AKADEMIYA2063

CACCI

COMPREHENSIVE ACTION FOR CLIMATE CHANGE INITIATIVE

No. 17, October 2024

CACCI FIELD NOTES

Climate Change and Adaptation Pathways for Senegal

Souleymane Sadio Diallo, Mouhamadou Hady Diallo, and Mahamadou Tankari

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. In this Field Note, AKADEMIYA2063 scientists employ advanced economic simulation models to evaluate the impact of policies and provide robust, data-driven insights to further enhance the positive impacts of adaptation measures in Senegal.

CACCI is supported by the U.S. Agency for International Development (USAID). The views expressed in this publication do not necessarily reflect those of USAID.

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: Diallo, S.S., M.H. Diallo, and M. Tankari. *Climate Change and Adaptation Pathways for Senegal*. CACCI Field Notes, No. 17. Kigali: AKADEMIYA2063. https://doi.org/10.54067/caccifn.017

Authors:

Souleymane Sadio Diallo is a Researcher at the Centre Ivoirien de Recherches Économiques et Sociales (CIRES), Unit: ssadio_tr@yahoo.fr.

Mouhamadou Hady Diallo is an Associate Scientist at AKADEMIYA2063: mhdiallo@akademiya2063.org.

Mahamadou Tankari is the Deputy Director of the Department of Capacity and Deployment at AKADEMIYA2063: mtankari@akademiya2063.org.

Contents

1. Introduction

Climate change in West African countries such as Senegal is characterized by rising temperatures, decreased summer rainfall, and extreme events such as floods and droughts. Agriculture, particularly peanut cultivation, is economically significant in Senegal. However, climate change severely threatens agricultural stability, and this exacerbates food insecurity, especially for the 38 percent of the population living below the national poverty line (ANSD 2018). Changes in rainfall and temperature patterns significantly impact agricultural and food production systems, particularly in Eastern Senegal. This jeopardizes staple crops such as maize and rice, endangering food security for populations heavily reliant on agriculture (Brottem and Brooks 2018; Roudier et al. 2011). Furthermore, crop models predict a 5 percent to 25 percent reduction in groundnut yields, a staple for many households, particularly those in extreme poverty (World Bank 2017). Models also anticipate potential decreases in vital nutrients in crops such as maize due to high temperatures (Myers et al. 2014; Thomson and Mason 2018).

Studies such as those by Sarr et al. (2017) utilize Regional Climate Models (RCMs) from the CORDEX program to project climate change scenarios for Senegal. These models, validated over West Africa and using Coupled Model Intercomparison Project phase 5 (CMIP5) data, predict a decline in peanut yields across RCMs, especially under the RCP8.5 scenario. The findings underscore the urgent need for adaptation strategies to protect the peanut crop sector. Additionally, Konte et al. (2019) assess the impact of climate change on food crop yields in Senegal using the Factor Augmented Vector Auto Regression (FAVAR) approach. They identify two significant climate-related shocks: increased temperature (thermal shock) and decreased precipitation (rainfall shock). Their analysis, spanning from 1970 to 2014, reveals contrasting impacts of temperature and rainfall changes on various cereals, with rising temperatures benefiting rice and maize but negatively affecting sorghum, while reduced rainfall adversely impacts all cereal yields.

Similarly, Faye et al. (2018) assessed the impact of climate change on the yields of major cereal crops in Senegal. They employed a combination of linear correlation analysis and multivariate regression to examine the relationship between cereal yield and climate change. The findings indicated that both temperature and precipitation levels positively influence cereal yields in Senegal. However, the economic effect of temperature variation outweighs that of precipitation variation on cereal yield. Lower temperatures in Senegal significantly contribute to lower yields in cereal production.

Senegal faces significant vulnerability to climate change, which poses severe threats to its economic and social development. The country experiences erratic weather patterns, high variability in rainfall, increased frequency of droughts, and rising temperatures, all of which intensify the vulnerability of its ecosystems. This urgency is underscored by the fact that approximately 60 percent of the population's livelihood depends on agriculture and livestock, making that demographic particularly susceptible to these adverse changes (ANSD 2018; CDN 2020). Climate change significantly impacts the agriculture, livestock, and fisheries sectors, with broader impacts on coastal zones, water resources, biodiversity, health, and disaster management. For instance, agriculture is projected to be affected by increased evapotranspiration, disrupted crop varieties, and declining soil fertility under a 2°C scenario.

Although some steps have been made in response to this – such as the initiatives in the Arachidic Basin Region that include reforestation, hydro-agricultural developments, and mangrove restoration to preserve agricultural productivity (Palm et al. 1997) – more can still be done. The Northern Zone employs reforestation with filao curtains, protective structures, and micro-irrigation practices to stabilize soil and manage water resources (Cairns and Prasanna 2018). In the Southern Zone, strategies focus on coastal ecosystem preservation, watershed management, and community awareness programs (Nziguheba et al. 2002). The Niayes Zone emphasizes dune fixation, water resource management, and community education (Bastiaanssen and Molden 2000).

Additionally, national programs like the Great Green Wall project play a significant role in enhancing agricultural resilience by promoting agro-sylvopastoral activities and soil conservation (Myers et al. 2014; Randriamamonji 2021). This initiative has shown progress in improving agricultural practices and mitigating climate impacts. Studies indicate positive effects on rainfall patterns and agricultural activities despite potential flood risks. Thus, adaptation strategies rooted in reforestation, sustainable water management, and community engagement are crucial for securing Senegal's agricultural future in the face of climate change (Fofana 2023; Roudier et al. 2011). Senegal has also implemented various policies to support climate change mitigation and adaptation. Following the Cancun Conference in 2010, the country initiated National Adaptation Plans (NAPs) to address long-term adaptation needs, complementing the existing short-term National Adaptation Programmes of Action – NAPAs (CDN 2020). Adaptation measures for 2025-2030 include early warning systems, sustainable land management, and the promotion of agricultural insurance.

However, questions remain regarding ongoing projects. What additional steps can be taken at various levels to further enhance the positive impacts of adaptation measures in Senegal? How can policymakers be guided to make the best decisions based on data? To address such persistent questions comprehensively, this research employs advanced economic simulation models to evaluate the impact of policies and provide robust, data-driven insights.

