

The Impact of Global Unequal Exchange of Land on Food Security and Biodiversity

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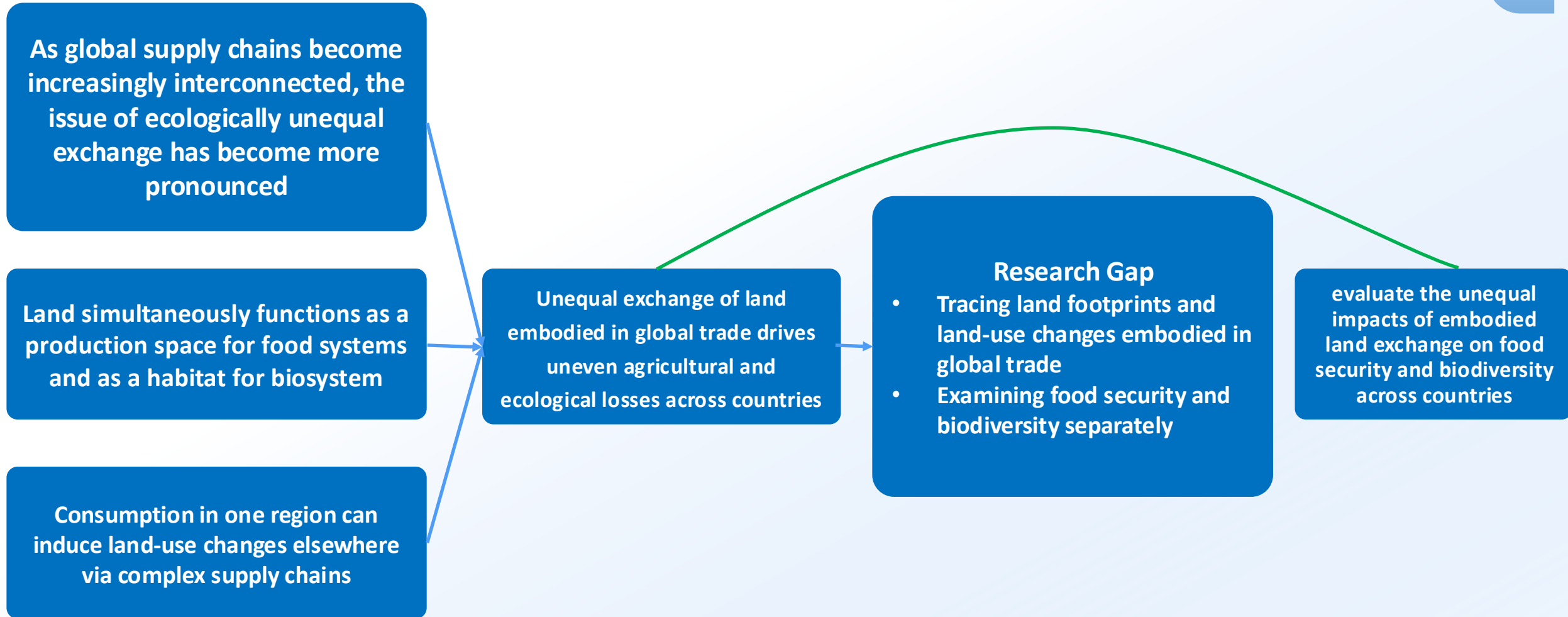


01

Research Background

PART ONE

■ Research Background





02

Methods

PART TWO

EEMRIO

- **Tracing the land footprint embodied in global trade**
- **Integrating with value-added to detect the inequality**

Indicators

- **Food security**
- **Biodiversity**

SDA

- **Detecting the driving factors of inequality**

EEMRIO

$$F = \hat{q}LY = \begin{bmatrix} q^1 & 0 & \dots & 0 \\ 0 & q^2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & q^6 \end{bmatrix} \times \begin{bmatrix} l^{11} & l^{12} & \dots & l^{16} \\ l^{21} & l^{22} & \dots & l^{26} \\ \vdots & \vdots & \ddots & \vdots \\ l^{61} & l^{62} & \dots & l^{66} \end{bmatrix} \times \begin{bmatrix} y^{11} & y^{12} & \dots & y^{16} \\ y^{21} & y^{22} & \dots & y^{26} \\ \vdots & \vdots & \ddots & \vdots \\ y^{61} & y^{62} & \dots & y^{66} \end{bmatrix}$$

$\hat{q}$

cropland

pasture

forest land

other land

184 countries

High-income
(GNI>12,630)

Upper-middle-income
(4,130<GNI≤12,630)

