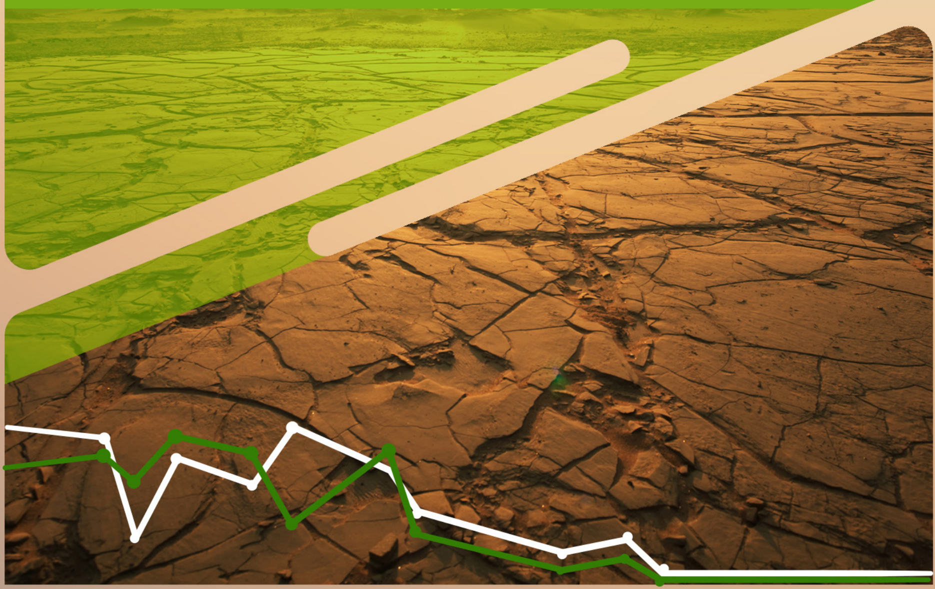
Impact of climate change on agricultural trade flows and food security in the Economic Community of West African States



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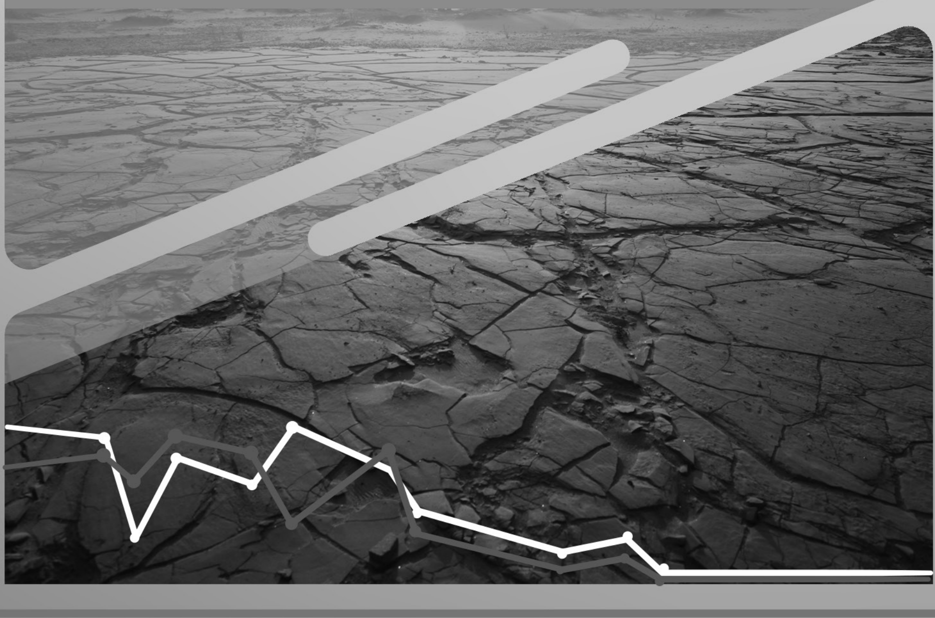

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Contents

Abstract

This paper presents a summary of a study conducted to investigate the impact of climate change on agricultural trade flows inside the Economic Community of West African States (ECOWAS) and between ECOWAS and non-ECOWAS countries. The study was conducted using a trade module of trade cost minimization within a bioeconomic optimization model for crop-land allocation. The results show that ECOWAS climate-influenced trade patterns will depend on prevailing socioeconomic conditions in the twenty-first century. No specific trade flow pattern is predicted, but specific countries are likely to become net food exporters in some years and net importers in others. In addition, several countries may become dependent on external trade to meet their domestic food requirements. The cost of importing food into ECOWAS countries will depend on the levels of common exterior tariffs. In that regard, the study shows that a 5 to 10 per cent reduction in common exterior tariffs could cut the overall cost of trade by approximately 3 to 7 per cent.

Acknowledgements

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1. Introduction

The impact of climate change on agriculture is expected to have a profound effect on the African continent if nothing is done to reduce greenhouse gas emissions and if no appropriate adaptation strategies are put in place (Intergovernmental Panel on Climate Change, 2014; Rosenzweig and Parry, 1994). There is now consensus that reductions in these emissions require global agreements between industrialized countries emitting large quantities of those gases. Regardless of whether agreements are concluded to reduce emissions to limit global temperature increases to less than 2oC by 2100, adaption measures must be expediently formulated in order to reduce the impact of emissions on food security in countries located in the tropics. It goes without saying that African countries must also take the steps required to reduce emissions and must adopt appropriate mitigation strategies, including by promoting reforestation and investing in cleaner and renewable energies. Given that climate models predict that an increase in temperatures will be accompanied with uneven changes in precipitation levels around the world, however, some countries may experience more rainfall than others. Consequently, while some countries may experience good crop harvests, others may not. In such a scenario, food trade among countries may help to combat food insecurity. The present report focuses on the West Africa region as a case study and is intended to deepen understanding of the relationship among the region's climate, agricultural production, food trade and food security. In a previous study, it was established that countries located in the northern hemisphere will be only marginally affected by climate change in terms of their ability to produce agricultural food products (Rosenzweig and Parry, 1994), while agricultural food production in countries located in the southern hemisphere, especially in the tropics, will be much more seriously affected. Specific countries in that hemisphere may fare better than others, however. It is therefore possible that regional trade and food imports from the northern hemisphere will become critically important if countries in the southern hemisphere are to address the negative effects of climate change (Stephan and Schenker, 2008).

There is compelling evidence that the adaptation of agricultural systems to mitigate the effects of climate change will require changes to current agricultural practices, including the use of innovative, heat-resistant seeds and the planting of agricultural crops that can withstand heat waves and droughts. Other recommended changes include increasing investment in dams and water reservoirs, with a view to improving irrigation. Indeed, significant investment will be needed to ensure the success of both stream-fed and groundwater irrigation schemes. Currently, most West African countries have inadequate resources for such investment because their Governments already face multiple social and economic challenges, including the need to invest in their health and education systems and in basic infrastructure. Even if investment is made to reduce the current burden on water supplies, the effectiveness of funded projects will still depend on the availability of adequate water resources. In that regard, several West African countries, including Benin, Ghana and Togo, recently experienced electricity shortages, resulting in several days of blackouts. This was due in part to the fact that the water levels in the Akosombo and Nangbeto dams had dropped significantly because of reduced rainfall. Food trade may therefore become a critical means to address food shortages in regions that have a water deficit due to irregular rainfall. Dynamic climate-induced comparative advantages that could arise from climate change, in which specific countries temporarily become net exporters of agricultural products, could be exploited in order to resolve food insecurity in West Africa (Food and Agriculture Organization of the United

