# 5

# Impact of Climate Change on Trade in Africa

Pierre Mamboundou, Fousseini Traoré, and Chahir Zaki

## Introduction

The literature on the complex relationship between trade and climate change is rich. While trade can affect climate change through dirty production techniques or carbon emissions due to transport (Brenton and Chemutai 2021), climate change can affect trade through its effect on agricultural productivity (Ben Zaied and Cheikh 2015; Chandio et al. 2020), production, and thus countries' specialization (Gouel and Laborde 2021), primarily due to high temperatures and water stress (Hamududu and Ngoma 2020). As Africa is a net importer of agricultural products, the consequence is that climate change will likely affect food security in the medium and long term.

Against this background, the objective of this chapter is twofold. First, we examine the extent to which African countries are exposed to climate change relative to other regions of the world. Second, we show how Africa's comparative advantages can be altered with rising temperatures and water stress. Our main findings show that climate change effects in Africa are more pronounced than in other regions, reflected in the increase in extreme weather events associated with rising temperatures and greater variability in precipitation. These developments are likely to increase the number of food insecure people. Furthermore, we identify how climate change can affect African countries' specialization based on products' sensitivity to changes in temperature and their dependence on water. We show that several crops (such as leguminous vegetables, edible nuts and coconuts, groundnuts, oilseeds, and oleaginous fruits) will be affected by climate change. Other crops' production may be less affected, but their future expansion may be limited by climate change–related factors.

The remainder of the chapter is organized as follows. The following section examines Africa's exposure to climate change. We then analyze the continent's shifting comparative advantages caused by climate change and the associated impacts on trade flows, and we also identify which agricultural products are most sensitive to climate change. The final section offers conclusions.

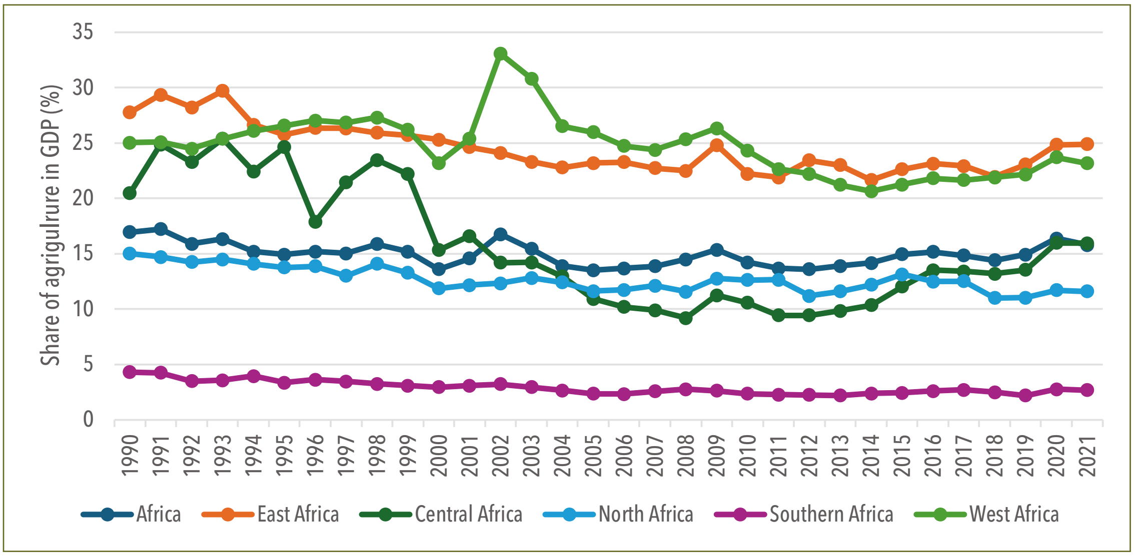
## Africa's Exposure to Climate Change

This section presents an overview of the effects of climate change and the consequences for African countries' agriculture sectors and the overall food system. It examines the structure and place occupied by the agriculture sector in the continent's economy to better understand the challenges imposed by climate change. The section concludes that intraregional trade could play a role in mitigating the effects of climate change on agriculture in Africa.

### The share and structure of agriculture in African countries' economies

On average over the period 1990 to 2021, agriculture contributed nearly 15 percent of Africa's GDP. However, this figure masks the varied contributions of individual regions (Figure 5.1). For example, agriculture contributes more than 25 percent of GDP in West and East Africa, 16 percent in Central Africa, and 13 percent in North Africa. Southern Africa has the lowest contribution, at around 3 percent (FAOSTAT 2023). Over the same period, the share of the agriculture sector in GDP in Africa fell by 1.15 percentage points, with the most significant declines in Central and North Africa (4.51 and 3.40 percentage points less, respectively). The concurrent rise in per capita income reflects the macroeconomic consequence of Engel's law (that is, the share of food expenditure in total consumption declines as income rises). At the same time, rapid urbanization has reduced both the land available for cultivation and the number of people employed in agriculture (Andrade et al. 2022; Djurfeldt 2015). In addition, the urbanization process makes employment in the agriculture sector less attractive than in other sectors (Christiaensen and Todo 2013; Ørtenblad, Birch-Thomsen, and Msese 2019), leading to a rural exodus. Cumulatively, these factors have an overall negative impact on agricultural production and rural development, although the economic structure of certain countries can counterbalance this dynamic.

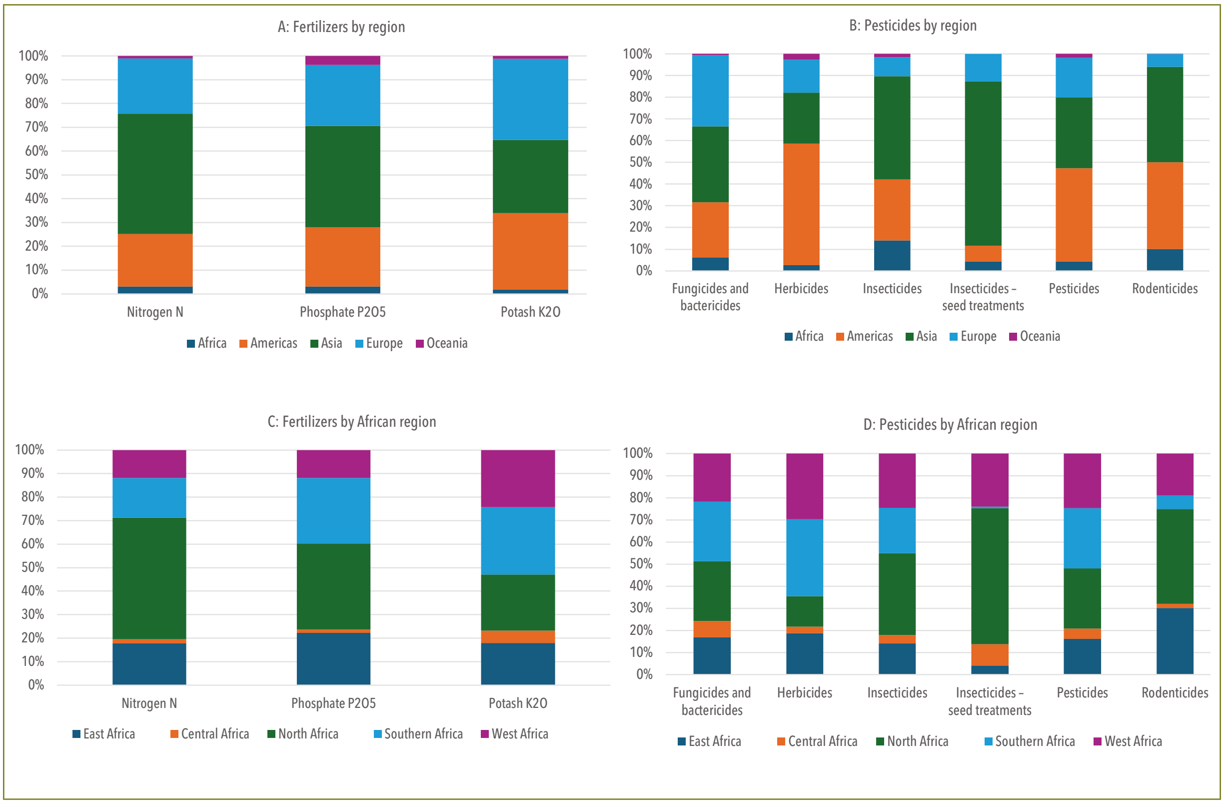
**Figure 5.1** Share of agriculture sector in GDP by region in Africa




**Source:** Authors' calculation from the FAOSTAT database, accessed in 2023.

Both extensive and intensive agriculture are practiced across Africa, although the former predominates (Abe-Inge et al. 2023; Asafu-Adjaye 2014; Jayne and Sanchez 2021). Extensive agriculture requires large areas of land for sufficient production and is primarily rainfed. This type of agriculture can contribute to deforestation, thus accelerating climate change (Zingore et al. 2015) and increasing the sector's vulnerability to climatic conditions (Asafu-Adjaye 2014; WMO 2020, 2022). At the continental level, the dominance of extensive agriculture results from poor control of available water caused by insufficient irrigation infrastructure, the lack of farm mechanization, and the resulting reliance on a large, mostly unskilled workforce on the one hand and the low use of soil fertilization on the other (Asafu-Adjaye 2014; Bjornlund et al. 2020). In fact, Svendsen, Ewing, and Msangi (2009); Rosegrant, Ringler, and De Jong (2009); and OECD and FAO (2016) note that less than 10 percent of agricultural land in sub-Saharan Africa is irrigated. The dependence on rainfall of the other 90 percent explains why agriculture remains a seasonal activity in most regions of the continent. Furthermore, over the period 1990 to 2021, the use of chemical fertilizers such as nitrogen, phosphate, and potash in African agricultural production comprised less than 5 percent of all global use (Figure 5.2). Likewise, the use of other chemical inputs (herbicides, insecticides, fungicides, and so on) in African agriculture represented less than 10 percent of all global use.

Figure 5.2 Use of fertilizers and pesticides in agriculture by world region and African region

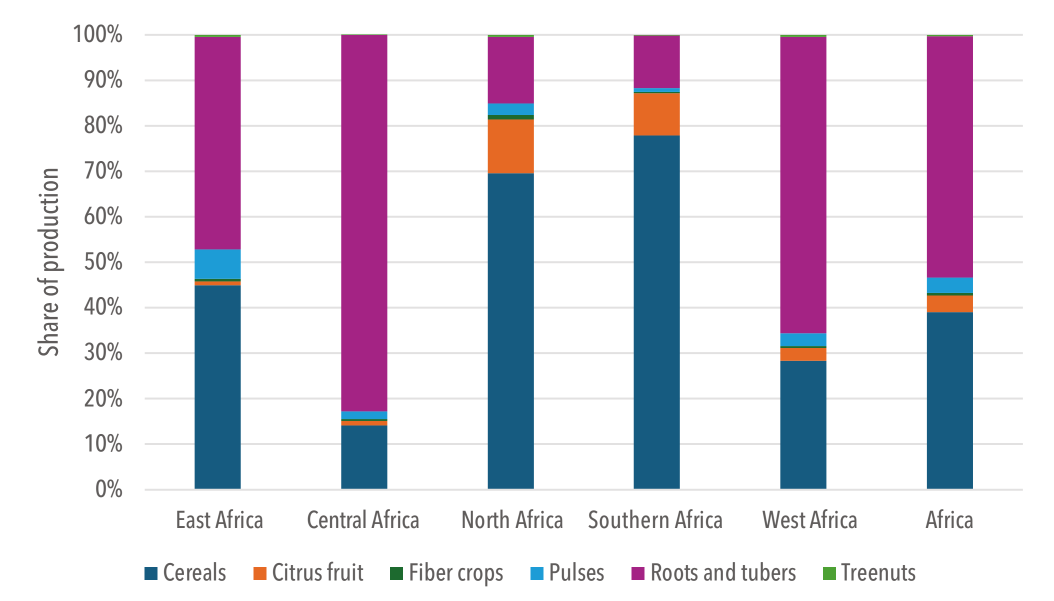



**Source:** Authors' calculations from the FAOSTAT database, accessed 2024.

On the continent, North, Southern, and West Africa use the most agricultural inputs, in terms of both pesticides and fertilizers. But overall, Africa's low use contributes to lower yields per hectare of crops than in other parts of the world. For example, over the period 1990 to 2021, cereal yields in Africa were 3.0 times lower than those recorded in the Americas, 2.5 times lower than in Asia and Europe, and 1.3 times lower than in Oceania. Yields of roots and tubers were one-half less in Africa than in the Americas, Asia, and Europe (FAOSTAT 2023).

Africa's overall low use of inputs and its relatively low yields have contributed to the persistence of undiversified agricultural systems, dominated by roots and tubers and cereals, which represent more than 80 percent of the continent's agricultural production (FAOSTAT 2023). The production of roots and tubers is dominant in Central, West, and East Africa (Figure 5.3). Conversely, cereal is mainly cultivated in Southern and North Africa, although cereals comprise nearly 45 percent of all crops in East Africa. The low yields and weak diversification of agricultural production by economic communities in Africa suggest that they are incapable of providing sufficient agricultural products to meet domestic needs, precluding them from contributing effectively to the goal of self-sufficiency in agricultural products.

