The Macroeconomics of Adaptation: CROSSEU lessons & findings

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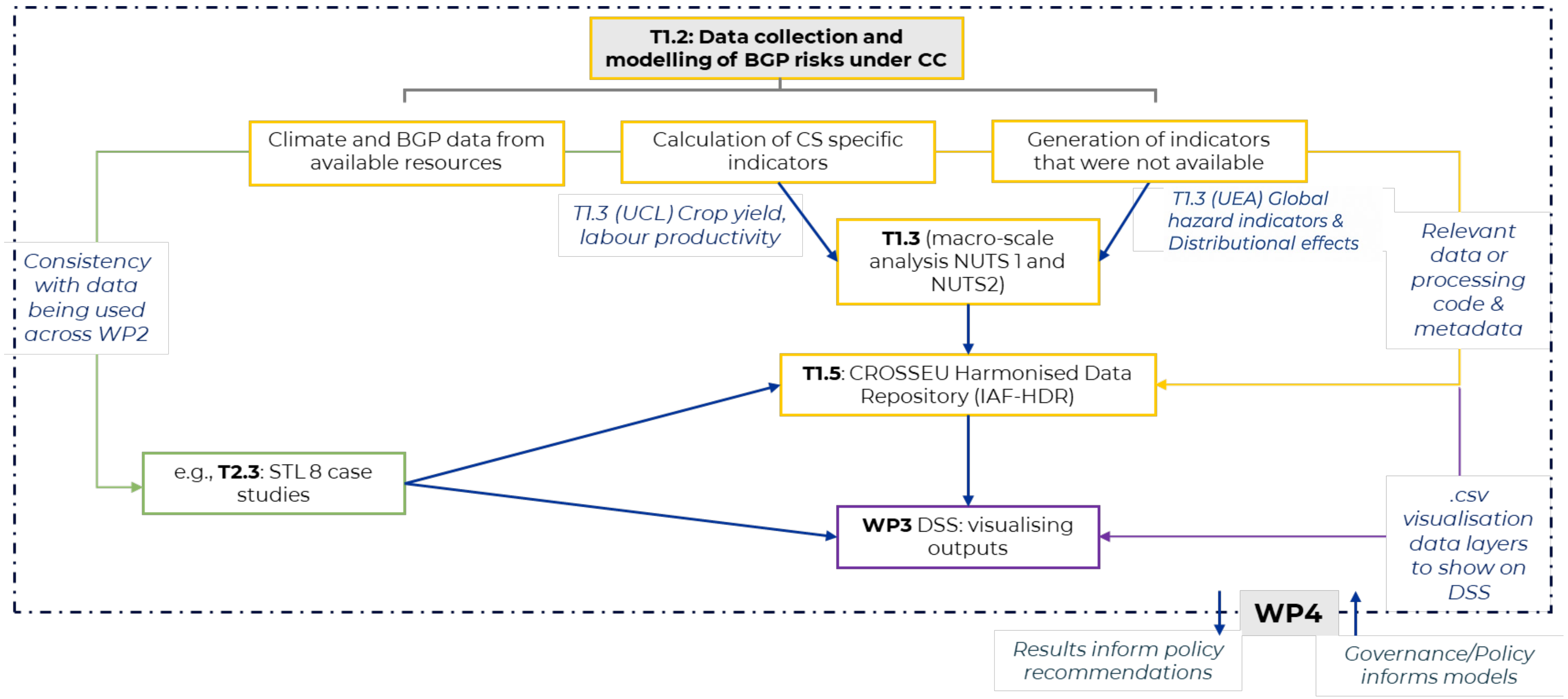
A brief introduction to the CROSSEU Project



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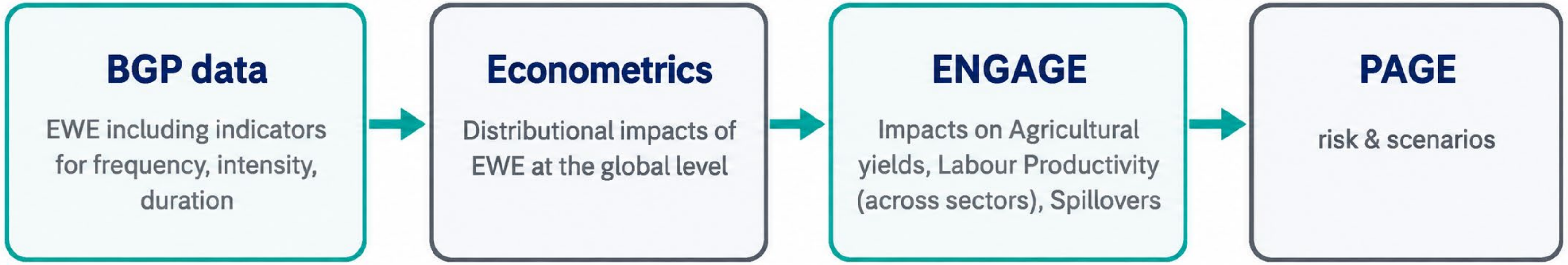
- CROSSEU links BGP indicators with socioeconomic models so that climate risks can be traced through income distribution, sectoral production, trade and welfare
  - It does this across both macro (global) and micro (local) scales: WP1 examines economy-wide effects, while WP2 explores local dynamics through case studies.
  - Today I focus on some of the global macroeconomic results, which are nevertheless well aligned with the broader case-study evidence.



