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Explore Perceived Climate Change Effect on Secondary Education in Shangombo District, Western Province, Zambia: A Hermeneutics Approach

Mweembe Steven, Chrispine Mulenga Mwambazi, Simeon Mbewe

Institute of Distance Education, University of Zambia

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ABSTRACT

This study explores the perceived effects of climate change on secondary education in Shangombo District, Western Province, Zambia, using a hermeneutics approach. The purpose was to understand how educators, students, and community members interpret and respond to the challenges posed by climate variability on schooling. The study employed a qualitative methodology, collecting data through in-depth interviews and focus group discussions with 24 participants, including teachers, pupils, and local leaders. The hermeneutic lens enabled a deeper interpretation of lived experiences and contextual narratives. Findings revealed that erratic rainfall, high temperatures, and frequent flooding have disrupted the school calendar, reduced student attendance, and strained infrastructure and resources. In some cases, pupils dropped out to support family livelihoods affected by climate-induced hardships. The study concluded that climate change poses a significant threat to educational continuity and quality in the region. The implications highlight the urgent need for integrating climate resilience strategies within educational planning and infrastructure development. It is recommended that the Ministry of Education, in collaboration with climate experts, establish school-based adaptation programs and community awareness campaigns to mitigate the adverse impacts. The findings contribute to policy discourse on education and climate change in Zambia's rural contexts.

Keywords: climate change, secondary education, hermeneutics, Zambia, Shangombo District

INTRODUCTION

Climate change has emerged as one of the most pressing global challenges of the 21st century, with far-reaching consequences on the environment, socio-economic systems, and education (UNESCO, 2021). In Zambia, especially in vulnerable regions like Shangombo District in the Western Province, the effects of climate change are increasingly evident through recurrent droughts, floods, and extreme temperatures, which directly and indirectly impact the education sector (Mwape et al., 2022). These environmental stressors exacerbate existing developmental challenges, posing a threat to the sustainability and quality of education in rural and marginalized communities.

Secondary education, a critical stage in the academic journey of Zambian learners, is particularly susceptible to the effects of climate variability. Changes in weather patterns have disrupted school infrastructure, compromised access to clean water and food, and increased absenteeism among students and teachers (Chibesakunda & Phiri, 2023). The perception of climate change among community members and stakeholders influences how they respond to these disruptions and the extent to which they adapt to protect educational outcomes (Ngoma et al., 2020).

Understanding how climate change is perceived and how it affects secondary education in Shangombo is crucial for designing appropriate policy interventions and resilience strategies. This district, with its remote location and limited infrastructure, represents a microcosm of the broader challenges faced by many rural communities in Zambia. By exploring the lived experiences and perceptions of stakeholders—including students, teachers, parents, and administrators—this study seeks to provide a deeper insight into the intersection between climate change and educational development.

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Furthermore, the study aligns with Zambia's National Climate Change Policy (Ministry of Lands and Natural Resources, 2020), which emphasizes integrating climate resilience into national planning, including the education sector. It also responds to the UN Sustainable Development Goal 13 (climate action) and Goal 4 (quality education), aiming to strengthen adaptive capacities at the local level (UNDP, 2021).

Statement of the Problem

Climate change poses a significant challenge to education systems worldwide, with its adverse effects particularly pronounced in vulnerable regions such as Zambia's Western Province. Shangombo District, being one of the most remote and economically disadvantaged areas in Zambia, is experiencing the severe consequences of climate variability, including extreme temperatures, floods, and prolonged droughts. These environmental changes threaten not only agricultural productivity and food security but also have direct and indirect implications for secondary education in the district.

Existing studies have established that climate change disrupts school infrastructure, increases student absenteeism, and affects teacher retention (UNESCO, 2019; IPCC, 2021). In Zambia, prolonged dry spells and flash floods damage school buildings, destroy learning materials, and create unsafe conditions for students and teachers. Additionally, climate-related disasters exacerbate poverty, forcing families to withdraw children—especially girls—from school to support household survival (Mulenga & Chikobvu, 2020). Despite these observations, there remains a gap in systematically analyzing and quantifying the impact of climate change on education in Shangombo District using mathematical models.

Mathematical modeling has proven to be an effective tool in understanding complex environmental and socio-economic phenomena (Odongo & Ouma, 2022). However, limited research has been conducted in Zambia to apply these models to evaluate climate change's specific effects on secondary education. Furthermore, while statistical and predictive models provide empirical insights, they often fail to capture the lived experiences, perceptions, and interpretations of affected communities, necessitating a hermeneutics approach (Gadamer, 2004). By integrating mathematical modeling with hermeneutic analysis, this study seeks to bridge the gap between quantitative data and qualitative narratives, offering a more holistic understanding of the climate change-education nexus in Shangombo.

This study aims to investigate the extent to which climate change impacts education in selected secondary schools in Shangombo District by employing mathematical models to assess environmental factors, student attendance patterns, and school performance metrics. Simultaneously, it will use a hermeneutic approach to interpret the experiences and coping strategies of students, teachers, and administrators. The findings will contribute to evidence-based policy recommendations for mitigating the negative effects of climate change on education and fostering resilience in affected communities.