**Figure 5.3** Average share of major crops in production (tons) by region in Africa, 1961–2022




**Source:** Authors' calculations from the FAOSTAT database, accessed 2023.

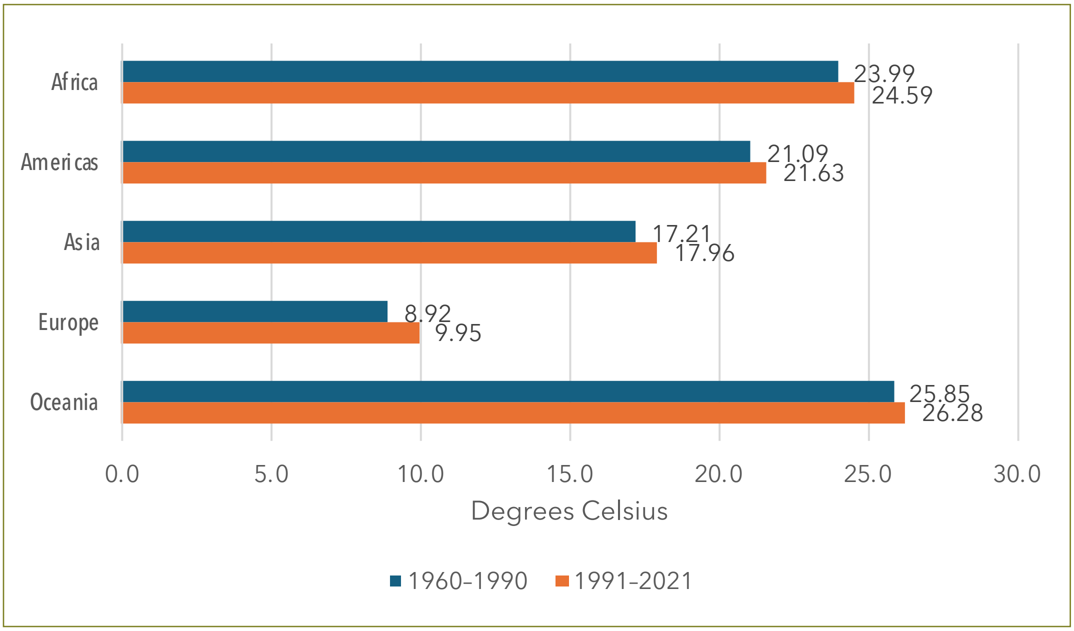
Low yield and low crop diversification can also be explained by the type of farms in Africa. African agriculture is mainly based on small family farms that grow food primarily for subsistence (Christiaensen and Demery 2018). In addition, these small farms are generally led by farmers with low levels of education and management skills, who do not use modern production tools (such as tractors and irrigation systems) due to their low income, and who face difficulty in accessing the financing necessary to innovate in their practices and improve their production (Christiaensen and Demery 2018; Mathinya et al. 2022). In addition, as subsistence farmers' socioeconomic conditions are generally difficult, their farms mainly produce agricultural goods intended for own consumption rather than for sale. These farms may also prioritize reduction of their costs by not hiring skilled workers (potentially more expensive) and by investing less in production infrastructure. Such choices contribute to reducing their productivity and slowing their diversification (Mwangi and Kariuki 2015).

Although agriculture is one of the main contributors to GDP in several African regions, where it accounts for more than 20 percent of GDP, the sector's contribution to wealth creation is declining, explained in part by farmers' lack of control over water, the low use of inputs, and the low productivity of agricultural capital (both human and physical). The same is true for agricultural employment, which is also decreasing. While the predominance of small farms limits employment opportunities, the development of medium and large farms, which favors more use of machines compared with labor, also contributes to reducing employment opportunities. Compounding the situation, climate change and rapid population growth are reducing the land available for agriculture (Jayne, Yeboah, and Henry 2017). The attractiveness of non-agriculture sectors, where incomes are generally higher, combined with urbanization have made agricultural employment less appealing, to the benefit of the industrial and service sectors that revolve around agriculture (Jayne et al. 2022). Faced with this already worrisome situation, vulnerability to climate change creates an uncertain future for the performance of the agriculture sector in Africa.

## Climate change in Africa

The increase in extreme natural phenomena such as heavy rains, floods, droughts, and heat waves is evidence of the effects of climate change in Africa (IPCC 2023; WMO 2022). These events, the result of increased greenhouse gas (GHG) emissions globally, particularly affect Africa, although Africa emits 7 times less GHGs than Europe and 15 times less than North America (IPCC 2023). Increasing GHG emissions are disrupting ecosystems worldwide, as illustrated by rising temperatures and ocean levels, acidification of oceans, and even reduced available arable land (due to desert advancement and declines in soil fertility and yields) (IPCC 2023). Over the period 1990 to 2021, all continents experienced a temperature rise of an average 0.3 degrees Celsius (°C) per decade (Figure 5.4) (WMO 2020, 2022). Africa is the second hottest continent after Oceania and ranks third in temperature variation (+0.62°C versus +0.98°C in Europa, +0.74°C in Asia, +0.53°C in America, and +0.40°C in Oceania).

**Figure 5.4** Average temperature (°C) in 1960–1990 and 1991–2021, by world region




**Source:** Authors' calculation from the University of East Anglia (UEA) database, accessed 2024.

Similarly, sea levels are rising along the tropical coasts of the South Atlantic and Indian Oceans at a rate higher than the global average (IPCC 2023; WMO 2022). At the same time, in 2022, the Horn of Africa recorded the most severe drought in 40 years, caused by a sharp drop in rainfall, while higher than normal rainfall was recorded in the Sahel, the Rift Valley, the central Nile catchment and northeast Africa, the Kalahari Basin, and the lower Congo River (UN 2022; WMO 2020, 2022). These events have led to significant negative consequences for natural resources and infrastructure on one hand, and for the labor productivity and well-being of populations on the other (IPCC 2023; WMO 2022).

Natural resources have been affected by climate change via a reduction in water resources and crop areas and by the disappearance of some species (AGRA 2020; Berrang-Ford, Pearce, and Ford 2015; Hultgren et al. 2022; IPCC 2023). For example, in 2020, above-average rainfall in Zambia destroyed more than 700 hectares of crops in Namwala district alone (a southern province of the country). The same year in Niger, nearly 10,000 hectares of crops were submerged under water.

In addition, grazing land for animals was reduced. Climate change–related extreme events also contribute to the destruction of infrastructure (roads, bridges) essential for the smooth running of economic and social activities (IPCC 2023; von Braun et al. 2023). The collapse of the Corniche Monument in the Republic of Congo and the Palar Bridge in Cameroon (Maroua), as well as the destruction of infrastructure in Algeria, Madagascar, Mauritius, and Morocco, are perfect illustrations. The increased public spending linked to the construction, maintenance, and repair of these buildings reduces the resources that can be allocated to other development objectives (IPCC 2023).

Another effect of climate change, although less studied, is on labor productivity (De Lima et al. 2021; Haqiqi et al. 2020). On this point, sub-Saharan Africa is particularly vulnerable. Indeed, with heat stress, the ability to carry out outdoor activities such as agricultural and livestock work will be reduced. As a result, the amount of agricultural labor could fall, leading to a drop in labor productivity in this labor-intensive sector (Matsumoto, Tachiiri, and Su 2021). Likewise, animals used for agricultural work can be affected by heat stress, which can promote animal weight loss and reduce their fertility, negatively affecting their productivity in the medium to long term (Thornton et al. 2022). In a region where the agriculture sector is mainly traditional, and where agricultural employment represents 58 percent of jobs in West and Central Africa, 22 percent in North Africa and the Middle East, and 19 percent in Southern Africa, this situation will have a direct negative impact on food availability and access to food. This perspective, combined with rising food prices and the proliferation of infectious diseases, will lead to significant welfare losses, characterized by an increase in displacement of populations and cases of malnutrition (FAO 2017; FAO and WFP 2020; Kinda and Badolo 2019; von Braun et al. 2023). For instance, more than 1 million Somalis were displaced within the country because of the 2022 drought, the decline in their means of subsistence, and the famine that ensued. In Ethiopia, more than 500,000 internally displaced people were recorded in 2022 because of drought (IPCC 2023). These situations lead to an increase in the vulnerability of populations in general and of poor populations in particular (von Braun et al. 2023).

Climate change in Africa is reflected in the increase in both frequency and intensity of extreme weather phenomena and the acceleration of the disruption of ecosystems due to rising temperatures and greater rainfall variability. Climate change lowers the productivity of production factors (reducing the quality and quantity of production, due to new plant and animal diseases), reduces livestock yields, and increases the arduousness of agricultural activity (Ceci et al. 2021; Singh et al. 2023), directly impacting the resources needed to ensure livelihoods. The result is an increased vulnerability of populations more exposed to food insecurity and/or poor nutrition.

## Climate change and agriculture in Africa

Climate change is a complex phenomenon that can constitute a threat to agricultural practices in certain areas but can be an opportunity in other areas in Africa (Jarvis, Lane, and Hijmans 2008; Jarvis et al. 2012; Loum and Fogarassy 2015; Pereira 2017). On a continent where agricultural activity is dominated by extensive agriculture, soil degradation (through a decline in organic matter), irregular precipitation, rising temperatures, scarce water resources, and even the increased frequency of extreme climatic events all have negative impacts on agricultural development (Chandio et al. 2020; Craparo et al. 2015; IPCC 2014, 2023). Through the reduction in area dedicated to agricultural activities, the proliferation of new plant diseases, and the drop in yields of several crops, climate change has already contributed to a decline in the production of many agricultural goods and in the sector's contribution to GDP, as seen above (Bongase 2017; Hossain et al. 2021; Killeen and Harper 2016; Rowhani et al.

2011). Certain studies estimate that 40 to 80 percent of cultivated areas are degraded, which represents losses of 30 to 60 kilograms of nutrients per hectare per year and damage of several billion dollars (IPCC 2023; Kala, Kurukulasuriya, and Mendelsohn 2012).

Arid and semi-arid zones such as the Sahel are more affected by climate change, as only 3 to 30 percent of land in these zones is not yet degraded (AGNES 2020). For instance, increased soil degradation and temperatures and reduced rainfall have led to a drop in agricultural production of 3 percent per year since 1990 in the Sahel (Doukkali, Tharcisse, and Tudal 2018). In Senegal specifically, erosion and salinization have degraded more than 60 percent of arable land (AGNES 2020). Nigeria records losses of 30 million tons of topsoil per year, while Ethiopia loses almost 1 billion tons of topsoil per year (AGNES 2020). In Tanzania, increased intraseasonal rainfall variability—which corresponds to the length of the break between two rain cycles in a year—has reduced maize, sorghum, and rice yields by 4.2 percent, 7.2 percent, and 7.6 percent, respectively (Rowhani et al. 2011). On a continental scale, Rowhani et al. (2011) forecast a drop in agricultural yields of 8 percent by 2050, with a reduction of 17 percent for wheat, 15 percent for sorghum, 10 percent for millet, and 5 percent for corn. This dynamic could lead to the loss of more than one-half of the cultivated agricultural area in Africa by 2050 (IFAD 2021).

This trend will have two effects: (1) it will induce a drop in people's income, increasing their financial precariousness (Adhikari, Nejadhashemi, and Woznicki 2015; Baarsch et al. 2020; IFAD 2021); and (2) it will reduce food security in terms of food availability, access to food, and the nutritional quality of food (Ebi and Ziska 2018; FAO, IFAD, UNICEF, and WHO 2020; Mihret Dessie and Shumetie Ademe 2017; Teressa 2021). Indeed, most African populations are dependent on agricultural activities, which employ up to almost 60 percent of the workforce in certain regions (OECD and FAO 2021; Tongwane and Moeletsi 2018). Therefore, the irregularity of production due to climate change will reduce the quantities sold and consequently the income generated from agricultural activities (IPCC 2007; OECD and FAO 2021). In addition, the associated scarcity in the supply of agricultural and food products could have a consequence for their prices (Haggar and Schepp 2011; Herrero et al. 2010; Stuch, Alcamo, and Schaldach 2021). Likewise, rising temperatures and irregular rainfall have a negative impact on the nutrient supply of certain foods because they prevent the proper development of plants (Bhadra et al. 2022). A decline in the nutritional quality of agricultural products will be noticed. The combination of these different effects will increase food poverty and insecurity.

The overall negative effects of climate change on agriculture can be nuanced. In some regions, climate change may improve climate conditions and consequently the yield of some crops such as coffee, wheat, and maize (Affoh et al. 2022; Ovalle-Rivera et al. 2015). In such cases, farmers may increase their production and may benefit from an increase in prices if production has fallen substantially in other areas.