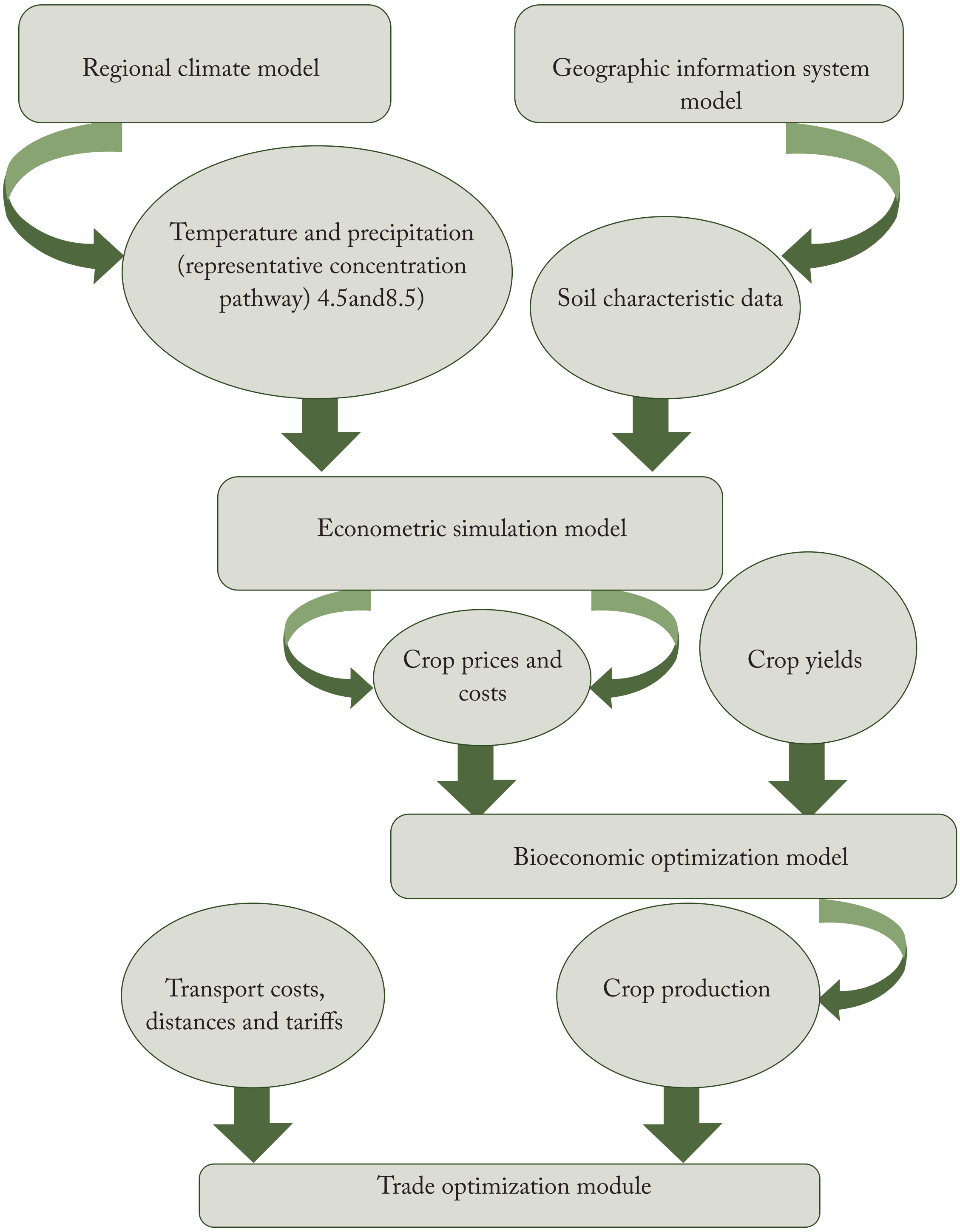
Nations, 2015). There are several reasons why trade in agricultural commodities could help countries and communities to adapt to and mitigate the effects of climate change (Stephan and Schenker, 2008). First, trade could act as a veritable insurance policy against the risk of climate change. Accordingly, trade would be the means by which food availability is maintained in regions affected by reduced agricultural productivity. Second, free trade flows could help to spread the costs of climate adaptation measures among stakeholders: free trade would allow regions that are net exporters of food to shoulder some of the increased cost of food that are borne by regions facing food deficits. This, however, once again raises questions relating to food accessibility that were raised in a previous study (Julia and Duchin, 2007), namely, that, although food can be imported, the majority of a country's inhabitants might not be able to afford it. This could lead to food insecurity if a country's inhabitants have insufficient purchasing power to buy food. This study therefore contains an examination of how food trade could help to reduce food insecurity in West Africa. Specifically, this paper is intended to: (a) differentiate between countries that are net suppliers of food from those that have food deficit in various scenarios, while identifying the most cost-effective ways to move food from excess supply countries to excess demand countries; (b) measure the impact of trade and agricultural policies on trade flows within the Economic Community of West African States (ECOWAS); and (c) evaluate the implications of trade flows on food security. To achieve these objectives, several questions must be addressed, including: (a) how effectively could food be moved from excess supply countries to excess demand countries? (b) what are the implications of food trade on the costs relating to climate change adaptation? and (c) what are the food security implications of the observed trade flows? In order to prospectively answer those questions, a bioeconomic optimization model for 14 West African countries was developed. These countries included Benin, Burkina Faso, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, the Niger, Nigeria, Senegal, Sierra Leone and Togo. The model was calibrated for observed land use as of 2004, was simulated up to 2100 and included drivers such as crops yields and prices within a few climate and socioeconomic scenarios. A trade module minimizing trade costs was then developed in order to identify excess supply versus excess demand countries, with a view to developing cost-effective mechanisms to move food from excess supply countries to excess demand countries.

2. Materials and methods

This paper is presented as follows: the first section elaborates on the methodological approaches used in the study, while the following section explains the model parameterization, scenario development and the model simulation results. It concludes with policy recommendations fomlated on the basis of those results.

The study used a bioeconomic optimization model based on a representative risk-neutral profit maximizer assumption. Within this model, a food trade module was developed. The food trade module was built as a transport model, intended to optimally transfer food from excess supply countries to excess demand countries. This model was then applied to the West Africa region in order to analyse the impact of climate change on food and trade systems. The model incorporated a wide range of data, including from previous studies. Initially, a regional climate model was used to predict temperature and precipitation from 2004 to 2100 under two representative concentration pathways (RCP4.5 and RCP8.5). Second, an econometric crop simulator was used to simulate crop yields under those RCPs. Third, the simulated yields in the two RCPs were coupled with projected crop price data in four socioeconomic scenarios and incorporated into a profit-maximizing bioeconomic model, with a view to predicting crop and livestock land use and production. Lastly, those crop levels were used to predict trade flows in the West Africa region, while also taking transport costs and trade tariffs outside the ECOWAS free trade zone into account.

Figure I: Structure of the trade module



2.1 Climate change and socioeconomic scenarios

The climate scenarios were designed to project climate variables according to two RCPs. From those RCPs, temperature, precipitation and evapotranspiration values were projected for the West African region, and those climate variables were used to simulate crop yield values under RCP4.5 and RCP8.5. A regional climate model was the main tool used to generate baseline and climate change data for the ECOWAS region. The regional climate modelling technique consisted of using initial conditions, time-dependent lateral meteorological conditions and surface boundary conditions in order to drive high-resolution limited area models. The driving data was derived from Coupled Model Intercomparison Project Phase 5 global climate models or Earth system models and could include greenhouse and aerosol forcing. The basic strategy was to use the global climate models to simulate the global circulation response to large-scale forcing and to use the regional climate model to account for sub-global climate model grid scale forcing in the context of complex topographical features and land cover heterogeneities, and enhance the simulation of atmospheric circulation and climatic variables at fine spatial scales. This technique was the most appropriate tool for generating regional climate change data for West Africa and has previously been used extensively in the region (Sylla and others, 2012).

The two RCP scenarios were coupled with four socioeconomic pathways. These shared socioeconomic pathways (SSPs) were used to derive data for index prices and costs in the bioeconomic model. The four SSPs were formulated on the basis of the following criteria: two dominant forces (State actors and non-State actors) interacting with two policy drivers (short-term priorities and long-term priorities), resulting in four possible scenarios. In the first scenario (SSP1), State actors were dominant, meaning that strong institutions existed, but Governments were focused on short-term gains, leading to a great need for cash. As a result, inflation was slightly above average. In the second scenario (SSP2), State actors were focused on long-term priorities, including a slow and painstaking transition to sustainable development. Consequently, general price levels were controlled effectively and inflation was low. In the third scenario (SSP3), non-State actors, including non-governmental organizations and civil society actors, were fully developed. A healthy balance therefore existed between civil society and the private sector that was productive overall. That scenario assumed moderate levels of inflation. In the fourth scenario (SSP4), non-State actors were dominant and sought to achieve short-term goals. Institutions were weak, countries were poorly governed and resources were used to solve crises rather than to invest in a sustainable future. As a result, inflation levels remained high.

