Climate change impacts across agroecological zones on agriculture in Kenya: an economy-wide analysis

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This policy brief is part of a series of ten policy briefs written under the GIZ-funded project "Capacity building and advanced support for policy analysis using economic models in Benin, Kenya and Namibia".

This work partially builds on research funded by the German Research Foundation (DFG) as part of the DFG Research Unit "Climate Change and Health in Sub-Saharan Africa".

April 2023

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Executive summary

Kenya's economy heavily relies on agriculture, which accounts for over 20% of the GDP and more than 40% of employment. Agriculture, though, faces a substantial threat from climate change. Small-scale farmers and pastoralists, who rely on rain-fed agriculture, face high poverty rates and have limited coping options, suffer immensely from prolonged droughts and heavy rainfall. The effects of climate change on agriculture differ across agroecological zones, driven by climatic conditions, the composition of current production and production potentials. This study aims to assess the economy-wide implications of climate change affecting the agricultural sector in Kenya by 2050. Results may support policymakers in designing policies to reduce the negative impacts of climate change on agriculture. Results show that climate change is likely to significantly decrease agricultural production, leading to a decline in GDP, falling wages and income. Accordingly, household welfare falls. The agroecological zones, e.g., rift valley and western, that rely on crop production as a primary livelihood source, are likely to be the most affected. The study concluded that tailored climate adaptation policies are needed according to agroecological conditions. They may comprise investing in irrigation for arid and semi-arid regions, introducing drought-resistant seeds, and expanding agricultural extension services to increase farmers' awareness about climate change and coping opportunities. Strengthening the connection between meteorological services and agricultural extension services is also crucial.

Impacts du changement climatique sur l'agriculture et l'ensemble de l'économie du Kenya avec différentiation des zones agroécologiques

Résumé

L'économie du Kenya dépend fortement de l'agriculture, qui contribue à plus de 20 % au Produit Intérieur Brut (PIB) et occupe plus de 40 % de l'emploi national. L'agriculture est cependant confrontée à une menace importante liée au changement climatique. Les petits exploitants agricoles et les éleveurs, qui dépendent de l'agriculture pluviale, sont confrontés à des taux de pauvreté élevés et disposent d'options limitées pour faire face à la situation, et souffrent énormément des sécheresses prolongées et des fortes précipitations. Les effets du changement climatique sur l'agriculture diffèrent d'une zone agroécologique à une autre, en fonction des conditions climatiques, de la structure de la production actuelle et du potentiel de production. Cette étude vise à évaluer les implications économiques du changement climatique sur le secteur agricole au Kenya à l'horizon 2050. Les résultats peuvent aider les décideurs politiques à concevoir des politiques visant à réduire les effets négatifs du changement climatique sur l'agriculture. Les résultats montrent que le changement climatique est susceptible de réduire de manière significative la production agricole, entraînant une baisse du PIB, des prix des facteurs de production et des revenus des ménages. En conséquence, le bien-être des ménages diminue. Les zones de la vallée du Rift et de l'ouest du pays, qui dépendent de la production agricole comme principale source de revenus, sont susceptibles d'être les plus touchées. L'étude conclut que des politiques adéquates d'adaptation au changement climatique sont nécessaires en fonction des conditions agroécologiques. Elles peuvent consister à investir dans l'irrigation pour les régions arides et semi-arides, à introduire des semences résistantes à la sécheresse et à développer les services de vulgarisation agricole pour sensibiliser les agriculteurs au changement climatique et aux possibilités pour y faire face. Il est également essentiel de renforcer les liens entre les services météorologiques et les services de vulgarisation agricole pour un partage d'information pour aider dans le sens de l'adaptation.

Climate change impacts across agroecological zones on agriculture in Kenya

1. Background

Agriculture is a crucial driver of enhancing economic growth, alleviating poverty, and achieving food security in Kenya. The sector contributes approximately 23% to the country's Gross Domestic Product (GDP) (KNBS, 2021), employs more than 40% of the population (GoK, 2019) and is the primary livelihood source for most Kenyan people (GoK, 2017), particularly those residing in rural regions (Amwata, 2020). Moreover, the sector accounts for over 60% of total exports (KNBS, 2021). Consequently, the agricultural sector is a significant economic pillar in the Kenya Vision 2030 (GoK, 2007)[1].

Climate change is a significant global challenge facing humanity in the 21st century. In Kenya, temperatures are anticipated to increase by 1.7°C by the 2050s and by roughly 3.5°C at the end of the century (World Bank, 2021). The average rainfall is projected to increase by mid-century, particularly during the short rain season occurring between October and December. Besides, extreme rainfall events are expected to increase in frequency, duration and intensity, while drought may prevail in other periods of the year. Rainfall in the arid and semi-arid zones is generally predicted to decrease (World Bank, 2021).

Agriculture is vulnerable to the negative impacts of climate change. Climate change can restrict access to agricultural inputs in Kenya, including water and arable land, ultimately leading to a decline in agricultural production (Constant and Winkler, 2013). Moreover, farmers who rely on rain-fed agriculture have been negatively affected by severe weather patterns characterised by prolonged droughts and heavy rainfall (Manzi and Gweyi-Onyango, 2021). Kenyan smallholder farmers and pastoralists are highly vulnerable to drought due to their reliance on rain-fed agriculture, high poverty rates, and limited coping capacity (D'Alessandro *et al.*, 2015)[2]. Their sensitivity to extreme weather events highlights a lack of resilience and effective coping mechanisms in arid and semi-arid regions (Manzi and Gweyi-Onyango, 2021).