Lower-middle-income
(1,640<GNI≤ 4,130)

Low-income
(GNI≤ 1,640)

China

India

Study period

1990-2021

■ Methods

Food Securities Indicators

Food availability

Average Dietary Energy Supply Adequacy

Food access

Prevalence of Undernourishment

Food utilization

Percentage of Population Using at Least Basic Drinking Water Services

Food stability

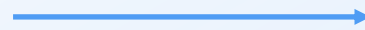
Cereal Import Dependency Ratio

For positive indicators:
$$X_{ij} = \frac{X_{ij} - X_{\min j}}{X_{\max j} - X_{\min j}}$$

For negative indicators:
$$X_{ij} = \frac{X_{\max j} - X_{ij}}{X_{\max j} - X_{\min j}}$$

Biodiversity Indicator

Species Habitat Index (SHI)



net Species Habitat Balance

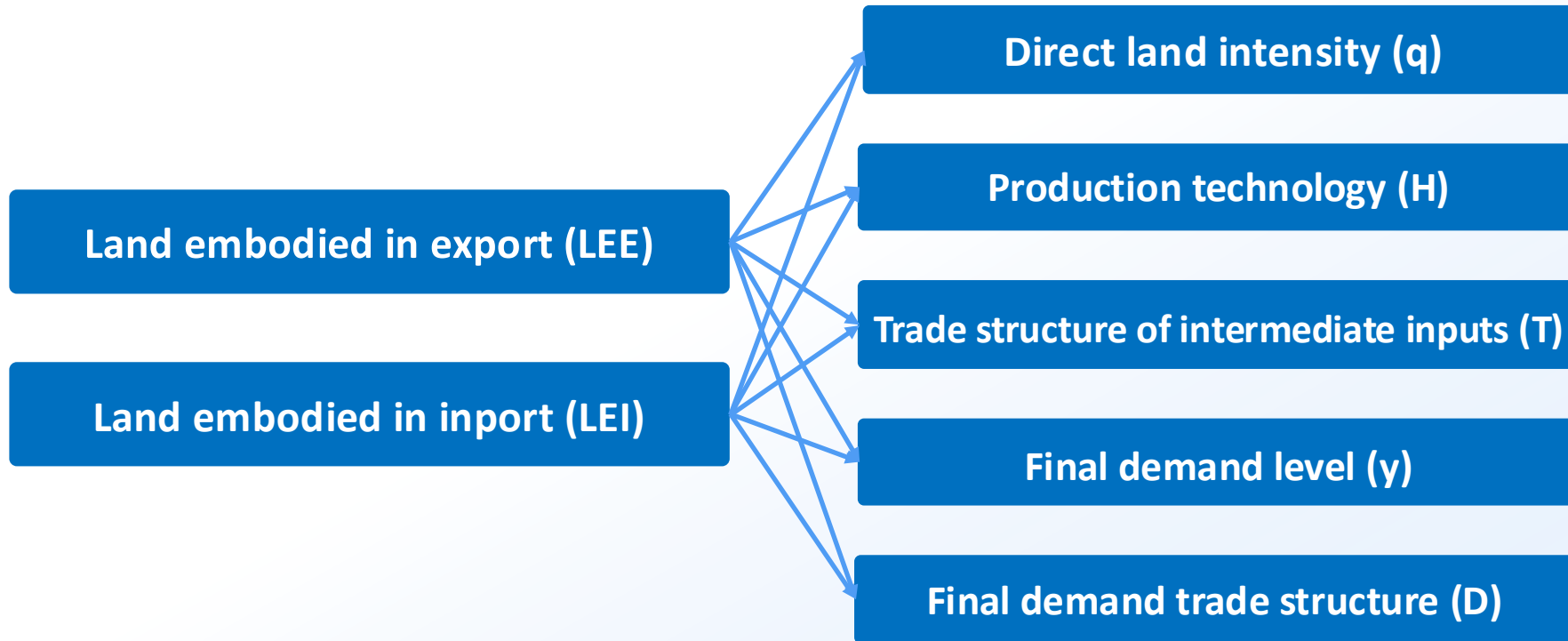
$$iwaSHI_r = \frac{\sum_{s \neq r}^N im_{sr} * (100 - SHI_s)}{\sum_{s \neq r}^N im_{sr}}$$

$$ewaSHI_r = \frac{\sum_{s \neq r}^N ex_{rs} * (100 - SHI_r)}{\sum_{s \neq r}^N ex_{rs}}$$

$$ceSHB_r = iwaSHI_r - ewaSHI_r$$

■ Methods

Structural Decomposition Analysis



$$q = e\hat{x}^{-1}$$

$$h^r = \sum_{s=1}^N A^{sr}$$

$$t^{sr} = a^{sr} / h^r$$

$$y^r = \sum_{s=1}^N y^{sr}$$

$$d^{sr} = y^{sr} / y^r$$

each driver is divided into domestic (r) and foreign effects (-r)



