The biodiversity footprint of urban consumption in China declined by one quarter between 2012 and 2017

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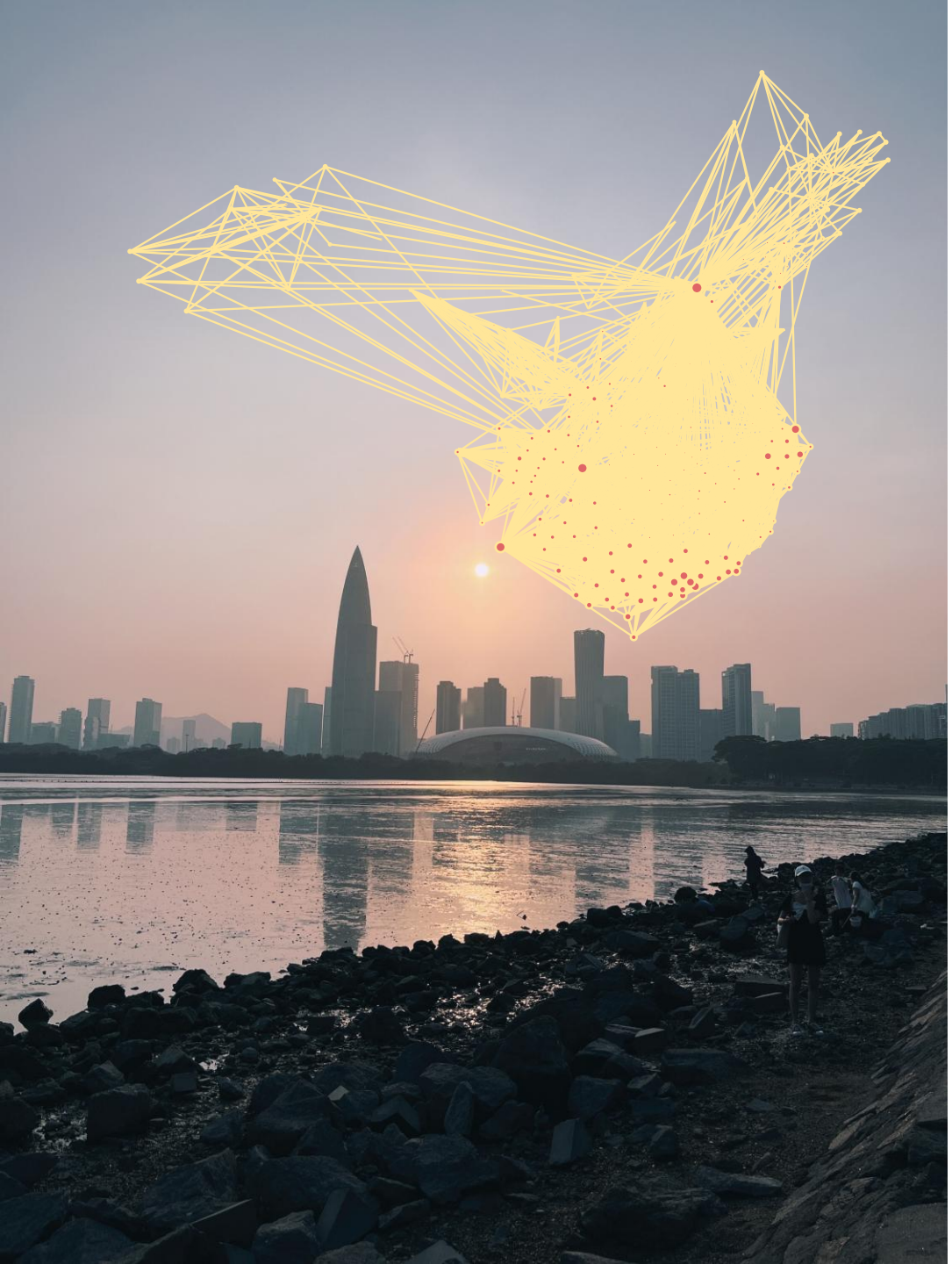
Background

- **Biodiversity is lost and its trend never stops**: The 2022 global LPI shows an average 69% decline in monitored populations between 1970 and 2018.

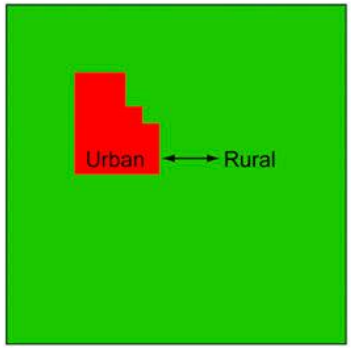
- The biodiversity crisis is a business crisis: Biodiversity loss ranks as the 3rd global risk by severity over the next 5-10 years to World Economic Forum in Davos 2022.

- Over the last 30 years, global urban land increased from 0.2% to 2.4% of the terrestrial land, and more than half of the world's population now live in urban areas, which has increased people's consumption in urban areas and threatened habitats of species.

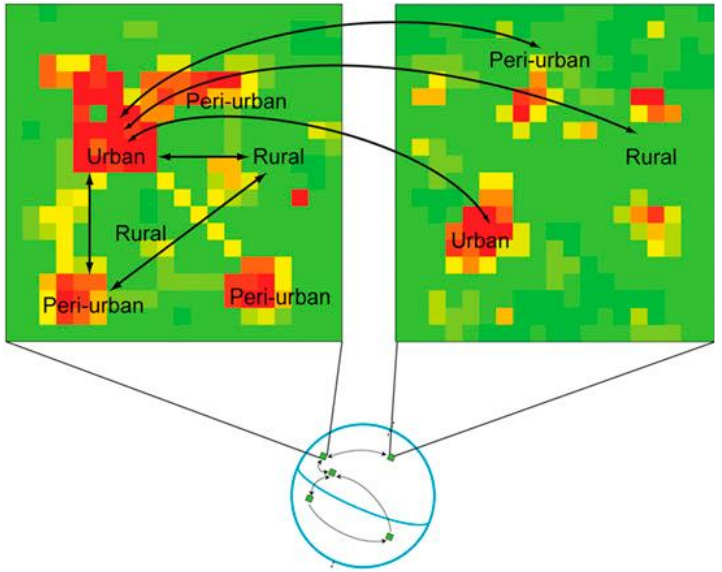
(Living Planet Report,2022; The Global Risks Report, 2022)