Kenya can be divided into seven agroecological zones based on soil type, and climatic characteristics, as illustrated in Figure 1. These zones include: a) central asals, b) central highlands, c) coast, d) north asals, e) semi-arid uplands, f) rift valley, and h) western.

Table 1 illustrates the critical characteristics of each zone. It shows that the climatic conditions and production capacities vary across zones. For instance, the Western zone with high rainfall and moderate temperatures accounts for more than 50% of total crop production and 25% of total livestock production. This zone is suitable for growing mixed staples (e.g., maize, wheat, cabbages, carrots, and potatoes) and cash crops (e.g., tea, coffee, sugarcane, and cotton). Animals reared in this zone include dairy cows, beef cattle, and sheep. In contrast, the climate of the Central and North asals zones cover about 80% of the country's land area (GoK, 2019) but have almost no crop production. Animal production is the primary livelihood for pastoral communities. The most common animals reared in these zones are cattle, goats, sheep, and camels. Besides, agriculture is primarily subsistence-based and irrigated (Kogo, Kumar and

[1] The Kenya Vision 2030 aims to revolutionise the agricultural sector by introducing institutional reforms, enhancing productivity, reconfiguring land utilisation, widening market entry, and developing Kenya's arid and semi-arid lands, thereby creating a more advanced, market-oriented and innovative industry.

[2] In Kenya, irrigated agriculture accounts for 1% of overall land surface (Authors' calculation based on Amwata (2020)). In contrast, rainfed agriculture is the dominant agricultural production system, accounting for 16% of the country's land (Kogo, Kumar and Koech (2021)).

Koech, 2021). Crops grown in these zones are drought-resistant crops such as millet, sorghum, and beans. However, due to unpredictable rainfall patterns, crop productivity is low, and farmers often experience crop failures. Consequently, the changes in climatic variables (i.e., rainfall and temperature) would affect agricultural production across zones differently.

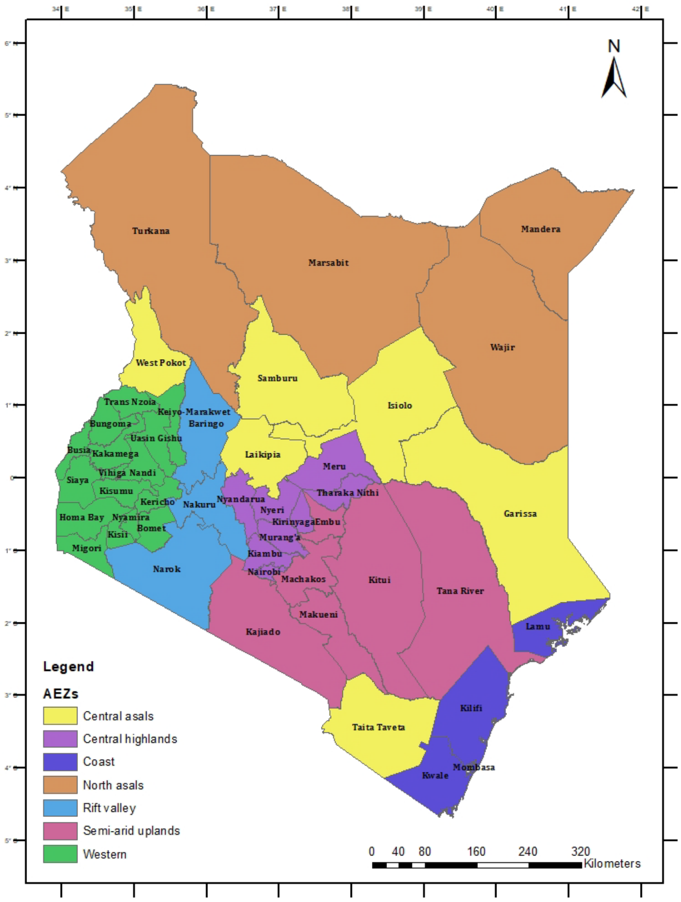

Figure 1: Agroecological map for Kenya

Source: Authors' compilation based on GoK (2019).

Table 1: Key features of agroecological zones in Kenya

	Rainfall (mm)	Temperature (°C)	Crops (% of total)	Livestock (% of total)
Central asals	<200 - 600	23 – 37	3.0	11.9
Central highlands	1,600 - >2,000	25 – 37	18.3	10.3
Coast	600 - 1,200	24 – 32	4.8	4.1
North asals	400 - 800	23 – 34	0.1	25.6
Semi-arid uplands	600 - 1,200	21 - 24	8.4	13.3
Rift valley	600 - 1,200	12 – 27	12.8	8.7
Western	1,200 - 1,800	16 – 28	52.7	26.1
Total			**100.0**	**100.0**

Source: Authors' compilation based on D'Alessandro et al. (2015); GoK (2022); GoK (2019); Kabubo-Mariara and K. Karanja (2007); KMD (2020); Kogo et al. (2021); KNBS (2022a); KNBS (2022b).

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This study aims to assess the economy-wide implications of climate change affecting the agricultural sector in Kenya by 2050 considering differences across agroecological zones. This information can support policymakers in designing policies to reduce the negative impacts of climate change.