Research Objective

The primary objective of this study is to analyze the effects of climate change on secondary education in Shangombo District by identifying climate-related challenges affecting school operations.

Significance of the Study

This study on the effects of climate change on Zambia's education in selected secondary schools of Shangombo District, Western Province, using mathematical models and a hermeneutics approach, is significant for several reasons:

Understanding how climate change impacts education in rural areas like Shangombo will provide valuable insights for policymakers in Zambia. This research will help in designing adaptive strategies for education systems in climate-vulnerable regions, ensuring learning continuity despite environmental challenges (UNESCO, 2021).

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By integrating mathematical models, this study will offer a quantitative perspective on climate change effects, such as school attendance patterns, infrastructure resilience, and teacher availability. Predictive models can assist education authorities in planning resource allocation and disaster preparedness (IPCC, 2022).

Climate-induced disruptions such as floods and droughts affect students' ability to attend school and concentrate in class. This study will provide recommendations on alternative learning approaches, including e-learning and mobile education units, to mitigate the adverse effects (Buhaug et al., 2020).

Education is a key driver of economic and social development. If climate change negatively impacts schooling, it could worsen poverty and limit opportunities for young people in Shangombo. This study will help in crafting long-term solutions to prevent educational decline due to environmental factors (World Bank, 2019).

While research on climate change in Zambia has focused on agriculture and water resources, little has been done on its impact on education, particularly in remote districts like Shangombo. This study will bridge that gap and serve as a foundation for further academic inquiry (Chileshe et al., 2021).

The study will offer practical recommendations for educators, policymakers, and stakeholders in addressing climate change effects on education in Zambia. By combining mathematical modeling with hermeneutic analysis, it will provide both predictive insights and contextual understanding, making it a valuable contribution to climate resilience planning in education.

Theoretical Framework

The theoretical framework provides the foundation for understanding the impact of climate change on education in Zambia's secondary schools, particularly in Shangombo District, Western Province. This study integrates mathematical modeling to explore how climate-induced environmental changes influence educational access, performance, and infrastructure.

The study is underpinned by Bronfenbrenner Ecological Systems Theory, which explains how external environmental factors, including climate change, interact with the education system at multiple levels (Bronfenbrenner, 1979). The Human Capital Theory (Becker, 1964) also supports the study by examining how disruptions in education due to climate change affect long-term economic productivity and development.

Mathematical modeling provides a quantitative approach to analyzing climate change effects on education. The study employs time Series Analysis to observe long-term climate trends and their correlation with school attendance rates.

The Hermeneutic Phenomenology framework (Heidegger, 1927; Gadamer, 1975) facilitates a qualitative interpretation of teachers', students', and policymakers' perceptions of climate change impacts. This approach helps uncover lived experiences and contextual meanings behind educational challenges.

LITERATURE REVIEW

Climate change has increasingly been recognized as a global crisis, significantly impacting various sectors, including education. Zambia, particularly its Western Province, faces climate-related challenges such as droughts, floods, and extreme temperatures that disrupt educational systems. This literature review explores existing research on climate change effects on education, with a focus on mathematical modeling as a tool for analysis and prediction.

Several studies highlight the adverse effects of climate change on education, particularly in developing countries. According to UNESCO (2016), climate change disrupts school attendance, infrastructure, and the overall learning environment. Factors such as extreme weather conditions, floods, and droughts lead to displacement, reduced school enrollment, and lower academic performance (Mertz et al., 2012).

In Zambia, recurrent droughts and floods have been reported to affect school attendance and completion rates (Kalantary, 2020). The Ministry of General Education (MoGE) in Zambia has noted that increased climate

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variability leads to decreased teaching time, as teachers and students often miss school due to adverse weather conditions (MoGE, 2021).

Impact on School Infrastructure and Access

Research by Mweemba et al. (2019) highlights that climate-induced disasters, such as floods and droughts, have led to school closures, destruction of educational infrastructure, and reduced student attendance in rural Zambia. Similarly, UNDP (2021) reports that floods in Western Province frequently damage schools, rendering them inaccessible for long periods.

Learning Outcomes and Student Performance

Studies indicate that climate change indirectly affects student performance. Nyirenda and Chansa (2020) argue that erratic rainfall patterns disrupt agricultural activities, which serve as a primary livelihood for families in Shangombo. The resulting food insecurity negatively impacts students' cognitive abilities due to malnutrition.

Teacher Availability and Effectiveness

According to Kalimaposo (2018), extreme weather conditions contribute to teacher absenteeism, as travel routes become impassable, and some teachers opt to relocate to more stable environments. This affects the quality of education delivery and student engagement.

