AKADEMIYA2063

CACCI
COMPREHENSIVE ACTION FOR CLIMATE CHANGE INITIATIVE

No. 04, July 2023

# CACCI FIELD NOTES

## Economic Impacts of Climate Change and Adaptation Strategies in Mali

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## About the CACCI Field Notes

AKADEMIYA2063 CACCI Field Notes are publications by AKADEMIYA2063 scientists and collaborators based on research conducted under the Comprehensive Action for Climate Change Initiative (CACCI) project. CACCI strives to help accelerate the implementation of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) by meeting the needs for data and analytics and supporting institutional and coordination capacities. In Africa, CACCI works closely with the African Union Commission, AKADEMIYA2063, the African Network of Agricultural Policy Research Institutes (ANAPRI), and climate stakeholders in selected countries to inform climate planning and strengthen capacities for evidence-based policymaking to advance progress toward climate goals.

Published on the AKADEMIYA2063 website (open access), CACCI Field Notes provide broad and timely access to significant insights and evidence from our ongoing research activities in the areas of climate adaptation and mitigation. The data made available through this publication series will provide evidence-based insights to practitioners and policymakers driving climate action in countries where the CACCI project is being implemented.

AKADEMIYA2063's work under the CACCI project contributes to the provision of technical expertise to strengthen national, regional, and continental capacity for the implementation of NDCs and NAPs.

AKADEMIYA2063 is committed to supporting African countries in their efforts against climate change through provision of data and analytics using the latest available technologies. This Field Note reviews Mali's climate change and adaptation pathway scenarios, and then assesses their prospects and projected impacts.

CACCI is supported by the U.S. Agency for International Development (USAID) through the Feed the Future Innovation Lab for Food Security Policy Research, Capacity, and Influence (PRCI) led by Michigan State University (MSU). The views expressed in this publication do not necessarily reflect those of the funder.

## About AKADEMIYA2063

AKADEMIYA2063 is a pan-African non-profit research organization with headquarters in Kigali, Rwanda and a regional office in Dakar, Senegal. Inspired by the ambitions of the African Union's Agenda 2063 and grounded in the recognition of the central importance of strong knowledge and evidence-based systems, the vision of AKADEMIYA2063 is an Africa with the expertise we need for the Africa we want. This expertise must be responsive to the continent's needs for data and analysis to ensure high-quality policy design and execution. Inclusive, evidence-informed policymaking is key to meeting the continent's development aspirations, creating wealth, and improving livelihoods.

AKADEMIYA2063's overall mission is to create, across Africa and led from its headquarters in Rwanda, state-of-the-art technical capacities to support the efforts by the Member States of the African Union to achieve the key goals of Agenda 2063 of transforming national economies to boost economic growth and prosperity.

Following from its vision and mission, the main goal of AKADEMIYA2063 is to help meet Africa's needs at the continental, regional and national levels in terms of data, analytics, and mutual learning for the effective implementation of Agenda 2063 and the realization of its outcomes by a critical mass of countries. AKADEMIYA2063 strives to meet its goals through programs organized under five strategic areas—policy innovation, knowledge systems, capacity creation and deployment, operational support, and data management, digital products, and technology—as well as innovative partnerships and outreach activities. **For more information**, visit www.akademiya2063.org.

**Suggested Citation:** Fofana, I. 2023. *Economic Impacts of Climate Change and Adaptation Strategies in Mali*. CACCI Field Notes, No. 04. Kigali: AKADEMIYA2063. https://doi.org/10.54067/caccifn.04

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## 1. Introduction

In a show of their resolve to act on global climate change and in response to the 2015 Paris Agreement, 52 African countries had submitted their Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) by 2021. These countries, except one, included National Adaptation Plans (NAPs) in their NDCs, although six of these NAPs were developed separately. The NDCs reflect efforts by individual countries to reduce national greenhouse gas (GHG) emissions and adapt to the impacts of climate change, while the NAPs are strategic planning documents which detail each country's medium- and long-term priorities and interventions for adapting to climate change.

The Africa Adaptation Acceleration Program (AAAP), led by the Global Center on Adaptation (GCA) and the African Development Bank (AfDB), aims to mobilize US$ 25 billion to scale up and accelerate climate change adaptation initiatives across Africa. The AAAP will support countries in making transformational shifts in their development pathways by centering adaptation and resilience to climate change in their critical growth-oriented and inclusive policies.

AKADEMIYA2063 is supporting GCA and AfDB with the mainstreaming of climate change adaptation into agricultural policies and expenditures, by providing technical assistance to inform and facilitate the effective implementation of NAPs, as well as to identify adaptation pathways and related policy options. This work is currently being undertaken in two African countries, Kenya, and Mali. This report presents the case of Mali.

Extreme weather is not a new phenomenon in Mali. However, the country's vulnerability to climate change is exacerbated by factors that limit the society's and government's ability to mitigate and adapt. These factors include the high reliance on natural resource-based livelihoods and a protracted political crisis. Mali's vulnerability score in the ND-GAIN Index, which measures the country's exposure, sensitivity, and capacity to adapt to climate change is 0.60 (rank 176/182), while the ND-GAIN Index score for adaptation readiness is 0.30. The country's current and future climate change challenges, combined with the difficult political and socio-economic conditions make Mali highly vulnerable to climate change.

At the 2015 Paris Agreement, Mali committed at an international level in its NDC, to fight climate change through mitigation and adaptation actions that would strengthen the capacities and resilience of its population involved in the energy, agriculture and forestry sectors. At the strategic level, the country has integrated climate change into its planning processes, particularly in the implementation of the Framework for Economic Recovery and Sustainable Development (CREDD), the National Environmental Protection Policy and, since 2011, in the National Climate Change Policy.

This report defines Mali's climate change and adaptation pathway scenarios, and then assesses their prospects and projected impacts.

## 2. Methodology

Economic simulation models are practical tools to support evidence-based planning and the implementation of development programs. They establish a relationship between program inputs and expected outputs and outcomes. As such, they facilitate the prioritization of public interventions and investments. This ex-ante analysis of climate change and adaptation strategies is carried out using a mix of macro- and micro-economic models. The macro-economic model captures issues related to growth, employment, and income generation, while the micro-economic model addresses issues related to income distribution, poverty, food security and nutrition. The macro- and micro-models are linked in a top-down fashion through a set of interrelated variables used in both models. The models are applied to Mali's economy using data from the most recently updated databases.