The ambiguous effects of climate change on agriculture, characterized by negative effects in some areas of the continent and positive effects in others, raises the priority of intraregional or intracontinental trade as a mitigation option. Indeed, if the volatility of domestic production is greater than the regional or continental trend in an economic community affected by a shock, an increase in intraregional and intracontinental trade should help stabilize the supply (availability) of agricultural products and consequently their prices (Badiane, Odjo, and Jemaneh 2014; Koester 1986; Kpodar and Imam 2016). To test this, we extend the previous work of Badiane, Odjo, and Jemaneh (2014) and build and analyze a production instability index. The index is based on the coefficient of variation of the quantities produced of an agricultural product in a country's production series, adjusted by the coefficient of determination of the linear trend model adapted to the series:

$$TCV_i = CV_i * \sqrt{1 - R_i^2} \qquad (1)$$

where $CV_i$ is the coefficient of variation in the series of a country's production quantities of the commodity of interest; $R_i^2$ is the adjusted coefficient of determination of the linear trend model fitted to the series; and $TCV_i$ is the trend-corrected coefficient of variation in country production quantities.

We obtained a trend-corrected coefficient of variation for each country. Next, we derive the regional production instability index by taking a pseudo weighted average of the national index values obtained previously for countries of the same region:

$$TCV_{reg}^2 = \sum_{i}^{n} s_i^2 \cdot TCV_i^2 + 2\sum_{i<}^{n}\sum_{j}^{n} s_i \cdot s_j \cdot r_{ij} \cdot TCV_i \cdot TCV_j \qquad (2)$$

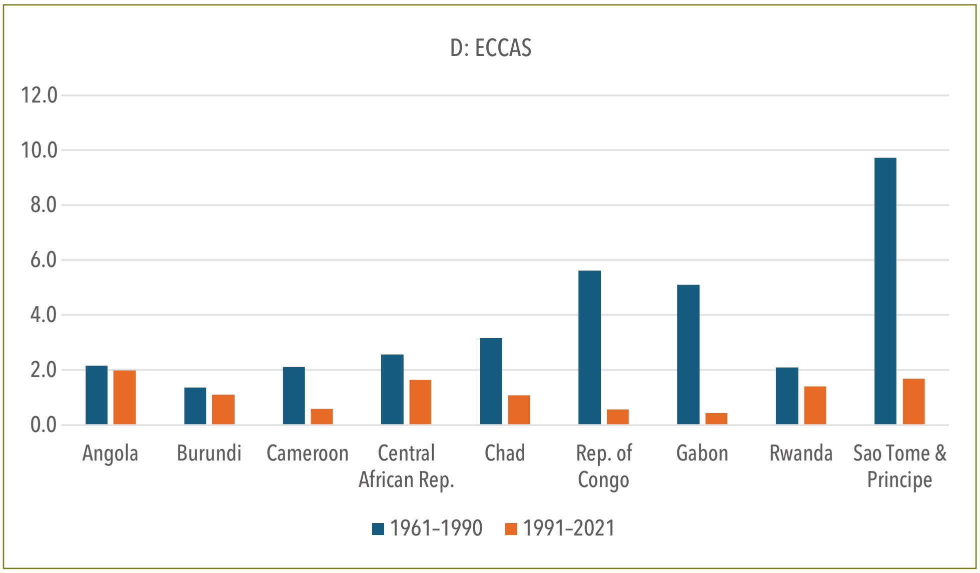
where *n* is the number of member countries in the regional grouping of interest; $S_i[S_j]$ is the share of a country in the region's overall production of the commodity under analysis; and $r_{ij}$ is the coefficient of correlation between the series of production quantities in countries *i* and *j*.

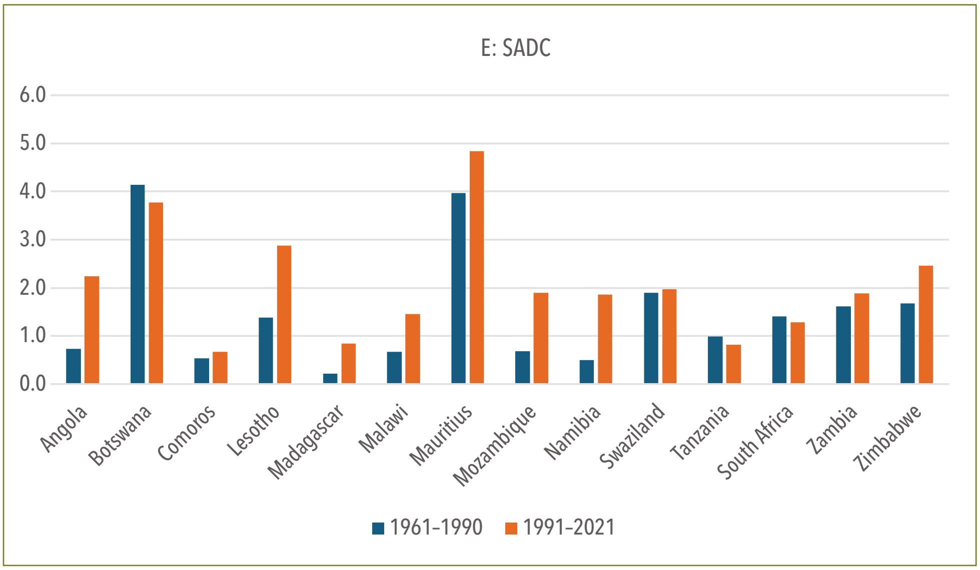
Finally, we normalized the measure of production instability at the country level by dividing it by the measure of instability at the regional level:

$$Normalized\ TCV_i = {TCV_i}\Big/{\sqrt{TCV_{reg}^2}} \qquad (3)$$

As an illustration, we applied the index to data for the dominant crops on the continent, namely roots and tubers and cereals. We selected the period 1961 to 2021, for which data are available. Practically, we divided the period into two subperiods to see how national volatility evolves compared with regional volatility under the effect of climate change. Thus, as Figure 5.5 shows, cereal production instability in Libya and Mauritania in the Arab Maghreb Union (AMU)—with a normalized index higher than 1.0—was higher than the regional dynamics over the period 1961 to 1990, and lower from 1991 to 2021. In the Common Market for Eastern and Southern Africa (COMESA), instability deteriorated in Djibouti between the two periods, while in Egypt and the Comoros, it remained below the regional average. In this regional economic community (REC), Madagascar is the only country where cereal production instability improved between the two subperiods. In the Economic Community of Central African States (ECCAS), the normalized index of all member countries was higher than the regional average over the period 1961 to 1990. Over the second subperiod, instability fell significantly below the regional average in Cameroon, Republic of Congo, and Gabon. In the Economic Community of West African States (ECOWAS), cereal production instability increased between the two subperiods in most countries, except for a few coastal countries, including Benin, Guinea, Guinea Bissau, Nigeria, and Togo, where it remained below the regional average. Finally, in the Southern African Development Community (SADC), only the Comoros, Madagascar, and Tanzania had indexes below the regional average.

**Figure 5.5** Cereal production instability by REC, 1961–2021, normalized coefficient of variation



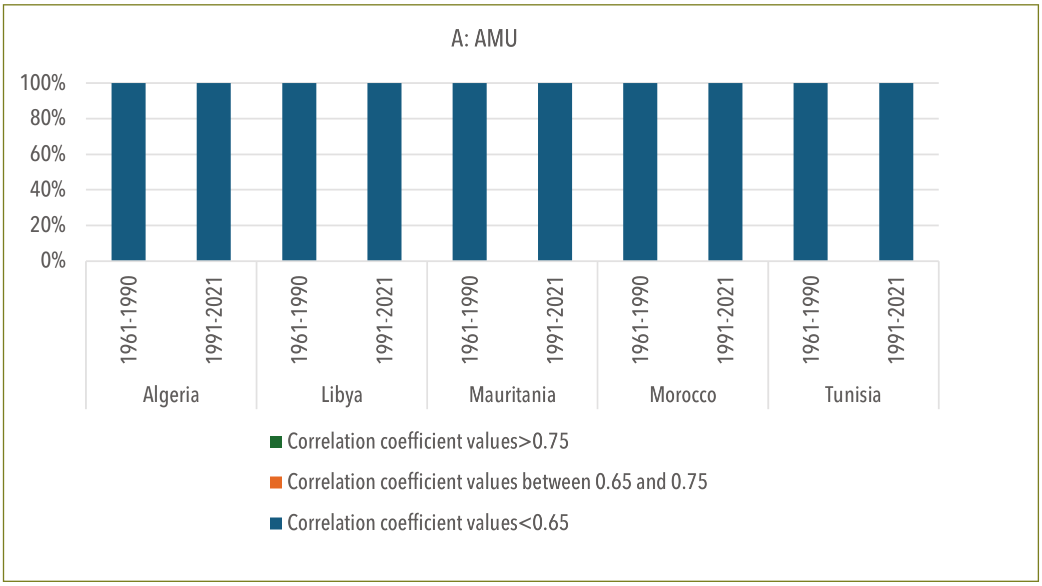

**Source:** Authors' calculations from the FAOSTAT database.

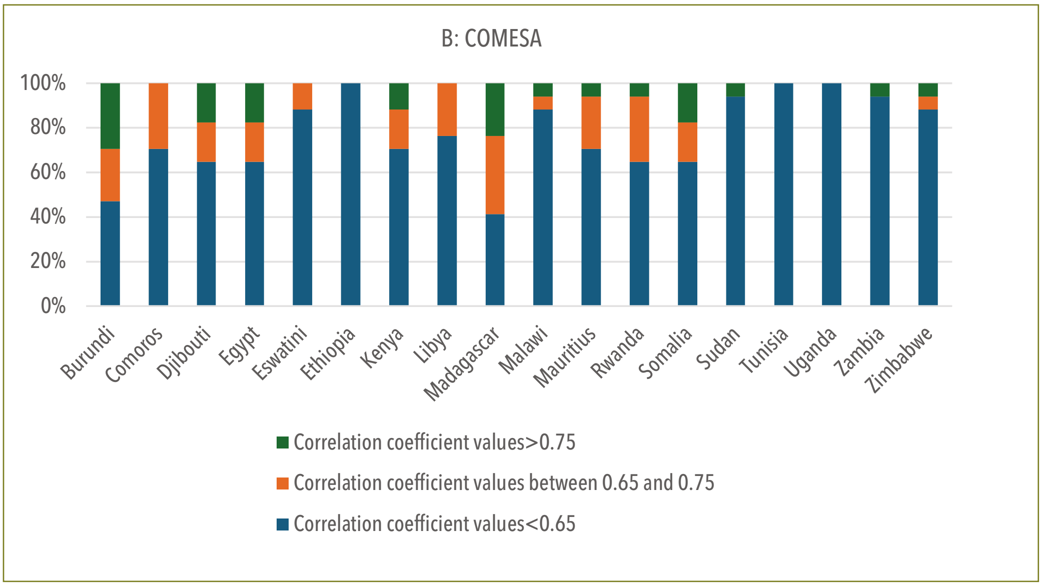
Analysis of the volatility of cereal production by REC shows that the national index in most countries is greater than 1, which reflects a national volatility higher than the regional trend. To analyze the distribution of fluctuations in cereal production, obtained by calculating for each product the values of the Pearson correlation coefficient between a country's production quantities and those of each of its neighbors in the REC, we defined three thresholds:

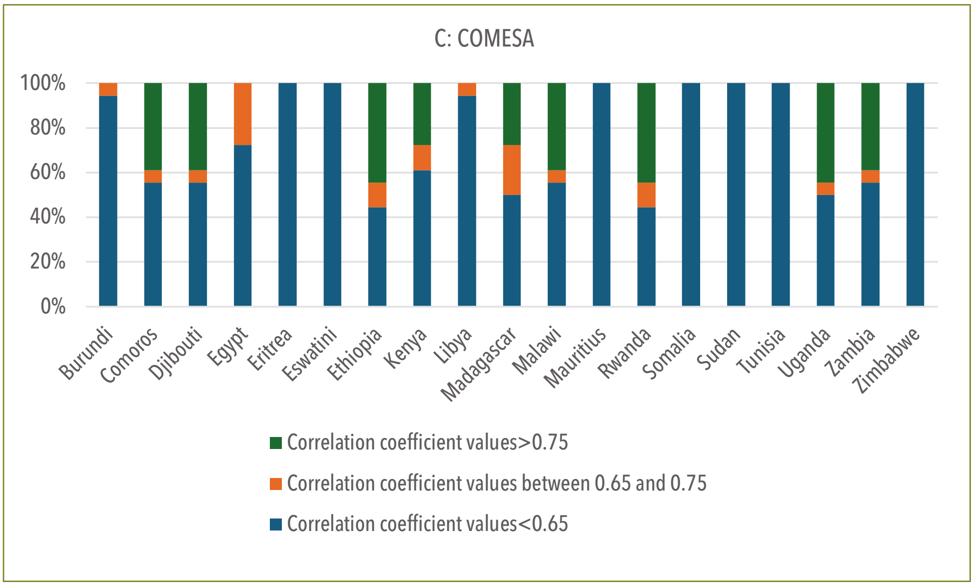
- When the correlation coefficient is less than 0.65, a country's production is weakly correlated.
- When the correlation coefficient is 0.65 to 0.75, a country's production is moderately correlated (Badiane, Odjo, and Jemaneh 2014).
- When the correlation coefficient is greater than 0.75, a country's production appears to be strongly correlated.

Based on these calculations, within the RECs, most countries have weakly correlated production fluctuations (Figure 5.6).

