The Nexus between Climate Change, Agricultural Productivity and Economic Growth in Zimbabwe: An Econometric Analysis

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ABSTRACT

This study examines the nexus between climate change, agricultural productivity, and economic growth in Zimbabwe over the period 1990 to 2024. The study was motivated by the increasing vulnerability of Zimbabwe's agriculture-dependent economy to a changing climatic environment which continues to affect agricultural output and economic performance. Using time-series econometric techniques including ARDL and VAR with FEVD, the research explores the relationship between climate variables, agricultural productivity, and GDP growth to understand how climate shocks transmit through the agricultural sector into the broader economy. The findings suggest that climate change has an important influence on agricultural productivity, and that changes in agricultural output are associated with variations in economic growth. The study further indicates that agriculture remains a significant channel through which climate conditions may affect the overall economy. It therefore concludes that climate change presents a serious challenge to sustainable growth in Zimbabwe, especially in the context of continued reliance on rain-fed agriculture. Based on these findings, the study recommends increased investment in irrigation infrastructure, promotion of climate-smart agricultural practices, and stronger support for smallholder farmers.

Keywords: Climate Change, Agriculture, Productivity, Economic Growth, ARDL Model

INTRODUCTION

It is no secret that climate change has become a global "talk of the season" since the industrialization era, which led to sustained anthropogenic pressure on the global climate system. According to the **IPCC,** the United Nations body for assessing climate science, global anthropogenic GHG emissions increased by **about 70% between 1970 and 2004** (Shukla et al., 2022)**.** Through international agreements such as the recent Paris Agreement of 2015, in which countries are obligated to set NDCs in line with the global goal to reduce warming to 1.5ºC by 2030, we have seen them pivoting to greener methods of production to curb the long-term present effects of a warmer earth (UNFCCC, 2015). Developing nations though being the least contributors to exacerbated climate change, with Africa only contributing 3% to global emissions, suffer the most as they lack the adaptive capacity required to mitigate and prevent the effects of climate change (UNFCC, 2006). Despite needing approximately $1.6 trillion between 2022 and 2030 to meet its NDCs, Africa loses up to 15% of its GDP per capita growth to climate change and its related impacts (AFDB, 2022). This indicates a feedback loop between climate change and economic growth, were economic growth influences climate change and climate change influences economic growth. Zimbabwe has observed fairly stable climatic conditions over the years, however research from the past three decades indicates significant climatic shifts, notably the onset of the ENSO, alternating between El Nino and La Nina over seven year climate patterns (Manatsa *et al.*, 2010). Institutional reports such as, World Bank (2024), document the temperature induced premature ending of growing seasons. This transition poses an existential threat to rain-fed agricultural systems, particularly in the semi-arid agro-ecological regions III, IV and V where there is an extremely limited safety margin.

Over the centuries, agricultural productivity has evolved from the Neolithic revolution through the industrial revolution which reduced the labour required for production, to the modern era characterized by biotechnology and genetic modification (History Guild, 2025). This evolution shifted the primary drivers of growth from land and labour to efficiency-led productivity. Consequently, the period 1961 to 2020 saw vast transformations in the global agricultural sector in areas such as production, productivity and resource use, with output increasing by nearly fourfold (Jelliffe,et al, 2024). In the 1960s agriculture was evenly divided between the global north and the global south, however, since the 1980s agriculture has been expanding more rapidly in the global south, driven by rising world population, shifts in food demand, technological advancements and policy changes. Data from 2020 shows that the global south accounted for 73% of agriculture production a significant increase from 44% in 1961 (Jelliffe,et al, 2024). Reliance on agriculture is particularly acute in the SADC region as up to 90% of member states, rely heavily on the Agricultural sector for employment, livelihoods, and GDP contribution, with agriculture making up 17% of Zimbabwe's GDP and 60-70% of the employed are in agriculture (FAO, 2026). Agricultural processes require constant rainfall patterns and temperatures, and the effects of climate change have led to erratic rainfall, with dry spells, droughts, and floods (Pindiriri *et al.*, 2024). However, this critical economic pillar remains highly vulnerable to climate shocks that now characterize the modern agricultural landscape. Ultimately, the stability of regional economies remains inextricably linked to the sector's ability to adapt to these environmental pressures.

In theory, economic growth is broadly categorized as a process of structural transformation (Busse,et al, 2018). Resources move from low-productivity traditional sectors such as agriculture to high productivity modern sectors such as technology and manufacturing, this shift is often referred to as the Kuznetsian theory (Herrendorf and Rogerson, 2013). Advanced economies are seen to follow this clear path while the majority of modern developing nations particularly in Sub-Saharan Africa experience a different trend (Getnet, *et al,* 2024). In SSA growth is frequently characterized by reliance on comparative advantage in the primary production sector, they remain in a structurally underdeveloped or structurally developing phase where agriculture contributes significantly to employment averaging between 43% and 77% (World Bank, 2025). This reliance is especially pronounced in Zimbabwe with agriculture employing about 70% of the population (Ministry of Foreign Affairs and Economic Development, 2025).

Climate change has emerged as a defining global and developmental challenge, with disproportionately severe consequences for agriculture-dependent economies. While global efforts to mitigate emissions continue, developing countries such as Zimbabwe remain highly vulnerable due to limited adaptive capacity and a strong reliance on climate-sensitive sectors. The agricultural sector, despite its historical evolution and central role in employment and GDP, faces increasing instability from shifting climatic patterns. At the same time, the structural transformation pathways typically associated with economic growth remain incomplete in many Sub-Saharan African economies, where agriculture continues to dominate. This creates a crucial intersection between climate change, agricultural productivity, and economic growth, underscoring the need for empirical investigation into how climate variability affects agricultural performance and, in turn, influences the trajectory of economic growth in Zimbabwe.

Recent empirical literature on Zimbabwe and Sub-Saharan Africa presents mixed conclusions regarding climate-growth dynamics. Scholars such as Pindiriri et al. (2024) and Dhobha et al. (2025) note severe localized rural vulnerability, while regional empirical evidence from Khalifa (2025) in Tunisia and Ekpenyong & Ogbuagu (2015) in Nigeria highlights non-linear transmission channels of heat and rainfall volatility to GDP. However, existing Zimbabwean studies often rely on static Ricardian cross-sections or unidimensional OLS frameworks (Chenjerai & Pasara, 2025). These approaches overlook temporal cointegration, structural breaks, and the exact volatility contribution of climate shocks across macro-sectors.

The fundamental problem underlying Zimbabwe's macroeconomic trajectory is the high degree of sensitivity between climate-induced agricultural volatility and national economic growth. Agriculture's contribution to the country's GDP remains volatile, with a declining trend from 2008 (19%) to 2024 (8.7%) (World Bank, 2026). Despite agriculture being the primary engine of the economy, the sector remains extremely vulnerable to erratic climatic variables creating a destabilizing feedback loop, where environmental shocks at the farm level translate into systemic contractions in Gross Domestic Product (Pindiriri, et al.,

2024). While this affects the entire macroeconomic structure through the government's fiscal balance and disruptions in the manufacturing sector, smallholders are the primary victims of this volatility through disrupted incomes and food security, while the former are only secondary victims. Agricultural output remains volatile as a result of over-reliance on rain fed agriculture, particularly in vulnerable semi-arid agro-ecological regions IV and V (Mwadzingeni,et al, 2025). In 2019 over 21 000 cattle died due to drought prolonged water and feed shortages (FAO, 2020). To capture major shifts including structural adjustments through land reforms and significant drought cycles the study covers the period 1990-2024. To address this instability, this study quantifies the long-run co-integrated relationship and short-run dynamics between climate variables, agricultural productivity, and national output. By applying rigorous statistical tools, the research aims to disentangle the specific transmission channels of climate shocks, providing the empirical foundation needed to de-link Zimbabwe's economic growth from environmental unpredictability.

To address these empirical gaps, this study is guided by the following research questions and hypotheses:

1. Do climate variables have an effect on agricultural productivity in Zimbabwe?

   H_{01}: Climate variables do not have a significant effect on agricultural productivity in Zimbabwe.

2. Does agricultural productivity affect economic growth in Zimbabwe?

   H_{02}: Agricultural productivity does not have a significant effect on economic growth in Zimbabwe.

3. Does agricultural volatility influence economic growth fluctuations in Zimbabwe?

   H_{03}: Agricultural volatility does not significantly influence economic growth fluctuations in Zimbabwe.

