Land-use emission leakages from China’s dietary shift and afforestation amplify food insecurity and economic losses under the 2 °C target

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Wageningen, the Netherlands
May 22, 2025

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Motivation: Dietary shifts and afforestation under the 2 °C Target

Shifting to healthier diets can reduce greenhouse gas(GHG) emissions

- Shifting to healthier, less animal-based diets is the most effective demand-side option to mitigate climate change (IPCC AR6, 2022).
- Afforestation of freed-up land from dietary shifts leads to further emission removals (K. Chan, et al. 2022).

Afforestation can enhance carbon sequestration but cause land competition

- Afforestation is a cost-effective and readily available climate change mitigation option (J. C. Doelman, et al. 2020).
- Afforestation require large areas of land which can lead to competition for land between food production and climate change mitigation (J. C. Doelman, et al. 2019).

Stringent global climate change mitigation policy would increase food insecurity

- The Paris Agreement calls for nations to limit global mean temperature rise well below 2 °C above pre-industrial levels and pursue efforts to limit warming to 1.5 °C.
- Stringent climate mitigation policy would worsen global hunger and food consumption more than climate change itself (T. Hasegawa, et al. 2018).

Contributions of China's dietary shift and afforestation to the feasibility of 2 °C target remain unclear

- When implemented unilaterally by China, these measures may support domestic carbon neutrality while triggering emission leakages abroad through trade-induced land-use changes.
- The extent to which China's dietary shift and afforestation contribute to the feasibility of the 2 °C climate target remains unclear.

Why China?

largest agriculture producer and importer

largest greenhouse gases emitter

7% of global arable land

19% of global population

Research gap and question

What has been studied for China?

- Environmental benefits of dietary shifts and afforestation (e.g. Y. Guo, et al., 2022; M. Ren, et al., 2023; L. Zhang, et al., 2022)

What is missing in studies on China?

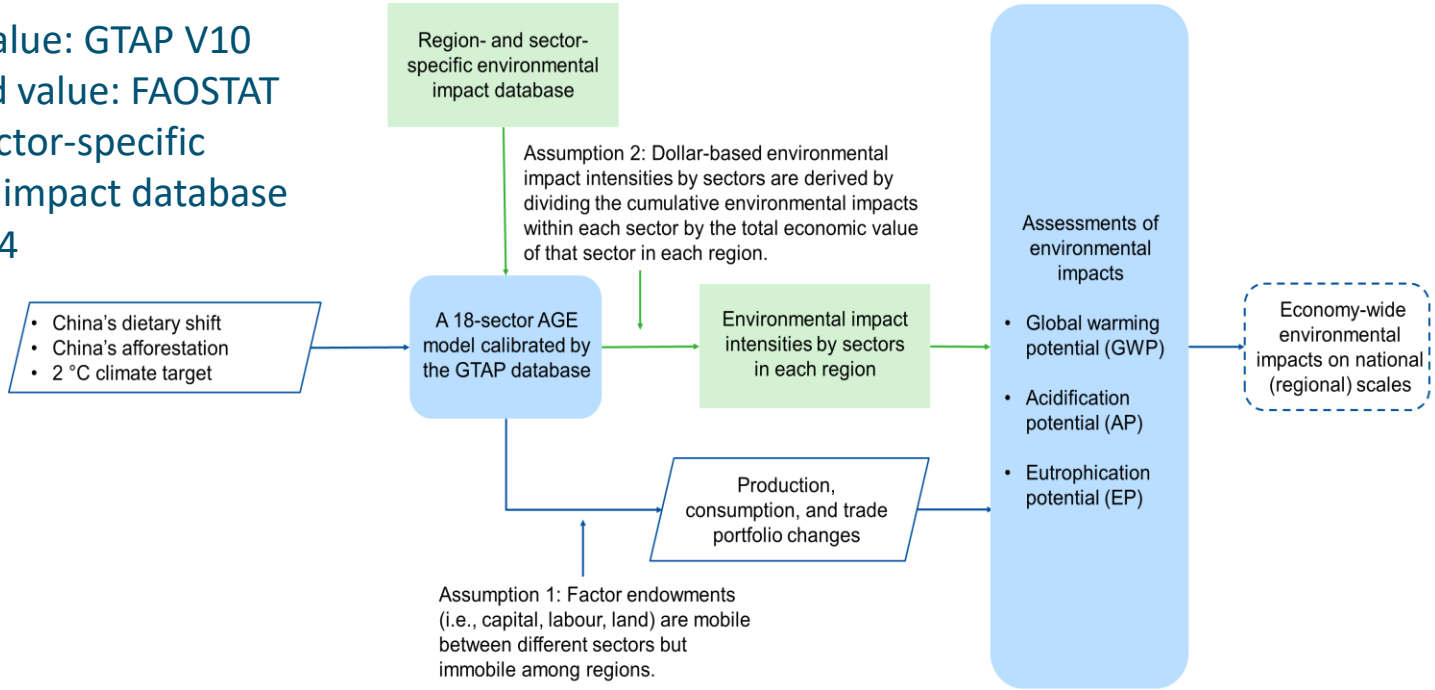
- Interplay of dietary shifts and afforestation in the land system with the decarbonisation of the energy system in a Paris Agreement 2°C target

- Food security and economic aspects of dietary shifts and afforestation under the 2 °C target

To what extent do China's dietary shift and afforestation contribute to the feasibility of the 2 °C target?

Integrated environmental-economic modelling framework based on applied general equilibrium (AGE) models

