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Assessment of the economic cascading effect on future climate change in China: Evidence from agricultural direct damage

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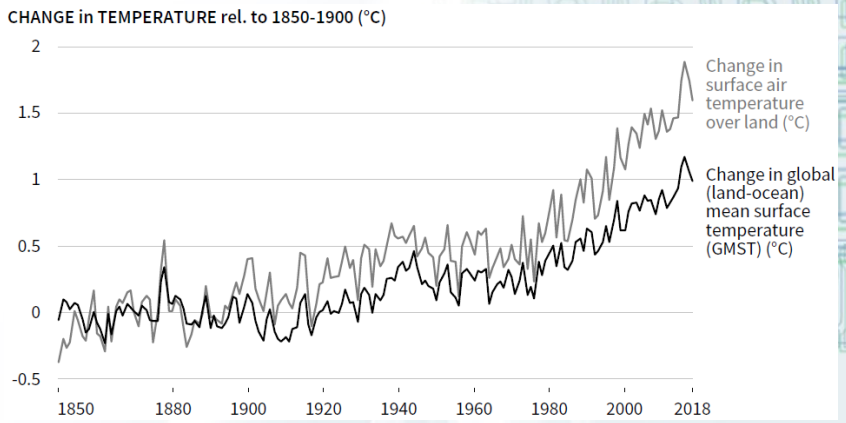
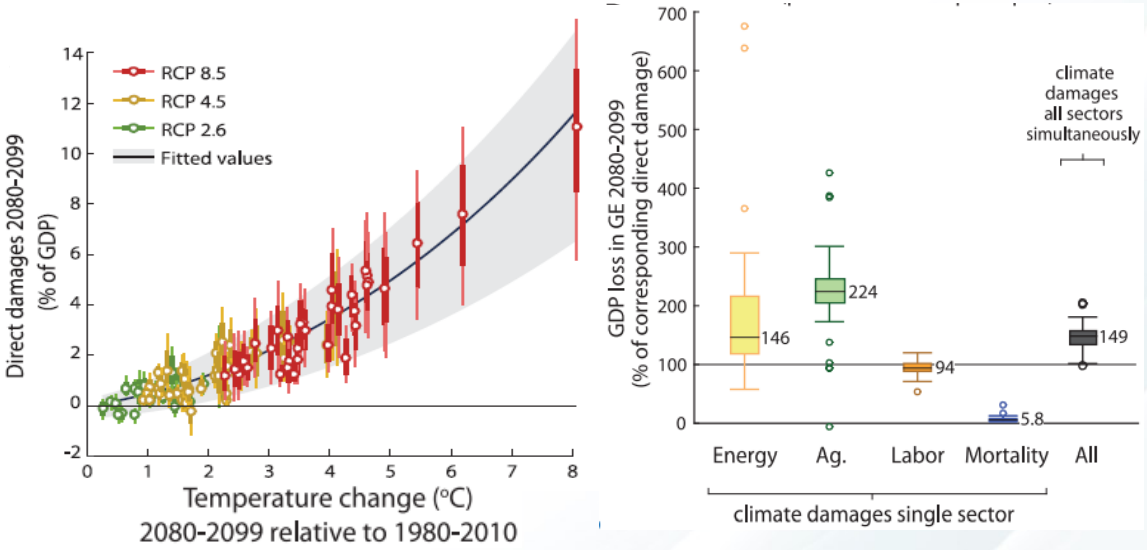
Background--Climate change/Economic impact

Mounting evidence indicates that the climate is changing, prompting a growing effort to understand the likely **economic impact** of these changes.