LITERATURE REVIEW

Relationship Between Climate Variables and Agricultural Productivity

De Lima et al (2021) took the unconventional route in analysing the impacts of climate change on agriculture. Where the majority of research analyses climate change impacts through the usual direct crop-response channels such as rainfall, temperature, or yield models, they took an indirect labour-mediated approach. The authors found that heat stress on agricultural workers increases the impact of climate change on crops. Their study uses GTAP, a CGE model, modifying it so that agricultural labour productivity solely depends on physiological heat stress limits. Results showed a strong negative effect in North Africa, the Middle East and the Indian sub-continent. In Zimbabwe agriculture is labour intensive, high temperatures during peak farming periods may not only affect the biological process of crops but rising temperatures also constrain physiological capacity of agricultural workers, reducing working hours, lowering efficiency thereby worsening yields indirectly. De Lima et al *(*2021) accounted for the increased labour employment during these periods and still found that agricultural productivity declined significantly, a result that may be attributed to the employment of unskilled labour to compensate for heat induced efficiency losses.

Due to the non-stationary nature of macroeconomic data, Ekpenyong and Ogbuagu (2015) employed an ARDL model to robustly estimate the long-term impact of climate variables on Nigerian agriculture. Their empirical results indicate a significant negative correlation, where a 100% increase in carbon emissions, a proxy for broader climate shifts, precipitated a 22.26% decline in productivity. Given that carbon emissions are a key driver of temperature increases and precipitation variability, their results provide indirect but strong evidence of the climate–agriculture nexus central to this study. Ozone layer depletion is driven by GHG emissions including carbon, further exacerbating rising temperatures which affect traditional crop production in developing countries such as Zimbabwe. In contrast (Khalifa, 2025) using a similar model found that rainfall had negative effects on Tunisia's GDP. The study showed that an increase in rainfall from the previous year had a notable negative impact on GDP per capita. This solidifies the notion that excessive rainfall can lead to adverse outcomes such as crop destruction, flooding and soil erosion all of which reduce crop yields, weakening agricultural performance. In Zimbabwe, where rainfall patterns have become increasingly erratic,

such dynamics may disrupt planting and harvesting cycles, further constraining productivity. Taken together, these studies highlight that while climate variables are critical determinants of agricultural productivity and economic performance, their effects are context-specific and may be non-linear. This justifies the need for country-specific time series analysis, as undertaken in this study, to better understand the climate–agriculture–growth nexus within Zimbabwe's unique environmental and economic conditions.

Contribution of Agricultural Output to Economic Growth

Khalifa (2025) employs VAR and ARDL models to investigate the impact of climate change, agricultural productivity and food security on economic growth in Tunisia for the period 1990-2022. Results revealed that agricultural productivity from previous years significantly contributed to the country's short term and long-term economic growth**.** Agricultural productivity accounted for the largest share of economic growth variability with a strong influence of up to 77% long term. **Mirroring the agricultural landscape of Zimbabwe**, Tunisia's sector is predominantly rain-fed, leaving it highly exposed to the effects of climate change. Consistent with previous research, this study uses agriculture, forestry, and fishing value-added (% of GDP) to proxy agricultural productivity (Khalifa, 2025) concluded that the immediate effects of agricultural factors on economic growth may not be apparent, however the long term impacts are significantly positive. This highlights the need for strategic and sustained interventions in the sector.

Chenjerai and Pasara (2025) empirically examined the contribution of agriculture output to economic growth in Zimbabwe from the period 1980-2018 using Ordinary Least Squares (OLS). They went on to extend their analysis by performing Johansen cointegration tests to capture long-run dynamics. While they concluded that agriculture and growth are closely linked, their OLS-based analysis does not include an error-correction mechanism that would help detect structural inefficiencies in Zimbabwe. As a result, their findings may place too much emphasis on the stability of this relationship, while overlooking the short-run volatility and productivity constraints that this study examines in greater depth.

Runganga and Mhaka (2021) noted that in order to achieve inclusive growth, there is need for African countries to enhance labour-intensive agricultural production due to the abundance of natural resources and labour in these areas. While promoting short-term inclusivity, continuing on this path may hinder long-term development by entrenching low-productivity and delaying structural transformation. Similar to (Ekpenyong and Ogbuagu, 2015; Dumrul and Kilicaslan, 2017; Khalifa, 2025) they also used the ARDL model in their study of the impact of agriculture on economic growth in Zimbabwe from 1970-2019. However unlike (Khalifa, 2025) their results showed a significant positive short term impact of agriculture on economic growth with no impact in the long-run. This may be due to context specific dynamics, where agriculture acts as an immediate economic driver in Zimbabwe through employment and income generation. The lack of a long run relationship is likely due to structural constraints, common issue in the Zimbabwean context. These contrasting findings, despite the use of similar ARDL methodologies, suggest that the agriculture–growth relationship is highly context-dependent, with agriculture contributing to short-term economic expansion but lacking the structural capacity to sustain long-run growth in the absence of productivity improvements and broader economic transformation.

Agricultural Output Volatility and GDP Growth

Salako et al (2015) and (Khalifa, 2025) utilize Forecast Error Variance Decomposition (FEVD) within a VAR framework to demonstrate that agricultural output shocks are a primary driver of macroeconomic volatility in developing economies, often accounting for a significant portion of GDP fluctuations. Salako et al (2015) found that in the short run agriculture accounted for about 28.11% and 27.36% of variation in real GDP growth between year 3 and 4 respectively. This value slowly declined with agriculture accounting for 22.85% of variation in GDP by year 10. These findings suggest the sector's influence is more potent in the immediate short-run and gradually dissipates in the long run before stabilizing. While (Salako *et al.*, 2015) observed a slow decline in variance contribution by year 10, the high degree of rain-fed dependency in Zimbabwe may result in a more persistent volatility signature**.** On the other hand (Khalifa, 2025) results underscore the dominant role of agricultural production which accounted for 80.14% of the variance in GDP in year 2 and

maintained a strong influence of 73-77% in the long run. Their findings indicate that agricultural productivity shocks act as causal precursors to broader economic instability, with persistent effects on GDP growth over multiple periods.

Kahn et al (2021) in their study on the long-term effects of climate change on economic activity, found that persistent deviations from its historical norm could reduce global GDP per capita by 7.22% by 2100, in their use of stochastic models they found that even advanced economies are not immune to these growth contractions. Developing countries often face the brunt end of the stick with limited funds being directed towards repair rather than investment and lower adaptive capacity. Evidence is shown in research by (Diffenbaugh and Burke, 2019) where they found that climate change has already decreased GDP per capita by up to 30% in developing nations over the last half-century, relative to developed nations. This offers a historical projection indicating that agrarian economies are likely to diverge further from developed economies in the future. Literature shows that climatic volatility acts as a primary innovation driving macroeconomic instability, with persistent temperature deviations inducing negative impulses on GDP, particularly within agrarian economies. Research indicates that climate-induced volatility has already significantly reduced GDP per capita in developing nations over the past half-century.

World Bank (2024) Zimbabwe's Country Climate and Development Report (CCDR), used CGE and forecasted that climate change could result in up to 12% reduction in Zimbabwe's GDP by 2050. This modelling demonstrates that micro-level agricultural shocks, such as maize yield failures and heat stress, directly translate into systemic macroeconomic contractions. By focusing on innovation accounting, this analysis quantifies how agricultural instability drives national output fluctuations.

The empirical evidence highlights that the relationship between agricultural performance and macroeconomic stability is not merely a matter of output levels, but one of volatility transmission. By employing FEVD, the reviewed literature establishes that a substantial portion of the unpredictability in national output, ranging from the short-run shocks observed by (Salako *et al.*, 2015) to the overwhelming long-run dominance found by (Khalifa, 2025), is fundamentally rooted in agricultural innovations. Utilizing FEVD in this study provides the necessary innovation accounting to quantify the specific weight of agricultural instability within Zimbabwe's growth path, shifting the policy narrative from simple growth targets to the critical need for structural resilience against climate-driven volatility.