The development of urban systems



（a）Spatial expansion between urban and rural areas

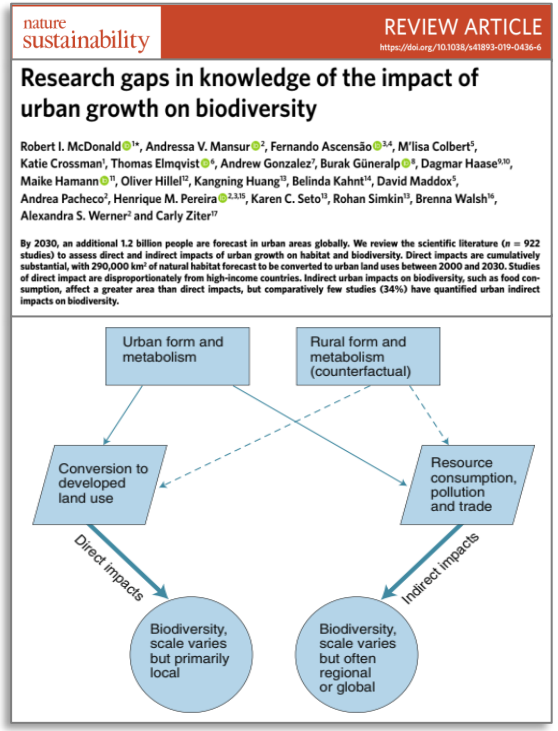


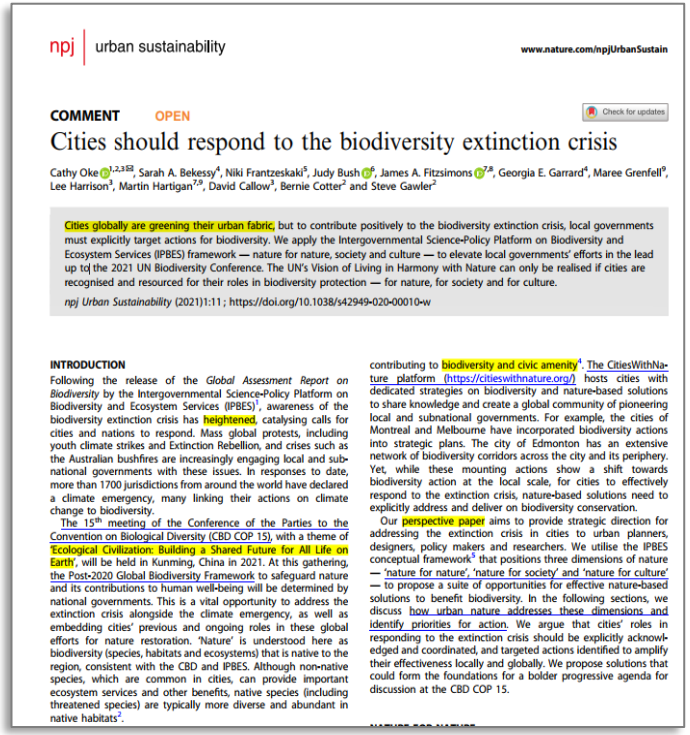
（b）Teleconnections with land, food, water and other resources

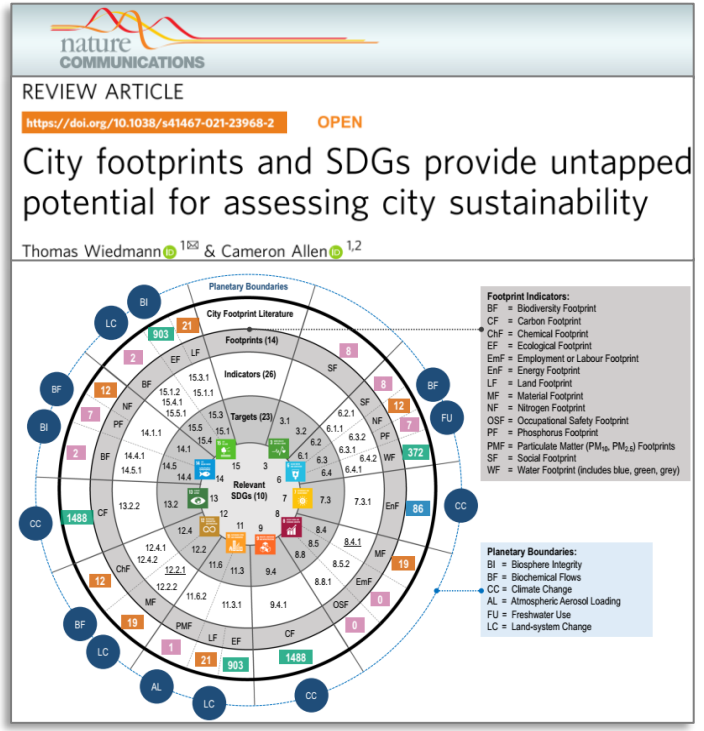
(Seto et al., 2012, PNAS)

Research Gaps:

- Tele-connected effect of urban consumption on biodiversity at the city level
- Driving forces of this biodiversity impact for different cities



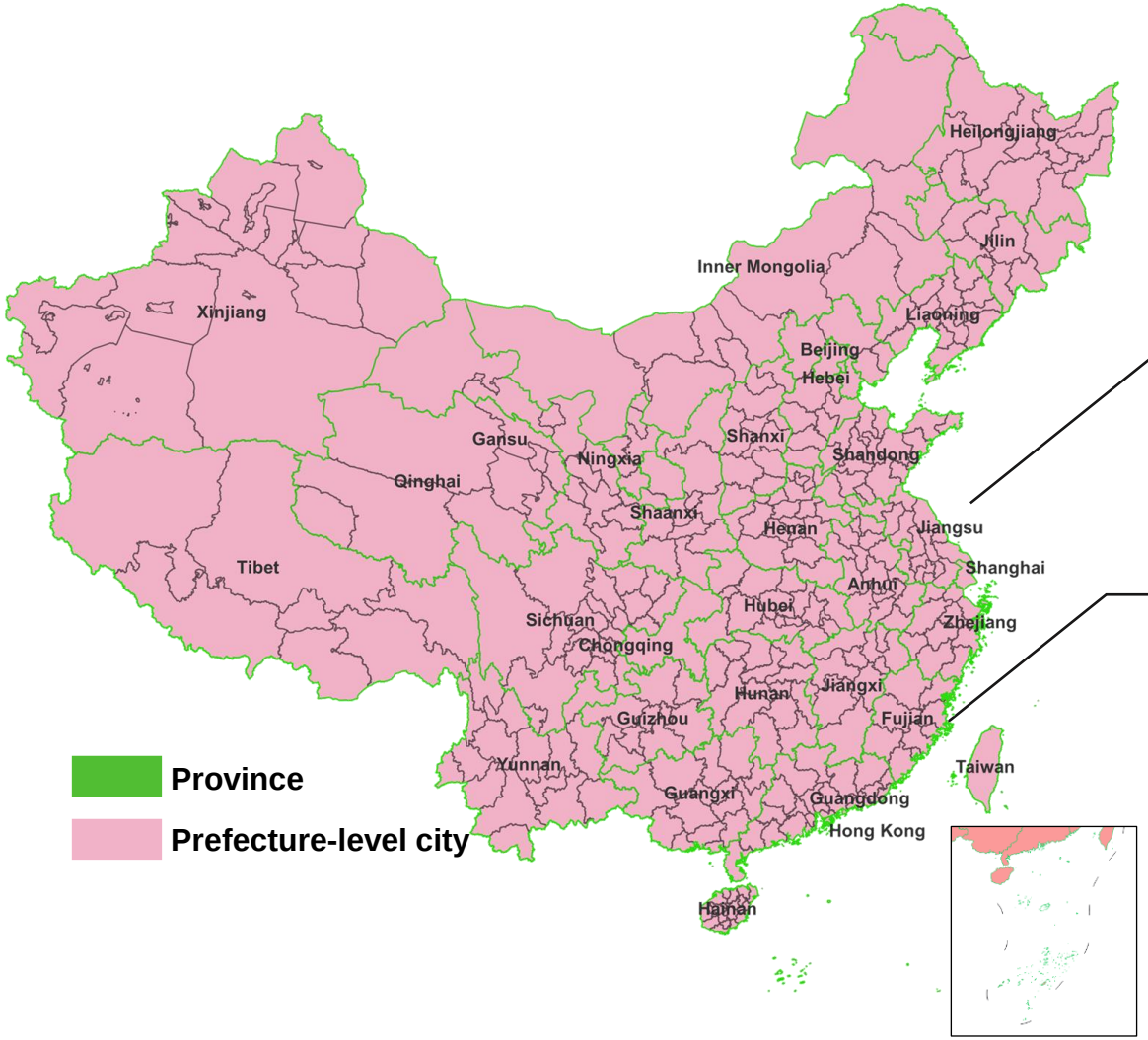




(McDonald et al., 2019, NS; Oke et al., 2021, npj urban sustainability; Wiedmann &Allen, 2021, NC)