2. Methods

2.1 Database

A Social Accounting Matrix (SAM) for Kenya for the year 2019 has been designed at the International Agricultural Trade and Development Group at Humboldt-Universität zu Berlin based on Elnour, Siddig and Grethe (2022), and extended with support from the staff of the Kenya National Bureau of Statistics. This SAM possesses distinctive characteristics due to its incorporation of data regarding agroecological zones (Figure 1).

The SAM identifies 49 activities producing 49 commodities, of which 20 are agricultural commodities. Agricultural activities are classified according to agroecological zones into 53 sectors. Additionally, the SAM includes twenty-one production factors: four types of capital, thirteen land types and four labour categories. Capital is classified based on its application, including crop farming, livestock, other forms of agriculture such as forestry and fishing, and non-agricultural activities. In contrast, land is disaggregated according to agroecological zones and farming types (irrigated or not). Labour is classified based on skill level (skilled and unskilled) and gender (male and female). Besides, households are categorised into twenty-eight groups, depending on seven agroecological zones, location (rural and urban) and income level (poor and non-poor).

2.2 Model and closure rules

We use the computable general equilibrium (CGE) model STAGE (McDonald and Thierfelder, 2015) . A CGE model combines economic theory and numerical models to establish the impact of shocks in an economy. Real economic data is used to fit a set of equations that replicate the structure of the economy. From this framework, it is possible to simulate the effect of exogenous shocks, such as policy changes, including economy-wide interactions. The following presents a summary of the CGE model used:

- Production is structured by a three-level nest of Constant Elasticity of Substitution (CES) and Leontief production functions. At the top level, aggregate value-added, and intermediate inputs are combined using a CES function. Production factors are aggregated using CES functions at different levels, whereas the intermediate input component is aggregated using a Leontief production function (the second level). Aggregate primary factors (i.e., labour and land) are combined using CES functions (the third level).
- Producers sell their products either in the local or foreign markets, based on relative prices, as determined by a Constant Elasticity of Transformation (CET) function.
- Households supply production factors to productive activities through factor markets in exchange for wages that constitute a significant portion of their incomes. After paying taxes and making savings, households spend their income on purchasing products. Households maximise their utility subject to Stone-Geary utility functions,

selecting the optimal mix of commodities and services while considering purchase prices, preferences, and income constraints.

We apply flexible exchange rate regime closure. The model is saving-driven. All production factors are fully employed across all markets and fully mobile across sectors, except agricultural capital, which is only mobile among crop activities, livestock activities and fishing and forestry activities . The model numéraire for the scenarios is the CPI. The government savings are fixed, and the household tax rate is flexible. Therefore, any policy implemented in the model is financed through income tax on households.

2.3 Scenarios

This study distinguishes two distinct scenarios: the reference scenario, which illustrates the economy under normal climatic conditions, and the climate change scenario, which accounts for changes in agricultural productivity induced by climate change in Kenya.

The climate change scenario is developed based on two climatic scenarios, specifically Shared Socioeconomic Pathways (SSP). These scenarios are designed by the Intergovernmental Panel on Climate Change (IPCC) to explore future trajectories for human development, energy use, and greenhouse gas emissions.

In the first scenario, SSP 126, greenhouse gas emissions are expected to decrease due to improvements in energy efficiency, renewable energy adoption, and carbon capture and storage technologies. As a result, a temperature rise of 1.8°C is projected by the end of the century. The second scenario, SSP 585 assumes increasing emissions, a growing global population, extensive use of fossil fuels, and severe climate change consequences. In this scenario, the anticipated temperature rise by the end of the century is 4.3°C.

In our climate change scenario, we determine the impacts of climate change on agriculture by 2050, considering the yield differences between the above-mentioned climatic trajectory scenarios. We estimate these impacts through a three-step process. First, we calculate annual yield growth rates for each sector under two climate scenarios using yield data provided by Potsdam Institute for Climate Impact Research (PIK). These data are produced using Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b) (Frieler *et al.*, 2017; Müller *et al.*, 2022). Second, we calculate the growth difference between the two scenarios by subtracting their respective annual growth rates, considering the SSP 126 scenario as the reference scenario for our calculation. This assumption implies that humans are aware of climate change and will behave rationally to reduce the future harmful effects of climate change. Finally, we calculate the compounded growth rate difference by exponentiating the growth difference to the number of years.

To consider the effects of climate change on livestock productivity, we rely on biomass and maize productivity data to mimic the changes in pasture availability. Specifically, we calculate the average changes in vegetation and maize productivity in the Western, Rift valley, and Central highlands zones and apply them to livestock. For the other zones, including Central asals, North asals and Semi-arid uplands, we use changes in vegetation productivity as a proxy for the impacts. It's worth noting that livestock primarily depends on pasture as primary fodder source in the latter zones.

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In our CGE model, the compounded growth rate differentials are multiplied by the total factor productivity, expressing the changes in agricultural productivity due to climate change (Appendix A). The shock is applied to the base period SAM of 2019. The effect can thus be interpreted as the climate change impact of a pessimistic compared to an optimistic scenario occurring through the impact pathway "crop yields" on the economy of Kenya in its current structure (sectoral composition, population size, income level).

3. Results

3.1 Domestic production

Crop production drops significantly due to the yield shock, as shown in Figure 2. Also, livestock production drops, cause by reduction in maize production and vegetation. Production of forests, construction, water and electricity, and services (i.e., private and public) drop due to decreasing domestic demand (i.e., final or intermediate products).