**Figure 5.6** Distribution of correlation coefficients between each country's production of cereal and that of its neighbors

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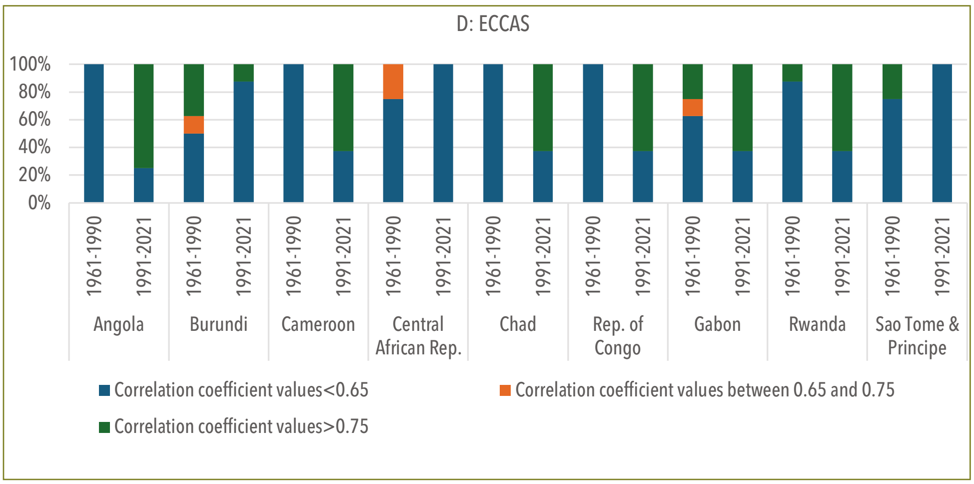
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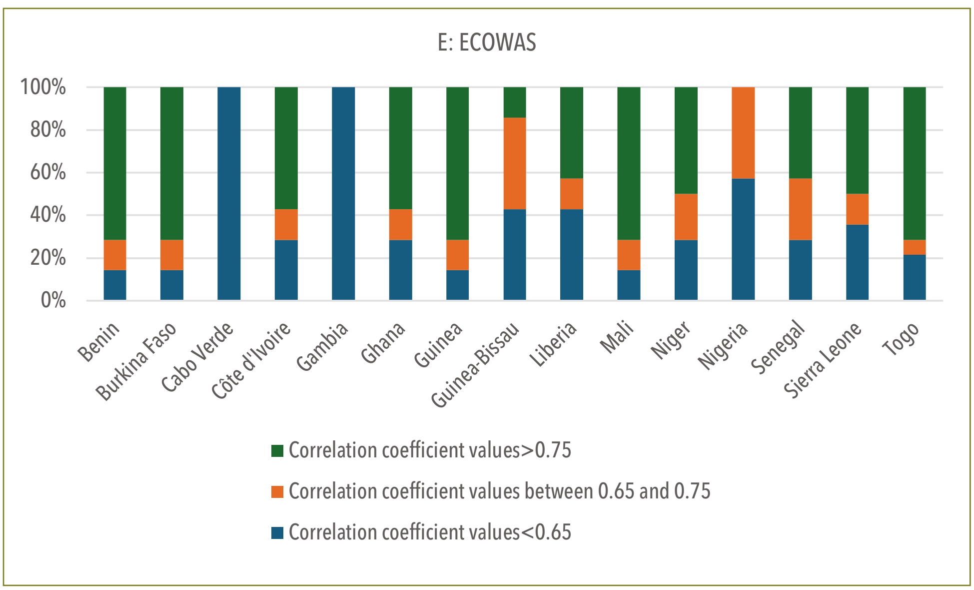
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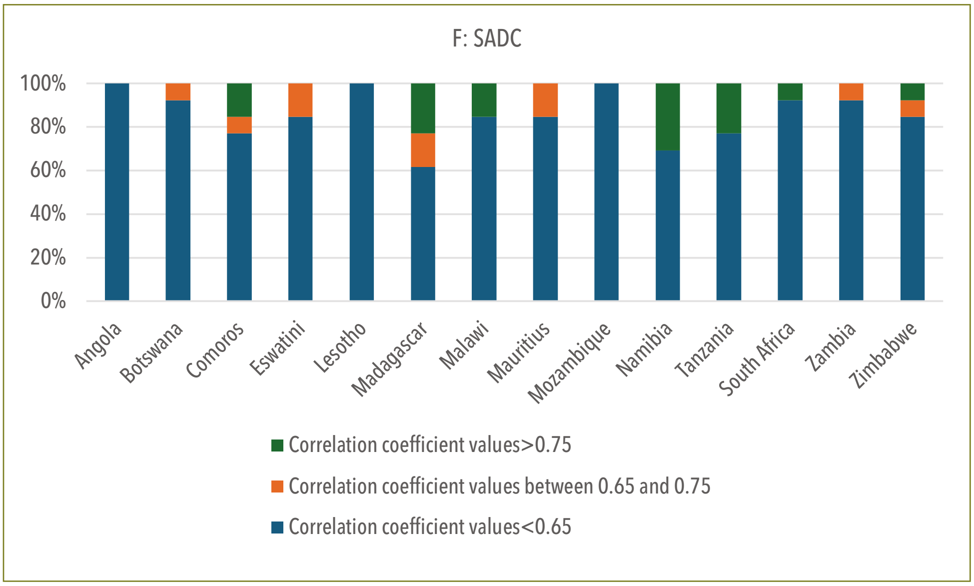
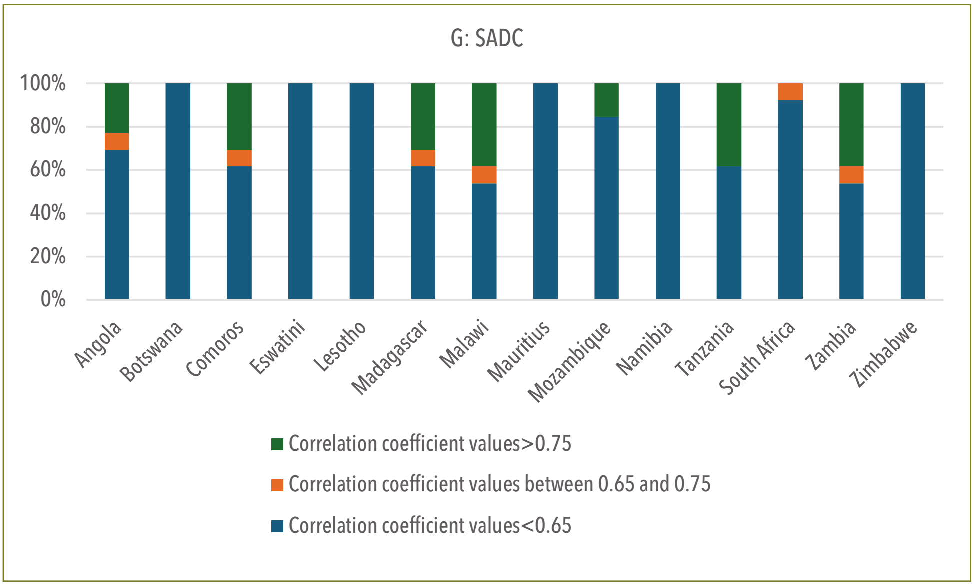


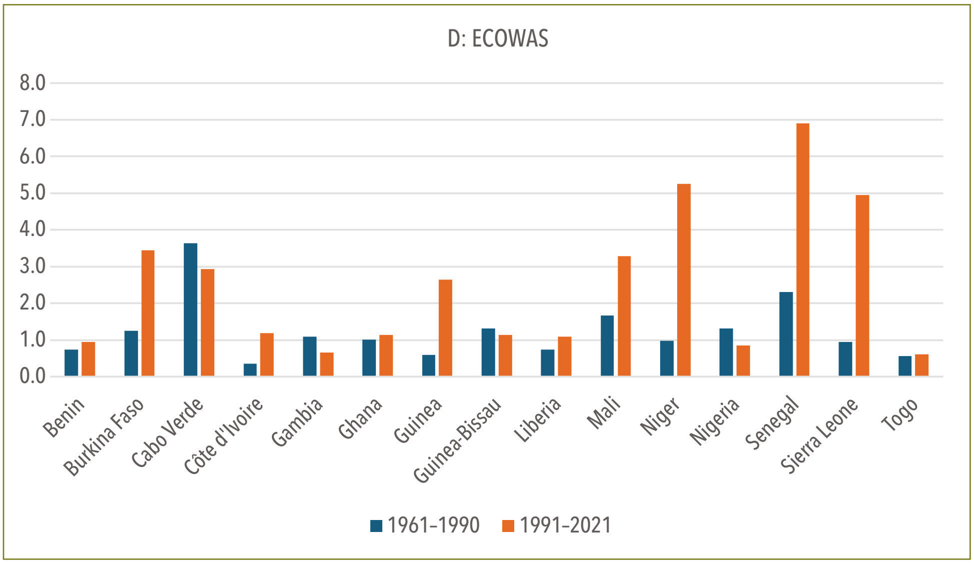



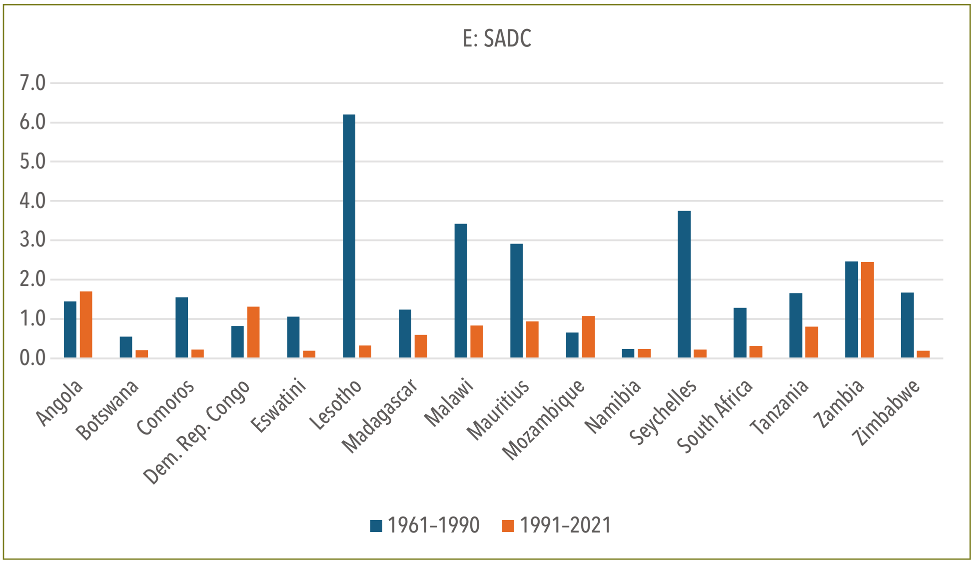

**Source:** Authors' elaboration.

Thus, the development of cereal trade at both the regional and continental level can stabilize product availability. That is, development of intraregional and/or intracontinental trade can alleviate shortages and stabilize prices.

A similar analysis for roots and tubers reveals a trend different from that of cereals. Apart from ECOWAS, in which the level of the national index compared with the regional trend improved between the two subperiods, the other RECs experienced the opposite (Figure 5.7).