Methods

1. Linking the IUCN Red List records with the MRIO table



(a) Downscaled the provincial species records to the prefectural-city level

(i) Species with range maps:

Range map & Administrative map

(ii) Species without range maps:

IUCN records & Administrative map

(b) Linking the IUCN Red List records with the MRIO table

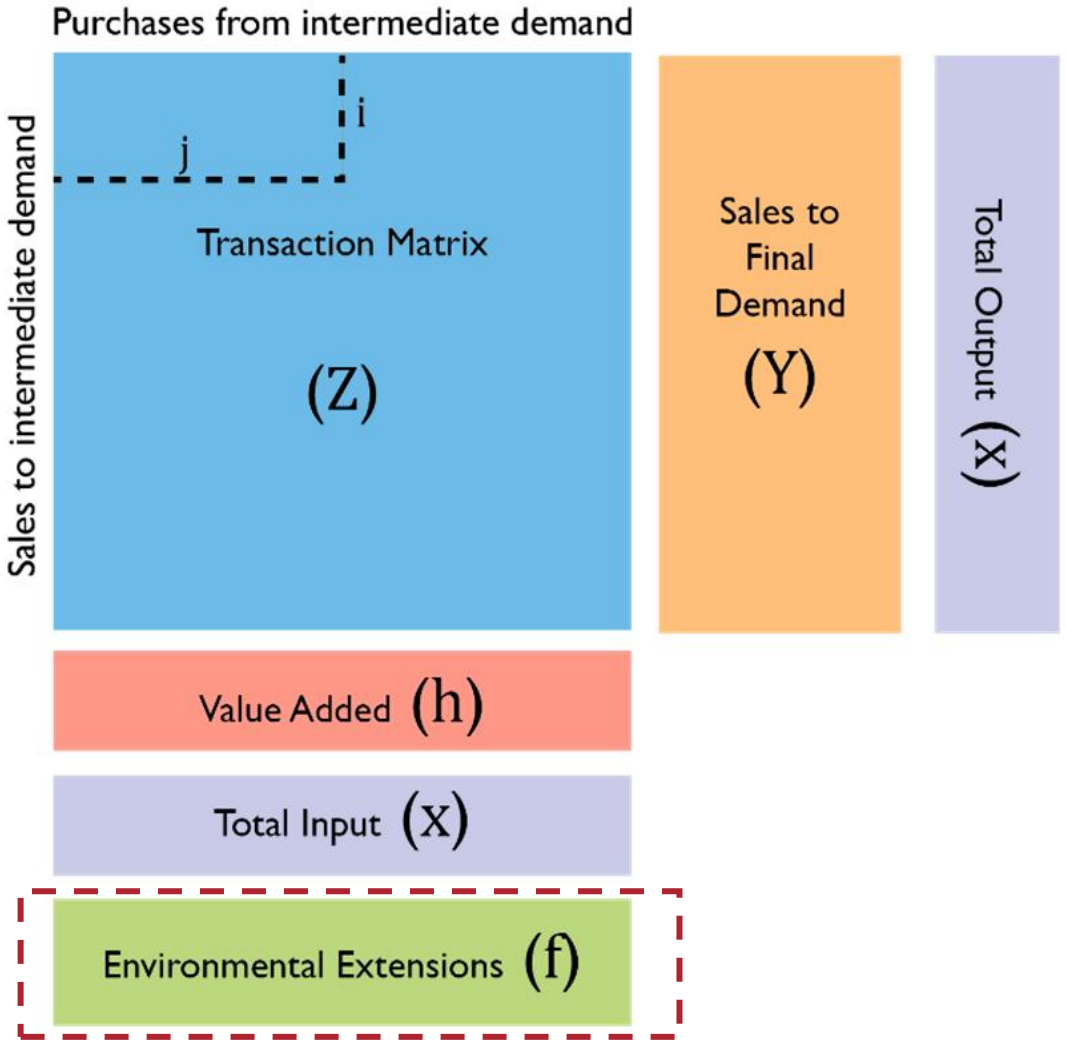
Multi-regional IO table structure

Multi-reigonal IO table for 31 provinces

Muti-regional Input-Output table			Intermediate Use									Final Demand											Export	Total Output
			Province 1			…	Province 31			Province 1					…	Province 31								
			Sector 1	…	Sector 42	…	Sector 1	…	Sector 42	F1	F2	F3	F4	F5	…	F1	F2	F3	F4	F5				
Intermediate input	Province 1	Sector 1	$Z_{1,1}$			…	$Z_{1,31}$			$F_{1,1}$					…	$F_{1,31}$						EX	TO
		…																						
		Sector 42																						
	…	…	…			…	…			…					…	…								
	Province 31	Sector 1	$Z_{31,1}$			…	$Z_{31,31}$			$F_{31,1}$					…	$F_{31,31}$								
		…																						
		Sector 42																						
Import			$IM_{inter\ use}$							$IM_{final\ demand}$														
Value added	Conpensation of employees		$V_{1,1}$			…	$V_{1,31}$																	
	Net taxes on production		$V_{2,1}$			…	$V_{2,31}$																	
	Depreciation on the fixed capital		$V_{3,1}$			…	$V_{3,31}$																	
	Operationg surplus		$V_{4,1}$			…	$V_{4,31}$																	
Total input			TI																					

Environmental extension/Satellite account Q

2. Environmentally-extended MRIO model

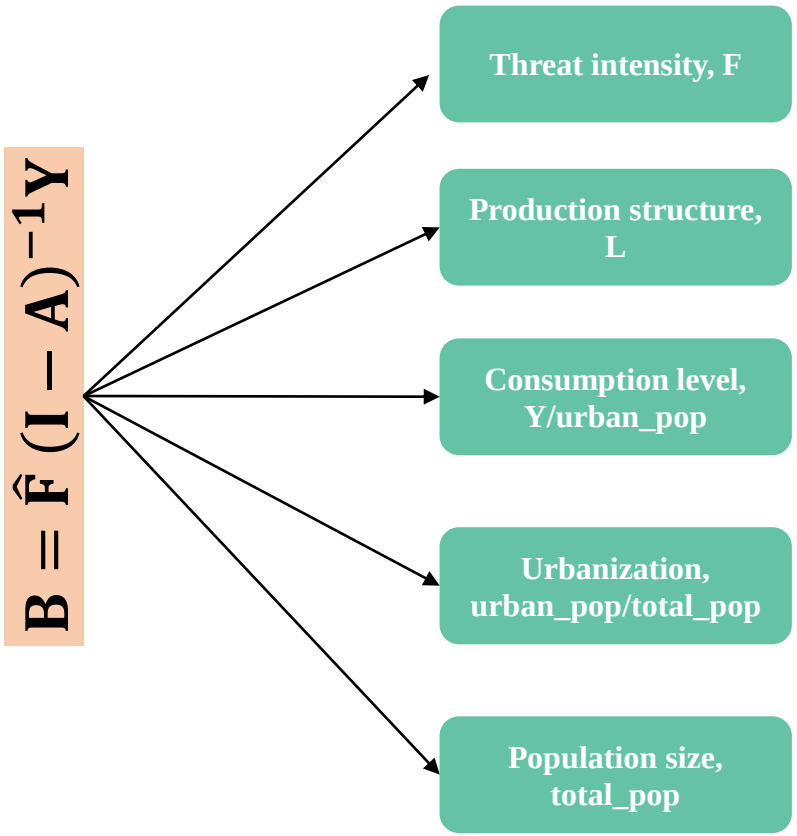


$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}$$

$$\mathbf{F} = \mathbf{f}/\mathbf{X}$$

$$\mathbf{B} = \hat{\mathbf{F}}\,(\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}$$