2. Methodology

The methodological approach used in this research combines two advanced economic analysis tools: a Positive Mathematical Programming (PMP) microeconomic model and a Computable General Equilibrium (CGE) model. This combination leverages the flexibility of the microeconomic model while simultaneously accounting for the interactions of all sectors and agents within the economy through the CGE model.

2.1. Positive Mathematical Programming (PMP)

The PMP technique is a method often used to analyze resource allocation decisions, particularly in the agricultural production process. More specifically, it is a method for calibrating agricultural production and resource use models using non-linear yield or cost functions. According to Howitt (1995), non-linear parameters are shown to be implicit in land use decisions observed at the regional or farm level. For a detailed presentation of the steps involved in calibrating PMP-type models, see De Frahan et al. (2007).

The PMP approach consists of a method for calibrating mathematical programming models to reproduce the observed behavior of economic agents over a reference period using the information provided by the dual variables of the calibration constraints. The dual information is used to calibrate a non-linear objective function to reproduce the observed activity levels for the reference period but without the calibration constraints. The advantage of this approach is that it does not require a series of observations to reveal economic behavior, but, at the same time, it does not allow statistical inference to be made to validate the results (De Frahan et al. 2007).

The model used in this study includes 15 crops and 13 regions. It is calibrated using data from Senegal's Harmonised Survey of Household Living Conditions (EHCVM), conducted by Senegal's National Statistics and Demography Agency (ANSD) during the 2018-2019 period, in order to assess the impact on poverty and inequality.

The model developed can be used to assess the impact of the various simulation scenarios considered. In particular, it provides information on variations in productivity and the use of agricultural land, which are fed into the computable general equilibrium model.

2.2. Static Computable General Equilibrium (CGE) model

To assess the macroeconomic and sectoral impacts of climate change, we designed a computable general equilibrium model calibrated using a Social Accounting Matrix (SAM) of the Senegalese economy for the year 2021. This includes 41 sectors of economic activity and 41 products. To provide a detailed analysis of the impact of climate change and given the vulnerability of agricultural subsectors to climate shocks, agriculture has been broken down into 12 crop production subsectors and four animal production subsectors, to which forestry must be added. The SAM is an update of Randriamamonjy's SAM (2021) using 2018 data. For this exercise, it has been updated to reproduce the structure of the Senegalese economy in 2021.

The model was developed by Fofana (2023). It is a standard static general equilibrium model adapted to the problem of climate change with a long-term loop that allows the temporal dimension of the effects of climate factors to be adequately apprehended. Thus, labor, capital and land are perfectly mobile between sectors of the economy, making it possible to take into account the possibility of a long-term adjustment of the economy. Current public expenditure and the government budget balance relative to GDP are fixed. The inclusion of a compensatory tax or a subsidy applied to the gross income of households makes it possible to capture the effects of the variation in public revenue following the climate shock on the well-being of households. The model assumes that the Senegalese economy is a small, open economy, so the country does not influence international import and export prices. These therefore remain exogenous in the model. The current account balance of the balance of payments relative to GDP is also fixed, thereby linking external financing to the economy's performance. Similarly, the volume of total investment relative to GDP is fixed. In addition, total investment determines total savings, which is made up of private savings (household and business savings), as well as public and foreign savings.

This closure rule allows the full effect of the climate shock to be captured; in other words, welfare transfers between generations are not allowed. Flexible prices balance the demand and supply of domestic production traded on the domestic market. The general price index is used as the numeraire. It is fixed.

2.3. Simulation scenarios

Initially, the study considers two simulations. The entry point for these simulations is the agricultural sector. The first simulation, which corresponds to the reference situation of business as usual (BaU), evaluates the impact of changes in productivity in the agricultural sector, which follows the trend observed over the last 20 years in Senegal. The second scenario assesses the impact of climate change on the agricultural sector (CC). The figures were obtained from a detailed literature review, which provides estimates of the impact of climate change on crop yield in Senegal and, failing that, in the West African sub-region.

The main innovation of the approach lies in the way in which the simulation of the climate shock is introduced. Most computable general equilibrium models used to assess the impact of climate shocks adopt a deterministic approach, thereby ignoring the random nature of climate-related events and their implications for agricultural yields. In the present study, we have introduced shocks using a random approach to take into account the uncertainty associated with the occurrence and magnitude of climate shocks. The shocks are distributed with uniform probability within minimum and maximum variations (Table 1).

Table 1: Simulation scenarios (% yield change)

	BaU			CC	
	Maximum	**Minimum**		**Maximum**	**Minimum**
Millet	10.6	-3.5		24.1	-5.0
Sorghum	56.2	-31.7		-5.4	-25.0
Paddy rice	11.3	-9.9		-2.0	-11.0
Maize	38.3	-19.9		-18.6	-47.5
Niebe	69.4	-32.4		0.4	-19.3
Groundnut	60.3	-66.8		12.0	-5.0
Okra	20.1	-36.7		-11.3	-14.2
Sorrel	9.5	-12.8		-11.3	-14.2
Pasteque	11.1	-7.4		-11.3	-14.2
Onion	38.9	-33.3		-4.9	-8.9
Cotton	13.6	-11.7		9.4	-8.3
Other Cereal	23.3	-16.1		-8.52	-21.28
Other Tuber	21.3	-13.6		10.5	-5.4
Other Leguminous	58.2	-19.3		3.5	-14.2
Other Crops	9.5	-12.8		0.4	-19.3

Source: Authors' compilation from the review of the literature studies

The shocks were repeated 1000 times and the mean changes and standard deviations are calculated for the variables of interest and discussed below. We begin by simulating the impact using the PMP model. This model allows us to generate the effect on land productivity and the variation in land demand per crop. These results are used to construct an interval for each crop's variation in land productivity and land use, taking the lowest and highest variation recorded in the 1000 observations. These interventions are used as input for the simulation in the CGE model to assess the overall impact on the economy.

