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Does Bank credit mitigate nature and climate change effects in cereal production

Peter Wamalwa, Anne Kamau,
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Abstract

The study analyzed the relationship between climate change, bank credit, and cereal production in Kenya based on quarterly data covering the period 2000-2023 using autoregressive distributed lag approach. The study used CO_2 emissions, average precipitation, and average temperature as indicators of climate change and private sector credit and credit to agriculture sector as indicators of bank credit. The empirical findings show that there is a long-run relationship between cereal production and banks' domestic credit, CO_2 average precipitation, average temperature, and cereal production area. The results also indicate that bank credit, average precipitation and increase in cereal production area stimulate cereal production, while CO_2 emissions and average temperature reduces cereal production in the long run. In the short run, precipitation, bank credit, mechanization increase cereal yield, while CO_2 emissions and acreage under cereal cultivation, and average temperature reduce cereals production. The increase in CO_2 emissions and average temperature interfere with growth and development of plants and hence the yields. However, bank credit enables farmers to counteract the impacts of climate change as it facilitates purchase of farm inputs, which in turn boost cereal production. These findings imply that there is need to mitigate climate change, because it has adverse impact on cereal production. There is also a need to enhance lending to the agriculture sector so that farmers can boost cereal production, enhance capacity to mitigate climate change as well as wither the impact of climate change on cereal production.

Key words: *Bank Credit, Climate Change Risk, Cereal Production*

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1.0 Introduction

A large proportion of the population in Kenya (about 70 percent) is rural based and depends on agriculture for a living. Enhanced and stable growth of the agriculture sector is important as it plays a vital role not only in generating income for the rural population through on-farm and off-farm employment opportunities but also through its contribution to price stability. Whereas the share of agriculture in real GDP has been declining from about 22.5 percent in 2009 to about 17.6 percent in 2023, it continues to be an important sector as it employs over 60 per cent of the workforce (Government of Kenya (GOK), 2007; KNBS, 2024). Cereals such as maize, wheat, rice, sorghum, millet and barley, constitute a major staple food for Kenyan households and with the growing population, the demand has also risen (Macauley, 2015).

Despite the importance of the agriculture sector in Kenya, there are myriads of challenges, especially for cereal production, which has been declining in the recent past. In particular, maize production declined from 44.6 million bags in 2018 to 34.3 million bags in 2022. Wheat production also declined by 19.6 percent to 270 Metric Tonnes, with the gap in domestic consumption being met through imports (Kenya National Bureau of Statistics (KNBS), 2024). Moreover, the per capita availability of cereals has been declining. The decline in cereal production has mainly been attributed to changes in climate and loss of soil fertility, particularly in rainfed cropping systems, which are more sensitive to climate change than irrigated cropping systems (Kurukulasuriya *et al*., 2006; Macauley, 2015), with implications on domestic food prices and inflation thus complicating the formulation and implementation of monetary policy, (Odongo *et al*. 2022).

While declines in productivity of these staple crops are alarming, they also represent an opportunity to invest in Climate Smart Agricultural (CSA) practices such as new improved seeds, drought-resistant seeds, alley cropping, coupled with small-scale irrigation or production diversification, that would increase productivity and mitigate climate change risks. However, savings are negligible among the small holder farmers and agricultural credit, which would be essential in financing inputs and modern technology for higher productivity therefore remains minimal. There is no evidence to show that the use of credit to mitigate the impact of climate change and nature related decline in cereal production has increased cereal production per capita in Kenya. On the one hand, access to bank credit by farmers is low - below 5 percent of total credit, while those that have access to credit employ farm practices that degrade biodiversity and hence reduce soil fertility and cereals yield per acre. On the other hand, difficulties in accessing credit enable farmers to adopt organic farming practices which preserve soil fertility and increase cereal production.

Previous studies have shown that one of the most important factors for initiating and sustaining growth in agricultural production is access to finance. Enhancing access to credit to farmers therefore enables them to bridge the financing gap for farm operations with possible positive implications on production and yields, (Tiryaki and Göker, 2021). However, there is no consensus on the impact of credit on mitigating climate change and nature risks on cereal production in Kenya. This study therefore attempts to determine the impact of bank credit on cereal production. The study focuses on cereals production because, they constitute significant proportion of food and cash crops in Kenya. The growth of cereal is affected by climate change in two ways: first, while adequate rains are essential for growth and development of cereals and high yields, excess rain causes leaching of important compounds, essential for plant health, growth and development. Second, drought increases nitrogen fixation, which is a critical compound for plant growth. However, extreme temperature manifested in heat stress results to wilting and drying of crops which reduces yields. Kenya experiences both flooding and drought which the financial sector can counteract through provision of credit.

It is against this background that this study analyzes the role of bank credit in counteracting climate change and nature related risks in the cereal production in Kenya, an economy characterized by variability in rainfall and temperature. Cereals consist of a large proportion of household diet and hence households spend a significant proportion of disposable income on them. Consequently, change in the quantity of cereal produced and their prices affect household food intake and food inflation. Food inflation is the most variable component of overall inflation due to supply side shocks emanating from climate related effects.

Specifically, the study uses the ARDL methodology to analyze the role of bank credit in counteracting climate change and nature related risks. In this regard, both the short-term and long-term interrelations among variables are investigated, using quarterly data over the period 2000–2023.

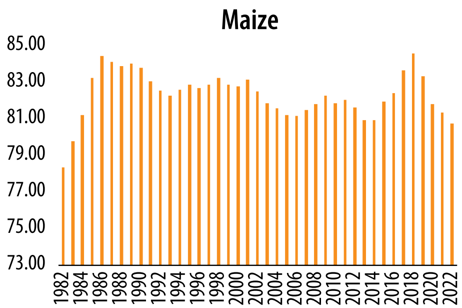
The empirical results show that there is a long-run relationship between cereal production and banks' domestic credit, CO_2, average precipitation, average temperature, and cereal production area. In addition, bank credit, average precipitation and increase in cereal production area stimulate cereal production, while CO_2 emissions and the average temperature reduces cereal production. The increase in CO_2 emissions and average temperature interfere with growth and development of crops and hence the yields. However, bank credit enables farmers to counteract the impacts of climate change to buy input and implements that boost cereal production.

The remainder of this paper is structured as follows: section 2 provides a background on the cereal production, climate change risks and credit to agricultural sector in Kenya; section 3 reviews relevant literature on the relationship between climate change, cereal production and effect of bank credit on cereal production; section 4 details the empirical model, while section 5 presents the results and section 6 concludes.