3. structural decomposition analysis (SDA)



Threat intensity:

$$f(\Delta\hat{\mathrm{F}}) = \frac{1}{2}\Delta\hat{\mathrm{F}}(\mathrm{I} - \mathrm{A}_{t0})^{-1}\mathrm{V}_{t0}\mathrm{U}_{t0}\mathrm{P}_{t0} + \frac{1}{2}\Delta\hat{\mathrm{F}}(\mathrm{I} - \mathrm{A}_{t1})^{-1}\mathrm{V}_{t1}\mathrm{U}_{t1}\mathrm{P}_{t1}$$

Production structure:

$$f(\Delta(\mathrm{I} - \mathrm{A})^{-1}) = \frac{1}{2}\hat{\mathrm{F}}_{t1}\Delta(\mathrm{I} - \mathrm{A})^{-1}\mathrm{V}_{t0}\mathrm{U}_{t0}\mathrm{P}_{t0} + \frac{1}{2}\hat{\mathrm{F}}_{t0}\Delta(\mathrm{I} - \mathrm{A})^{-1}\mathrm{V}_{t1}\mathrm{U}_{t1}\mathrm{P}_{t1}$$

Consumption level:

$$f(\Delta\mathrm{V}) = \frac{1}{2}\hat{\mathrm{F}}_{t1}(\mathrm{I} - \mathrm{A}_{t1})^{-1}\Delta\mathrm{V}\mathrm{U}_{t0}\mathrm{P}_{t0} + \frac{1}{2}\hat{\mathrm{F}}_{t0}(\mathrm{I} - \mathrm{A}_{t0})^{-1}\Delta\mathrm{V}\mathrm{U}_{t1}\mathrm{P}_{t1}$$

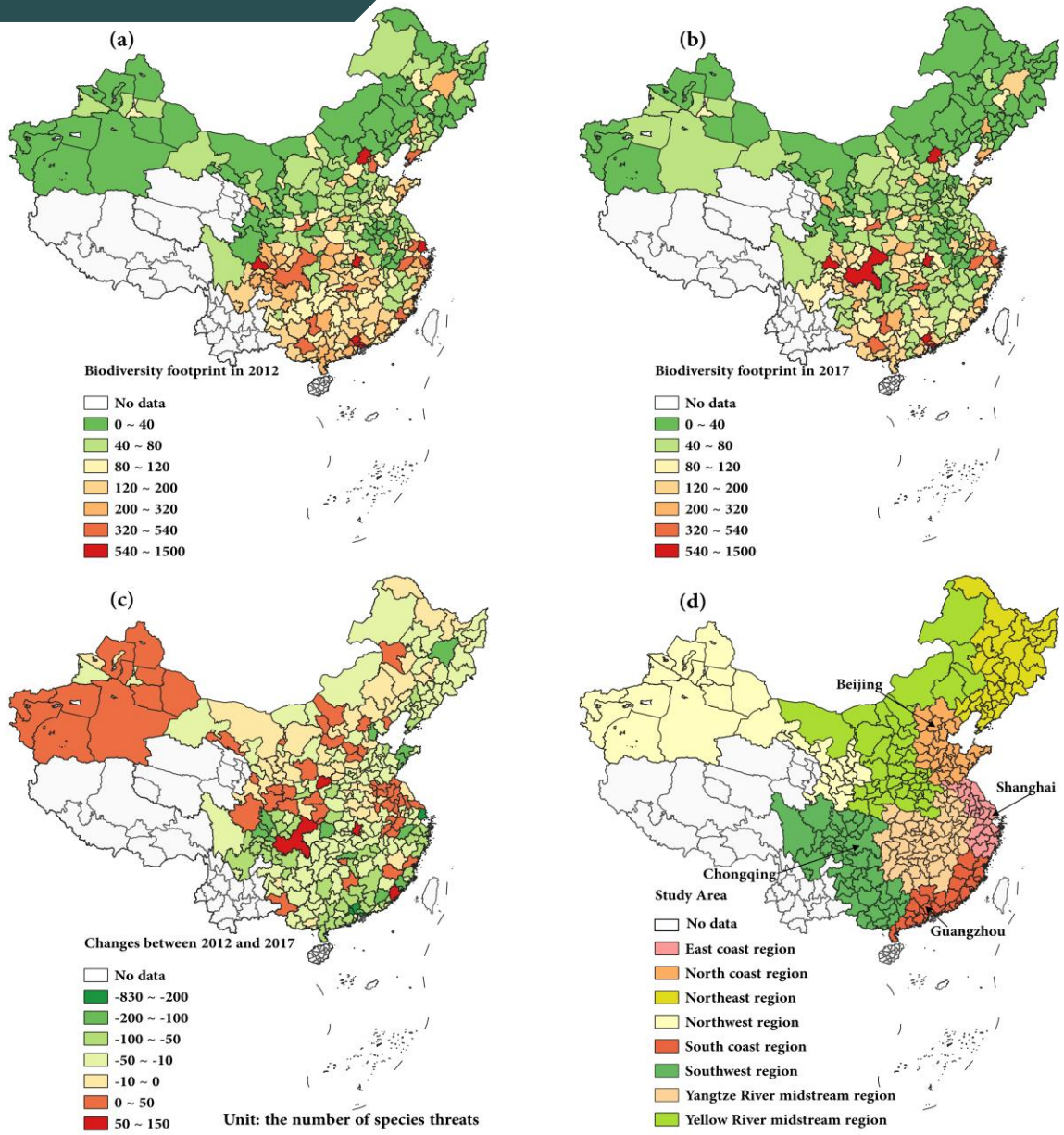
Urbanization:

$$f(\Delta\mathrm{U}) = \frac{1}{2}\hat{\mathrm{F}}_{t1}(\mathrm{I} - \mathrm{A}_{t1})^{-1}\mathrm{V}_{t1}\Delta\mathrm{U}\mathrm{P}_{t0} + \frac{1}{2}\hat{\mathrm{F}}_{t0}(\mathrm{I} - \mathrm{A}_{t0})^{-1}\mathrm{V}_{t0}\Delta\mathrm{U}\mathrm{P}_{t1}$$

Population size:

$$f(\Delta\mathrm{P}) = \frac{1}{2}\hat{\mathrm{F}}_{t1}(\mathrm{I} - \mathrm{A}_{t1})^{-1}\mathrm{V}_{t1}\mathrm{U}_{t1}\Delta\mathrm{P} + \frac{1}{2}\hat{\mathrm{F}}_{t0}(\mathrm{I} - \mathrm{A}_{t0})^{-1}\mathrm{V}_{t0}\mathrm{U}_{t0}\Delta\mathrm{P}$$