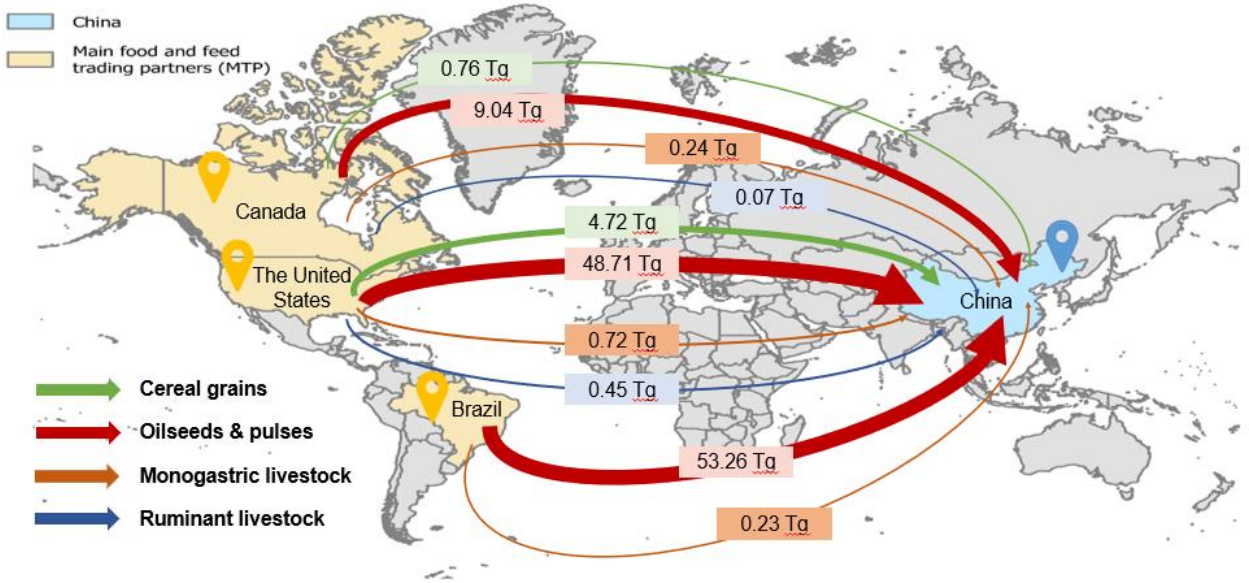
- **Database:**
- ✓ Dollar-based value: GTAP V10
- ✓ Quantity-based value: FAOSTAT
- ✓ Region- and sector-specific environmental impact database
- **Base year:** 2014



Regional coverage: 4 regions

- China
- China's main food and feed trading partners (MTP, including Brazil, the United States, and Canada)

MTP accounts for over 75% of China's total food and feed trade value in 2014 (GTAP, 2014).



Sectoral aggregation: 18 sectors

- **6 crop sectors**: cereal grains, vegetables & fruits, roots & tubers, oilseeds & pulses, sugar crops, non-food crops
- **3 livestock sectors**: non-ruminant meat, dairy products, ruminant meat
- **1 forestry sector**
- **8 non-agricultural sectors**: cereal bran, alcoholic pulp, oil cake, compound feed, processed food, nitrogen fertiliser, phosphorous fertiliser, non-food

Linking AGE with a Global Timber Model (GTM)

GTM is a partial equilibrium, dynamic optimization model of the global timber market and carbon stocks with the differentiation of forests by type and age. (Sohngen and Mendelsohn, 2007)

- The forestry and the AGE models are linked through calibration of the forest carbon sequestration component of the AGE model.

- *To ensure that for the same carbon tax (e.g. 27/t CO2-eq) two models give the same forest carbon sequestration response.*

- *The calibration adjusts the incremental annual carbon intensity of forests by running the AGE model to mimic forestry model assumptions.*

(A. Golub, et al. 2013)