IPCC Special Report on Climate Change and Land, 2019

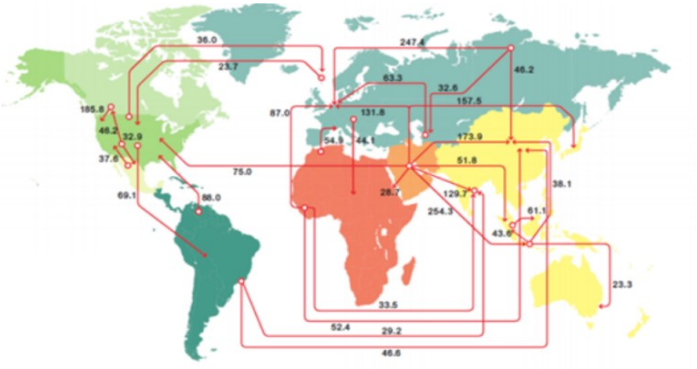


Solomon et al. 2017 *Science*

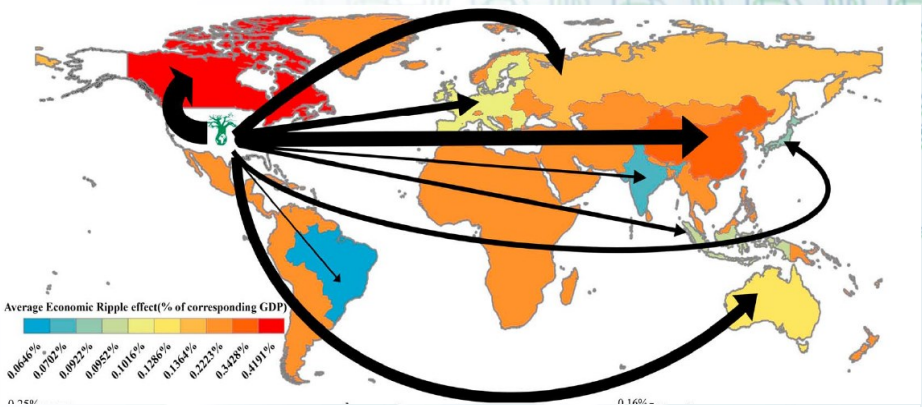
The combined value of market and nonmarket **damage** across analyzed sectors—agriculture, crime, coastal storms, energy, human mortality, and labor—increases quadratically in global mean temperature, costing roughly **1.2%** of gross domestic product per +1°C on average.

Due to **industry linkages**, they simulated the **indirect economic impact (IEI)** caused by climate change between 2080 and 2090 using an indirect economic assessment model.

Background--Economic ripple effects/Industrial linkage

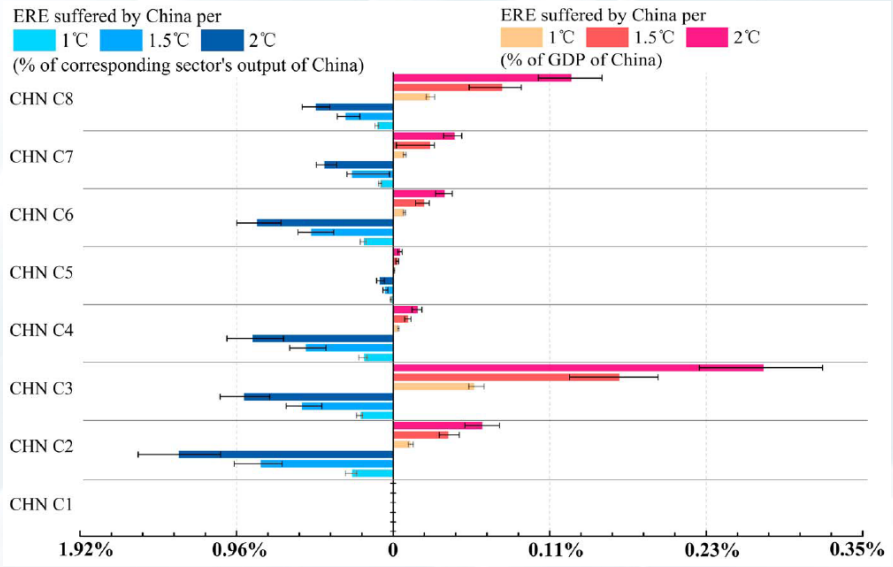


Trade networks among regions
Supply and demand chains among sectors



Economic ripple effects (ERE)

They found that if a loss of GDP of 0.88% occurs with a 1°C annual mean temperature (AMT) increase in the United States, the ERE of approximately 0.12% will be generated onto the global GDP; with a 2°C increase, the ERE will triple.