**Figure 5.7** Roots and tubers production instability by REC, 1961–2021 normalized coefficient of variation

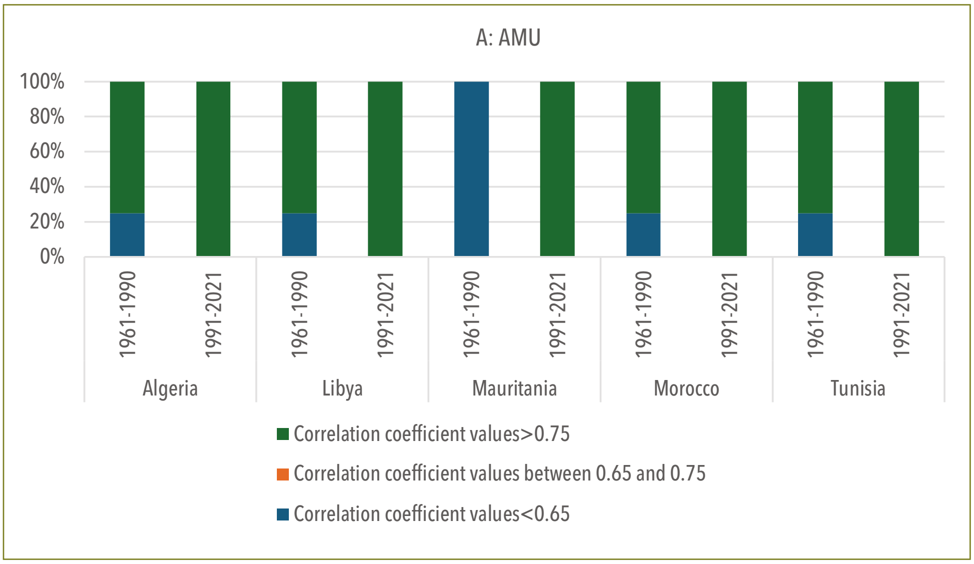


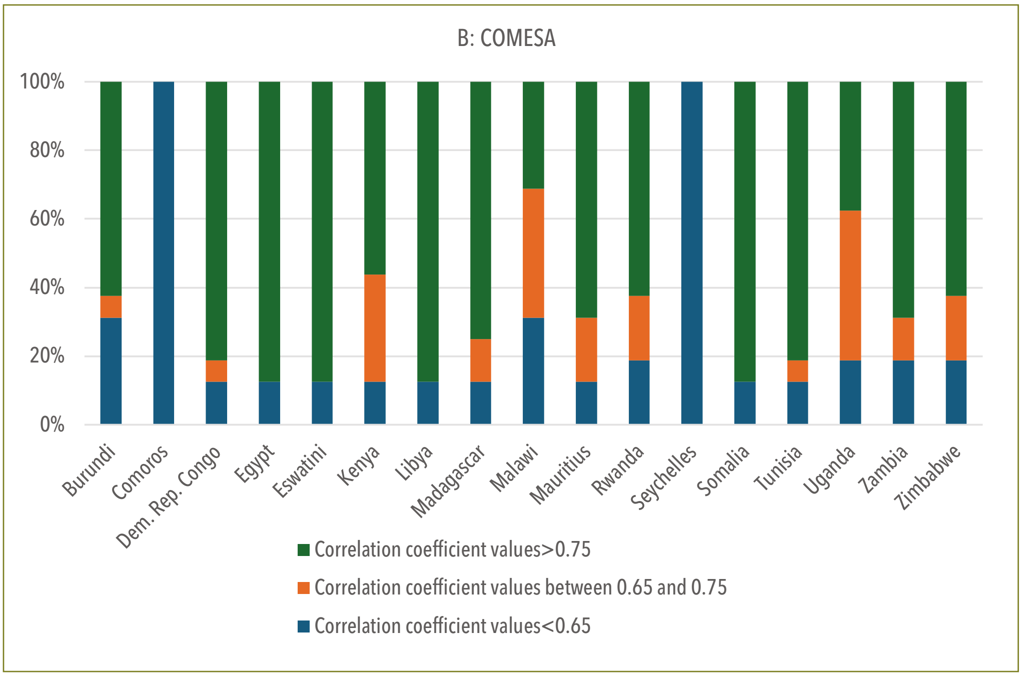



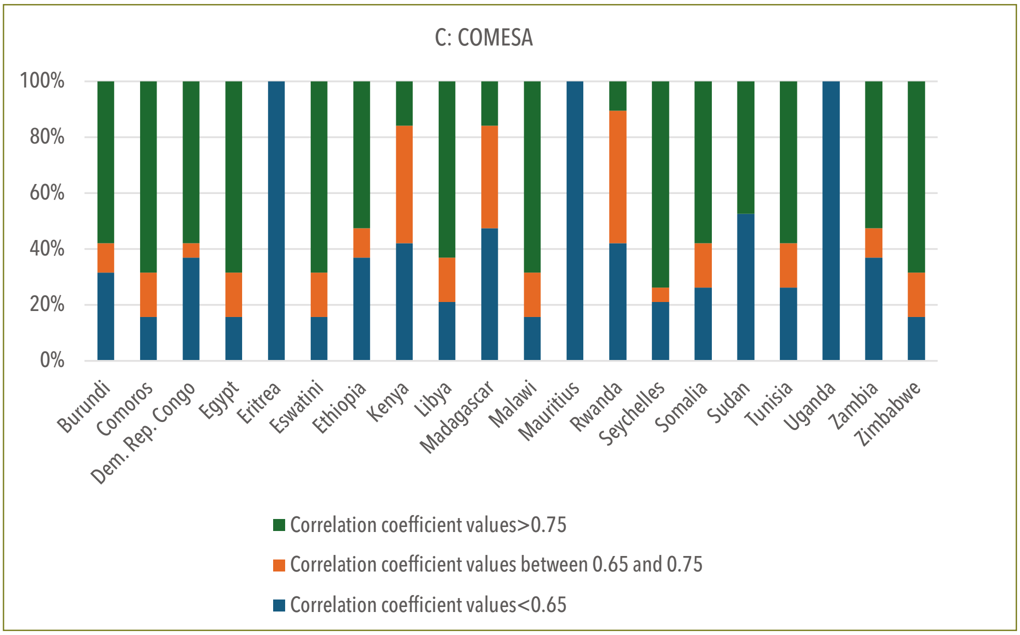

**Source:** Authors' calculation from the FAOSTAT database.

In addition, the production fluctuations in roots and tubers are mainly strongly correlated within RECs for both subperiods (Figure 5.8).

**Figure 5.8** Distribution of correlation coefficients between each country's production of roots and tubers and that of its neighbors

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Mauritius
Rwanda
Seychelles
Somalia
Sudan
Tunisia
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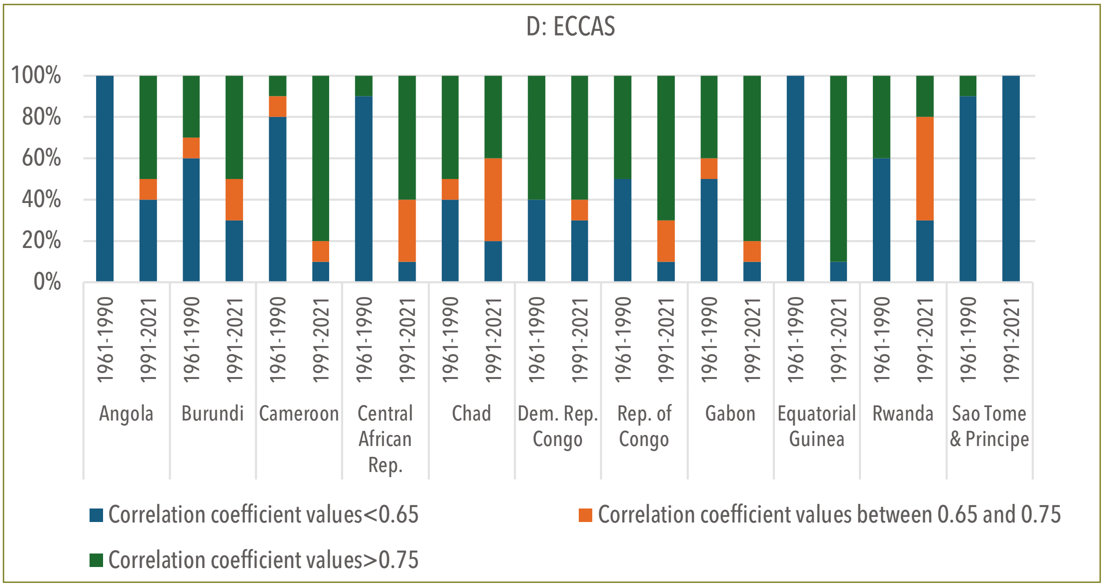
Zimbabwe
Correlation coefficient values>0.75
Correlation coefficient values between 0.65 and 0.75
Correlation coefficient values<0.65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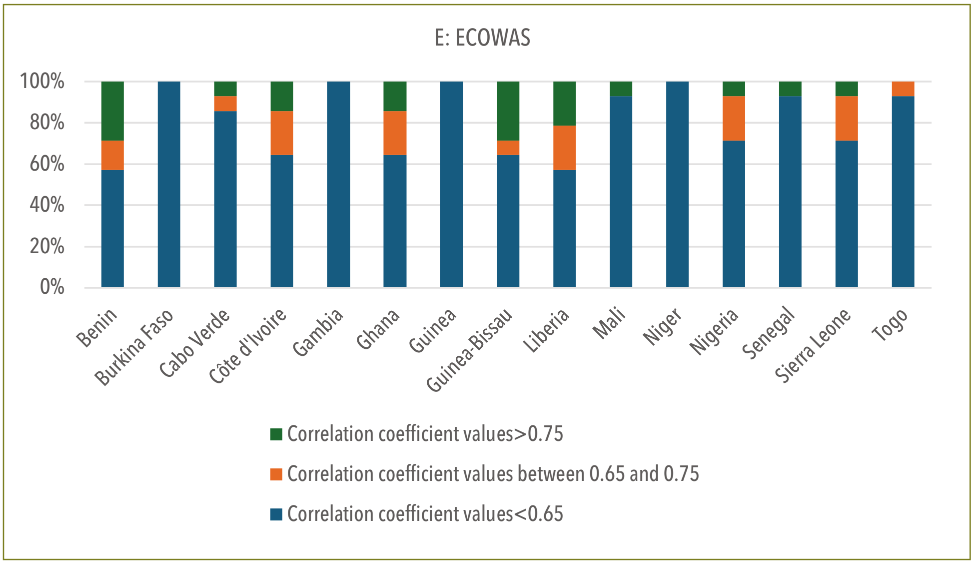
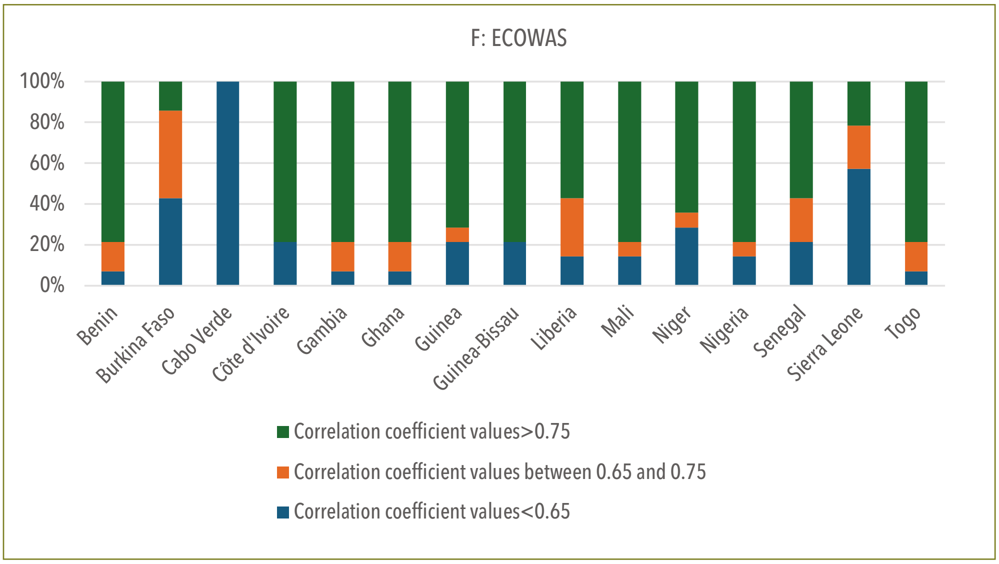
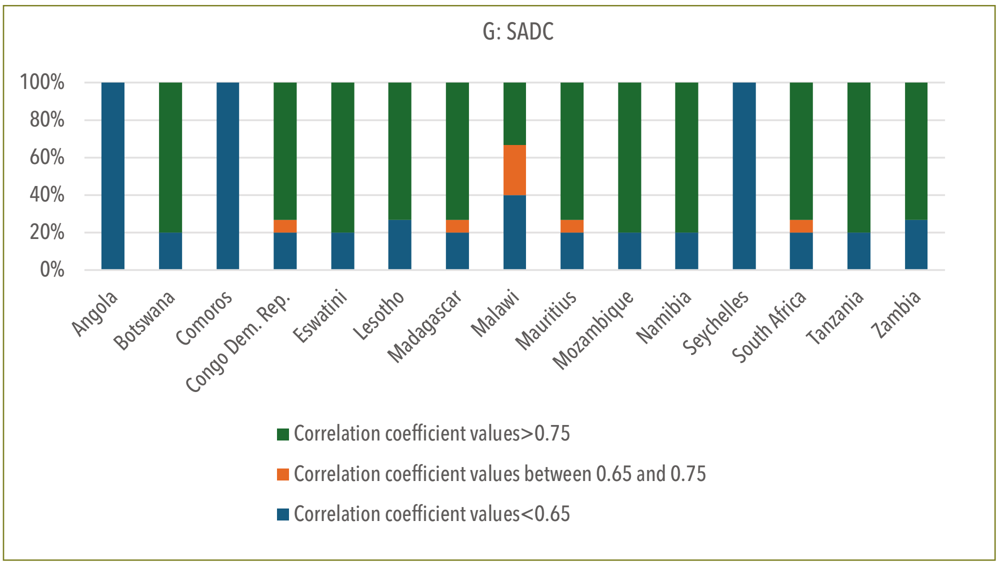
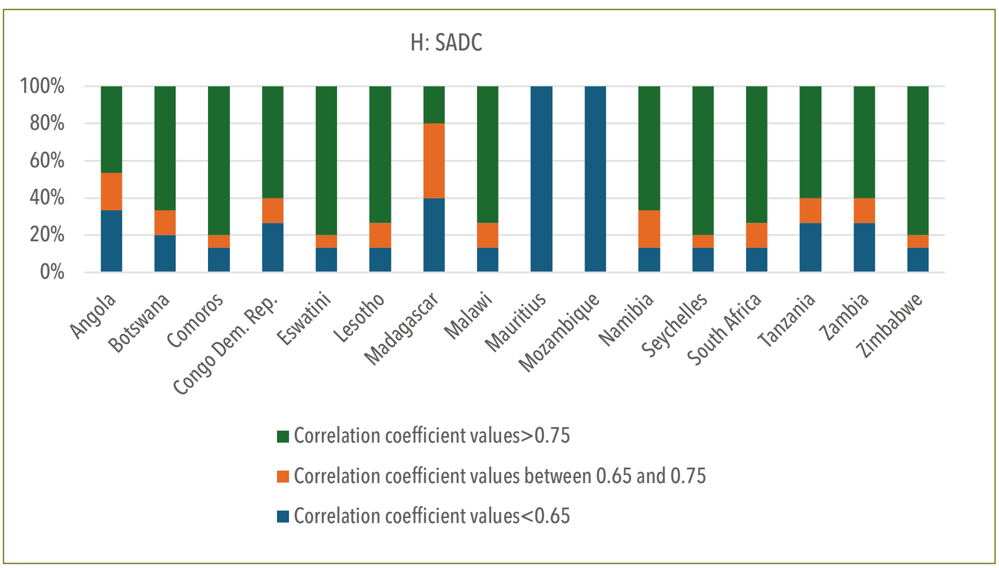
Cameroon
Central African Rep.
Chad
Dem. Rep. Congo
Rep. of Congo
Gabon
Equatorial Guinea
Rwanda
Sao Tome & Principe
Correlation coefficient values<0.65
Correlation coefficient values between 0.65 and 0.75
Correlation coefficient values>0.75