This modelling chain helps answer policy questions that go beyond GDP losses: who is most affected, which sectors absorb the shocks, how impacts spill over, and what adaptation can realistically offset.

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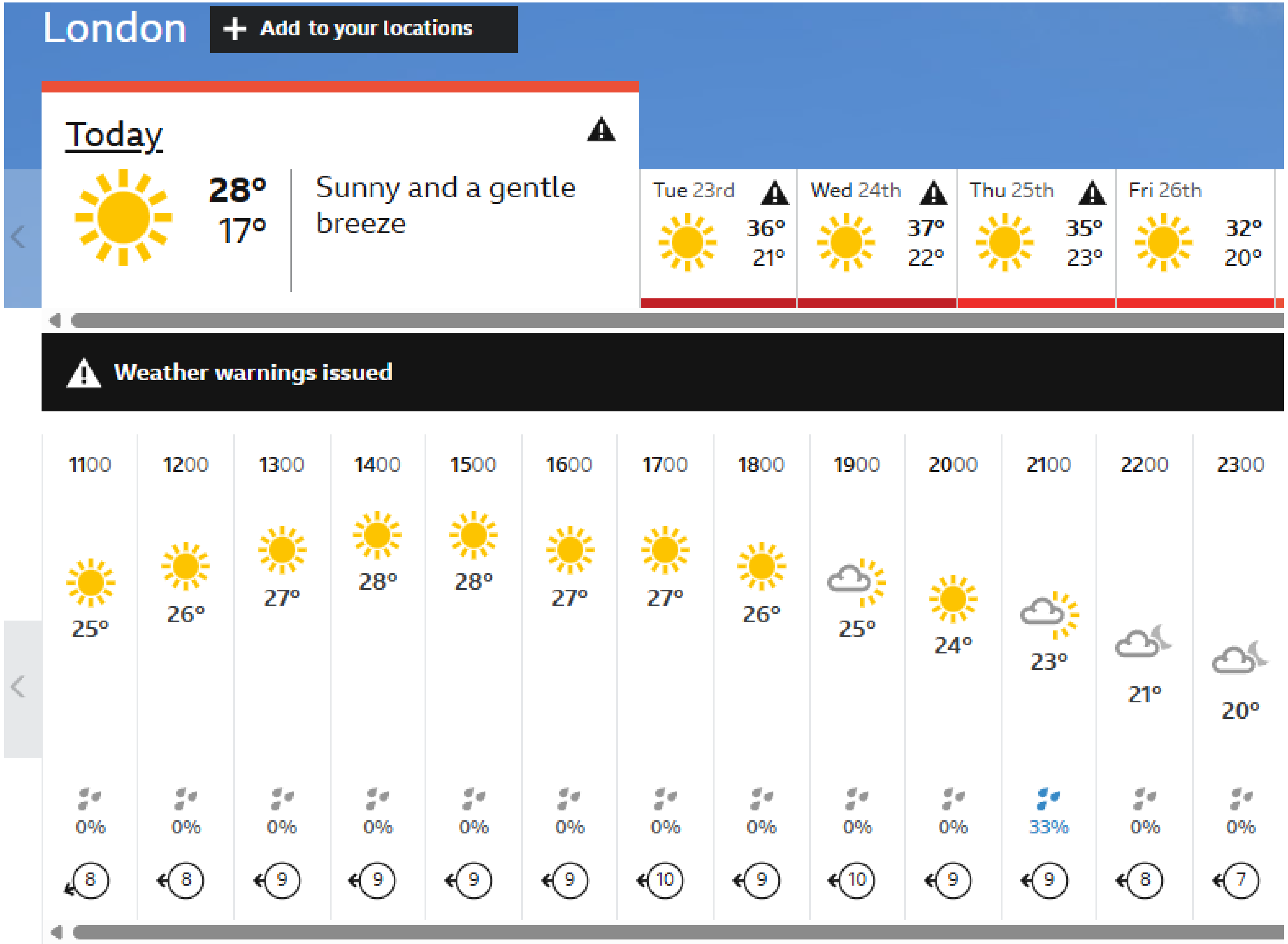
London
Add to your locations
Today
28°
17°
Sunny and a gentle breeze
Tue 23rd 36° 21°
Wed 24th 37° 22°
Thu 25th 35° 23°
Fri 26th 32° 20°
Weather warnings issued
1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300
25° 26° 27° 28° 28° 27° 27° 26° 25° 24° 23° 21° 20°
0% 0% 0% 0% 0% 0% 0% 0% 0% 0% 33% 0% 0%
8 8 9 9 9 9 10 9 10 9 9 8 7

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London

Add to your locations

Today

28° 17° Sunny and a gentle breeze

Tue 23rd	Wed 24th	Thu 25th	Fri 26th
36° 21°	37° 22	35°	32°

Weather warnings issued

1100	1200	1300	1400	1500	1600	1700	1800	1900
25°	26°	27°	28°	28°	27°	27°	26°	25°
0%	0%	0%	0%	0%	0%	0%	0%	0%
8	8	9	9	9	9	10	9	10

Four-day extreme heat warning begins as temperatures could hit 38C

Ben Rich

Lead Weather Presenter

21 June 2026 · 3592 Comments

Updated 9 hours ago

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JACOB OTTAWAY/BBC

Motorists - and even an inflatable alligator - found themselves stuck in flood water in Ipswich

George King
Suffolk

4 June 2026

h | Fri 26th
35° | 32°

ur-day extreme heat warning gins as temperatures could hit 38C

Updated 9 hours ago

0% 0% 0

8 8

4 March 2026 **Author(s):** Chloe Brimicombe

Wet winter, hot summer? What 'climate whiplash' means for the UK

Source(s): Conversation Media Group, the

After a dry 2025 with the UK's warmest summer on record, winter 2026 delivered something very different: rain for 50 days in a row in parts of Devon and Cornwall, one of the rainiest seasons on record and only 80% of average sunshine.

