs, and local government energy heads. The selection of four counties was strategic in that Lakes State shares both the urban and rural areas. The study sites in Lakes State were delimited to Wulu County, with fifteen participants interviewed; Yirol East, fifteen participants interviewed; Chuei-bet, fifteen participants were interviewed; and Rumbek Central County, with thirty-five participants interviewed respectively.

### Sampling Technique and Sample Size

The study applied a proportionate sampling technique to ensure fair and accurate representation in the sample size selected from the four target counties in Lakes State. The participants from the four counties were purposely selected for their understanding of forest cover and land use in the Lakes State of South Sudan. This study's selection of purposive sampling reaffirms Etikan (2016), who applied purposive sampling to select some small participants from the target population. Hence, the sample size for this study comprised fifteen (15) local farmers, fifteen (15) traders, fifteen (15) forest and energy department heads, two (2) State Ministers, ten (10) nongovernmental organisations NGOs officials, and eighteen academicians (Table 1). This qualitative research study design was selected because it allowed the researcher to capture people's views, attitudes, and opinions about the linkages between energy poverty and climate change impacts in Lakes State from key informants.

**Table 1: Shows the Sample Size in the Four Selected Counties of Lakes State**

Counties	Target Population	Surveyed and Key Informant Interviews	Response Rate	Percentage of Response Rate
Wulu	Farmers	2	2	
	Traders	3	3	
	Academicians	5	4	
	NGOs	2	2	
	Forest and Energy Department Heads	3	3	

Counties	Target Population	Surveyed and Key Informant Interviews	Response Rate	Percentage of Response Rate
				17.5%
<b>Chuei-bet</b>	Farmers	2	2	
	Traders	3	3	
	Academicians	5	4	
	NGOs	2	2	
	Forest and Energy Department Heads	3	3	
				17.5%
<b>Yirol East</b>	Farmers	2	2	
	Traders	3	3	
	Academicians	5	5	
	NGOs	2	2	
	Forest and Energy Department Heads	3		
			3	19%
<b>Rumbek Central</b>	Farmers	5	3	
	Traders	8	8	
	Academicians	10	10	
	NGOs	2	1	
	Forest and Energy Department Heads	8	8	
	Ministers (MoEF and Trade & Industry in Lakes State)	2	2	
				40%
<b>Total</b>		<b>80</b>	<b>75</b>	<b>94%</b>
<b>Total percentage</b>		<b>6%</b>	<b>94%</b>	<b>100%</b>

Source: Author, 2024

Yamane (1967) provides a simplified formula for the calculation of Sample Size (Creswell *et al.*, 2007; Mack & Woodsong, 2005). Using Yamane's formula (1967) for the Sample Size of  $n = \frac{N}{1+Ne^2}$  : Where n = sample size, N= total population of four selected counties was 358,597 and e = the confidence interval or margin of error, where a 90% confidence error was selected for this qualitative

case study design, and the calculation of 90% resulted in 0.1%. The result of this formula,  $n = \frac{358597}{1+358597*(0.1)} = 99.9\%$  arrived at the selection of 80 key informant interviews (KII) from the target Population in Lakes State. The margin of 5%-20% which was used to add or subtract the actual

population, was used to reduce 100 participants to 80 participants in this study.

### **Data Collection Methods and Sampling Procedures**

This study employed qualitative methods to collect both primary and secondary data. For primary data collection, the study utilised qualitative tools and techniques, including questionnaires, key informant interviews, direct observation, and field note-taking. For secondary data collection, content analysis was applied to review various sources, including reference books, journal articles, and Google Scholar searches. These sources provided insights into the linkages between energy poverty and climate change impacts. Additionally, key policy documents such as the South Sudan Land Act (2009) and the Energy Policy Acts (2015) were analysed to understand the legal and institutional frameworks governing energy infrastructure and management in Lakes State. By using these methods concurrently, the study effectively captured diverse views and opinions, ensuring a comprehensive approach to addressing its research objective.