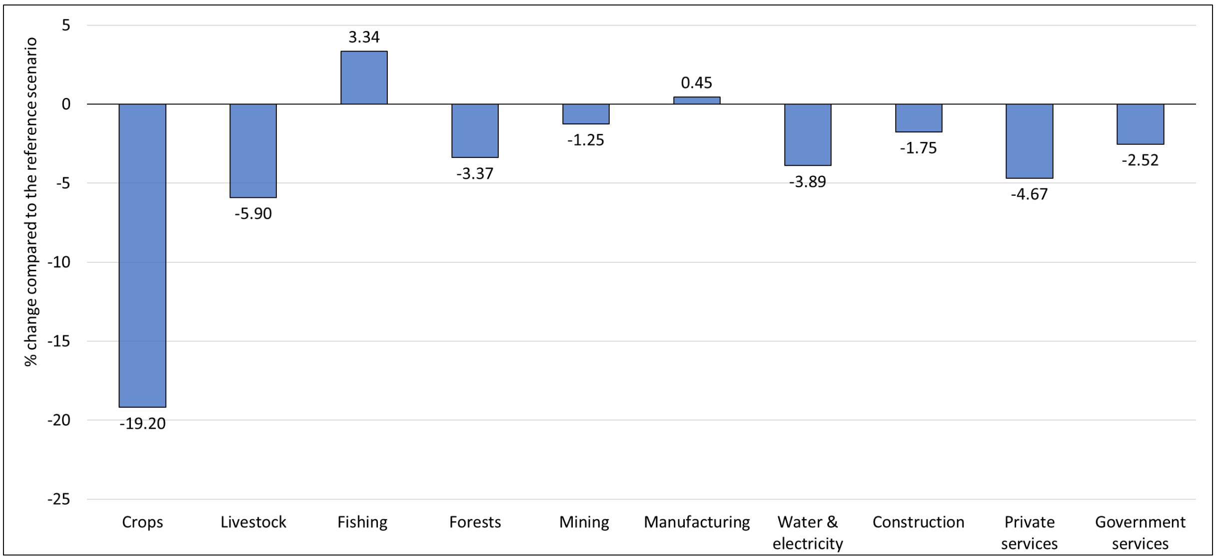

Figure 2: Effects on quantities of sectoral domestic production, % change compared to the reference scenario

Source: Authors' calculations based on simulation results.

Fish production rises, driven by a significant decrease in factor prices of unskilled labour (male and female). A slight increase in manufacturing production is driven by the rise in its intermediate demand by the fishing sector (e.g., fishing nets and diesel fuel).

Table 2 displays the impact on crop production in various agroecological zones. The Western and Central highland zones experience a substantial decrease of 11% and 8%, respectively. This decline is due to a significant reduction in cereals (rice, sorghum, and millet), cash crops (tea, coffee, and sugarcane), and vegetables and fruits. Crop production in the Rift valley zone drops by almost 30% primarily due to reduced production of maize, rice, and sugarcane. In contrast, the decline in crop production in the Semi-arid upland zone is dominated by decreasing fruit (e.g., mango) and coffee production. In the remaining zones not displayed in Table 2, there is a significant decline of 42% in crop production, mainly caused by a decrease in the production of pulses, oilseeds, wheat, and vegetables.

Table 2: Effects on crop production across the agroecological zone

	Quantity in base million units	Change compared to the reference scenario	
		%	Absolute
Central highlands	369.56	-8.3	-30.75
Semi-arid uplands	50.01	-25.5	-12.75
Rift valley	76.33	-28.7	-21.87
Western	558.64	-11.3	-63.27
The rest of the zones	471.70	-34.0	-167.36
Total crop production	**1,546.08**	**-19.1**	**-295.99**

Source: Author's calculations based on simulation results.

3.2 Factor prices

Overall domestic production declines by 5%, driving down demand for production factors, specifically labour and land. As a result, factor prices drop significantly compared to the reference scenario (Figure 3). In contrast, the average agricultural capital price rises, driven by the growth of the livestock capital price. This is because of declining livestock productivity causes scarcity of livestock products, resulting in a significant increase in livestock prices and thus incentives to source more production factors.

Female labour wages decline relatively more compared to male labour, as shown in Figure 4. This result can be attributed to a substantial decline in agricultural production, which on average employs a higher share of female workers compared to other sectors.