Lastly, the two RCP scenarios were coupled with the four SSP scenarios to create the eight scenarios discussed in this paper.

2.2 Crop yield simulation

Crop yields are usually simulated on the basis of several variables (Izaurralde and others, 2006; Chang, 2002). Those variables may include climate factors, such as temperature, precipitation, evapotranspiration, CO2 concentration levels, soil type (three soil types were considered in this paper: clay, loam and sand), and management approaches and technologies, including fertilizer usage, crop rotation and irrigation. In West African agriculture, most crops are grown without the use of fertilizers or irrigation. Yields are therefore dependent on factors such as climate variables and soil type. Biophysical crop simulators, such as the environmental policy integrated climate model, are used primarily to predict environmental outcomes, including agricultural runoff and emissions levels. This research project sought to estimate crop yields without directly identifying specific environmental outcomes. An econometric yield estimation approach was therefore used. The yield function used was drawn from previous research (Gornott and Wechsung, 2016) and can be expressed as:

$$Y_{it} = Z_{it} CO2_t^{\delta} \left(\prod_{j=May}^{Oct} T_{ijt}^{\alpha_j}\right) \left(\prod_{j=May}^{Oct} P_{ijt}^{\beta_j}\right) \left(\prod_{k=1}^{9} S_{ik}^{\gamma_k}\right) \quad (1)$$

Or in logarithmic terms:

$$Y_{it} = Z_{it} CO2_t^{\delta} \left(\prod_{j=May}^{Oct} T_{ijt}^{\alpha_j}\right) \left(\prod_{j=May}^{Oct} P_{ijt}^{\beta_j}\right) \left(\prod_{k=1}^{9} S_{ik}^{\gamma_k}\right) \quad (1)$$

where and are, respectively, the agroclimatic and soil zones index, and time index; is technological progress; is the monthly main temperature; is the monthly main precipitation; is the soil characteristics; and is the CO_2 concentration in the atmosphere at time .

The dynamic of technological progress1 is given by:

$$\log(Z_{it}) = 0.06 * \left(\frac{t}{1+t}\right) + 0.98 * \log(Z_{it-1}) + U_{it}\ ;\ \ Z_{i0} = 1 \quad (3)$$

Where is a white noise with a truncated normal distribution.

2.3 The bioeconomic profit maximization model

The bioeconomic model is designed as an optimization problem in which the representative farmer maximizes profits by choosing from among seven crop systems (McCarl and Spreen, 1980; Egbendewe-Mondzozo, 2011). These systems include paddy rice, cereals (maize, sorghum and millet), vegetables, fruits and nuts (bananas, cassava, plantains, potatoes, sweet potatoes and yams), oil seeds (beans, cashew nuts, cowpeas, groundnuts and soybeans), and sugarcane, cotton and indigenous crops (cocoa, coffee and sesame), in accordance with the Global Trade Analysis Project classification of crops and livestock types, the latter of which include cattle, sheep, chickens and other animals. The land unit used in the model is based on dividing West Africa into 39 agroclimatic zones and three types of soil (loam, clay and sandy) within those zones. This parsing results in 84 land units or agroclimatic and soil zones in which the farmer can seek to maximize profits. In order to show country units rather than agroclimatic and soil zones, country boundaries on the zones are overlaid and weighted areas used to estimate production at the country level. The model is then calibrated using a positive mathematical programming method (Howitt, 1994). The calibrated model helps to define an agricultural land penetration rate of plus/minus 1 per cent for each five-year period, with a view to measuring land allocation and crop yields dynamically in the two RCP scenarios. Production costs and prices are projected in each SSP scenario by indexing the values from 2004. The model predicts land allocation from 2010 to 2100 in five-year increments (Lokonon and others, 2016). The total output computed is entered into the trade module to predict trade flows on the basis of climate change-driven dynamic comparative advantages.

2.4 Trade module

This is a dynamic transportation model in which food is moved from countries that are net suppliers to countries that have a net food need. Let be the quantity of crops to be moved from country to country in time . The excess supply in country is given as and the excess demand in country is given as. Let be the distance from country to country and is the unit transport cost. If is the import from outside the ECOWAS free trade zone and is the common exterior tariff parameter by crop , then the transport model could be written as follows:

$$\underset{x_{c,i,j,t}\,;\, imp_{c,i,t}}{\text{MIN}} \sum_c \sum_i \sum_j \sum_t \left(x_{c,i,j,t} \times \gamma \times Dist_{i,j} + \delta_c \times imp_{c,i,t}\right) \quad (1)$$

1 It is assumed in the study that technological progress will increase yields by 1 per cent annually. To avoid non-stationary process, technological change is captured by equation 3.

Subject to:

$$\sum_{j} x_{c,i,j,t} \leq a_{c,i,t}, \forall c, i, t \quad (2)$$

$$\sum_{i} x_{c,i,j,t} + imp_{c,j,t} \geq b_{c,j,t}, \forall c, j, t \quad (3)$$

$$x_{c,i,j,t} \geq 0;\ imp_{c,i,t} \geq 0\ , \forall c, i, j, t \quad (4)$$

The objective function (1) consists of choosing a shipment quantity and imports from outside the ECOWAS region so that the cost of trade is minimized. Constraint (2) stipulates that total shipments must be less than or equal to the available supply. Constraint (3) expresses the fact that total shipments plus imports must be greater than or equal to excess demands. Constraint (4) is the requirement that shipments and imports must be positive.

3. Trade module parameterization

3.1 Crop production levels

The trade module assumes crop production estimates generated by the bioeconomic optimization model. Those production levels are the estimates of the total supply available from domestic ECOWAS producers. The model allows imports from outside the ECOWAS region, namely, from Europe, Asia, the Americas and other countries in Africa. All imports from outside the ECOWAS region are subject to the common exterior tariff. Total production levels are calibrated to 2004 production levels. Only four crop types (paddy rice, cereals, vegetables and fruits, and oil seeds) are included as traded crops. It should be noted that, in general, ECOWAS countries do not allow free trade in those crops but might consider selling excess supplies of them to ECOWAS member countries in need. The other three crop types (sugarcane-sugar beets, cotton, and cocoa, coffee and sesame) are not included in the trade module because they are mostly cash crops and are thus exported out of the ECOWAS region.

3.2 Crop demand

Total demand for crops is computed using constant elasticity demand functions in the form , in which prices and gross domestic product vary in the four socioeconomic scenarios. The scale parameters are calibrated for each crop and each country on the basis of 2004 base year demand quantity data provided by the Food and Agriculture Organization of the United Nations in 2015 and price and income elasticity values drawn from the Modelling International Relationships in Applied General Equilibrium model (Decreux and Valin, 2007). To make these demands dynamic, the demand functions are indexed to the average yearly population growth of 3.5 per cent, and income elasticity growth rates of between 3 and 8.5 per cent for each five-year period are assumed. The elasticity data set is available only for specific countries and group of countries in the region. The countries considered individually in the study are Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal and Togo. The other countries (the Gambia, Guinea-Bissau, Liberia, Mali, the Niger and Sierra Leone) are grouped under the label "Other ECOWAS". After the calibration and projection of the demands, the difference between demand and total production is calculated to estimate excess demands and excess supply for each country up to the year 2100. The value of , which is the average cost in United States dollars per ton-km, is set at $0.752 and is taken from a United States Agency for International Development report (2012) on transport costs in West Africa. The parameter , which is the distance between countries' capital cities, is calculated using a Geographic Information System imposed on a map of the ECOWAS region. The parameter ,which includes common exterior tariff rates of ECOWAS countries, is taken from an ECOWAS report (Economic Community of West African States, 2006). Given the nonlinearities in the demand functions, the trade module is solved with non-linear programming using generalized algebraic modelling system software.

4. Model results and discussion

The results of the study highlight the impact of RCP4.5 and RCP8.5 climate change scenarios (the "mitigation" and "business as usual" scenarios) on food crop trade flows relative to a baseline of no climate change for each socioeconomic scenario.