### **Data Analysis and Synthesis**

Data analysis and presentation were processed and analysed using content analysis in MS Excel and presented in the form of charts and graphs for easy interpretation and presentation. All the variables were coded in MS Excel software using a contents analysis, this include coding and use of key words from answered semi-structured questionnaires, observations and field notes taken from consultative key informant interviews with forest directors, counties local government officials, students and teachers at the Rumbek University of Science and Technology (RUST), and NGOs were consulted on energy and climate change programs they funded to assess the perceptions and knowledge of linkages between energy poverty and climate change impacts in Lakes State. Secondary sources talking about the laws, policies, and regulations used by the energy resources and climate change authorities in

regulating and managing the energy services in the Lakes state of South Sudan were surveyed.

The data collection through interviews, secondary documentary analysis, and observations were subjected to draw codes that was going through the answered questionnaires and noted down vital key words and sentences, themes were included through taking major categories of main ideas related to the topic and data obtained were analyzed using content analysis and the results were placed in graphs, and charts in MS Excel software for easy interpretations and analysis while structural thematic analysis was involved in breaking down the data and interpreting them in terms of narrative and explanatory techniques. Data Analysis was made based on the interpretations of graphs, and charts.

### **Ethical Aspects**

According to Banjwa (2016), any research considered ethical issues as a moral activity. Ethical issues were taken into consideration from the entry to the exit from the research sites. This involved obtaining an introductory letter from the University of Nairobi (UoN), applying and securing a research permit from National Commission for Science, Technology and Innovation (NACOSTI) House and the researcher was using these documents to the relevant authorities in Lakes State including Local Government in Counties and Payams to ensure participants could take part in the study freely without any reservations. In the work done by Mugenda & Mugenda (2019), informed consent is the process in which a researcher seeks permission from the participants to voluntarily make the decision to answer the questions provided. The decision to participate in the study was voluntary, and each participant made an independent decision to take part without any coercion. To ensure confidentiality and privacy, the researcher protected the participants' identities during the data coding and entry.

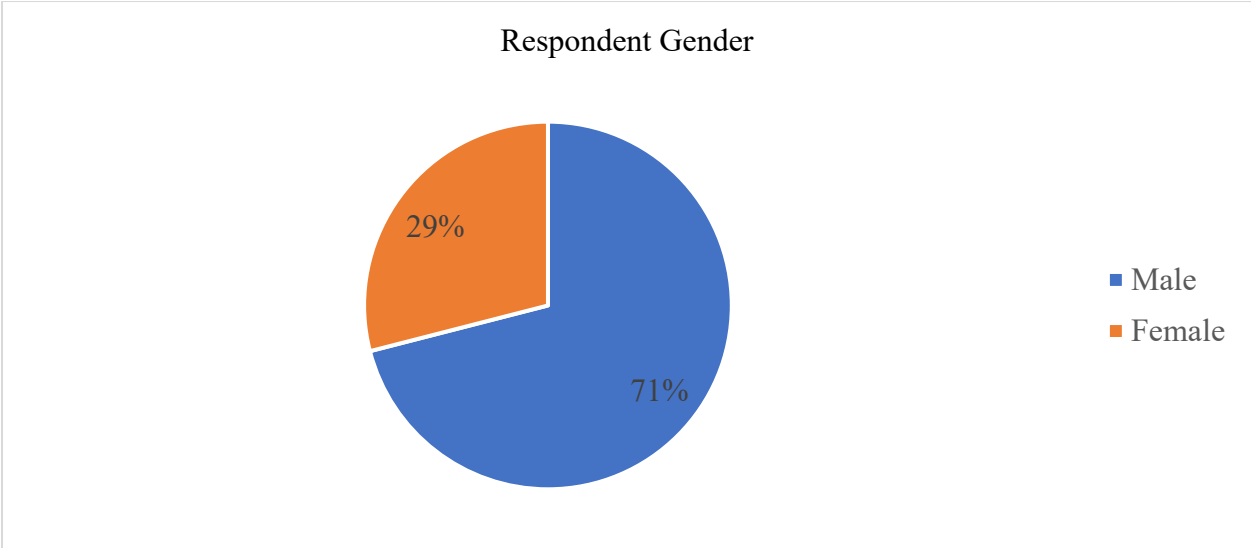
RESULTS

Demographic Information of the Respondents

The general information about the respondents was shared based on gender, age, level of education,

department or section of the respondent, and the period of respondents' stays in the Lakes State of South Sudan. In this study, the dominant gender of the respondents interviewed was male at 71% while women were 29% (Figure 2).