Results

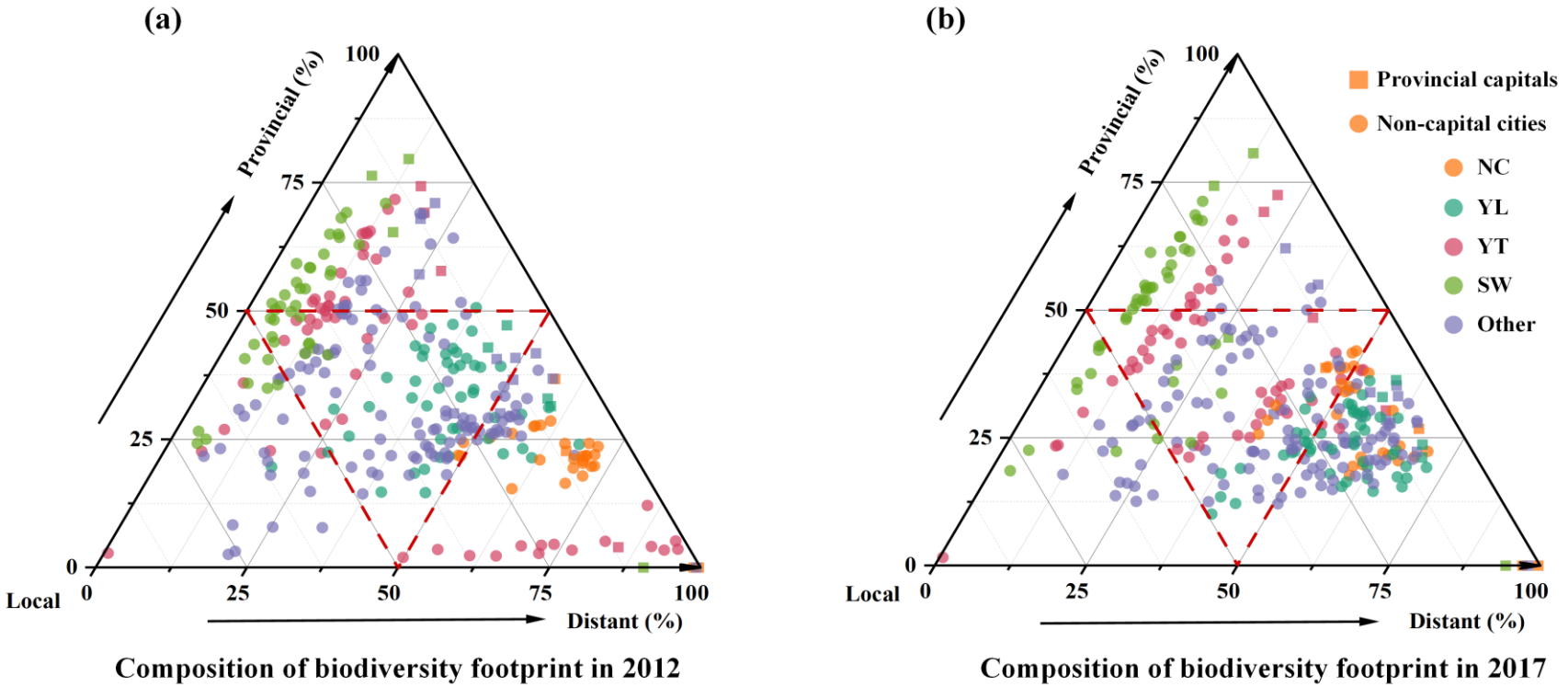


1. Urban consumption-embodied biodiversity footprint in China

- evenly distributed at the city level;
- Approximately 24% of urban consumption-embodied biodiversity footprint reduced

Figure 2. Urban consumption-embodied biodiversity footprint at the city level across China (a) in 2012, (b) in 2017, (c) changes in biodiversity footprint between 2012 and 2017, and (d) the study area.

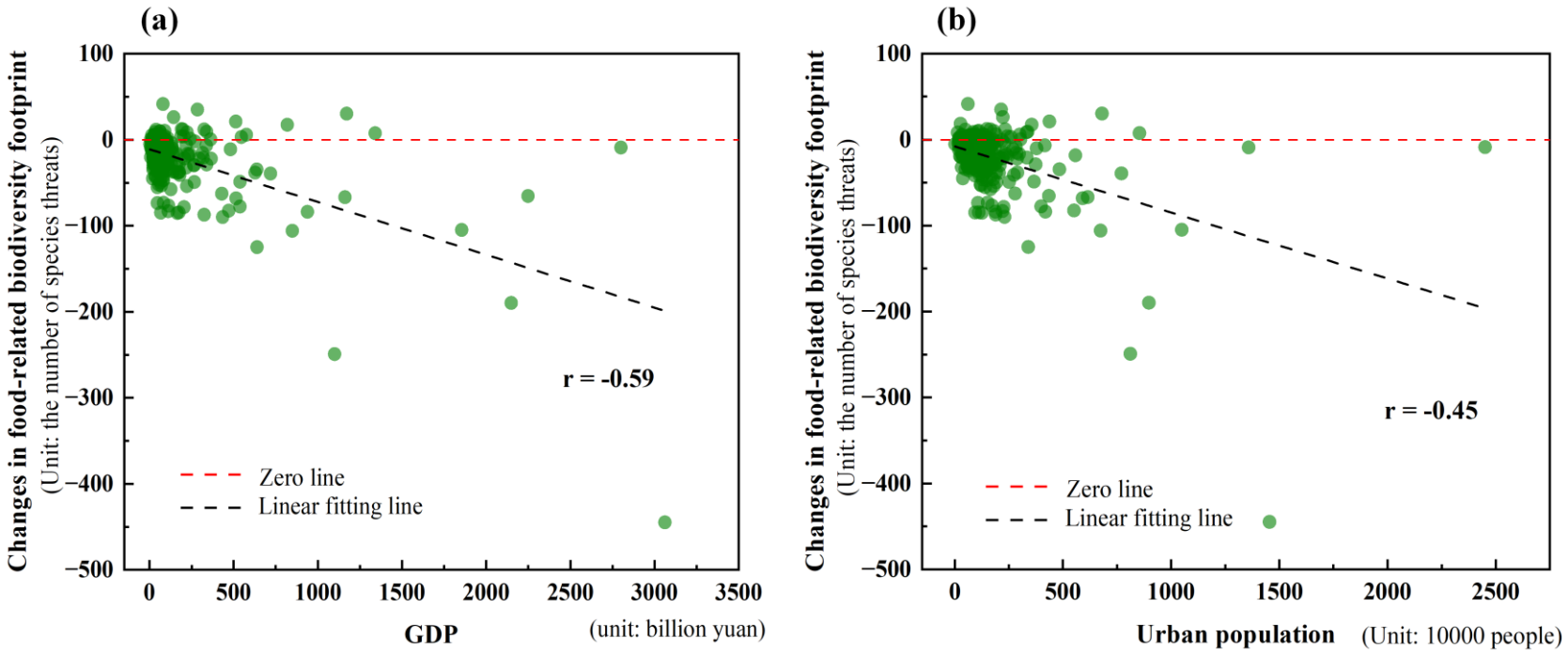
2. Change in the composition of biodiversity footprint



