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CLIMATE CHANGE RISKS AND OPPORTUNITIES FOR EUROPEAN AGRICULTURE

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Abstract

European agriculture is increasingly exposed to climate change through a range of biophysical and economic channels, with impacts varying substantially across regions. This study analyses climate change risks and opportunities for European agriculture using the subnational version of the UCL Environmental Global Applied General Equilibrium (ENGAGE) model, calibrated to a 2017 Social Accounting Matrix consistent with Eurostat's NUTS-2 data and the FIGARO framework. The model explicitly represents 244 EU regions and disaggregated agricultural activities, allowing for a detailed assessment of regional heterogeneity. Climate impacts are introduced through two key mechanisms: heat-stress-induced reductions in labour productivity, estimated using the Wet Bulb Globe Temperature methodology, and crop yield changes derived from ISIMIP projections. Scenarios are evaluated under two Representative Concentration Pathways, RCP 4.5 and RCP 8.5. Results indicate that climate change is likely to amplify regional divergence in agricultural performance across Europe. Southern and parts of central European regions experience pronounced production losses due to declining yields and intensified heat stress, while some northern regions benefit from warmer conditions, leading to higher production and exports. These asymmetric impacts stimulate interregional and international trade adjustments generating uneven welfare and income effects. Overall, the findings highlight both significant climate-induced risks and market opportunities, underscoring the value of subnational general equilibrium analysis for designing targeted, climate-resilient agricultural policies in Europe.

Keywords: Computable General Equilibrium, Climate Change, Agriculture, Labour, Trade

JEL classification: D58, J24, Q17, Q54

1. Introduction

The European Union (EU) is one of the world's leading producers and exporters of agricultural products. Agriculture occupies 40 percent of the total EU land area and provides 22 million direct jobs, with a similar number of indirect jobs (EEA 2019). The European agricultural sector is already facing the impacts of climate change, with warming trends rapidly expanding across the continent, precipitation shifting toward more intense rainfall events, and prolonged droughts in vulnerable regions (EEA 2019). These climatic developments, which can be either positive or negative depending on the crop and geographical region, have profound implications for the productivity, structure, and resilience of agricultural and food systems. The European Commission's 2025–2035 outlook describes a sector that remains resilient but faces growing uncertainty arising from climatic, sustainability, and market pressures, including changing consumer preferences and environmental constraints (EC 2025). At the same time, recent assessments underline that adverse weather already generates more than €28 billion in annual agricultural losses across the EU, with projections suggesting these losses could rise by up to two thirds by mid-century in the absence of stronger adaptation and risk-management policies (Fi-compass 2025). Together, these trends underscore the urgency of analytical frameworks capable of evaluating climate impacts while maintaining fidelity to Europe's diverse regional agricultural structures and socio-economic conditions.

Climate change is expected to influence European agricultural and food systems through multiple interlinked biophysical and economic pathways. Southern Europe is particularly exposed to substantial yield reductions driven by repeated episodes of drought and excessive heat, whereas some northern regions may experience modest benefits from increased temperatures, including longer growing seasons and improved conditions for crop growth. In many areas, climate impacts extend beyond changes in crop yield to include soil degradation from heavy rainfall, water scarcity, ecosystem fragility, heat-stress-induced losses in labour productivity, and increased volatility in production costs. These physical effects translate into economic pressures manifested as more pronounced price fluctuations, shifts in competitiveness among regions, and changes in trade patterns, producing a broad landscape of winners and losers. The resulting distributional effects pose challenges for policy cohesion and long-term resilience.

2. Methodology

To analyse these dynamics with sufficient spatial and economic granularity, this study uses the subnational version of the UCL's Environmental Global Applied General Equilibrium (ENGAGE) model. The subnational-ENGAGE model is calibrated to a 2017 Social Accounting Matrix (SAM) that was constructed to be fully consistent with Eurostat's NUTS-2 statistical data and with the inter-country and NUTS-2-level versions of Eurostat's Full International and Global Accounts for Research in Input-Output Analysis (FIGARO) (Remond-Tiedrez & Rueda-Cantuche 2019). As formalised by Eurostat, the NUTS system provides harmonised and comparable regional data; with 244 EU regions (see Figure 1), NUTS-2 is the territorial scale most commonly used for EU regional policy and socio-economic analysis. The SAM explicitly covers 244 NUTS-2 EU regions, 41 regions in the United Kingdom (UK), 17 main EU trade partners[1], and one Rest of the World region. The single agricultural activity in the NUTS-2 version of FIGARO was disaggregated using Eurostat's Economic Accounts for Agriculture, allowing for the explicit identification of key agricultural sectors (Eurostat 2024). This procedure provides a comprehensive representation of six agricultural sectors, including wheat, cereals, rice, oilseeds, other crops, and livestock, animal products and other agricultural services. In addition to these six agricultural sectors, the subnational-ENGAGE model includes nine other aggregated sectors[2].