Insights from Literature

A broad consensus within empirical literature confirms that agricultural productivity is a primary driver of economic growth in developing nations, with scholars such as Abidoye and Odusola (2015) and Nhemachena (2014) demonstrating that climatic variability exerts statistically significant negative pressure on national output. However, existing literature is heavily dominated by regional panel data studies that aggregate diverse African economies, a "one-size-fits-all" approach that risks smoothing over the acute structural breaks defining Zimbabwe's specific economic trajectory. As Shonhe (2022) highlights, post-2000 Zimbabwe underwent a fundamental reconfiguration of its agrarian structure through the Fast-Track Land Reform Program (FTLRP) and subsequent macroeconomic crises, creating unique accumulation patterns that diverge sharply from regional averages and necessitate a country-specific time-series analysis (1990–2024) utilizing structural dummy variables.

Crucially, localized studies on Zimbabwe exhibit a profound methodological divide that limits dynamic macroeconomic evaluation. Most existing research relies on either static Ricardian models or standard OLS regressions (e.g., Dhobha et al., 2025); Ricardian models are essentially time-blind cross-sectional frameworks that cannot account for temporal evolution or sudden climatic shocks, while OLS frameworks suffer from spurious regression risks due to macroeconomic non-stationarity and remain "nexus-blind" to lagged feedback loops. To resolve this, this study transitions to a multivariate Autoregressive Distributed Lag (ARDL) bounds-testing framework to capture dynamic short-run responses, long-run cointegrated relationships, and the speed of adjustment back to equilibrium via the Error Correction Term following a climate shock.

Furthermore, current Zimbabwean literature reveals a critical empirical disconnect between prospective institutional policy simulations and historical reality. While high-level CGE models (e.g., World Bank, 2024) provide useful projections, their reliance on static theoretical calibrations lacks empirical memory, failing to reflect how the economy historically absorbs non-linear shocks. Unidimensional time-series models offer little relief, as univariate ARIMA specifications remain climate-blind and GARCH models focus strictly on internal variance persistence. Shifting the analytical lens to Vector Autoregression (VAR) allows climate-driven agricultural fluctuations to enter as dynamic internal innovations that ripple across interconnected macroeconomic sectors.

Ultimately, this study fills the existing "quantification gap" by employing Forecast Error Variance Decomposition (FEVD) alongside Impulse Response Functions (IRFs) to move beyond simple directional causality (Charles, 2014; Runganga & Mhaka, 2021; Dhobha et al., 2025). By anchoring FEVD analysis in 34 years of historical data (1990–2024), the study provides a data-driven "volatility footprint" that measures the exact magnitude and duration of agricultural shocks on GDP. This ensures that the evaluation of Zimbabwe's economic vulnerability is not an abstract theoretical exercise, but an accurate diagnostic grounded in the country's proven historical patterns of transmission.

RESEARCH METHODS

Data Collection and Sources

The study focuses on the national economy of Zimbabwe. The analysis is conducted at a macroeconomic aggregate level using national data and not regional or household data. This is particularly essential in assessing the overall impact of climate variables on the country's national agricultural output and GDP. The data for the study was obtained from a combination of online databases including FAOSTAT, World Development Indicators (WDI) and ZIMSTAT. Table 1 shows the data that was used, description for each variable and the source from which it was obtained.

Table 1: Sources of Data

Variable	Description	Source
Economic Growth	GDP (Annual % Growth)	WDI
Agricultural Productivity	Agriculture, forestry and fishing Value Added (constant USD 2015)	WDI
Temperature	Temperature Change on Land	FAOSTAT
Average Temperature	Average mean surface air temperature	CCKP
Rainfall	Annual Rainfall	ZIMSTAT
Gross Fixed Capital Formation	Gross Fixed Capital Formation (Constant USD 2015)	WDI
Fertilizer Consumption	Kg/hectare of arable land	WDI
D_{2008}	Dummy for 2008 Hyperinflation	–
D_{Shocks}	Dummy GNU and monetary policy shocks from 2009	–

Annual rainfall data was derived by aggregating monthly national rainfall Statistics sourced from ZIMSTAT (2023) Environmental Statistics Report, originally compiled by the Zimbabwe Meteorological Services Department. Theoretical justification for variable selection is grounded in standard macroeconomic and production functions (Solow, 1956; Romer, 1990). Capital accumulation (GFCF) and agricultural input intensification (Fertilizer) represent core drivers of factor productivity. Rainfall and temperature enter the production framework as exogenous environmental constraints directly altering crop yield function capacity in rain-fed agricultural systems. To account for severe macro-structural dislocations over the 1990–2024 sample period, structural dummy variables are incorporated. D_{2008} captures hyperinflationary macroeconomic collapse and agricultural disruptions associated with agrarian restructuring, while D_{Shocks} controls for post-2009 multi-

currency transitions and systemic policy adjustments. Additionally, severe recurrent ENSO drought episodes (e.g., 1991/92, 2008, 2015/16, 2019, 2023/24) are controlled for within climatic anomaly metrics.

Analysis of Climate Variables and Agricultural Productivity in Zimbabwe

To investigate the long-run relationship between climate variables and agricultural productivity, this study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran et al (2001). This model is chosen for several key advantages including its robustness in providing unbiased estimates of the long-run coefficients even with a small sample size. The model can be applied regardless of whether the variables are purely I(0), purely I(1), or a mixture of both, which is the case in this study. In addition, it estimates both the long-run and short-run dynamics of the relationship simultaneously through an Error Correction Model (ECM). The general linear functional form is specified as follows:

$$Yield_t = \beta_0 + \beta_1 Rainfall_t + \beta_2 Temp_t + D_{2008} + \varepsilon_t$$

Where:

- $Yield_t$ is the dependant representing cereal yield per hectare.
- β_0 is the intercept. Representing the value of agricultural productivity wen all explanatory variables are equal to 0.
- $Temp_t$ is change in temperature on land representing temperature anomaly.
- $Rainfall_t$ annual Rainfall (mm). This captures the total water availability for rain-fed farming systems.
- β_1 *and* β_2 are coefficients
- D_{2008} *is the dummy variable for the 2008 hyperinflation shock*
- ε_t is the stochastic error term, capturing all other factors that influence productivity not included in the model.

The ARDL is suitable for small sample sizes ($N = 34$) and robust when handling variables integrated of mixed orders [$I(0)$ and $I(1)$] without requiring pre-testing unit root parity. ARDL simultaneously isolates long-run equilibrium relationships and short-run dynamic error-correction mechanics (ECT).

Analysis of Agricultural Contribution to Zimbabwe's GDP Growth (1990–2024)

To measure the contribution of agriculture to GDP, there is need for a model that can capture both short-run impacts and long-run relationships. The ARDL model is most suited for this. By specifying GDP as the dependent variable, we can directly estimate the effect of agricultural output on economic growth. This approach is flexible, works well with variables that have different orders of integration, specifically, I(1) and I(0), and is robust for small sample sizes.

A bounds test will be conducted to confirm that a stable long-run relationship exists where agriculture contributes to GDP. If cointergration is confirmed, an estimation of the long-run coefficient for agriculture (λ_2) is done to quantify its contribution to GDP. Short-run coefficients are analysed to understand the immediate impacts. The model is structured to explain GDP growth using agricultural performance, while also controlling for other factors like technology/agricultural inputs, investment and historical shocks.

$$\text{GDP_g} = \beta_0 + \lambda_1 GDP_g_{t-1} + \lambda_2 Yield_t + \lambda_3 \text{Fertilizer} + \lambda_4 \text{GFCF} + \lambda_5 D_{2008} + \lambda_6 D_{Shocks} + \varepsilon_t$$

Where:

- GDP_g is GDP growth rate
- GDP_g_{t-1} is GDP growth from the previous period
- $Yield$ is cereal yield(kg/hectare)
- Fertilizer and GFCF are control variables
- D_{2008} *and* D_{Shocks} are dummy variables representing shocks to the economy
- $\lambda_1, \lambda_2 \lambda_3, \lambda_4, \lambda_5$ *and* λ_6 are coefficients and β_0 is the intercept

- ε_t is the stochastic error term, capturing all other factors that influence productivity not included in the model.