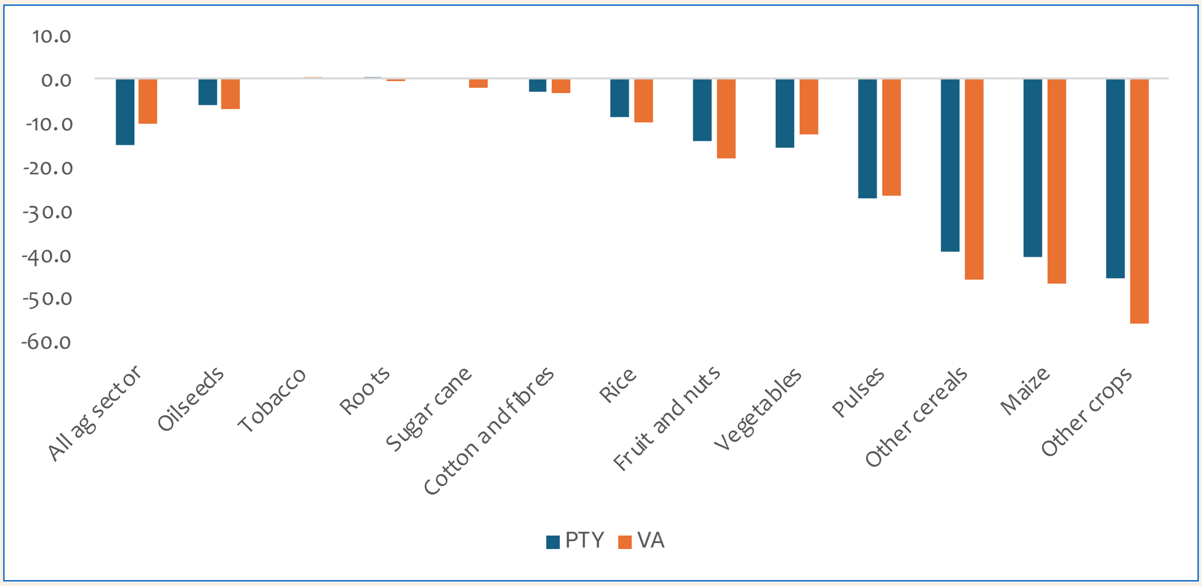
3. Simulation Results

This section presents the results of the simulations. After discussing the impacts on agriculture, it presents the effects on non-agricultural sectors and the Senegalese economy as a whole.

3.1. Effects on agriculture

Climate change could significantly reduce productivity in the agricultural sector (Figure 1). The results indicate that productivity could fall by 15 percentage points. This significant drop in productivity for the agricultural sector as a whole is explained by the fact that all agricultural sub-sectors could face significant adverse effects.

Figure 1: Productivity and value-added impact of climate change on agriculture



Source: Authors' calculation

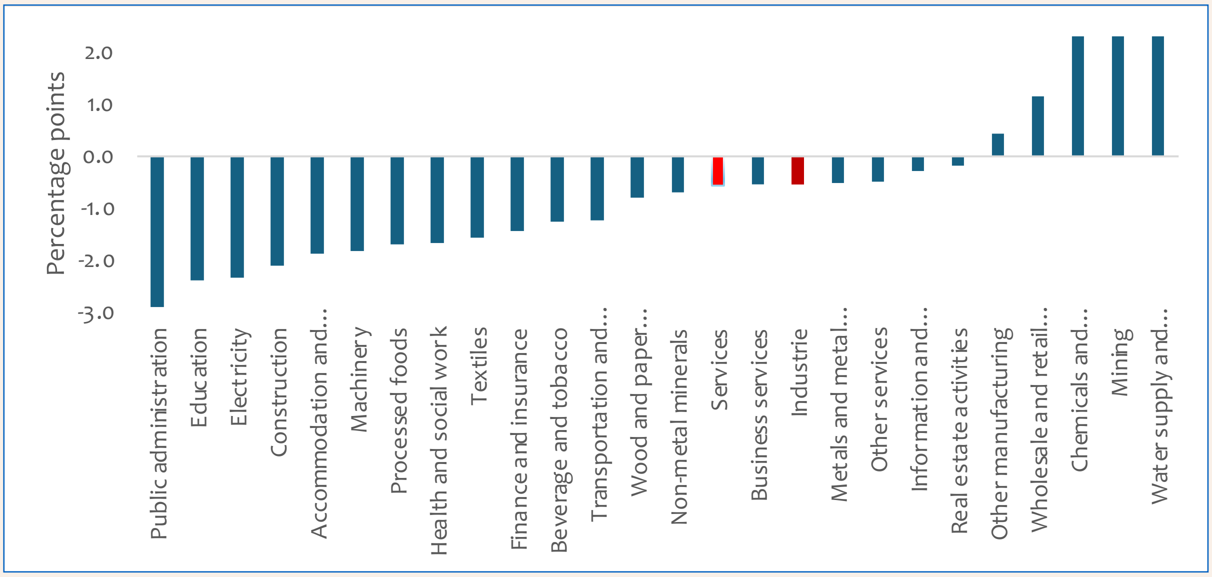
The decrease in productivity across the agricultural sector as a whole is driven by the negative impacts on the cereal sectors, including maize (-40.8 percentage points), rice (-8.8 percentage points) and other cereals (-39.5 percentage points). In addition to these sectors, a climate shock could hurt fruit and nuts (-14.4 percentage points), vegetables (-15.8 percentage points), pulses (-27.2 percentage points) and other crops (-45.6 percentage points).

This decrease in productivity would result in a significant decline in the value-added and output of the various agricultural sub-sectors. The simulations indicate that overall value added in the agricultural sector could fall by 10.2 percentage points compared to the reference scenario. This will be driven by those sub-sectors in which productivity has fallen sharply.

3.2. Effects on non-agricultural sectors

The simulations indicate that climate change, which significantly affects the agricultural sector, could also hurt the non-agricultural sectors of the Senegalese economy due to sectoral interrelationships and general equilibrium effects (Figure 2).

Figure 2: Impact of climate change on value added in non-agricultural sectors - variation in percentage points compared to the BaU scenario



Source: Authors' calculation

The services sector as a whole could record a slight decline of around 0.6 percentage points, compared with a 0.5 percentage point decline for industry relative to the BaU scenario. The negative impact on these sectors is mainly due to the sectoral linkages within the Senegalese economy.