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Lesson 1: climate extremes are distributional shocks

Aggregate losses hide who is losing most.

Inequality

144
countries combined with percentile-level income data

P10
lower tail of the distribution is repeatedly exposed

↑
Gini and 90/10 ratios under several hazards

Empirical finding

Heatwaves, droughts and extreme precipitation tend to reduce incomes more strongly at the lower end of the distribution, widening inequality.

Interpretation

Climate shocks interact with labour markets, sectoral dependence, institutional capacity and financial buffers. Vulnerability is structural, not incidental.

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Climate variable name and definitions depicting how intensity (I) interacts with frequency (F)

Name	Definition
HW_IF	Standardised NF13 heatwave magnitude interacts with standardised NF13 heatwave number
CW_IF	Standardised NF13 coldwave magnitude interacts with standardised NF13 coldwave number
Icing_IF	Standardised annual area-weighted number of icing days interacts with the mean affected area (in km^2)
Hot_IF	Standardised annual area-weighted number of hot days interacts with the mean affected area (in km^2)
R10mm_IF	Standardised number of days with > 10mm rainfall over agricultural land interacts with average total agricultural area exposed to rainfall > 10mm, standardised to the total agricultural area (in km^2)
R95dmax_ IF	Standardised annual agricultural-area-weighted share of R95 exceedance days that interact with the within-year maximum cropland share exposed to an R95 exceedance
Drought_IF	Annual drought severity (mean SPEI over areas with SPEI < –1) interacts with the share of land affected by drought.

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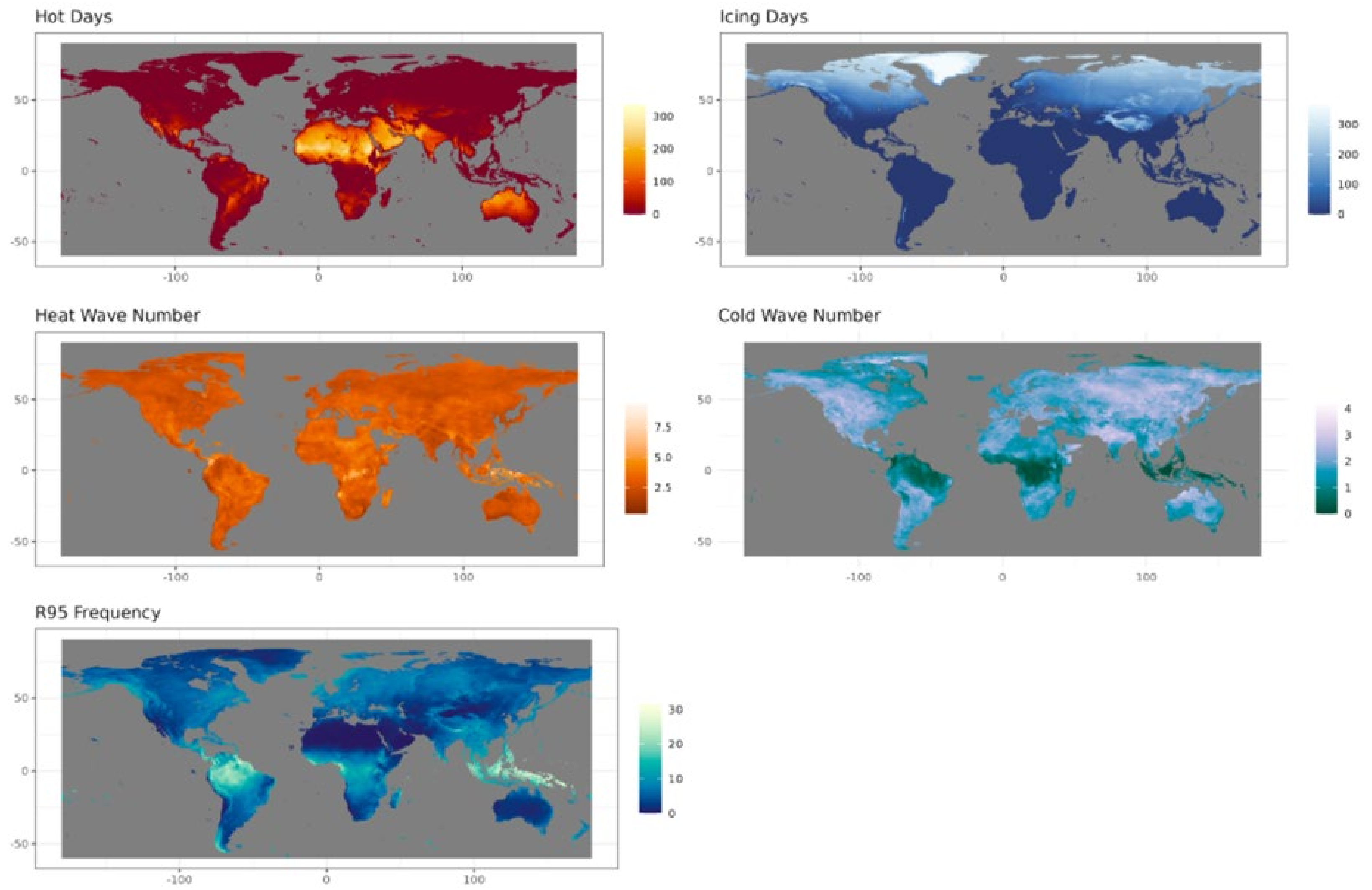
The modelled frequency of key climate variables aggregated over the time-period 1992-2024