Analysis of the Impact of Agricultural Volatility on GDP Growth

To evaluate the transmission of climatic volatility into Zimbabwe's macro-economy, this study employs a VAR framework integrated FEVD. The VAR model is uniquely suited for this objective as it captures the dynamic interdependencies between sectoral variables, allowing us to observe how a shock in one area ripples through the entire system. By applying FEVD to this VAR system, the study performs innovation accounting. This allows the research to move beyond simple forecasting and instead decompose the total uncertainty in Zimbabwe's GDP growth to quantify exactly what percentage of economic instability is attributable to agricultural volatility. The VAR model can be represented as a system of equations as follows:

$$GDPt = \propto_0 + \sum_{i=1}^{p} \propto_{1i} GDP_{t-1} + \sum_{i=1}^{p} \propto_{2i} d_{Agric_{VA_{t-1}}} + \beta_1 d_{Rainfall} + \beta_2 Avg_{temp} + d_GFCF_{t-1}\gamma_2 D_{Shocks} + \varepsilon \quad (1)$$

$$Agric_{VA_t} = \theta_0 + \sum_{i=1}^{p} \theta_{1i} d_{Agric_{VA_{t-1}}} + \sum_{i=1}^{p} \theta_{2i} GDP_{t-1} + \beta_3 d_{Rainfall} + \beta_4 Avg_{Temp} + \gamma_2 D_{Shocks} + \varepsilon_2 \quad (2)$$

Where**:**

- $GDPt$ and $Agri_VAt$ are current values of Economic Growth and Agricultural Productivity.
- GDP_{t-1} and $d_Agric_VA_{t-1}$ are the lagged values showing the memory of the economy, like how much last year's harvest can affect this year's GDP.
- $Rainfall$ and $Temp$ are control variables appearing in both equations as climate affects both specific farming output and the overall national economy simultaneously
- $\propto_0$ and θ_0 ae intercepts
- D_{Shocks} is a structural dummy to ensure the model isn't biased by the monetary policy changes from 2009 going forward.
- $\varepsilon \; and \; \varepsilon_2$ represent the error terms
- $\beta_1, \beta_2, \beta_3 \; and \; \beta_4$ are coefficients

To ensure the FEVD is valid, a Cholesky decomposition is applied to the covariance matrix. The ordering reflects theoretical assumptions about which variable shocks first. In this study, the logical ordering based on the conceptual framework is**:** Agric_VA then GDP_G.

While ARDL establishes directional co-integrating vectors and short-run dynamics, VAR-FEVD handles endogeneity across systemic macroeconomic sectors. FEVD provides innovation accounting to measure the exact percentage contribution of agricultural and climate shocks to national GDP uncertainty over multiple forecast horizons. Optimal lag lengths for the ARDL and VAR models were selected based on the Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) to minimize dynamic specification error while preserving degrees of freedom.

RESULTS AND DISCUSSION

Climate Variables and Agricultural Productivity in Zimbabwe

Table 2: Stationarity Test

Variable	ADF Statistic	Lag Order	Stationarity	Levels I(0)	1st DifferenceI(1)
yield	-1.4083	2	Stationary I(1)	0.5654	0.000*
rainfall	-2.1438	2	Stationary I(1)	0.2299	0.000*

temp	-5.7275	2	Stationary I(0)	0.000*	–

The ADF test results show yield and rainfall stationary at first difference and temp stationary in levels indicated by the p-value<0.05, which allows us to reject the null hypothesis of unit root present.

Table 3: Residual Diagnostics

Test	F-Statistic	Prob.Value
Normality(Jarque-Bera)	0.18171	0.9131*
Serial Correlation(LM Test)	1.121188	0.2276*
Heteroscedasticity(Breusch-Pagan)	0.464326	0.8006*
CUSUM-Q	Stable	–

For residual diagnostic tests, the null hypothesis typically assumes that model assumptions hold. Consequently, a p-value > 0.05 indicates a failure to reject the null hypothesis. For example, in the Breusch-Pagan test, H_0 assumes homoscedasticity. Since all test results yielded p-values above 0.05, there is no significant evidence against the model assumptions at the 5% level. The model is considered dynamically stable because the plot of the cumulative sum of squared residuals stays within the 5% critical boundaries. This indicates that there are no structural breaks in the variance and the parameters remain constant throughout the study period.

Table 4: Bounds Test

F- Statistic	Lower Bound I(0)	Upper Bound I(1)
7.3143	3.1	3.87

The calculated F-statistic of 7.3143 is significantly greater than the upper bound critical value of 3.87 at the given significance level. Following the decision rule established by (Pesaran,et al, 2001) we reject the null hypothesis of no cointergration. This indicates that a stable, long-run equilibrium relationship exists between agricultural output and climate variables.

Table 5: ECM Regression

Variable	Coefficient	Standard Error	t Statistic	Pvalue
d(Rainfall)	0.4702	0.2714	1.7324	0.0960*
d(Rainfall(-1))	0.9630	0.2159	4.4600	0.0002*
d(Temp)	-165.3625	75.8638	-2.1797	0.0393*
d_2008	-546.3955	217.4869	-2.5123	0.0191*
CointEq(-1)*	-0.7487	0.1305	-5.7371	0.0000*
Adjusted R^2 = 0.77 Significance: 0.05 = ''*				

All variables in the model are statistically significant at the 5% level, meaning we can reject the null hypothesis of no cointergration with 95% confidence. The ECT (CointEq) with a coefficient of -0.75 is negative and highly significant. This confirms a long-run relationship exists between climate variables and agriculture output. Current rainfall has a weak effect with a coefficient of 0.47, but lagged rainfall is a stronger, positive driver of agricultural output. Temperature has a significant negative impact, as temperature rises, cereal yield tends to decline. The dummy variable for 2008 hyperinflation shows a significant negative shock to agricultural output. The adjusted R^2 of 0.77 means the model explains 77% of the variation in the dependent variable, after accounting for the number of predictors. This indicates a very high goodness-of-fit.

The ARDL bounds test results show the F-Statistic 7.31 > I(1) at 5% significance level. This is strong evidence to reject the null hypothesis H_{01}, confirming the existence of a long run relationship between climate variables and agricultural productivity in Zimbabwe. The ECT of -0.75 is negative and highly significant indicating a strong and rapid adjustment to equilibrium of 75% following short-run shocks. This demonstrates stable and

efficient convergence without overshooting, in contrast with expectations of unstable dynamics in climate-dependent systems (Dell, Jones and Olken, 2012; Pindiriri, *et al.*, 2024), where |ECT| > 1 often signals rebound effects in rain-fed agriculture. The moderate ECT magnitude suggests Zimbabwean farmers exhibit some smoothing capacity through informal coping mechanisms including crop diversification, sale of assets, non-farm incomes and some form of limited irrigation, preventing extreme output volatility. This rapid yet controlled adjustment similar to (Salako *et al.*, 2015) 72%, reflects agricultural sector resilience despite rain-fed dominance in regions IV and V. Stable convergence indicates agriculture's shock absorption capacity, supporting its role as a reliable growth transmission channel rather than a destabilizing volatility source.

Short-run dynamics reveal immediate temperature effects with a one unit increase in temperature resulting in a –165 units change in cereal yield, other factors held constant. Alongside the negative temperature effects is strong lagged rainfall recovery with a one unit increase in rainfall from the previous year resulting in 0.96 units increase in yield in the current period. This contrasts with (Schlenker and Lobell, 2010) who found that temperature impacts materialize over crop growth cycles with lagged effects. The immediate temperature response in Zimbabwe reflects acute heat stress on crops during critical growth phases, rather than cumulative biological damage. Kahn et al (2021) suggest that in some agrarian contexts, these temperature effects can become permanent through soil degradation.

Similar to Abidoye and Odusola (2015) findings where total annual rainfall was a significant positive driver across Africa, lagged rainfall effects are positive and statistically significant. Current rainfall shows marginal immediate effects with a unit increase in rainfall in the current period resulting in a 0.46 unit increase in cereal yield. As supported by (Shonhe, 2022) the 2008 crisis shows a negative and statistically significant coefficient indicating that the shock significantly reduced agricultural output. Overall, the results confirm that climate variables are cointegrated with agricultural productivity, leading to the rejection of H_{01}. However, the nature of this relationship in Zimbabwe is complex, non-linear, and influenced by adaptation and structural instability.

Agricultural Contribution to Zimbabwe's GDP Growth (1990–2024)

Table 6: Stationarity Test

				P-Values (p<0.05*)	
Variable	**ADF Statistic**	**Lag Order**	**Stationarity**	**Levels I(0)**	**1st DifferenceI(1)**
Gdp_g	-3.7097	0	StationaryI(0)	0.0084	–
Agriculture_va	-1.5713	0	StationaryI(1)	0.4860	0.0001
Fertilizer	-2.2582	0	StationaryI(1)	0.1909	0.0000
GFCF	-2.6143	0	StationaryI(1)	0.1622	0.0000

The ADF test results indicate a mix of I(0) and I(1) variables at 5% significance level, p<0.05. GDP is stationary at levels while agriculture_va, fertilizer and gfcf are stationary at first difference. These results justify the use of an ARDL framework rather than a standard Johansen Cointegration Test.