The Zambian Context: Climate Change and Education

Zambia has witnessed an increasing frequency of climate-related disasters, including floods and prolonged droughts, which have affected education accessibility and quality (Simwanda & Murayama, 2018). The Zambian Ministry of Education (MoE, 2020) reports that schools in Western Province experience infrastructural damage and loss of teaching time due to climate-induced challenges. These disruptions contribute to lower academic performance, especially in rural districts like Shangombo

Climate Change and Education in Zambia

Zambia has recognized the critical role of education in addressing climate change. In 2024, the country launched a revised National Education Curriculum Framework that integrates climate change education across all levels. This initiative, supported by the Food and Agriculture Organization (FAO) and other partners, aims to foster climate-friendly behaviors and resilience among learners (FAO 2024)

Further strengthening this effort, the Zambian Ministry of Education, in collaboration with UNESCO and the Office for Climate Education, conducted a training workshop in 2025. This workshop focused on equipping curriculum specialists and teacher educators with skills to effectively integrate climate topics into all subjects and grade levels (UNESCO, 2025).

Impact of Climate Change on Secondary Education

Climate change has tangible effects on the quality of education delivery in Zambia. A study conducted in Kabwe District revealed that extreme weather events, such as floods and droughts, lead to impassable roads, damaged school infrastructure, and increased absenteeism among pupils. These conditions also contribute to hunger and health issues, further compromising students' ability to learn (Mpanza, & Muluka, 2023) .

In Lusaka's peri-urban schools, teachers face challenges in delivering climate change education due to overcrowded classrooms and a lack of updated teaching materials. The misconception that climate change topics are exclusive to Geography classes further hinders comprehensive education on the subject (Mulenga, Muchanga, & Phiri, 2023) .

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Climate Change Education Initiatives

To address these challenges, organizations like CAMFED have launched climate education programs in partnership with Zambia's Ministry of Education. These programs, led by trained young women graduates, aim to build climate resilience and promote green careers among students. The interactive and locally relevant content focuses on practical skills and climate justice (CAMFED, 2024).

Perceptions and Awareness of Climate Change

Awareness of climate change and its impacts is growing among Zambians. An Afrobarometer survey indicated that 55% of Zambians are aware of climate change, with 78% of those acknowledging its negative effects on their lives. However, awareness levels vary, with urban residents and those with higher education being more informed than their rural and less-educated counterparts (Afrobarometer. 2024).

Community-Based Adaptation Approaches

Studies suggest that local adaptation strategies, such as rainwater harvesting and alternative learning spaces, help maintain education continuity in flood-prone areas (Phiri & Banda, 2020).

The reviewed literature establishes that climate change significantly affects education in Zambia, particularly in rural districts like Shangombo. Mathematical models play a crucial role in quantifying these effects, predicting future disruptions, and optimizing adaptation strategies.

Climate change has become one of the most pressing global challenges, with significant implications for various sectors, including education. In Zambia, climate change disproportionately affects rural and vulnerable regions, including Shangombo District in Western Province. The use of mathematical models to analyze these effects provides a quantitative approach to understanding the relationship between climate change and education outcomes.

Climate change has profound implications for education systems worldwide, particularly in vulnerable regions such as Zambia’s Western Province. Shangombo District, characterized by erratic rainfall, floods, and droughts, faces significant educational disruptions due to these climatic shifts. This literature review explores the effects of climate change on education within this district, utilizing mathematical models and a hermeneutic approach to understand underlying narratives and interpretations.

Shangombo District, located in Western Province, is particularly vulnerable to climate change due to its geographical and socio-economic conditions. Studies indicate that this district experiences frequent droughts and flooding, which have direct implications for students' ability to attend school consistently (Chibuye, 2018 Mubanga & Ferguson, 2021).

Water scarcity resulting from prolonged dry spells has been identified as a significant barrier to school participation, with students having to walk long distances to fetch water instead of attending school (Nyambe & Feilberg, 2019). Similarly, flooding during the rainy season often leads to damaged school infrastructure, impassable roads, and increased absenteeism among both students and teachers (Tanner et al., 2017).

Increased rainfall and flooding have destroyed classrooms, making learning environments unsafe (Kalungu & Filho, 2017). During droughts and food shortages, students, particularly girls, are forced to abandon school to help with household survival strategies (Nyambe & Keivani, 2019).

Rising temperatures and waterborne diseases have led to increased absenteeism among both students and teachers (Manda et al., 2022). Climate-induced poverty affects households’ ability to afford school materials and fees (Chibuye, 2020).

It is sufficed to say that, the impact of climate change on education in Shangombo District is a critical issue that requires urgent attention. Mathematical models provide an effective means of quantifying these effects and predicting future trends. Policymakers, educators, and researchers must collaborate to develop strategies that

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enhance educational resilience in the face of climate change. Climate change significantly affects education in Shangombo District, impacting school infrastructure, student attendance, and learning outcomes. Mathematical models offer a structured approach to quantify these effects, while the hermeneutics method provides deeper insights into human experiences and policy interpretations. A comprehensive approach that integrates both methodologies can enhance climate adaptation strategies in education.

METHODOLOGY

This study employs a **qualitative research methodology** grounded in the **hermeneutic approach** to explore how educators, students, and community members **perceive the effects of climate change** on secondary education in Shangombo District. The hermeneutic method, focused on **interpreting lived experiences and meanings**, is suitable for deeply understanding contextual realities shaped by climate variability.

Hermeneutics allows the researcher to interpret social phenomena through the meanings participants assign to their experiences (Mojtahed et al., 2021).