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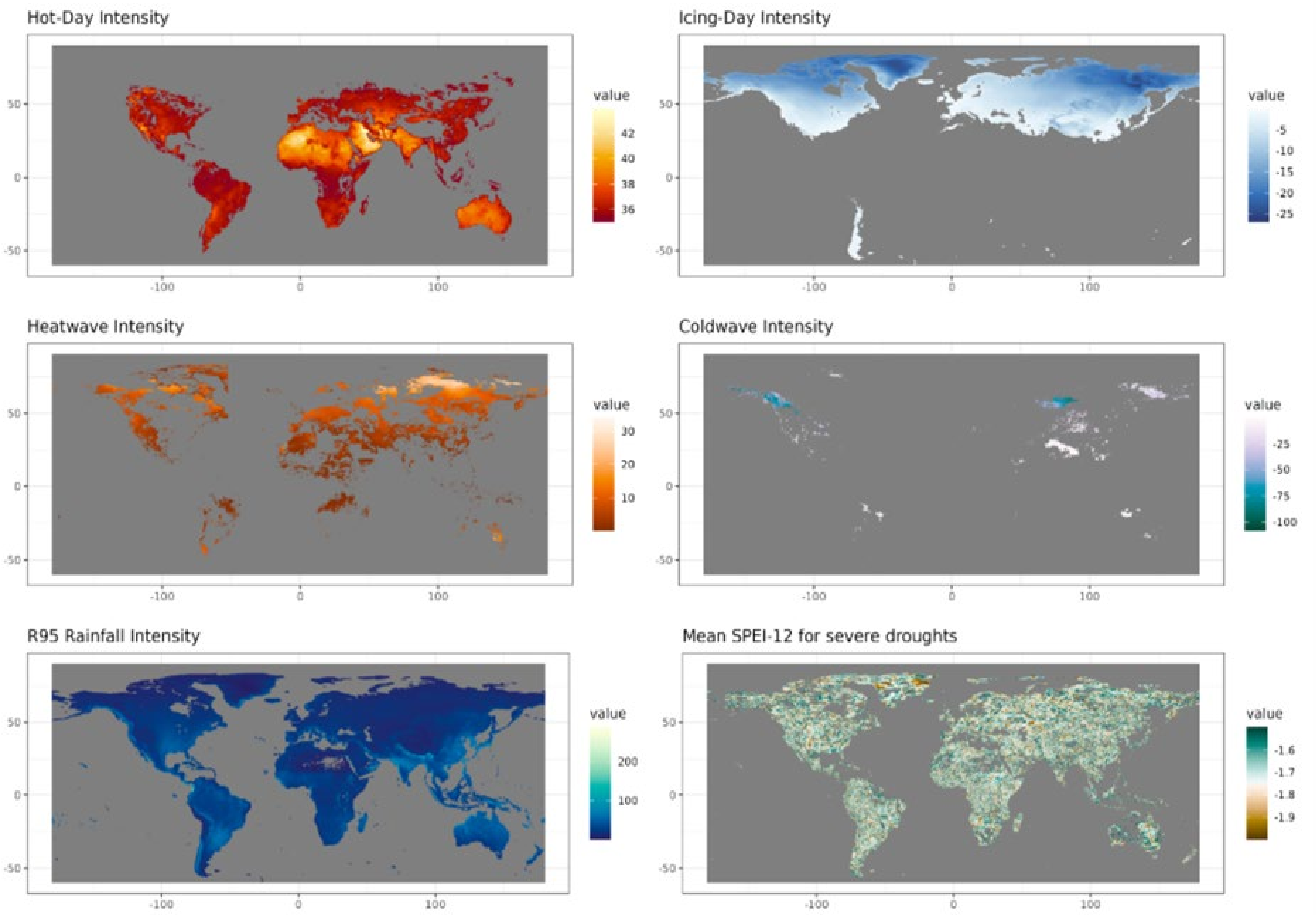
The modelled intensity of key climate variables aggregated over the time-period 1992-2024.