4.1 Baseline scenario

In the baseline scenario, the effects of climate change are assumed to be absent. This scenario is driven by yields that would result if present-day climate conditions remained unchanged until the end of this century. Potential trade is then calculated on the basis of calculations of excess demand and supply in various countries. The model is then used to determine the minimum cost for shipping food from excess supply countries to excess demand countries. The results of this baseline scenario vary according to crop type and SSP. The SSPs are then used to simulate prices over the course of the century.

Paddy rice originates in Guinea and Nigeria and is shipped to other countries in SSP1 over the course of the century. Trade flows do not remain static, but increase in specific years and decrease in others. Ghana, Togo and the Other ECOWAS category become net importers of paddy rice from Guinea, whereas countries importing from Nigeria include all the remaining countries in the ECOWAS region, with the exception of Guinea. No paddy rice trade is predicted in the SSP2 scenario. In the SSP3 scenario, only Ghana is predicted to import paddy rice from Nigeria between the years 2050 and 2080, while, in SSP4, many other countries, including Côte d'Ivoire, Ghana, Guinea and Togo, become exporters of rice for a period of time.

Cereals are traded only in the SSP1 scenario between Burkina Faso (the exporting country) to Nigeria (the importing country). Trade is expected to fluctuate throughout the century.

A similar pattern of trade is observed in SSP2, but exports cease in 2030. In the SSP3 scenario, a similar trade flow is observed, with exports ceasing in 2060. Contrary to the limited trade flows in the aforementioned SSPs, trade flows increase in the SSP4 scenario, with all ECOWAS countries exporting cereals, with the exception of Côte d'Ivoire, Ghana, Guinea and Togo.

In SSP1, vegetables, fruits and nuts are exported by Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal and Togo to various other countries. However, specific exporting countries are expected to become net importers in specific years. In SSP2, only Côte d'Ivoire and Senegal export vegetables, fruits and nuts (to Guinea in the year 2010). In SSP3, Côte d'Ivoire increases overall exports by exporting to Nigeria until 2020. Senegal also exports to Nigeria and Togo in 2010 and 2020. Many other countries export vegetables, fruits and nuts in the SSP4 scenario: indeed, Benin, Côte d'Ivoire, Ghana, Guinea, Togo and other ECOWAS countries export vegetables, fruits and nuts to Burkina Faso until 2080 in order to meet extremely high demand for food in that country.

In the SSP1 scenario, Benin and Burkina Faso export oil seeds to Côte d'Ivoire, Ghana and Guinea from 2080 to 2100. In scenario SSP2, trade occurs between the years 2030 and 2050, and many more countries, namely, Burkina Faso, Côte d'Ivoire, Ghana, Nigeria and other ECOWAS countries, export oil seeds to countries such as Benin, Senegal and Togo. Specific exporting countries also receive imports from other countries in specific years. In the SSP3 scenario, trade occurs mainly during the last half of the century: exporting countries include Benin, Burkina Faso, Nigeria and Other ECOWAS countries. No oil seed trade takes place in the SSP4 scenario.

This simulation of trade without climate change constitutes a baseline for comparison with simulations under RCP4.5 and RCP8.5.

4.2 Impact of climate change on paddy rice trade

The difference from the baseline that climate change makes on the trade flow of rice in RCP4.5 is shown in table 1. Relative to that baseline, the model predicts that rice may be exported from Côte d'Ivoire to Burkina Faso and Ghana from 2090 to the end of the century in SSP1. Other countries, including Guinea and Nigeria, may reduce or increase their trade, but without any consistent pattern. In SSP2, Nigeria may experience a decrease in its exports to Ghana between 2050 and 2080 and an increase thereafter. It is predicted in the model that there will be no rice traded within the ECOWAS region in SSP3. In SSP4, trade will include exports from Côte d'Ivoire, Ghana, Guinea and Togo to other countries, but without any specific pattern emerging.

Table 1: Rice trade flow changes from baseline under RCP4.5

		2020	2030	2040	2050	2060	2070	2080	2090	2095	2100
SSP1: cash, control and calories											
Côte d'Ivoire	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	572.6	1 478.7	1 865.2
Côte d'Ivoire	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	555.6	452.3	416.4
Guinea	Senegal	0.0	0.0	0.0	-1.0	0.0	-1.0	-0.5	-0.9	-1.0	-1.0
Guinea	Togo	0.0	0.0	0.0	-1.0	0.0	0.0	0.1	-0.2	-0.2	-0.3
Guinea	Other ECOWAS	-1.0	-1.0	-0.4	1 135.2	1.6	1 150.6	991.4	0.0	0.0	0.0
Nigeria	Benin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Nigeria	Burkina Faso	0.0	0.0	0.0	-0.8	0.0	0.0	-0.1	-0.3	-0.6	-0.7
Nigeria	Côte d'Ivoire	0.0	0.0	-1.0	0.0	-0.1	-0.3	16.2	-1.0	-1.0	-1.0
Nigeria	Ghana	-1.0	-0.4	0.1	0.1	0.1	0.2	0.2	-1.0	-1.0	-1.0
Nigeria	Senegal	0.0	0.0	-1.0	1 086.9	-0.1	809.7	140.7	0.0	0.0	0.0
Nigeria	Togo	0.0	0.0	-1.0	0.6	-0.9	-0.4	0.0	0.0	0.0	0.0
Nigeria	Other ECOWAS	-1.0	-1.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
SSP2: self-determination											
Nigeria	Ghana	0.0	0.0	0.0	-1.0	-0.6	-1.0	-1.0	976.8	4 320.3	5 521.2
SSP4: save yourself											
Côte d'Ivoire	Burkina Faso	0.0	0.0	-0.6	0.0	0.2	88.8	0.0	0.0	0.0	0.0
Côte d'Ivoire	Ghana	0.0	0.0	50.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	0.0	-0.4	-0.2	-0.2	0.0	-0.7	-1.0	0.0
Guinea	Senegal	-1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Togo	-1.0	3.2	-0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Other ECOWAS	11.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	-1.0	0.1	0.0	0.0	0.0	0.0	0.1	-0.4	-0.7	-1.0
Nigeria	Burkina Faso	-1.0	0.0	0.3	4.5	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Côte d'Ivoire	-1.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Ghana	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Togo	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Other ECOWAS	0.3	836.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	-1.0

Trade flows under RCP8.5 are shown in table 2. In SSP1, Côte d'Ivoire could export rice to Burkina Faso from the year 2090 until the end of the century and could export rice to Ghana from 2070. No trading of rice will occur within the ECOWAS region under SSP2, whereas in SSP3, Nigeria will export rice to Ghana from the middle of the century until 2080. In SSP4, exports from several countries, including Côte d'Ivoire, Ghana, Guinea and Nigeria, will be sent to other ECOWAS countries, but no prevailing trends in trade patterns are observed.

Table 2: Rice trade flow changes from baseline under RCP 8.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Cote d'Ivoire	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 004.3	2 590.0
Cote d'Ivoire	Ghana	0.0	0.0	0.0	0.0	0.0	126.1	292.5	513.3	222.3
Guinea	Senegal	0.0	0.0	0.0	-1.0	0.0	-0.3	-0.5	-1.0	-1.0
Guinea	Togo	0.0	0.0	0.0	-1.0	0.0	428.6	0.0	-0.2	-0.4
Guinea	Other ECOWAS	-1.0	-0.7	-0.2	1 347.1	1.2	850.8	457.9	0.0	0.0
Nigeria	Benin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Nigeria	Burkina Faso	0.0	0.0	0.0	-0.4	0.0	0.0	0.0	-0.4	-1.0
Nigeria	Cote d'Ivoire	0.0	0.0	-1.0	-0.1	-0.5	-1.0	-1.0	-1.0	-1.0
Nigeria	Ghana	-1.0	0.1	0.1	0.1	0.1	-0.1	-0.4	-1.0	-1.0
Nigeria	Senegal	0.0	0.0	-1.0	1 080.2	-0.2	0.0	0.0	0.0	0.0
Nigeria	Togo	0.0	0.0	-1.0	0.5	0.1	-1.0	0.0	0.0	0.0
Nigeria	Other ECOWAS	-1.0	-0.9	0.3	-0.4	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Nigeria	Ghana	0.0	0.0	0.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0
SSP4: save yourself										
Côte d'Ivoire	Burkina Faso	0.0	0.0	-1.0	-1.0	-1.0	0.0	342.7	241.7	747.0
Côte d'Ivoire	Ghana	0.0	0.0	-0.3	0.0	25.7	132.5	76.4	221.0	44.0
Côte d'Ivoire	Togo	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0
Guinea	Ghana	74.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Senegal	-1.0	-1.0	-1.0	-0.9	472.6	401.1	320.2	245.9	251.2
Guinea	Togo	-1.0	0.0	-1.0	2.2	164.9	171.3	175.7	183.5	185.7
Guinea	Other ECOWAS	-1.0	1.6	727.0	556.8	21.2	0.0	0.0	0.0	0.0
Nigeria	Benin	-1.0	-1.0	-0.6	0.3	0.5	0.7	0.9	1.2	1.9
Nigeria	Burkina Faso	-1.0	-1.0	-1.0	43.4	1 108.1	1 065.1	672.1	717.8	153.0
Nigeria	Cote d'Ivoire	-1.0	-1.0	353.8	165.9	0.0	0.0	0.0	0.0	0.0
Nigeria	Ghana	-1.0	1.7	333.0	249.0	154.8	89.7	0.0	0.0	0.0
Nigeria	Senegal	0.0	0.0	605.5	151.2	0.0	0.0	0.0	0.0	0.0
Nigeria	Togo	0.0	-1.0	154.6	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Other ECOWAS	-1.0	338.8	326.5	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	0.0	0.0	0.0	0.0	0.0	-0.9	0.0	0.0	-1.0