03

Results

PART THREE

Results

The scale of land teleconnections expanded with global trade integration

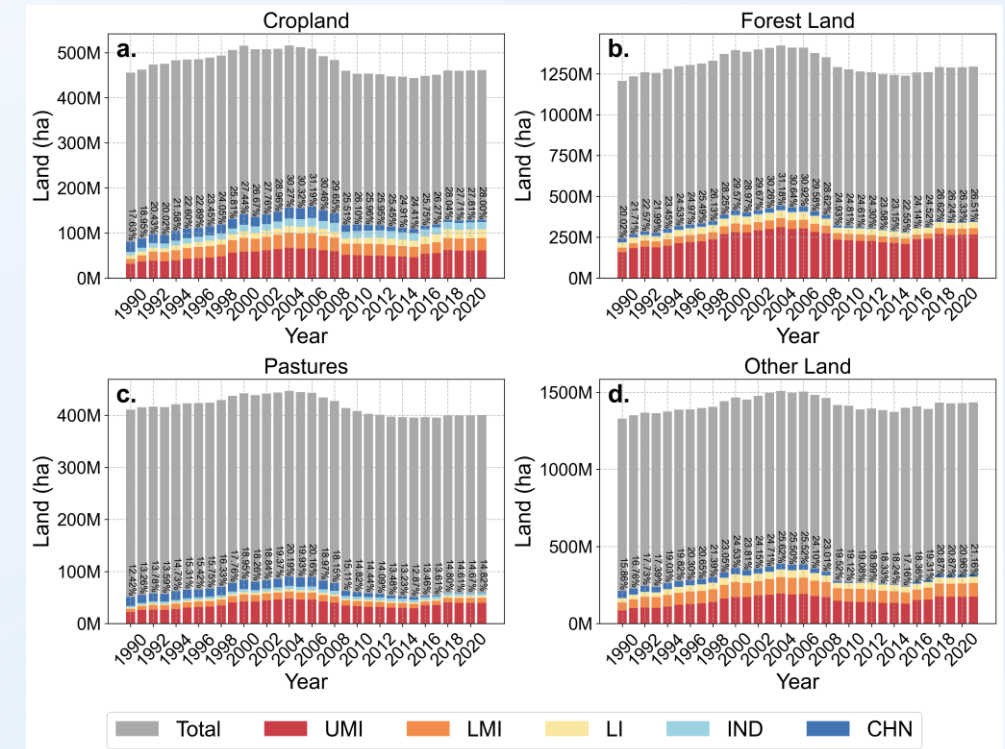
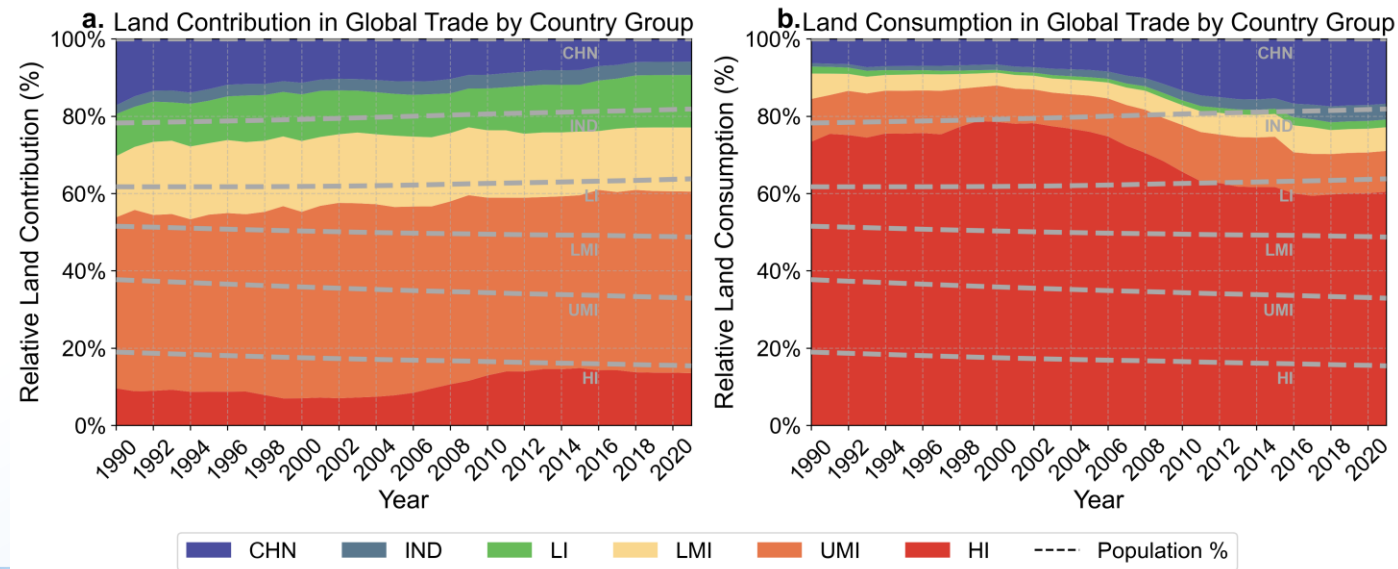
915M ha