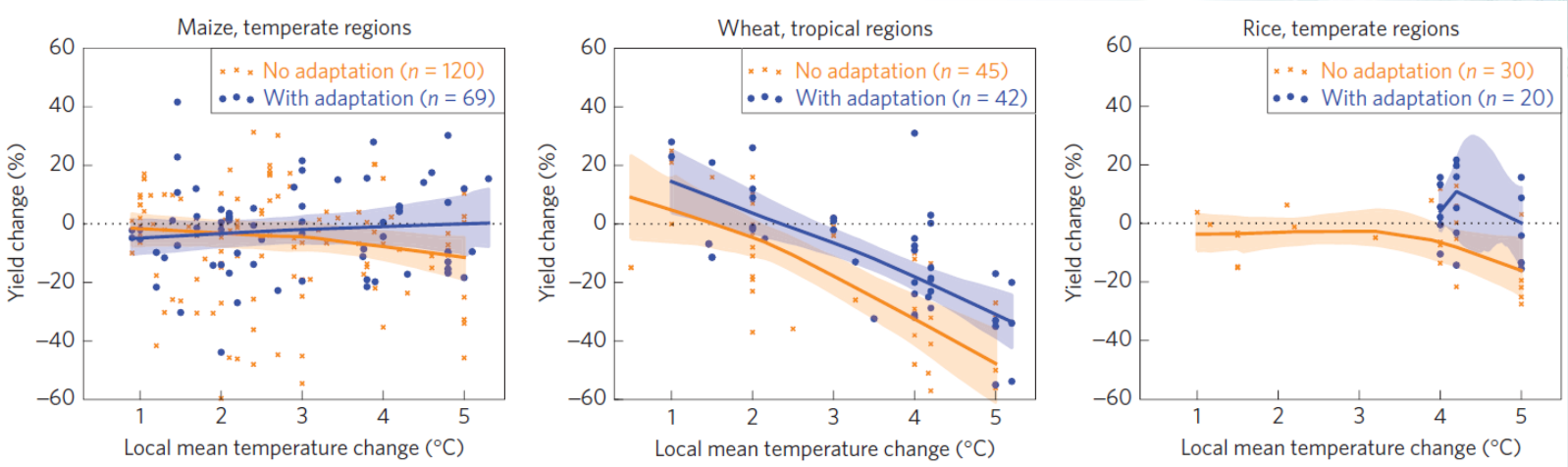


Z.Zhang et al. 2018 *Earth's Future*

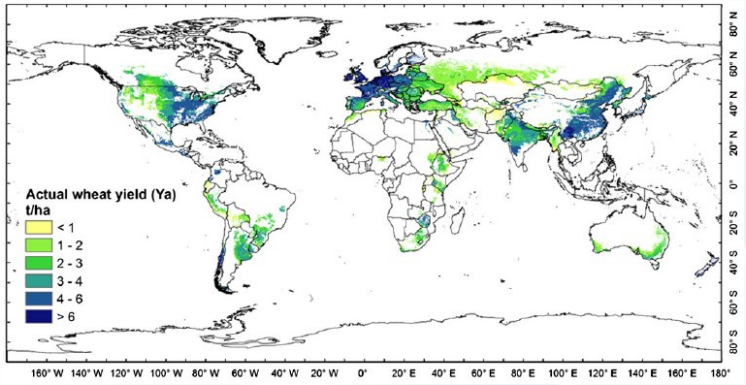
And the economic impact **China suffers** as a result of US economic changes may **increase by 4.5 times** as AMT increases from 1 to 2° C.

Background--Crop yield/China

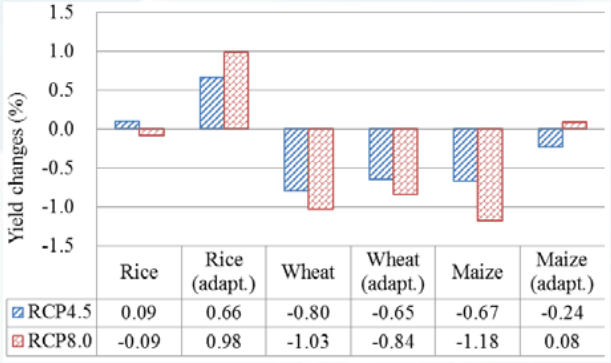
Agriculture is one of the economic sectors that is most vulnerable to climate change. The most significant and direct impact of climate change on agriculture is the **negative impact on crop yields**.



