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# Analysis of the Effects of Climate Change on the Income of Malian Farmers

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**Abstract:** The objective of this study is to examine the effects of climate change on the agricultural income of Malian producers during the period 1990-2021. Before testing for cointegration between variables, it is important to conduct the unit root test to ensure that no variable is integrated at order 2, i.e. I (2). This is essential because the ARDL procedure assumes that all variables are integrated of order I (0) or I (1). We used the ARDL estimator to analyze the time series data in this study. According to different theories, the variables explaining climate variability negatively affect agricultural production. The results show that climate change negatively influences agricultural income. Specifically, the average rainfall in the months of June-July and August-September are not very detrimental to Malian crops, but in contrast to these effects, the impacts of the quadratic variables, i.e., with a high square (threshold effect), negatively affect farm income. The results of the June-July average temperatures negatively affect income and are in contrast to the threshold effects of those of August-September. This study does not take into account future adaptations that farmers may implement. Thus, the impacts can be mitigated, but for this to happen, it is imperative to strengthen farmers' capacities to adapt to climate change in Mali.

**Keywords:** Climate Change, Agricultural Income, ARDL, Mali

## 1. Introduction

Climate change is an unequivocally complex phenomenon that will have definite effects on agriculture [1]. These effects may be more pronounced in some countries than in others, due to the great spatial variability of the climate and the socio-economic development of the country [2]. From the effects of climate disruption on agricultural and food income, to rising sea levels, which increase the risk of flooding, the consequences of climate change are global in terms of effects and scale [3]. The impact of climate change on agriculture is multifaceted, with effects on people, farm capital and outcomes [1]. According to estimates, climate change will decrease agricultural productivity by 9-21% over the next few decades, resulting in increased conflict over natural resources and the abandonment of agropastoral activities [4, 5, 6]. The agricultural sector is in a position to be permanently impacted by climate change, which manifests itself directly through increased food prices [2]. The impact of climate change, which manifests itself directly through changes in land and water regimes. The potentially negative impacts of climate change on crop yields and farmers' livelihoods are expected to increase the number of hungry people in the world by 20% by 2050 [3].

Several studies have shown that rainfall variation has a negative and significant impact on smallholder income during the cropping season [9, 10, 2]. In a study of 11 African countries where 9064 farmers were randomly selected by region and using the Ricardian approach to crop yields. [4] found that there is a negative influence of temperature on net revenue from rainfed land, while the influence is positive for net revenue from irrigated land. The work of [5] on the effect of temperature and rainfall variability on the net income of cereal crops in Togo shows the negative influence of climate variation. [6] analyzed farmers' perceptions of the effect of climate change on agriculture and assessed the impact of climate change on farmers' agricultural income. The Ricardian model was used to assess the impact of climate variables on income. The results indicate that a reduction in precipitation appears to be more detrimental to farmers' agricultural income than an increase in temperature. A reduction in precipitation would, ceteris paribus, lead to a decrease in net farm income.

Africa in general, and West Africa in particular, is more vulnerable to climate change and variability due to certain physical and socio-economic characteristics that predispose it to be disproportionately affected by the negative effects of climate variations [7]. Indeed, the agricultural sector represents a large share of the economic activity sectors mainly in rural areas. The majority of the population is rural, since approximately 78.5% of the country's inhabitants live in rural areas [8]. In Mali, agriculture remains the engine of economic development thanks to the agronomic and edaphic potential of this agricultural sector. Statistics from the Ministry of Agriculture, Livestock and Fisheries [9], show that agriculture employs 96% of rural households with nearly 54% of the active population. In Mali, the contribution of the agricultural sector to GDP is high, increasing from 33.02% in 2010 to 38.34% in 2020. In addition, cereals (millet, sorghum, corn, fonio) contribute an average of 45% to the GDP of the primary sector. However, a key agricultural input, water, is still a major problem in most of the country's farms. This problem is particularly worrying for the largest farms. Faced with climate change, agricultural producers remain vulnerable. It is in this context that we asked ourselves the question of the extent to which climate change can influence the income of Malian farmers.