embodied land in global trade, 1990

1,780M ha

embodied land in global trade, 2021

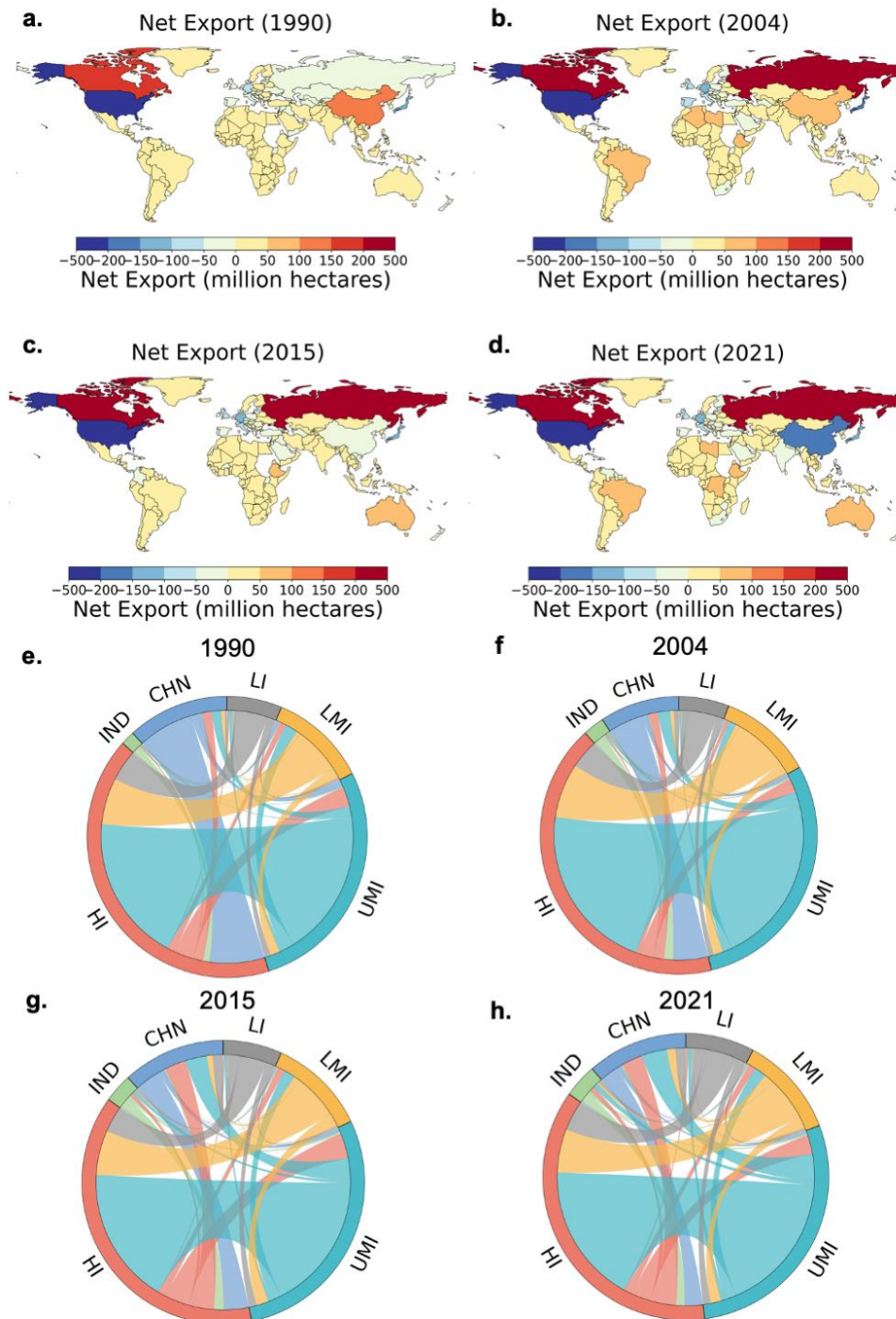
HI-countries consistently act as net appropriators of embodied land and consume more than 60% of land embodied in trade while relying heavily on external land resources