E: ECOWAS
100%
80%
60%
40%
20%
0%
Benin
Burkina Faso
Cabo Verde
Côte d'Ivoire
Gambia
Ghana
Guinea
Guinea-Bissau
Liberia
Mali
Niger
Nigeria
Senegal
Sierra Leone
Togo
Correlation coefficient values>0.75
Correlation coefficient values between 0.65 and 0.75
Correlation coefficient values<0.65




**Source:** Authors' calculation from the FAOSTAT database.

This unfavorable pattern in each REC means that an increase in intraregional or intracontinental trade would not fill national deficits. Thus, neither regional nor continental trade can stabilize supplies, nor can they mitigate price variations.

## Climate Change and Trade in Africa: What Is the Evidence?

### Shifting comparative advantages and trade flows

Climate change will significantly impact trade flows due to shifting comparative advantages associated with rising temperatures, variations in precipitation, and plant pests and diseases. As highlighted above, one of the main findings of the literature is that both within- and cross-country comparative advantages will be affected due to the heterogeneity of climate change impacts. Since the late 1990s, several studies have looked at the potential impact of climate change on trade flows, mainly using two methodological approaches: simulation and econometric models. We focus here on six studies that use these methods.

In a seminal study, Ringler et al. (2010) assess the impact of climate change on yields and trade flows of African countries by 2050 using a model disaggregated by agroecological zones (Gulf of Guinea, Sudano-Sahelian, Southern, Eastern, and Central). Given the heterogeneous impact on yields (positive versus negative changes), little change occurs in net cereal imports for sub-Saharan Africa. Indeed, increases in net cereal imports in some areas balance out decreases in other regions. Across agroecological zones, Eastern Africa will experience the largest increase in net cereal imports (+15 percent) due to large negative changes in maize yields, while the Soudano-Sahelian zone will experience a 6 percent decline in net cereal imports due mainly to positive changes in yields. No significant changes were found for the other zones.

In the wake of the work by Costinot, Donaldson, and Smith (2016), studies by Gouel (2022) and Gouel and Laborde (2021) look at the impact of climate change in agriculture and the role of trade in the adaptation process, respectively. While Gouel and Laborde (2021) focus on the role of trade and find that export shares for maize, wheat, and rice will decrease for Africa by 2080 due to declining yields, Gouel (2022) goes further and provides more details, using a model that includes seven individual African countries and the rest of sub-Saharan Africa as a group, and considers 35 products. The results show, on average, a negative impact of climate change for Africa by 2080. Net agricultural trade (net exports as a proportion of agricultural production) deteriorates in most countries (ranging from −67 percent for Egypt to −9 percent for Nigeria) except South Africa, Kenya, and Ethiopia, where it improves by 1.42 percent, 0.70 percent, and 4.85 percent, respectively. Table 5.1 presents the changes in exports and imports of crops by country/region. As previously noted, only Ethiopia, Kenya, and South Africa register a positive impact; the remaining parts of the continent see a fall in their exports and an increase in their imports.

**Table 5.1 Climate change impact on exports and imports in Africa (change in %)**

| Country/region | Exports | Imports |
|---|---|---|
| Egypt | −34.20 | 5.27 |
| Morocco | −97.24 | 11.29 |
| Nigeria | −90.05 | 8.86 |
| Senegal | −92.42 | 15.32 |
| Ethiopia | 112.49 | 9.79 |
| Kenya | 21.40 | 0.54 |
| South Africa | 4.46 | 0.12 |
| Rest of Sub-Saharan Africa | −59.49 | 7.14 |

**Source:** Authors' computation based on Gouel (2022).

The third study based on a simulation model was conducted by UNU-UNECA (2017) and focused on ECOWAS. Four crop systems are considered in the trade module: paddy rice, cereals, vegetables and fruits, and oilseeds. The simulations run up to 2100 are based on different shared socioeconomic pathways (SSPs).[1] Depending on the SSP considered, total intraregional trade may stagnate (SSP3 for rice; SSP2 for fruits and vegetables; SSP4 for oilseeds) or decline (SSP3 and SSP4 for cereals; SSP4 for fruits and vegetables), with significant cross-country heterogeneity. Overall, no clear trend appears: specific countries are likely to become net food exporters in some years and net importers in others. Extra-ECOWAS imports of rice will either increase or stagnate depending on the country: the highest increases are in Côte d'Ivoire (806 percent in 2040), Ghana (710 percent in 2020), and Benin (643 percent in 2045).

In addition to simulation-based studies, two pieces of research rely on econometric (ex post) evaluations. The first study, by Barua and Valenzuela (2018), assesses the impact of high temperature and precipitation on agricultural exports of low- and middle-income countries from 1962 to 2014 on six product groups (grains, oilseeds, fruits and vegetables, tropical crops, livestock, and dairy and eggs). The results suggest that at the global level, a 1°C increase in temperature yields a 1.6 percent drop in agricultural exports. Curiously, no effect is found for precipitation. One can wonder if the absence of effect for precipitation is due to either an omitted nonlinear trend or the inclusion of the dispersion of the variable instead of its level. In Africa, a 1°C increase in temperature yields a 14 percent fall in agricultural exports, the highest impact found, and nine times the world average.

The second econometric study, by Jones and Olken (2010), also assesses the impact of high temperature and precipitation on exports of developing countries. The findings suggest that a 1°C increase reduces the growth of poor countries' exports by 2.4 percentage points. For the subsample of exports to the United States, dairy products and eggs (−12.35 percentage points) and cereals and preparations (−12.24 percentage points) are the most impacted agricultural products. Finally, here too, no significant impact of precipitation is found.

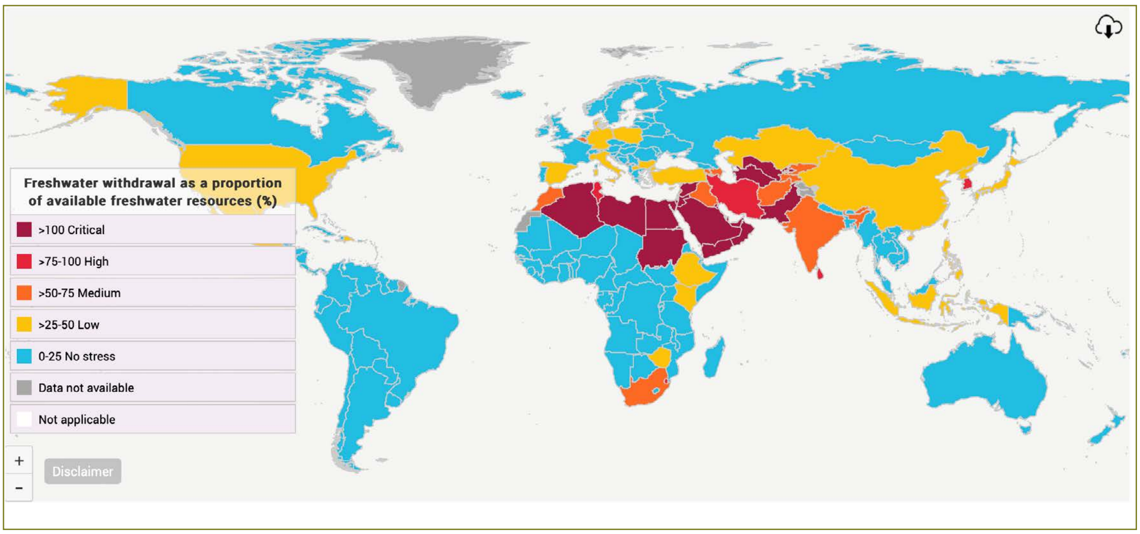
1 SSP1 refers to a world where state actors are dominant and strong institutions exist; in SSP2 the focus is on long-term priorities with a rigorous transition to sustainable development; SSP3 represents a case where nonstate actors are fully developed; SSP4 corresponds to a state of the world where nonstate actors are dominant and institutions and governance in the public sector are weak.

## A typology of products' sensitivity to climate change and their comparative advantages

To assess the sensitivity of different agricultural products to climate, we rely on two main criteria: products' water content and their sensitivity to temperature. We also examine the link between these two variables and the comparative advantage of African countries in order to identify how the countries' comparative advantage might be affected by climate change.

To identify whether products are sensitive to water, we classify them into two categories: those for which the water content is greater than the median of the specific water demand[2] (high water sensitivity) and those for which it is below the median (low water sensitivity). Water content is defined as the specific water demand for each commodity group (in cubic meters per ton), a parameter used to compute the data analyzed in Chapter 3 of this report. This index is of particular importance, given that several African countries (especially in North Africa) are characterized by a high level of water stress (Figure 5.9). In addition, sub-Saharan Africa has a low level of water productivity (measured by GDP per cubic meter of total freshwater withdrawal) relative to other developing regions, such as Latin America and East Asia and the Pacific, and a low level of renewable freshwater resources per capita (Figure 5.10).

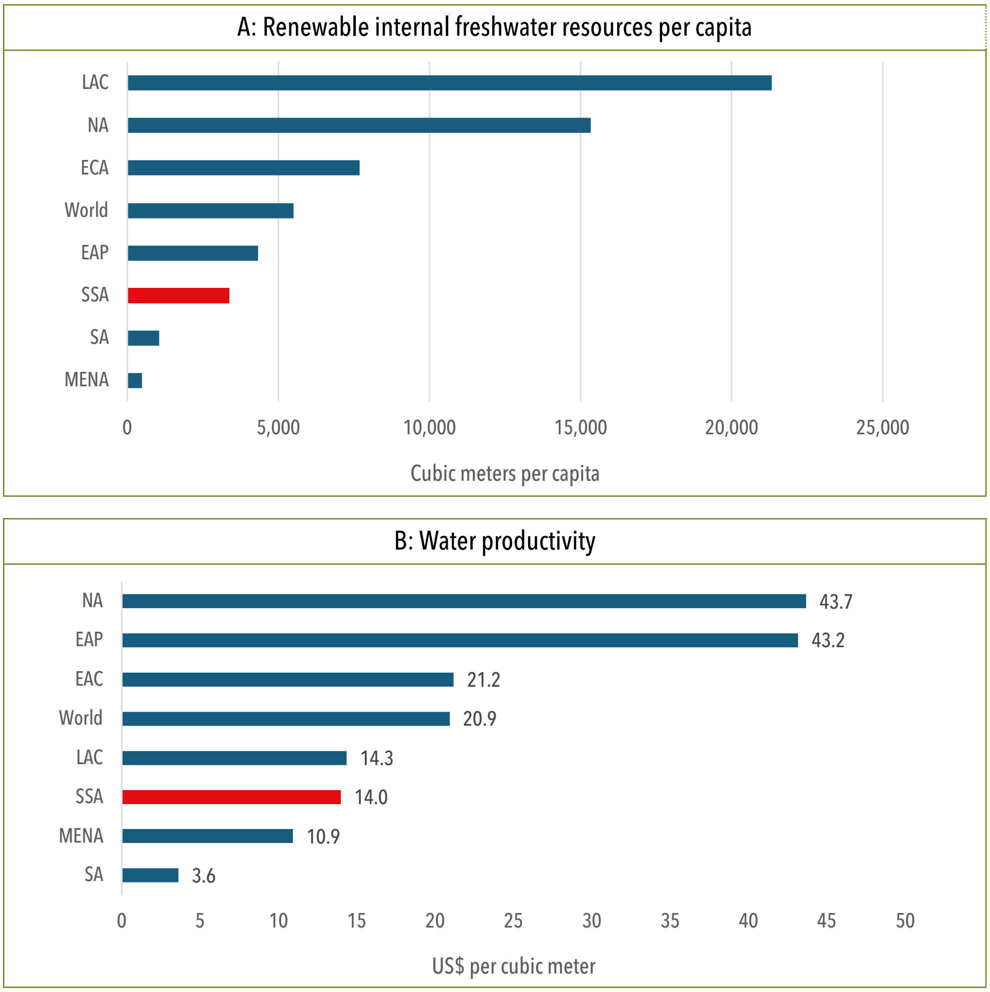
**Figure 5.9** Global level of water stress, 2020




**Source:** FAO exported from UN Water: https://sdg6data.org/en/indicator/6.4.2
**Note:** Freshwater withdrawal as a proportion of available freshwater resources.