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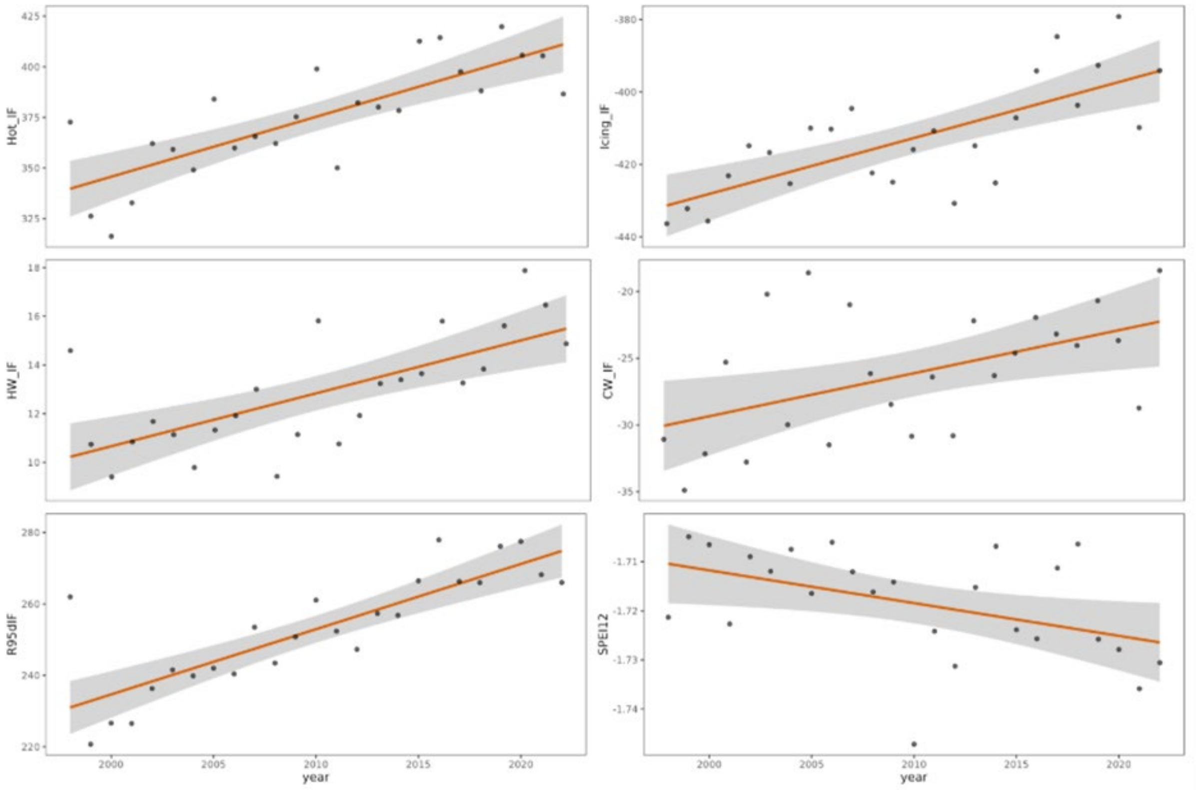
Global trend in the interaction between intensity and frequency of modelled climate variables from 1992-2022.



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Results

VARIABLES	(1) 90-10th ratio ln_r_avg_wel	(2) 90-10th ratio ln_r_avg_wel	(3) 90-10th ratio ln_r_avg_wel	(4) 90-10th ratio ln_r_avg_wel	(5) Gini ln_r_avg_wel	(6) Gini ln_r_avg_wel	(7) Gini ln_r_avg_wel	(8) Gini ln_r_avg_wel
HW_IF	0.021***	0.021***	0.021***	0.023***	0.003***	0.003***	0.002***	0.003***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.000)	(0.000)	(0.000)	(0.000)
CW_IF	0.034***	0.032***	0.034***	0.038***	0.002***	0.002***	0.003***	0.003***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)
Icing_IF	0.006***	0.007***	0.007***	0.006***	0.000**	0.000***	0.000***	0.000*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Hotdays_IF	0.009***	0.007**	0.007**	0.007**	0.002***	0.001***	0.001***	0.001***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
R95dIFmax	0.008***	0.005	0.003	0.007**	0.004***	0.004***	0.004***	0.004***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
ln_r_Agri_GDP	-0.937***				-0.243***			
	(0.010)				(0.002)			
ln_r_Ind_GDP		-0.896***				-0.235***		
		(0.010)				(0.002)		
ln_r_Serv_GDP			-0.922***				-0.239***	
			(0.010)				(0.002)	
PC_GDPsip				-1.343***				-0.348***
				(0.014)				(0.003)
Constant	-39.535***	-40.246***	-37.536***	-57.154***	-1.777***	-1.847***	-1.083***	-6.834***
	(1.838)	(1.840)	(1.828)	(1.805)	(0.178)	(0.179)	(0.181)	(0.156)
Observations	153,492	153,592	153,692	153,492	153,492	153,592	153,692	153,492
Time Effect	YES	YES	YES	YES	YES	YES	YES	YES
Country Effect	YES	YES	YES	YES	YES	YES	YES	YES

CrossEU

Results

VARIABLES	(1) 90-10 ln_r_avg_wel	(2) 90-10 ln_r_avg_wel	(3) 90-10 ln_r_avg_wel	(4) 90-10 ln_r_avg_wel	(5) Gini ln_r_avg_wel	(6) Gini ln_r_avg_wel	(7) Gini ln_r_avg_wel	(8) Gini ln_r_avg_wel
Drought_IF	0.001***	0.001***	0.001***	0.001***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
ln_r_Agri_GDP	-0.740***				-0.259***			
	(0.010)				(0.003)			
ln_r_Ind_GDP		-0.714***				-0.249***		
		(0.010)				(0.003)		
ln_r_Serv_GDP			-0.714***				-0.252***	
			(0.010)				(0.003)	
PC_GDPsip				-1.069***				-0.371***
				(0.015)				(0.004)
Constant	-46.256***	-42.169***	-43.756***	-58.999***	-1.623***	-1.011***	-0.469**	-6.616***
	(2.239)	(2.219)	(2.232)	(2.223)	(0.208)	(0.208)	(0.219)	(0.189)
Observations	111,193	111,393	111,393	111,193	111,193	111,393	111,393	111,193
Country Effect	YES	YES	YES	YES	YES	YES	YES	YES