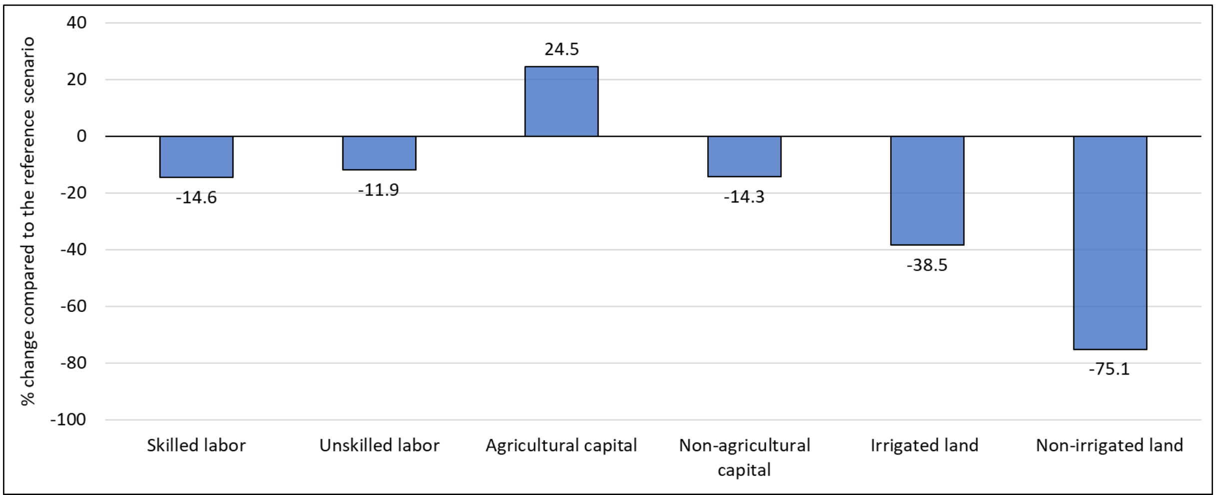

Figure 3: Effects on prices of production factors, % change compared to the reference scenario

Source: Authors' calculations based on simulation results.

Figure 4: Effects on labour prices across gender, % change compared to the reference scenario

Source: Authors' calculations based on simulation results.

Figure 5 illustrates the effects on land prices across different agroecological zones. Land prices drop across all zones, with a more significant decrease observed in the Western, Central highlands, and Semi-arid uplands zones. This results from the more substantial reduction in land productivity in these three zones.

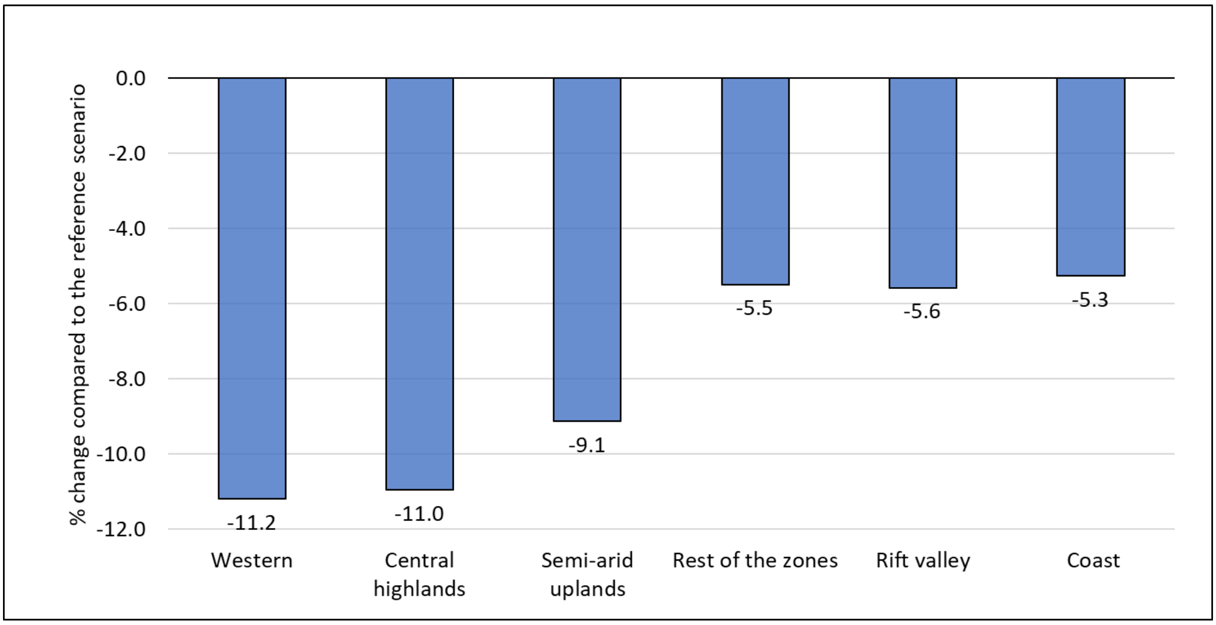

Figure 5: Effects on prices of land classified according to agroecological zones, % change compared to the reference scenario

Source: Authors' calculations based on simulation results.

3.3 Household welfare

All households experience strong welfare losses due to the significant reduction in factor income and increasing consumer prices of agricultural products (Figure 6).

Rural households lose less compared to those in urban areas. This difference can be attributed to a low decrease in agricultural capital prices (Figure 3), mainly owned by rural households.

Urban poor households lose more than other household groups (Figure 5). This result can be explained by higher income shares from labour in their factor income, for which wages decrease the most.