These results can be explained by the nature and intensity of the upstream and downstream links observed in the economy. Indeed, an analysis of these links shows that in 2021, upstream and downstream of the reference year, the interdependence between the agricultural sector and industry and service sector is strong. The simulation indicates that:

- The accommodation and food services sector is negatively impacted by the performance of the agricultural sector due to its high degree of dependence on that sector, which provides around 8 percent of its intermediate consumption. Thus, the effects of climate change could result in a drop of almost 2 percentage points in the accommodation and food services sector compared with the reference scenario.
- Public administration and education are negatively affected by climate change shocks on agricultural yields, resulting in a decline of 2.9 and 2.4 percentage points, respectively. In addition to the negative effects associated with the decline in government revenue due to the contraction in economic activity and its consequent impact on public finances, these sectors could also suffer from their dependence on other sectors negatively impacted by climate change. This is particularly the case with regard to the dependence of Public Administration on the electricity sector, the information and telecommunications sector, the business services sector, and the other manufacturing sectors, which respectively provide 7.1 percent, 11.8 percent, 12.8 percent, and 17.66 percent of the sector's intermediate consumption.
- The electricity sector also records a decline of 2.3 percentage points due to the overall impact of climate change on the economy and its links with other sectors, many of which are negatively affected. In particular, the electricity sector supplies 18.5 percent of the intermediate consumption of the metals and metal products sector (-0.5 percentage points), 15 percent of the intermediate consumption of the real estate sector (-0.2 percentage points), etc.

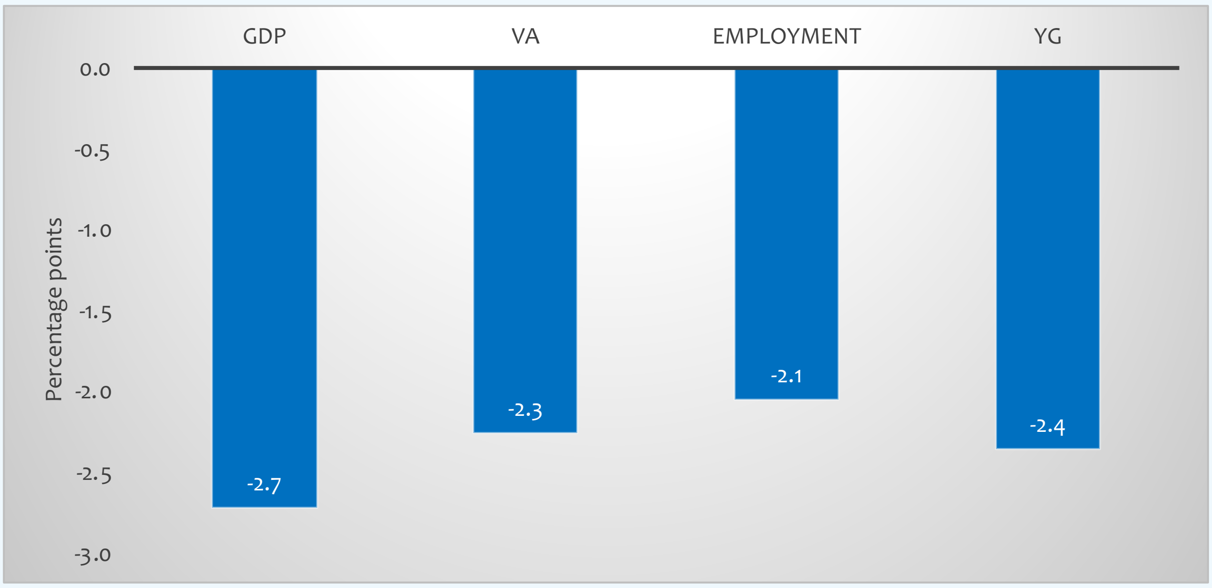
In contrast to these sectors, some non-agricultural sub-sectors or industries experience an increase in activity. These include mining (+2.7 percentage points on the BaU), chemicals and petroleum products (+2.6 percentage points), water supply and sewage (+2.6 percentage points), and wholesale and retail trade (+1.1 percentage points).

The evaluation's findings indicate that climate change will have a detrimental effect on the majority of economic sectors. However, certain industries, such as mining and oil, are less vulnerable to climate change. Senegal should therefore employ these sectors to raise internal resources to finance adaptation actions in addition to the external support that the nation could attract as part of worldwide climate mobilization. Indeed, by strategically managing and using revenues from mining and oil resources, Senegal can effectively finance climate change adaptation measures, thereby ensuring long-term sustainability and resilience to climate impacts.

3.3. Effects on the national economy overall

Because of the size of the agricultural sector and the structure of the Senegalese economy, changing the productivity level and the allocation of agricultural land will have an impact on the economy as a whole. Figure 3 shows the impact of climate change on GDP, the total value added, jobs, and government income.