Table 7: Residual Diagnostics

Test	**F-Statistic**	**Prob.Value**
Normality(Jarque-Bera)	1.8333	0.3998
Serial Correlation(LM Test)	0.7445	0.3467
Heteroscedasticity(Breusch-Pagan)	1.2898	0.2714
CUSUM-Q	Stable	–

The model passes all standard diagnostic checks at the 5% significance level, as all p-values are greater than 0.05. The residuals are normally distributed and there is no evidence of serial correlation, meaning error in one period are not related to error in another. There is no evidence of heteroscedasticity ensuring that standard error is reliable. The model parameters are stable over time, confirming there are no structural breaks in the data, shown in Appendix B.

Table 8: Bounds Test

F- Statistic	Lower Bound I(0)	Upper Bound I(1)
8.1970	2.79	3.67

The calculated F-statistic of 8.1970 is significantly greater than the upper bound critical value of 3.67 at the given significance level. Following the decision rule established by (Pesaran,et al, 2001) we reject the null hypothesis of no cointegration. This indicates that a stable, long-run equilibrium relationship exists between the dependent and independent variables, allowing us to proceed to ECM estimation.

Table 9: ECM Regression

Variable	Coefficient	Standard Error	t Statistic	Pvalue
d(GDP_G(-1))	0.2333	0.1061	2.1987	0.0382*
d(agriculture_va)	$1.69x10^8$	$3.09x10^9$	5.4678	0.0000*
d_2008	-8.1997	5.2848	-1.5515	0.1344
d_shocks	-2.6095	1.3193	-1.9778	0.0601
CointEq(-1)*	-0.7715	0.1112	-6.9363	0.0000*
Adjusted R^2 = 0.75 Significance: 0.05 = ''*				

The ECM coefficient of -0.77 is negative and highly significant confirming a long-run relationship and fast adjustment to equilibrium following a shock. The previous period's GDP growth has a significant positive effect on the current dependent variable. Agriculture_VA has a positive and highly significant impact suggesting it is a major short-term driver of growth. The shock dummies are both statistically insignificant, indicating that that they did not have a measurable short-term impact in this model. The adjusted R^2 of 0.75 indicates that the model explains 75% of the variation in the dependent variable, representing a strong fit for an error correction model.

Table 10: Levels Equation

Variable	Coefficient	Standard Error	t value	Pvalue
agriculture_va	$-5.65x10^9$	$3.24x10^9$	-1.7446	0.0944
fertilizer	-0.1692	0.2270	-0.7451	0.4638
gcfc	0.3217	0.2819	1.1413	0.2655
C	16.9291	9.8168	1.1724	0.0980

Note: Significance code, 0.05 = ''*

The levels equation representing the long-run relationship between variables shows that, at the 5% significance level, none of the independent variables have a statistically significant long-run impact on GDP growth, as all p-values exceed 0.05.

The estimated coefficients for the contribution of agriculture to GDP reveal the dual nature of agriculture's contribution to economic growth in Zimbabwe. Results show a strong short run contribution and a weak and statistically insignificant contribution in the long run. These findings are similar to (Chinamatira and Śmiglak-Krajewska, 2025) confirming that agricultural production has a significant positive impact on economic growth in the short run. The significant short-run coefficients lead us to the rejection of H_{02}. Agriculture contributes significantly to employment and rural incomes resulting in a direct feed into GDP. A good agriculture season leads to higher rural incomes and increased consumption, linking agricultural productivity to aggregate demand which boosts GDP within the same period. Results show that a one unit increase in agricultural productivity results in a more than proportional 1.71unit increase in GDP within the same period, other factors being constant. These results are supported by the (AFDB, 2023), which noted that a 36% growth in agriculture recently contributed to an overall 7.8% in economic growth.

Lagged GDP growth reveals significant growth persistence, where previous period GDP has an effect on cur-

rent growth. The 0.23 coefficient indicates that a 1unit increase in GDP growth from the previous year contributes an additional 0.23units to current growth, ceteris paribus, reflecting economic inertia typical in developing economies with structural rigidities. While agriculture drives immediate shocks, GDP's autoregressive structure prolongs volatility across periods. This limited persistence heightens Zimbabwe's vulnerability to repeated agricultural disruptions, amplifying climate effects on macroeconomic stability.

Similar to (Runganga and Mhaka (2021) in the long run the effects of agricultural productivity on GDP growth are small and statistically insignificant. The lack of structural transformation in Zimbabwe means agriculture remains highly subsistence based with a weak transition into manufacturing which results in agriculture's failure to generate sustained long-term growth. In addition agriculture in Zimbabwe is characterized by low mechanization and reliance on manual labour meaning any increase in output is not large enough to drive long run GDP growth (IMF, 2020).

Another major factor limiting agriculture's long run contribution to GDP growth in Zimbabwe is weak value addition. Agricultural products are exported in their raw form and there is limited agro-processing, therefore the agricultural value captured in GDP is low. From objective 1, agriculture is highly vulnerable to climate shocks making it climate sensitive and unstable, this instability prevents long term contribution to growth. The effect of policy shocks and institutional constraints is not to be ignored with 2008 hyperinflation period having a large (-546) statistically significant impact on yield which acts as a short run transmission mechanism of climate shocks on GDP.

Impact of Agricultural Volatility on GDP Growth

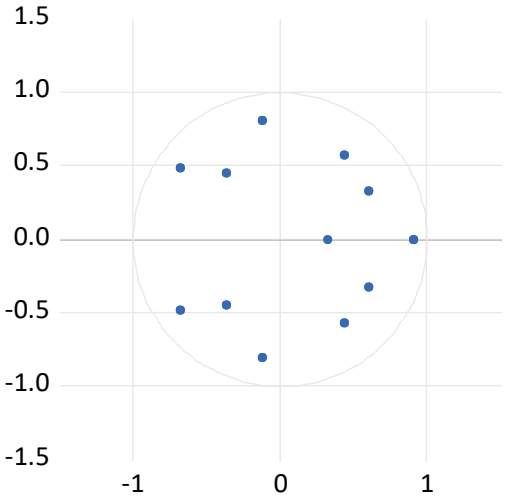


Figure 1: AR Roots

The graph is a test result of VAR stability; all unit roots are inside the circle indicating that the model is stable.

Table 11: Residual Diagnostics

Test	F-Statistic	Prob.Value
Normality(Jarque-Bera)	1.8333	0.3998
Serial Correlation(LM Test)	1.8612	0.0697
Heteroscedasticity(Breusch-Pagan)	3.6955	0.2179
AR Table	No Roots lie outside the unit circle	–

The model successfully passes all residual diagnostic tests at the 5% significance level, as the p-values for normality, serial correlation, and heteroscedasticity are all above 0.05. AR Table confirms the model's stability, as no roots lie outside the unit circle.

Table 12: Variance Decomposition of GDP_G

Period	S.E	GDP_G	D_AGRIC_VA	D_GFCF	AVG_TEMP	D_RAIN_MA
1	8.399168	21.50473	62.68992	15.80535	0.000000	0.000000
2	10.00870	15.50617	47.52379	22.64827	5.432573	7.523609
3	10.39942	15.03703	44.51853	24.59084	5.495810	7.785698
4	10.83951	14.17681	43.53736	26.71360	5.086831	7.925337
5	11.49471	12.66237	42.07732	29.11558	5.855781	7.813359
6	11.61474	12.50338	41.83530	29.34184	6.089510	7.708020
7	11.66148	12.56835	42.12664	29.11411	6.041145	7.646439
8	11.69190	12.64722	41.92228	29.22680	6.009872	7.695517
9	11.72618	12.60798	41.95789	29.29737	5.988410	7.654967
10	11.74826	12.56245	41.84402	29.45995	5.983214	7.653906

Source: Computed by Author from Eviews12

Agriculture Value Added is the most significant source of variation in GDP growth, explaining approximately 62.7% in the first period and stabilizing around 41.8% by period ten. Temperature and Rainfall have no impact in the immediate short run but grow to contribute roughly 6% and 7.6% respectively to GDP volatility in the long run. The results suggest that agricultural productivity and capital investment are the primary drivers of GDP fluctuations in this model

Consistent with Khalifa (2025) findings, the variance decomposition of GDP growth shows overwhelming persistence of shocks from the agriculture sector. The results indicate that agricultural output volatility is not just a minor factor but it is the single largest contributor to the forecast error variance of Zimbabwe's GDP Zimbabwe's GDP in both the long and short-run. The FEVD gives us strong evidence to reject H_{03}. In the immediate short run, year one, a shock to agricultural value added explains a huge 62.7% of the variation in GDP growth. This demonstrates a powerful and immediate transmission of agricultural shocks to the macro-economy. By contrast, shocks to investment account for only 15.8%, while GDP's own shocks account for 21.5%. Notably, the immediate impact of climate shocks is zero. This is a feature of the Cholesky ordering used in the VAR model, which assumes that climate shocks take at least one period to influence GDP through the agricultural channel.