Results

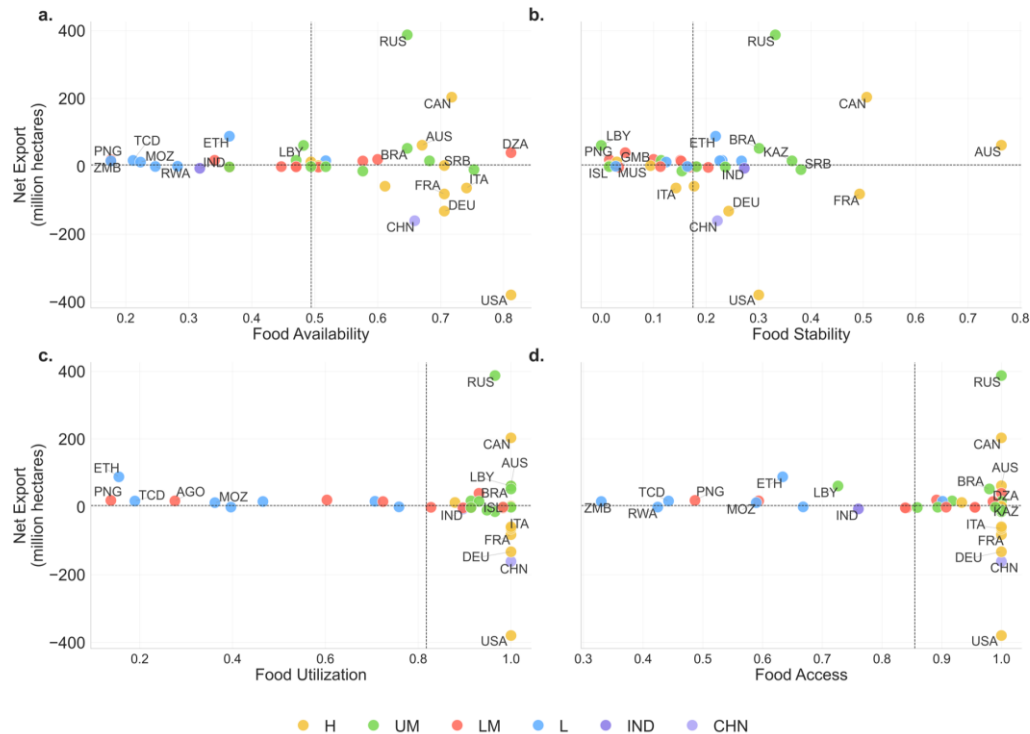
The exchange of embodied land is characterized by persistent inequality

- High-income countries (HI) acted as a net appropriator of all major land types from all other country groups (Eastern Europe and the Middle East, the United Arab Emirates, Switzerland, Monaco, and Israel)
- UMI countries consistently emerged as the dominant exporters, supplying nearly half of the total land embodied in global trade (Latin America and Southeast Asia, Paraguay and Thailand)
- China shift from a major net exporter to the second-largest net importer