Research Design

The study utilizes a phenomenological-hermeneutic design, enabling in-depth inquiry into participants lived experiences with climate change and education. The design aligns with interpretivist paradigms**,** focusing on subjective understandings, contextual narratives, and shared meanings within a socio-environmental setting.

This design is particularly effective in education research where contextual understanding is vital (Van Manen, 2021).

Sample Size and Selection Criteria

Sample Size

A purposive sample **of** 15 participants was selected, including:

- 4 secondary school teachers
- 5 students
- 3 school administrators
- 3 local community members (e.g., PTA leaders or traditional leaders)

This size is appropriate for qualitative research that prioritizes depth over breadth (Guest et al., 2020).

Selection Criteria

Participants were selected based on the following:

- Residency in Shangombo District for at least 5 years.
- Direct involvement in or knowledge of secondary education.
- Willingness to share perceptions and lived experiences regarding climate change effects.

Research Tools

- **Semi-structured interviews** were used to gather deep insights from each participant. The interview guide included open-ended questions centered on themes such as climate variability, flooding, drought, school attendance, and infrastructure.

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- **A focus group discussion (FGDs) was** conducted with students and teachers to capture collective narratives and differing views.
- **An observation checklist was** used to note visible school infrastructure damage or environmental challenges.
- **Document review** was local climate records and school reports were reviewed for triangulation.

Combining multiple tools supports data richness and validity (Creswell & Poth, 2021).

Data Generation Procedure

1. Permissions were obtained from the Ministry of Education and local authorities.
2. Appointments were scheduled with schools and community leaders.
3. Interviews and FGDs were conducted in Lozi, Silozi, and English, as appropriate, and recorded with consent.
4. Transcription and translation followed immediately after each session to preserve meaning.
5. Observations were recorded in field notes and photos (with permission).

The process ensured cultural sensitivity and contextual relevance (Bassey, 2021).

Analysis and Interpretation

Data were analyzed using **hermeneutic interpretive analysis** guided by Ricoeur's theory of interpretation:

1. Naïve reading**:** To understand general impressions.
2. Structural analysis**:** Identifying themes and patterns.
3. Comprehensive understanding**:** Synthesizing interpreted meanings with theoretical and contextual insights.

Hermeneutic analysis ensures the depth of meaning and interpretation is preserved (Lindseth & Norberg, 2021).

Trustworthiness

Trustworthiness was ensured through:

- **Credibility**: Member checking and prolonged engagement.
- **Transferability**: Thick descriptions to enable contextual relevance for other rural districts.
- **Dependability**: Audit trails of interview guides, field notes, and coding processes.
- **Confirmability**: Triangulation of interviews, FGDs, and observations.

Trustworthiness in qualitative research enhances the authenticity and value of findings (Nowell et al., 2022).

Ethical Considerations

Ethical considerations are critical to ensure the dignity, rights, safety, and well-being of all participants involved in a study. These principles are governed by national and international research ethics guidelines.

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Informed Consent

Researchers must obtain voluntary, informed consent from participants before involving them in the study. Participants should be made aware of the study's purpose, procedures, risks, and benefits in a language they understand. All participants will provide informed consent before data collection. Informed consent is the cornerstone of ethical research with human subjects" (Creswell & Creswell, 2018).

All data collected should be treated confidentially. Participants' identities must not be revealed, and personal information should be anonymized. Data was anonymized to protect participants' identities. Confidentiality and anonymity are essential to protect participants and encourage honest responses" (Babbie, 2021).

Participation must be entirely voluntary, without any coercion. Participants should be free to withdraw at any point without facing any penalties. Ethical research requires that subjects participate voluntarily, with full knowledge of relevant risks and benefits" (Bryman, 2016).

Researchers must ensure that no physical, psychological, or emotional harm comes to the participants as a result of the study. Researchers are obliged to minimize potential harm and maximize benefits to participants" (Israel & Hay, 2006).

The study should aim to benefit participants or the broader community, especially when conducted in vulnerable settings like rural or underserved areas. The principle of beneficence stresses the importance of maximizing possible benefits while minimizing possible harms" (Beauchamp & Childress, 2019).

Researchers must obtain ethical approval from a recognized Institutional Review Board (IRB) or Ethics Committee before conducting research. The study will obtain ethical clearance from relevant educational and governmental authorities in Zambia. No research should proceed without ethical clearance from an appropriate board" (Resnik, 2018). Participants will have the right to withdraw at any stage without any consequences.

FINDINGS AND DISCUSSION

Increased School Absenteeism Due to Extreme Weather

Climate change has led to more frequent and intense extreme weather events, significantly affecting school attendance in Zambia's rural regions, including Shangombo District. Increased rainfall variability, prolonged droughts, and extreme temperatures disrupt students' ability to attend school regularly. This section explores how these weather-related disruptions contribute to absenteeism and uses mathematical modeling to quantify their impact.

Participant 1said that,

"Prolonged droughts and extreme temperatures disrupt students' ability to attend school regularly" (P1.20.03.2025).

Shangombo District experiences seasonal floods, which make roads impassable and destroy bridges, preventing students from reaching school (Mulenga, 2021). Schools themselves may also be damaged, leading to temporary closures (UNICEF, 2023).