Challinor et al. 2014 *Nature Climate Change*



Juraj Balkovič et al. 2014 *Global and Planetary Change*



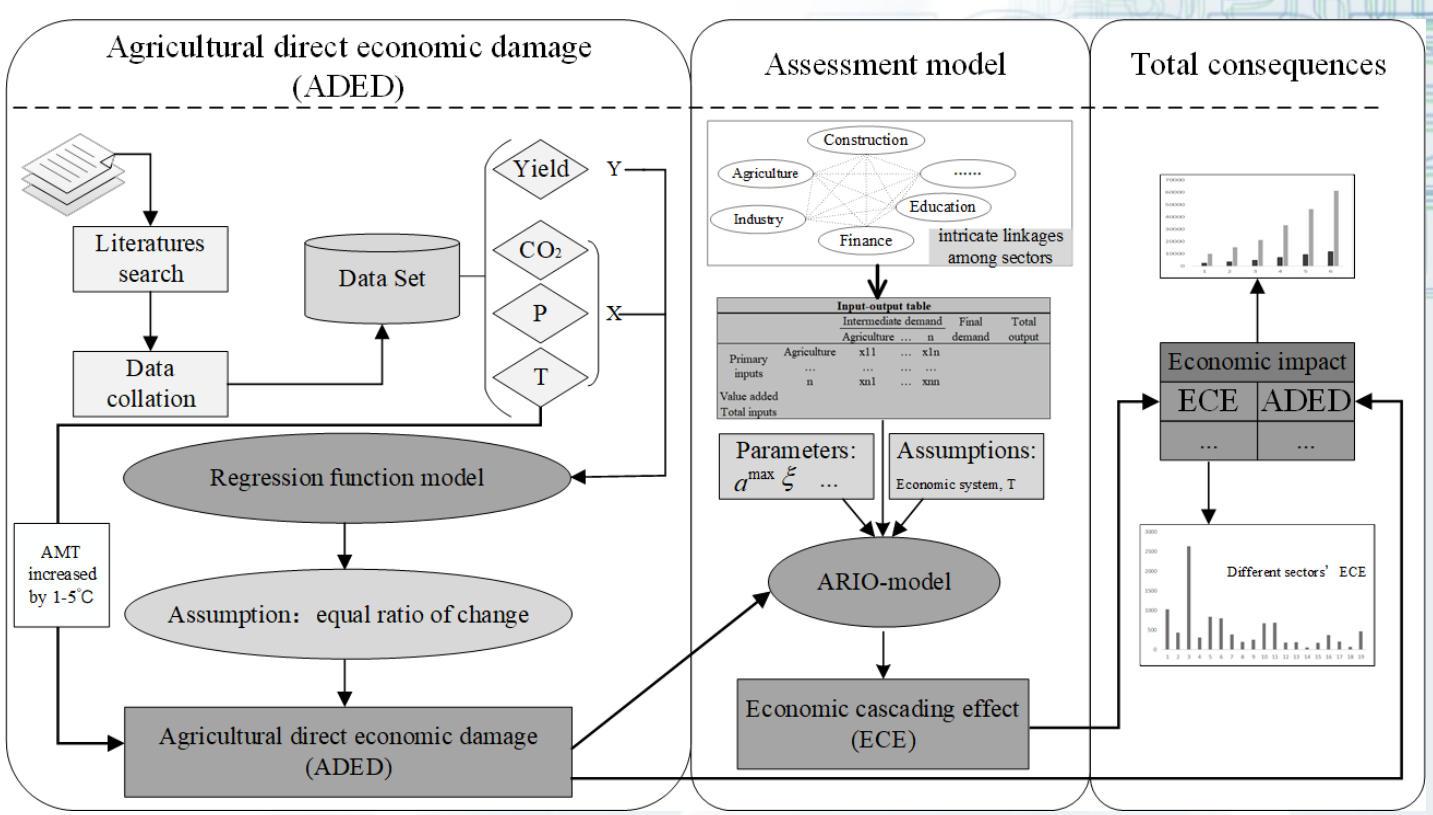
	Rice	Rice (adapt.)	Wheat	Wheat (adapt.)	Maize	Maize (adapt.)
RCP4.5	0.09	0.66	-0.80	-0.65	-0.67	-0.24
RCP8.0	-0.09	0.98	-1.03	-0.84	-1.18	0.08

J. Liu. 2015 *CJUES*

Idea--China/Economic impact/Agriculture damage

Assess the possible potential economic impact of future climate change on China.

- To explore the future macroeconomic impact of climate change on China's agriculture and even its national economy
- To reveal the amplification effect of industrial linkage on ADED.



Overview of the different components of the framework.

- **Agricultural direct economic damage (ADED):** the damage to the direct economic output of the agricultural sector due to the impact of future climate warming on the decrease in yields. ——Model input
- **Adaptive regional input–output model (ARIO):** dynamically simulate the complex supply-demand relationship among sectors, and assess the macroeconomic effect at regional and sectoral levels through effects on intermediate consumption and demand. ——Model approach
- **Economic cascading effect (ECE):** due to the complex industrial linkage among sectors in the economic system, the ADED must have an impact on other economic sectors. ——Model results

Methods--Input-output table/ARIO

The basic framework of the input-output table

		Processing demand				Final Demand	Total Output
		Agriculture	Sector 2	……	Sector n		
Processing outlays	Agriculture	x_{11}	x_{12}	……	x_{1n}	y_{11}	Q_1
	Sector 1	x_{21}	x_{22}	……	x_{2n}	y_{21}	Q_2
	……	……	……	……	……	……	……
	Sector n	x_{n1}	x_{n2}	……	x_{nn}	y_{n1}	Q_n
Value added		V_1	V_2	……	V_n		
Total outlays		Q_1	Q_2	……	Q_n		

