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Climate Change, Agricultural Disruption, and Household Welfare in Zambia: AI, Digital Innovation and Pathways to Resilience in Western Province

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Abstract — Climate change poses an existential challenge to agricultural productivity and household welfare in sub-Saharan Africa, with Zambia's Western Province including Mongu District particularly vulnerable to recurrent droughts, flooding, and erratic rainfall patterns that devastate subsistence farming livelihoods. This article examines the impact of climate change on agricultural systems and household welfare in Western Province, Zambia, contextualising local realities within global scholarship on artificial intelligence, digital transformation, and data-driven climate resilience. The study argues that AI-powered climate analytics, precision agriculture technologies, blockchain-enabled supply chain management, and community-based digital early warning systems offer promising pathways for building climate resilience in vulnerable rural communities. Evidence is drawn from a descriptive survey of households in Mongu District, supplemented by global scholarly literature. Findings confirm that climate variability significantly reduces crop yields, food security, and household income, while identifying digital technology adoption, diversified livelihoods, and social capital as key resilience resources. Policy implications for government, civil society, and international partners are discussed.

Keywords — *Climate Change; Agriculture; Household Welfare; Zambia; Western Province; Artificial Intelligence; Digital Transformation; Climate Resilience.*

1. Introduction

The impacts of anthropogenic climate change on agricultural systems and rural household welfare in sub-Saharan Africa constitute one of the most urgent development challenges of the twenty-first century (Vettriselvan et al., 2026a; Shanthi et al., 2025). Rising temperatures, shifting precipitation patterns, increased frequency of extreme weather events, and prolonged droughts are systematically eroding the agricultural productivity foundations on which millions of rural households depend for food security, income, and livelihood stability (Ashifa, 2021a; Ranganathan et al., 2024). In Zambia, the Western Province has been identified as among the most climate-vulnerable regions, experiencing recurrent flood and drought cycles that devastate maize, cassava, and sorghum production the primary food and income crops for Mongu District communities (Vettriselvan & Anto, 2018). The emergence of artificial intelligence, machine learning, and digital innovation in agricultural and environmental management offers new possibilities for climate adaptation and resilience building in vulnerable rural communities (Arockia et al., 2025; Venice et al., 2025a). AI-powered climate modelling platforms, precision agriculture advisory systems, satellite-based crop monitoring tools, and blockchain-enabled agricultural supply chain management are transforming the landscape of climate-smart agriculture in technology-adopting contexts (Venice et al., 2025b; Akila et al., 2025). However, the translation of these technological advances into livelihood benefits for subsistence farmers in remote communities like those in Mongu District requires deliberate policy action, infrastructure investment, and community engagement strategies (Meena et al., 2025; Vettriselvan et al., 2025a). This article bridges the Zambian climate-agriculture nexus with global digital transformation scholarship, examining how AI and digital technologies can support climate resilience in vulnerable agricultural communities while acknowledging the structural barriers that currently limit such technology adoption.

2. Literature Review

2.1 Climate Change and Agricultural Vulnerability

The Intergovernmental Panel on Climate Change (IPCC) has documented that sub-Saharan Africa faces disproportionate climate change impacts relative to other world regions, with projections indicating significant declines in agricultural productivity under all warming scenarios (Vettriselvan et al., 2025b; Gayathri et al., 2025b). In Zambia, temperature increases of 1.5–2°C by 2050 are projected to reduce maize yields by 10–20%, with more severe declines in semi-arid regions such as Western Province (Ashifa, 2021b; Mohanbabu & Vettriselvan, 2025a). Flood events increasingly frequent due to climate change cause immediate crop destruction, soil erosion, and infrastructure damage that compound longer-term productivity declines (Ashifa, 2022; Vettriselvan & Rajan FSA, 2019). The household welfare impacts of agricultural

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climate shocks extend well beyond income loss to encompass food insecurity, malnutrition, asset depletion, health deterioration, and disruption of children's schooling (Ashifa, 2020a; Ashifa, 2020b; Ranganathan et al., 2024). Women and female-headed households are particularly vulnerable to climate-induced agricultural shocks, facing compounded disadvantage through gender-based constraints on land access, credit availability, and climate information access (Ashifa et al., 2019; Rasi & Ashifa, 2019; Vettriselvan & Anto, 2018).

2.2 AI and Digital Tools in Climate-Smart Agriculture

Artificial intelligence and machine learning have opened transformative possibilities for climate-smart agriculture, enabling unprecedented precision in crop monitoring, weather forecasting, soil analysis, and market price prediction (Venice et al., 2025a; Vasantha et al., 2025). AI-powered satellite imagery analysis platforms can detect early signs of crop stress, drought progression, and flood inundation at field level providing actionable information to farmers days or weeks before visible damage manifests (Arockia et al., 2025; Akila et al., 2025).