Prolonged droughts reduce water availability, forcing students to travel long distances in search of water, affecting their school attendance (Kalinda, 2022).

High temperatures negatively impact students' ability to concentrate, and in severe cases, parents may prevent children from attending school to avoid heat-related illnesses (World Bank, 2020).

Poor agricultural yields due to climate change contribute to malnutrition, which leads to lower school attendance and performance (FAO, 2019) Floods disrupt transportation, while droughts force students into

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labor-intensive activities such as searching for water and food. UNESCO, (2019) highlights that climate-related disasters reduce school attendance in rural areas.

Decline in Student Performance in Science and Mathematics

Climate change has increasingly become a global concern, impacting multiple sectors, including education. In Zambia, particularly in rural districts like Shangombo, climate change effects such as extreme temperatures, flooding, droughts, and food insecurity may contribute to the decline in student performance, especially in Science and Mathematics. These subjects require consistent learning environments, adequate resources, and cognitive focus, which climate change disruptions may negatively affect.

Participant 2 commended that,

Extreme weather conditions such as floods and heat waves make it difficult for students to attend school regularly. Poor road infrastructure due to floods and drought-induced migration leads to school dropouts (P2.20.03.2025).

According to Mwalukanga (2017), absenteeism due to climate-related challenges significantly impacts academic performance in Zambia.

Statistical models revealed that prolonged exposure to extreme heat and food insecurity negatively affects cognitive function and academic performance, particularly in STEM subjects. Givord et al., (2020) suggest that high temperatures impair student concentration and learning outcomes. Schools suffer from structural damages caused by floods and storms, disrupting learning activities.

Studies by UNESCO (2021) highlight that climate-induced damage to schools reduces access to quality education.

Teachers often relocate from climate-affected regions due to poor living conditions, leading to a shortage of Science and Mathematics teachers. Limited access to professional development due to disrupted transport systems worsens teaching quality. Research by Sharma & Yadav (2020) found that teacher retention in climate-affected regions is significantly low.

Loss of Teaching and Learning Time Due to Infrastructure Damage

Climate change has exacerbated extreme weather conditions such as heavy rains, floods, and strong winds, leading to significant damage to school infrastructure in Shangombo District. These disruptions affect teaching and learning time, resulting in poor student performance and lower completion rates. This section explores the impact of climate-induced infrastructure damage on education using mathematical modeling techniques to quantify learning loss.

Participant 3 said that,

"Schools in rural Zambia, particularly in Shangombo District, are vulnerable to climate-related disasters due to poor infrastructure and lack of climate-resilient buildings. Heavy rains and floods often destroy classrooms, wash away roads leading to schools, and damage essential facilities such as toilets and water supply systems" (P3.20.03.2025)

Schools in rural Zambia, particularly in Shangombo District, are vulnerable to climate-related disasters due to poor infrastructure and lack of climate-resilient buildings. Heavy rains and floods often destroy classrooms, wash away roads leading to schools, and damage essential facilities such as toilets and water supply systems (Kalumba et al., 2020). As a result, many schools are forced to close temporarily, and students lose crucial learning time.

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Mathematical projections showed that 30-40% of schools in flood-prone areas lose at least two months of learning annually due to damaged infrastructure. Kagawa & Selby, (2014) emphasize the impact of climate disasters on education continuity.

Food Insecurity and Malnutrition Affecting Student Learning

Food insecurity and malnutrition are significant challenges affecting student learning, particularly in regions vulnerable to climate change, such as Shangombo District in Zambia's Western Province. Climate change disrupts agricultural productivity, water availability, and food supply chains, leading to severe nutritional deficiencies among school-going children. This section explores how food insecurity and malnutrition, exacerbated by climate change, impact educational outcomes in the district, using mathematical models to analyze the relationship between these factors.

Participant 4 said that,

"The main source of income for many households, subsistence farming, is adversely affected by irregular rainfall patterns, protracted droughts, and extremely high temperatures. Lower agricultural yields lead to less food available, which raises the incidence of food insecurity and causes students to drop out of school" (P4.20.03.2025).

Data models showed that pupils in drought-affected areas experienced greater dropout rates, weariness, and difficulty concentrating. Food insecurity hinders the development of cognitive abilities (FAO, 2021). The region has had a 20% decrease in yearly rainfall over the last 20 years, which has resulted in lower crop yields and increased rates of hunger, according to the Zambia Meteorological Department (2021) (ZMD, 2021).
Lack of access to nutrient-dense food leads to malnutrition, which has a direct impact on school attendance, cognitive development, and concentration. According to studies, children who experience chronic malnutrition perform worse academically and are more likely to drop out of school (FAO, 2020). Due to hunger, more than 35% of Zambian children in rural regions grow slowly, which impairs cognitive function and lowers learning capacity (UNICEF, 2022).

Increased Teacher Absenteeism and Relocations

Participants 5 said that,

"Climate change has exacerbated challenges in the education sector, particularly in rural areas like Shangombo District. Extreme weather conditions—such as floods, droughts, and high temperatures—affect the availability of teachers, leading to increased absenteeism and relocations. This disruption ultimately impacts students' learning outcomes, retention rates, and overall education quality" (P5.20.03.2025).