4.3 Impact of climate change on the trade of cereals

The impact of climate change on the trade of cereals under RCP4.5 and the various socioeconomic scenarios is shown in table 3. In SSP1, a clear pattern of trade flow emerges, albeit with a few exceptions. Positive trade volumes of cereals may move from Burkina Faso to Côte d'Ivoire, Guinea and Togo; from Nigeria to Benin, Ghana and Togo; from Senegal to Guinea and Togo; and from Other ECOWAS to Côte d'Ivoire, Guinea and Nigeria. Most of that trade will occur from the middle to the end of the century, while only a small volume of trade will occur at the beginning of the century. In SSP2, Burkina Faso will trade cereals at positive volumes with Nigeria from 2020 to 2040, whereas in SSP3, positive volumes of cereals will move from Burkina Faso to Nigeria during the entire century. Benin will begin exporting cereals in scenario SSP4, but no consistent trade pattern emerges.

Table 3: Cereal trade flow changes from baseline under RCP4.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Burkina Faso	Côte d'Ivoire	0.0	0.0	0.0	488.6	1 528.8	2 350.7	1 590.8	3 513.3	4 052.1
Burkina Faso	Ghana	0.0	0.0	0.0	3 012.7	3 895.6	4 967.9	6 048.1	4 817.3	7 565.2
Burkina Faso	Guinea	0.0	0.0	0.0	1.7	3 147.7	0.0	656.3	5 604.0	7 212.1
Burkina Faso	Nigeria	0.4	0.2	0.4	0.1	-1.0	-0.6	-0.3	-1.0	-1.0
Burkina Faso	Togo	0.0	0.0	0.0	0.0	528.9	614.1	0.0	0.0	2 097.7
Nigeria	Benin	0.0	0.0	0.0	0.0	551.3	0.0	0.0	3 609.9	3 932.7
Nigeria	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 043.3	0.0
Nigeria	Togo	0.0	0.0	0.0	0.0	698.8	0.0	0.0	2 499.1	1 749.9
Senegal	Guinea	0.0	0.0	0.0	183.6	0.0	0.0	11.6	0.0	0.0
Senegal	Togo	0.0	0.0	0.0	0.0	0.0	754.4	0.0	783.7	0.0
Other ECOWAS	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0
Other ECOWAS	Guinea	0.0	0.0	0.0	2 275.1	0.0	3 962.3	4 237.8	943.1	0.0
Other ECOWAS	Nigeria	858.6	1 345.6	76.0	0.0	0.0	0.0	0.0	0.0	0.0
SSP2: self-determination										
Burkina Faso	Nigeria	2.9	0.7	491.8	0.0	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Burkina Faso	Nigeria	0.2	0.3	0.6	3.7	5 324.4	3 207.6	642.4	109.0	186.3
SSP4: save yourself										
Benin	Côte d'Ivoire	48.3	0.0	0.0	0.0	1 688.3	554.2	0.0	0.0	0.0
Benin	Ghana	0.0	0.0	45.8	0.0	0.0	0.0	0.0	0.0	0.0
Benin	Guinea	0.0	1.1	4.3	1.8	-1.0	2.2	606.4	847.1	1 680.3
Benin	Nigeria	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benin	Togo	0.0	-0.1	-1.0	0.0	0.0	0.0	361.0	52.2	0.0
Burkina Faso	Côte d'Ivoire	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-0.2	-0.2	-0.5
Burkina Faso	Ghana	751.4	-0.1	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Burkina Faso	Guinea	198.7	-0.2	-0.9	-1.0	0.1	-1.0	-1.0	-0.9	-1.0
Burkina Faso	Nigeria	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkina Faso	Togo	0.0	0.0	5 505.2	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0

		2020	2030	2040	2050	2060	2070	2080	2090	2100
Nigeria	Benin	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0	-1.0
Senegal	Togo	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Côte d'Ivoire	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Ghana	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Guinea	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Nigeria	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Togo	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4 shows predicted trade flow differences from the baseline under RCP8.5 in the various socioeconomic scenarios. In SSP1, the previous trade pattern observed under RCP4.5 is replicated, but with changes in trade volume, whereas in SSP2, trade volumes increase. A consistent decline in trade from baseline figures is observed in SSP3. A more consistent decline of trade volumes relative to the baseline is also observed in SSP4.

Table 4: Cereals trade flow changes from baseline under RCP8.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Burkina Faso	Benin	0.0	0.0	0.0	0.0	789.7	0.0	0.0	0.0	0.0
Burkina Faso	Côte d'Ivoire	0.0	0.0	0.0	676.2	1 896.1	0.0	934.8	3 519.6	4 201.8
Burkina Faso	Ghana	0.0	0.0	0.0	3 050.0	4 031.1	5 019.8	6 075.9	5 012.8	7 325.6
Burkina Faso	Guinea	0.0	0.0	0.0	0.0	594.0	816.7	816.1	5378.2	8 159.4
Burkina Faso	Nigeria	0.5	0.2	0.5	-0.1	-0.7	0.0	-0.2	-1.0	-1.0
Burkina Faso	Togo	0.0	0.0	0.0	333.0	560.5	0.0	0.0	0.0	0.0
Nigeria	Benin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3 615.0	4 146.6
Nigeria	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1 861.7	426.6
Nigeria	Togo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2 587.4	3 985.8
Senegal	Guinea	0.0	0.0	0.0	0.0	0.0	219.3	0.0	0.0	0.0
Senegal	Nigeria	0.0	64.8	20.2	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	Togo	0.0	0.0	0.0	294.9	839.3	0.0	0.0	700.6	0.0
Other ECOWAS	Côte d'Ivoire	0.0	0.0	0.0	366.9	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Guinea	0.0	0.0	0.0	2 473.4	2 583.6	2 874.6	4 111.0	1 170.0	0.0
Other ECOWAS	Nigeria	1 692.9	2 301.4	1 195.6	0.0	0.0	0.0	0.0	0.0	0.0
SSP2: self-determination										
Burkina Faso	Nigeria	3.2	2.5	809.7	0.0	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Burkina Faso	Nigeria	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
SSP4: save yourself										

		2020	2030	2040	2050	2060	2070	2080	2090	2100
Benin	Guinea	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0
Benin	Nigeria	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Benin	Togo	0.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkina Faso	Côte d'Ivoire	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Burkina Faso	Ghana	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Burkina Faso	Guinea	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Burkina Faso	Nigeria	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkina Faso	Togo	0.0	0.0	0.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Nigeria	Benin	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0	-1.0
Senegal	Togo	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Côte d'Ivoire	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Ghana	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Guinea	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Nigeria	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Togo	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.4 Impact of climate change on the trade of vegetables, fruits and nuts

The impact of climate change in the RCP4.5 scenario on the trade in vegetables, fruits and nuts relative to the baseline is presented in table 5. In SSP1, exports from Côte d'Ivoire to Burkina Faso at the beginning of the century will drop relative to the baseline, while exports from Benin will increase from 2070 until the end of the century. The export of vegetables, fruits and nuts from Ghana, Guinea, Nigeria and Togo to the other West African countries will continue but with no clear trading pattern. No trading within the ECOWAS region occurs in SSP2 for vegetables, fruits and nuts. In SSP3, Ghana and Nigeria increase their trade volumes to other countries from 2070 until the end of the century. In SSP4, there is a decline in the overall trade of vegetables, fruits and nuts.