2.0 Cereal Production, Climate Change Risk Indicators and Credit to Agriculture Sector

Cereals in Kenya mainly comprise of maize, wheat, rice, sorghum, millets, and barley. The most important staples in terms of production and consumption are maize, wheat, and rice, with maize taking the lead in terms of acreage production and daily subsistence needs for most of the households. Some farmers also use cereal as livestock feed, while the industrial sector, relies on cereal and cereal products as inputs in the production of processed food, alcohol and vegetable oil. Production of cereals is highly dependent on rainfall, as result the quantity of cereals produced fluctuates in tandem with variability in precipitation and temperatures. Maize yield is highly susceptible to climate change and extreme weather events. While the area under maize production increased on average by 2.5 percent in the last ten years to an estimated 2.2 million hectares in 2022, production has been variable with a bias towards a decline (**Figure 1**).

Figure 1: Cereal Production (Percent Share of Total)



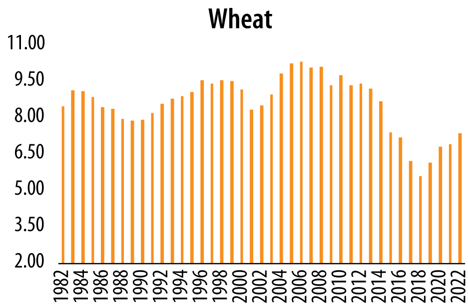
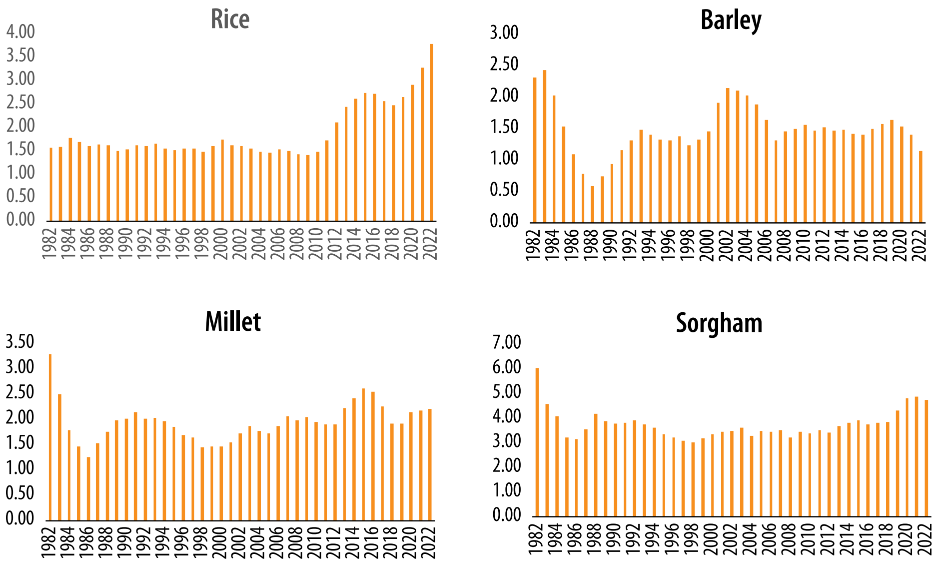


Figure 1: Cereal Production (Percent Share of Total)



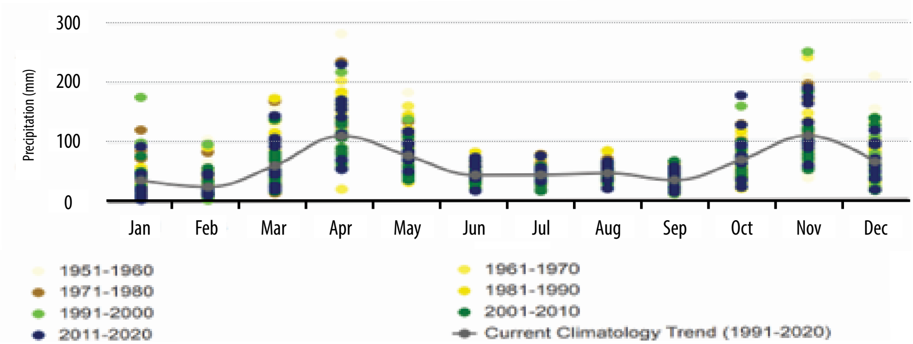
Source: Food for Agriculture Organization Database Accessed in July 2024

Precipitation and temperature (which is one of the most important parameters for climate change) are significant and critical for maize production and therefore, among the most important factors influencing maize yield. In Kenya, water deficit increasing temperature has had negative effects on crop production. A distinct warming trend has been evident since 1960s. During this time the annual mean temperature has risen by approximately 1.0℃, at an estimated average rate of 0.21℃ per decade (World Bank 2021). The most significant rise in temperature was observed during March to May season, which is the primary rainy and humid season (**Figure 2a**). The rising temperatures have resulted in increased aridity and droughts, with moderate drought events occurring on average after every three to four years and major droughts every ten years. The changing weather patterns makes it difficult for farmers to accurately time planting and harvesting.

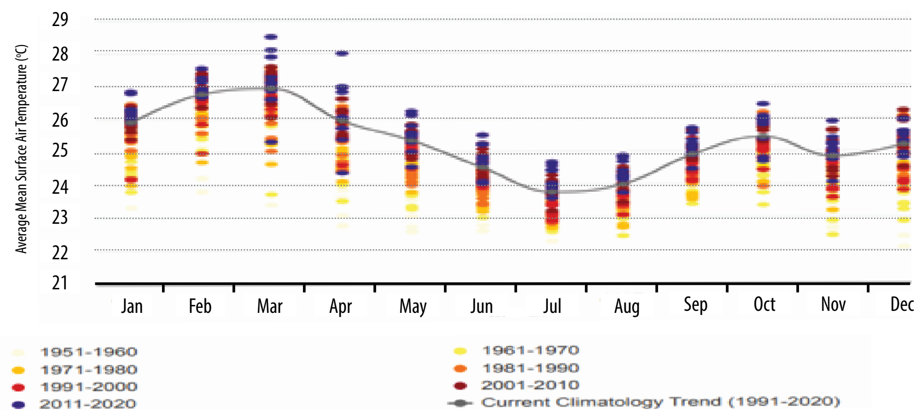
While the effects of climate change are directly reflected in low crop yields, climate change has also provided a conducive environment for breeding of pests such as army worms and desert locusts, which have played part in the decline in maize yield in Kenya. For example, the prolonged rainy season in 2017-2018 that was followed by drought conditions in 2019-2020 resulted in invasion of army worms and desert locusts, which affected cereal crops, sugarcane and pasture. However, production of wheat, rice and sorghum seem to have increased in the last five years, implying a possibility of crop substitution.