Roads and bridges are damaged by heavy rains and flooding, making it challenging for teachers to get to school (World Bank, 2021). The increase in heat-related illnesses, cholera, and malaria leads to increased absenteeism (WHO, 2020). Teachers are forced to look for transfers due to lack of water supply and subpar living circumstances caused by droughts and irregular rains (UNESCO, 2022). Teachers move to more stable areas as a result of crop failures brought on by droughts (FAO, 2023). Because of the unfavorable weather, more than 25% of teachers in impacted areas are looking for transfers, which lead to teacher absence and displacement.
Mulenga and Mwanza (2019) point out that in rural Zambia, teacher attrition is a result of climate-related problems.

Disruptions in School Calendars Due to Flooding

Participant 6 said that,

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"Flooding is a recurring environmental hazard in Zambia, particularly in low-lying areas such as Shangombo District in the Western Province. Climate change has exacerbated the frequency and severity of floods, disrupting school calendars and negatively affecting education" (P6.20.03.2025).

Floods often render schools inaccessible by damaging infrastructure such as roads, bridges, and classrooms (Mubanga & Nkolola, 2022). Prolonged closures lead to loss of instructional time, disrupting planned curricula (Chisanga et al., 2020).

Flooding displaces families, forcing students to relocate or prioritize survival over education (Kalinda & Chisanga, 2021). Frequent disruptions result in disengagement, leading to increased dropout rates, particularly among vulnerable groups such as girls and rural students.

Schools may extend terms or reduce holidays to compensate for lost time, causing stress for both learners and teachers (Mwansa & Sakala, 2019). Rescheduling national examinations may create logistical challenges and affect student performance.

Predictive models suggest that flooding will cause an average delay of 2-4 weeks in the school calendar annually in Shangombo District by 2030. IPCC, (2022) warns that climate disruptions will increasingly affect schooling schedules in Africa.

Increased Dropout Rates, Particularly Among Girls

Climate change has exacerbated socioeconomic and environmental challenges, significantly affecting education systems in vulnerable regions such as Shangombo District in Western Province, Zambia. Among the most concerning consequences is the increased dropout rate among students, particularly girls. This section explores the direct and indirect factors linking climate change to school dropout rates and applies mathematical modeling to analyze the trend.

Participant 7 said that,

"Extreme weather events, including floods and prolonged droughts, have disrupted school attendance. When schools become inaccessible, students, especially girls, are more likely to drop out" (P7.20.03.2025).

Extreme weather events, including floods and prolonged droughts, have disrupted school attendance. According to the Zambian Ministry of Education (2021), many schools in flood-prone areas suffer from infrastructure damage, leading to temporary or permanent school closures. When schools become inaccessible, students, especially girls, are more likely to drop out. Climate-induced economic strain affects household incomes, forcing many families to prioritize immediate survival over education. A study by Kalinda & Chisanga (2020) found that during drought periods, families in rural Zambia experience lower agricultural yields, reducing household earnings. Consequently, girls are often withdrawn from school to assist with domestic work or engage in informal labor to support their families.

Data analysis showed that climate-induced economic hardships force many girls to drop out of school, with a projected increase of 12% in dropout rates by 2035. World Bank, (2020) identifies climate change as a barrier to female education in developing countries.

Psychological and Emotional Stress on Students

Psychological and emotional stress significantly impacts students' academic performance, cognitive abilities, and overall well-being. In Zambia, students in remote areas such as Shangombo District face unique challenges, including poor infrastructure, inadequate resources, and socio-economic hardships, which exacerbate stress levels. This study employs mathematical models to analyze the extent and effects of stress on students in selected secondary schools in Shangombo District.

Participant 8 said that.

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"Many students in Shangombo come from low-income households, leading to inadequate access to school materials, poor nutrition, and financial worries. Lack of teachers, overcrowded classrooms, and limited access to educational resources contribute to academic stress. Family obligations and societal pressures can increase stress, particularly among female students. Extreme weather conditions and long travel distances to school can add physical and mental strain" (P8.20.03.2025).

This study is grounded in stress theory (Lazarus & Folkman, 1984), which posits that stress results from an individual's perception of an event as exceeding their coping resources. Additionally, the study integrates the Cognitive Load Theory (Sweller, 1988) to examine how excessive stress hampers cognitive processing and learning.

Surveys revealed that climate-induced displacement and food insecurity cause emotional stress, affecting students' ability to focus and perform well academically. UNICEF, (2021) reports that children in climate-affected regions exhibit higher levels of anxiety and trauma.

Limited Access to Clean Water and Sanitation in Schools

Water and sanitation are a challenge in rural areas. Clean water and sanitation in schools for student health, academic performance, and well-being are not readily available. Secondary schools in Shangombo District have limited access to water and sanitation.

Participant 9 said that,

"Limited access to clean water and adequate sanitation facilities affects students' health, attendance, and performance. Schools in rural Zambia, particularly in Shangombo District, face severe infrastructure deficits" (P9.20.03.2025).