## 2. Methodology and Data Source

### *2.1. Theoretical Framework*

Agricultural supply has always been an important concern of economists. Going back in time, more precisely to the 18th century, [16, 17, 18], were already putting land at the center of their analyses as "the principal source of value", along with labor. Over time, several approaches have been proposed in the literature to explain the variability of agricultural production in the face of climate change. Essentially, we can note the production function approach [20], the Ricardian approach to crop yields [21] or the structural approach [22].

In addition to this literature, to analyze the effects of climate change on farm income, we will use the Ricardian model to estimate this study. The Ricardian model for analyzing the impacts of climate change on agriculture originates from the work of Mendelsohn and colleagues [11]. It is still referred to as the hedonic method in reference to the pioneering theoretical work of the 19th century classical economist David Ricardo. According to Ricardo, farmers are assumed, all other things being equal, to maximize their profits by using land whose productivity naturally decreases over time, in relation to climate and soil quality. Thus, under the assumption of well-functioning markets, the potential profitability of a parcel of land should be reflected in its market value. Therefore, spatial variations in climate lead to spatial variations in land values. Based on this assumption, the hedonic approach uses temporal data to estimate the long-term relationships between agricultural land values and climate variables. Empirically, land values or net farm income are regressed on climate variables, soil type variables, geographic variables, and economic variables that are independent of farmer choice [23]. This method also assumes that prices are constant [24] and that farmers adjust their inputs and farming practices to best take advantage of farm location, and climate [22, 24]. The estimated coefficients for the climate variables reflect the economic cost of the effect of climate change on agriculture, holding other factors constant.

### *2.2. Empirical Framework*

#### *2.2.1. Specification of the Model*

We adopted a linear function for estimating the change in income per farm worker as a function of the time trend in climate variables. According to several authors such as [25, 26], this form is the most suitable for this type of analysis. Generally, the cultivation period in Mali is between the month of June and September coinciding with the watering period. However, certain periods are considered more critical, depending on the low or high effects of the variables (June-July and August-September). Indeed, a lack of water during these periods acts considerably on the yield by decreasing it. Crops are also sensitive to low temperatures during August-September and high temperatures during June-July. The climatic variables (rainfall and temperature) considered in the empirical analysis are those related to the critical periods for agricultural production growth in Mali. Thus, the model is presented as follows:

$$Y_t = \beta_0 + \beta_1 Rainf_{JJ} + \beta_2 Rainf_{JJ}{}^2 + \beta_3 Rainf_{AS} + Rainf_{AS}{}^2 + \beta_1 Temp_{JJ} + \beta_2 Temp_{JJ}{}^2 + \beta_3 Temp_{AS} + Temp_{AS}{}^2 + Fert_t + \varepsilon_t$$

Or:

$Y_t$: Agriculture value added per worker;

$Rainf_{JJ}$: average rainfall of the months of June-July of the year t;

$Rainf_{AS}$: average rainfall in August-September of year t;

$Temp_{JJ}$: average temperature of the months of June-July of the year t;

$Temp_{AS}$: average temperature of the months of June-July of the year t;

$Fert_t$: fertilizer used during the growing season;

$\varepsilon_t$: error term.