By year three, the initial powerful effect of agricultural shocks moderates slightly but remains the dominant force, explaining 44.5% of GDP growth variance. At this stage, the influence of climate shocks begins to emerge, with AVG_TEMP and D_RAIN_MA jointly explaining approximately 13.3% of the variation, illustrating the lagged transmission from climate to the broader economy. As the forecast horizon extends to the long run, the system settles into a stable equilibrium. The contribution of agricultural shocks stabilizes at a remarkably high 41.8% in year ten. This confirms that nearly half of all long-term uncertainty in Zimbabwe's economic growth path is driven by volatility within the agricultural sector. This contrasts (Salako *et al.*, 2015) findings where agriculture accounted for 28% of the variation in GDP growth for Nigeria, the findings from this study show a much larger contribution of 62.7% in the immediate short-run. While Nigeria's economy is cushioned by a substantial oil sector, Zimbabwe's almost total reliance on agricultural raw materials and rural livelihoods creates a distinct unbuffered link to national growth. Furthermore (Salako *et al.*, 2015) observed a gradual decline in the sector's influence, with agriculture's contribution to GDP variance dropping to 22.85% by year ten. This indicates a mean-reverting effect where other sectors eventually dilute the initial shock. Conversely, results from this study show that in Zimbabwe, the contribution stabilizes at a significantly higher 41.8%. Agriculture shocks still dominate GDP variance because frequent climate shocks keep hitting the system. Even with fast adjustment observed in objective 1, persistent external climate forces create ongoing volatility. This indicates a persistent volatility signature where agricultural instability remains the dominant driver of economic uncertainty over a decade-long horizon. The strong and immediate 62.7% transmission in year one suggests that Zimbabwe's value chains are highly integrated but also highly vulnerable. Because agriculture provides the primary inputs for the manufacturing sector and dictates the disposable income of the rural majority, a single harvest failure acts as a systemic supply and demand shock simultaneously.

CONCLUSIONS AND RECOMMENDATIONS

The study concludes that Zimbabwe's economic growth is deeply intertwined with its agricultural sector which is significantly influenced by climate variability. First, climate change plays a critical role in determining agricultural productivity. The relationship is not only significant but also characterized by strong responses to shocks. This reflects the vulnerability of Zimbabwe's agriculture to climatic fluctuations and the limited capacity for adaptation. Second, agriculture serves as a transmission mechanism and key driver of economic activity in the short run but fails to sustain long-term growth. This is largely due to structural weaknesses, including low productivity, lack of industrial linkages, and minimal value addition. The final and most important impact is seen through agricultural output volatility emerging as the primary source of economic instability. The findings demonstrate that fluctuations in agricultural production translate into fluctuations in GDP growth. This highlights the systemic importance of agriculture in Zimbabwe's economy and the risks associated with its instability. Overall, the study establishes that Zimbabwe's economic growth is not only dependent on agriculture but is also highly vulnerable to its instability, which is largely driven by climate variability.

The sentiments echoed throughout this research paper emphasise the notion that climate change is not only an environmental problem but a macroeconomic issue. The effects of climate variability transmitted through agricultural productivity provide a compelling case for the government to treat smallholder resilience not only as a social welfare issue but rather as a national economic priority. Policy priority should shift from merely increasing output to managing volatility. Since nearly half of the long-term uncertainty in Zimbabwe's growth is agricultural, this research provides the empirical weight to argue that climate-proofing and supporting irrigation schemes for smallholder farmers are not just agricultural investments, but macroeconomic stabilization tools. The government should prioritize investment in irrigation infrastructure, drought-resistant seed varieties, and climate-smart agricultural practices. This will reduce dependence on rainfall and stabilize agricultural output. Reducing the variance in the agricultural sector would, by extension, reduce nearly 42% of the "noise" in the national budget and GDP growth path. Additionally, there is need to improve access to credit for smallholders, enabling farmers to smooth production and reduce vulnerability to climate shocks. Improved access to credit also facilitates expansion and increases the economies to move away from subsistence and smallholder farming to commercial farming for local consumption, export and agro-processing. Policies should focus on developing agro-processing industries to increase the value of agricultural products. This will enhance agriculture's contribution to long-term economic growth and reduce dependence on raw exports, which are more sensitive to macroeconomic factors. Finally, Zimbabwean government should reduce its over-reliance on agriculture by designing fiscal policy promoting growth in manufacturing and services sectors. Diversification will help cushion the economy against agricultural shocks.

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Conflict of Interest

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REFERENCES

1. Abidoye, B.O. and Odusola, A.F. (2015) "Climate change and economic growth in Africa: an econometric analysis," *Journal of African Economies*, 24(2), pp. 277–301.
2. AFDB (2022) *Africa loses up to 15% of its GDP per capita annually because of climate change – African Development Bank Acting Chief Economist Kevin Urama*, *African Development Bank Group*. African Development Bank Group. Available at: https://www.afdb.org/en/news-and-events/press-

releases/africa-loses-15-its-gdp-capita-annually-because-climate-change-african-development-bank-acting-chief-economist-kevin-urama-54660 (Accessed: April 1, 2026).
3. AFDB (2023) *Zimbabwe Food and Agriculture Delivery Compact*. Available at: https://www.afdb.org/sites/default/files/documents/publications/zimbabwe_country_food_and_agriculture_delivery_compact.pdf.
4. Alexander, M. (2013) "An econometric analysis of the relationship between agricultural production and economic growth in Zimbabwe," *Russian journal of agricultural and socio-economic sciences*, 23(11), pp. 11–15.
5. Arguez, A. and Vose, R.S. (2011) "The Definition of the Standard WMO Climate Normal: The Key to Deriving Alternative Climate Normals," *Bulletin of the American Meteorological Society*, 92(6), pp. 699–704. Available at: https://doi.org/10.1175/2010BAMS2955.1.
6. Barrios, S., Bertinelli, L. and Strobl, E. (2010) "Trends in rainfall and economic growth in Africa: A neglected cause of the African growth tragedy," *The Review of Economics and Statistics*, 92(2), pp. 350–366.
7. Borbor, B.S. and Brew, L. (2022) "Forecast Analysis of Ghana's Gross Domestic Product in Economic Growth Using Time Series ARIMA," *Asian Research Journal of Mathematics*, 18(2), pp. 47–55.
8. Brown, R.L., Durbin, J. and Evans, J.M. (1975) "Techniques for testing the constancy of regression relationships over time," *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 37(2), pp. 149–163.
9. Burke, M., Hsiang, S.M. and Miguel, E. (2015) "Global non-linear effect of temperature on economic production," *Nature*, 527(7577), pp. 235–239.
10. Busse, M., Erdogan, C. and Mühlen, H. (2018) "Structural transformation and its relevance for economic growth in Sub-Saharan Africa," *Review of Development Economics*, 23, pp. 33–53. Available at: https://doi.org/10.1111/rode.12543.
11. Callen, T. (2023) "Gross Domestic Product: An Economy's All." Available at: https://www.imf.org/-/media/files/publications/fandd/back-to-basics/callen-gdp.pdf (Accessed: April 17, 2026).
12. Charles, N. (2014) "Economic impacts of climate change on agriculture and implications for food security in Zimbabwe," *Afr. J. Agric. Res*, 9(11), pp. 1001–1007.
13. Chenery, H.B. and Taylor, L. (1968) "Development patterns: among countries and over time," *The Review of Economics and Statistics*, pp. 391–416.
14. Chenjerai, M. and Pasara, M.T. (2025) "The Role of Agricultural Output and Sustainability in the Economic Growth Matrix in Zimbabwe," in M.T. Pasara (ed.) *Public Finance Management in the Development Matrix of the Global South*. Cham: Springer Nature Switzerland (Advances in African Economic, Social and Political Development), pp. 157–175. Available at: https://doi.org/10.1007/978-3-032-00525-0_8.
15. Chinamatira, D.R. and Śmiglak-Krajewska, M. (2025) "Agricultural Production and Economic Growth in Zimbabwe," *Journal of Agribusiness and Rural Development*, 78(4). Available at: https://doi.org/10.17306/j.jard.2025.4.00029r1.
16. Chonabayashi, S., Jithitikulchai, T. and Qu, Y. (2020) "Does agricultural diversification build economic resilience to drought and flood? Evidence from poor households in Zambia," *African Journal of Agricultural and Resource Economics*, 15(1), pp. 68–80. Available at: https://doi.org/10.53936/afjare.2020.15(1).05.
17. Chuzu, E. (2014) "Determination of the impact of climate change on economic growth in Zimbabwe (1980-2011)." Available at: http://www.alumni.uz.ac.zw/handle/10646/3143 (Accessed: January 31, 2026).
18. *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* (2022).
19. De Lima, C.Z. *et al.* (2021) "Heat stress on agricultural workers exacerbates crop impacts of climate change," *Environmental Research Letters*, 16(4), p. 044020.
20. Dell, M., Jones, B.F. and Olken, B.A. (2012) "Temperature shocks and economic growth: Evidence from the last half century," *American Economic Journal: Macroeconomics*, 4(3), pp. 66–95.
21. Dhobha, H., Mutema, P. and Madondo, E. (2025) "Exploring the nexus between climate change and economic growth in the context of Zimbabwe.," *African Journal of Agriculture, Nutrition & Hospitality (AJANH)*, 2(1). Available at:

https://journals.co.za/doi/pdf/10.31920/3050-2276/2025/v2n1a1 (Accessed: February 18, 2026).
22. Diao, X., McMillan, M. and Rodrik, D. (2019) "The Recent Growth Boom in Developing Economies: A Structural-Change Perspective," in M. Nissanke and J.A. Ocampo (eds.) *The Palgrave Handbook of Development Economics*. Cham: Springer International Publishing, pp. 281–334. Available at: https://doi.org/10.1007/978-3-030-14000-7_9.
23. Diffenbaugh, N.S. and Burke, M. (2019) "Global warming has increased global economic inequality," *Proceedings of the National Academy of Sciences*, 116(20), pp. 9808–9813. Available at: https://doi.org/10.1073/pnas.1816020116.
24. Dumrul, Y. and Kilicaslan, Z. (2017) "Economic impacts of climate change on agriculture: Empirical evidence from ARDL approach for Turkey," *Journal of Business Economics and Finance*, 6(4), pp. 336–347.
25. Ekpenyong, I. and Ogbuagu, M. (2015) "Climate Change and Agricultural Productivity in Nigeria: An Econometric Analysis." Rochester, NY: Social Science Research Network. Available at: https://doi.org/10.2139/ssrn.2636868.
26. Enders, W. (2004) "Applied Econometric Time Series.'2th ed,'" *New York (US): University of Alabama* [Preprint]. Available at: https://time-series.net/assets/docs/enders4_pptsch04.684612.pdf (Accessed: April 18, 2026).
27. Engle, R.F. and Granger, C.W. (1987) "Co-integration and error correction: representation, estimation, and testing," *Econometrica: journal of the Econometric Society*, pp. 251–276.
28. FAO (2020) *Preventing livestock death using locally available materials.*, *FAORegionalOffice-Africa-RAF*. FAO. Available at: https://www.fao.org/africa/news-stories/news-detail/Preventing-livestock-death-using-locally-available-materials-/en (Accessed: April 7, 2026).
29. FAO (2026) *Zimbabwe | Building capacity related to Multilateral Environmental Agreements in African, Caribbean and Pacific countries (ACP MEAs 3) | Organización de las Naciones Unidas para la Alimentación y la Agricultura*. Available at: https://www.fao.org/in-action/building-capacity-environmental-agreements/activities/africa/zimbabwe/es/ (Accessed: January 17, 2026).
30. Feldstein, M., Horioka, C. and Savings, D. (1992) "The Solow growth model," *Quarterly Journal of Economics*, 107(2), pp. 407–437.
31. Fischer, H.E., Boone, W.J. and Neumann, K. (2023) "Quantitative research designs and approaches," *Handbook of research on science education*. Routledge, pp. 28–59. Available at: https://api.taylorfrancis.com/content/chapters/edit/download?identifierName=doi&identifierValue=10.4324/9780367855758-3&type=chapterpdf (Accessed: April 15, 2026).
32. Fuglie, K. (2018) "R&D capital, R&D spillovers, and productivity growth in world agriculture," *Applied Economic Perspectives and Policy*, 40(3), pp. 421–444.
33. Getnet, H., Angelsen, P. and Garcia, P. (2024) *Dynamic Patterns of Growth and Structural Transformation: Comparative Regional Insights and Strategic Lessons*. Available at: https://doi.org/10.21203/rs.3.rs-5667350/v1.
34. Ghosh, S., Mukhoti, S. and Sharma, P. (2025) "Quantifying rainfall-induced climate risk in rainfed agriculture: A volatility-based time series study from semi-arid India," *Agricultural Water Management*, 319, p. 109775.
35. Gollin, D. (2010) "Agricultural productivity and economic growth," *Handbook of agricultural economics*, 4, pp. 3825–3866.
36. Gollin, D. (2023) "Agricultural productivity and structural transformation: evidence and questions for African development," *Oxford Development Studies*, 51(4), pp. 375–396. Available at: https://doi.org/10.1080/13600818.2023.2280638.
37. Haque, Md.S. (2022) "Inductive and/or Deductive Research Designs," in M.R. Islam, N.A. Khan, and R. Baikady (eds.) *Principles of Social Research Methodology*. Singapore: Springer Nature Singapore, pp. 59–71. Available at: https://doi.org/10.1007/978-981-19-5441-2_5.
38. Herrendorf, B. and Rogerson, R. (2013) "Growth and Structural Transformation."
39. History Guild (2025) "The Agricultural Revolution," *History Guild*. Available at: https://historyguild.org/the-agricultural-revolution/ (Accessed: April 4, 2026).
40. Howard, P.H. and Sterner, T. (2017) "Few and Not So Far Between: A Meta-analysis of Climate Damage Estimates," *Environmental and Resource Economics*, 68(1), pp. 197–225. Available at: https://doi.org/10.1007/s10640-017-0166-z.