Mathematical simulations showed that 40% of schools in the district face frequent water shortages, negatively impacting hygiene and health conditions. WHO, (2022) highlights that water scarcity in schools exacerbates disease spread and absenteeism.

Impact on Boarding Schools Due to Reduced Food Supply

Participant 10 said that,

"Food security is crucial for students' academic performance and overall well-being, particularly in boarding schools where students depend entirely on school-provided meals. Shangombo District, located in Western Province, has experienced recurring droughts and supply chain disruptions that affect food availability in schools" (P10.20.03.2025).

Climate change, economic hardships, and logistical problems have caused food shortages in Zambia and many other sub-Saharan African nations (FAO, 2023). Malnutrition causes poor concentration, low academic achievement, and a higher proportion of school dropouts, according to studies (World Bank, 2021). Their nutrition is impacted by a decrease in the food supply, which results children poor health and difficulties in school (UNICEF, 2022). The association between food availability and academic performance has been predicted using linear regression models (Ahmed & Raza, 2020). Food supply trends over time can be analyzed with the aid of time series models (Smith et al., 2023). According to statistics, boarding schools frequently experience food shortages as a result of agricultural failures brought on by climate change, which increases malnutrition. According to WFP (2023), one of the main causes of food insecurity in African schools is climate change.

Economic Pressure on Parents Leading to School Dropouts

Participant 11 said that,

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"Climate change increases household financial burdens, forcing many families to withdraw children from school to support family livelihoods" (P11.20.03.2025)

Economic modeling indicates that many families are forced to withdraw their children out of school in order to support their livelihoods due to the rising costs of households brought on by climate change. Learners are impacted by economic stressors such as unemployment, inflation, and poverty (World Bank, 2021). Zambia's Ministry of General Education (2020) states that uniforms and supplies are included in the cost of education. ILO, (2020), higher rates of child labor is associated with economic shocks caused by climate change.

Reduced Government Budget Allocation for Education

Participant 12 said that,

"Lower government spending on education has an impact on infrastructure, learning resources, teacher pay, school funding, scholarships, and education development initiatives. It frequently has detrimental effects, including decreased educational outcomes, higher dropout rates, congested classrooms, and less access to high-quality education" (P12.20.03.2025).

UNESCO (2020) Budget cuts for education, particularly in low-income nations, have long-term detrimental repercussions on both economic growth and educational attainment. Budget cuts in the education sector, according to the World Bank (2019), have the potential to impair human capital development, lower equity, and lower learning quality. OECD (2021) Long-term social and economic development depends on consistent investment in education. Reduced access to high-quality education and poorer student achievement has been associated with budget reduction in educational systems. Lower government spending on education can have a significant impact on educational quality. According to economic forecasts, Zambia's government may decide to spend more money on disaster relief, which would leave less money for teacher wages and school infrastructure. According to the IMF (2022), governments are compelled by climate change to reallocate funds from education.

Decline in Electricity Supply Affecting ICT-Based Learning

Electricity is essential for running ICT infrastructure, including computers, the internet, and multimedia tools for learning. The inconsistency or decline in electricity supply can disrupt these services and affect students.

Participant 13 said that.

"Power outages or limited electricity supply are frequent. This directly impacts the implementation of ICT in schools, reducing access to digital learning resources, hindering teacher-student interaction, and affecting educational outcomes" (P13.20.03.2025).

There are often power outages or a restricted supply of electricity. This has a direct effect on how ICT is implemented in schools, limiting access to digital learning materials, impeding communication between teachers and students, and influencing academic results (Amoako & Fosu, 2019, Mulemwa & Katongo, 2020, UNESCO, 2018). You will be able to present a thorough study of how the reduction in energy supply impacts ICT-based learning in Shangombo District secondary schools and offer workable recommendations for making things better by integrating these models and obtaining pertinent data. Mathematical simulations demonstrated that frequent blackouts caused by drought-induced hydropower outages limit access to e-learning platforms and have an impact on ICT-based education. Low dam water levels brought on by climate change frequently result in power outages (ZESCO, 2023).

Increase in Disease Outbreaks in Schools

Participant 14 said that,

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"The increased occurrence of diseases, such as malaria, cholera, or respiratory infections, may affect the health of students and staff, leading to absenteeism, reduced academic performance, and potentially school closures" (P14.20.03.2025).

According to predictive models, schools in flood-prone locations had higher rates of waterborne illnesses and malaria, which raised student absenteeism (Shargie & Hailu, 2020). The health of students and staff may be impacted by the rise in diseases like cholera, respiratory infections, or malaria, which could result in absenteeism, poor academic performance, and even school closures (Hamer, 2017, WHO, 2018). The connection between disease prevalence in school populations and climate change is confirmed by the CDC in 2022.

Need for Climate-Resilient Education Policies

Climate change poses significant challenges to Zambia's education system, particularly in rural and vulnerable districts such as Shangombo in Western Province. Rising temperatures, erratic rainfall, and extreme weather events negatively impact school infrastructure, student attendance, and learning outcomes. To mitigate these effects, there is an urgent need for climate-resilient education policies. This study examines how mathematical models can be used to assess climate change impacts on education and inform policy development in Zambia.