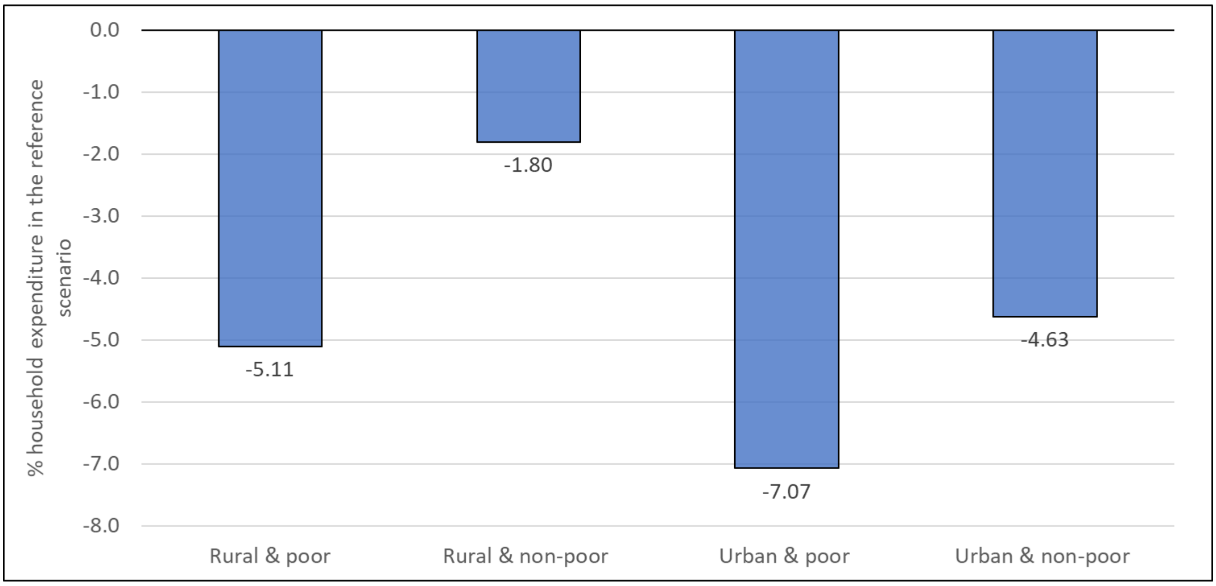

Figure 6: Effects on household welfare, Equivalent Variation (EV) as a share of household expenditure in the reference scenario[3]

Source: Authors' calculations based on simulation results.

Effects on household welfare across agroecological zones are shown in Figure 7. Households in the Central highlands, Rift valley, and Western zones lose more than other household groups. This is due to a significant reduction in factor income, driven by the negative impacts of climate change on crop yields, which have a share in agricultural output in these zones.

3.4 Macroeconomic effects

Climate change reduces total production in Kenya by almost 5% (Figure 8), which translates into declining demand and prices of production factors. Consequently, household income drops, driving down consumption by 6%. Total investment falls by 2%.

Furthermore, total exports decrease by 12%, caused by a reduction in agricultural production, mainly tea. Simultaneously, total imports go down by 7%, due to reduced domestic consumer

[3] Equivalent variation (EV) refers to a change in income that would have an equivalent effect on utility as all price and income changes combined.

demand, as shown in Figure 8. As a result, the exchange rate depreciates. Based on the above consequences, the real GDP drops by 5%.

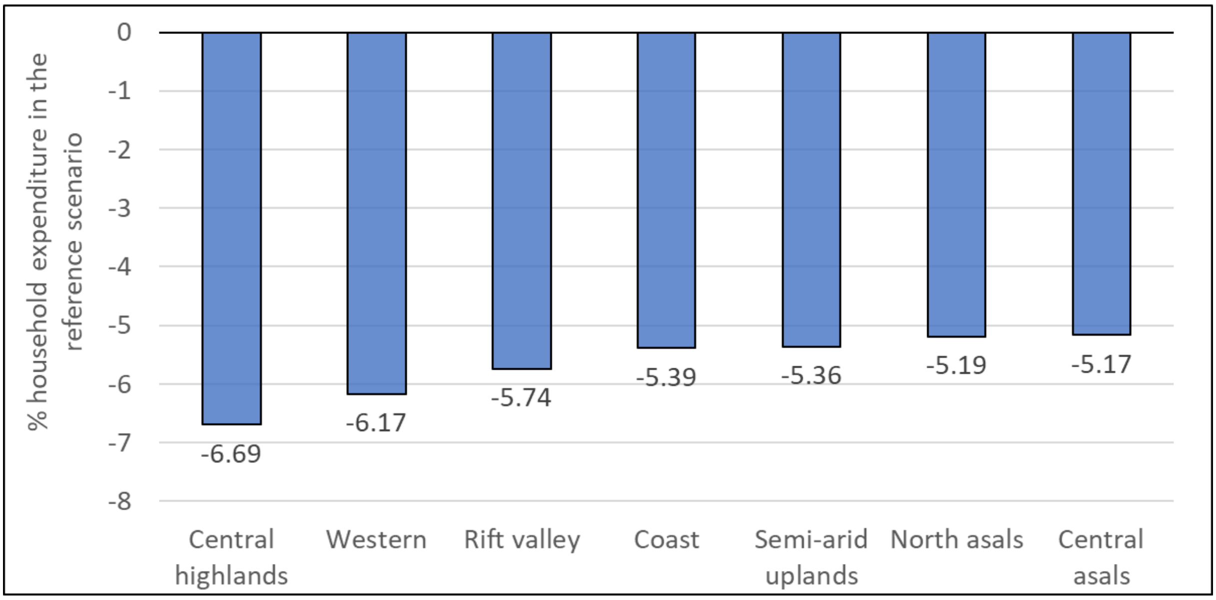

Figure 7: Effects on household welfare across agroecological zones, EV as a share of household expenditure in the reference scenario

Source: Authors' calculations based on simulation results.