Forestry carbon stock (FCS) as outputs

Net GHGs = Total GHGs - Total FCS

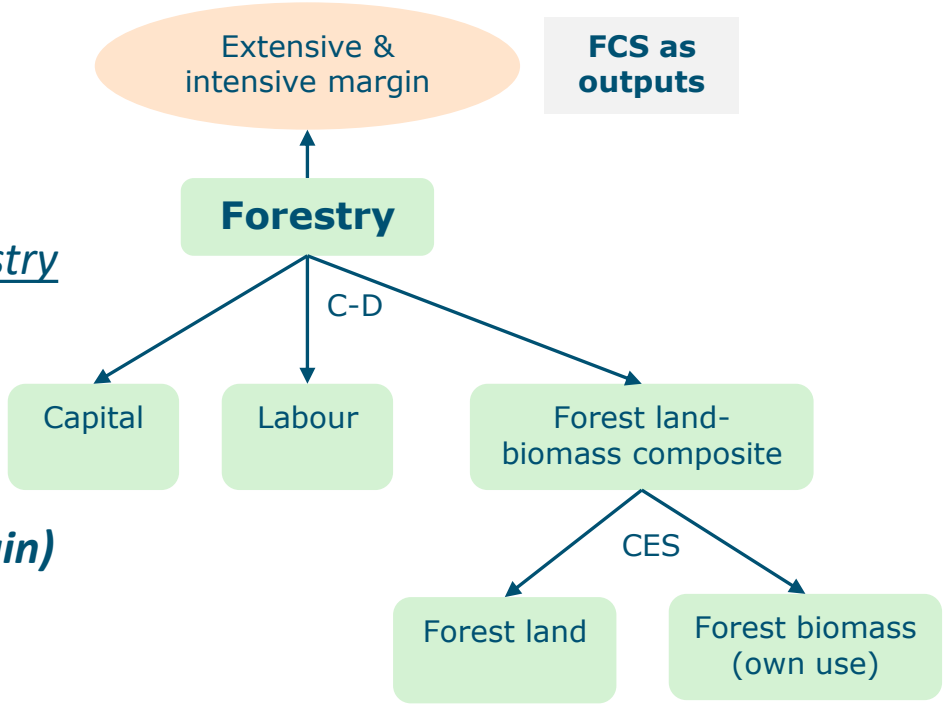
FCS can be increased by

- *increasing the carbon intensity of forestry* ***(intensive margin)***

  → modified management and aging with constant forest land

- *expanding forest land* ***(extensive margin)***

  → more forest land with constant carbon intensity

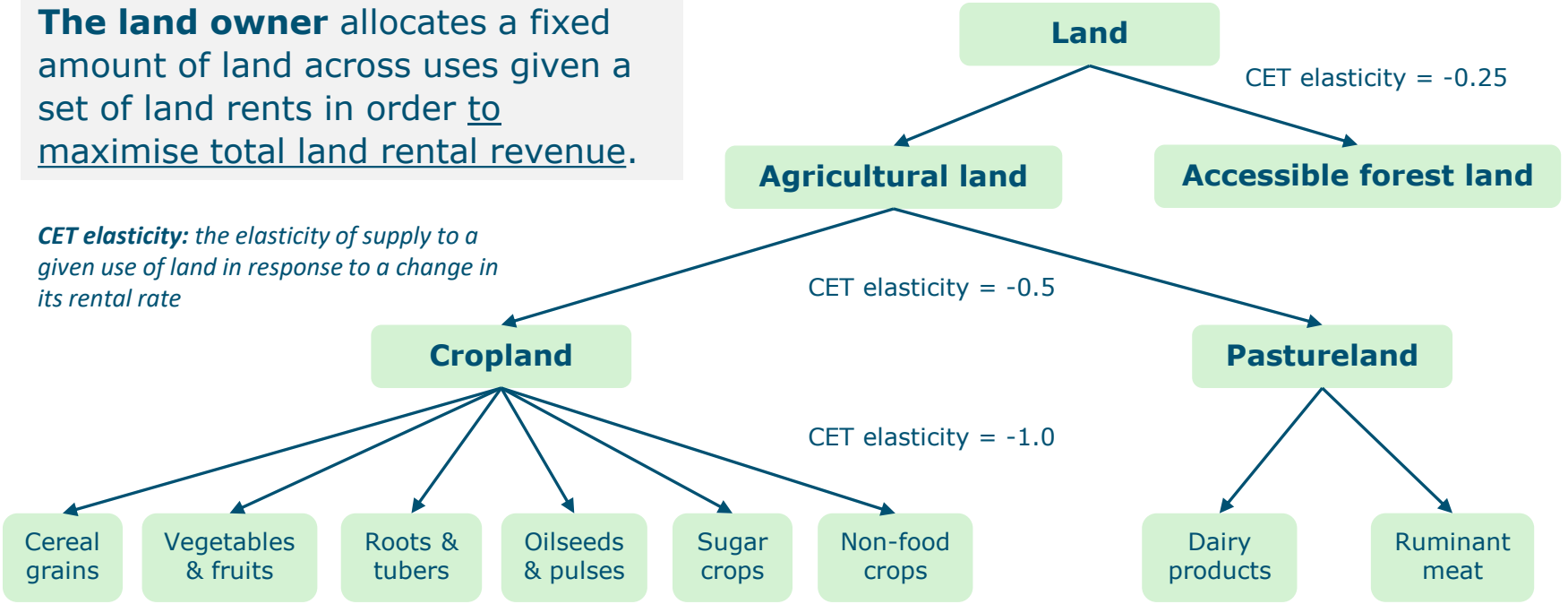


(A. Golub, et al. 2009)

Land allocation: Constant elasticity of transformation (CET) function

The land owner allocates a fixed amount of land across uses given a set of land rents in order to maximise total land rental revenue.

CET elasticity: *the elasticity of supply to a given use of land in response to a change in its rental rate*



(T. Hertel, et al. 2009)

Scenarios

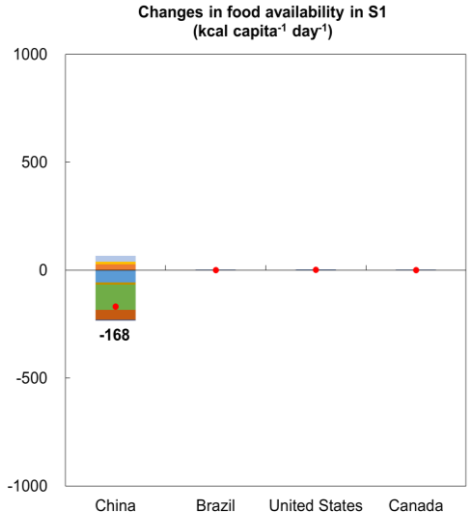
Scenarios	Descriptions
S1: Food scenario	**China's dietary shift towards a less animal-based diet,** closing 20% of the gap between current food consumption and the **Chinese Dietary Guidelines 2022** in line with SDG 2.1 (safe, nutritious and sufficient food), SDG target 2.2 (end all forms of malnutrition), and SDG 2.c.1 (food price anomalies).
S2: Land scenario	**China's afforestation policy** based on China's National Forest Management Plan (2016–2050) in line with SDG 15.1.1 (forest area as a proportion of total land area) and SDG 15.2 (increase afforestation and reforestation). → ***To expand forest land in China by 23 Mha (equivalent to 4% of China's agricultural land) by 2030***
S3: Climate scenario	**A global uniform carbon tax with carbon tax revenue recycling** aligned with the 2 °C climate target set by the Paris Agreement in line with SDG 13.2.2 (total greenhouse gas emissions). → ***To reduce net total GHG emissions in China and its main food and feed trading partners by 25% by 2030***
S4: Combined scenario	Combining food, land, and climate scenarios.

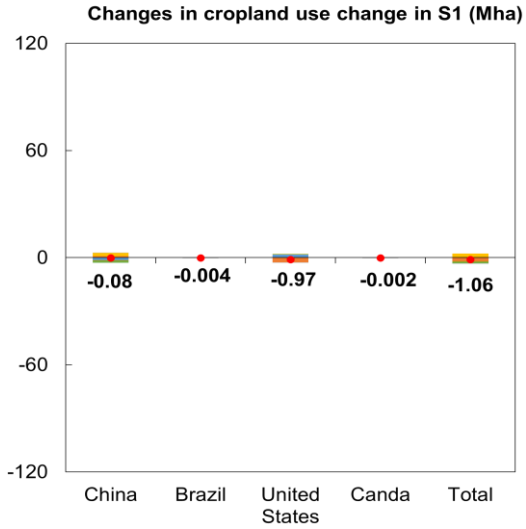
China's dietary shift (S1) with less meat and more dairy leads to an additional 14 Mha of agricultural land use abroad

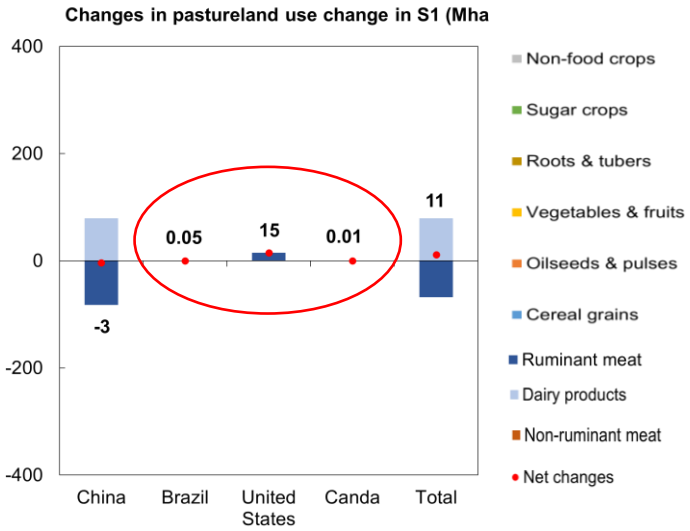
China's dietary shift:
- Oilseeds & pulses (+10%)
- Vegetables & fruits (+6%)
- Dairy products (+52%)

Cropland use:
- China: -0.06% (-0.08 Ma)
- MTP: -0.38% (-0.98 Mha)

Pastureland use:
- China: -0.9% (-3 Mha)
- MTP: +3.3% (+15 Mha)