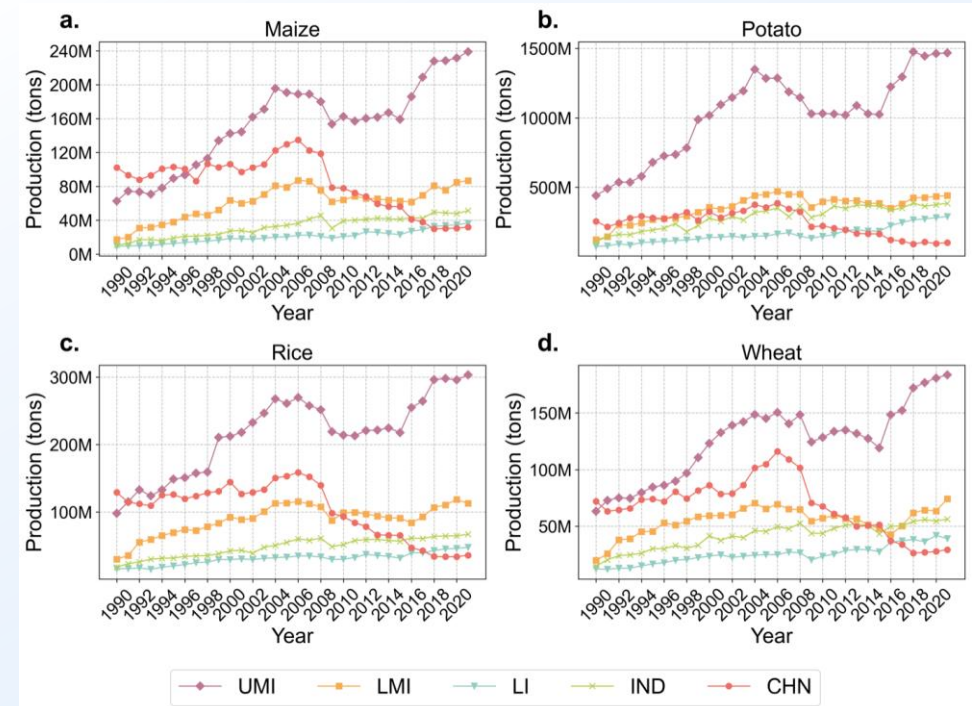
Results

Many low-income net embodied land exporters perform worse on food-security



Many LI and LMI exporters sit below global-average availability, access and utilization

Exported cropland could otherwise support domestic staple production



37 Mt maize alone contains enough calories to feed roughly 123 million people for one year

Results

Biodiversity loss is outsourced through land-related trade

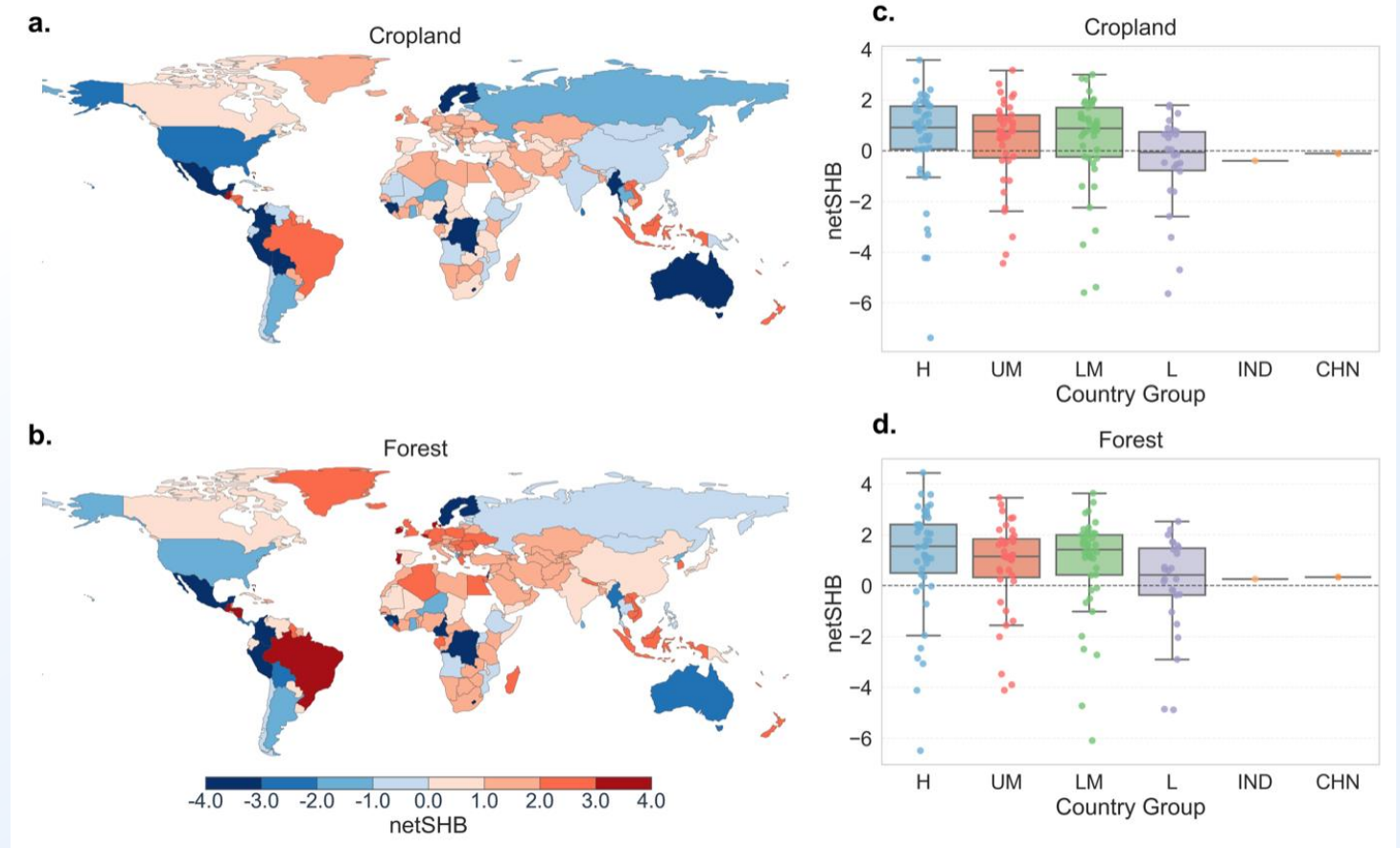
netSHB distinguishes countries externalizing biodiversity loss from those bearing it domestically for external demand