[1] Major extra-EU trading partners represented explicitly in the model include Argentina, Australia, Brazil, Canada, Switzerland, China, Indonesia, India, Japan, South Korea, Mexico, Norway, Russia, Saudi Arabia, Turkey, the United States, and South Africa. All remaining countries and regions are aggregated into a single Rest of the World account.

[2] Other sectors represented in the model include Industry (except construction); construction; wholesale and retail trade, transport, accommodation and food service activities; information and communication;

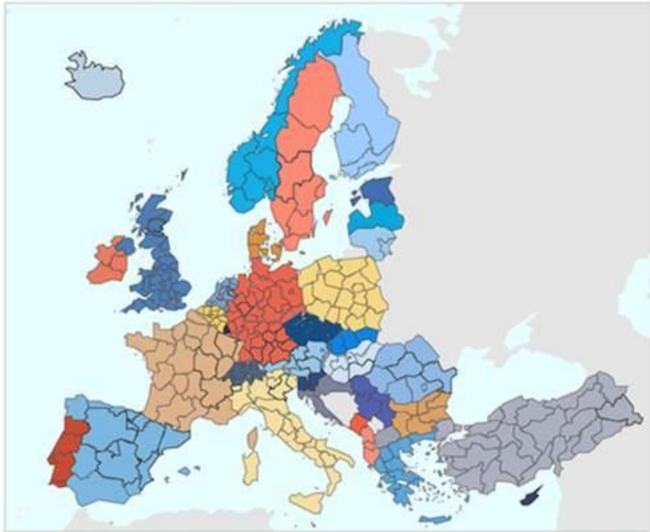

Figure 1: NUTS2 regions across Europe. Source: Eurostat.

3. Scenario analysis

The scenario analysis captures climate impacts on both labour productivity and agricultural yields. Heat-stress-induced reductions in labour productivity are estimated at the NUTS-2 level using the Wet Bulb Globe Temperature methodology, which incorporates monthly temperature and humidity data (Kjellstrom et al. 2009; Roson & Sartori 2016). Sector specific productivity losses, with a focus on agriculture, are aggregated to annual percentage changes under baseline and future climate scenarios and introduced as labour productivity shocks. In parallel, climate impacts on crop yields are derived from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), which provides global, gridded projections of yield changes for major crops (Warszawski et al. 2014). These projections are spatially aggregated to the NUTS-2 level and mapped to the model's agricultural sectors. The scenario analysis centres on two representative concentration pathways, RCP 4.5 and RCP 8.5, which frame the range of plausible climate futures.

This subnational analysis offers several key advantages for European agricultural research. By assessing shocks at the regional scale, the model identifies divergent regional trajectories that national-level models omit, revealing how climate change reshapes comparative advantages and production patterns given region-specific agronomic and economic conditions. The subnational framework allows the model to track how impacts in one region propagate across local, national and international supply chains, influencing production systems, trade patterns and regional welfare outcomes. Such an approach is essential for evaluating EU-wide strategies in which adaptation investments, insurance schemes, and structural reforms interact with economy-wide and general equilibrium adjustments. The ability to simulate region-specific responses also supports the design of targeted resilience strategies and enhances the alignment of climate policy with other development objectives.

4. Results and discussion

The results suggest that climate change is likely to amplify regional divergence in agricultural performance across Europe. Under RCP 8.5, regions in southern and parts of central Europe experience more severe contractions in agricultural production due to larger yield declines and intensified heat stress, whereas

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financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities; public administration, defence, education, human health and social work activities.

some northern regions may benefit from a warmer climate and ultimately experience increases in production and even larger increases in exports. European regions are directly affected by changes in local climate and indirectly by climate-induced changes in competitiveness. These asymmetries generate changes in income and welfare that are unevenly distributed across regions, with particularly pronounced consequences in climate-exposed territories. The model also indicates that interregional and international trade intensifies, partially offsetting domestic shocks and reorienting production and consumption in ways that have meaningful implications for price stability and food system resilience.