The methodology is implemented in a stepwise manner. First, the simulation scenarios are developed through an exhaustive review of existing literature to collect evidence on climate change impacts and effects of adaptation options on agricultural productivity. Second, evidence on the productivity effects of climate shocks is used in the macro-model to assess economic growth and changes in employment and income by type of production factor and household category. Third, income changes from the macro-model are used in the micro-model to evaluate the poverty and food security outcomes.

### 2.1. Review of Climate Change Impacts on Agricultural Yields

Available literature provides evidence on the likely impacts of climate change on agriculture in Africa. The first step in implementing this methodology involves conducting an extensive review of evidence on the impacts of climate change on the agricultural sector in Mali, West Africa, and Africa. The review covers several agricultural activities (i.e., crops, livestock, forestry, and fisheries). Predictions of the likely effects of climate change on yields are documented in annexed Tables A.3 to A.8.

Modifying management practices at the farm level such as use of irrigation, crop protection with chemicals, use of fertilizers, and adjusting sowing dates have been proven to enhance crop adaptation to climate change. This review also examines existing evidence on how these practices can contribute to mitigating the impacts of climate change on Mali's agricultural yields.

### 2.2. Modeling the Macro-Economic Impacts of Climate Change

The ex-ante analysis of climate change and adaptation pathways primarily uses a Computable General Equilibrium (CGE) model that is customized to Mali's economy using a Social Accounting Matrix (SAM). The CGE models are macro-economic models that combine economic theory and empirical data to capture the effects of economic policies and shocks. They consider the interdependencies between different sectors, agents, and markets in the economy. They can therefore shed light on the wider economic impacts of policies and shocks, sometimes revealing their indirect or unintended effects. Considering the long-term outlook and impacts of climate change shocks, we developed a static CGE model for Mali with long-term, macro-economic closure rules.

Key features of the model are borrowed from the static version of the CGE model developed by Decaluwé et al. (2013).[1] This standard CGE archetype is modified to fit climate change issues by adopting a long-term closure rule that more accurately considers the aspect of time. As such, labor, agricultural land, and other forms of capital are fully mobile between economic activities, representing the long run where the economy has time to adjust. Current public expenditures and fiscal balances are fixed relative to Gross Domestic Product (GDP). The integration of a compensatory mechanism through taxes or subsidies on household gross income, makes it possible to capture the effects of variations in government income on household welfare following climate change shocks. Mali is a small country in terms of its trading links with the rest of the world, i.e., the country has no influence on international prices of both imported and exported products, which remain fixed in the model. The external current account balance is kept fixed relative to GDP, thereby effectively linking external financing to the performance of the economy. The volume of investment is also kept fixed relative to GDP through household savings. The model is therefore investment-driven in the sense that total investments determine total savings, i.e., the sum of private, government, and foreign savings. This closure rule enables the capturing of the full effects of climate change shocks. In other words, inter-generational transfers of welfare are not allowed. Flexible prices equilibrate the demand and supply of domestically marketed products, and the exchange rate is the numeraire in the model.

Many studies use a deterministic approach to assess the effects of climate change on agriculture. However, deterministic shocks ignore the uncertainty associated with climate change and its implications on yields as depicted in annexed Tables A.2 to A.7. In this analysis, we use a stochastic approach to consider the uncertainties inherent to climate change and its effects on agricultural yields. Climate change shocks are translated into variations in agricultural productivity, and consequently, are propagated throughout the economy through the upstream and downstream linkages of the agricultural sector with the rest of the economy.

The primary data sources for CGE models are country SAMs which are "a comprehensive, flexible, and disaggregated framework that elaborates and articulates the generation of income by activities of production and the distribution and redistribution of income between social and institutional groups" (Round, 2003). Mali's 2018 SAM accounts for 42 industries (including 18 agricultural activities), five factors of production (including agricultural land and three categories of labor), and 10 representative household groups. Randriamamonjy (2021) provides more detailed information on the 2018 SAM for Mali.

1 More details on the CGE model are provided by Decaluwé et al (2013).

### 2.3. Modeling the Micro-Economic Effects of Climate Change

Micro-economic models deal with the economic decisions and actions of economic agents in reaction to policy shocks. They integrate the heterogeneous behavior of individuals and firms while accounting for the aggregate costs and benefits of interventions or shocks (Bourguignon and Spadaro, 2006). There is growing interest in combining CGE and Micro-Simulation (MS) models to assess the effectiveness of macro-economic policies and shocks. CGE models address macro-economic and sectoral issues such as growth, employment, and earnings. However, unlike MS models, they do not capture issues related to income distribution, inequality, and poverty. Relatedly, MS models focus on individual and firm level distributive effects but fail to capture general equilibrium effects, as well as macro and sectoral issues linked to policies and shocks. Combined CGE-MS analysis can be conducted in many ways and the choice among the available approaches depends on data availability, the research questions and time constraints (Cockburn, Savard, and Tiberti 2014).

The proposed MS model builds on the flexibility of the reweighting technique. This technique involves altering the sample weights in the MS model to reproduce changes in employment and earnings from the CGE model, and other population variables. The new weights are generated in such a way that fresh aggregate population values for selected variables are reproduced with minimal adjustments to the original weights. In other words, the approach minimizes the distance between new and old weights subject to a set of constraints on aggregate values. Shocks are therefore generated by the CGE model and transmitted to the MS model. Consistency between the two models is created by adjusting the household weights. In a comparison of the behavioral and the reweighting micro-simulation approaches, Herault (2010) concludes that the two approaches delivered similar results when applied to the issue of trade liberalization in South Africa.

The CGE and MS models are linked through the productive factors, i.e., three categories of labor, agricultural land, and other forms of capital. One of the advantages of the reweighting approach is the ability to project the changing dynamics for several population groups, for instance, based on region, gender and age. This feature is important in the context of climate change studies which assess long-term impacts on people's livelihoods.

The MS model is implemented using the latest available survey data. The 2017/2018 Mali Living Standards Measurement Study (LSMS)[2] is used to calibrate the MS models and to conduct the micro-economic analysis.

### 2.4. Simulation Scenarios

The economic impacts of climate change and adaptation pathways are assessed by comparing two scenarios: (i) Business-as-Usual (BaU) scenario; and, (ii) Climate change (CC) scenarios. The first scenario, or BaU, is based on the agricultural yield trends for the past 20 years, i.e., 2000-2019 (Table 1). The low bounds are the average values of negative changes in agricultural yields. The high bounds are the average values of positive changes in agricultural yields. The BaU scenario therefore does not take climate change into account, and instead projects the continuation of historical trends in the agricultural sector and the economy in general. This serves as the reference scenario which the outcomes of other scenarios are compared to.