Figure 3: Macroeconomic impact of climate change

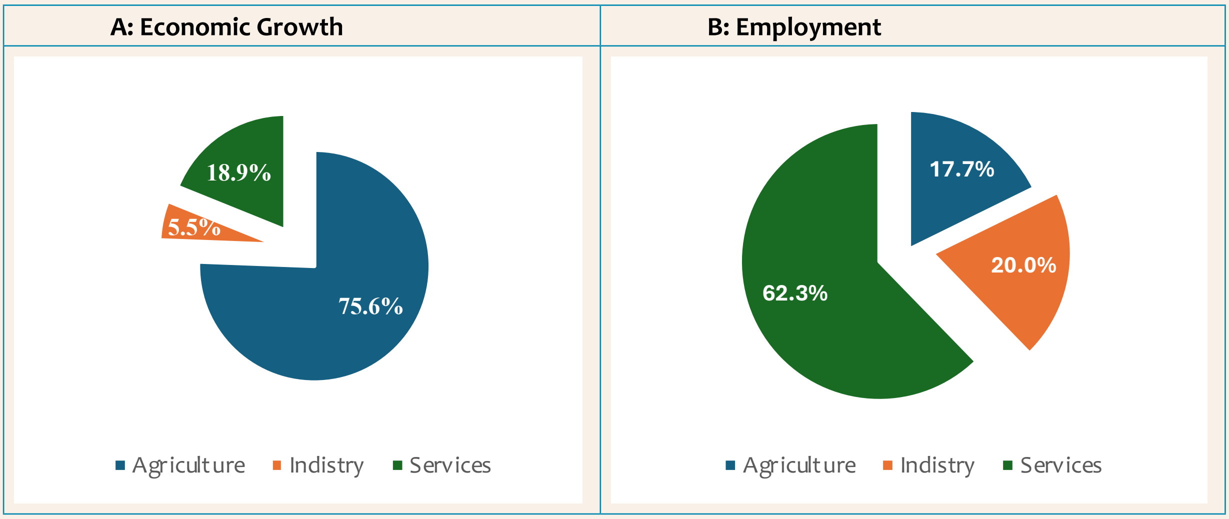


Source: Authors' calculation

The results indicate that climate change will have a significant negative impact on economic activity. It appears that total value added could fall by 2.3 percentage points compared with the baseline scenario. This decline is explained by the drop in total value added in the agricultural sector, which could fall by 10.3 percentage points, leading to a decrease in the activities of other sectors. The results indicate that the total value added by the industry sector could fall by 0.53 percentage points and that of the services sector by around 0.58 percentage points.

The economy's underperformance translates into a fall in GDP of 2.7 percentage points. This situation could lead to job losses in the Senegalese economy, with employment falling by around 2.1 percentage points as a result of reduced demand for labor, both in the agricultural sector and in the rest of the economy. The decline in activity in the agricultural sector is accompanied by a fall in demand for labor in this sector of around 2.2 percentage points. At the same time, employment levels fall by 1.9 percentage points in industry and 2.1 percentage points in services. The contribution of each sector to the fall in GDP and employment is shown in Figure 4.

Figure 4: Impact of climate change on the loss of economic growth and jobs



Source: Authors' calculation

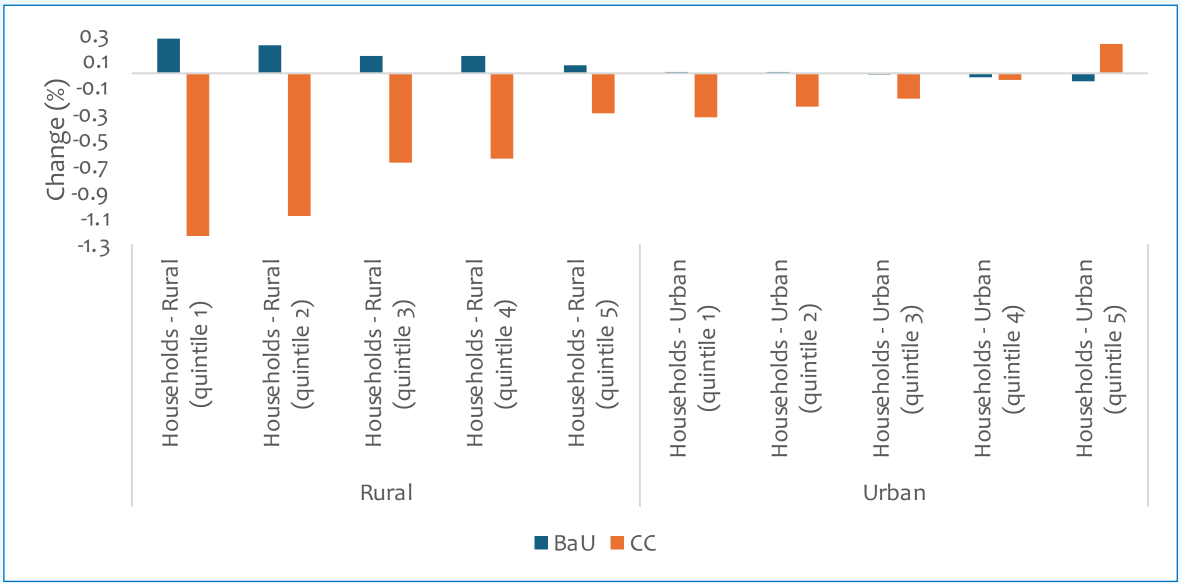
As expected, the agricultural sector would contribute most to the fall in GDP, accounting for 75.6 percent of the decline. This can be explained by the fact that the entry point for assessing the impact of climate change is the fall in agricultural productivity. The decline in the sector's productivity, as indicated above, has a very strong impact on the level of activity in the sector and drags down the rest of the economy. As the analysis in Figure 4 shows, this leads to a fall in production in non-agricultural sectors. Upstream and downstream links mean these two sectors also significantly contribute to the fall in GDP. For example, the services sector could account for almost 19 percent of the fall in GDP as a result of climate change, compared with around 5.5 percent for industry.

The decline in demand for labor, which is reflected in all sectors, means that the sectoral contribution to the fall in employment appears to be significant in all sectors of activity. The results indicate that the services sector could make the biggest contribution to the fall in employment. This could amount to 62.3 percent, compared with 20 percent for industry and 17.7 percent for agriculture. The high share of the services sector is explained by the high labor intensity of services. Senegal's business ecosystem is dominated by a large number of micro, small and medium-sized businesses (MSMEs), many of which operate in the services sector. Furthermore, 97 percent of these businesses operate informally and are highly vulnerable to shocks. Many MSMEs have a precarious market position, and job cuts are the easiest way for them to maintain some stability.

3.4. Effects on household income and consumption expenditure

The results of the simulations show that, overall, climate change could negatively impact almost all households (Figure 5). It will result in a fall in income for all categories of households except for the richest households in urban areas.