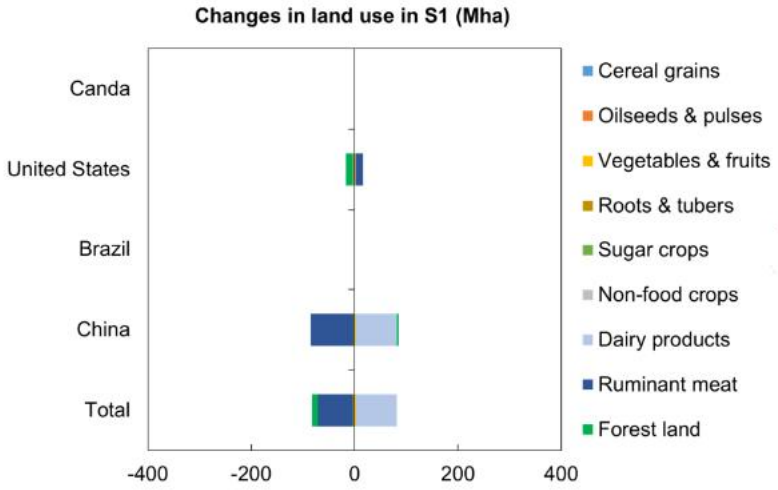


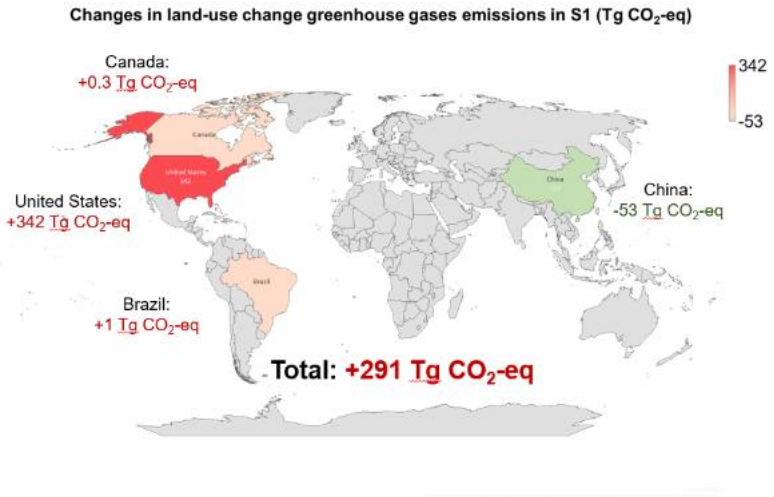




Deforestation in China's trading partners exceeds the carbon sequestration from afforestation on freed-up land under China's dietary shift (S1)

With deforestation





China's dietary shift (S1) causes 364 Tg CO_2-eq of emission leakage, more than tripling the domestic mitigation

GHG emissions from crop:

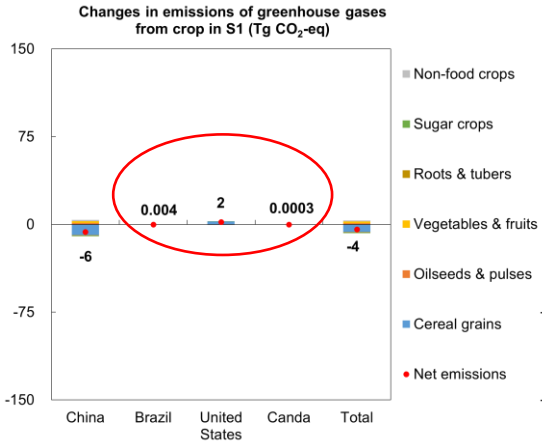
- China: -1.7% (-6 Tg CO_2-eq)
- MTP: +1.3% (+2 Tg CO_2-eq)

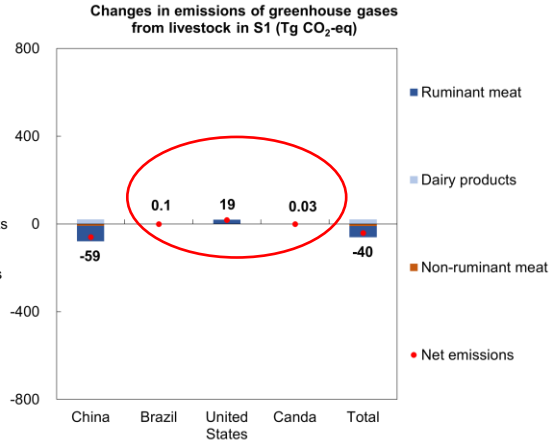
GHG emissions from livestock:

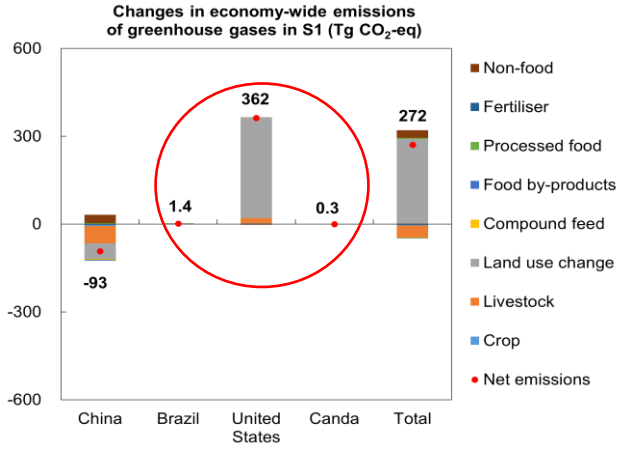
- China: -18.3% (-59 Tg CO_2-eq)
- MTP: +2.5% (+19 Tg CO_2-eq)

Economy-wide GHG emissions:

- China: -0.8% (-93 Tg CO_2-eq)
- **MTP: +4.6% (+364 Tg CO_2-eq)**





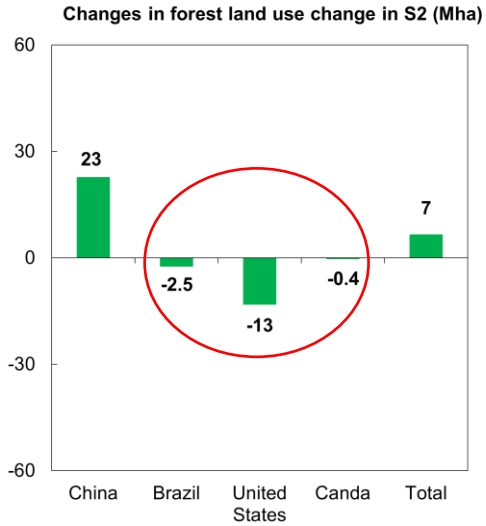


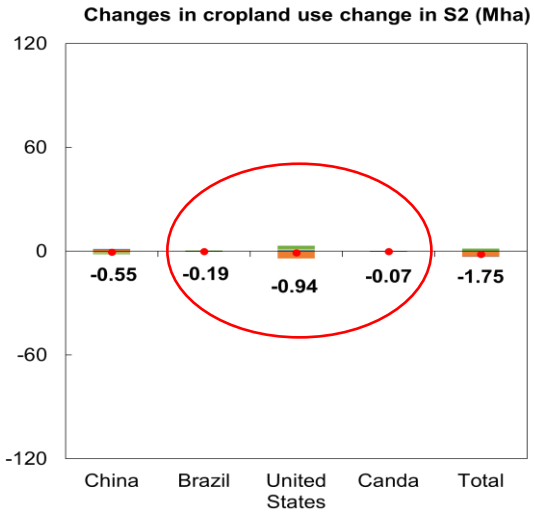
China's afforestation policy (S2) expands food production overseas, resulting in 16 Mha of additional agricultural land use