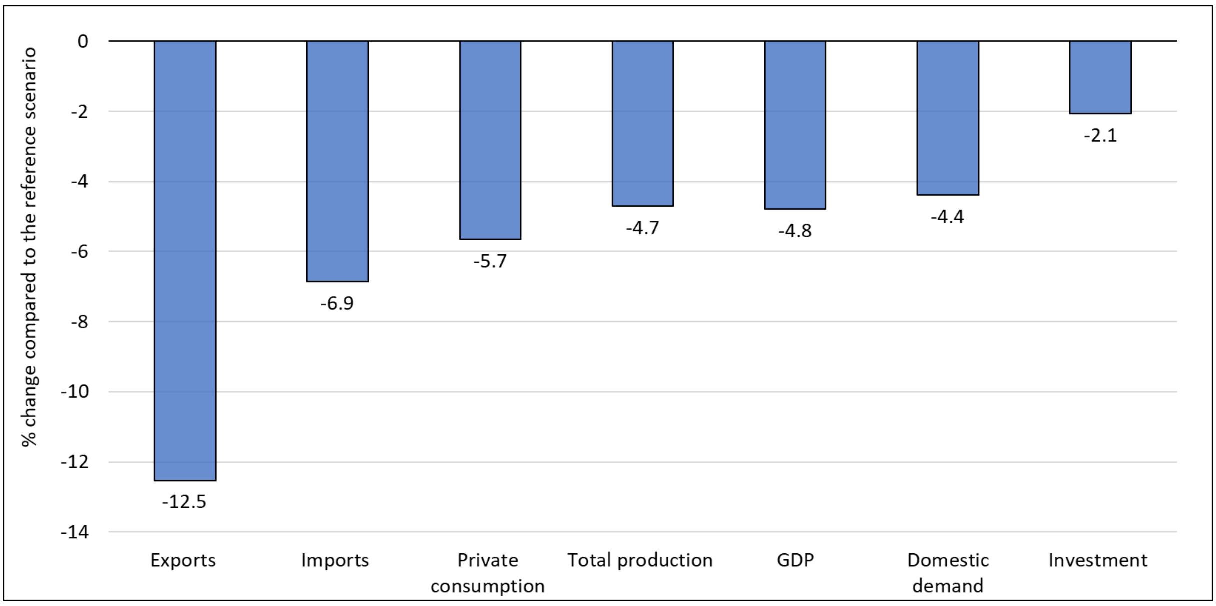

Figure 8: Effects on economy-wide indicators, % change compared to the reference scenario

Source: Author's calculations based on simulation results.

4. Conclusion and discussion

This study assesses climate change impacts on agriculture in Kenya, considering climatic variation across agroecological zones. We develop one scenario that depicts the cumulative effects of climate change between 2019 and 2050. The analysis is conducted using a comparative static CGE model.

The study finds that climate change would reduce GDP, mainly driven by the significant reduction in agricultural production. Consequently, purchase prices of agricultural products increase. Besides, reducing total production drives down demand for production factors, resulting in falling wages. Household welfare decreases due to the substantial reduction of income and significant increases in consumer prices.

The reduction in agricultural production caused by climate change has a negative impact on Kenyan households, particularly those residing in the central highlands, rift valley, and western zones. These regions account for the majority of crop production, which serves as the primary means of livelihood for households in these regions.

The effects of climate change on local weather conditions are uncertain and the real climate change effects may differ substantially from the simulations presented here. For crop yield projections, our work relies on state-of-the-art plant growth models. But our projections of the future productivity of animals are based on weak evidence. Especially in the drought prone northern regions of the country, effects on animal stocks and livelihoods may be substantially stronger than simulated here.

Finally, we only consider the impact of climate change through agricultural yields. Other impact pathways such as increasing human heat stress or changes in the prevalence of diseases may add but are not accounted for here.

5. Policy implications

Climate change has the potential to greatly impact agricultural production in Kenya. Effects will differ among agroecological zones. Policies to cope with climate change thus need to be tailored to regional conditions. For instance, in the long run, increasing investment in irrigation for arid and semi-arid regions could mitigate negative effects. At the same time, introducing drought-resistant seeds would benefit farmers across all zones. In the short run, expanding agricultural extension services can increase farmers' awareness about changing climatic conditions, helping them to prepare and adjust. Especially for short term adjustment of agricultural practices, strengthening the connection between meteorological services and agricultural extension services to inform farmers about weather patterns allowing them to adjust timely is considered important.

References

Amwata, A. D. (2020). Situational Analysis of the Agriculture Sector in Kenya. *Ministry of Agriculture, Livestock and Fisheries, Nairobi, Kenya*.

Constant, L. A. and Winkler, H. (2013). Linkage of Agricultural Productivity Improvement and Climate Mitigation Action in Africa: 1–17.

D'Alessandro, S., Caballero, J., Simpkin, S. and Lichte, J. (2015). Kenya Agricultural Risk Assessment. *Agricultural Blobal Practice Note, World Bank, Washington, D.C., USA* 17.

Elnour, Z., Siddig, K. and Grethe, H. (2022). A 2019 Social Accounting Matrix for Kenya Including Malaria Epidemiological and Agroecological Zones. *Working Paper No. 103/2022.*

Department of Agricultural Economics, Faculty of Life Sciences, Humboldt-Universität zu Berlin.