Figure 2 illustrates how physical climate change risks (exogenous yield changes introduced to the economic model) are translated to economic risks (the resulting changes in production, export, and regional welfare produced by the model). Yield changes represent direct biophysical impacts to crop yields and agricultural productivity due to different levels of temperature increase. Production changes reflect both direct and indirect effects, as farmers reallocate resources among crops in response to yield shocks that vary across crop categories. These adjustments, influenced by relative changes in prices, productivity and intersectoral competitiveness, lead to region-specific gains or losses in agricultural output. Export responses reflect in addition changes in interregional competitiveness and trade patterns, as regions gain or lose the ability to produce certain crops more efficiently than others. These shifts in comparative advantage—a region's relative efficiency in producing a good—are influenced by how severely climate impacts local and international productivity and prices. Welfare impacts represent aggregate household utility effects, represented by changes in regional income.

	Physical risk				Economic risk								
	Yield changes				Production changes				Export changes				Welfare changes
Regions	Rice	Wheat	Cereals	Other crops	Rice	Wheat	Cereals	Other crops	Rice	Wheat	Cereals	Other crops	
AFR	-2.6%	-8.0%	-7.1%	-7.1%	-1.9%	-4.9%	-2.7%	-5.1%	-2.9%	-4.5%	-5.7%	-10.5%	-1.3%
AUS	-2.7%	-6.9%	-4.9%	-4.6%	-0.1%	-6.5%	3.0%	-5.4%	-1.9%	-7.8%	3.5%	-8.6%	0.3%
CAN		5.5%	-3.5%	5.5%		23.2%	-3.8%	8.4%		28.2%	-7.5%	9.5%	2.4%
CHI	-2.3%	-8.1%	-4.5%	1.6%	-2.0%	-4.3%	-3.4%	3.7%	-4.9%	-9.8%	-5.3%	9.2%	-1.0%
CSA	-2.7%	-6.9%	-5.6%	-5.2%	-1.6%	-1.5%	-0.2%	-5.9%	-0.3%	-1.2%	1.0%	-7.7%	-0.3%
EEU	-2.0%	-5.6%	-2.3%	0.1%	-2.2%	-0.6%	0.4%	1.6%	-3.3%	-0.7%	1.5%	3.0%	0.2%
FSU	-2.1%	-2.9%	-2.4%	2.5%	-0.1%	2.5%	1.0%	3.9%	0.4%	4.8%	3.2%	7.6%	-0.1%
IND	-2.7%	-7.6%	-5.7%	-5.4%	-4.8%	-5.2%	-1.1%	-4.6%	-4.3%	-5.7%	-2.5%	-8.3%	-2.8%
JPN	-2.6%	-7.3%	-4.4%	-3.2%	-1.0%	3.5%	7.4%	-1.6%	1.1%	6.0%	11.2%	-0.8%	-0.1%
MEA	-2.4%	-8.0%	-4.6%	-5.1%	-0.8%	-2.5%	0.0%	-2.0%	-1.1%	-1.4%	2.5%	-2.9%	-0.9%
MEX	-2.7%	-8.2%	-5.6%	-6.3%	1.1%	0.8%	-0.1%	-6.7%	3.5%	1.0%	0.0%	-8.2%	-0.6%
ODA	-2.3%	-8.9%	-6.1%	-5.5%	-3.3%	-9.5%	-4.9%	-5.1%	-0.9%	-10.8%	-5.2%	-7.1%	-2.3%
SKO	-2.5%	-7.2%	-4.1%	-3.1%	-3.6%	-6.6%	1.3%	-2.0%	-4.4%	-6.6%	3.5%	-2.9%	-0.7%
UK		-2.3%	-1.6%	0.7%		2.2%	2.3%	4.4%		5.9%	4.3%	6.5%	0.2%
USA	-2.4%	-8.1%	-4.6%	0.8%	-3.2%	-10.5%	-1.1%	1.4%	-4.5%	-12.3%	-1.6%	1.5%	0.6%
WEU	-2.4%	-5.7%	-2.6%	-0.8%	-0.2%	1.3%	2.4%	0.9%	-0.6%	1.7%	3.6%	1.0%	0.7%

Figure 2: Percentage changes in regional welfare, and crop yield, production and exports relative to a business-as-usual baseline in 2050 under the high-emissions SSP5-8.5 scenario. Africa (AFR), Australia (AUS), Canada (CAN), China (CHI), Central and South America (CSA), Eastern Europe (EEU), Former Soviet Union (FSU), India (IND), Japan (JPN), Middle east (MEA), Mexico (MEX), Other Developing Asia (ODA), South Korea (SKO), United Kingdom (UK), USA (USA) and Western Europe (WEU).