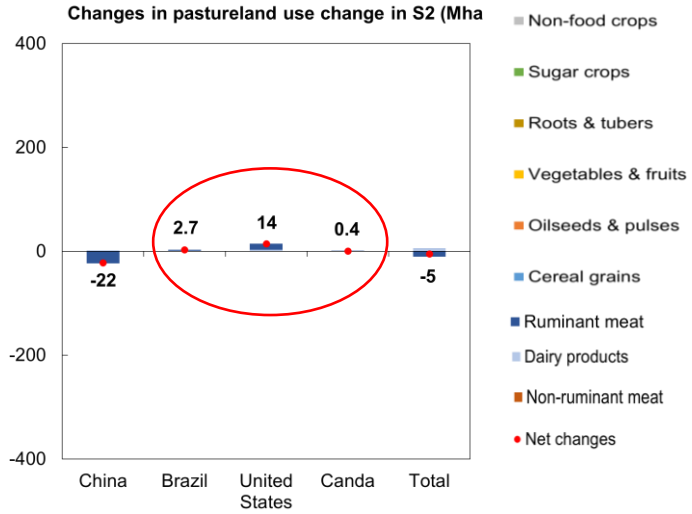
Forest land use:
- China: +20% (+23 Ma)
- MTP: -3.43% (-16Mha)

Cropland use:
- China: -0.42% (-0.55 Mha)
- MTP : -0.46% (-1.20 Mha)

Pastureland use:
- China: -5.63% (-22 Mha)
- MTP: +3.85% (+17 Mha)

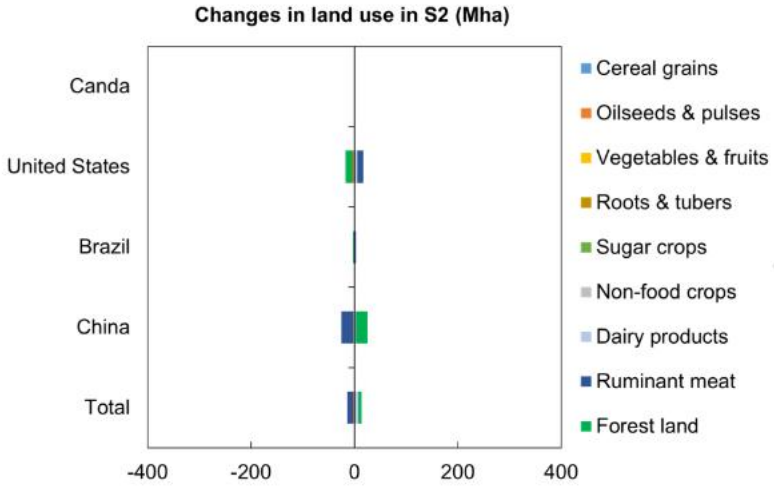


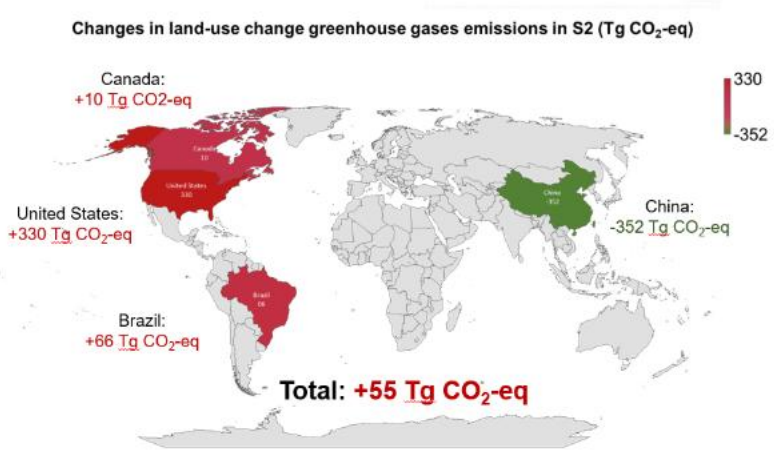




Deforestation in China's trading partners exceeds the carbon sequestration from China's afforestation policy (S2)

With deforestation





China's afforestation policy (S2) causes 424 Tg CO_2-eq of emission leakage, largely offsetting the domestic reduction

GHG emissions from crop:

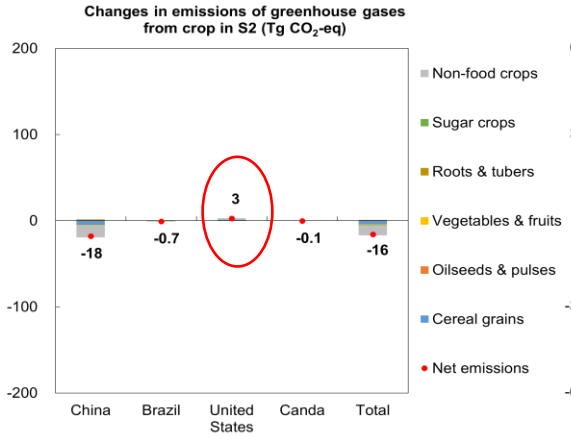
- China: -4.9% (-18 Tg CO_2-eq)
- MTP: +1.3% (+2 Tg CO_2-eq)

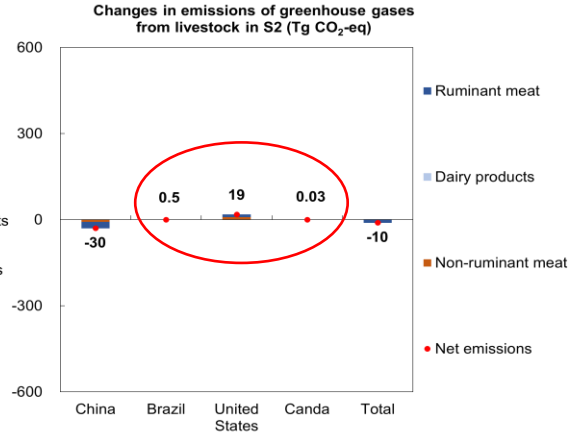
GHG emissions from livestock:

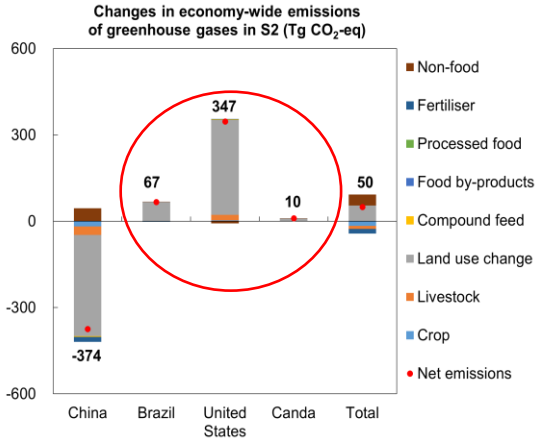
- China: -9.2% (-30 Tg CO_2-eq)
- MTP: +2.5% (+19 Tg CO_2-eq)

Economy-wide GHG emissions:

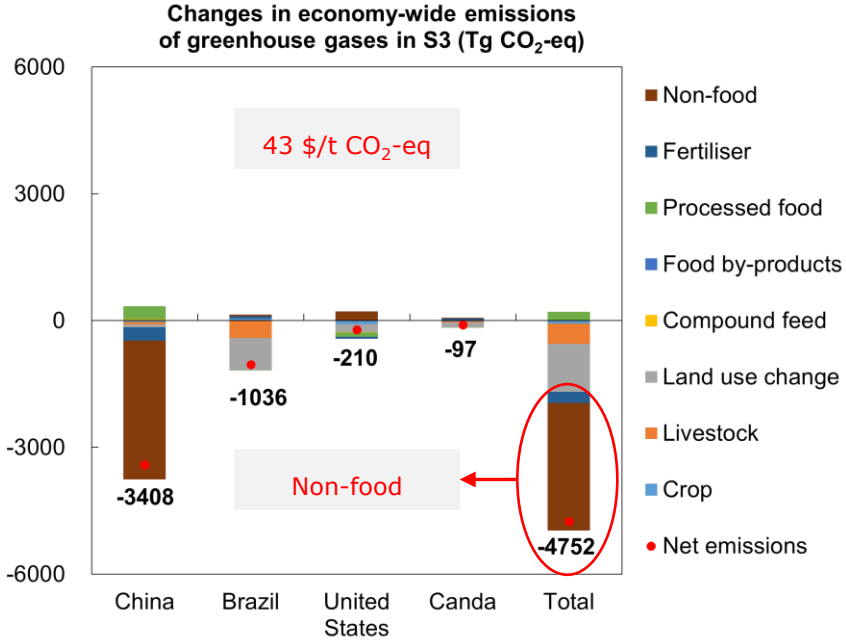
- China: -3.4% (-374 Tg CO_2-eq)
- **MTP: +5.3% (+424 Tg CO_2-eq)**



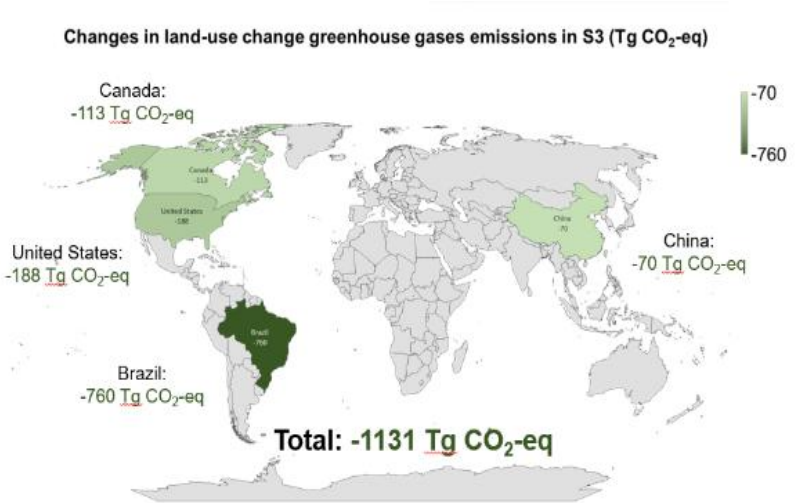




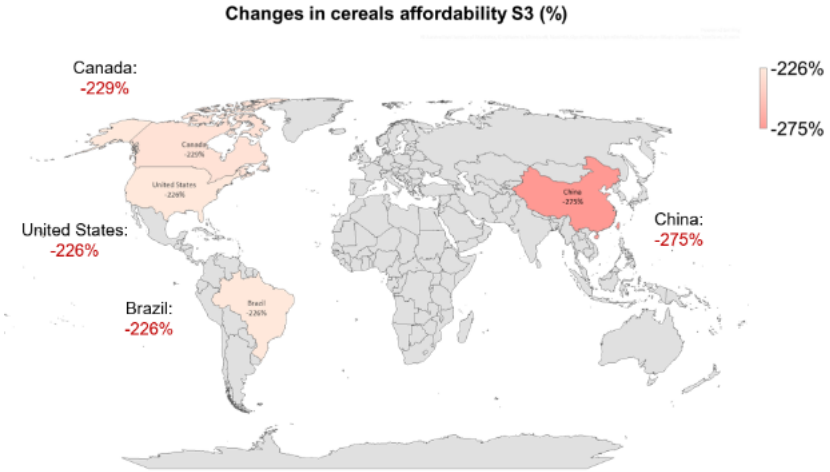
Non-food sector is the largest contributor for greenhouse gases reduction under the 2 °C target (S3)