**Table 1:** *Changes in agricultural yields in Mali, 2000-2019*

| | Range of Yield Variation (%) | | |
|---|---|---|---|
| **Agricultural Activities** | **Mean** | **High bound** | **Low bound** |
| Maize | 6.5 | 26.4 | -13.4 |
| Rice | 3.3 | 13.2 | -8.8 |
| Other Cereals | 0.2 | 11.0 | -10.6 |
| Pulses | 1.4 | 11.1 | -6.6 |
| Oilseeds | 6.5 | 27.3 | -14.3 |
| Roots & Tubers | 3.0 | 13.4 | -5.6 |
| Vegetables | 1.0 | 3.5 | -3.6 |
| Sugarcane | 4.3 | 9.9 | -4.2 |
| Cotton | 0.6 | 9.4 | -8.3 |

2 « Enquête Agricole de Conjoncture Intégrée aux Conditions de Vie des Ménages 2017 ».

| Agricultural Activities | Range of Yield Variation (%) | | |
|---|---|---|---|
| | Mean | High bound | Low bound |
| Fruits & Nuts | 0.7 | 22.6 | -21.1 |
| Other Crops | 1.2 | 7.1 | -3.6 |
| Cattle | -0.8 | 3.7 | -5.2 |
| Poultry | -0.1 | 7.0 | -4.1 |
| Other Livestock | 2.2 | 10.7 | -13.6 |
| Forestry | 1.1 | 1.1 | 0.0 |
| Fisheries | 1.6 | 15.7 | -19.4 |

**Source:** FAO (2022).

The second scenario is the climate change (CC) scenario which is built on the existing empirical evidence on the impacts of climate change on agricultural yields and production. Table 2 presents the results of the Mali review with further details available in annexed Tables A.3 to A.8. These annexed tables display variations in agricultural yields driven by changes in global temperatures (i.e., from 0.5°C to 5.5°C) and precipitation levels.[3] The analysis considers the extreme values (low and high bounds) predicted by these studies.

**Table 2:** Climate change impacts on agricultural yields in Mali

| Agricultural Activities | Yield Variation (%) | |
|---|---|---|
| | Low bound | High bound |
| Maize | -57.0 | 13.5 |
| Rice | -25.0 | 4.4 |
| Other Cereals | -17.1 | 6.2 |
| Pulses | -4.9 | 0.0 |
| Oilseeds | -13.5 | 0.0 |
| Roots & Tubers | -7.1 | 0.0 |
| Vegetables | -14.2 | -11.3 |
| Sugarcane | -9.5 | -7.3 |
| Cotton | -7.7 | 6.2 |
| Fruits & Nuts | -7.1 | -7.0 |
| Cattle | -36.0 | -5.0 |
| Poultry | -36.0 | -5.0 |
| Other Livestock | -36.0 | -5.0 |
| Forestry | -18.0 | 14.0 |
| Fishery | -42.0 | -3.0 |

**Source:** Author's compilation from the review of the literature studies.

The BaU and climate change scenarios are introduced in line with the stochastic approach to consider the historical variability of agricultural yields, and the uncertainties inherent in climate change and its effects on agricultural yields. Shocks on agricultural yields are implemented using the Monte Carlo Technique, i.e., random selections of yield variations. Shocks are distributed uniformly using uniform probability with minimum and maximum variations (Tables 1 and 2). Several thousand (9,000) scenarios were implemented. Mean changes and standard deviations (SD) are computed for output variables and discussed in the next section.

3 The literature reviewed focused on Mali and West Africa which limitation in term of number of observations did not allow us to assess the impact at different levels of warming.

# 3. The Economic Impacts of Climate Change

## 3.1. Effects on Agriculture

Comparison of the CC scenario with the BaU scenario indicates that climate change shocks substantially reduce agricultural productivity (Table 3). Under the BaU scenario, agricultural productivity increases slightly at an average annual rate of 0.9 percent compared to 2019 levels (between -0.5 percent and 2.3 percent at 95 percent confidence level). Agricultural productivity is severely affected by climate change shocks with a decline of 13.3 percent in average annual productivity compared to 2019 levels (between -11.7 percent and -14.4 percent at 95 percent confidence level). Average annual agricultural productivity therefore falls by 14.2 to 16.7 percentage points, in the CC scenario compared to BaU.

The results also indicate that productivity falls across all agricultural activities under the CC scenario compared to BaU (Table 3). **Maize, oilseeds, fisheries,** and **livestock** are the activities most affected by climate change shocks. These are followed by **rice, vegetables, sugarcane,** and **roots and tubers**. **Cotton** and **forestry** activities are less affected by climate change shocks. Changes in agricultural productivity and value-added follow a similar pattern (Table 4).

**Table 3:** Changes in Mali's agricultural productivity

| | Business-as-Usual | | Climate change | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| **Agriculture** | **0.9** | **0.7** | **-13.3** | **0.8** |
| Maize | 6.1 | 1.2 | -21.6 | 2.1 |
| Rice | 2.6 | 0.6 | -9.9 | 0.9 |
| Other cereals | 0.0 | 0.6 | -4.5 | 0.6 |
| Pulses | 2.3 | 0.5 | -4.9 | 0.0 |
| Oilseeds | 7.0 | 1.2 | -13.5 | 0.0 |
| Roots | 4.2 | 0.6 | -7.1 | 0.0 |
| Vegetables | -0.2 | 0.2 | -12.7 | 0.1 |
| Sugarcane | 3.1 | 0.4 | -8.4 | 0.1 |
| Cotton and fibers | 0.1 | 0.5 | -0.7 | 0.4 |
| Fruits and nuts | 1.8 | 1.3 | -7.1 | 0.0 |
| Other crops | 1.6 | 0.3 | -9.4 | 0.6 |
| Cattle and raw milk | -0.7 | 0.3 | -20.7 | 0.9 |
| Poultry and eggs | 1.1 | 0.3 | -20.3 | 0.9 |
| Other livestock | -1.4 | 0.7 | -20.7 | 0.9 |
| Forestry | 0.5 | 0.0 | -1.7 | 0.9 |
| Fisheries | -1.6 | 1.0 | -22.0 | 1.1 |

Source: Simulation results.