Mobile-based AI advisory applications deliver localised, contextually relevant agronomic recommendations to smallholder farmers, enabling real-time adaptation of planting decisions, irrigation management, and pest control practices in response to emerging climate conditions (Venice et al., 2025c; Swadhi et al., 2025a). Blockchain technology is being deployed in agricultural value chains to enhance supply chain transparency, reduce post-harvest losses, enable fair pricing for smallholder produce, and provide tamper-proof records of agricultural inputs and outputs (Venice et al., 2025d; Rajeswari et al., 2026). These capabilities have particular significance for climate-vulnerable agricultural systems, where transparent and equitable market access can partially offset productivity losses caused by weather shocks by connecting farmers to premium markets for climate-resilient crops (Venice et al., 2025e; Devi et al., 2025).

2.3 Social Capital, Community Resilience, and Digital Inclusion

Social capital the networks of trust, reciprocity, and collective action that bind communities together has been identified as a critical resilience resource for climate-affected agricultural households (Kariveliparambil et al., 2026a; Kariveliparambil et al., 2026b). Communities with strong social capital networks are better positioned to share climate risk through informal insurance mechanisms, pool agricultural labour and resources during peak seasons, and collectively advocate for government support during climate emergencies (Ashifa, 2019; Vettriselvan et al., 2025c). The integration of digital community platforms including mobile money systems, farmer cooperative management tools, and climate early warning alert networks can amplify the resilience functions of existing social capital while extending their reach to previously isolated community members (Venice et al., 2025a; Vinodh et al., 2026a). Digital inclusion imperatives require that climate technology adoption initiatives be designed with explicit attention to equity, ensuring that women, elderly individuals, persons with disabilities, and other marginalised community members are not excluded from the benefits of digital climate resilience tools (Meena et al., 2025; Ashifa, 2019; Vettriselvan et al., 2025d). Culturally appropriate design, local language content, and community-based facilitation are essential enabling conditions for equitable digital technology adoption in rural Zambian communities (Vettriselvan et al., 2025b; Gayathri et al., 2025a).

2.4 Health, Well-being and Climate Vulnerability

The health dimensions of climate change vulnerability are profound and multidirectional (Ashifa, 2020a; Zahoor et al., 2025; Elkin et al., 2025). Climate-induced agricultural shocks generate food insecurity and malnutrition, directly impairing physical health and cognitive development among children with cascading effects on educational participation and long-term human capital accumulation (Ashifa, 2021a; Ranganathan et al., 2024). Mental health impacts of climate disasters including anxiety, depression, and post-traumatic stress are increasingly documented among flood and drought-affected farming communities (Elkin et al., 2025; Zahoor et al., 2025). The emotional intelligence and self-leadership capacities of community members and local leaders are significant protective factors for psychosocial recovery following climate shocks (Zahoor et al., 2025; Vettriselvan et al., 2025a).

3. Methodology

This study employed a descriptive survey design to investigate the impacts of climate change on agricultural systems and household welfare in Mongu District, Western Province, Zambia. A mixed-methods approach combining household surveys, key informant interviews, and focus group discussions with farming community members was used (Kombo & Tromp, 2014; Orodho & Kombo, 2012). A stratified sample of 120 households was drawn from four selected farming communities, supplemented by purposive selection of 15 key informants including agricultural extension officers, local government officials, and community leaders. Quantitative household survey data were analysed using descriptive statistics and frequency distributions; qualitative interview and focus group data underwent thematic analysis with cross-reference to the scholarly literature.

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4. Findings and Analysis

4.1 Climate Change Experiences and Agricultural Impacts

The overwhelming majority of household respondents (92%) reported experiencing significantly more frequent and severe weather events over the past decade compared to earlier periods, consistent with documented regional climate change trends (Vettriselvan & Anto, 2018; Ashifa, 2022). Flooding was identified as the most impactful climate hazard by 68% of respondents, followed by drought (24%) and pest infestations associated with shifting climate conditions (8%). Average reported crop yield declines attributable to climate change ranged from 30–60% depending on crop type and specific location, with respondents in flood-prone areas reporting total crop loss in one or more seasons over the past five years (Ashifa, 2021b; Vettriselvan et al., 2025b).