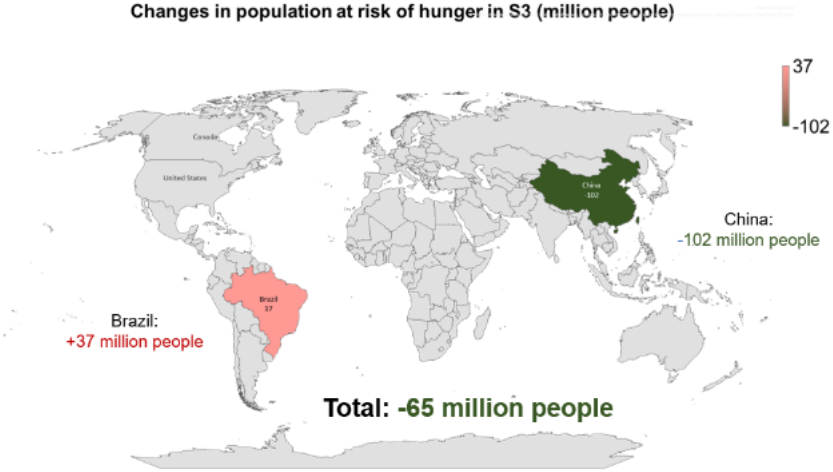


No deforestation

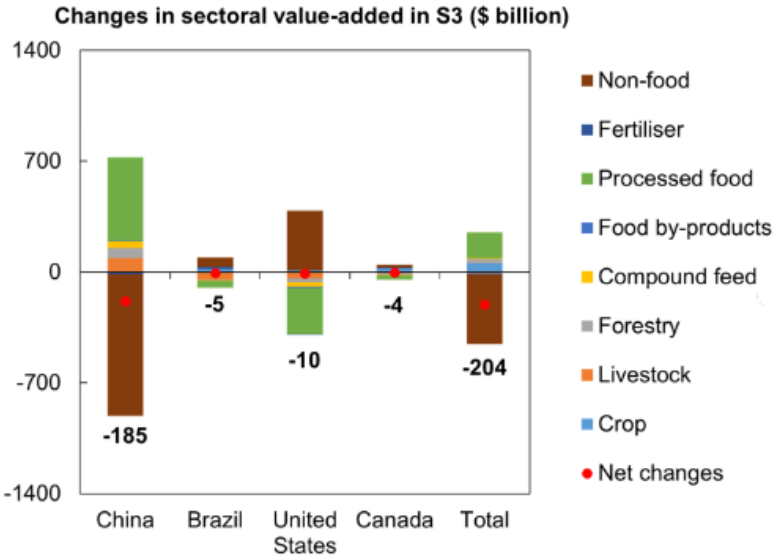


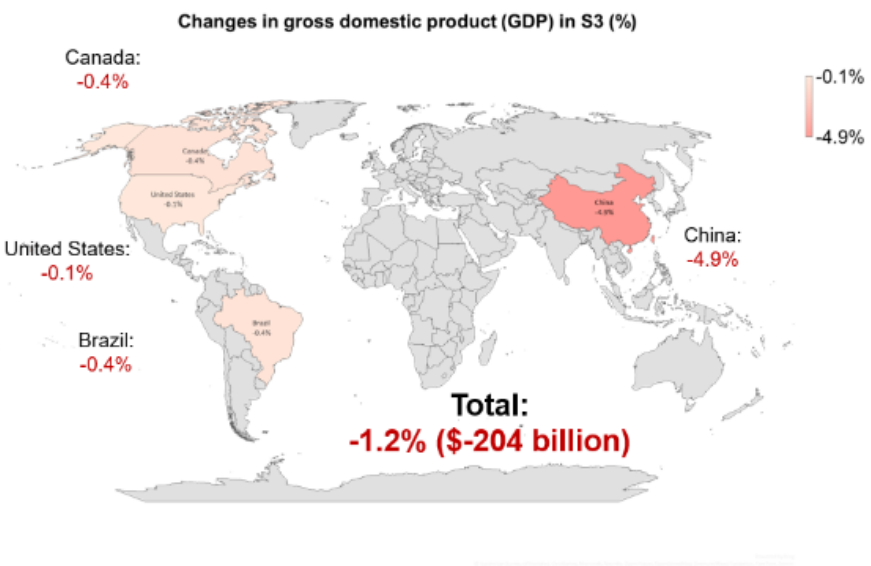
2 °C target with carbon tax revenue recycling (S3) reduces population at risk of hunger by 65 million people



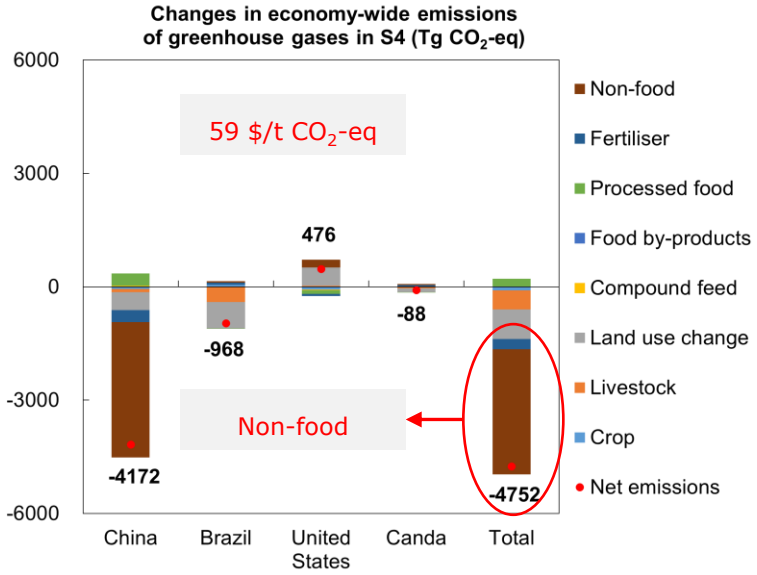


2 °C target with carbon tax revenue recycling (S3) causes $204 billion gross domestic product (GDP) losses

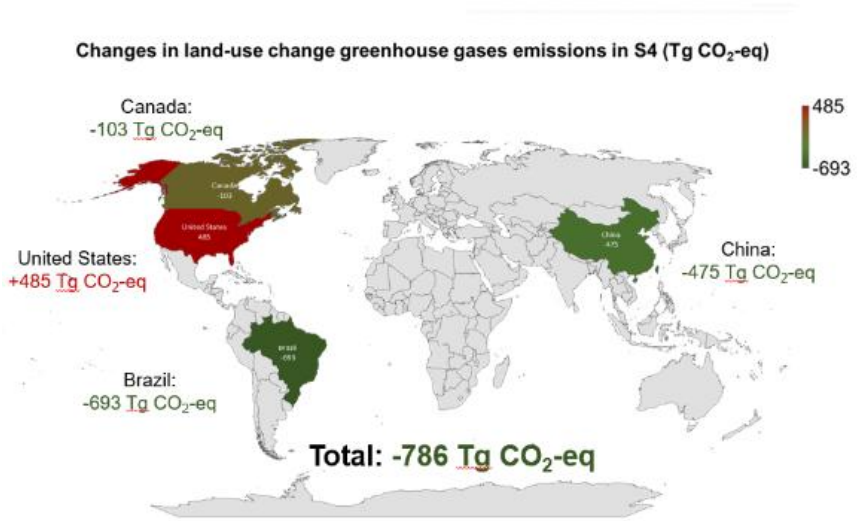




Land-use emission leakages from China's dietary shift and afforestation necessitate more stringent mitigation in non-food sectors to meet the 2 °C target (S4)