Figure 5: Impact of climate change on household income

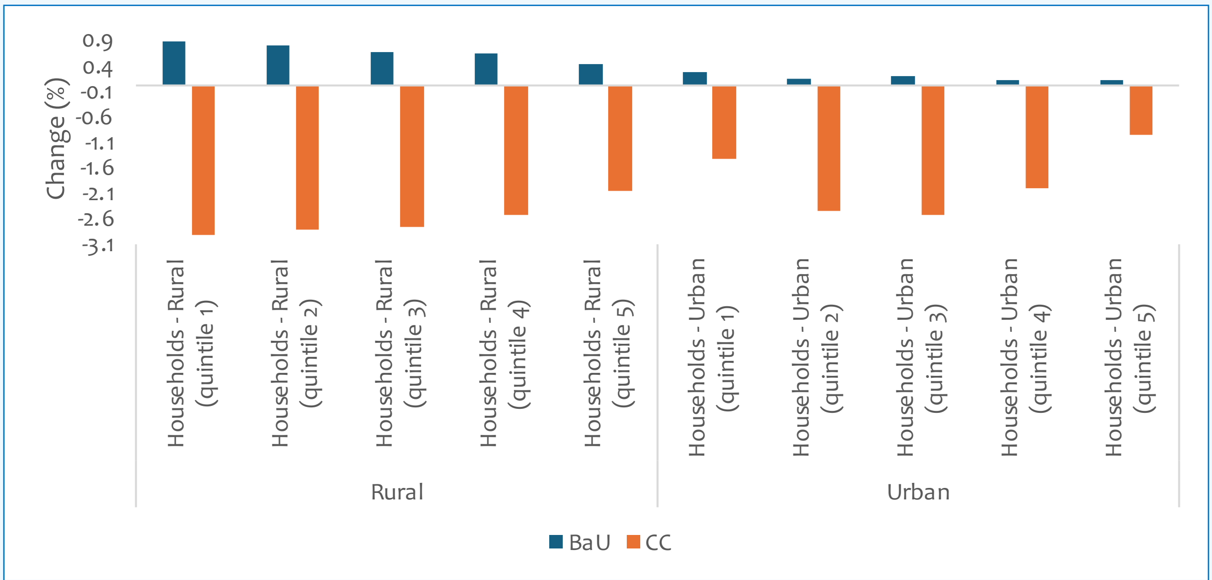


Source: Authors' calculation

The negative effect is greater in rural than in urban areas. In rural areas, the fall in income could vary from -1.5 percentage points for the poorest rural households to -0.35 percentage points for the richest rural households. As for the impact on urban households, the results of the simulations indicate that the income of the poorest households could fall by 0.33 percentage points. On the other hand, the richest households could escape the negative effect of climate change on income. They could even see a slight increase in their income.

Given the negative impact on incomes, almost all households will have to cope with a fall in consumption and well-being, as shown by the results in Figure 6.

Figure 6: Impact of climate change on household consumption



Source: Authors' calculation

According to the results, all categories of households will be negatively affected by climate change. Given the scale of the effects on agricultural production, rural households will be more affected than those living in urban areas. In addition, the poorer the households, the greater the negative impact on their consumption.

4. The Contribution of Climate Change Adaptation Strategies

There is evidence that the adoption of certain agricultural and agronomic practices and technologies can reduce the negative effects of climate change on agricultural productivity. This study tests four adaptation options:

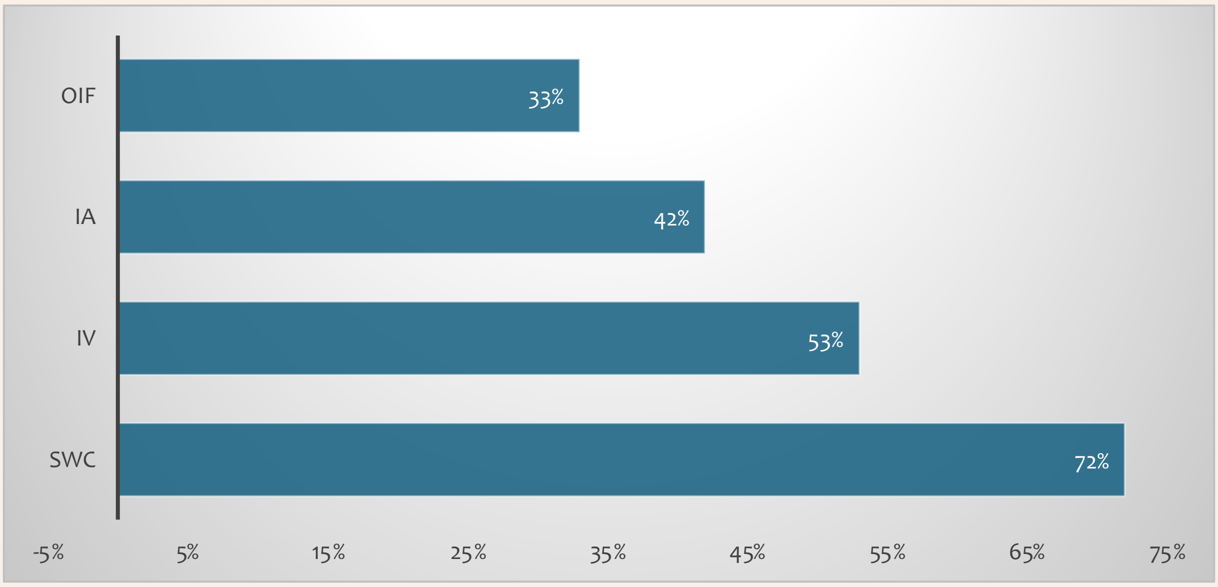
- The use of techniques to restore or conserve soil and water, i.e. reducing soil use, terracing, ridging, the use of dykes and mulching;
- The use of improved varieties resistant to climate change;
- Irrigation;
- The use of organic and inorganic fertilizers.

There is empirical evidence that adopting specific agricultural and agronomic practices and technologies can reduce the negative effects of climate change on productivity. The impact of these adaptation strategies on crop yields has been widely documented by research articles published in credible scientific publications. These include:

- ***Soil and Water Conservation (SWC) :***
  - Reducing the duration of soil exploitation increases crop yields by 8 percent in Mali (World Bank 2019).
  - Earthworks, ridges and bunds increase crop yields by 44 percent in Mali (World Bank 2019).
  - Mulching increases crop yields by 46 percent in Mali (World Bank 2019).
  - Soil and water conservation increases maize yields by 14 percent to 50 percent in Africa (Lebel et al. 2015).
- ***Improved varieties (IV):***
  - Increases crop yields by 36 percent in Mali (World Bank 2019).
  - Increases maize yields by 20-50 percent in West Africa (CGIAR 2010).
- ***Irrigation (IA):***
  - Increased agricultural yields by 56 percent in Burkina Faso (World Bank 2091).
  - 38 percent increase in agricultural production in sub-Saharan Africa (Mabhaudhi et al. 2018).
  - 23 percent increase in rice yield in Ghana (Koide et al. 2021)
- ***Organic and inorganic fertilizers (OIF):***
  - Organic fertilizers increase crop yields by 73 percent in Mali (World Bank 2019).
  - Adoption of organic farming increases crop yields by 54 percent in Burkina Faso (World Bank 2019).
  - Adoption of on-farm biogas increases crop yields by 45 percent in Burkina Faso (World Bank 2019).
  - Adoption of oil and protein crops increases crop yields by 45 percent in Burkina Faso (World Bank 2019).