**Table 4:** Changes in agricultural value-added in Mali

| | Business-as-Usual | | | Climate change |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| **Agriculture** | **0.6** | **0.6** | **-15.0** | **0.7** |
| Maize | 4.3 | 0.8 | -17.9 | 2.2 |
| Rice | 2.1 | 0.5 | -11.3 | 0.5 |
| Other cereals | 0.4 | 0.5 | -6.3 | 0.3 |
| Pulses | 1.8 | 0.4 | -7.4 | 0.0 |

| | Business-as-Usual | | Climate change | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Oilseeds | 6.2 | 1.1 | -15.0 | 0.0 |
| Roots | 4.0 | 0.5 | -10.7 | 0.0 |
| Vegetables | 0.1 | 0.2 | -12.1 | 0.0 |
| Sugarcane | 2.3 | 0.3 | -10.2 | 0.0 |
| Cotton and fibers | 0.3 | 0.6 | -6.3 | 0.2 |
| Fruits and nuts | 1.9 | 1.1 | -8.6 | 0.0 |
| Other crops | 3.2 | 0.5 | -12.6 | 0.8 |
| Cattle and raw milk | -0.5 | 0.2 | -20.4 | 0.6 |
| Poultry and eggs | 0.9 | 0.2 | -18.5 | 0.4 |
| Other livestock | -1.2 | 0.8 | -24.3 | 0.7 |
| Forestry | 0.4 | 0.0 | -4.7 | 0.4 |
| Fisheries | -1.1 | 0.7 | -18.4 | 0.6 |

**Source:** Simulation results.

### 3.2. Effects on Non-agricultural Sectors

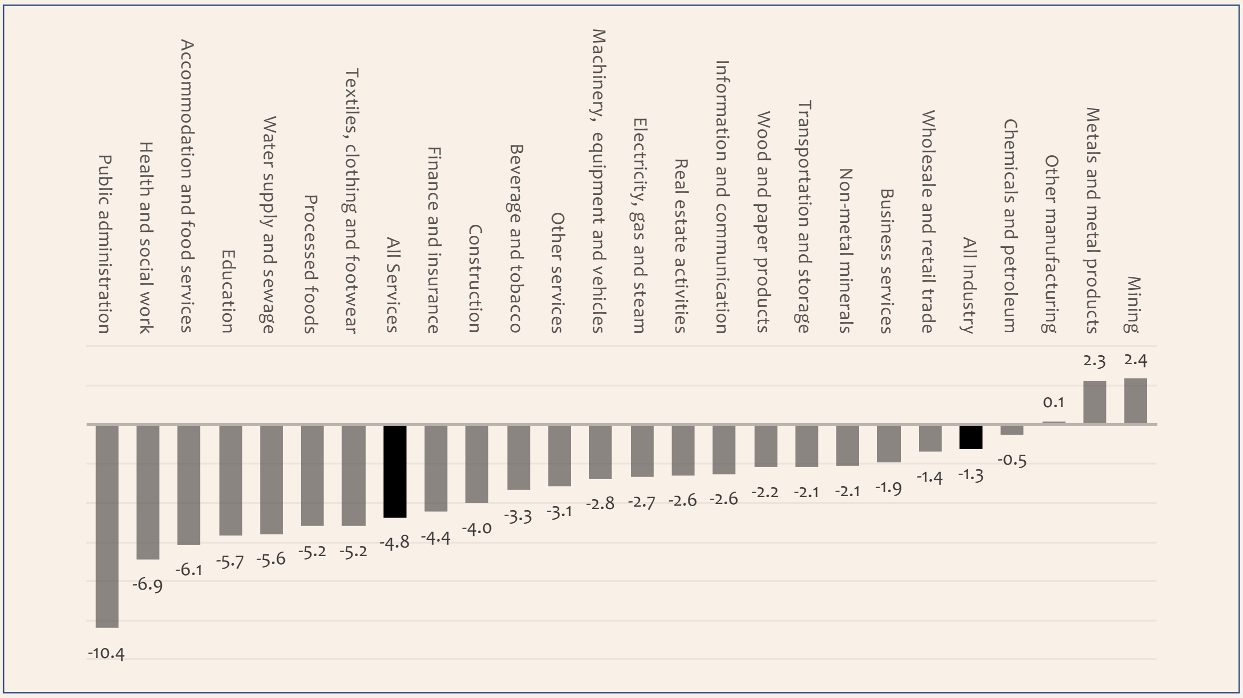
Declines in agricultural value-added affect the rest of the economy through the backward and forward linkages of the agricultural and non-agricultural sectors. Mali's industrial sector shows strong linkages with the agricultural sector. Input intensity is measured by the ratio of input costs to value-added and represents backward linkages. In 2018, the industry and services input intensity of the agricultural sector was 11.7 percent and 4.4 percent respectively. Forward linkages which are measured by the share of total demand for agricultural products from the industry and services sectors were 23.8 percent and 1.1 percent respectively in 2018. Notably, industry value-added declines less than services value-added under the CC scenario (-1.3 percent vs. -4.8 percent respectively) because of the relatively high exposure of the industry sector to external trade and the real exchange rate depreciation effect. The exposure to external trade (i.e., ratio of exports to production) for the industry and services sectors was estimated at 33.3 percent and 5.1 percent respectively in 2018.

Several non-agricultural industries are severely hit by climate change shocks on agricultural yields (Figure 1):

- Public administration, health and social work, and education are affected negatively by climate change shocks on agricultural yields compared to the BaU scenario because of their linkages with the agricultural and food industries (agricultural and food products represent 13 percent to 28 percent of total input cost). Moreover, the underperformance of the economy and the related impacts on government revenues and expenditures (fiscal policy effect) also have additional negative effects.
- Accommodation and food services, and food processing are among the most affected industries as agricultural products represent 34 percent and 80 percent respectively, of the total input costs of these industries.
- Textile value-added also declines significantly because of the industry's dependence on cotton and fibers as its main input (41 percent of total input cost).
- Water supply and sewage services are also severely affected because of the backward linkages with the agricultural sector, i.e., agricultural sector demand, which largely stems from the livestock industry that represents 22 percent of total demand.
- Construction, and the beverage and tobacco industries are also negatively impacted because of their linkages with the agricultural sector, represented primarily by forestry and other cereals respectively.

Several non-agricultural industries stand to benefit from the climate change shocks on agricultural yields through the real exchange rate depreciation effect, i.e., the relative increase in domestic prices compared to external prices. The metals and mining industries, with export propensity rates of 76.6 percent and 65.4 percent respectively, increase their value-added under the CC scenario compared to the BaU scenario. The category 'Other manufacturing' also benefits slightly from the CC shock because of its exposure to external trade (2.2) and the relatively modest impact of the CC shock on its main agricultural input, i.e., forestry products.