Figure 2: Shows the Gender of Respondents

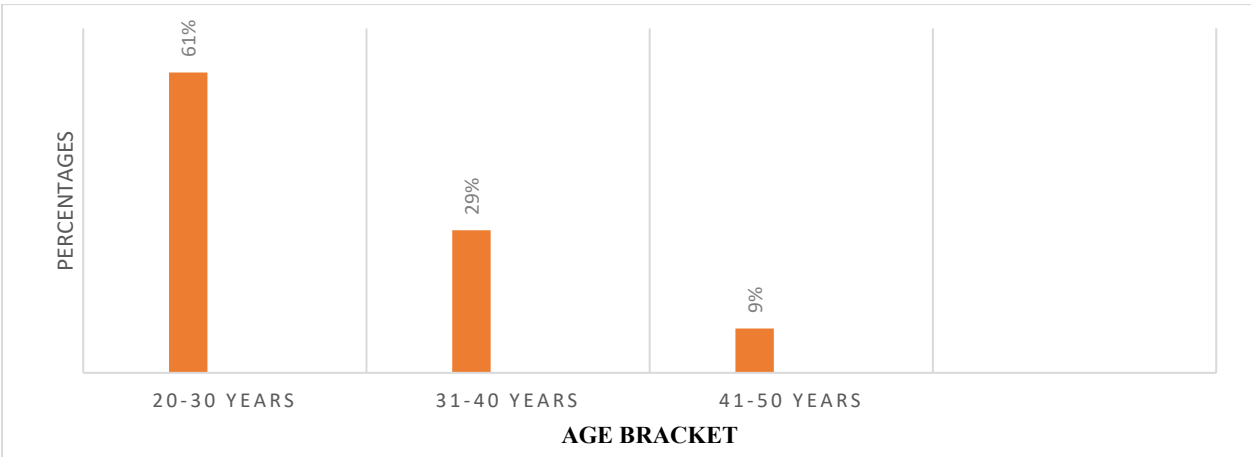


Source: Author, 2024

The study established that the majority of the respondents (61%) were aged between 20 to 30 years, (29%) were aged 31 to 40 years, while a small

portion of the respondents (9%) were aged between 41 – 50 years (Figure 4.2).

Figure 3: Shows the Age of Respondents'

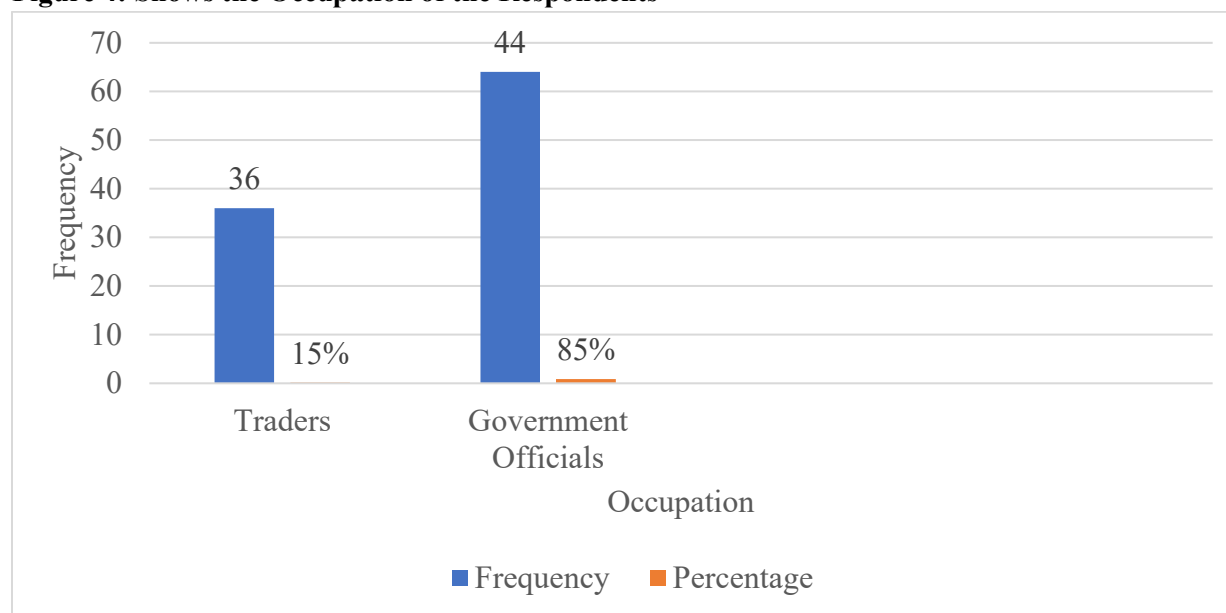


Source: Author, 2024

The study established that the majority of the respondents interviewed were working for the

government in the urban areas (85%) while only 15% were working in the rural areas.