Simulations indicate that climate change could lead to a drop in GDP of around 2.7 percentage points. To offset this loss, adaptation strategies need to increase the area under cultivation under the different adaptation strategies. For each adaptation option, Figure 7 below shows the increase in land required to offset the economic loss.

Figure 7: Percentage of cultivated area to be covered according to the different adaptation options (%)



Source: Simulation results

The proportion of cultivated area using organic and inorganic fertilizers is up by 33 percent on 2021 levels and by 42 percent for irrigated cropping areas, compared with 53 percent for crops grown with improved varieties. On the other hand, the area under soil and water conservation is expected to increase more strongly than the other three options, rising to more than 72 percent compared with 2021.

5. Conclusion and Recommendations

This assessment combines a positive mathematical programming model and a computable general equilibrium model to evaluate the impact of climate change on Senegal. The simulation results indicate that Senegal could experience a significant decrease in economic activity due to climate change. Specifically, the national Gross Domestic Product (GDP), which measures the level of economic activity over a year, would fall by 2.7 percentage points in the climate change scenario without adaptation measures compared to the reference situation. This decline is likely accompanied by a fall in employment (-2.1 percentage points), a fall in overall value added (-2.3 percentage points), and a significant decrease in government revenues.

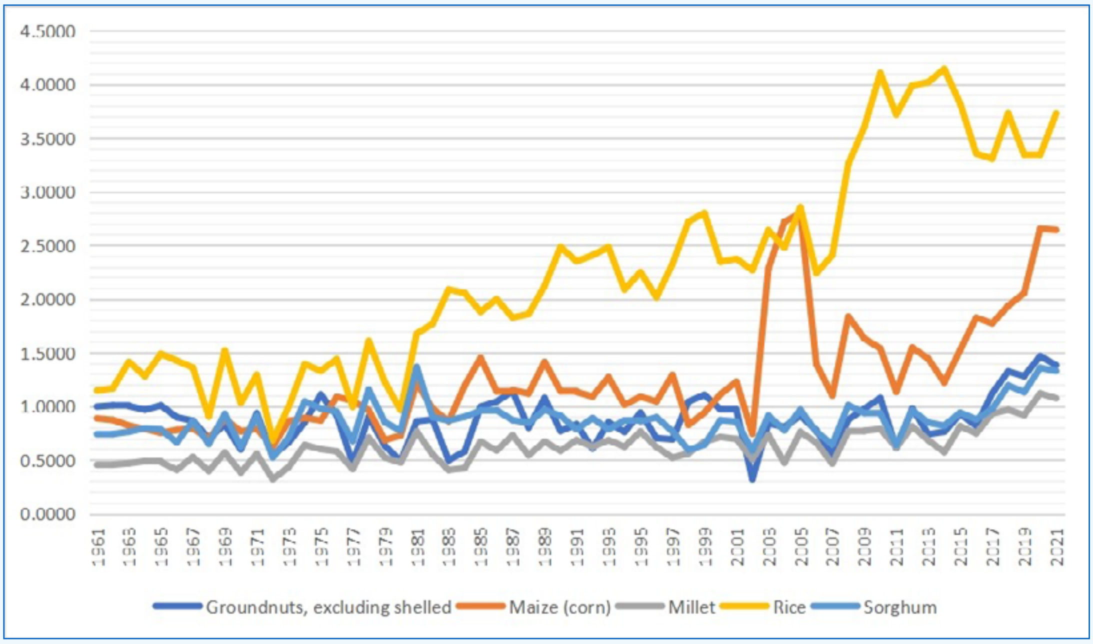
As might be expected, climate change will have significant negative effects on household well-being. The drop in economic activity will result in a decline in household consumption in both rural and urban areas. The effect will be more pronounced in rural areas, with a differentiated impact across social categories. The poorest households will be the most affected, with a decline in real consumption of around 4 percentage points, compared with 2.4 percentage points for the richest rural households. At the same time, the richest urban households will experience a drop in consumption of around 1 percentage point.

To adapt effectively to the challenges of climate change, Senegal needs to implement a coordinated, multi-sectoral approach that integrates climate adaptation into national and local development planning. Our assessment shows that adopting smart agricultural practices can help address the economic losses caused by climate change-related shocks. In particular, the study shows that the country has alternative solutions that would enable it to stem the economic losses that could be induced by climate change. To offset these economic losses, Senegal would need to:

- Increase the area of irrigated farmland.
- Increase the adoption of improved varieties resistant to climate change.
- Expand the area farmed using soil and water conservation techniques.
- Enhance the use of organic or inorganic fertilizers.

The study indicates the efforts required for each of these options. However, it does not address the possibility of combining these options, which could offer a different perspective.

Annex 1: Yields across years for selected crops



Source: FAOSTAT, 2023

6. References

ANSD (Agence Nationale de la Statistique et de la Démographie). 2018. Senegal Poverty Profile.

Bastiaanssen, W. G., and D.J. Molden. 2000. "Irrigation performance indicators based on remotely sensed data: A review of literature." *Irrigation and Drainage Systems* 14(4): 291-311.

Bidinger, F. R., C.T. Hash, and R. Kenga. 2009. "Adaptation of sorghum and pearl millet to climate change in West Africa." *Agricultural Systems* 101(3): 127-133.

Brottem L., B. Brooks. 2018. "Crops and Livestock under the Sun: Obstacles to Rural Livelihood Adaptations to Hotter 21st Century Temperatures in Eastern Senegal." Land Degradation and Development, 29(1): 118–126. https://doi.org/10.1002/ldr.2844

Burney, J., and R. Naylor. 2012. "Smallholder irrigation as a poverty alleviation tool in sub-Saharan Africa." *World Development* 40(1): 110-123.

Cairns, J. E., and B.M. Prasanna. 2018. "Developing and deploying climate-resilient maize varieties in the developing world." *Current Opinion in Plant Biology* 45: 226-230.