Figure 2: Variability and Trends of Climate Change Indicators in Kenya, 1951-2020

2(a): Precipitation Across Seasonal Cycle (mm)



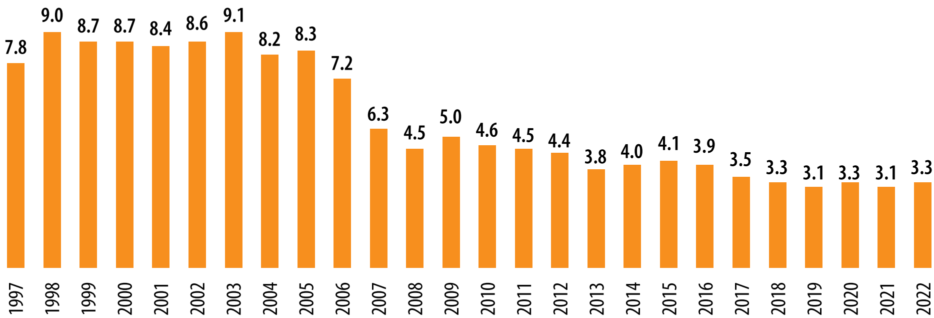
2(b): Mean Surface Air Temperature (°C)



Source: World Bank Climate Change Knowledge Portal Accessed in July 2024

The agricultural sector often faces unique challenges, including seasonality of income, uncertainty related to weather and market conditions, and the need for substantial upfront investments. Credit to the sector therefore is crucial to farmers as it provides farmers with access to funds enabling them to improve productivity, expand their operations, and manage risks. However, in Kenya the share of bank credit to agriculture sector has declined over the years (**Figure 3**).

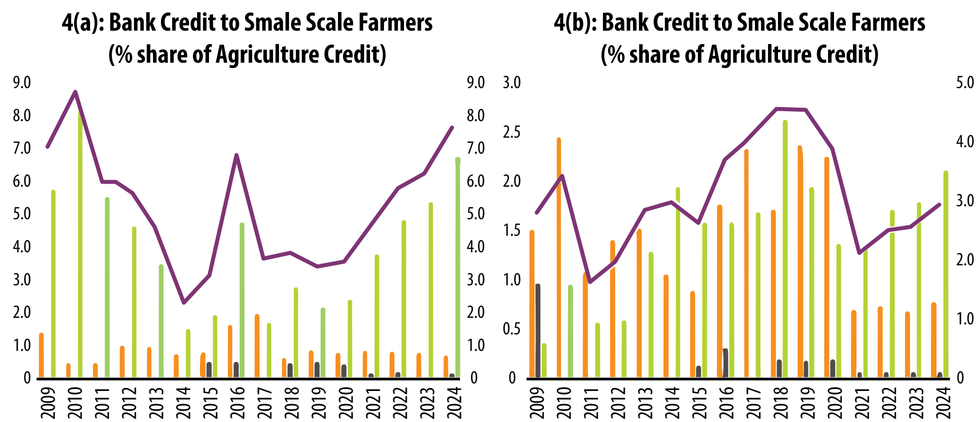
Figure 3: Credit to Agriculture Sector (Percent Share of Total)



Source: Food for Agriculture Organization Database Accessed in July 2024

The main cereal crops receiving bank credit include maize, barley and wheat. Even though the credit has increased since 2019, it remains below the historical average. Maize farmers receive a larger share of credit to the agriculture sector compared to wheat and barley. Similarly small holder farmers receive a larger share of credit from banks compared to large holder farmers (**Figure 4**).

Figure 4: The Bank Credit to Cereal Farmers (%) Share of Total Agriculture Credit



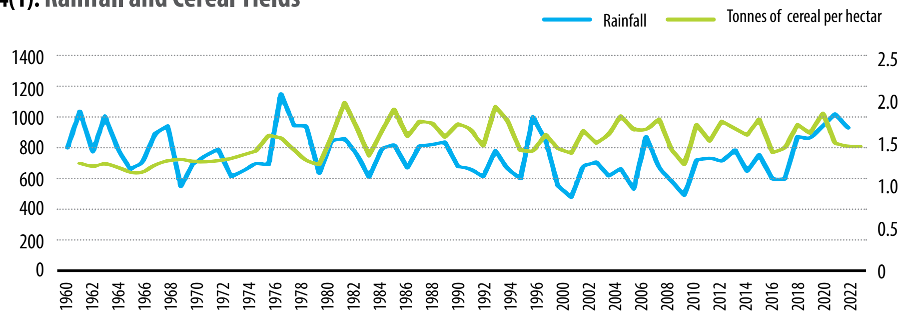
Source: Central Bank Database

Access to bank credit enables farmers to acquire farm inputs and machines, hire qualified agronomists, which increases yields. However, the reliance on weather conditions to grow crops increases the susceptibility of the crops to weather changes. More importantly, the growth and development of cereal depends on the amount of rainfall received at each and every stage. This is because rainfall and temperature influence nitrogen fixation, growth of pest and weeds. Weather also influences the timing of farm operations, and their effectiveness. As a result, variability of weather conditions results to missed timings and interferes with nitrogen fixation, which is essential for the growth of maize.

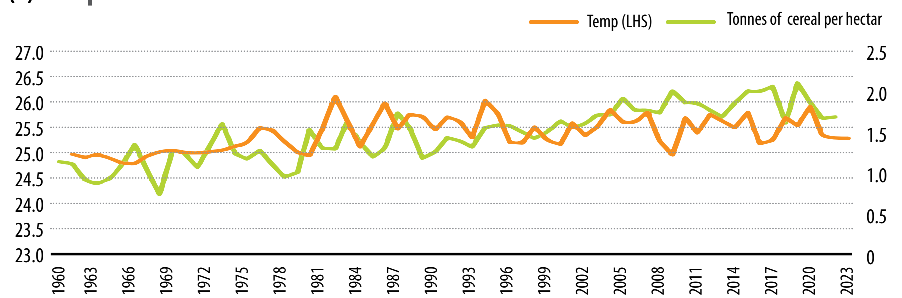
Even though farmers can counteract the adverse effects of weather pattern changes by borrowing from the financial sector, the growth and development of crops is impaired as result of unconducive weather patterns and climate change. This results to decline in cereal yield. Indeed, yield per hectare averaged 1.6 tones, despite efforts to increase lending to farmers (**Figure 5**). More importantly cereal production fluctuated in tandem with rainfall and temperature, implying that climate change has a significant impact on cereal yield.