2 We also redid the calculation using as a threshold a higher percentile (90%) of water content instead of the median, with almost identical results.

**Figure 5.10** Water indicators by global region, 2020




**Source:** World Development Indicators online dataset.
**Note:** A: Renewable internal freshwater is measured in cubic meters. B: Water productivity is measured at constant 2015 US$ GDP per cubic meter of total freshwater withdrawal. EAC = East Asia and Pacific; EAP = Europe and Central Asia; MENA = Middle East and North Africa; NA = North America; LAC = Latin America and Caribbean; SA = South Asia; SSA = Sub-Saharan Africa.

We use temperature data from the Food and Agriculture Organization of the United Nations (FAO) to estimate the elasticity of yield to temperature by running the following regression for each product:

$$\Delta Yield_{it} = \alpha_0 + \alpha_1 \Delta Temp_i + \delta_t + \eta_i + \varepsilon_{it} \qquad (4)$$

where the dependent variable $\Delta Yield$ is the change in yield for product $k$ in country $i$ and year $t$; $\Delta Temp$ is the change in temperature; and $\delta_t$ and $\eta_i$ are year and country fixed effects, respectively.[3] These fixed effects help control for time and country unobservables to avoid spurious correlations. For instance, temperature is correlated with distance from the equator, and a large body of literature suggests that this is correlated with poor institutions (Olsson 2005),[4] which may explain low agricultural yield. $\varepsilon_{it}$ is the error term. This regression is run

3 Our sample covers all African countries over the period 1961 to 2022. Because we have monthly change in temperature, we calculate an annual average for each country.
4 The literature shows that distance from the equator in degrees latitude is positively associated with institutional quality and economic development.

for each product separately to get its estimated elasticity (see the appendix to this chapter, Table A5.1). Later, we classify products into two categories: (1) when the elasticity is statistically significant (at 1 percent, 5 percent, and 10 percent), the product is defined as temperature sensitive; and (2) when the elasticity is not significant, the product is temperature insensitive. Note that while our calculations do not reflect trade elasticities, these elasticities measure the change in yield due to the change in temperature. Thus, if yields are affected, total output and therefore exports will be affected.

Finally, to calculate the comparative advantage of each country, we rely on the Contribution to Trade Balance (CTB) index (modified version of Stellian and Danna-Buitrago et al. 2022),[5] as follows:

$$CTB_{,k} = \frac{1}{Y}\left[X_k - M_{.,k} - w_k(X - M\ )\right] \qquad (5)$$

where $w_k = \frac{X_k + M_k}{X + M_t}$ refers to the share of *k* Harmonized System 4-digit (HS4) product[6] in Africa's trade with the rest of the world between 2012 and 2022; *Y* refers to Africa's GDP; and X and M are Africa's total exports and imports, respectively. This index is similar to the revealed comparative advantage index, with some differences. First, exports are replaced by the trade balance and the share of each product in the zone's trade to account for imports. Second, to reveal comparative advantages (disadvantages), the observed trade balance ( $X_k - M_k$ ) must be greater (lower) than the theoretical balance ( $w_k(X - M)$ ). Thus, positive (negative) values of CTB refer to a comparative advantage (disadvantage). Third, the index is normalized on the GDP (Y) of the country in question to account for the size of its economy.

Based on these three indexes, we classify African unprocessed products[7] into several groups (Table 5.2).

**Table 5.2** Typology of agriculture products' sensitivity to climate change

| | **High water sensitivity** | | **Low water sensitivity** | |
|---|---|---|---|---|
| **Advantage** | **Temperature sensitivity** | **Temperature insensitivity** | **Temperature sensitivity** | **Temperature insensitivity** |
| Revealed comparative advantage | Very high risk | High risk | High risk | Low risk |
| No revealed comparative advantage | Moderate risk | Low risk | Moderate risk | Very low risk |

**Source:** Authors' elaboration.
**Note:** (1) The comparative advantage of each country is measured by the Contribution to Trade Balance (CTB) index. If the index is positive (negative), the country has a comparative advantage (disadvantage). (2) Temperature sensitivity is measured by the elasticity of yields with respect to temperature. If it is statistically significant (insignificant), the product is defined as temperature sensitive (insensitive). (3) Water sensitivity is measured by the specific water demand. If the water content is greater (less) than the median, products are characterized by a high (low) water sensitivity.

5 Intra-Africa trade is excluded when computing the index. This index is calculated using the 2012 to 2022 average for trade flows at the HS4 level.
6 HS4 refers to the Harmonized System classification.
7 We include only unprocessed products for which we were able to find data on water and temperature sensitivity; thus, some products are not included in our analysis.

First, when an African country has a comparative advantage in a certain product that is sensitive to both water and temperature, we identify the latter as having a very high risk with respect to climate change. Second, when a country has a comparative advantage in a product that is sensitive to either water or temperature, the latter has a high risk, as the country may experience a decline in its comparative advantage when climate conditions deteriorate. Third, a moderate risk prevails if the product is sensitive to water and/or temperature, but the country has no comparative advantage: the potential development of this product in the medium term will be constrained by climate conditions. Finally, low risk characterizes a product that has a comparative advantage but is not sensitive to temperature or to water content, while a very low risk exists if that temperature- and water-insensitive product does not have a comparative advantage, as the country's specialization is not affected.

## Potential impact of climate change on trade flows

Table 5.3 and Table 5.4 present the products corresponding to the typologies described above. It is important to note that, generally, the optimal temperature ranges differ not only between crops but also at different growth stages of the same crop. This is why it is crucial to understand the crop calendar of cool-weather crops, as they may require different levels of sunshine, rainfall, humidity, and warmth (Molua and Lambi 2007).

The first group of products associated with a ***very high risk*** includes products that are sensitive to both water and temperature and that have a comparative advantage. This includes leguminous vegetables (shelled or unshelled, fresh, or chilled, such as green beans, peas, broad beans and horse beans); edible nuts and coconuts (whether or not shelled or peeled); groundnuts (not roasted or otherwise cooked, whether or not shelled or broken) oilseeds; and oleaginous fruits. The second group includes products associated with a *high risk*. Products sensitive to heat but not to water include mainly vegetables (tomatoes, onions, carrots, cucumbers, and artichokes) and some fruits (apples, apricots, cherries, and bananas). This is because these products' optimum temperature ranges from 25 to 30°C. Generally, warm weather crops grow best at temperatures between 18 and 27°C. Products sensitive to water but not to heat include nuts (excluding coconuts, Brazil nuts, and cashew nuts, fresh or dried, whether or not shelled or peeled). Ramirez and Kallarackal (2015) show that the duration of flowering and fruiting of several species has increased by a few days and the cool hours have also grown shorter, leading to a decrease in the production of several species.

*Moderate risk* products include those that are sensitive to water and/or temperature but have no comparative advantage. Thus, with climate change, it is difficult to conceive that such products can be cultivated in Africa. They include rice, oats, grain sorghum, buckwheat, millet, and canary seeds; soya beans and oilseeds; and linseed and sunflower seeds, in addition to maize. This is in line with the results of Sun et al. (2019) and Gouel and Laborde (2021), who find that exports of maize (and wheat) will decline under climate change. Among the reasons why soybean belongs to the group of moderate risk products, Deryng et al. (2014) also show that this crop could improve globally through to the 2080s due to $CO_2$ fertilization effects.

Finally, *low risk* products include potatoes, cabbages, cauliflowers, lettuce, dates, figs, pineapples, avocados, guavas, mangoes, citrus fruits, and grapes. ***Very low risk*** products include rye, barley, rapeseed, and colza seeds.

**Table 5.3** Temperature and water sensitivity for products with a comparative advantage

| Sensitivity | High water sensitivity | Low water sensitivity |
|---|---|---|
| Temperature sensitive | • Leguminous vegetables; shelled or unshelled, fresh or chilled<br>• Nuts, edible; coconuts, Brazil nuts, and cashew nuts; fresh or dried, whether or not shelled or peeled<br>• Groundnuts; not roasted or otherwise cooked, whether or not shelled or broken<br>• Oilseeds and oleaginous fruits, other, in HS Chapter 12; whether or not broken | • Tomatoes, fresh or chilled<br>• Onions, shallots, garlic, leeks, and other alliaceous vegetables; fresh or chilled<br>• Carrots, turnips, salad beetroot, salsify, celeriac, radishes, and similar edible roots; fresh or chilled<br>• Cucumbers and gherkins; fresh or chilled<br>• Vegetables; other, in HS Chapter 7; fresh or chilled<br>• Manioc, arrowroot, salep, Jerusalem artichokes, sweet potatoes, and similar roots and tubers<br>• Bananas, including plantains; fresh or dried<br>• Apples, pears, and quinces; fresh<br>• Apricots, cherries, peaches (including nectarines), plums, and sloes; fresh |
| Temperature insensitive | • Nuts (excluding coconuts, Brazil nuts, and cashew nuts); fresh or dried, whether or not shelled or peeled | • Potatoes; fresh or chilled<br>• Cabbages, cauliflowers, kohlrabi, kale, and similar edible brassicas; fresh or chilled<br>• Lettuce and chicory; fresh or chilled<br>• Dates, figs, pineapples, avocados, guavas, mangoes, and mangosteens; fresh or dried<br>• Citrus fruit; fresh or dried<br>• Grapes; fresh or dried<br>• Melons (including watermelons) and papaws (papayas); fresh<br>• Fruit, fresh; other, in HS Chapter 8<br>• Locust beans, seaweeds and other algae, sugar beet, sugarcane; fresh, chilled, frozen, or dried |

**Source:** Authors' elaboration.
**Note:** Red cells refer to products that have a very high risk (sensitive to both water and temperature and have a comparative advantage) or high risk (sensitive to either water or temperature and have a comparative advantage). Green cells refer to products that have a low risk (not sensitive to water or temperature and no comparative advantage).

**Table 5.4** Temperature and water sensitivity for products without a comparative advantage

| Sensitivity | High water sensitivity | Low water sensitivity |
|---|---|---|
| Temperature sensitive | • Rice | • Wheat and meslin<br>• Maize (corn) |
| Temperature insensitive | • Oats<br>• Grain sorghum<br>• Buckwheat, millet, and canary seeds; other cereals<br>• Soya beans, whether or not broken<br>• Oilseeds; linseed, whether or not broken<br>• Sunflower seeds, whether or not broken | • Rye<br>• Barley<br>• Rapeseed or colza seeds, whether or not broken<br>• Seeds, fruit, and spores; of a kind used for sowing |

**Source:** Authors' elaboration.
**Note:** Yellow cells refer to products that have a moderate risk (sensitive to water and/or temperature, but the country has no comparative advantage). Green cells refer to products that have a low risk (not sensitive to water or temperature and no comparative advantage).

## Conclusions

The climate change–trade nexus has been much debated over the past decade. For Africa, the issue is paramount. This chapter showed that agriculture still represents a significant share of African economies, although the trend is declining as countries grow and their economies become more diversified. In addition, all of the most important indicators of climate change in Africa—such as temperature increases and sea level rise—are above global averages. Therefore, given the continent's degree of exposure and the size of the shocks it faces, significant impacts are expected from climate change–induced events in Africa.

Our findings support the conclusion that Africa's comparative advantage in agriculture will be highly affected by climate change, due to rising temperatures, the increased frequency of extreme events (in particular, droughts), plant pests and diseases, and reduced labor productivity. Although a certain degree of heterogeneity can be expected both within and between countries, the main message is that for most crops grown on the continent, climate change will reduce their yields. This in turn will lead to a fall in farm revenues, an increase in food imports, and a decrease in exports, and thus a widening trade deficit in agriculture and a deteriorating food security situation. Regional cereal trade can be expected to have some stabilizing effect that will mitigate these impacts. However, this is less the case for roots and tubers.

The above-mentioned negative outcomes are amplified by African countries' huge dependence on rainfed agriculture and by their low levels of input use. To paint a complete picture, we developed a typology of products' sensitivity to climate change (water and temperature) and their comparative advantage and proposed a risk profile for Africa's trade potential: the higher the sensitivity to climate change and the degree of comparative advantage, the higher the risk associated with climate change. Our typology highlighted four groups of products: those at very high risk (leguminous vegetables, edible nuts, and oilseeds); high risk (vegetables and some fruits, such as apples and bananas); moderate risk (mainly cereals and some oilseeds, such as soya beans and sunflower seeds); and low risk (mainly barley and colza seeds). Notably, most agricultural products traded or consumed in Africa appear to be at risk. Mitigating this risk and adapting to emerging climate conditions must be paramount, particularly in a global environment characterized by recurrent tensions and the resurgence of noncooperative trade policies such as export restrictions.