Climate change ⇒ Crop yield decline ⇒ Agriculture output damage

Total output decline ⇐ Other sectors ⇐

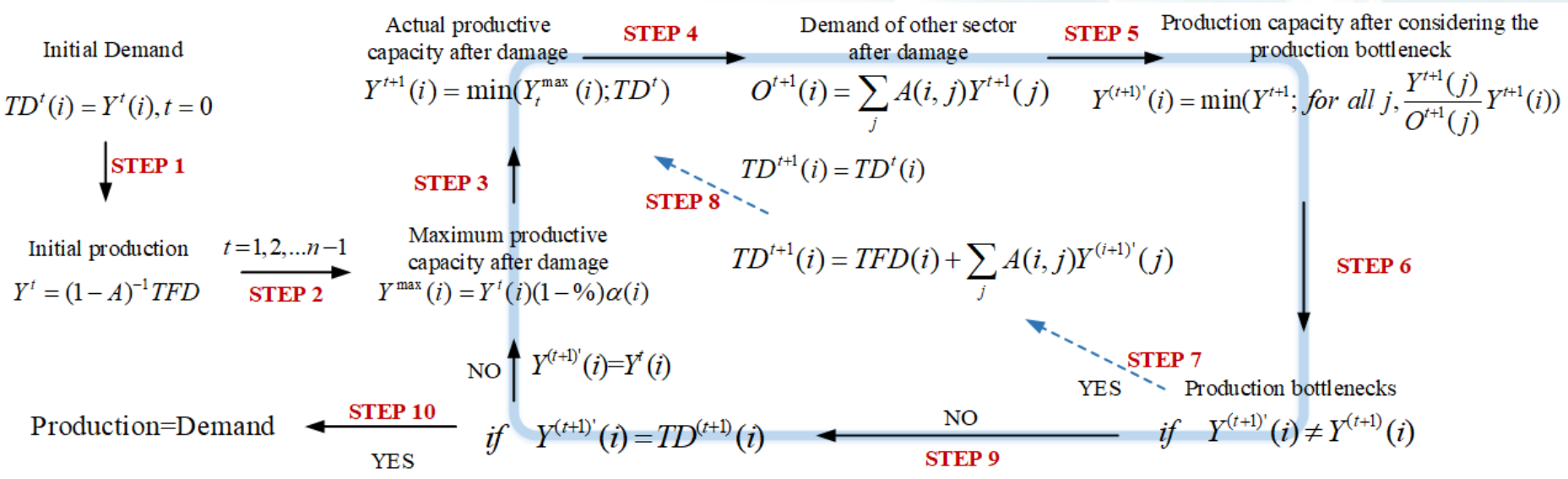
The input-output (IO) table can comprehensively and systematically reflect the interrelation of sectors of the national economy from production to final use in the whole goods movement process.

Methods--Input-output table/ARIO

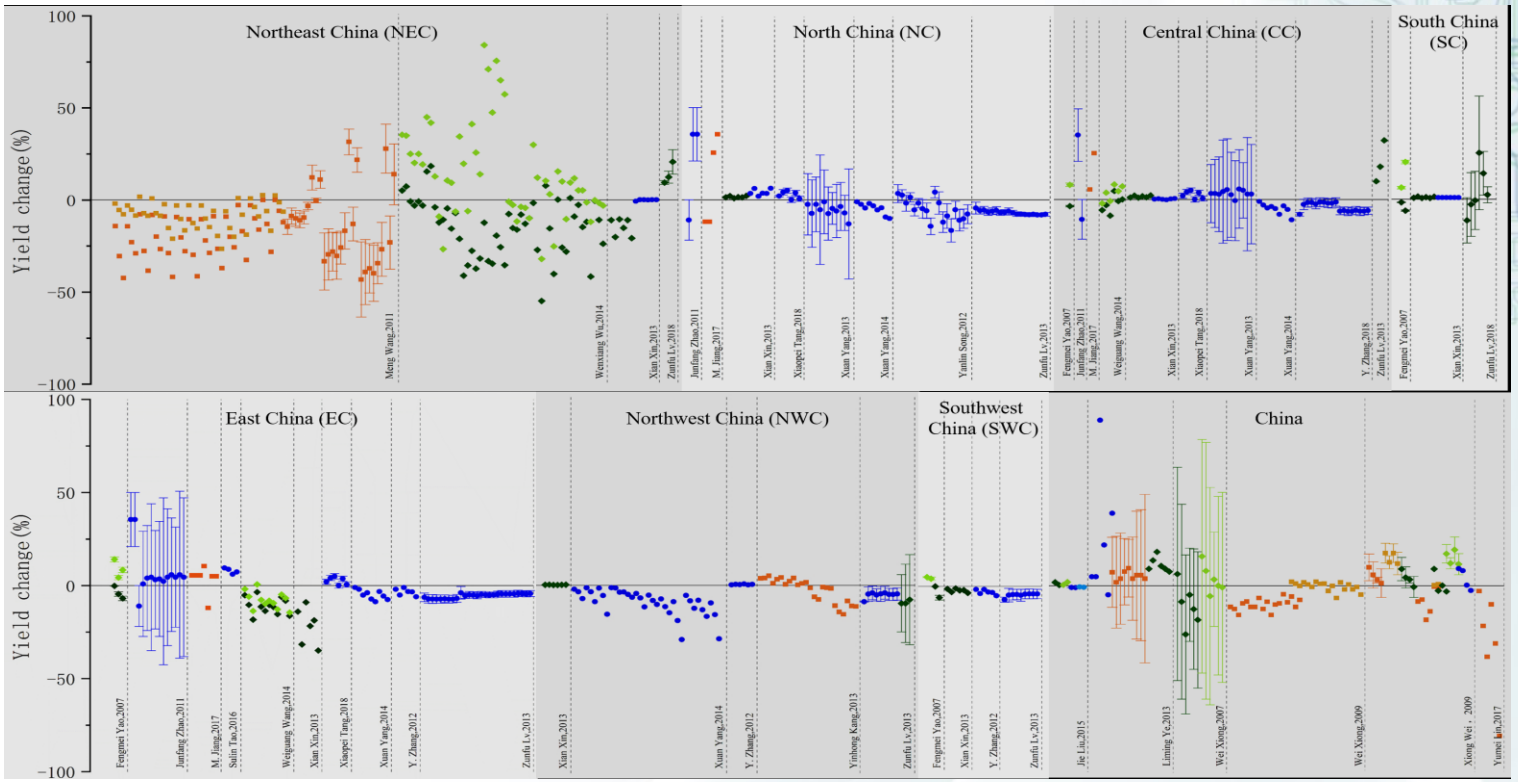
The core formula of *Adaptive Regional Input–Output* (ARIO) model:

Intermediate Demand

production | IO matrix | local final demand | exportation | damage to households and industries



Data--Agriculture direct economic damage



Regression model:

$$\Delta Y_{ijmn} = \alpha_0 + \alpha_1 \times \Delta T_{mn} + \alpha_2 \times \Delta P_{mn} + \alpha_3 \times CO_{2i} + \varepsilon_{ijmn}$$

Term	Coefficient	s.e.m.	t	P
ΔT	-2.61	0.71	-3.73	<0.001***
ΔP	0.06	0.15	-0.40	0.771
CO_2 fertilization (no=0; yes=1)	9.23	1.27	6.76	<0.001***

The impact of climate change on crop yields was mainly reflected in temperature increases, **with an average yield loss of 2.61% per ℃.**

Liu et al. 2019 *Science of the Total Environment*

Data—Assumptions/ADED/Parameters

- The assumption of ADED: the change of yield is equivalent to the change in agricultural economic output

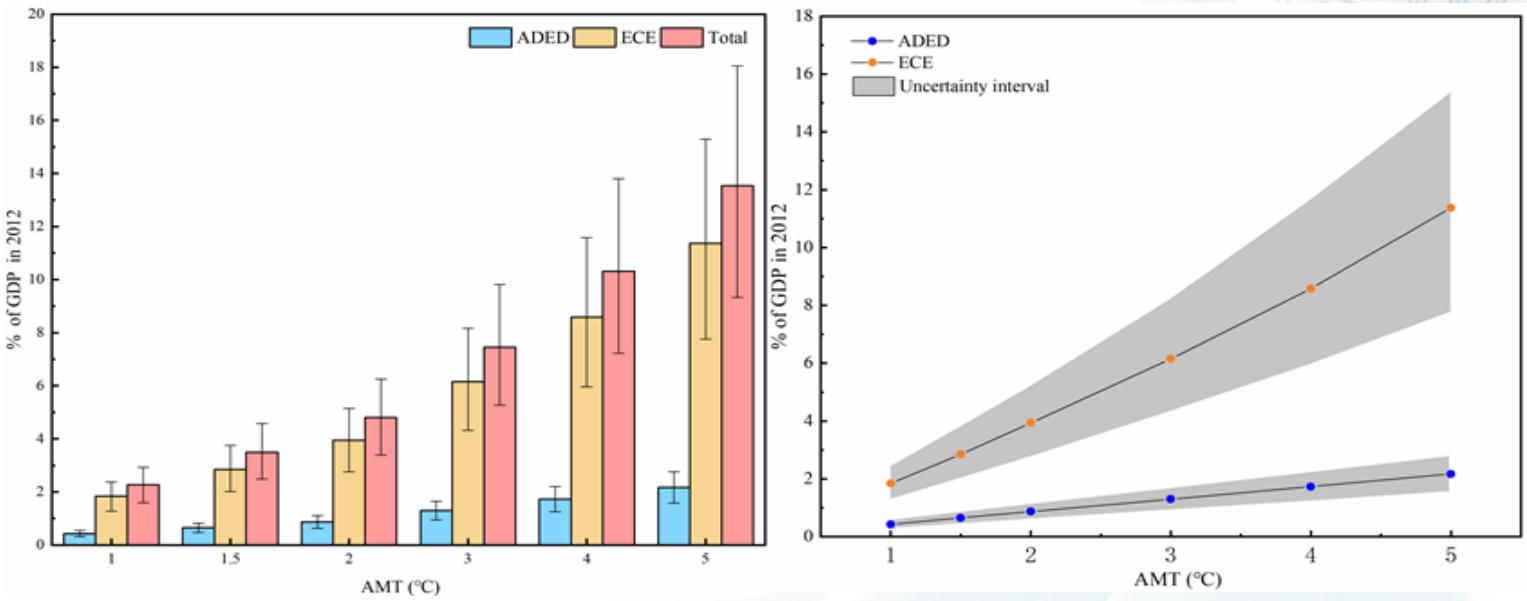
ΔT (℃)	1	1.5	2	3	4	5
Yield change (%)	-2.61 (± 0.71)	-3.92 (± 1.07)	-5.22 (± 1.42)	-7.83 (± 2.13)	-10.44 (± 2.84)	-13.05 (± 3.55)
ADED (% of GDP in 2012)	0.43 (± 0.12)	0.65 (± 0.18)	0.87 (± 0.24)	1.30 (± 0.35)	1.73 (± 0.47)	2.17 (± 0.59)

ΔT: AMT increased by 1-5℃ compared with 2012.