Figure 5: Yields per Hectares, Mean Temperature and Rainfall in Kenya

4(1): Rainfall and Cereal Yields



4(b): Temperature and Cereal Yields



3.0 Literature review

Literature on climate change, cereal production and bank credit nexus follows various strands. The first and initial strand asserts that variability in rainfall and temperature influences cereal production through their impact on growth and development of plants, ease and effectiveness of undertaking farm operations as well as storage and delivery of farm produce to the market or factories for processing.

Other studies focused on the degradation or improvement in soil fertility and air quality as a result of climate change. For example, Loum and Fogarassy (2015) examined the effects of rainfall and temperature on cereal crops using Gambia's data from 1960-2013. The regression results indicated that fluctuations in rainfall and temperature adversely affect cereal production, but CO_2 emission has a positive effect on cereals. Bayraç and Doğan (2016) investigate the effect of CO_2, rainfall and temperature on agricultural output and yield using data from 1980-2013 for Turkey. They found evidence that changes in CO_2, rainfall and temperature impedes agricultural production. Chandio *et al*. (2020) examined the relationship between climate change factors such as CO_2 emissions, temperature, precipitation and cereal yield in Turkey between 1968-2014 by estimating an ARDL model. They established that there is a long-run relationship between climate change and cereal yield. They also found that an increase in average amount of precipitation increases the yield of cereal in both the long and short term, while Ali *et al*. (2021) found that climate change reduces global crop production.

The impact of climate change on agriculture in a country cannot be confounded to country specific factors since climate change is an externality, with differential impact on agricultural activity across countries. Hence, cross country studies capture the differential impact of climate change on agricultural sector, for example, Lee *et al*. (2012), analyzed the negative effects of climate change on the agricultural sector and cereal production in 13 Asian countries between 1998 and 2007. The results from panel regression analysis, show that higher temperatures and more rainfall in the summer months increased agricultural production, while high autumn temperatures reduced yield in South and Southeast Asia. Hayaloğlu (2018) examined the impact of climate change on the agricultural sector and economic growth in the 1990-2016 periods for the 10 countries most affected by climate change. The analysis established that climate change negatively affects economic growth and agricultural output. Kumar *et al*. (2021) investigated the effect of climate change on grain production between 1971 and 2016 in low middle income countries, the results from DOLS, FGLS and FMOLS models showed that there is a cointegration relationship between grain production and climate change. The analysis further showed that an increase in temperature decreases grain production, but precipitation and CO^2 emissions have a favorable impact.

Preceding studies do not incorporate credit and finance in the analysis. As a result, the studies do not account for the impact of access to finance and credit on counteracting the impact of climate change on cereal production and adoption of efficient cereal production methods. Shahbaz *et al*. (2013) analyzed the relationship between Pakistan's financial development and agricultural growth during the period 1971-2011. Evidence from the ARDL and VECM models show that financial development increases agricultural growth. They also established that expansion of the agricultural sector deepens the financial sector. However, Yalçınkaya (2018) found that causality runs from agricultural production to agricultural credit, that is agricultural production is positively related to the amount of credit extended to the agricultural activities. The study on Nigeria also established that financial sector development has a favourable impact on agricultural output (Raifu and Aminu, 2019). While Zakaria *et al*. (2019) found that financial development initially reduces agricultural productivity due to farmers accessing credit to obtain farm inputs and implements but productivity increases as more credit is accessed in south Asia in 1973–2015.

Similarly, Chandio *et al*. (2021) investigated whether financial sector development affected cereal production during the period 1977-2014 in Pakistan. They controlled for CO_2 emissions, fertilizer consumption and improved seed distribution in their ARDL model. They find that CO_2 emissions have a negative impact on cereal production in the short and long term, while credit boost grain production. Credit to agricultural sector enable farmers to adopt efficient methods and modern technologies, that improves yields. Chandio *et al*. (2022) also examined whether climate change and financial development are affecting agricultural production for ASEAN-4 countries using data from 1990-2016. The results from the CS-ARDL model indicate that climate change adversely affects agricultural production and that there is a U-shaped relationship between financial development and agricultural production. Furthermore, Grivins *et al*. (2023) find that banks play an important role in facilitating the transition to more sustainable models of agriculture in Latvia, Denmark, and the UK.

However, climate change reduces agricultural productivity and yields, which undermine the ability of farmers to repay their loans. As a result, financial institutions ration credit to the sector, to mitigate credit risk (Kaur Bar *et al*., 2021). This not only reduces the capacity of farmers to bridge the financing gap to acquire new and climate change resilience methods of farming but also to adopt green technologies. In this regard, Von Negenborn *et al*., (2018) analyzed the impact of evapotranspiration and precipitation on the agricultural sector and credit risk in Madagascar, they establish that evapotranspiration and precipitation affect credit risk.

In summary, the existing literature indicates that climate change has a significant impact on the agricultural production of many countries. At the same time, development in the financial sector that increase credit to agricultural sector enhance agricultural production both in the long and short run. The increase in agricultural activity deepens the financial sector and enables farmers to adopt green methods and technologies. However, at the same time, climate change manifested in floods and drought reduce agricultural output and incomes, which elevate credit risks. This compels lenders to reduce lending to the agricultural sector, which constraint the sector from adopting methods of farming and technologies that increase productivity and mitigate climate change.

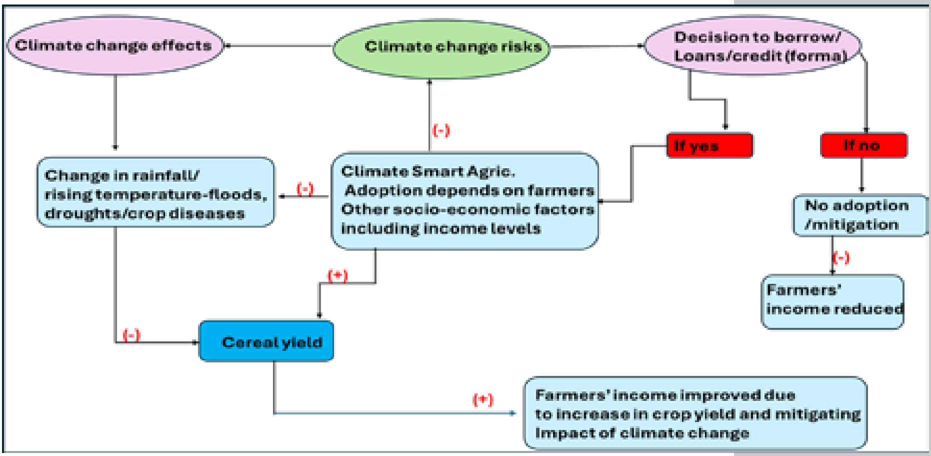
4.0 Methodology

4.1 Conceptual and theoretical framework

The conceptual framework includes three main channels through which the climate change risks affect cereal production in Kenya. Climate change risks impact the environment and cereal production negatively thus reducing crop yield and farmers income. Credit/loans extended to farmers are expected to assist them mitigate or adopt measures to reduce/eliminate the impact of climate related risks, thereby increasing income from increased cereal production. **Figure 6** provides the conceptual framework for the study. The movement is from the top to the bottom and all the negative impacts are marked with a negative (-) while the positive impacts are marked with a positive (+). Climate change risks impact on farmers decision to borrow to mitigate adverse effects through climate smart Agriculture (CSA), insurance and other measures, that eventually generate incomes through increased cereal production. The negative effects from climate change can be reduced significantly if farmers acquire measures to mitigate them beforehand.