The UK subnational results, presented in Figure 3, clearly demonstrate how climate impacts propagate unevenly across regions when biophysical shocks interact with market adjustments. Yield changes show marked spatial heterogeneity, with worsening outcomes in parts of Scotland and northern England contrasted with relative resilience or gains in Wales and South West regions. These biophysical shocks translate into similarly uneven production responses. Declines in wheat output are concentrated in northern regions, while eastern England, main wheat producer region, shows production gains. Export responses amplify this divergence, with eastern regions strengthening their export position as competitiveness improves. Welfare impacts reflect the combined effects of yield, production, and trade adjustments. Regions able to expand production and exports experience welfare gains, while more climate-exposed regions face welfare losses despite.

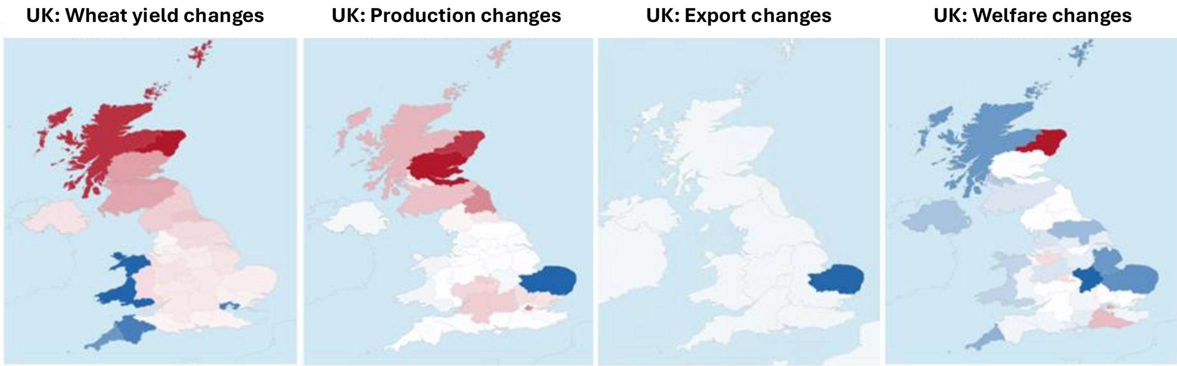

Figure 3: Percentage changes in welfare, and crop yield, production and exports in the UK relative to a business-as-usual baseline in 2050 under the high-emissions SSP5-8.5 scenario.

Overall, the findings highlight that European agriculture faces significant climate-induced risks but also possesses opportunities to reconfigure production systems, enhance resilience, and adapt to emerging climate and market conditions. The subnational-ENGAGE model provides a crucial framework for understanding these dynamics, combining spatial detail, economic consistency, and integration with biophysical information. Its ability to reveal the regional economic distribution of climate impacts and policy outcomes makes it particularly valuable for supporting climate-resilient agriculture and the design of localised adaptation strategies.

References

EEA. (2019). Climate change adaptation in the agriculture sector in Europe. European Environment Agency Report. No 04/2019

EC (2025). EU agricultural outlook, 2025-2035. European Commission, DG Agriculture and Rural Development, Brussels

Fi-compass (2025). Insurance and Risk Management Tools for Agriculture in the EU. https://www.fi-compass.eu/library/market-analysis/insurance-and-risk-management-tools-agriculture-eu.

Eurostat. (2024). Economic accounts for agriculture manual. https://doi.org/10.2785/780737

Kjellstrom, T., Kovats, R. S., Lloyd, S. J., Holt, T., & Tol, R. S. J. (2009). The direct impact of climate change on regional labor productivity. Archives of Environmental and Occupational Health, 64(4), 217–227.

Remond-Tiedrez, I., & Rueda-Cantuche, J. (2019). EU inter-country supply, use and input-output tables: Full international and global accounts for research in input-output analysis (FIGARO).

Roson, R., & Sartori, M. (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP9 Database. WORLD BANK POLICY RESEARCH WORKING PAPER. https://doi.org/10.1596/1813-9450-7728

Warszawski , L., Frieler, K., Huber, V., Piontek, F., Serdeczny, O., & Schewe, J. (2014). The inter-sectoral impact model intercomparison project (ISI-MIP): Project framework. Proceedings of the National Academy of Sciences of the United States of America, 111(9), 3228–3232.