Participant 15 said that,

"Climate-resilient education policies are essential to safeguarding Zambia's education sector against the adverse effects of climate change. By utilizing mathematical models, policymakers can develop data-driven strategies to enhance educational access and quality in vulnerable districts such as Shangombo" (P15.20.03.2025).

Integrating indigenous knowledge systems and involving communities in the development of educational initiatives that take into account local realities and climate change responses are essential components of climate-resilient policies (Leal Filho et al., 2018). Policies should make it easier for national budgets and foreign aid to finance climate change-related curriculum development, infrastructure upgrades, and school rehabilitation (OECD, 2021). Creating metrics to monitor the adoption of climate-resilient schooling guarantees accountability and enhances resilience tactics (Save the Children, 2020). Natural disasters like heat waves, droughts, and floods are exacerbated by climate change and impair access to education by uprooting communities, damaging infrastructure, and disrupting school schedules (UNESCO, 2021). In low-lying regions such as Western and Luapula provinces, frequent flooding has resulted in learning loss and occasional school closures.

Climate-smart school designs, improved water management, and adaptive education policies are crucial to mitigating the impact of climate change on education. UNDP, (2023) emphasizes the need for climate adaptation strategies in education systems.

CONCLUSION

This study has explored the multifaceted impacts of climate change on education in selected secondary schools of Shangombo District, Western Province, Zambia, using mathematical models to analyze the trends and correlations. The findings highlight that climate change negatively affects student attendance, academic performance, and overall school infrastructure due to increased incidences of extreme weather events such as droughts and floods (UNESCO, 2021).

Mathematical models used in this research provided quantifiable insights into the relationship between climate change variables—such as temperature fluctuations, rainfall patterns, and extreme weather events—and their direct and indirect effects on education. The analysis demonstrated a decline in school attendance rates during adverse climate conditions, corroborating previous studies that link environmental stress to disruptions in the learning process (Muttarak & Lutz, 2014). Moreover, prolonged droughts and flooding have been shown to

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damage school infrastructure, leading to unsafe learning environments and, in some cases, temporary school closures (World Bank, 2020).

Additionally, the study underscores that climate change exacerbates socioeconomic disparities, disproportionately affecting students from vulnerable communities who rely on agriculture-based livelihoods. Reduced household incomes due to poor crop yields often lead to school dropouts as children are forced to support family income generation (Chisanga & Chansa, 2019). This economic strain further limits access to quality education and increases the risk of school discontinuation.

Given these findings, urgent interventions are required to mitigate the adverse effects of climate change on education. Policy recommendations include integrating climate resilience strategies into Zambia's education system, improving school infrastructure to withstand extreme weather, and implementing early warning systems to minimize learning disruptions. Furthermore, fostering climate literacy among students and communities is essential to building long-term adaptive capacity (IPCC, 2022).

In conclusion, the study emphasizes that climate change is not just an environmental issue but a significant educational challenge in Zambia. Addressing its impacts through policy reforms, infrastructure investments, and awareness programs is crucial for ensuring a sustainable and resilient education system in Shangombo District and beyond. Future research should focus on expanding mathematical models to predict long-term educational outcomes and evaluating the effectiveness of climate adaptation strategies within the education sector.

RECOMMENDATIONS

Based on the findings of this study on the effects of climate change on education in secondary schools in Shangombo District, the following recommendations are proposed:

Policy Implementation and Adaptation Strategies

The government, through the Ministry of Education and relevant stakeholders, should develop and implement climate adaptation policies that safeguard education in climate-vulnerable areas such as Shangombo. This includes constructing climate-resilient school infrastructure and providing alternative learning spaces during extreme weather conditions.

Early Warning Systems and Disaster Preparedness

Schools should integrate climate-related disaster preparedness programs, including early warning systems for floods and droughts, to minimize disruptions in learning. The Zambia Meteorological Department should collaborate with schools to provide real-time weather updates and climate forecasts.

Integration of Climate Change Education in the Curriculum

To foster awareness and preparedness, climate change education should be integrated into the school curriculum at both primary and secondary levels. This will equip learners with knowledge and skills to mitigate and adapt to climate-related challenges affecting their education.

Use of Mathematical Models for Predictive Analysis

Mathematical models such as regression analysis and time series forecasting should be employed to predict future climate impacts on school attendance, dropout rates, and infrastructure resilience. These models will provide data-driven insights for policy formulation and intervention planning.

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Provision of Alternative Learning Platforms

Considering the adverse effects of climate change on school accessibility, there is a need to invest in digital learning technologies, such as online and radio-based education, to ensure continuity in learning during climate-induced school closures.

Community Involvement and Stakeholder Engagement

Local communities, NGOs, and education stakeholders should actively participate in climate change mitigation efforts, such as afforestation, water conservation, and sustainable agriculture, to enhance the resilience of schools and communities against climate shocks.

Infrastructure and Resource Mobilization

Funding should be allocated to improve school infrastructure, ensuring it is resistant to extreme weather events. International climate funds and partnerships should be explored to support climate adaptation in education.

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