- A greater share of biodiversity footprint was shifted beyond cities' borders

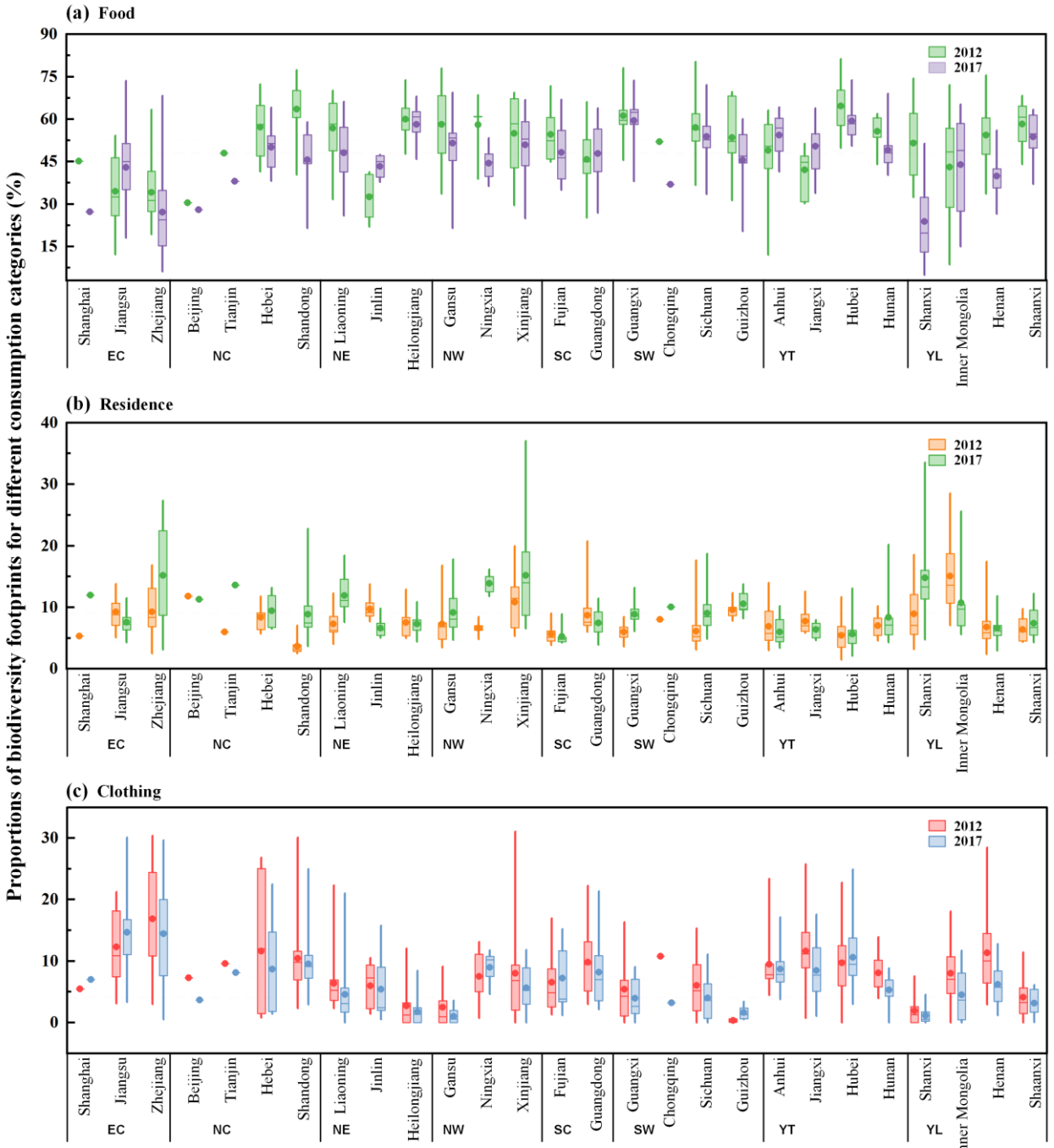
Figure 3. The composition of urban consumption-embodied biodiversity footprint in (a) 2012 and (b) 2017. Squares and dots in ternary diagrams represent the provincial capitals and non-capitals, respectively. NC: north coast region, YL: the Yellow River midstream region, YT: the Yangtze River midstream region, SW: southwest region, Other: east coast, northeast, northwest, and south coast regions.

3. Biodiversity footprint variation across consumption categories



- the reduction in food-related footprint was the dominant part of the large-scale shrinkage in biodiversity footprint.

Figure 4. Changes in food-related biodiversity footprint against gross domestic production (GDP) and urban population for 309 cities. r is the Pearson's correlation ($p < 0.001$).



- a combination of an absolute reduction in food consumption, and an increasing proportion of non-food categories

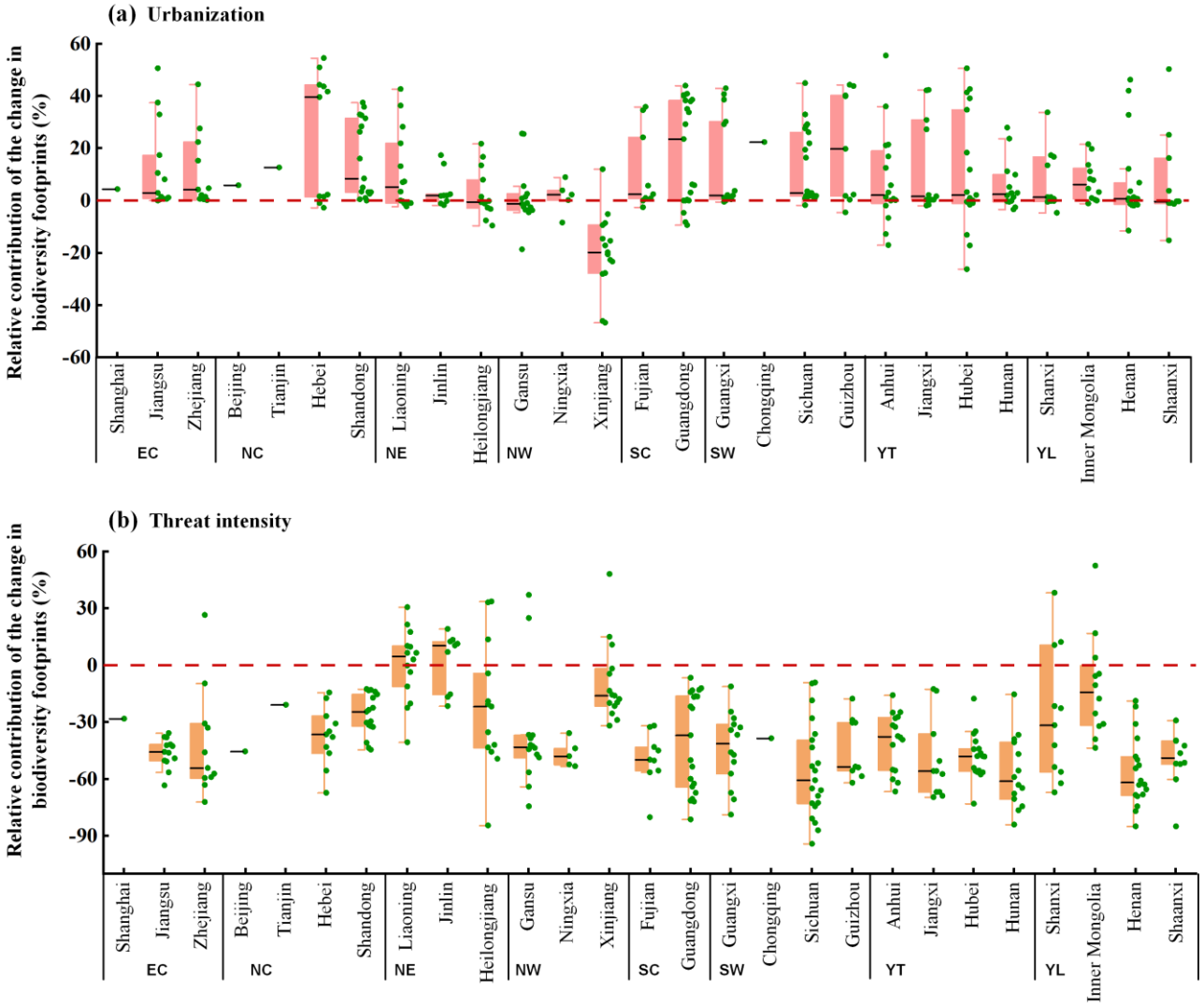
Food: from 52.64% to 47.97%

Residence: from 7.69% to 9.03%

Clothing: from 7.91% to 6.46%

Figure 5. Proportions of biodiversity footprint from different categories of consumption in 2012 and 2017. (a) food; (b) residence; (c) clothing.

4. Driving forces of biodiversity footprint change



- urbanization was one of the main contributors to change in biodiversity footprint
- the decline in threat intensity, approximately in 90% of Chinese cities, became a factor that effectively reduced the biodiversity footprint

Figure 6. The relative contributions of driving forces to the city-level biodiversity footprint for 309 cities. The contributions of (a) urbanization, (b) threat intensity, and (c) consumption level.