**Figure 4: Shows the Occupation of the Respondents**

**Source:** Author, 2024

Regarding educational levels, the majority of the respondents interviewed had attained a Master's Degree (30%), followed by diploma holders (25%) and doctoral degree (21%). The respondent who had attained a secondary level of education accounted for (12%) while those with primary education or a Bachelor's Degree made up 9% and others with 3%. With respect to marital status, the majority of the respondents (83%) were married, while (17%) were unmarried. In this study, the marital status was considered significant, as it relates to family sizes, energy needs, and economic dependence on forest resources. Hence, this means that married men and women participated more in the research study than the unmarried ones. The larger percentage of married people who participated indicates that knowledge about how energy poverty contributes to deforestation was well perceived by the participants.

The study examined the duration of the respondents' residences in Lakes State and found that 60% had lived there for 6 – 10 years, while 40% had resided in Lakes State for 1 – 5 years. This enquiry was important as the lengths of stay reflect the respondents' experience and involvement in

activities related to energy use, deforestation, and environmental management in Lakes State. In this study, the Stay duration of the respondents was investigated because it presents the duration of the respondents' stay and how he/she been carrying out these activities in Lakes State.

### **Linkages between Energy Poverty and Climate Change in Lakes State**

Based on the respondents' responses on the linkages between energy poverty and climate change, the majority of respondents in Lakes State stated that energy poverty is closely linked to climate change through the burning of forests, cow dung, and garbage. The burning of the forests and garbage releases carbon dioxide and other GHG emissions into the atmosphere, causing global warming. The burning of cow dung and other animals' dung releases methane, which is a dangerous gas that contributes to lung diseases and eye infections in the households of the poor rural population. The respondents also stated that shifting agricultural land uses and heavy reliance on firewood collection and charcoal production as primary sources of energy are also among the biggest contributors to GHG emissions and deforestation in Lakes State of

South Sudan. The trees are cut down in large numbers for the seek to create a space for both commercial logging and subsistence agriculture. This encouraged deforestation and climate change to occur.

In Lakes State, the respondents reported that municipal water waste treatment facilities within the town and city toilets contribute to auxiliary emissions of other GHGs. The fugitive emissions, which are unintended and often undetected leaks of vapours, liquids, and gases from pipelines, factories, and other component processes of pumping latrines, compressors, and piping flanges, harm and contribute to negative impacts on the air we breathe. The burning of forests, agricultural residues, and animal dung contributes to combustion emissions, which serve as the primary source of carbon dioxide and other GHGs emissions to the atmosphere. The respondents also added cooling and warming towers, and houses primarily release emissions when gases are stripped as water comes into contact with air during the cooling and warming process. These drifts of water droplets carried by airflow contain pollutants, including chemicals used for water treatment, contributing to air pollution in households.

A director for agriculture and forestry management, aged 40 years, who is a Bachelor's degree holder, stated, "forests are shrinking gradually just because the communities are looking for spaces to cultivate their crops and keep their animals. This leaves the land dry and causes desertification, encouraging climate change to occur. For example, the drought used to occur throughout the years in this area of Wulu County because trees are cut down and grasses dried up easily due to the sunshine heating them, as well as anthropogenic activities of burning forests for the regeneration of greener pasture, settlement, and agricultural lands.