**Figure 1:** Changes in value-added for the industry and service sectors in Mali, CC against BaU scenario (%)

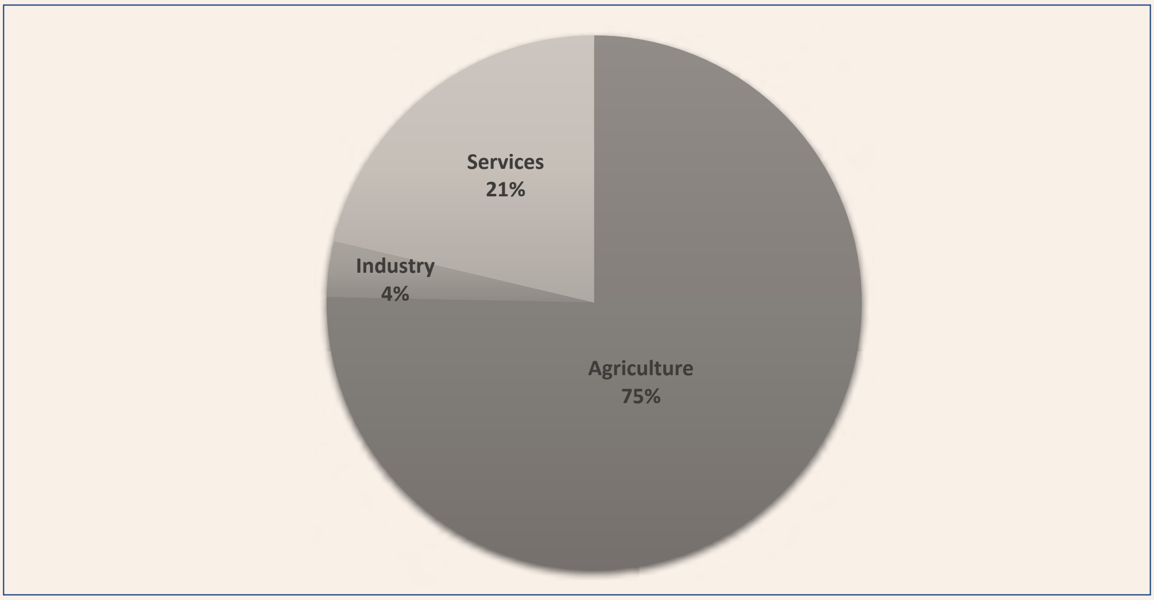



**Source:** Simulation results.

### 3.3. Effects on the National Economy

Climate change impacts on agricultural yields reduce Mali's economic output (measured in terms of GDP) by 8.9 percent compared to the BaU scenario. The shrinking agricultural sector is largely responsible for the shrinking GDP, contributing up to 75 percent to this decline (Figure 2). The services sector also contributes significantly (21 percent) to the declining GDP while the industrial sector's contribution is minimal (4 percent). These effects are consistent with the structure of the economy where the shares of agriculture, industry and services in Mali's economy were estimated at 41 percent, 22 percent, and 37 percent respectively in 2018.

**Figure 2:** Sector contribution to GDP decline, under CC scenario




**Source:** Simulation results.

### 3.4. Effects on Employment and Factor Rewards

Comparison of the CC and the BaU scenarios revealed that climate change shocks on agricultural yields would hit high-skilled laborers more severely than their low-skilled and medium-skilled counterparts in terms of changes in employment numbers and earnings (Table 5). In addition, the returns to agricultural land and other forms of capital decline significantly.

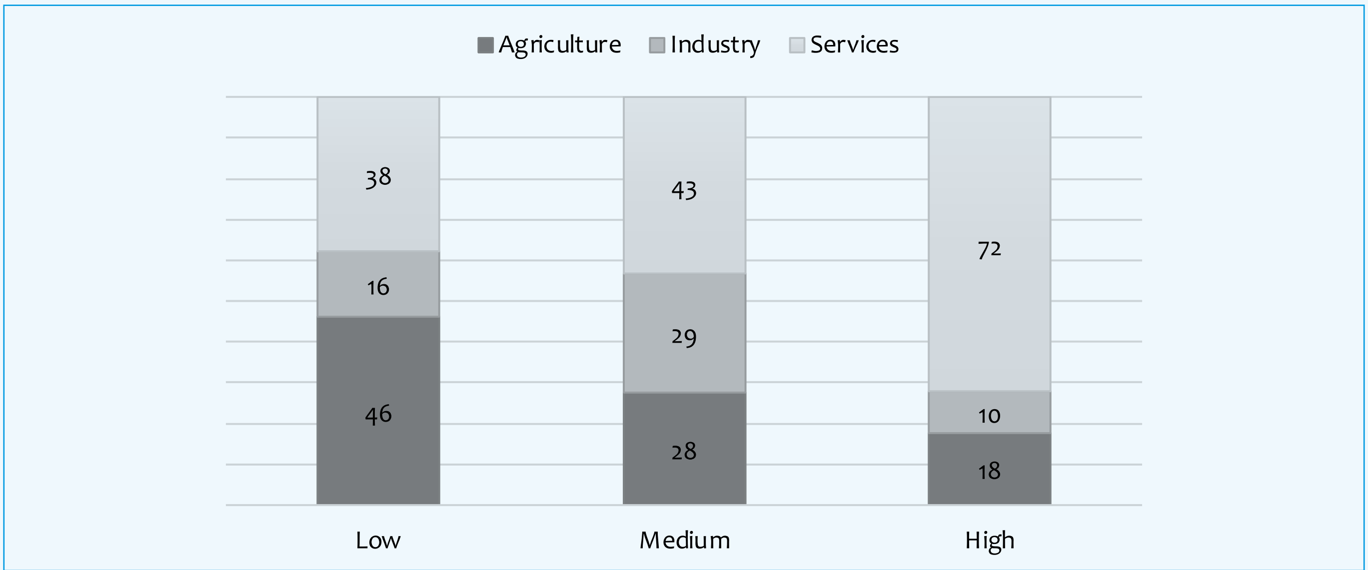
**Table 5:** Changes in employment numbers and employment earnings by category in Mali, CC compared to BaU scenarios (%)

| | Numbers | Earnings |
|---|---|---|
| Labor, Low-skill | -6.8 | 1.8 |
| Labor, Medium-skill | -5.3 | 0.8 |
| Labor, High-skill | -6.3 | -1.8 |
| Agricultural Land | 0.0 | -9.4 |
| Other Capital | 0.0 | -7.3 |

**Source:** Simulation results.

As low-skilled employment earnings are generated predominantly in the agricultural sector (Figure 3), in the long-run, increased employment of low-skilled workers compensates for the large productivity declines in agricultural activities which are severely hit by climate shocks. Medium-skilled employment is less negatively affected by climate change shocks because of the high involvement of this category of laborers in the industrial sector compared to other categories (Figure 3). As seen earlier, industry value-added fares relatively better than agriculture and services value-added given climate change shocks.