Table 5: Vegetables, fruits and nuts trade flow changes from baseline under RCP4.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Benin	Burkina Faso	0.0	0.0	0.0	0.0	0.0	151.6	7 266.7	5 588.0	6 866.6
Côte d'Ivoire	Burkina Faso	-1.0	-0.2	-0.1	-0.3	-1.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Ghana	-1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Guinea	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	3 273.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Senegal	0.0	0.0	0.0	0.2	-0.1	-0.3	-0.4	-0.4	-0.4
Côte d'Ivoire	Togo	0.0	0.0	0.0	1346.6	-0.3	-0.7	-0.9	-0.6	-0.5
Côte d'Ivoire	Other ECOW-AS	0.0	0.0	0.0	-1.0	-1.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	-0.3	0.3	0.3	0.0	-0.3	-0.2	-0.2
Ghana	Other ECOW-AS	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0
Guinea	Nigeria	257.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Togo	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0
Guinea	Other ECOW-AS	-1.0	0.3	-0.2	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	-1.0	0.2	0.6	0.2	-0.3	-1.0	-1.0	-1.0	-1.0
Nigeria	Burkina Faso	-1.0	0.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0

		2020	2030	2040	2050	2060	2070	2080	2090	2100
Nigeria	Senegal	0.0	22.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Togo	0.0	116.7	3.0	-1.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Other ECOW-AS	-1.0	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	Other ECOW-AS	-0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	-1.0	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Côte d'Ivoire	Guinea	-0.9	0.0	0.0	0.0	0.0	0.0	9 471.9	0.0	0.0
Côte d'Ivoire	Nigeria	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	34 533.7	0.0	0.0
Ghana	Guinea	0.0	0.0	0.0	0.0	0.0	10 542.2	4 996.0	14 248.6	0.0
Nigeria	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	76 359.2	12 204.7	0.0
Nigeria	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28 816.4	4 291.3
Nigeria	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	124.8
Nigeria	Guinea	0.0	0.0	0.0	0.0	0.0	1 287.4	0.0	13 586.7	43 117.1
Nigeria	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Senegal	0.0	0.0	0.0	0.0	0.0	272.7	13 893.8	23 088.9	37 787.7
Nigeria	Togo	0.0	0.0	0.0	0.0	0.0	0.0	26 683.8	0.0	0.0
Nigeria	Other ECOW-AS	0.0	0.0	0.0	0.0	0.0	20 795.5	21 720.2	38 347.6	51 431.8
SSP4: save yourself										
Benin	Burkina Faso	-1.0	-0.3	-0.3	-0.1	0.3	0.1	-0.1	-0.1	-0.1
Côte d'Ivoire	Burkina Faso	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	-0.2	0.1	0.8	0.5	-1.0	0.0	0.0	0.0	0.0
Nigeria	Benin	388.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	-0.3	-0.1	-0.2	0.0	-0.6	-1.0	0.0	0.0	0.0

The impact of climate change in the RCP8.5 scenario on the trade in vegetables, fruits and nuts relative to the baseline is presented in table 6. In SSP1, Benin exports vegetables, fruits and nuts to Burkina Faso from 2070 until the end of the century. Exports from Côte d'Ivoire, Ghana, Nigeria and Togo experience some increases and some decreases relative to the baseline. There is no trade of vegetables, fruits and nuts within the ECOWAS region in scenario SSP2. Exports from Côte d'Ivoire to Guinea and Nigeria decrease in 2020 in scenario SSP3, while in SSP4, exports from Côte d'Ivoire to Nigeria, Senegal, and Togo increase steadily relative to the baseline. A similar increase in exports from Nigeria to Benin is also observed, and consistent declines in exports relative to the baseline are observed in the cases of Benin to Burkina Faso and Togo to Burkina Faso.

Table 6: Vegetables, fruits and nuts trade flow changes from baseline under RCP8.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Benin	Burkina Faso	0.0	0.0	0.0	0.0	0.0	952.7	8 723.0	11 444.1	14 771.7
Côte d'Ivoire	Burkina Faso	-1.0	-0.8	-0.4	-0.2	-1.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Ghana	-1.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Guinea	0.0	0.0	27.4	0.0	0.0	-1.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	2 473.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Senegal	0.0	0.0	0.0	0.1	-0.1	-0.4	-0.5	-0.5	-0.4
Côte d'Ivoire	Togo	0.0	0.0	0.0	1 453.6	-0.3	-0.7	-1.0	-0.8	-0.7
Côte d'Ivoire	Other ECOWAS	0.0	0.0	0.0	-0.5	-1.0	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	-1.0	0.2	0.3	-0.1	-0.3	-0.4	-0.4
Ghana	Other ECOWAS	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0
Guinea	Nigeria	60.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Togo	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0
Guinea	Other ECOWAS	-1.0	-0.4	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	-1.0	-1.0	1.0	0.2	-0.3	-1.0	-1.0	-1.0	-1.0
Nigeria	Burkina Faso	-1.0	0.1	5.7	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Senegal	0.0	56.6	64.7	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Togo	0.0	0.0	5.9	-1.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Other ECOWAS	-1.0	0.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	Nigeria	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	Other ECOWAS	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	-1.0	-0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Côte d'Ivoire	Guinea	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Côte d'Ivoire	Nigeria	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SSP4: save yourself										
Benin	Burkina Faso	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Côte d'Ivoire	Burkina Faso	-1.0	2 089.0	1 626.6	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	52.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Senegal	0.0	0.0	100.5	176.0	252.1	300.3	311.4	335.3	404.9
Côte d'Ivoire	Togo	0.0	0.0	1 768.0	2 021.6	2 288.0	2 546.5	2 788.8	3 074.3	3 367.7
Ghana	Burkina Faso	-1.0	-0.7	2.4	5.7	11.0	8 847.4	8 815.4	8 725.7	8 579.8
Guinea	Burkina Faso	0.0	379.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Nigeria	366.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Senegal	0.0	25.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Other ECOWAS	0.0	627.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	0.0	0.0	6 909.3	7 238.9	7 604.4	7 988.4	8 337.2	8 644.3	8 903.5
Nigeria	Burkina Faso	0.0	3 710.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Togo	Burkina Faso	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	0.0	0.0	0.0

4.5 Impact of climate change on the trade in oil seeds

Table 7 shows the impact of climate change in RCP4.5 on the trade in oil seeds, compared with a baseline without climate change. In SSP1, the export of oil seeds from Benin and Burkina Faso to Ghana, Guinea and Côte d'Ivoire declines towards the end of the century. The only exception to this trend is an increase in exports from Benin to Guinea in 2100. In SSP2, trade in oil seeds increases for some countries and declines for others at the beginning of the century but without any consistent pattern. In scenario SSP3, trade increases in specific years, such as Burkina Faso exporting to Togo in 2050 and 2060, and decreases in other years, such as with Benin exporting to Ghana in 2080, although, once again, no consistent pattern emerges. There is no change from the baseline in the trade of oil seeds in the SSP4 socioeconomic scenario.