### **Laws and Policies on Forests and Energy Poverty Control in Lakes State**

This study sought to establish the influence of laws and policies establishment for energy poverty control. A respondent aged 41-50 years and a PhD holder stated that, "*We have the Energy Policy of 2015 and Land Act 2009, which outline energy provision and land conservation measures. However, due to economic challenges and people's reluctance to take up responsibilities, law enforcement agencies have been discouraged from implementing policies such as the requirement to plant ten trees for every tree cut down one tree.*"

Energy resources management policies are only partially effective due to limited enforcement, poor infrastructure, and a lack of investment in energy projects. Challenges faced when implementing energy policies include a lack of funding, poor infrastructure, and limited technical capacity. The respondents indicated that there are various strategies for engaging the communities to stop deforestation, such as replanting tree initiatives, using alternative renewable energy sources, and participating in community awareness campaigns on sustainable forest use. Concerning alternative energy solutions, the respondents indicated that; use of improved cook stoves, which are energy efficient, and using biofuel such as briquettes are effective solutions to reduce indoor air pollution. In addition, the expanding access to these energy technologies can help to reduce the reliance on traditional biomass energy.

### **DISCUSSION**

The discussion covers the questions asked based on the assessment of the linkages between energy poverty and climate change in Lakes State of South Sudan. Energy poverty is linked to climate change in several ways. Biomass is one of the renewable energy sources through the growth of plants, but it increases greenhouse gases (GHGs) when burned for cooking, lighting, and heating. This release of carbon dioxide through the burning process

increases global warming on the Earth's surface. Respondents put forth that poor communities are often more vulnerable to climate change impacts due to their limited adaptive capacity and reliance on climate-sensitive resources such as agriculture, forests, and water.

Furthermore, the study indicated that the main source of energy for lighting in Lakes State is: Solar lamps, torches, and candles, as they provide an affordable and renewable lighting source to the local rural population. In areas where solar power is unavailable, candles or kerosene lamps are often used. The study also indicated the Energy Policy of 2015 and the Land Act 2009 as the laws and policies that outline energy and land conservation measures. However, due to economic challenges and people's reluctance to take up responsibilities, law enforcement agencies have been discouraged from implementing policies such as the requirement to plant ten trees for every tree cut down one tree." Energy resources management policies are only partially effective due to limited enforcement, poor infrastructure, and a lack of investment in energy projects.

### **Linkages between Energy Poverty and Climate Change in Lakes State**

Energy poverty is linked to climate change in several ways. Biomass, a renewable energy source derived from plant growth, contributes to greenhouse gas (GHG) emissions when burned for cooking, lighting, and heating. According to the participants, they stated that bushes, grasses, agricultural residues, dung, and garbage burning were the sources for carbon dioxide and other GHGs emissions in the Lakes State of South Sudan. The release of carbon dioxide during this process increases global warming. This finding aligns with Butt *et al.* (2023), who demonstrated the role of tropical deforestation in the regional climate change of the Amazon. Respondents indicated that poor communities are particularly vulnerable to climate change due to limited adaptive capacity and reliance on climate-sensitive resources such as agriculture,

forests, and water, which are increasingly affected by droughts and floods.

However, this study stated that energy poverty is closely linked to climate change through the burning of forests, animal dung, and garbage. The burning of the forests and garbage releases carbon dioxide and other GHG emissions, leading to global warming. The burning of cow dung and other animals' dung releases methane, which is a dangerous gas that contributes to lung diseases and eye infections in the households of the poor rural population. The respondents also stated that shifting agricultural land uses and heavy reliance on firewood collection and charcoal production as primary sources of energy are also among the biggest contributors to GHG emissions in the Lakes State of South Sudan. The trees are cut down in large numbers for the seek to create a space for subsistence agriculture, which encourages deforestation and climate change to occur.

Therefore, the results reaffirm Churchill *et al.* (2022), who used household data panel in Australia to investigate the temperature shocks on the propensity to be energy poverty to predict the effect of global warming on the incidence of energy poverty over the rest of the century. The authors' findings revealed that cold days increase energy poverty by 0.01% - 0.03% while hot days had a comfortable temperature range between 20-24<sup>0</sup> c. The insufficiency of energy affordability, accessibility, and the high cost of energy to the rural population of Lakes State has led them to rely on forest depletion. In addition, Belaïd (2023) in Egypt investigates the impacts of income poverty and house costs on fuel poverty. The authors' findings revealed that high energy prices can cause considerable risks to low-income populations and climate change policy.