#### *2.2.2. Empirical Model*

We use the Auto Regressive Distribution Lags ARDL approach of [27], as it has several advantages in time series analyses. It is most appropriate for inspecting the existence of relationships in small short-term and long-term data. In addition, the ARDL model allows us to test for variables with different orders of integration (they do not have to be integrated of order 2). Our empirical design would be established first on determining the stationarity of the variables using the ADF stationary test. All variables must be stationary in I (0) and I (1) in order to proceed to the next step which consists of applying the cointegration analysis (Bound test). The model is written as follows:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Rainf\_JJ_{t-1} + \alpha_3 Rainf\_JJ^2_{t-1} + \alpha_4 Rainf\_AS_{t-1} + \alpha_5 Rainf\_AS^2_{t-1} + \alpha_6 Temp\_JJ_{t-1} + \alpha_7 Temp\_JJ^2_{t-1} + \alpha_8 Temp\_AS_{t-1} + \alpha_9 Temp\_AS^2_{t-1} + \alpha_{10} fert_{t-1} + \sum_{i=1}^{p} \beta_{1i} \Delta Y + \sum_{i=1}^{q1} \beta_{2i} \Delta Rainf\_JJ_{t-1} + \sum_{i=1}^{q2} \beta_{3i} \Delta Rainf\_JJ^2_{t-1} + \sum_{i=0}^{q3} \beta_{4i} Rainf\_AS_{t-1} + \sum_{i=0}^{q4} \beta_{5i} Rainf\_AS^2_{t-1} + \sum_{i=0}^{q5} \beta_{6i} Temp\_JJ_{t-1} + \sum_{i=0}^{q6} \beta_{7i} Temp\_JJ^2_{t-1} + \sum_{i=0}^{q7} \beta_{8i} Temp\_AS_{t-1} + \sum_{i=0}^{q8} \beta_{9i} Temp\_AS^2_{t-1} + \sum_{i=0}^{q9} \beta_{10} fert_{t-1} + \varepsilon_t$$

Avec, Δ: the first difference; $\alpha_0$: the constant; $\varepsilon_t$: the error term.

p, q1, q2, q3, q4, q5, q6, q7, q8 = the maximum number of lags for each variable in the study;

$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \alpha_7, \alpha_8, \alpha_9, \alpha_{10}$ = the parameters of the long-term relationship;

$\beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \beta_9$ = the parameters of the short-term relationship (ECM).

### *2.3. Data Source*

Agricultural income is measured by agricultural value added per worker. Climate change is represented by the variables precipitation and temperature. Other agricultural inputs are identified by the amount of fertilizer consumption.

***Table 1.*** *Data source.*

| Variables | Source | Unité |
|---|---|---|
| Agriculture value added per worker | RESAKSS | dollars |
| average rainfall for June-July | FAOSTAT | millimeter |
| average rainfall in August-September | FAOSTAT | millimeter |
| average temperature of June-July | FAOSTAT | Degree celsuis |
| average temperature in August-September | FAOSTAT | Degree celsuis |
| fertilizer | RESAKSS | Kilogram/hectare |

Source: from the author, 2021.

# 3. Results and Discussion

### *3.1. Descriptive Analysis*

***Table 2.*** *Descriptive analysis.*

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Agriculture value added per worker | 32 | 929.575 | 194.0601 | 664 | 1261 |
| average rainfall for June-July | 32 | 59.02839 | 6.499604 | 48.85 | 72.84 |
| average rainfall in August-September | 32 | 81.37193 | 12.28551 | 53.57 | 110.59 |
| average temperature of June-July | 32 | 33.18378 | .4064159 | 32.34 | 33.71 |
| average temperature in August-September | 32 | 30.91534 | .4345657 | 29.69 | 31.63 |
| fertilizer | 32 | 15.7744 | 7.750288 | 6.013216 | 33.94842 |

### *3.2. Stationarity Test*

Before testing the cointegration between the variables, it is important to conduct the unit root test in order to ensure that no variable is integrated at order 2, i.e. I (2). This is essential, because the ARDL procedure assumes that all variables are integrated of order I (0) or I (1). If a variable is considered to be I (2), the calculated F-statistics produced by [17] can no longer be valid. In this regard, the most common and widely used test is the Augmented Dickey-Fuller (ADF) test [16]. The results of the ADF unit root tests of the variables are presented in the table below.