**Figure 3:** Employment earnings by labor category and economic sector in Mali




**Source:** Simulation results.

### 3.5. Effects on Inequality and Poverty

As shown in Table 6, income inequality, measured by the Gini Index, falls by -0.5 percent under the CC scenario compared to BaU, as high-skilled employment numbers and earnings decline more than in other skill categories. However, poverty increases under the climate change (CC) scenario compared to BaU and employment numbers decline for all skill categories.

The number of the poor, i.e., individuals with total consumption expenditures less than the national poverty line of 269,485 CFA francs, increases by 0.9 percent under the CC scenario compared to BaU. This represents an additional 166,000 individuals falling into poverty under the CC scenario compared to BaU. More importantly, the number of the extreme poor, i.e., individuals with total consumption expenditures less than the international poverty line of 145,769 CFA francs, increases by 1.3 percent under the CC scenario compared to BaU. This represents an additional 54,000 individuals spending less than US$ 1.25 (in 2011 purchasing power parity (PPP) exchange rate).

**Table 6:** Change in poverty and hunger, CC compared to BaU Scenarios

| | Percentage (%) | Number of Individuals |
|---|---|---|
| Gini Index | -0.5 | - |
| National Poverty | 0.9 | 166,305 |
| Extreme Poverty | 1.3 | 54,259 |

**Source:** Simulation results.

## 4. The Contribution of Climate Change Adaptation Strategies

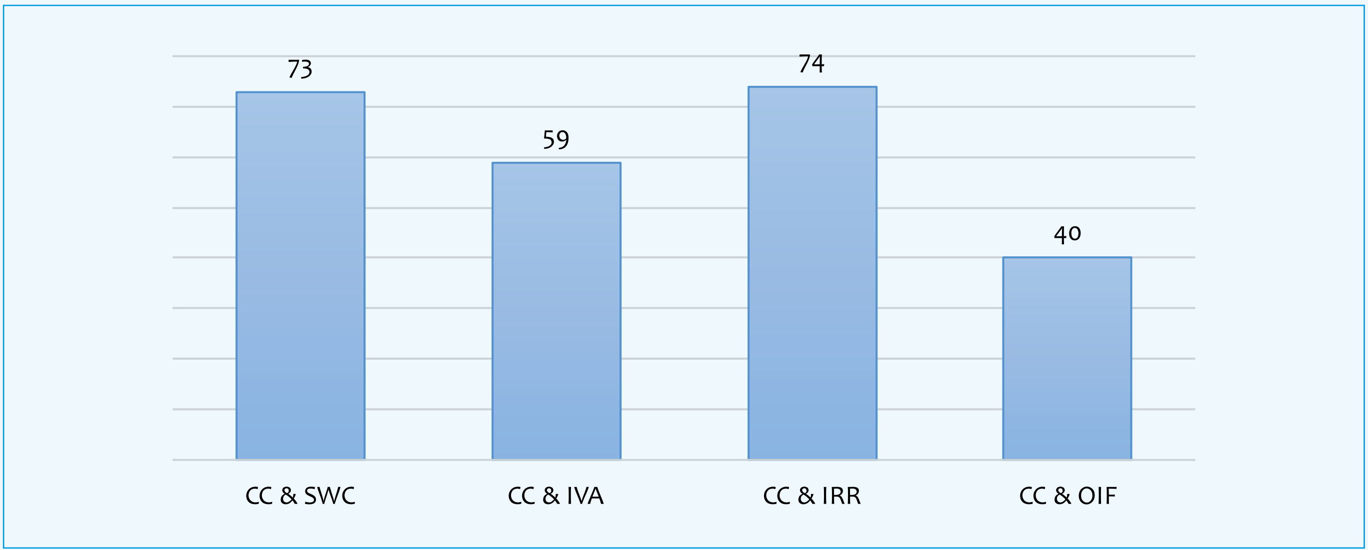
Four adaptation strategies are tested. These are: (i) Soil and water conservation (reduced tillage, terracing, ridging, bunds, and mulching), (ii) Use of improved varieties, (iii) Irrigation, and (iv) Use of organic and inorganic fertilizers. Empirical evidence on the impacts of these adaptation strategies on crop yields has been obtained from existing research results, and is presented here:

- *Soil and water conservation*
    - Reduced tillage increased crop yields between 8 percent and 75 percent in **Mali** (World Bank 2019).
    - Terracing, ridging, and bunds increased crop yields between 44 percent and 92 percent in **Mali** (World Bank 2019).
    - Mulching increased crop yields between 46 percent and 92 percent in **Mali** (World Bank 2019).
    - Soil and water conservation increased maize yields between 14 percent and 50 percent in **Africa** (Lebel et al. 2015).
- *Improved varieties*
    - Increased crop yields between 36 percent and 85 percent in **Mali** (World Bank 2019).
    - Increased maize yields between 20 percent and 50 percent in **Western Africa** (CGIAR 2010).
- *Irrigation*
    - Increased crop yields by 56 percent in **Burkina Faso** (World Bank 2019).
    - Increased rice yields by 23 percent in **Ghana** (Koide et al. 2021).
- *Organic and inorganic fertilizers*
    - Organic fertilizers increased crop yields between 73 percent and 101 percent in **Mali** (World Bank 2019).
    - Inorganic fertilizers increased crop yields by 68 percent in **Mali** (World Bank 2019).

We then assessed the share of cultivated area that should be covered by each adaptation option to compensate for the economic output losses (measured in terms of GDP) caused by climate change shocks in agriculture. The results are presented in Figure 4.

The shares of cultivated area with organic and inorganic fertilizer use and improved varieties rise by 40 and 59 percent respectively in comparison to 2018 levels. The share of cultivated area under soil and water conservation rises by 73 percent while that under irrigation rises by 74 percent (Figure 4). This implies that in order to compensate for the economic losses caused by climate change, the area under soil and water conservation, for instance, would have to increase by 73 percent.

**Figure 4:** Percentage of cultivated area to cover under various adaptation options (%)




**Source:** Simulation results.

Note: CC: Climate Change; SWC: Soil and Water Conservation; IVA: Improved Varieties; IRR: Irrigation; OIF: Organic and Inorganic Fertilizer.