Lakes State has had thick forests in the areas of Wulu, Chuei-bet, Yirol East and some parts of Rumbek Central Counties, but these forests are seriously shrinking in size and length because of urban settlement and both subsistent and

commercial agricultural expansions towards the forest zones have reduced the forest sizes and growth. The participants stated Rumbek Central County was one of the counties that had been deforested a long time ago, mostly from century. The burning of garbage, dung, and bush burning were stated as the variables used for the measurement of carbon emissions. In the study area, almost 90% of Lakes State rely on charcoal production and firewood collection as the primary sources for energy services.

### **Laws and Policies on Energy Poverty Control in Lakes State**

South Sudan's forest policies focus on conservation, sustainable management, and combating illegal logging. Most of the South Sudan policies are in draft, lacking proper clarity for law enforcement agencies to do implementation on how to punish the perpetrators. Therefore, this result agrees with Adkins (2015), who found that the lack of clarity in the legal and regulatory frameworks for forest conservation contributes to deforestation. The authors noted that better adaptation and mitigation strategies and implementation of forest laws and policies can reduce the negative effects of deforestation and climate change impacts. Conversely, Ndebele & Zenda (2023) showed that soil and water conservation, as well as water harvesting, are the best adaptive practices to combat the climate change impacts in Lakes State. In addition to that, Iyke (2024) demonstrated that climate change enhances energy poverty security risks. The authors noted that investment in clean energy can reduce the negative impacts of climate change on energy security. Miyamoto (2020) put forth that effective laws and policies can reduce deforestation and climate change impacts on the environment.

The legal framework for energy resource management in Lakes State is underdeveloped. The existing policies are aimed at promoting renewable energy but suffer from poor implementation and limited scope. The results agree with the findings of

Dissani (2021), who concluded that energy use, the State must favour energies based on alternative energy more than fossil and biomass fuel energies, which are more polluting energies. The authors noted that these polluting energies can be reduced through the establishment of clear energy frameworks.

The existing legal frameworks for energy in South Sudan include: the South Sudan Land Act of 2011, the National Forest Policy of 2015-2025, the South Sudan National Environment Policy of 2015, the Water Resources Policy of 2012 and 2016, and the National Energy Policy of 2015. Effectiveness of Laws and Policies on Forest Resources Management: These laws are not highly effective due to a lack of enforcement capacity, corruption, and limited resources for monitoring and management. The results agree with Ahmed & Aliyu (2019), who revealed that policy formulation through proper legislation prohibiting the general public from indiscriminate tree felling and bush burning can reduce deforestation and climate change. Acheampong (2023) found that weak governance and institutional policy led to deforestation and energy poverty. However, Ayik's (2020) findings show that the alternative use of modern energy services is appropriate to meet the Sustainable Development Goal seven (SDG7) on affordable and clean energy to combat the ill health of traditional energy use.

*Respondent, "As a person in charge of the department, my work is to make sure that all traders, business personnel's and guides in the forests work together, and understand the importance of all different tree species in the forest on how they moderate the local climate, provide food, and other socio-economic activities. We have to learnt a lot about this concept about how we can conserve the Mahogany and Teak species, which are mainly targeted by loggers, timber producers, and charcoal making persons. The forest guides should not look only at the money given to them*



*privately, but go beyond what other tasks the forest would do for them and their children. All laws and policies are there, but the people to implement them in the action areas are what we doubt. One of the forest department heads who was involved in the interviews said that",*

Trust among the key decision makers is low, especially given the ongoing economic crisis. This crisis is not only affecting the general public but also those responsible for implementing laws and policies. As a result, governance and policy enforcement are facing significant challenges at both the community and institutional levels. The laws and policies are well spelt out in the South Sudan Constitution of 2011, the Forest Act of 2011, among other documents, but implementation is hard because of hunger and poverty, which increases the likelihood of the implementation of laws and policies of protecting indigenous tree species.

Challenges in forest management implementation include weak enforcement mechanisms, lack of community awareness and participation, and lack of alternative energy sources to reduce reliance on forests. Community Involvement in Forest Management: The community can be involved in forest management through awareness programs, reforestation initiatives, and participation in forest monitoring. Therefore, the result reaffirms (Acheampong, 2023), who put forth that weak governance and institutional policy render deforestation and energy poverty. Local leadership and education are crucial for effective community engagement (Bodo *et al.*, 2021). Reforestation and Afforestation Programs (Dissani *et al.*, 2021). Okoye (2020) recommended that energy policy reforms through government efforts to improve energy-poor households by subsidising and reducing energy costs and tariffs could increase accessibility and affordability of electricity to the poor energy households in Sub-Saharan African Countries (Okoye, 2020). Some small-scale reforestation programs exist, often initiated by

NGOs. However, the government lacks a comprehensive, large-scale effort to restore forests.