Figure 6:

Conceptual framework for climate change impacts, Credit, CSA practices and farmers' income



Source: Authors' Illustration

It is expected that farmers adopt climate smart Agriculture, or any other method/measure that will assist in dealing with the effects of climate change risks. By doing so, they will be able to get a high crop yield and incomes, thereby mitigating against the negative effects of climate risks. Financing through loans/credit facilitates farmers adopting the necessary technology for smart agriculture thus increasing the chances of high crop yield. The study assumes that farmers are rational economic agents who make rational decisions when solving a problem. Thus, they will adopt CSA to mitigate the losses that come from climate change risks. Adoption has implications of increasing farmers' incomes. On the contrary, if a farmer does not adopt for lack of financing, they will bear the losses that emanate from climate change risks through reduced crop yields and incomes eventually leading to low agricultural output and low economic growth.

Literature documents clearly the effects of climate change risks to crop production. Climate change risks emanate from global warming due to emissions of GHG gases in the environment that distort the ecosystem for crop production. Suitable weather, that is, favorable temperatures, rainfall and sunshine, are necessary for crop production. In addition, rich moist soil containing necessary nutrients and organisms will ensure seeds germinate and grow to produce a high crop yield. Climate change risks come to disturb this ecosystem leading to lower crop yield due to flooding, drought, or differing biological and moisture of soil content leading to changes in flowering and harvesting seasons, to diseases and pests and low crop yields (Chang, 2012). Global warming, however, has one positive effect on the environment. There is increased fertilization resulting from increased concentration of carbon dioxide in the atmosphere (Chang, 2012).

The relationship between credit and cereal production may be discussed under loan theory. Theoretically, banks advance credit to persons or firms, depending on how they assess their riskiness and ability to repay back. Credit advanced to the farmers or for agricultural use may be described under the loan theories of information asymmetries, moral hazard and adverse selection advanced by Akerlof (1970). Farming activity is viewed as a risky business, with little to no guarantee of the expected output due to exposure to high risk factors. Thus, in advancing loans, there may be incidences of information asymmetry, moral hazards or adverse selection. In the case of information asymmetry, the farmer has full knowledge of the farm's potential while the bank manager may not be privy to that information or vice versa where the return on farming is portrayed to be so high to lure creditors to that sector. Moral hazard occurs when there is a possibility of individuals not revealing why they are borrowing and may likely default. Thus, banks tend to charge high interest rates for the loans advanced to the agriculture sector to cover their risks. Rothschild and Stiglitz (1976) expound on the theory of adverse selection where the loan default probability increases when interest rates increase while the quality of borrowers is deteriorating as well. Thus, advancing properly priced credit from formal channels would accord the farmers, means to mitigate against adverse effects of climate change on cereal production.

4.2 Data and definition of variables

Following from the literature reviewed and objectives set out, the study seeks to investigate the short- and long-term effects of credit, climate change and on cereal crop production in Kenya. The relevant variables for the study are drawn from the literature and comprise of climate related data defined as temperature, precipitation (rainfall) and CO_2 emissions, cereals production data, and acreage, all sourced from the Food and Agricultural Statistics FAOSTAT data base. The second set of variables comprise of credit extended to agriculture for cereal production, mechanization and macro variables represented by lending rates and GDP. The credit data is sourced from the Central Bank of Kenya - the banking survey while the mechanization and macro variables are sourced from World Development Indicators (WDI). **Table 1** presents the variables used in the study, where the data is sourced from and the apriori expectations from the reviewed literature.

Table 1: Variables Definition, Data sources and Apriori Expectations

Variables	Definition	Data Source	Apriori expectations
Cereal Production	Total Cereal production in metric tonnes	Food and Agricultural Organization Statistics (FAOSTAT)	Explained variable for objective one of the study
Agriculture credit	Agriculture credit, from private sector credit extended to the sector monthly	Banking survey, central bank of Kenya	Positive impact on cereal production (He *et al*, 2022); Yalçınkaya (2018) found agricultural production to have positively related the amount of credit extended
Temperature	Monthly temperature variations	Food and Agricultural Organization Statistics (FAOSTAT)	Negative impact when the temperatures are high. Loum and Fogarassy (2015); Attiaoui & Boufateh (2019) and Pickson *et al* (2020), found a positive relationship between rainfall and cereal production; Ali *et al* (2021) found that temperature variability (high) reduces global crop production
Precipitation	Rainfall variability/precipitation/monthly rainfall	FAOSTAT	Positive/Negative depending on the amount (precipitations)
CO_2	Monthly CO_2 emissions	FAOSTAT	Loum and Fogarassy (2015) and Kumar *et al* (2021) found that CO_2 emissions have a positive effect on cereals production. While Bayraç and Doğan (2016) and Chandio *et al*. (2020) find a Negative impact on cereal production. This variable may take either sign

Variables	Definition	Data Source	Apriori expectations
Acreage	The land size under production of cereals	Ministry of Agriculture	Found to have a positive impact on cereal production (He *et al*
Mechanization	Level of use of mechanization techniques	World Development Indicators (WDI)	Sarigul *et al*.,2023; He *et al*., 2022; studies positive effects on cereal production with improved mechanization

4.3 Empirical Model

The study utilized the autoregressive distributed lag (ARDL) empirical model based on the work of Pesaran and Shin (1996), Pesaran and Pesaran (1997) and Pesaran *et al*. (2001). The study seeks to understand the short and long run impacts on cereal production in Kenya. Several other studies have applied the ARDL method in assessing effects of climate and other variables on cereal production, He *et al*, (2022). The choice of this method is based on the advantages it has over other methods of assessing long-term relationships. First, it is suitable in cases of small sample sizes, Gatak and Sidiki (2001). Secondly, it allows for explanatory variables to be integrated of different orders, (Pesaran and Shin, 1996). Thirdly, it allows for use of variables with different lag lengths and yields short and long run parameters. The use of ARDL facilitates avoidance of estimation problems associated with use of Johansen cointegration, like the determination of the ordering of the VAR, consideration of the number of endogenous and exogenous variables to be included/excluded and determination of the optimal lag lengths, which have implications on the outcomes. Thus, the ARDL is the most appropriate method for analysis for this study.