Discussion

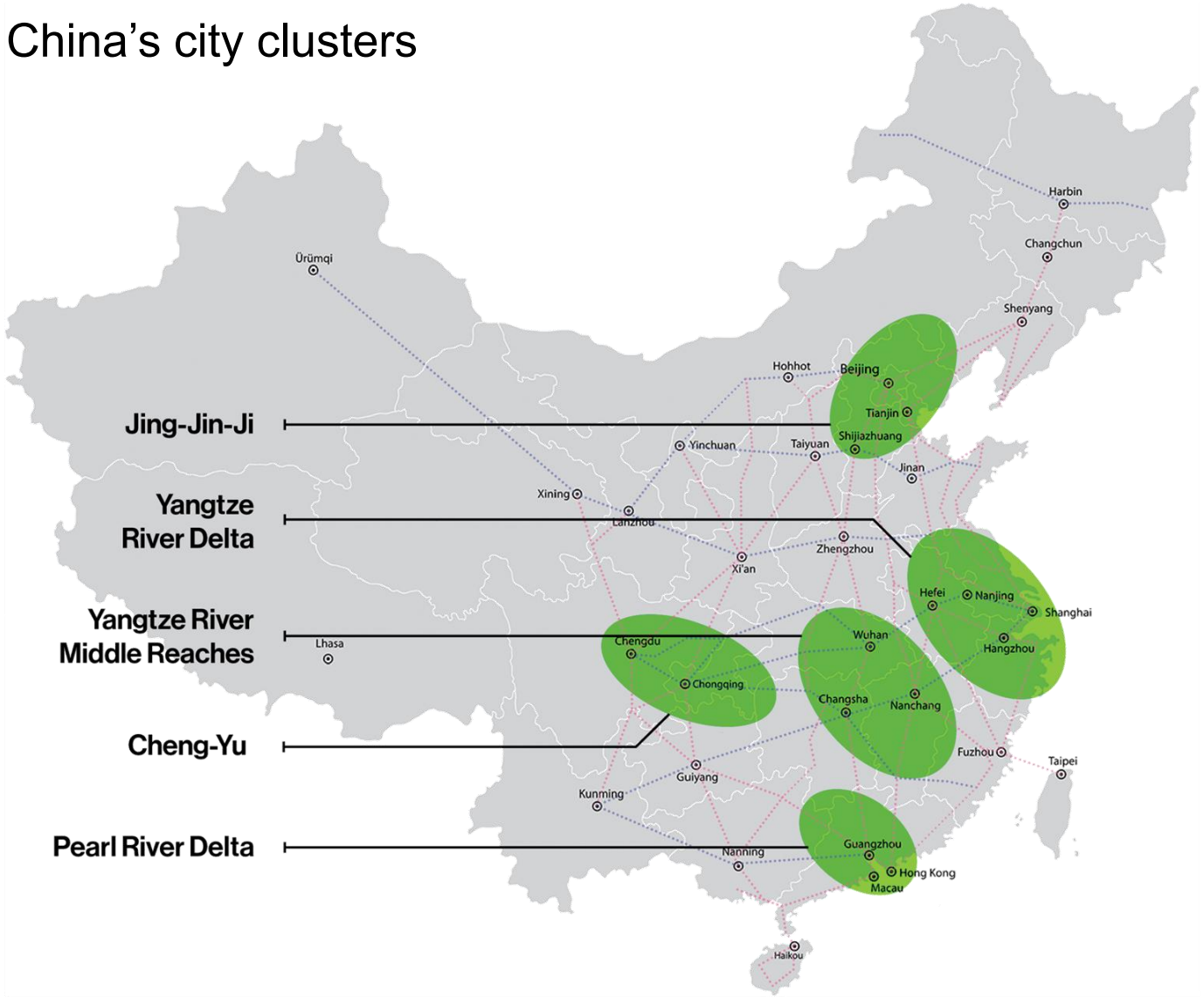
1. The large-scale shrinkage in biodiversity footprint

Similar to the study of CO2 emissions;

Caused by multiple reasons: technological innovation, consumption pattern, national governance and so on.

2. The more tele-connected biodiversity impact across China

a. China’s city clusters



Five major city clusters generate over half of the nation’s GDP and house over half its urban population