41. IMF (2020) "Unlocking Zimbabwe's Agricultural Potential."
42. Jelliffe, J., Fuglie, K. and Morgan, S. (2024) "Productivity-led Pathways to Sustainable Agricultural Growth: Six Decades of Progress," *EuroChoices*, 23(3), pp. 4–13. Available at: https://doi.org/10.1111/1746-692X.12434.
43. Johansen, S. (1991) "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models," *Econometrica: journal of the Econometric Society*, pp. 1551–1580.
44. Johnston, B.F. and Mellor, J.W. (1961) "The role of agriculture in economic development," *The American Economic Review*, 51(4), pp. 566–593.
45. Kahn, M.E. *et al.* (2021) "Long-term macroeconomic effects of climate change: A cross-country analysis," *Energy Economics*, 104, p. 105624. Available at: https://doi.org/10.1016/j.eneco.2021.105624.
46. Khalifa, J. (2025) "The Impacts of Climate Change, Agricultural Productivity, and Food Security on Economic Growth in Tunisia: Evidence from an Econometrics Analysis," *Research on World Agricultural Economy*, pp. 577–599. Available at: https://doi.org/10.36956/rwae.v6i1.1457.
47. Khanday, S. and Khanam, D. (2023) "THE RESEARCH DESIGN," 06, p. 376.
48. Mammo, B. (2022) "Climate Change and its Impact on Agricultural GDP Growth in Ethiopia: A Time Series Analysis," *International Journal of Academic Research in Economics and Management Sciences*, 11(2), p. Pages 307-322. Available at: https://doi.org/10.6007/IJAREMS/v11-i2/13971.
49. Manatsa, D. *et al.* (2010) "Analysis of multidimensional aspects of agricultural droughts in Zimbabwe using the Standardized Precipitation Index (SPI)," *Theoretical and Applied Climatology*, 102(3), pp. 287–305. Available at: https://doi.org/10.1007/s00704-010-0262-2.
50. Martins, P.M.G. (2019) "Structural change: Pace, patterns and determinants," *Review of Development Economics*, 23(1), pp. 1–32. Available at: https://doi.org/10.1111/rode.12555.
51. McMillan, M., Rodrik, D. and Verduzco-Gallo, Í. (2014) "Globalization, structural change, and productivity growth, with an update on Africa," *World development*, 63, pp. 11–32.
52. Mendelsohn, R., Nordhaus, W.D. and Shaw, D. (1994) "The impact of global warming on agriculture: a Ricardian analysis," *The American economic review*, pp. 753–771.
53. Ministry of Finance and economicDevelopment (2020) *National Development Strategy 1*. NDS 1. Harare: Zimbabwe Government. Available at: https://zimbabwe.un.org/en/153007-2021-2025-national-development-strategy-nds-i (Accessed: February 18, 2026).
54. Ministry of Foreign Affairs and Economic Development (2025) *Ministry of Foreign Affairs & International Trade - Agriculture*. Ministry of Foreign Affairs & International Trade. Available at: https://www.zimfa.gov.zw/index.php/about-us/zimbabwe-in-brief/agriculture (Accessed: April 7, 2026).
55. Ministry of Lands, Agriculture, Fsheries and Rral Development (2020) *Agriculture Food Systems and Rural Transformation Strategy*. 2.
56. Missaglia, M. and Vaggi, G. (2025) "Dualism, Development, Growth and Structural Change: Arthur Lewis Comes Back," in M. Missaglia and G. Vaggi, *Introduction to Development Economics*. Cham: Springer Nature Switzerland, pp. 117–128. Available at: https://doi.org/10.1007/978-3-031-67926-1_8.
57. Mwadzingeni, L., Ilo, O.P. and Simatele, M.D. (2025) "Exploring the perception and awareness of the impacts of climate change on livelihoods in selected rural and urban households in Zimbabwe," *South African Geographical Journal*, 0(0), pp. 1–27. Available at: https://doi.org/10.1080/03736245.2025.2587859.
58. Ndubuisi, O.G. and FNisafetyE, F. (2025) "An In-depth Exploration of the Research Methodologies Employed in Environmental Science." Available at: https://www.seahipublications.org/wp-content/uploads/2025/07/IJIHENS-S-7-2025.pdf (Accessed: April 15, 2026).
59. Nkoro, E. and Uko, A.K. (2016) "Autoregressive Distributed Lag (ARDL) cointegration technique: application and interpretation," *Journal of Statistical and Econometric methods*, 5(4), pp. 63–91.
60. Nordhaus, W. (2018) "Projections and Uncertainties about Climate Change in an Era of Minimal Climate Policies," *American Economic Journal: Economic Policy*, 10(3), pp. 333–360. Available at: https://doi.org/10.1257/pol.20170046.
61. Nordhaus, W. (2019) "Climate Change: The Ultimate Challenge for Economics," *American Economic Review*, 109(6), pp. 1991–2014. Available at: https://doi.org/10.1257/aer.109.6.1991.

62. Nyoni, T. (2018) "Box-Jenkins ARIMA approach to predicting net FDI inflows in Zimbabwe." Available at: https://mpra.ub.uni-muenchen.de/id/eprint/87737 (Accessed: April 18, 2026).
63. Ogundari, K. and Onyeaghala, R. (2021) "The effects of climate change on African agricultural productivity growth revisited," *Environmental Science and Pollution Research*, 28(23), pp. 30035–30045.
64. Pesaran, M.H., Shin, Y. and Smith, R.J. (2001) "Bounds testing approaches to the analysis of level relationships," *Journal of Applied Econometrics*, 16(3), pp. 289–326. Available at: https://doi.org/10.1002/jae.616.
65. Pindiriri, C., Alwang, J., Virginia Polytechnic Institute and State University, Virginia, USA, *et al.* (2024) "Relationship between poverty and climate: Does climate variability drive rural poverty in Zimbabwe?," *African Journal of Agricultural and Resource Economics*, 19(3), pp. 276–293. Available at: https://doi.org/10.53936/afjare.2024.19(3).16.
66. Pindiriri, C., Alwang, J., Sharma, D., *et al.* (2024) "Relationship between poverty and climate: Does climate variability drive rural poverty in Zimbabwe?," *African Journal of Agricultural & Resource Economics*, 19(3). Available at: https://afjare.org/wp-content/uploads/2025/04/4.-Pindiriri-et-al.pdf (Accessed: March 17, 2026).
67. Robert Mendelsohn (2009) "Climate change and Economic Growth," (working paper no. 60). Available at: https://www.uncclearn.org/wp-content/uploads/library/577590nwp0box353767b01public10gcwp060web.pdf.
68. Romer, P.M. (1990) "Endogenous Technological Change," *Journal of Political Economy*, 98(5, Part 2), pp. S71–S102. Available at: https://doi.org/10.1086/261725.
69. Runganga, R. and Mhaka, S. (2021) "Impact of agricultural production on economic growth in Zimbabwe." Available at: https://mpra.ub.uni-muenchen.de/id/eprint/106988 (Accessed: February 18, 2026).
70. Salako, M.A. *et al.* (2015) "Agriculture, economic growth and development nexus: VAR Variance decomposition evidence from Nigeria," *International Journal of Economics, Commerce and Management*, 3(6), pp. 460–473.
71. Schlenker, W. and Lobell, D.B. (2010) "Robust negative impacts of climate change on African agriculture," *Environmental Research Letters*, 5(1), p. 014010. Available at: https://doi.org/10.1088/1748-9326/5/1/014010.
72. Schultz, T.W. (1964) "Transforming traditional agriculture." Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/19641802933 (Accessed: April 18, 2026).
73. Shonhe, T. (2022) "The politics of mechanisation in Zimbabwe: tractors, accumulation and agrarian change," *The Journal of Peasant Studies*, 49(1), pp. 179–199. Available at: https://doi.org/10.1080/03066150.2021.1918114.
74. Shukla, P.R. *et al.* (eds.) (2022) *Climate change 2022: mitigation of climate change*. Geneva: IPCC.
75. Siami Namini, S. (2017) "Granger Causality Between Gross Domestic Product and Economic Sectors in Developing Countries: A Panel Co-integration Approach," *International Journal of Economics and Financial Issues*, 7, pp. 53–58.
76. Stern, N. (2016) "Economics: Current climate models are grossly misleading," *Nature*, 530(7591), pp. 407–409.
77. Tuaneh, G.L., Didi, E.I. and Etuk, E.H. (2021) "Markov-Switching Vector Autoregressive (MS-VAR) Modelling (Mean Adjusted): Application to Macroeconomic data," *Archives of Business Research*, 9(10), pp. 261–274. Available at: https://doi.org/10.14738/abr.910.11085.
78. UNFCC (2006) "United Nations Fact Sheet on Climate Change - Africa is particularly vulnerable to the expected impacts of global warming." Available at: https://unfccc.int/files/press/backgrounders/application/pdf/factsheet_africa.pdf (Accessed: April 18, 2026).
79. UNFCCC (2015) "Adoption of the Paris Agreement," *Conference of the parties*. UNFCC, p. 32. Available at: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.
80. World Bank (2019) *Zimbabwe Public Expenditure Review with a Focus on Agriculture*. World Bank, Washington, DC. Available at: https://doi.org/10.1596/32506.

81. World Bank (2024a) *Country Climate and Development Report-Zimbabwe*. World Bank.
82. World Bank (2024b) *Zimbabwe Economic Update 2024: Improving Resilience to Weather Shocks and Climate Change*. Washington, DC: World Bank. Available at: https://doi.org/10.1596/42793.
83. World Bank (2025) *World Bank Open Data*, *World Bank Open Data*. Available at: https://data.worldbank.org (Accessed: April 7, 2026).
84. World Bank (2026) *Agriculture, forestry, and fishing, value added (% of GDP)*, *World Bank Open Data*. Available at: https://data.worldbank.org (Accessed: January 27, 2026).
85. Yeleliere, E., Antwi-Agyei, P. and Guodaar, L. (2023) "Farmers response to climate variability and change in rainfed farming systems: Insight from lived experiences of farmers," *Heliyon*, 9(9). Available at: https://www.cell.com/heliyon/fulltext/S2405-8440(23)06864-0 (Accessed: December 19, 2025).
86. ZIMSTAT (2023) *2023 Environment Statistics Report Physical Conditions*. ZIMSTAT.