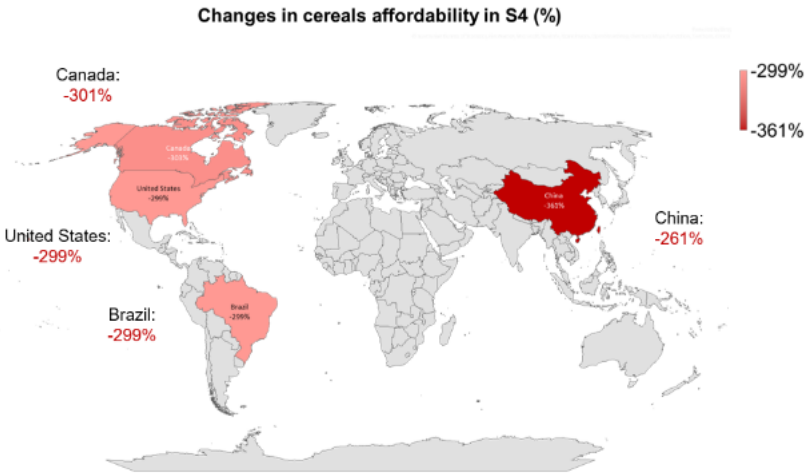
With deforestation

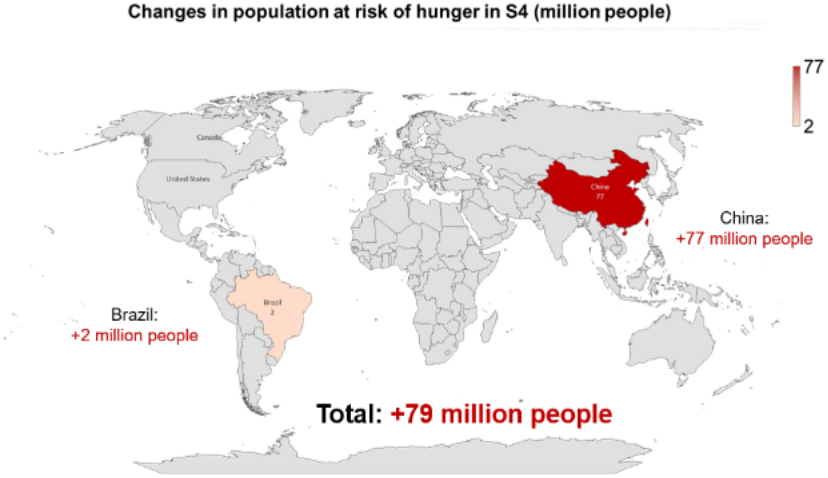


Land-use emission leakages from China's dietary shift and afforestation amplify food insecurity under the 2 °C target (S4)

S3: -65 million people

S4: additional 145 million people

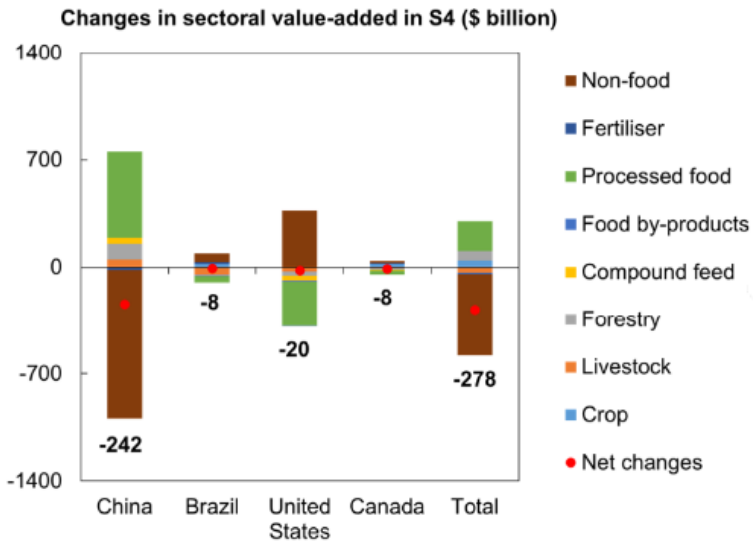


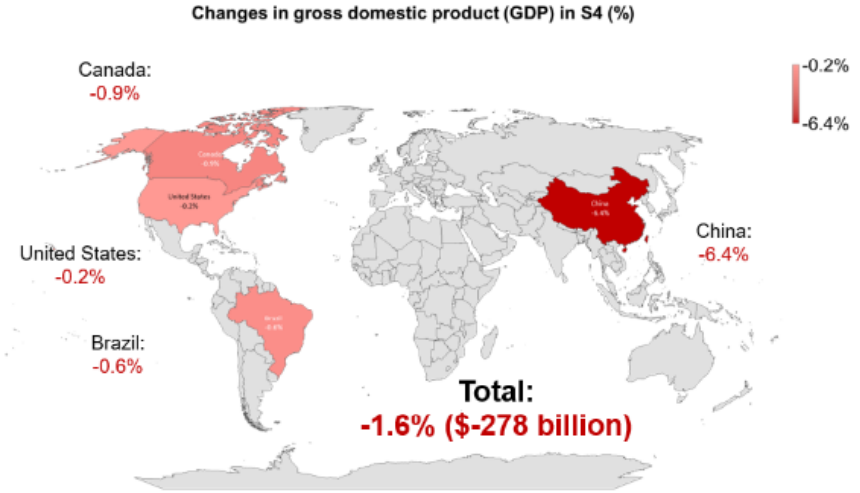


Land-use emission leakages from China's dietary shift and afforestation amplify economic losses under the 2 °C target (S4)

S3: $204 billion

S4: additional $74 billion





Conclusions

- **China's dietary shift** with less meat and more dairy leads to an additional 14 Mha of agricultural land use abroad and causes 364 Tg CO_2-eq of emission leakage, more than tripling the domestic mitigation.
- **China's afforestation policy** expands food production overseas, resulting in 16 Mha of additional agricultural land use and 424 Tg CO_2-eq of emission leakage, largely offsetting the domestic reduction.
- **These emission leakages, primarily driven by land-use change**, necessitate more stringent mitigation in **non-food sectors** to meet the 2 °C target.
- Without coordinated global action, these unilateral measures amplify pressures on **carbon tax** (36%), **food price** (65%), **the population at risk of hunger** (145 million people), and **economic losses** ($74 billion).

Thank you!

Questions?

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