The legal framework for energy resource management in Lakes State is underdeveloped. The existing policies are aimed at promoting renewable energy but suffer from poor implementation and limited scope. The results agree with Adkins (2015), who noted that a lack of clarity in the legal and regulatory frameworks for forestry must be addressed. *The effectiveness of energy resource management policies* is only partially effective due to limited enforcement and infrastructure, and a lack of investment in energy projects. *Challenges in Implementing Energy Policies* include a lack of funding, weak governance structures, poor infrastructure, and limited technical capacity. Nguyen & Su (2021) stated that policy implications that address energy poverty can lead to a significant reduction in deforestation through easing the resilience of forest-based fuels. Communities can engage in activities such as replanting trees, using alternative energy sources, and participating in awareness campaigns on sustainable forest use so as to stop deforestation. Alternative Energy Solutions include the use of modern energy, such as improved cooking stoves that use less wood or charcoal are viable alternatives. Expanding access to these technologies can help reduce the reliance on traditional biomass for energy.

## CONCLUSIONS

Based on the findings of this study, there is a clear connection between energy poverty and climate change in the Lakes State of South Sudan. The local population heavily relies on biomass, mainly wood and charcoal, as their primary source of energy due to a lack of access to affordable and sustainable alternatives like electricity and clean cooking solutions. This has accelerated the rate of deforestation in the region, depleting forest resources and exacerbating climate change impacts on the environment. In Lakes State of South Sudan, energy poverty is a key driver of deforestation due to the State's reliance on biomass (wood and

charcoal) as the primary energy source for cooking and heating. With limited access to alternative energy sources like electricity or cleaner fuels, many households depend on biomass fuel. This leads to over-exploitation of forests and exacerbates deforestation, as more trees are cut to meet the growing economic and energy needs of the population. With 94% respondents responding Yes, energy poverty is linked to deforestation. This dependence variable drives the demand for wood fuel, contributing to deforestation, forest degradation, and habitat loss. Poverty exacerbates environmental degradation as impoverished populations often overexploit natural resources to meet their basic needs, contributing to deforestation, soil degradation, and biodiversity loss, which in turn accelerates climate change impacts in the State.

Due to limited electricity infrastructure, many households depend on firewood and charcoal for cooking, lighting, and heating, leading to extensive deforestation as people harvest trees to meet their energy and socio-economic needs. In Lakes State, electricity access is limited. Many rural households either lack access entirely or rely on small solar systems. Even in areas where there is some grid access, like Rumbek Central County, electricity is often only available for a few hours a day, if at all. Challenges in forest management implementation include weak enforcement mechanisms, a lack of community awareness and participation, and a lack of alternative energy sources to reduce reliance on forests. Community involvement in Forest Management can involve creating awareness programs, reforestation and afforestation initiatives, and participation in forest monitoring. Local leadership and education are crucial for effective community engagement. Some small-scale reforestation and afforestation programs exist, often initiated by NGOs and UN agencies in the State. However, the government lacks a comprehensive, large-scale effort to restore forest ecosystems.

The primary sources of energy in Lakes State are traditional biomass, such as wood fuel, agricultural residues, cow dung, and charcoal. Due to high poverty levels, limited infrastructure, and lack of access to modern energy, the local population continues to use unsustainable energy sources, further increasing the strain on forest resources and exacerbating climate change impacts. Although national laws and policies exist to promote sustainable energy efficiency, implementation is weak in the Lakes State. There is a gap between national energy policies and their actual enforcement at the local level, contributing to ongoing climate change and energy poverty. Policies meant to alleviate energy poverty, like subsidies for cleaner energy or forest conservation programs, have not been effectively adopted in the State.

### Recommendations

The following recommendations are informed by the findings of the study

- The government and developmental partners should increase community capacity-building programs and equip communities with the skills to use and maintain clean energy technologies.
- Local authorities should be empowered to enforce deforestation laws and implement sustainable land-use policies, as well as to promote Community-Based Forest Management that engages local communities in managing forests and promoting sustainable energy practices.

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