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## Appendix 5.1

**Table A5.1** Regressions results: Effects of variation of temperature on variation of yield for each agricultural product (based on equation 4)

| Insensitive product | Coefficient | SE | t-stat | | Insensitive product | Coefficient | SE | t-stat |
|---|---|---|---|---|---|---|---|---|
| Barley | 0.00002 | 0.00005 | 0.47538 | | Tangerines, mandarins, clementines | 0.00000 | 0.00001 | 0.05615 |
| Rye | 0.00094 | 0.00067 | 1.39445 | | Lemons and limes | −0.00001 | 0.00001 | 1.35805 |
| Oats | −0.00012 | 0.00009 | 1.32548 | | Quinces | 0.00000 | 0.00001 | 0.51549 |
| Sorghum | 0.00000 | 0.00005 | 0.01524 | | Cherries | −0.00004 | 0.00005 | 0.71717 |
| Buckwheat | 0.00004 | 0.00018 | 0.23211 | | Strawberries | 0.00001 | 0.00001 | 0.52114 |
| Fonio | −0.00019 | 0.00019 | 0.97685 | | Raspberries | −0.00001 | 0.00001 | 1.36139 |
| Triticale | −0.00188 | 0.00152 | 1.24060 | | Other berries and fruits of the genus *Vaccinium*, n.e.c. | 0.00000 | 0.00001 | 0.09767 |
| Cereals, n.e.c. | −0.00009 | 0.00007 | 1.28635 | | Grapes | −0.00003 | 0.00003 | 1.22180 |
| Potatoes | −0.00001 | 0.00001 | 1.41225 | | Watermelons | −0.00002 | 0.00003 | 0.64094 |
| Taro | 0.00003 | 0.00003 | 1.01460 | | Cantaloupes and other melons | 0.00001 | 0.00001 | 1.64223 |
| Edible roots and tubers with high starch or inulin content, n.e.c., fresh | 0.00005 | 0.00004 | 1.34414 | | Figs | −0.00002 | 0.00002 | 1.14778 |
| Sugarcane | −0.00004 | 0.00002 | 1.61066 | | Mangoes, guavas, and mangosteens | 0.00000 | 0.00001 | 0.33467 |
| Sugar beet | −0.00002 | 0.00002 | 1.06000 | | Pineapples | 0.00000 | 0.00001 | 0.27879 |
| Beans, dry | 0.00002 | 0.00006 | 0.38448 | | Dates | 0.00001 | 0.00001 | 0.63399 |
| Broad beans and horse beans, dry | −0.00003 | 0.00008 | 0.36550 | | Cashew apple | 0.00002 | 0.00001 | 1.37600 |
| Peas, dry | −0.00034 | 0.00031 | 1.08430 | | Papayas | −0.00001 | 0.00000 | 1.58706 |
| Chickpeas, dry | −0.00008 | 0.00040 | 0.19940 | | Other fruits, n.e.c. | 0.00000 | 0.00000 | 0.47619 |

| Insensitive product | Coefficient | SE | t-stat | | Insensitive product | Coefficient | SE | t-stat |
|---|---|---|---|---|---|---|---|---|
| Cowpeas, dry | 0.00020 | 0.00013 | 1.51353 | | Coffee, green | 0.00035 | 0.00033 | 1.06812 |
| Pigeon peas, dry | 0.00014 | 0.00011 | 1.28222 | | Cocoa beans | 0.00037 | 0.00044 | 0.84709 |
| Bambara beans, dry | 0.00005 | 0.00012 | 0.37838 | | Hop cones | 0.00000 | 0.00007 | 0.03687 |
| Other pulses, n.e.c. | −0.00187 | 0.00155 | 1.21070 | | Pepper (*Piper* spp.), raw | −0.00001 | 0.00007 | 0.21100 |
| Chestnuts, in shell | 0.00000 | 0.00000 | 1.16244 | | Chilies and peppers, dry (*Capsicum* spp., *Pimenta* spp.), raw | −0.00006 | 0.00005 | 1.20766 |
| Almonds, in shell | −0.00008 | 0.00026 | 0.31013 | | Vanilla, raw | −0.00141 | 0.00099 | 1.42326 |
| Walnuts, in shell | −0.00005 | 0.00020 | 0.26909 | | Cloves (whole stems), raw | 0.00011 | 0.00117 | 0.09089 |
| Kola nuts | 0.00012 | 0.00010 | 1.18908 | | Nutmeg, mace, cardamoms, raw | 0.00005 | 0.00020 | 0.22739 |
| Hazelnuts, in shell | 0.00003 | 0.00004 | 0.96338 | | Other stimulant, spice, and aromatic crops, n.e.c. | 0.00011 | 0.00008 | 1.29939 |
| Soya beans | 0.00000 | 0.00006 | 0.04784 | | Pyrethrum, dried flowers | 0.00044 | 0.00072 | 0.61172 |
| Coconuts, in shell | −0.00006 | 0.00005 | 1.11538 | | Jute, raw or retted | −0.00001 | 0.00005 | 0.15296 |
| Oil palm fruit | 0.00003 | 0.00002 | 1.38571 | | Kenaf, and other textile bast fibers, raw or retted | −0.00019 | 0.00017 | 1.12262 |
| Olives | −0.00017 | 0.00012 | 1.43246 | | Sisal, raw | 0.00002 | 0.00024 | 0.07319 |
| Karite nuts (sheanuts) | 0.00003 | 0.00006 | 0.55822 | | Other fiber crops, raw, n.e.c. | −0.00011 | 0.00007 | 1.44324 |
| Sunflower seed | −0.00015 | 0.00010 | 1.56128 | | Unmanufactured tobacco | 0.00004 | 0.00004 | 0.85450 |
| Rapeseed or colza seed | 0.00004 | 0.00006 | 0.67782 | | Natural rubber in primary forms | −0.00003 | 0.00016 | 0.16188 |
| Tung nuts | −0.00027 | 0.00021 | 1.26003 | | Raw milk of cattle | 0.00004 | 0.00005 | 0.84222 |
| Seed cotton, unginned | 0.00008 | 0.00006 | 1.31424 | | Raw milk of sheep | 0.00010 | 0.00054 | 0.18403 |
| Linseed | −0.00020 | 0.00029 | 0.67395 | | Raw hides and skins of sheep or lambs | −0.00050 | 0.00094 | 0.53505 |

| Insensitive product | Coefficient | SE | t-stat | | Insensitive product | Coefficient | SE | t-stat |
|---|---|---|---|---|---|---|---|---|
| Other oilseeds, n.e.c. | 0.00001 | 0.00005 | 0.21814 | | Raw milk of goats | 0.00065 | 0.00040 | 1.59654 |
| Cabbages | 0.00000 | 0.00001 | 0.17456 | | Hen eggs in shell, fresh | −0.00006 | 0.00005 | 1.28778 |
| Asparagus | 0.00002 | 0.00002 | 1.15287 | | Eggs from other birds in shell, fresh, n.e.c. | 0.00002 | 0.00003 | 0.50943 |
| Lettuce and chicory | −0.00003 | 0.00002 | 1.31696 | | Raw milk of camel | −0.00012 | 0.00023 | 0.53768 |
| Cauliflowers and broccoli | 0.00000 | 0.00001 | 0.48107 | | Beeswax | −0.01328 | 0.00908 | 1.46178 |
| Eggplants (aubergines) | 0.00000 | 0.00001 | 0.42308 | | Roots and tubers, total | 0.00116 | 0.00079 | 1.47623 |
| Onions and shallots, dry (excluding dehydrated) | 0.00000 | 0.00001 | 0.64583 | | Sugar crops, primary | 0.00000 | 0.00000 | 0.29644 |
| Leeks and other alliaceous vegetables | 0.00001 | 0.00002 | 0.28515 | | Treenuts, total | −0.00022 | 0.00014 | 1.58222 |
| String beans | 0.00000 | 0.00001 | 0.28750 | | Vegetables, primary | 0.00003 | 0.00002 | 1.52792 |
| Okra | −0.00004 | 0.00003 | 1.62800 | | Fruit, primary | 0.00000 | 0.00000 | 1.55853 |
| Locust beans (carobs) | 0.00004 | 0.00004 | 0.91063 | | Milk, total | −0.00015 | 0.00009 | 1.64035 |
| Other vegetables, fresh, n.e.c. | −0.00001 | 0.00001 | 0.90406 | | Citrus fruit, total | 0.00000 | 0.00001 | 0.68488 |
| Oranges | 0.00001 | 0.00000 | 1.32919 | | Fiber crops, fiber equivalent | 0.00007 | 0.00013 | 0.51485 |

| Sensitive product | Coefficient | SE | t-stat | | Sensitive product | Coefficient | SE | t-stat |
|---|---|---|---|---|---|---|---|---|
| Wheat | −0.00012 | 0.00003 | 3.69136 | | Green garlic | −0.00002 | 0.00001 | 2.72216 |
| Rice | −0.00006 | 0.00003 | 2.36293 | | Other beans, green | −0.00003 | 0.00001 | 4.77093 |
| Maize (corn) | −0.02224 | 0.00669 | 3.32555 | | Peas, green | −0.00006 | 0.00002 | 3.40120 |
| Millet | −0.00027 | 0.00007 | 3.80677 | | Broad beans and horse beans, green | −0.00002 | 0.00001 | 2.83721 |
| Sweet potatoes | −0.00004 | 0.00001 | 3.80198 | | Carrots and turnips | −0.00002 | 0.00001 | 3.32731 |
| Cassava, fresh | 0.00001 | 0.00001 | 1.73267 | | Green corn (maize) | 0.00002 | 0.00001 | 2.09052 |
| Yams | 0.00001 | 0.00001 | 1.77285 | | Bananas | −0.00001 | 0.00000 | 1.72273 |
| Lentils, dry | 0.00084 | 0.00028 | 2.93776 | | Plantains and cooking bananas | −0.00002 | 0.00001 | 1.73647 |
| Vetches | 0.00120 | 0.00046 | 2.60741 | | Pomelos and grapefruits | −0.00001 | 0.00000 | 1.85714 |
| Lupins | 0.00064 | 0.00029 | 2.22358 | | Other citrus fruit, n.e.c. | 0.00002 | 0.00001 | 1.82418 |
| Cashew nuts, in shell | −0.00109 | 0.00039 | 2.79558 | | Apples | −0.00001 | 0.00001 | 1.94678 |
| Pistachios, in shell | −0.00452 | 0.00168 | 2.69742 | | Pears | −0.00005 | 0.00001 | 7.04965 |
| Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c. | 0.00009 | 0.00003 | 2.71160 | | Apricots | −0.00007 | 0.00001 | 5.78226 |
| Groundnuts, excluding shelled | −0.00013 | 0.00004 | 3.68732 | | Peaches and nectarines | −0.00011 | 0.00001 | 7.91971 |
| Castor oilseeds | 0.00025 | 0.00012 | 2.08223 | | Plums and sloes | −0.00003 | 0.00001 | 3.78917 |
| Safflower seed | −0.00014 | 0.00008 | 1.78851 | | Other stone fruits | −0.00002 | 0.00001 | 1.91071 |
| Sesame seed | 0.00031 | 0.00010 | 2.99513 | | Avocados | 0.00003 | 0.00001 | 2.27679 |
| Melonseed | 0.00046 | 0.00013 | 3.51003 | | Other tropical fruits, n.e.c. | 0.00001 | 0.00000 | 1.86765 |
| Artichokes | −0.00002 | 0.00001 | 1.98464 | | Tea leaves | 0.00026 | 0.00008 | 3.21665 |
| Spinach | −0.00001 | 0.00000 | 1.67955 | | Cinnamon and cinnamon-tree flowers, raw | −0.00220 | 0.00048 | 4.63179 |

| Sensitive product | Coefficient | SE | t-stat | | Sensitive product | Coefficient | SE | t-stat |
|---|---|---|---|---|---|---|---|---|
| Tomatoes | 0.00001 | 0.00001 | 1.76110 | | Anise, badian, coriander, cumin, caraway, fennel and juniper berries, raw | −0.00008 | 0.00004 | 1.97500 |
| Pumpkins, squash, and gourds | −0.00006 | 0.00002 | 2.52423 | | Ginger, raw | 0.00012 | 0.00006 | 2.07179 |
| Cucumbers and gherkins | −0.00003 | 0.00001 | 5.95819 | | Raw hides and skins of cattle | −0.00111 | 0.00024 | 4.57231 |
| Chilies and peppers, green (Capsicum spp. and Pimenta spp.) | −0.00003 | 0.00001 | 2.57724 | | Raw hides and skins of goats or kids | −0.00285 | 0.00119 | 2.39004 |
| Onions and shallots, green | 0.00003 | 0.00002 | 1.94771 | | Cereals, primary | −0.02171 | 0.00655 | 3.31669 |
| Eggs, primary | −0.00024 | 0.00005 | 4.61132 | | Pulses, total | 0.00011 | 0.00005 | 2.03640 |
| Oil crops, cake equivalent | −0.00012 | 0.00005 | 2.44511 | | Oil crops, oil equivalent | −0.00014 | 0.00007 | 1.90960 |

**Source:** Authors' elaboration using Stata.
**Note:** If the elasticity is statistically significant (at 1 percent, 5 percent, or 10 percent), the product is assumed to be sensitive. If not, it is insensitive. n.e.c = not elsewhere classified; SE = standard error.