$\text{netSHB} > 0$

imports embody more biodiversity loss than exports

$\text{netSHB} < 0$

exports embody more biodiversity loss than imports



HI countries show the highest average positive netSHB, whereas LI countries exhibit the lowest values.

Results

Physical land flows and monetary returns move unevenly through global value chains, HI countries consistently generated the highest value-added per hectare of land embodied in export

27x

HI value-added per hectare of cropland vs LI

8x

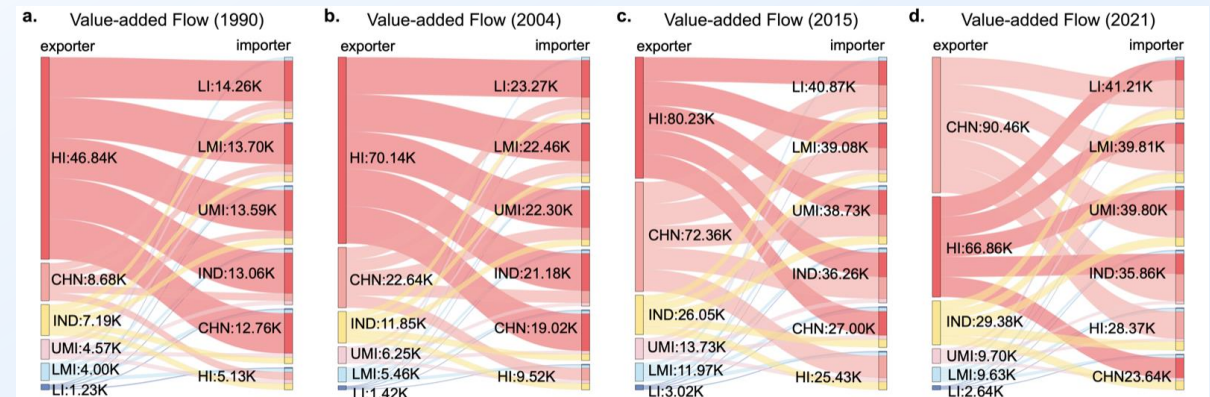
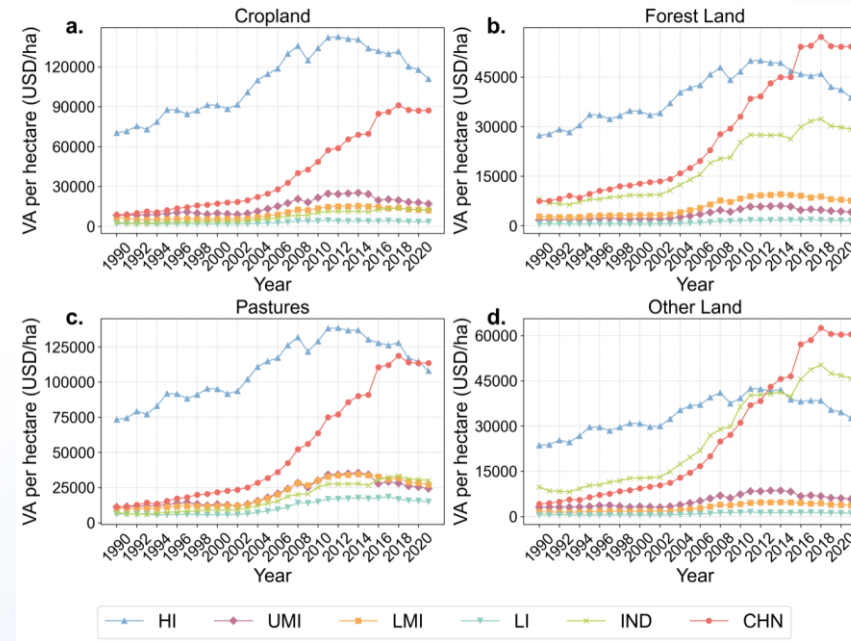
HI vs LMI

5x

HI vs UMI

The value added embodied in HI countries' exports is largely borne by LI and LMI countries

By 2021, China's value-added per hectare surpassed that of HI countries for most land categories



Low-income countries provide large quantities of embodied land but retain an unequal small share of the monetary gains.