b. China’s poverty alleviation program

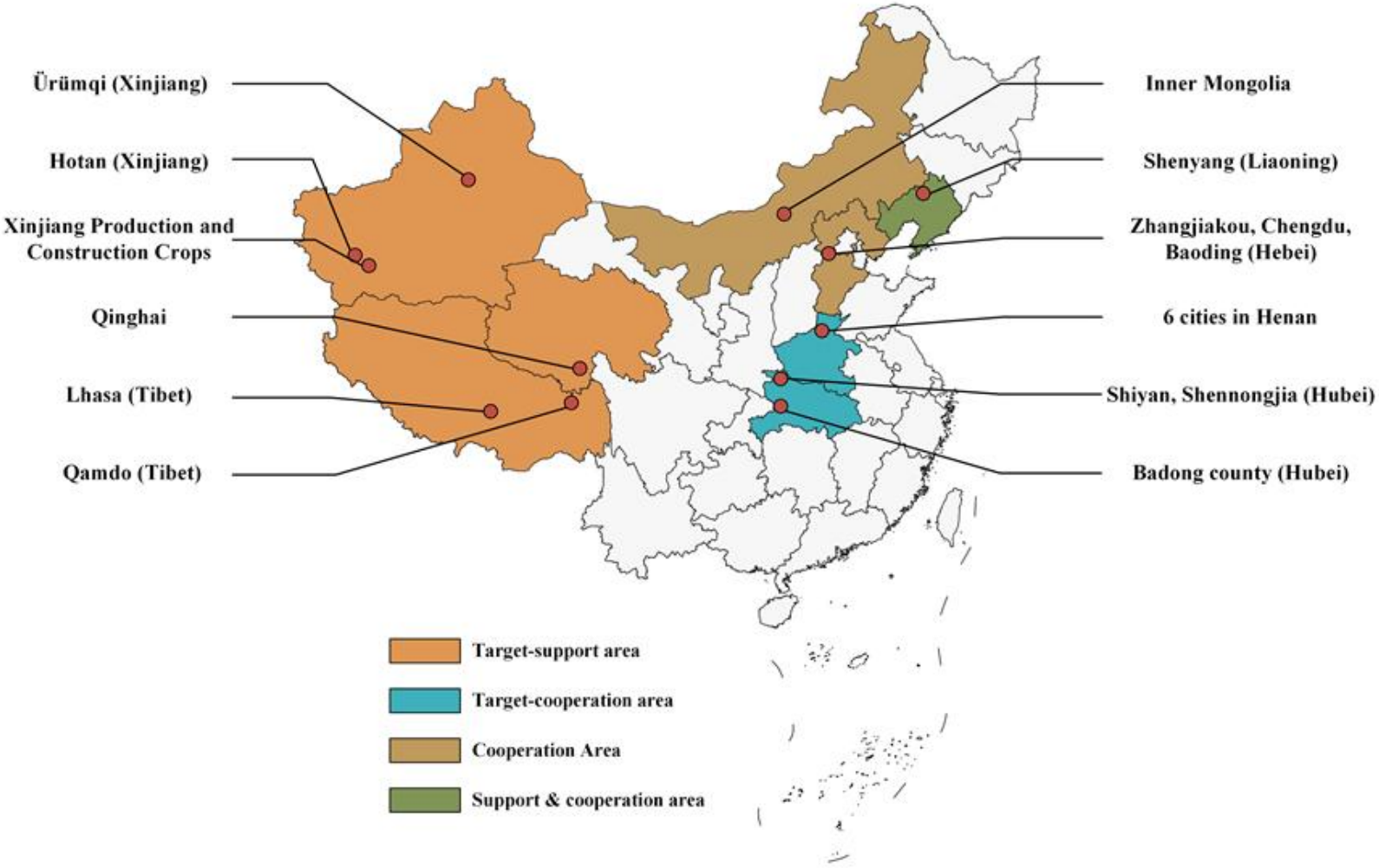
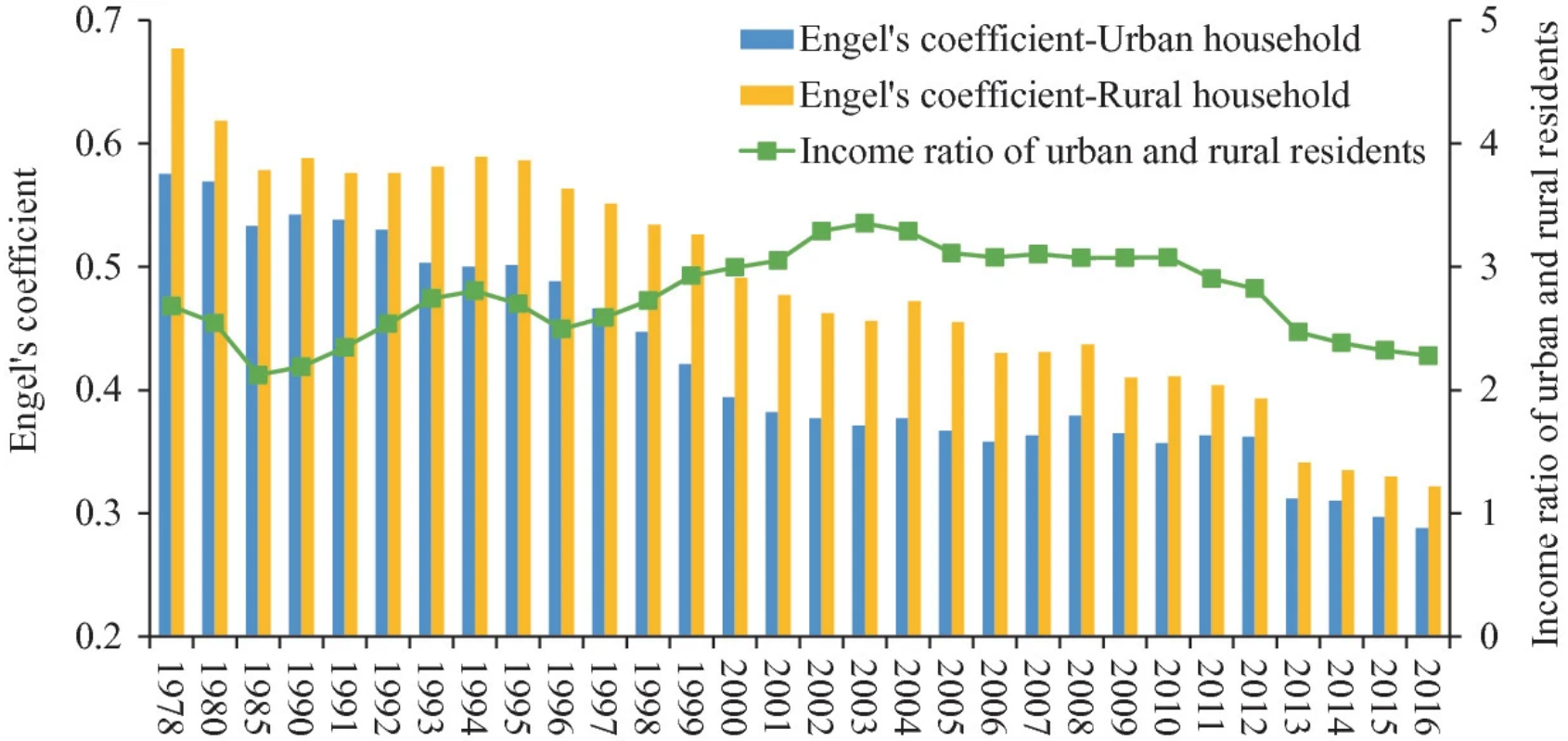


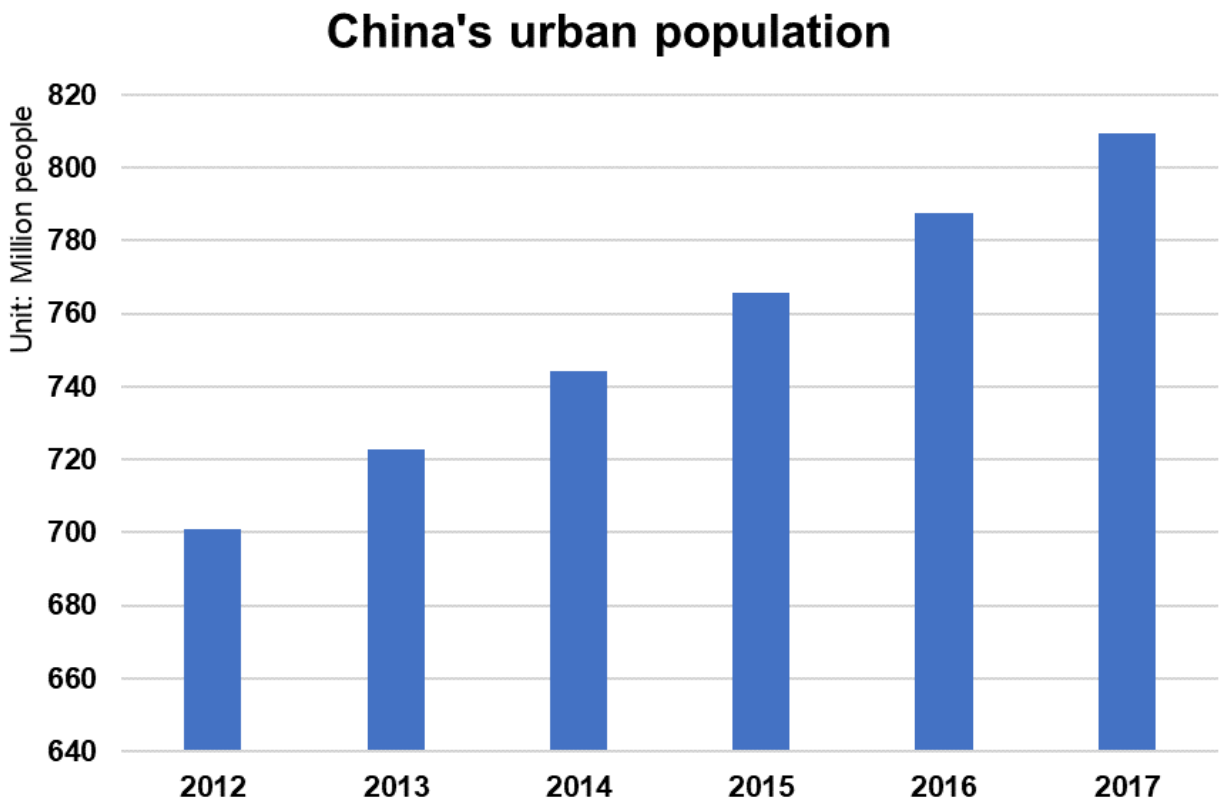
Figure S5. Target-support and cooperation areas from Beijing in China’s poverty alleviation (Source: http://fpzg.cpad.gov.cn/)

3. Reduction in food-related biodiversity impact



(Yansui Liu., 2021, Urban-rural transformation geograhy)

4. Urbanization and sustainable supply chains as drivers



Sustainable supply chains:
Technology advancement

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