Cairns, J. E., J. Hellin, K. Sonder, J.L. Araus, J.F. MacRobert, C. Thierfelder, and B.M. Prasanna. 2013. "Adapting maize production to climate change in sub-Saharan Africa." *Food Security* 5(3): 345-360.

CDN (Contribution Déterminée au Niveau National). 2020. République du Sénégal. https://unfccc.int/sites/default/files/NDC/2022-06/CDNSenegal%20approuv%C3%A9e-pdf-.pdf

De Frahan, B.H. et al. 2007. "Positive Mathematical Programming for Agricultural and Environmental Policy Analysis: Review and Practice." In: *Handbook Of Operations Research In Natural Resources*, edited by A. Weintraub, C. Romero, T. Bjørndal, R. Epstein, and J. Miranda. Boston, MA: Springer.

Faye, B., H. Webber, M. Diop, M. Mamadou, J.D. Owusu-Sekyere, J. Naab, and T. Gaiser. 2018. "Potential Impact of Climate Change on Peanut Yield in Senegal, West Africa." Field Crops Research, Volume 219: 148-159. https://doi.org/10.1016/j.fcr.2018.01.034

Fermont, A. M., P, Tittonell, Y. Baguma, and K.E. Giller. 2009. "Towards understanding factors that govern fertilizer response in cassava: lessons from East Africa." *Nutrient Cycling in Agroecosystems* 86(1): 133-151.

Fofana, I. 2023. "Standard Applied General Equilibrium Model." Kigali: AKADEMIYA2063.

Giller, K. E., E. Witter, M. Corbeels, and P. Tittonell. 2009. "Conservation agriculture and smallholder farming in Africa: The heretics' view." *Field Crops Research* 114(1): 23-34.

Herweg, K. and E. Ludi. 1999. "The performance of selected soil and water conservation measures—case studies from Ethiopia and Eritrea." *Catena* 36(1-2): 99-114.

Howitt, R. E. 1995. "Positive mathematical programming." *Am. J. Agric. Econ.* 77(2): 329–42.

Inocencio, A., M. Kikuchi, M. Tonosaki, A. Maruyama, I. de Jong, and H. Sally. 2007. *Costs and performance of irrigation projects: A comparison of sub-Saharan Africa and other developing regions.* IWMI Research Report 109.

Ismail, A. M., U.S. Singh, S. Singh, M.H. Dar, and D.J. Mackill. 2013. "The contribution of submergence-tolerant (Sub1) rice varieties to food security in flood-prone rainfed lowland areas in Asia." *Field Crops Research* 152: 83-93.

Kassam, A., T. Friedrich, F. Shaxson, and J. Pretty. 2009. "The spread of conservation agriculture: justification, sustainability and uptake." *International Journal of Agricultural Sustainability* 7(4): 292-320.

Konte, M., A. Gnalenba and P. Behanzin. 2019. Impact of Climate Change on Food Crop Yields in Senegal: FAVAR Approach. *Journal of Economic Science Research* 2(1).

Mbow, C., P. Smith, D. Skole, L. Duguma, and M. Bustamante. 2014. "Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa." *Current Opinion in Environmental Sustainability* 6: 8-14.

Myers, S. S., M.R. Smith, S. Guth, C. Golden, B. Vaitia, N.D. Mueller, A.D. Dangour and P. Huybers. 2014. "Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition." *Annual Review of Public Health* 38(1).

Namara, R. E., L. Horowitz, B. Nyamadi, and B. Barry. 2011. *Irrigation development in Ghana: Past experiences, emerging opportunities, and future directions.* Ghana Strategy Support Program (GSSP) Working Paper 0025.

Nziguheba, G., R. Merckx, C. A. Palm, and P. Mutuo. 2002. "Combined use of Tithonia diversifolia and inorganic fertilizers for improving maize production in a phosphorus deficient soil in western Kenya." *Agroforestry Systems* 55(2): 165-174.

Palm, C. A., R.J. Myers, and S.M. Nandwa. 1997. "Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment." *Replenishing Soil Fertility in Africa* 51: 193-217.

PNUD (Programme des Nations Unies pour le développement). 2010. *Rapport National sur le Développement Humain: Changement Climatique, Sécurité alimentaire et Développement Humain*. https://planipolis.iiep.unesco.org/sites/default/files/ressources/senegalrndh2010.pdf

Randriamamonji, J. 2021. *2018 Social Accounting Matrix for Senegal: A Nexus Project SAM*. Washington, DC: International Food Policy Research Institute (IFPRI). https://doi.org/10.2499/p15738coll2.134814.

Roudier, P., et al. 2011. Rice Yield in Africa with a Focus on Climate Trends and Variability. Weather, Climate, and Society.

Sarr, A. B., et al. 2017. Climate Change Impacts on Peanut Yields in Senegal Using CORDEX Regional Climate Models. Journal of Agricultural Science.

Thierfelder, C., and P.C. Wall. 2010. "Rotations in conservation agriculture systems of Zimbabwe: effects on soil quality and water relations." *Experimental Agriculture* 46(2): 267-283.

Thomson, A. M., and Mason, E. 2018. The Impact of Climate Change on Micronutrient Availability in Africa. Current Climate Change Reports.

Vanlauwe, B., A. Bationo, J. Chianu, K.E. Giller, R. Merckx, U. Mokwunye, N. Sanginga et al. 2010. "Integrated soil fertility management: operational definition and consequences for implementation and dissemination." *Outlook on Agriculture* 39(1): 17-24.

World Bank. 2017. World Development Indicators Database.

You, L., C. Ringler, U. Wood-Sichra, and R. Robertson. 2011. *Irrigation and water management in Africa: Options for improvement.* IFPRI Discussion Paper 01102.

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.

AKADEMIYA2063 Headquarters | Kicukiro/Niboye KK 341 St 22 | 1855 Kigali-Rwanda
AKADEMIYA2063 Regional Office | Corniche des Almadies, Lot N*3 | 24933 Dakar-Senegal

+250 788 318 315 | +221 33 869 28 81

kigali-contact@akademiya2063.org | dakar-contact@akademiya2063.org

www.akademiya2063.org

@AKADEMIYA2063