Table 7: Oil seed trade flow changes from baseline under RCP4.5

SSP1: cash, control and calories										
Benin	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
Benin	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9
Benin	Guinea	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-1.0	2 051.5
Burkina Faso	Guinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0
SSP2: self-determination										
Burkina Faso	Nigeria	0.0	81.4	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	0.0	344.6	-0.5	-1.0	0.0	0.0	0.0	0.0	0.0
Ghana	Nigeria	0.0	47.0	-0.9	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	25.3	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	Togo	0.0	80.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Benin	0.0	275.1	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Ghana	0.0	0.0	179.2	0.5	-1.0	0.0	0.0	0.0	0.0
Other ECOWAS	Guinea	0.0	3.5	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Nigeria	0.0	682.3	8.8	-0.4	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Benin	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	935.8	0.0
Benin	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
Benin	Guinea	0.0	0.0	0.0	0.0	-1.0	-1.0	431.7	658.7	0.0
Benin	Nigeria	0.0	0.0	0.0	0.0	0.0	13.0	0.0	-1.0	142.0
Benin	Togo	0.0	0.0	0.0	0.0	-1.0	-0.4	0.3	0.0	723.2
Burkina Faso	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	7.4	0.0	0.0
Burkina Faso	Ghana	0.0	0.0	0.0	0.0	8.1	-1.0	417.7	721.7	0.0
Burkina Faso	Guinea	0.0	0.0	0.0	12.7	23.0	-1.0	-1.0	111.4	0.0
Burkina Faso	Nigeria	0.0	0.0	0.0	0.0	0.0	266.4	0.0	-1.0	239.0
Burkina Faso	Togo	0.0	0.0	0.0	220.9	121.3	0.0	0.0	0.0	0.0
Côte d'Ivoire	Benin	0.0	0.0	0.0	0.0	28.9	0.0	0.0	0.0	0.0
Côte d'Ivoire	Guinea	0.0	0.0	0.0	0.0	98.5	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	0.0	0.0	0.0	0.0	119.5	0.0	0.0	0.0	0.0
Nigeria	Benin	0.0	0.0	0.0	43.9	0.0	0.0	0.0	0.0	0.0
Nigeria	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	80.6	0.0
Nigeria	Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	103.4	0.0
Nigeria	Togo	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	942.9	0.0
Senegal	Togo	0.0	0.0	0.0	0.0	63.6	92.7	0.0	0.0	0.0

		2020	2030	2040	2050	2060	2070	2080	2090	2100
Other ECOWAS	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	247.9	0.0	-1.0	2.3
Other ECOWAS	Ghana	0.0	0.0	0.0	0.0	0.0	138.3	0.0	-1.0	-0.1
Other ECOWAS	Guinea	0.0	0.0	0.0	0.0	0.0	270.2	0.0	-1.0	-0.1
Other ECOWAS	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.1
Other ECOWAS	Togo	0.0	0.0	0.0	0.0	0.0	19.4	0.0	-1.0	1208.0

The impact of climate change under RCP8.5 on the trade in oil seeds, compared with a baseline without climate change, is shown in table 8. In SSP1, the export of oil seeds from Benin to Côte d'Ivoire increases in 2100, while exports from Benin to Guinea decline in 2080 and 2090. In SSP2, oil seed trade flows evolve during the first half of the century but without following any specific pattern. In SSP3, oil seeds trade from Côte d'Ivoire to Ghana and Nigeria increases. A similar pattern is observed in the cases of Ghana to Nigeria and Guinea to Nigeria. Trade from other countries either declines or remains relatively stable, compared with the baseline. Lastly, in scenario SSP4, the oil seed trade remains steady or increases compared with the baseline, and Côte d'Ivoire, Ghana, Guinea, Nigeria and Togo become the main exporting countries.

4.6 Sensitivity to the exterior common tariff

All other things being equal, if the demand for food continues to increase owing to population and economic growth, ECOWAS countries may need to import food from outside the ECOWAS region on a continuing basis until the end of the century. The comparison between the baseline total trade costs and the trade costs in the two climate change scenarios (see table 9) shows that trade costs increase in SSP3 and SSP4 in RCP8.5 because of the high levels of food imports from outside the ECOWAS region, which are driven by the need to adapt to the effects of climate change.

These adaptation costs may be reduced by lowering the exterior common tariff. A reduction of

Table 8: Oil seed trade flow changes from baseline under RCP4.5

		2020	2030	2040	2050	2060	2070	2080	2090	2100
SSP1: cash, control and calories										
Benin	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Benin	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.9
Benin	Guinea	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	-1.0	0.0
SSP2: self-determination										
Burkina Faso	Nigeria	0.0	58.6	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	0.0	362.4	-0.6	-1.0	0.0	0.0	0.0	0.0	0.0
Ghana	Nigeria	0.0	42.0	-0.9	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Benin	8.3	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Benin	0.0	260.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Ghana	0.0	0.0	220.9	0.6	-1.0	0.0	0.0	0.0	0.0
Other ECOWAS	Guinea	0.0	0.7	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Nigeria	0.0	942.0	7.0	-0.6	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Senegal	0.0	181.1	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
Other ECOWAS	Togo	0.0	65.3	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
SSP3: civil society to the rescue?										
Benin	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
Benin	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0

		2020	2030	2040	2050	2060	2070	2080	2090	2100
Benin	Guinea	0.0	0.0	0.0	0.0	-1.0	-1.0	0.0	0.0	0.0
Benin	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0
Benin	Togo	0.0	0.0	0.0	0.0	-1.0	-1.0	0.0	0.0	0.0
Burkina Faso	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	0.0	0.0
Burkina Faso	Ghana	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0
Burkina Faso	Guinea	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0	0.0	0.0
Burkina Faso	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0
Côte d'Ivoire	Ghana	0.0	0.0	84.8	2.9	0.0	0.0	0.0	0.0	0.0
Côte d'Ivoire	Nigeria	245.5	254.9	92.7	0.0	0.0	0.0	0.0	0.0	0.0
Ghana	Nigeria	50.5	26.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Guinea	Nigeria	25.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nigeria	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
Nigeria	Togo	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0
Other ECOWAS	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Ghana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Guinea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Nigeria	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	-1.0
Other ECOWAS	Togo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0
SSP4: save yourself										
Côte d'Ivoire	Senegal	98.5	104.6	110.9	117.2	36.8	131.2	85.1	48.5	0.0
Côte d'Ivoire	Other ECOWAS	135.4	105.8	72.6	57.2	115.2	0.0	0.0	0.0	0.0
Ghana	Burkina Faso	0.0	0.0	0.0	0.0	83.4	89.1	94.3	76.3	26.5
Ghana	Senegal	0.0	0.0	0.0	0.0	86.2	0.0	51.7	38.4	0.0
Guinea	Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.0	27.7
Guinea	Togo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Nigeria	Benin	217.4	216.9	215.9	213.7	213.2	212.6	210.5	206.4	201.0
Nigeria	Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	74.2
Nigeria	Côte d'Ivoire	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.9
Nigeria	Senegal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	123.4
Togo	Burkina Faso	66.3	69.9	73.7	77.8	0.0	0.0	0.0	20.9	0.0

Table 9:Trade cost differences for food imports from outside the ECOWAS region under climate change scenarios RCP4.5 and RCP8.5

		SSP1	SSP2	SSP3	SSP4
Baseline		10 565 447	59 186 317	35 773 588	27 361 219
RCP4.5		8 857.48	54 044 690	12 879 351	27 003 937
Difference		-1.00	-0.09	-0.64	-0.01
RCP8.5		13 789.29	52 780 709	54 534 409	24 053 103
Difference		-1.00	-0.11	0.52	87 908.47

Table 10: Sensitivity analyses for the exterior common tariff decreases under RCP8.5

5 per cent decrease				
Original trade cost	13 789.3	52 780 709	54 534 409	24 053 103
Trade cost under 5 per cent exterior common tariff decrease	13 749	52 592 467	54 340 235	23 985 026
Change	-0.003	-0.004	-0.004	-0.003
10 per cent decrease				
Original trade cost	13 789.3	52 780 709	54 534 409	24 053 103
Trade cost under 10 per cent exterior common tariff decrease	13 708.8	52 404 226	54 146 062	23 916 950
Change	-0.006	-0.007	-0.007	-0.006

5 and of 10 per cent of the tariff is assumed the impact on total trade costs under RCP8.5 evaluated. The results of these two sensitivity analyses are shown in table 10.

From the sensitivity analysis, it can be concluded that, under RCP8.5, a decrease in exterior common tariff of 5 per cent will reduce adaption costs by between 0.003 and 0.004 per cent, depending on the prevailing SSP scenario. A 10 per cent tariff decrease will reduce the adaptation costs in RCP8.5 by between 0.006 and 0.007 per cent, depending on the prevailing SSP scenario.

4.7 Implications for food security in the Economic Community of West African States

Many West African countries will need to continue to import food from outside the ECOWAS region because domestic production is unable to keep up with those countries' increasing food requirements. To illustrate this point, changes from the baseline in rice imports from outside ECOWAS under RCP8.5 and SSP1 are shown in table 11.