Results

Final demand, land intensity and trade structure are key drivers reshaping land inequality

SDA separates the drivers of land embodied in exports and imports across three periods.

1990-2004

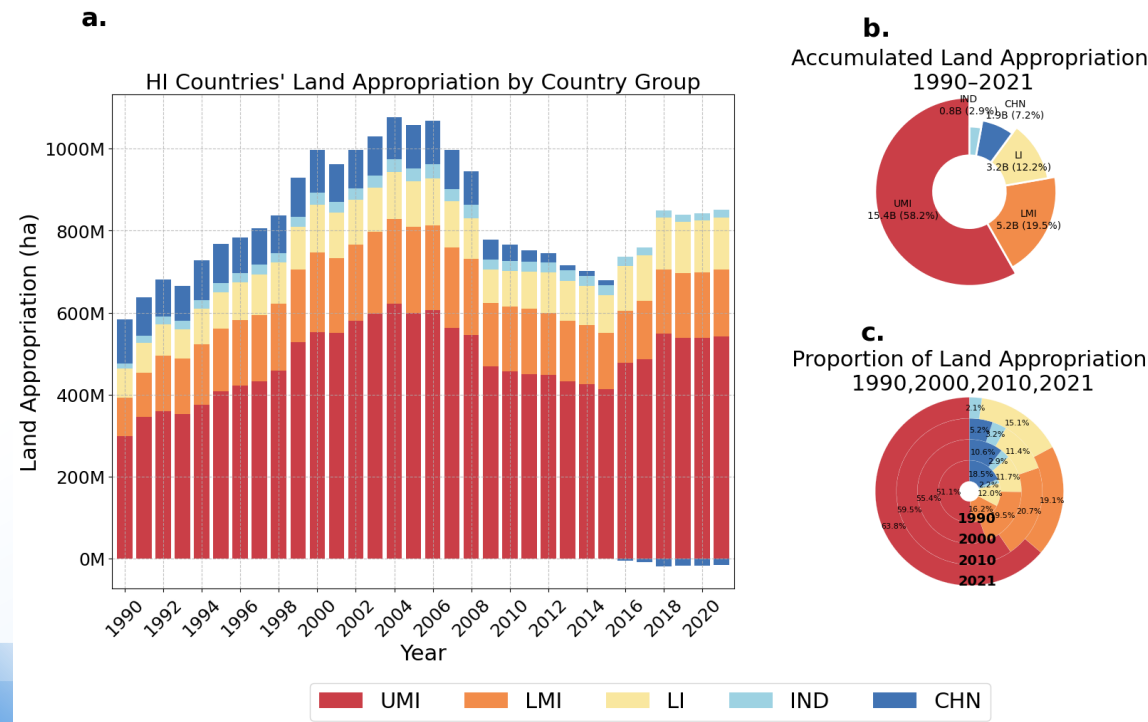
HI imports rose sharply, driven mainly by domestic final demand for land-intensive goods

2004-2015

Efficiency gains and changing trade patterns temporarily narrowed the imbalance

2015-2021

Drivers became more differentiated; China's lower land intensity reduced exports while UMI and LMI exports rose



The widening or narrowing of embodied land inequality is not explained by one factor alone; demand growth interacts with production technology and trade structure



04

Discussion

PART FOUR

■ Discussion

- Unequal land exchange has persisted for decades, with high-income countries continuously appropriating land embodied in trade from lower-income countries
- High-income countries' reliance on foreign land creates growing vulnerabilities in supply chains and resource security
- Unequal embodied land outflows constrain food security and development in lower-income countries while shifting biodiversity loss to these regions
- Lower-income countries receive disproportionately low monetary returns while bearing substantial land-related and environmental burdens
- These inequalities are deeply embedded in global markets and supply chains, making them difficult to address through ordinary trade mechanisms
- Rebalancing global land flows requires trade policy reform, value-chain upgrading, stronger land governance, and consumption pattern changes

THANK YOU!