## 5. Summary and Conclusion

This assessment of the economic impacts of climate change has clearly shown the urgent need for implementation of adaptation strategies. Should Mali continue with business-as-usual, climate change will reduce Mali's economic output (measured in terms of GDP) by 8.9 percent. The agricultural sector is primarily responsible for the GDP decline, contributing 75 percent to the economic contraction. Similarly, because of climate change the number of extremely poor people in Mali will increase by 1.3 percent. This represents an additional 54,000 individuals with total consumption expenditures that are lower than the international poverty line of 145,769 CFA francs. However, the extensive promotion and implementation of soil and water conservation, irrigation, improved crop varieties, and organic and inorganic fertilizers, will help combat the adverse effects of climate change. In order to better protect the country from the adverse effects of climate change, the areas under soil and water conservation, irrigation, improved crop varieties and fertilizers will have to increase by 73 percent, 59 percent, 74 percent and 40 percent respectively.

Based on these findings, this study makes the following recommendations: i) mainstreaming adaptation practices in the agricultural sector will require improved prediction capabilities and a better knowledge of climate suitability for crops. Improved predictions will help determine – with a level of certainty – how the climate will change in the short-term and assist in planning for cropping activities. This will also help in the identification of suitable places to grow specific crops based on climate. These combined measures would help enhance climate change adaptation efforts instead of only relying on traditional knowledge of the crop calendar; ii) promotion of climate smart practices such as soil and water conservation practices, irrigation and improved agricultural technologies to stem productivity declines in the agricultural sector and shield the economy from climate induced crises.

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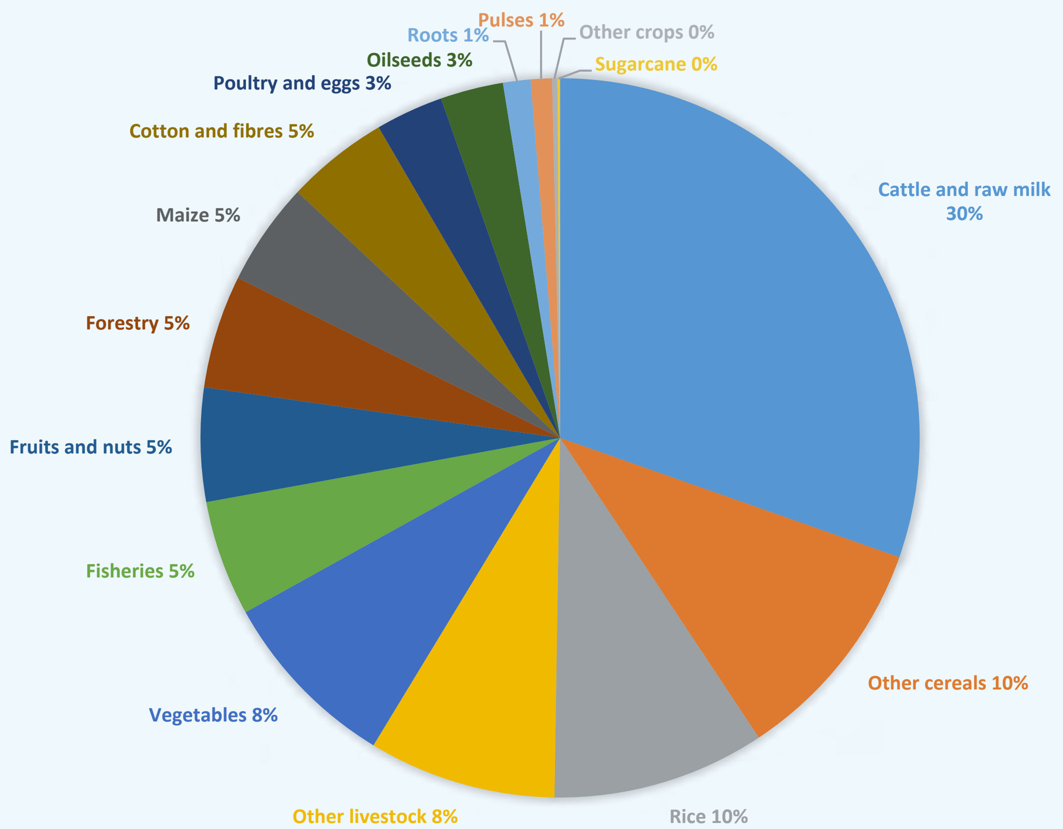
## Annexes

**Annex A1:** Contribution of agricultural activities to agricultural value-added in Mali, 2018



### **Annex A2:** Evidence of climate change impacts on livestock in Mali

| Country | Productivity Change () | | Journal/Publisher | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|
| Mali | -14 | -16 | Climatic Change/Springer Nature | Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005) | Greenhouse gases integrations |
| Mali | -5 | -36 | Climate Policy/Taylor & Francis | Butt, T. A., McCarl, B. A., & Kergna, A. O. (2006) | 1°–2.75°C |

### **Annex A3:** Evidence of climate change impacts on maize yields in Mali

| Region/ Country | Yield Variation () | | Publisher | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|
| Mali | 13.5 | -11.2 | Springer Nature. | Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005) | Greenhouse gases integrations |
| Mali | -30.4 | -52.1 | Springer Nature. | Kazi Farzan Ahmed, Guiling Wang, Miao Yu, Jawoo Koo & Liangzhi You (2015) | Minimum temperature 35.3°C (CESM-driven climate) and Maximum 36.8°C (MIROC-driven climate) |
| Mali | -51.0 | -57.0 | Elsevier Science | Traore, B., Descheemaeker, K., van Wijk, M. T., Corbeels, M., Supit, I., & Giller, K. E. (2017) | 2.9 □C and 3.3 □C (rcp4.5 and rcp8.5 scenaris ) |
| Mali | | -1.0 | Springer Nature. | Ebi, K. L., Padgham, J., Doumbia, M., Kergna, A., Smith, J., Butt, T., & McCarl, B. (2011) | IPCC A1B emissions scenario (3°C) |
| Mali | -17.2 | -21.7 | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |

### **Annex A4:** Evidence of climate change impacts on rice yields in West Africa

| Region/Country | Yield Variation | | Publisher | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|
| West Africa | -1.8 | 0.4 | IFPRI report | Nelson, G. C., M.W. Rosegrant, J. Koo, R. Robertson, T. Sulser, T. Zhu, C. Ringler, S. Msangi, A. Palazzo, M. Batka, M. Magalhaes, R. Valmonte-Santos, M. Ewing, and D. Lee. 2009. | 0.5°C to 4°C and 2% to 10% |
| West Africa | -6.0 | 1.0 | Science | Lobell D. B., Burke M. B., Tebaldi C., Mastrandrea M. D., Falcon W. P., and Naylor R. L., (2008) | 0.5°C to 2°C and -10% to +5% |
| West Africa | -4.4 | 0.5 | Book + FAO | Thomas, T. & Rosegrant, M. (2015) | 1.5°C to 2.3°C and -23mm to +30mm |
| West Africa (irrigated) | -20.0 | -12.4 | IFPRI Research Monograph | Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013). | 1°C to 3°C and 0 to 4.7% |
| West Africa (rainfed) | 0.5 | 4.4 | IFPRI Research Monograph | Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013). | 1°C to 3°C and 0 to 4.7% |
| West Africa (irrigated) | -20.0 | -20.0 | Global Change Biology | Van Oort, P. A. J., & Zwart, S. J. (2017) | Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario) |

| | | | | | |
|---|---|---|---|---|---|
| West Africa (rainfed) | -25.0 | -19.0 | Global Change Biology | Van Oort, P. A. J., & Zwart, S. J. (2017) | Base temperature 14°C and optimum temperature 31°C (RCP 8.5 scenario) |
| Côte d'Ivoire, Ghana, and Togo (rainfed) | -25.0 | -5.0 | IFPRI Research Monograph | Jalloh, A.; Nelson, G. C.; Thomas, T. S.; Zougmoré, R. and Roy-Macauley, H. (2013). | 1.0°–1.5°C and -400 mm to -100 mm |
| Benin | -9.0 | -3.0 | Erdkunde | Paeth, H., Capo-Chichi, A., & Endlicher, W. (2008) | 1.8°C to 4°C (IPCC emission scenario B2) |
| BurkinaFaso | -4.0 | -3.4 | Working Paper | Delphine Deryng,2015 | RCP 8.5 scenario |
| Senegal | -4.9 | -4.1 | Working Paper | Delphine Deryng,2015 | RCP 8.5 scenario |
| Nigeria | -25.0 | 8.0 | Climatic Change | Mereu, V. ; Gallo, A. ; Carboni, G. ; Spano, D. (2015) | IPCC A1B emission scenario |

## **Annex A5:** Evidence of climate change impacts on other cereals (millet and sorghum) yields in Mali, the Sahel, and West Africa

| Country | Yield Variation () | | Journal/Publisher | | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|---|
| Mali (Millet) | -11.5 | -6.3 | Climatic Change | Springer Nature | Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005) | Greenhouse gases integrations |
| Mali (Millet) | -12.0 | -7.0 | Field Crops Research | Elsevier Science | Traore, B., Descheemaeker, K., van Wijk, M. T., Corbeels, M., Supit, I., & Giller, K. E. (2017) | 2.9 ▯C and 3.3 ▯C (rcp4.5 and rcp8.5 scenaris ) |
| Mali (Millet) | -9.2 | -8.5 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |
| Mali (Sorghum) | -17.1 | -11.5 | Climatic Change | Springer Nature. | Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005) | Greenhouse gases integrations |
| Mali (Sorghum) | -5.4 | -9.0 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |
| Sahel (Sorghum) | -15.3 | 6.2 | Science | American Association for the Advancement of Science | Lobell D. B., Burke M. B., Tebaldi C., Mastrandrea M. D., Falcon W. P., and Naylor R. L., (2008) | 0.5°C to 2°C and -10% to +5% |
| West Africa (Sorghum) | -5.0 | 5.0 | Science | American Association for the Advancement of Science | Lobell D. B., Burke M. B., Tebaldi C., Mastrandrea M. D., Falcon W. P., and Naylor R. L., (2008) | 0.5°C to 2°C and -10% to +5% |

## **Annex A6:** Evidence of climate change impacts on agriculture

| Crop | Country | Yield Variation () | | Journal/Publisher | | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|---|---|
| Vegetables | Mali | -14.2 | -11.3 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |
| Fruits | Mali | -7.1 | -7.0 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |
| Forestry | Western Sahel | -18.0 | 14.0 | Journal of Arid Environments | Elsevier Science | Gonzalez, P., Tucker, C. J., & Sy, H. (2012) | 2°C and 4°C |
| Cotton | Mali | 3.5 | 6.2 | Climatic Change | Springer Nature. | Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005) | Greenhouse gases integrations |
| Cotton | Mali | -7.7 | -7.2 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |
| Oilseeds | SSA | | -13.5 | Rural Development Report | IFAD | Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019) | 1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario) |
| Roots | SSA | | -7.1 | Rural Development Report | IFAD | Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019) | 1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario) |
| Pulses | SSA | | -4.9 | Rural Development Report | IFAD | Brooks K., Dunston S., Wiebe K., Arndt C., Hartley F., and Robertson R. (2019) | 1.4°C to 4.5°C and 0.7% to 4.7% (RCP8.5 scenario) |
| Sugarcane | Mali | -9.5 | -7.3 | Report | World Bank | World Bank Group. 2019 | 1.5°C to 2°C -5.4% to +24.8% (RCP4.5, RCP 8.0 and RCP.8.5) |

**Note: SSA:** Africa South of Sahara.

## **Annex A7:** Evidence of climate change impact on fisheries

| Country | Yield Variation () | | Journal/Publisher | | Authors | Climate Change Scenario (Var. Temperature and Precipitation) |
|---|---|---|---|---|---|---|
| West Africa | -25.9 | -8.0 | African Journal of Marine Science | Taylor & Francis | Lam, V. W. Y., Cheung, W. W. L., Swartz, W., & Sumaila, U. R. (2012) | The SRES A1B scenario assumes that the greenhouse gas concentration was stabilised at 720 ppm by the year 2100 |
| West Africa | -26.0 | -8.0 | Nature Climate Change | Nature | Barange, M.; Merino, G.; Blanchard, J. L.; Scholtens, J.; Harle, J.; Allison, E. H.; Allen, J. I.; Holt, J.; Jennings, S. (2014). | IPCC scenario B2 andA1F1 scenario |
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AKADEMIYA2063 is supported financially by the United States Agency for International Development (USAID), the Bill and Melinda Gates Foundation (BMGF), the German Federal Ministry for Economic Cooperation and Development (BMZ), the African Development Bank (AfDB), the UK's Foreign, Commonwealth & Development Office (FCDO), the Global Center on Adaptation (GCA), and the Food and Agriculture Organization of the United Nations (FAO). The views expressed in this publication do not necessarily reflect those of the funders.

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