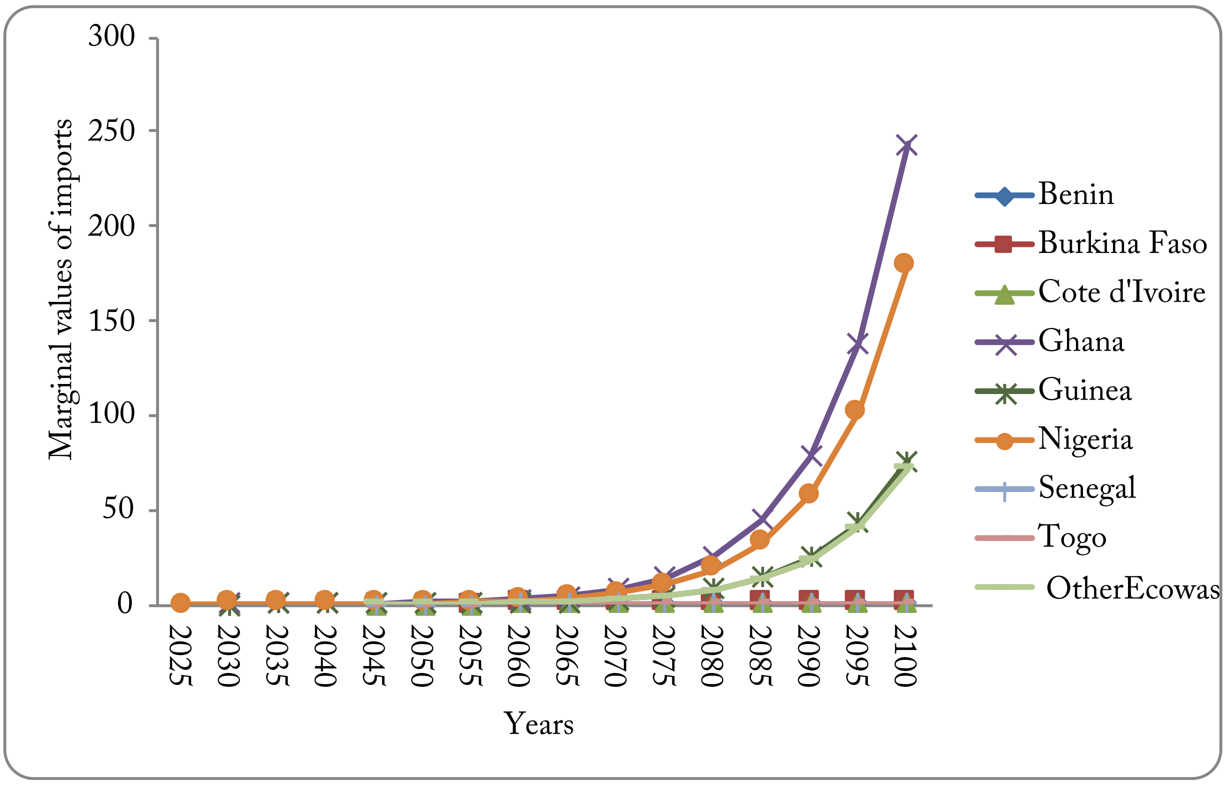
These results show, that, because of climate change, food imports to specific countries from outside ECOWAS are likely to increase. These results are also consistent with the results found by Rosenzweig and Parry (1994) under a number of climate change scenarios. The idea framework of food security is multidimensional and includes challenges such as the availability of food, which may combine domestic production with imports from external sources, the accessibility of food and the security and quality of food. The definition for food security agreed upon at the 1996 World Food Summit is as follows: food security exists when all people always have physical, economic and social

Table 11: Changes from baseline in rice imports to the ECOWAS region under RCP4.5 and SSP1

	2020	2025	2030	2035	2040	2045	2050
Benin	0.0	0.0	0.0	0.0	0.0	643.9	0.0
Burkina Faso	0.0	0.0	0.0	0.0	0.0	0.2	3.7
Côte d'Ivoire	0.2	0.2	0.2	1.0	806.9	0.0	0.0
Ghana	710.9	494.9	0.0	0.0	0.0	0.0	0.0
Guinea	181.0	38.6	0.0	0.0	0.0	0.0	0.0
Nigeria	433.8	0.0	0.0	0.0	0.0	0.0	0.0
Senegal	0.0	0.0	0.0	0.0	0.4	0.0	0.0
Togo	0.1	0.1	0.1	259.1	287.4	0.0	0.0
Other ECOWAS	0.4	1.6	26.2	2 203.2	259.4	0.0	0.0

access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Pinstrup-Anderson, 2009). While dietary needs and food preferences could be addressed at a household level, this study goes beyond the scope of a household analysis. Rather, it is a regional assessment of the ability of each country to meet its food requirements from either within or outside the ECOWAS region. What can be said in terms of food security at this point is therefore more closely related to the physical availability of food. Physical availability will be met as long as the countries outside ECOWAS, in particular those that are located in the northern hemisphere, are not significantly affected by climate change. It has, in fact, been shown that the northern hemisphere will not suffer significantly from climate change in terms of its ability to produce food (Rosenzweig and Parry, 1994). Questions remain about accessibility and the affordability of food, which depend on the marginal values of imports from outside the ECOWAS region. As an example, the marginal values of rice imports under RCP8.5 and SSP1 are provided in figure II, revealing how expensive food imported from outside ECOWAS could become over time.

Figure II: Marginal values of food imports per ton (United States dollars)



5. Conclusion

This study looked at the potential impact of climate change scenarios on trade flows in the ECOWAS region and included the following: a baseline scenario without climate change, a business as usual climate change scenario (RCP8.5) and a climate change mitigation scenario (RCP4.5). Crop production in those scenarios was evaluated according to four hypothetical socioeconomic scenarios, which served as factors driving prices and costs in the crop production process.

The results suggest that the impact of climate change on crop trade flows will depend on the crop type, the severity of climate change and the prevailing socioeconomic scenario. It is concluded that trade within ECOWAS may be limited owing to supplier shortages, although no clear pattern has emerged in terms of net exporters and net importers. In other words, countries that are net exporters in some years may become net importers in other years. The reliance on food imports from outside the ECOWAS region is therefore likely to be the key to maintaining food availability within ECOWAS countries. Given that the ECOWAS region as a whole may become a net importer of food, all imports will be subject to the exterior common tariff established in 2015. Thus, trade policy scenarios with 5 per cent and 10 per cent decreases in the tariff were run. The sensitivity results show that those reductions in the tariff may reduce adaptation cost by approximately 3 to 7 per cent in the RCP8.5 scenario. A change in the tariff, however, would not have any significant impact on trade flow apart from that reduction in cost. This is due to the structure of the model, which was designed to examine how food requirements can be met with food produced within ECOWAS or with imports from non-ECOWAS countries.

Previous studies have shown that, although climate change may affect food supplies in the tropics, food imports from the northern hemisphere may help to mitigate the effects of climate change (Rosenzweig and Parry, 1994). Under various climate change scenarios, food will remain available in ECOWAS countries, provided that those countries have the resources to import food from outside the region, including from Europe, Asia, Australia, the Americas and other countries in Africa. This study does not address the question of whether populations will have the economic resources to purchase the food that is available or questions relating to the safety of imported food. The results of this study imply that further efforts are needed in the ECOWAS region to increase agricultural production. Those efforts would include investment in agricultural research, extension services, irrigation equipment and biotechnology to improve domestic food production by ECOWAS countries. It is also assumed in this study that food requirements will be strongly influenced by the size of the region's population, which is growing by 3.5 per cent annually. Population growth may decline to levels seen in developed countries before the end of the century, however, making food requirement projections too large. Another limiting factor in the study is the fact that the structure of the model takes prices exogenously. Future model building efforts should be oriented towards endogenous price models that account for food supplies from outside the ECOWAS region. Future research in that area is needed, as is further research into available adaptation measures, including irrigation, biotechnology and other sustainable means to increase crop yields.

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The African Climate Policy Centre (ACPC) is a hub for demand-led knowledge on climate change in Africa. The center addresses the need for greatly improved climate information for Africa and strengthening the use of such information for decision making, by improving analytical capacity, knowledge management and dissemination activities.

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