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Results -- Full distribution (Agricultural sector)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Agri	Agri	Agri	Agri	Agri	Agri	Agri	Agri	Agri	Agri
VARIABLES	ln_ave_inc1	ln_ave_inc2	ln_ave_inc3	ln_ave_inc4	ln_ave_inc5	ln_ave_inc6	ln_ave_inc7	ln_ave_inc8	ln_ave_inc9	ln_ave_inc10
HW_IF	-0.016***	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***	-0.011***
	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
CW_IF	-0.012**	-0.010**	-0.009**	-0.008**	-0.009**	-0.009**	-0.009**	-0.009**	-0.009**	-0.009**
	(0.006)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Icing_IF	-0.022**	-0.016**	-0.011	-0.006	-0.005	-0.006	-0.006	-0.007	-0.007	-0.010
	(0.010)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Hotdays_IF	-0.022***	-0.015***	-0.012**	-0.011**	-0.011**	-0.011**	-0.012**	-0.010*	-0.011**	-0.011*
	(0.008)	(0.006)		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
ln_real_Agri_GDP	0.027***	0.024***	0.021***	0.019***	0.018***	0.019***	0.019***	0.019***	0.019***	0.009
	(0.009)	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
ln_Pop_1564	-0.489***	-0.644***	-0.681***	-0.690***	-0.680***	-0.677***	-0.666***	-0.662***	-0.662***	-0.716***
	(0.068)	(0.049)	(0.047)	(0.046)	(0.047)	(0.047)	(0.047)	(0.047)	(0.046)	(0.050)
Unemp_rate	-1.840***	-1.408***	-1.325***	-1.267***	-1.269***	-1.297***	-1.301***	-1.282***	-1.249***	-1.394***
	(0.189)	(0.138)	(0.131)	(0.130)	(0.131)	(0.131)	(0.131)	(0.131)	(0.130)	(0.139)
Female_rate	-0.234	-0.189	-0.173	-0.180	-0.180	-0.154	-0.128	-0.124	-0.143	-0.247**
	(0.161)	(0.117)	(0.112)	(0.111)	(0.111)	(0.112)	(0.112)	(0.112)	(0.111)	(0.119)
Trade_Openess	0.197**	0.201***	0.194***	0.198***	0.210***	0.202***	0.204***	0.205***	0.208***	0.199***
	(0.089)	(0.065)	(0.062)	(0.061)	(0.061)	(0.062)	(0.062)	(0.062)	(0.061)	(0.066)
DCPS	0.057**	0.078***	0.082***	0.081***	0.079***	0.076***	0.078***	0.081***	0.085***	0.105***
	(0.026)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)
IQ_PC	0.077***	0.077***	0.085***	0.089***	0.091***	0.090***	0.090***	0.090***	0.089***	0.071***
	(0.013)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)
polarisation	-5.414***	-3.628***	-2.789***	-2.273***	-1.834***	-1.393***	-0.959***	-0.501***	0.040	1.353***
	(0.165)	(0.120)	(0.114)	(0.113)	(0.114)	(0.114)	(0.114)	(0.114)	(0.113)	(0.121)
Constant	13.908***	16.320***	16.909***	17.090***	16.966***	16.913***	16.744***	16.709***	16.803***	18.188***
	(1.089)	(0.790)	(0.753)	(0.749)	(0.750)	(0.754)	(0.754)	(0.753)	(0.749)	(0.801)
Observations	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
R-squared	0.682	0.721	0.698	0.672	0.646	0.621	0.596	0.570	0.543	0.498
Number of country_id	145	145	145	145	145	145	145	145	145	145
Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Distributional effects of extreme weather events on agriculturally dependent countries.

Climate Events	Non-dependent	Dependent	Difference
Heatwave	↑ inequality	↓ inequality	Reversal (↓)
Coldwave	↑ inequality	~0	Weaker
Icing Days	↑ (small)	~0	Weaker
Hot Days	~0	↑↑ inequality	Stronger
Extreme Rain (R95dIFmax)	↑ inequality	↑↑↑ inequality	Much Stronger
Drought	↑ inequality	~0	Neutralised

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Distributional effects of extreme weather events across KG climate zones.

Climate Events	Arid (baseline)	Cold	Temperate	Trop-Temp	Tropical	Varied
Heatwave	↑ (widen)	~0	~0	↓	↓	~0
Coldwave	↑	↑↑	↑↑↑	↓	~0	~0
Icing Days	↑ (small)	~0	~0	unstable (↓)	unstable (↑)	↓
Hot Days	↑ (small)	↓	~0	(weak) ↓	↑↑	~0
Extreme Rain (R95dIFmax)	↑	↓	↓	↓	↓	↓
Drought	↑	↓	↓	~0	↓	~0