Consistent with previous studies, the dependent variable for the study is cereal production while the independent variables include the factors driving the production of cereals, in this case- credit extended to the sector; climate variables- CO_2 emissions, rainfall and temperature variability; agricultural production indicators include acreage or yield and level of mechanization of the farm, (Sarigul *et al*.,2023; He *et al*., 2022)

Two hypotheses are tested in the study as follows:

Hypothesis 1 (H1). Climate change risks (temperature variability/precipitation) negatively affect cereal production in Kenya.

Hypothesis 2 (H2). Agricultural credit mitigates effects of climate change and improves cereal production in Kenya

A linear representation of cereal production expressed as a function of acreage, temperature ($\mathbf{temp}$), rainfall ($\mathbf{rf}$), carbon emissions ($\mathbf{CO_2}$), acreage ($\mathbf{arcg}$) and mechanization ($\mathbf{mech}$), drawing from, He *et al*., (2022), represented in general form in **equation 1** below.

$$cp_t=\alpha_0+\alpha_1 X_t+\varepsilon_t \qquad [1]$$

Where cp_t is cereal production, X_t is a vector of the explanatory variables and ε_t is the error term. The equation can be rewritten in log form as shown in **equation 2**.

$$lcp_t=\alpha_0+ \alpha_1\, lacr_t + \alpha_2\, ltemp_t+ \alpha_3\, lrf_t + \alpha_4\, lCO_2t + \alpha_5\, lempa_t + \alpha_6 larcg_t+\alpha_7\, lmech_t+\varepsilon_t \qquad [2]$$

Where cp_t is cereal production {maize, wheat, rice, millet and barley }, while X_t are the explanatory variables, acr_t represented agriculture credit; $temp_t$ is temperature variability; rf_t rainfall; CO_{2t} represents carbon emissions; $empat_t$ refers to employment in agriculture; $arcg_t$ acreage; and represents mechanization level and is the error term. **Equation 2** is the long-term relationship expressed in natural logs for all the variables.

Following Pesaran *et al*., (2001) the error correction representation of the ARDL model is shown in **equation 3**:

$$\Delta lcp_t = \alpha_0+ \sum_{j=1}^{n} \gamma_1\, \Delta l\, cp_{t-j} + \sum_{j=1}^{n} \gamma_2\, \Delta lacr_{t-j}+ \sum_{j=1}^{n} \gamma_3\, \Delta l\, temp_{t-j} + \sum_{j=1}^{n} \gamma_4\, \Delta lrf_{t-j}+ \sum_{j=1}^{n} \gamma_5\, \Delta lCO_{2t-j} + \sum_{j=1}^{n} \gamma_6\, \Delta ltemp]]_{t-j}+\sum_{j=1}^{n}\gamma_7\, \Delta larcg_{t-j} +\sum_{j=1}^{n}\gamma_8\, \Delta lmech_{t-j}+z_1\, lcp_{t-1} + z_2\, lacreage_{t-1}+z_3\, ltemp_{t-1}+ z_4\, lrf_{t-1}+z_5\, lCO_{2t-1}+ z_6\, ltemp_{t-1}+z_7\, larcg_{t-1}+ z_8\, lmech_{t-1} + \varepsilon_t \qquad [3]$$

The z_n here $n\in(1, 8)$, are the long run multipliers whereas the short run dynamic coefficients are represented by the γ_n where n=1 to 8.

The null hypothesis is that $H_0 = z_1= z_2 = z_3 = z_4 = z_5 = z_6 = z_7 = z_8 = 0$ implying no cointegration, the alternative is that there is cointegration $H_1= z_1 \neq z_2 \neq z_3 \neq z_4 \neq z_5 \neq z_6 \neq z_7 \neq z_8 \neq 0$. This will be tested by applying F test proposed by Pesaran *et al* (2001).

5.0 Empirical Results and Discussion

Preliminary tests are carried out to confirm the stationarity of the variables before estimation. The unit root results are shown in the Appendix. The ADF test indicate that all the variables are non-stationary except for the area cultivated. The variables are stationary after differencing once hence they are integrated of order 1.

This paper analyses the contribution of bank credit in enabling farmers to counteract the impact of climate change to produce the cereal. In this regard, we regress cereal production, climate change and access to bank credit as in (Sarıgül, *et al*., 2023, Kaur *et al*., 2016; Bayraç *et al*., 2021). The variables in the empirical model are integrated of order one and others are stationary thus confirming the appropriateness of estimation based ARDL model.

The study further tested for cointegration to establish whether the variables have a long-term relationship using the bounds testing technique. The results presented in **table 2** for bounds test show the existence of a long-term equilibrium among total output, private sector credit, temperature, precipitation and area cultivated.

According to the results in **table 2**, the calculated statistical value $\mathbf{F}$ is 7.7, which is greater than the upper limit value at the significance level of 1% implying that there is cointegration among the variables under consideration, proving the presence of a long-term linkage among the series. In addition, the fact that the $\mathbf{ECT}_{t-1}$ is negative and significant at 1% indicates the presence of cointegration between the variables.

After confirming cointegration with the ARDL bounds test approach in the study, the long-run elasticity of the variables is estimated. First, the findings predicted by the ARDL model in **Table 2** are summarized. **Table 2** shows that the coefficient of precipitation is 0.25 and it is statistically significant at the level of 1%. This means that a 1% increase in precipitation also increases cereal production by 0.25%. This implies that there exists a positive linkage between rainfall and

Table 2: ARDL Estimate with Private Sector Credit from Commercial Banks

	Model 1 (with Rainfall)	Model 2 (With Temperature)
Output (-1)	0.416	0.435
	(0.120)	(0.131)
Precipitation	0.252	
	(0.074)	
Temp		-2.225
		(1.352)
PSC	0.177	0.242
	(0.159)	(0.172)
PSC(-1)	-0.399	-0.540
	(0.243)	(0.265)
PSC(-2)	0.255	0.335
	(0.152)	(0.169)
HA	0.875	0.934
	(0.152)	(0.164)
(HA(-1))	-0.462	-0.446
	(0.182)	(0.196)
C	0.299	7.628
	(1.577)	(4.260)
ECM	-0.584	-0.565
	(0.090)	(0.107)
Bounds test F	7.733 3	5.198 3
Bounds at 1%	3.65 4.66	3.65 4.66

grain production in in Kenya. This result corroborates the findings obtained by Attiaoui & Boufateh (2019), who shows that there is strong dependence of cereal farming on rainfall, with the best harvests recorded in the wettest years. Therefore, it indicates that a decrease in rainfall in the long term will have negative repercussions on cereal production. This finding is also in line with the findings of Pickson *et al*. (2020), in which, China's average rainfall positively affects cereal production.