***Table 3.*** *Stationarity test.*

| | Coefficient | In First Difference | Order of integration |
|---|---|---|---|
| Agriculture value added per worker | -0.079 | -8.780*** | I (1) |
| average rainfall for June-July | -6.017*** | | I (0) |
| average rainfall in August-September | -5.280*** | | I (0) |
| average temperature of June-July | -4.243*** | | I (0) |
| average temperature in August-September | -5.756*** | | I (0) |
| fertilizer | -1.354 | -6.366*** | I (1) |

### 3.3. Determination of the Number of Delays

To identify the optimal ARDL model that allows us to obtain meaningful results, we will use the Akaike information criteria (AIC). We have the following graph that informs us about the optimal ARDL model chosen.

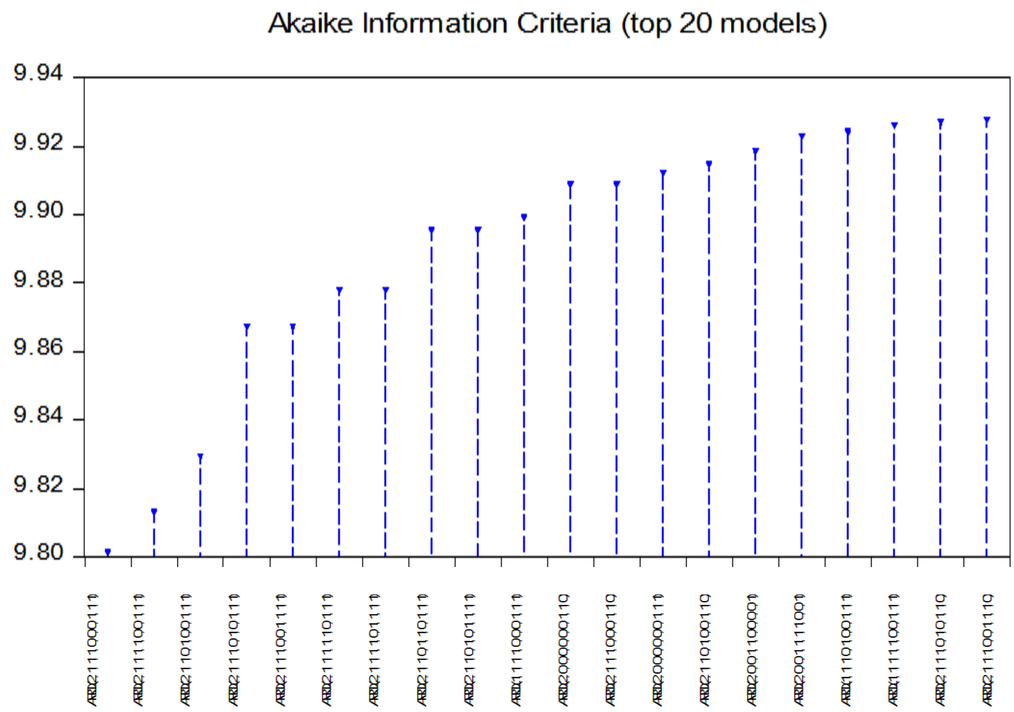


***Figure 1.*** *Optimal delay.*

The ARDL (2, 1, 1, 1, 0, 0, 0, 1, 1, 1) model is the most optimal of these twenty models, as it has the smallest AIC value.

### 3.4. Co-integration Test (Bound Test)

In order to ensure the existence of a long term relationship between the variables of our model, it is important to perform the cointegration test (Bound Test) under the following assumptions:

$H_0 = \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5$ (Lack of a long-term relationship)

$H_1 \neq \alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5$ (Existence of a long-term relationship)

The results of the Bounds test show that the Fisher statistic (F=4.540224) is greater than the upper bound of the critical value interval corresponding to the 1% error level. Therefore, we reject the hypothesis that there is no long term relationship, we conclude that there is a long term cointegration relationship for the estimated model.