4.2 Household Welfare Impacts

The household welfare consequences of climate-induced agricultural disruption were severe and multidimensional. Food insecurity affected 78% of respondent households in climate-shock years, with 45% reporting periods of meal reduction or elimination. Asset depletion including livestock sales, land mortgaging, and withdrawal of children from school was reported by 52% of households as a coping strategy during severe climate events (Ashifa, 2020a; Ranganathan et al., 2024). Women-headed households reported disproportionately severe welfare impacts, consistent with gender-differentiated vulnerability patterns documented in the regional literature (Ashifa et al., 2019; Vettriselvan & Anto, 2018).

4.3 Resilience Resources and Adaptation Strategies

Despite severe climate impacts, respondent households demonstrated significant adaptive capacity. Livelihood diversification including off-farm income generation, fishing, and petty trading was practised by 65% of households as a primary climate risk management strategy (Kariveliparambil et al., 2026a; Ashifa, 2019). Social capital networks particularly farmer cooperative membership, community savings groups, and kinship support systems provided critical informal insurance against climate shocks (Kariveliparambil et al., 2026b; Rasi & Ashifa, 2019).

Access to climate information primarily through radio and extension officer visits was reported by 40% of respondents, with mobile phone ownership (62%) identified as a potential platform for expanded digital climate advisory services (Venice et al., 2025a; Arockia et al., 2025).

4.4 Digital Technology Awareness and Adoption

Awareness of digital agricultural advisory services was low (18% of respondents), reflecting limited connectivity, digital literacy, and platform availability in the study area. However, interest in accessing digital climate and agricultural information through mobile devices was high (74%), indicating significant latent demand for digital climate resilience tools (Venice et al., 2025c; Vasantha et al., 2025). Community members who had accessed digital agricultural information primarily through extension officer-mediated platforms reported positive impacts on planting decisions and crop variety selection consistent with global evidence on mobile-based agricultural advisory effectiveness (Swadhi et al., 2025a; Akila et al., 2025).

5. Discussion

The findings from Mongu District communities present a compelling case for urgency in climate adaptation policy and investment in Zambia's Western Province. The severity of agricultural productivity losses and their cascading household welfare consequences encompassing food insecurity, asset depletion, health deterioration, and educational disruption underscore the inadequacy of current adaptation support for the most climate-vulnerable rural communities (Ashifa, 2022; Ranganathan et al., 2024; Vettriselvan et al., 2025a). The high mobile phone ownership rates and strong latent demand for digital climate information among respondent households identify mobile-based AI agricultural advisory services as the most immediately actionable digital technology pathway for climate resilience building in the study area (Venice et al., 2025a; Vasantha et al., 2025; Arockia et al., 2025).

The combination of AI-powered climate modelling, localised agronomic recommendations, and community-based digital facilitation represents a contextually appropriate and scalable approach to extending digital climate resilience tools to remote farming communities (Venice et al., 2025b; Swadhi et al., 2025a). The gender dimensions of climate vulnerability documented in this study demand explicit attention in adaptation policy design. Women farmers' constrained access to land, credit, markets, and information compounded by their disproportionate vulnerability to climate shocks requires targeted interventions that address both the structural barriers to women's agricultural participation and the climate change impacts that exacerbate existing gender inequalities (Ashifa et al., 2019; Vettriselvan & Anto, 2018; Meena et al., 2025).

6. Conclusion and Recommendations

This article has examined the impacts of climate change on agricultural productivity and household welfare

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in Mongu District, Western Province, Zambia, connecting local empirical evidence with global scholarship on AI, digital transformation, and climate resilience. The findings confirm severe and multidimensional climate impacts on rural livelihoods, while identifying significant assets including mobile connectivity, social capital, and adaptive capacity that policy can leverage for resilience building. The following recommendations are offered: (1) The Government of Zambia should establish a national digital climate advisory platform delivering AI-powered, localised agronomic recommendations through mobile devices in local languages (Venice et al., 2025a; Arockia et al., 2025); (2) gender-responsive climate adaptation programmes should be designed and funded to address the specific vulnerabilities of women farmers in Western Province (Ashifa et al., 2019; Vettriselvan & Anto, 2018); (3) farmer cooperative digital management platforms should be established to strengthen social capital networks and facilitate collective climate risk management (Kariveliparambil et al., 2026a; Venice et al., 2025c); (4) blockchain-enabled agricultural supply chain platforms should be deployed to improve smallholder market access and price transparency (Venice et al., 2025d; Rajeswari et al., 2026); and (5) climate early warning systems integrating AI satellite monitoring with community radio networks should be established in climate-vulnerable districts (Shanthi et al., 2025; Devi et al., 2025).

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