- The assumption of ARIO model: adjusted the exogenous parameters to enhance the adaptability of the model to assess the economic impact of climate change

Name	Description	Value
a^b	Production capacity in 2012	1
$a^{\max}$	Maximum production capacity	1.23
τ	Adaptive time of local production, export and intermediate consumption	6 mouths
ξ	Elasticity of final demand with respect to the commodity price	0.9

Result--ECE with different increases in AMT



The results of ADED, ECE and total economic impact in the 6 cases with increases in AMT of 1-5℃.

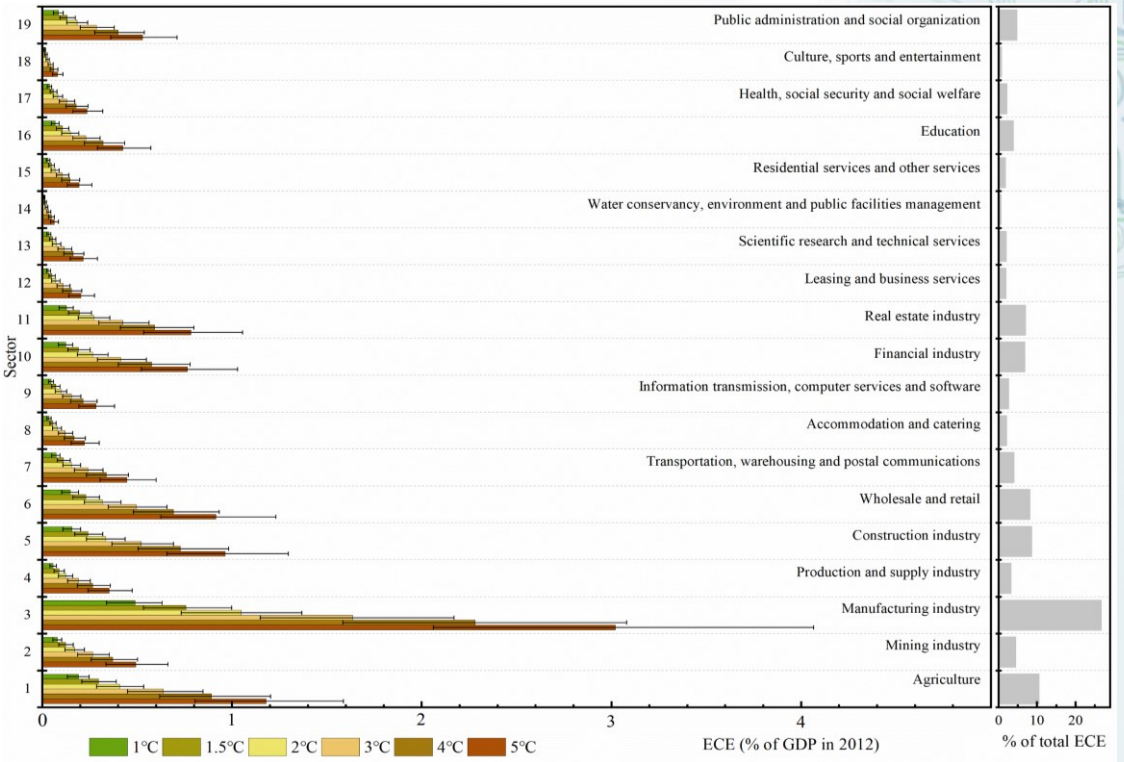
The growth rate of Economic cascading effect (ECE) decreased gradually with the increase in AMT from 1℃ to 5℃, but it was **4.24 ~ 5.25 times higher than that of ADED**. Due to the intricate industrial linkage among economic sectors, ADED under climate change will **significantly amplify** ECE.

Result--ECE in different sectors

Manufacturing industry is the most sensitive to the impact of ADED, accounting for 26.58%;

Agriculture is more sensitive to ADED than the other sectors, whose ECE would exceed one-tenth of the total ECE, at 10.39%.

Construction industry and wholesale and retail industry, their ECE accounts for 8%.



The comparison of ECE in 19 sectors with increases in AMT of 1-5℃.