***Table 4.*** *Bound test.*

| F-Bounds Test | | Null Hypothesis: No levels relationship | | |
|---|---|---|---|---|
| **Test Statistic** | **Value** | **Signif.** | **I(0)** | **I(1)** |
| F-statistic | 4.540224 | 10% | 1.8 | 2.8 |
| k | 9 | 5% | 2.04 | 2.08 |
| | | 2.5% | 2.24 | 3.35 |
| | | 1% | 2.5 | 3.68 |

***Table 5.*** *Short term relationship.*

| Variable | Coefficient | t-Statistic | Prob. |
|---|---|---|---|
| D (Agriculture value added per worker (-1)) | -0.226530*** | -2.968521 | 0.0117 |
| D (average rainfall for June-July) | 49.70841*** | 4.210231 | 0.0012 |
| D (average rainfall for June-July square) | -0.380691*** | -3.848068 | 0.0023 |
| D (average rainfall for August-September) | 30.53480*** | 10.52660 | 0.0000 |
| D (average temperature in August-September) | -651.7047 | -0.754934 | 0.4648 |
| D (average temperature in August-September square) | 11.82932 | 0.841851 | 0.4163 |
| D (fertilizer) | 1.231302 | 1.242393 | 0.2378 |
| CointEq (-1)* | -0.537137*** | -9.568761 | 0.0000 |

### 3.5. Estimation of the Short-Term Relationship (2, 1, 1, 1, 0, 0, 0, 1, 1, 1)

According to the results of table 5 above, we notice that the adjustment coefficient or error correction (CointEq (-1)) is statistically significant (Prob. = 0.0000), which confirms the existence of a long term relationship between the variables. Concerning the short term relationship between the independent variables and the dependent variable (Y), we find the existence of a negative relationship between the agricultural value added per worker and the climate change variables, which are highly significant.

***Table 6.*** *Long term relationship.*

| Variable | Coefficient | t-Statistic | Prob. |
|---|---|---|---|
| average rainfall for June-July | 186.1250*** | 3.500786 | 0.0044 |
| average rainfall for June-July square | -1.504218*** | -3.403075 | 0.0052 |
| average rainfall for August-September | 62.52573*** | 3.377105 | 0.0055 |
| average rainfall for August-September square | -0.288081** | -2.594222 | 0.0235 |
| average temperature in June-July | -16043.94** | -2.412234 | 0.0328 |
| average temperature in June-July square | 243.6398** | 2.428964 | 0.0318 |
| average temperature in August-September | 11872.41* | 2.230170 | 0.0456 |
| average temperature in August-September square | -189.5424* | -2.191557 | 0.0489 |
| fertilizer | 7.213899 | 1.630220 | 0.1290 |
| C | 70208.96 | 0.597122 | 0.5615 |

### *3.6. Estimation of the Long-Term Relationship (2, 1, 1, 1, 0, 0, 0, 1, 1, 1)*

The results of the effects of climate change on the agricultural income of Malian producers in this estimation are highly significant at the 5% and 1% thresholds, i.e. these variables have long-term effects. As a result of this estimation, we find a negative influence of the quadratic relationships of June-July and August-September rainfall on agricultural income. This supports the theory, on the one hand, of the importance of optimal rainfall to water crops, on the other hand, showing the existence of a negative threshold effect of rainfall to reduce the agricultural income of producers. These results are confirmed by the work of several authors on the negative effects of climate change on agricultural income [28, 29, 30, 2]. The average temperatures of June-July are high compared to August and September. These explain the negative influence of the average temperature of the month of June-July on farmers' agricultural income. Contrary to the quadratic temperature of August and September showing the presence of a negative effect on the agricultural income. This result of the negative effects of temperature corroborates with the work of [25, 31]. Fertilizer consumption increases farm income for Malian producers, but the result is not significant [19].