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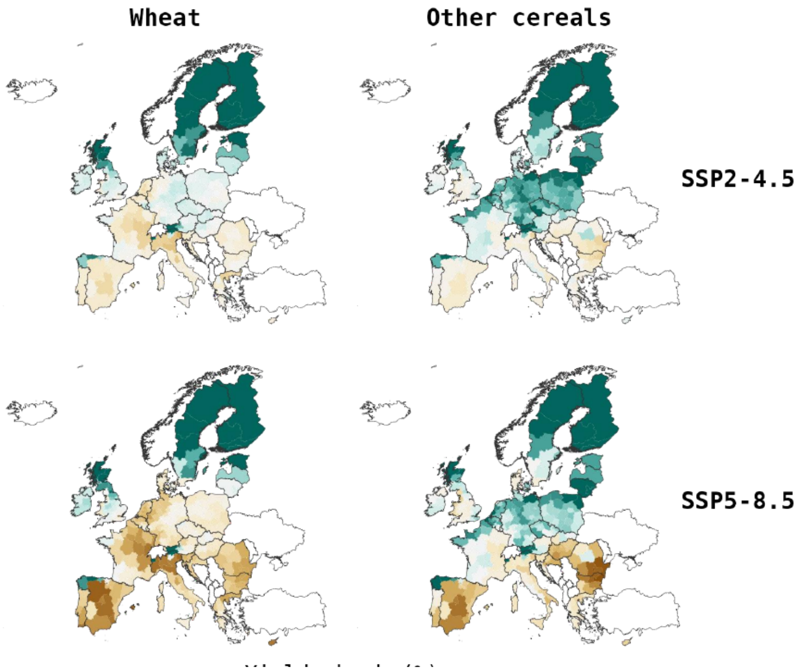
Lesson 2: climate risk changes economic geography

Physical impacts are spatially uneven before markets respond.

Exposure



End-of-century attainable yield shocks for wheat (left column) and other cereals (right column) under SSP2-4.5 (upper row) and SSP5-8.5 (lower row) across EU27+UK NUTS2 regions.

Crop-yield impacts show gains in parts of northern/central Europe and losses in Mediterranean and western agricultural systems.

GCM ensemble-mean labour productivity deviation from the 1981–2010 baseline (%), averaged over 2081–2100, for the agricultural, manufacturing, and services sectors (columns) under SSP2-4.5 and SSP5-8.5 (rows). Heat-related labour productivity losses persist across agriculture, manufacturing and services, with strong southern exposure.

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ENGAGE: translating shocks into economy-wide effects

Subnational CGE modelling captures spillovers beyond directly affected sectors.

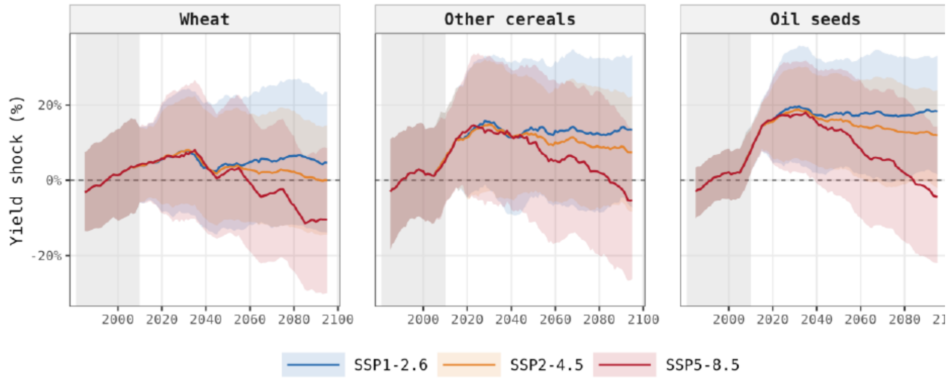

Figure 6: : Area-weighted EU27+UK mean attainable yield shocks for wheat (left), other cerea (centre), and oil seeds (right) over the period 1981–2100 under SSP1-2.6 (blue), SSP2-4.5 (orange), an SSP5-8.5 (red). Lines show the 10-year centred rolling mean of the GCM ensemble mean; shade bands show the corresponding GCM ensemble minimum-to-maximum range. Shocks ar expressed as percentage deviations relative to the 1981–2010 baseline period (grey shading). High

Model coverage

EU27 + UK	subnational regions
17 trade partners	plus Rest of World
11 sectors	including 6 agricultural sectors
2050 SSP2 baseline	climate shocks and adaptation

The key value of CGE modelling is not just estimating direct losses. It shows how adaptation affects prices, trade, factor income, and social welfare (supported by the econometric analysis).

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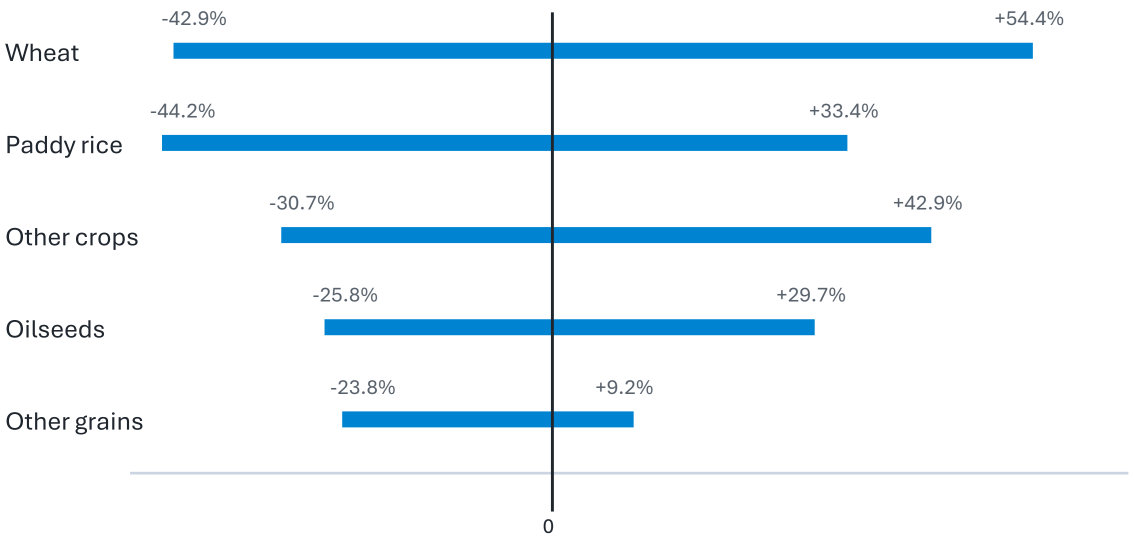
Lesson 3: modest aggregate losses can mask large regional divergence

Averages can be misleading for policy.