Frieler, K., Lange, S., Piontek, F., Reyer, C. P. O., Schewe, J., Warszawski, L., Zhao, F., Chini, L., Denvil, S., Emanuel, K., Geiger, T., Halladay, K., Hurtt, G., Mengel, M., Murakami, D., Ostberg, S., Popp, A., Riva, R., Stevanovic, M., Suzuki, T., Volkholz, J., Burke, E., Ciais, P., Ebi, K., Eddy, T. D., Elliott, J., Galbraith, E., Gosling, S. N., Hattermann, F., Hickler, T., Hinkel, J., Hof, C., Huber, V., Jägermeyr, J., Krysanova, V., Marcé, R., Müller Schmied, H., Mouratiadou, I., Pierson, D., Tittensor, D. P., Vautard, R., van Vliet, M., Biber, M. F., Betts, R. A., Bodirsky, B. L., Deryng, D., Frolking, S., Jones, C. D., Lotze, H. K., Lotze-Campen, H., Sahajpal, R., Thonicke, K., Tian, H. and Yamagata, Y. (2017). Assessing the impacts of 1.5 °C global warming – simulation protocol of the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). *Geoscientific Model Development* 10(12): 4321–4345.

GoK (2007). Kenya Vision 2030. *Government of Kenya, Nairobi, Kenya*.

GoK (2017). Capacity Building Strategy for Agriculture Sector. *Government of Kenya*.

GoK (2019). Transforming the agricultural sector and growth strategy: 2019-2029. *Government of Kenya*.

GoK (2022). Data Portal. *Government of Kenya, Ministry of Agriculture, Livestock, Fisheries, and Cooperatives, Nairobi, Kenya*.

KNBS (2021). *"Economic Survey 2021"*. Kenya National Bureau of Statistics, Nairobi, Kenya.

Kogo, B. K., Kumar, L. and Koech, R. (2021). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability* 23(1): 23–43.

Manzi, H. and Gweyi-Onyango, J. P. (2021). Agro-ecological Lower Midland Zones IV and V in Kenya Using GIS and Remote Sensing for Climate-Smart Crop Management: 965–991.

McDonald, S. and Thierfelder, K. (2015). A Static Applied General Equilibrium Model: Technical Documentation: STAGE Version 2: 1–87.

Müller, C., Elliott, J. W., Folberth, C., Jägermeyr, J., Khabarov, N., Seneviratne, S., Thiery, W. and Frieler, K. (2022). Inter-Sectoral Impact Model Intercomparison Project (ISIMIP2b). *Simulation Data from the Agriculture Sector (v1.0). ISIMIP Repository.*

World Bank (2021). Climate Risk Country Profile: kenya. *World Bank, Washington, DC, USA*.

Appendices

No	Agricultural sector by zone	Changes in yield due to climate change
1	Maize - Rift valley	-12.76
2	Maize - Western	-2.60
3	Maize - Rest of the zones	-29.77
4	Wheat - Rift valley	-32.58
5	Wheat - Rest of the zones	-28.15
6	Rice - Rift valley	-4.63
7	Rice - Semi-arid uplands	-27.45
8	Rice - Western	-8.04
9	Other cereals - Central highlands	-6.86
10	Other cereals - Semi-arid uplands	-7.95
11	Other cereals - Western	-8.87
12	Roots & tubers - Central highlands	-10.45
13	Roots & tubers - Western	-5.40
14	Roots & tubers - Rest of the zones	-4.53
15	Pulses & oil seeds - Semi-arid uplands	-29.44
16	Pulses & oil seeds - Western	-10.41
17	Pulses & oil seeds - Rest of the zones	-18.27
18	Fruits - Central highlands	-7.27
19	Fruits - Coast	-30.89
20	Fruits - Semi-arid uplands	-29.44
21	Fruits - Western	-10.41
22	Vegetables - Central highlands	-7.27
23	Vegetables -Western	-10.41
24	Vegetables -Rest of the zones	-18.27
25	Sugarcane - Rift valley	-11.97
26	Sugarcane - Western	-10.41
27	Coffee - Central highlands	-7.27
28	Coffee - Semi-arid uplands	-29.44
29	Coffee - Western	-10.41
30	Tea - Central highlands	-7.27
31	Tea - Western	-10.41
32	Others crops	-18.27

Appendix A: climate change impacts on yield across different crop sectors

Source: Authors' calculation based on data produced by ISIMIP2b model.

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No	Agricultural sector by zone	Changes in yield due to climate change
1	Exotic beef cattle - Central highlands	-10.27
2	Exotic beef cattle - Semi-arid uplands	-35.77
3	Exotic beef cattle - Western	-21.49
4	Dairy cattle - Central highlands	-10.27
5	Dairy cattle - Rift valley	-7.82
6	Dairy cattle - Western	-21.49
7	Poultry - Central highlands	-23.65
8	Poultry - Semi-arid uplands	-38.87
9	Poultry - Western	-2.60
10	Sheep & goats - Central asals	-22.00
11	Sheep & goats - North asals	-35.06
12	Sheep & goats - Semi-arid uplands	-35.77
13	Indigenous beef cattle - Central asals	-22.00
14	Indigenous beef cattle - North asals	-35.06
15	Indigenous beef cattle - Semi-arid uplands	-35.77
16	Indigenous beef cattle - Western	-21.49
17	Other livestock - Central highlands	-10.27
18	Other livestock - Western	-21.49
19	Other livestock - Rest of the zones	-21.49

Appendix B: climate change impacts on yield across different livestock sectors

Source: Authors' calculation based on data produced by ISIMIP2b model.