***Table 7.*** *Validation test.*

| | Long terme |
|---|---|
| Normality Test | 2.918<br>(0.708) |
| ARCH Test | 0.415<br>(0.686) |
| Breusch-Godfrey Test | 0.996<br>(0.004) |

### *3.7. Validation Test*

After the interpretation of the results, in this next step, we are going to focus on the verifications of the main hypotheses, namely: the hypotheses of the normality of the errors, test of heteroscedasticity and test of stability of the coefficients in order to keep the model globally significant, for an overall relevance of the regression and to avoid falling into spurious regressions. In the following (Table 7), we therefore accept the hypothesis of homoscedasticity (ARCH (0.415) > 0.05), test for normality (2.918) > 0.05 and find no autocorrelation (Breusch-Godfrey (0.996) > 0.05.

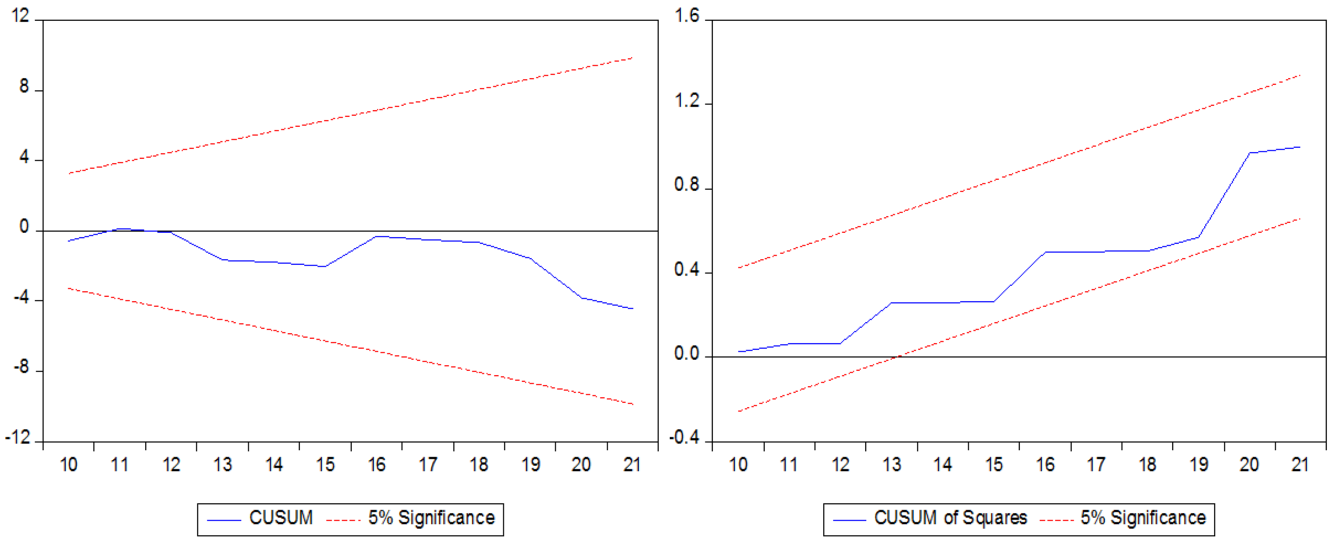


***Figure 2.*** *CUSUM and square CUSUM.*

### *3.8. CUSUM and CUSUM_2 Test*

According to the results of the CUSUM and CUSUM square tests performed by Eviews 10 software, we find that the recursive residuals always remain in the interval for the 5% confidence level, so the coefficients are stable over time, so we reject the hypothesis of a structural change.

## 4. Conclusion

This paper proposes an econometric investigation of the effect of climate change on the agricultural income of Malian producers. The results were obtained using the ARDL estimator over the period 1990-2021. The results of this study corroborate with the theory of the negative effect of climate change on agricultural income. The June-July and August-September precipitations, certainly increase the agricultural income, but also admit a threshold from which, they become harmful to the income of producers. In addition, the average temperature of the months of June-July is high for the various crops, which contributes to lower income, unlike the average temperature of the months of August-September. This study does not take into account future adaptations that farmers may implement. Thus, the impacts can be mitigated, but for this to happen, it is imperative to strengthen farmers' capacities to adapt to climate change in Mali.

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