Spatial divergence

Under high-emissions crop-yield impacts, European averages can look benign while regional outcomes diverge sharply.

Regional output range under AL85 (% change)



Policy implication

Adaptation cannot be designed from national or European averages alone. It needs spatial targeting, especially for exposed southern and Mediterranean regions.

The macroeconomic problem is redistribution of activity, not only absolute loss.

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Adaptation portfolio: three levers, three channels

Each adaptation option acts on a different part of the system.

Adaptation

Climate-resilient crop varieties

Reduce yield losses

Crop-productivity channel

Irrigation expansion

Reduce water stress

Rainfed to irrigated production

Mechanisation

Substitute capital for labour

Heat-stress labour channel

Combined adaptation helps identify avoided damages and residual climate risk after multiple measures are applied simultaneously.

Lesson 4: climate risks spill over through the economy

Local shocks can propagate through prices, trade, supply chains and welfare.

Spillovers

Local climate shock
yield or labour productivity loss

Markets & prices
input costs, output prices, demand

Trade & supply chains
imports, exports, competitiveness

Regional welfare & inequality
winners, losers, residual risk

The relevant boundary is the economic system, not the location of the weather event.

What this means for adaptation policy

1. Do not assess adaptation only at the point of impact.
2. Trace price, trade and supply-chain channels.
3. Monitor who gains, who loses and what residual risk remains.

Policy takeaway: ask not only where the hazard occurs, but where its economic effects travel.

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Lesson 5: adaptation reduces damages, but residual risk remains

Some risks are avoided; others are redistributed or persist.

Limits

Adaptation can mitigate crop losses and strengthen production-system resilience.

But effects are uneven: measures can benefit some regions while leaving others exposed or changing trade patterns.

Mechanisation improves flexibility but does not remove the underlying heat-related labour-productivity shock.

Lesson: adaptation is necessary, but it is not a substitute for mitigation or social protection.

Lesson 6: risk changes the economics of timing

Accounting for environmental risk strengthens the case for earlier action.

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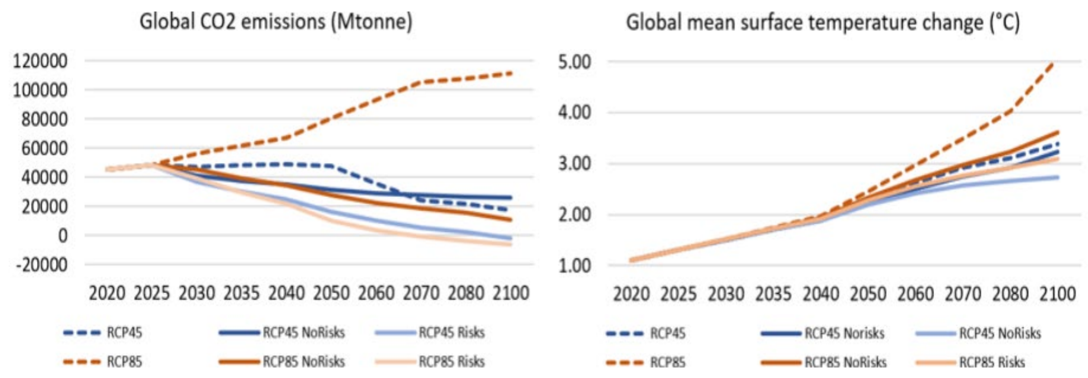

Original SDR → **Risk-adjusted SDR** → **Earlier action**

Standard discounting focuses on consumption growth. CROSSEU extends the logic to environmental risk exposure: future generations may be wealthier, but they also face higher climate risk.

When environmental risk is incorporated into the social discount rate, future damages receive more weight and earlier mitigation becomes more attractive.

Adaptation and mitigation are linked through risk: the less risk we reduce now, the more we transfer to future welfare.

Policy implications

Adaptation should be designed as economic resilience policy.

1	**Target spatially**	regional vulnerability and economic structure matter
2	**Combine measures**	crop, water and labour channels interact
3	**Protect distributionally**	climate shocks are regressive
4	**Monitor residual risk**	adaptation lowers risk but leaves exposure
5	**Link with mitigation**	risk-adjusted welfare favours earlier action

Lessons learned in a nutshell

1. Climate extremes are distributional shocks, not just aggregate output shocks.
2. Economic structure and adaptive capacity determine who absorbs losses.
3. Climate risks spill over through prices, trade and supply chains.
4. Climate change reshapes economic geography and comparative advantage.
5. Adaptation reduces damages but leaves uneven residual risk.
6. Risk-aware policy strengthens the case for earlier, integrated action.

Adaptation is most effective when it is treated as part of an integrated economic resilience strategy.

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