An increase in average temperature reduces cereal production by 2.25 percent and the result is statistically significant. This means that a 1% increase in average temperature leads to a reduction of cereal production by 2.25 over the long term. The negative impact of the average temperature on cereal production is similar to the study findings obtained by Attiaoui & Boufateh (2019) for Tunisia during 1975-2014 and Abdi *et al*. (2023) for East Africa during 1990-2018.

An increase in the area of cereal production increases cereal production by 0.875 %. The coefficient of cereal production area is positive and statistically significant. Our results for the cereal production area are similar to the outcomes of Ahsan *et al*. (2020), Chandio *et al*. (2021), and Xiang & Solaymani (2022), who found that the effect of cereal cultivation area on cereal production is positive.

An increase in the bank credit increases cereal production by 0.255 percent after 2 quarters. The long-run results show that the elasticity of banks' domestic credit stimulates cereal production. The channels of this linkage would be through purchases of quality farm inputs and financing farm operations. Our results are in line with the findings of Shahbaz *et al*. (2013) and Tiryaki and Göker (2021), who reveal that the effect of banks' domestic credit on cereal production is positive.

The results in table 3 include domestic credit, however, banks lend to diverse sectoral activities in Kenya. More importantly, bank credit to agriculture constitutes less the 10 percent of the total bank lending. Hence private sector credit may not be a good proxy for access to finance for agricultural sector, notwithstanding the fact that credit is fungible and other sectors may borrow to finance agricultural activities. The analysis therefore incorporates credit to agricultural sector to estimate its impact on cereal production. Furthermore, we incorporate CO_2 emissions in the regression model and results are presented in **table 3**.

The results in **table 3** show that the coefficient of precipitation is 0.26% and it is statistically significant at the level of 1%. The size of the coefficient on precipitation is almost similar in magnitude. This means that a 1% increase in precipitation also increases cereal production by 0.26%. This underscores the results in **model 1** above that there is strong dependence of cereal farming on rainfall, with the best harvests recorded in the wettest years. This finding of the study is in line with the findings of Pickson *et al*. (2020), which show that China's average rainfall positively affects cereal production.

An increase average temperature reduces cereal production by 1.54 percent and the decline is statistically significant. This means that a 1% enhancement in average temperature leads to a reduction of cereal production by 1.54 over the long term. In other words, there is a negative correlation between the average temperature and cereal production. The negative impact of the average temperature on cereal production is similar to the study findings obtained by Attiaoui & Boufateh (2019) for Tunisia during 1975-2014 and Abdi *et al*. (2023) for East Africa during 1990-2018.

An increase in the area of cereal production increases cereal production by 0.875 %. The coefficient of cereal production area is positive and statistically significant. Our results for the cereal production area are consistent with the outcomes of Ahsan *et al*. (2020), Chandio *et al*. (2021), and Xiang & Solaymani (2022), who found that the effect of cereal cultivation area on cereal production is positive. An increase in the bank credit increases cereal production by 0.22 percent. The results show that bank credit to agricultural sector boost cereal production

Results in **table 3** column 2 and 3 incorporate CO_2 emissions, to analyze their impact on cereal production. The results show that an increase in CO_2 emission reduces cereal output by about 0.351 percent and the reduction is statistically significant at 1%. This implies that increase in CO_2 emissions impedes growth and development as well as storage of cereal. This can be attributed to the fact that CO_2 emissions elevate temperature and hence increase loss of water/ moisture through evapotranspiration. On the one hand, loss of moisture and water impair growth and hence yields. On the other hand, excess rains and floods cause leaching, which deprives plants of important nutrients hence leading to reduction in yields. Indeed, Kenya experiences, extremes whether patterns, whereby excess rains and insufficient rain periods are associated with lower-than-expected cereal harvest.

Table 3: ARDL Estimate with Credit to Agriculture from Commercial Banks and Carbon Emissions

	1	2	3	4
Output (-1)	0.335	0.355	-0.012	0.320
	(0.115)	(0.127)	(0.172)	(0.169)
Precipitation	0.263			0.277
	(0.071)			(0.088)
				-0.118
Temperature		-1.537	-0.515	(0.112)
		(1.277)	(2.185)	
AGRIC_CREDIT	0.215	0.224	0.306	0.342
	(0.095)	(0.105)	(0.144)	(0.131)

	1	2	3	4
AGRIC_CREDIT(-1)	-0.173	-0.183	-0.339	-0.489
	(0.093)	(0.104)	(0.127)	(0.181)
HA	0.875	0.933	0.909	
	(0.143)	(0.159)	(0.264)	
HA(-1)	-0.393	-0.372	0.638	0.698
	(0.176)	(0.194)	(0.316)	(0.259)
CO_2 emissions		-0.351	-0.169	
			(0.168)	(0.145)
C	0.851	6.095	-5.686	-1.369
	(1.462)	(3.999)	(7.824)	(3.311)
Bounds test F	**9.317 3**	**5.672 3**		
Bounds at 1%	**3.65 4.66**	**3.65 4.6**		

The analysis in **tables 2** and **3** does not control for mechanization and human capital. In addition, the impact of bank credit and climate change is different across the cereals. Hence, pooled ARDL model may mask the differential impact of bank credit and climate change on yields. In this regard, we estimate a panel model with yields, controlling for mechanization, human capital development measured public spending on education as a proportion of total government spending. The share of education spending is correlated with the educational attainment and quality of human capital deployed in the agricultural sector (Dissou, *et al.*, 2016 and Recuero, & Olaberría, 2018). Mechanization is proxied for by the number of tractors and the number of tractors per 100 square Kilometers.