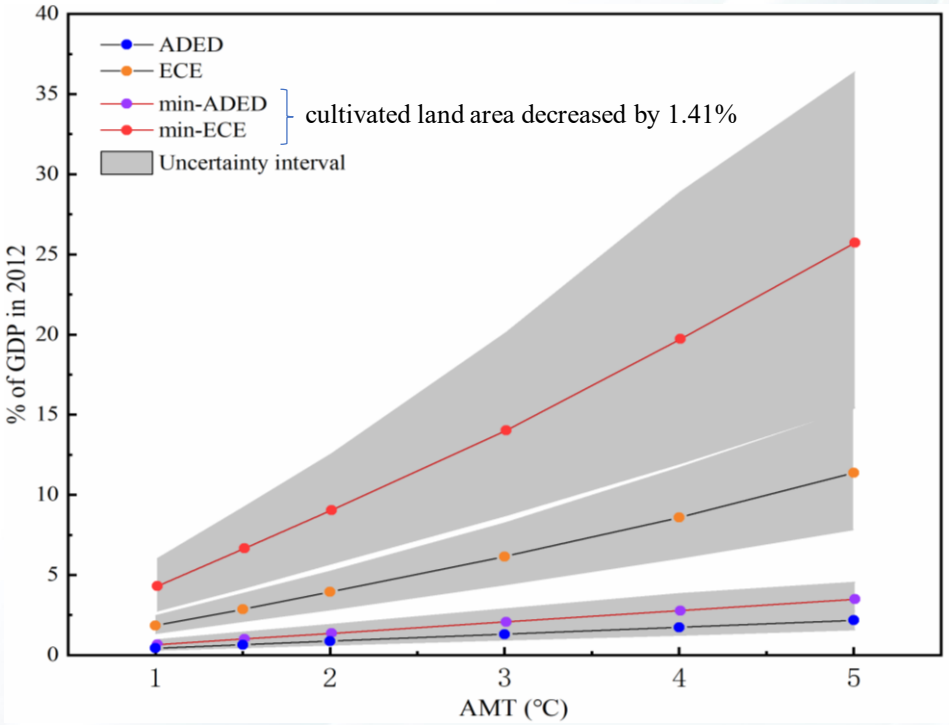
ID	Sector	ECE (% of GDP in 2012)					
		1℃ (±)	1.5℃ (±)	2℃ (±)	3℃ (±)	4℃ (±)	5℃ (±)
3	Manufacturing industry	0.19(0.06)	0.30(0.09)	0.41(0.12)	0.64(0.19)	0.89(0.27)	1.18(0.37)
1	Agriculture	0.08(0.02)	0.12(0.04)	0.17(0.05)	0.27(0.08)	0.37(0.11)	0.49(0.16)
5	Construction industry	0.49(0.15)	0.76(0.22)	1.05(0.31)	1.64(0.49)	2.28(0.7)	3.02(0.96)
6	Wholesale and retail	0.06(0.02)	0.09(0.03)	0.12(0.04)	0.19(0.06)	0.27(0.08)	0.35(0.11)
11	Real estate industry	0.16(0.05)	0.24(0.07)	0.33(0.10)	0.52(0.16)	0.73(0.22)	0.96(0.31)
10	Financial industry	0.15(0.05)	0.23(0.07)	0.32(0.10)	0.50(0.15)	0.69(0.21)	0.92(0.29)

Result--ECE in minimum demand for cultivated land area

When cultivated land area decreased by 1.41%, min-ADED will be **1.65 times that of ADED**, min-ECE will be **2.35 times that of ECE.**

Cultivated land area is a key factor affecting the output of the agricultural sector, and a decrease in this factor will have a significant impact on ECE.

Hence, it is necessary to fully consider the change in cultivated land area in policy and management adjustments intended to address climate change.



Comparison diagram of the change curves of min-ADED, min-ECE and ADED, ECE with increasing AMT.

Discussion

- This assumption that China's economic structure will "not change significantly" in the future. While the damage may be worsened by the rapid growth of the economy, or the country may be better adapted to climate change because of economic restructuring.

- To verify the stability of the model, we analyse the sensitivity of the parameters.

The increase in production capacity can reduce ECE to some extent, the shorter the adaptive time is, the smaller the ECE will be.

a^{max}	τ	ECE (% of GDP in 2012)
1	0	4
1.23	6 mouths	2.57
1.23	12 mouths	2.85
1.5	12 mouths	2.97

- However, due to the limitations of data sources and assessment methods, we have not yet obtained reliable results on the direct economic impact on other sectors. Therefore, in future research, we will try to comprehensively assess the economic impact of climate change in China.

Conclusion

I. There is a **significant amplification effect on ECE caused by ADED and industrial linkage** under future warming. Hence, while paying attention to the direct impact of climate change on a sector, we should also attach importance to the amplification effect of ECE, which is caused by industrial linkage.

II. ADED has different impacts on other sectors, among which the **manufacturing and agriculture** sectors are the most affected. Agriculture has a significant secondary economic impact due to its own direct economic damage. Therefore, to better adapt to climate change, we should keep a watchful eye on the differences in economic impact as warming occurs in different economic sectors.

III. The **dual effects of warming and decrease in cultivated land area will further amplify ECE**, so the formulation of policies should not only consider the current demand but also focus on the threat of warming to achieve long-term development.

Thanks !

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