Table 4: Panel Estimate for the Impact of Credit and Climate Change on Cereal Production

	1	2	3	4
LOG(TEMP)	0.022	2.835*		
	(1.702)	(1.630)		
Precipitation			0.005	
			(0.126)	
AGRIC_CREDIT	0.050***	0.078***		
	(0.029)	0.020		
LOG(PSC)			0.081***	
			(0.029)	
EXPEDU	0.054**	0.044**	0.058***	
	(0.017)	(0.017)	(0.018)	
	Short Run Equation			
COINTEQ01	-0.595***	-0.596***	-0.586***	
	0.098)	(0.104)	(0.093)	
DLOG(TEMP)	-1.080**	-1.026**		
	(0.527)	(0.499)		
Precipitation			0.072	
			(0.031)	
AGRIC_CREDIT	-0.092	-0.152		
	(0.136)	(0.141)		
DLOG(PSC)			-0.148	
			(0.143)	
D(EXPEDU)	0.046**	0.058	0.032	
	(0.024)	0.026)	(0.028)	

	1	2	3	4
LOG(HA)	0.720**	0.664	0.700	
	(0.116)	(0.086)	(0.108)	
LOG(TRACTORS)	-0.079		-0.062	
	(0.162)		(0.158)	
Tractors per 100 sqKM		-0.275		
		(0.198)		
C	-1.384	-2.912	-1.843	
	0.891	0.928)	0.915	

The results in **table 4** indicate that temperature and precipitation have no statistically significant impact on cereal yields. However, an increase credit to agriculture leads to about 0.05 percent increase in the yields. The increase is statistically significant at 1 percent level of significant. The implication of this results is that credit to agricultural sector may be used to purchase inputs that enhance productivity of land, reduce post-harvest wastage, acquire high yielding varieties of seeds and pay for skilled labour. In the context of endogenous model in which climate change is incorporated, credit enhances cereal production by easing the resource constraint to farmers, which enables them to adopt farming methods that not only enhance the resilience to climate change but also mitigate climate.

Temperature has statistically significant positive effect on cereal yields in the long, but in the short run it has a negative impact. This can be attributed to prolonged drought enhancing nitrogen fixation, which increase cereal yields in the long run. However, elevated temperature in the short run reduces moisture, which is critical for plant growth and development. An increase in the volume of precipitation by 1 millimeter, the yields increase by about 0.07 percent in the short run. This indicates that increase in precipitation provides plants with sufficient moisture for plant to undertake its biological process in the short-run but in the long run precipitation has no impact statically significant impact on yields. This implies that excess rains increase leaching or cause flood which impair plant growth and development.

Table 5 below present short parameter estimates per cereal. This will enable analysis of the differential impact of bank credit on cereal production. The error correction term is statistically significant and negative. This implies that 42 percent to 82 percent deviations from the long run equilibrium are corrected within the year. Precipitation is positively correlated with cereal yields just like precipitation in the aggregate equation in **table 4**. In the short run, expenditure on education increases yields by between 0.1 to 0.02 percent, except for barley. Public spending augments productive capacity and enable farmers to deploy skilled labour to increase productivity. An increase in the number of tractors increases maize, wheat rice and barley, but reduces millet and sorghum. This can be attributed to the fact that mechanization improves farm operations such tilling, application of fertilizer and harvesting which improves soil fertility and reduces wastage. However, for millet and sorghum, mechanization may be inducing losses. Suffice to note that millet and sorghum are labour intensive

Table 5: Impact of Climate Change and Credit on Cereals Production

	Maize	Wheat	Rice	Barley	Millet	Sorghum
ecm	-0.821***	-0.741***	-0.307***	-0.775***	-0.417***	-0.422***
	(0.009)	(0.014)	(0.010)	(0.006)	(0.007)	(0.010)
Precipitation	0.087***	0.105***	0.000	0.099***	0.125***	-0.051***
	(0.005)	(0.015)	(0.013)	(0.021)	(0.034)	(0.024)
AGRIC_CREDIT	0.189	0.051	0.451	-0.341	-0.331	0.563
	(0.009)	(0.037)	(0.038)	(0.053)	(0.095)	(0.066)
EXPEDU	0.017***	0.045***	0.027***	-0.032***	0.040***	0.112***
	(0.001)	(0.003)	(0.003)	(0.004)	(0.009)	(0.006)
ha	0.801***	0.787***	0.208***	0.730***	0.997***	0.638***
	(0.014)	(0.054)	(0.014)	(0.006)	(0.040)	(0.022)
Tractors	0.030**	0.123***	0.059***	0.584***	-0.626***	-0.092***
	(0.014)	(0.020)	(0.022)	(0.023)	(0.032)	(0.015)
C	-1.002	-2.455	0.270	-5.643	-1.557	-2.563
	(3.120)	(5.569)	(0.728)	(2.407)	(3.562)	(3.782)

6.0 Conclusion

This study sought to analyze the relationship between climate change, bank credit, and cereal production in Kenya. Climate change is proxied for by CO_2 emissions, average precipitation, and average temperature variables, while bank credit indicators consist of private sector credit and credit to agriculture sector. The study conducted unit root tests to ensure usage of only I(1) and I(0) variables consistent with the requirements of ARDL model utilized in this study. The study further conducted cointegration tests which showed that the variables are cointegrated and an ARDL model for aggregate cereal production controlling for climate change variables and credit was thus estimated.

The empirical findings show that there is a long-run relationship between cereal production and banks' domestic credit, CO_2, average precipitation, average temperature, and cereal production area. In addition, in the short run bank credit, average precipitation and increase in cereal production area stimulate cereal production, while CO_2 emissions and the average temperature reduce cereal production. The increase in CO_2 emissions and average temperature interfere with growth and development of crops and hence the yields. However, bank credit enables farmers to buy farm inputs and implement climate mitigation, resilience and copping measures, which counteract the impacts of climate change as manifested in floods and drought to boost cereal production.

The findings from the study imply that there is need to mitigate climate change, because it has adverse impact on cereal production. There is also need to enhance lending to agricultural sector so that farmers can boost cereal production, enhance capacity to mitigate climate change as well as wither the impact of climate change on cereal production. Moreover, commercial banks should continue lending to agriculture sector, prioritizing farmers that adopt climate change resilience and adaption practices. This, will enhance cereal production, increase incomes and enable farmers to repay their loans. On the other hand, increase in cereal production will increase food securities, support other industries and stabilize prices.

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Appendix

Table A1: Unit root test

	level	Stationarity	First difference
cereals	2.585	Nonstationary	-8.813***
ppt	5.95	Nonstationary	-11.37***
Credit growth	2.920	Stationary	
hectares	-9.898***	Stationary	
maize	5.215	Nonstationary	-8.705**
Wheat	-2.039	Nonstationary	-6.115*
Rice	0.655	Nonstationary	-5.932***
Millet	2.711	Nonstationary	-6.724***
Barley	3.555	Nonstationary	-9.180***
Sorghum	-2.195	Nonstationary	-7.016***
Temperature	1.311	Nonstationary	-10.540***

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