

Urban cluster development and agricultural land loss in China and India: A multi-scale and multi-sensor analysis

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Background

- By 2030, the urban population of China and India will grow by 700 million, the largest urban transition in history.
- Economics, urban planning, and political science research show that patterns of urban growth are not fully captured within administrative boundaries, and emphasize **urban clusters** as an important unit for policy and land-use planning.
- No prior remote sensing-based studies have evaluated **urban cluster growth** or its underlying causes.

Key findings

A. Hotspots of urban cluster growth

During 1992–2010, India's urban cluster growth hotspots were Greater Bangalore, the Mumbai–Hyderabad corridor, and the Delhi–Ludhiana corridor; there is no evidence of Delhi–Mumbai corridor growth. These hotspots are consistent over time and are concentrated around existing large cities, with little spillover into surrounding regions. In China, urban cluster growth hotspots were the Pearl River Delta, the Yangtze River Delta, the Shandong Peninsula, and the Beijing–Tianjin corridor. Over time, these hotspots shrank or expanded and new clusters emerged.

B. Analysis of urban land conversion

Both China and India have experienced rapid loss of cultivated land to urban expansion in the past two decades. During 2001–2010, India lost an area of agricultural land equivalent to five times the size of Delhi. Urban expansion in India's smaller cities results in more agricultural land conversion than urban expansion around bigger cities. In China, newly cultivated farmland has largely offset the loss of agricultural land to urban expansion. Agricultural intensification is negatively correlated with urban expansion in China.

C. Drivers of urban cluster growth and land conversion

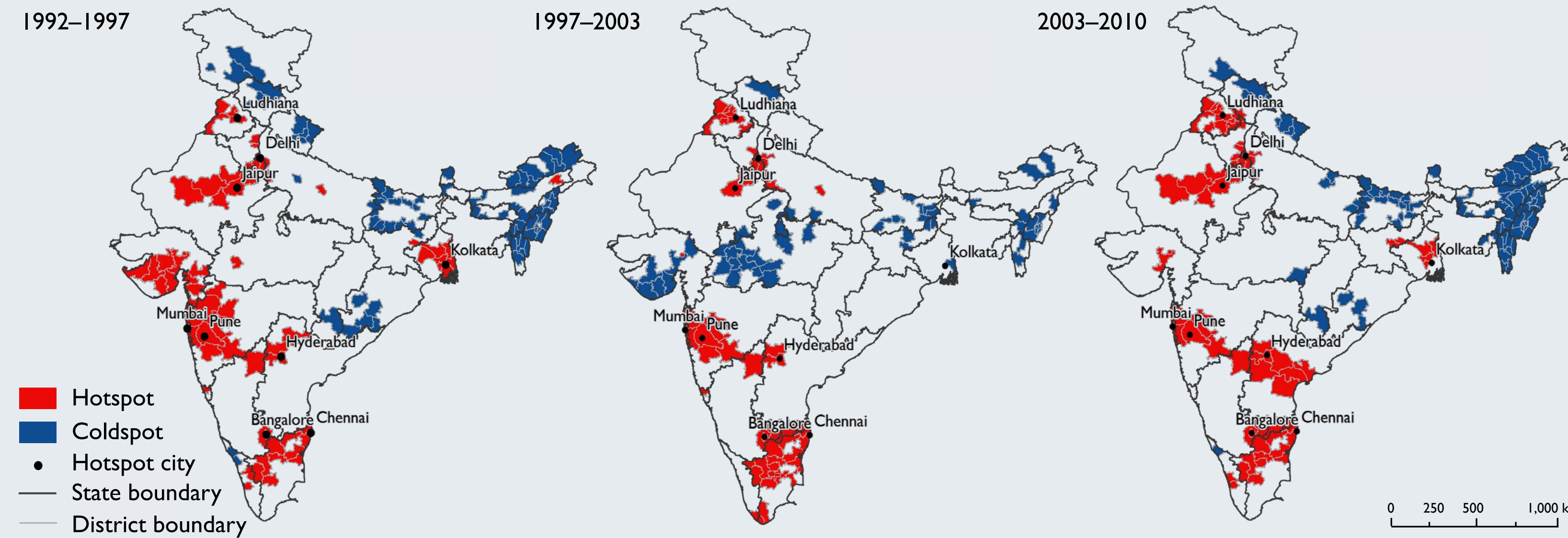
Foreign direct investment spurred urban cluster growth only in India's primate cities, Mumbai and Delhi. India's higher education institutions promote regional economic growth through infrastructure development and labor training. India's major urban renewal program, the JNNURM, has not caused urban land expansion. In China, urban cluster growth is driven by urban wages and FDI, and central government transfers are declining in significance. Agricultural investments induce urban land conversion in China, which may indicate a policy failure.

D. New remote sensing methods for characterizing urbanization

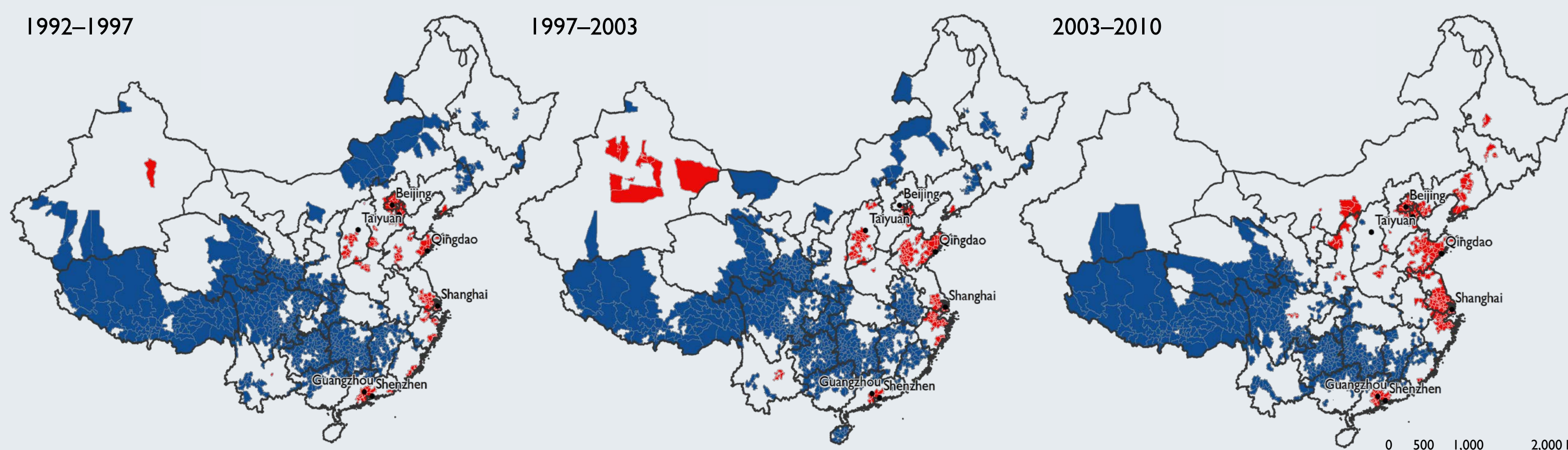
Spatial statistical analysis of time series DMSP/OLS nighttime light (NTL) data can detect urban growth hotspots at regional scales. The Vegetation Adjusted NTL Urban Index (VANUI) combines NTL with MODIS NDVI to provide global, timely information about inter-urban variability in form, infrastructure, and energy use. Using SeaWinds with NTL allows for characterization of 3D urban structure.

A. Hotspots of urban cluster growth

Night-time lights shows cluster growth around major urban areas and transport corridors in India



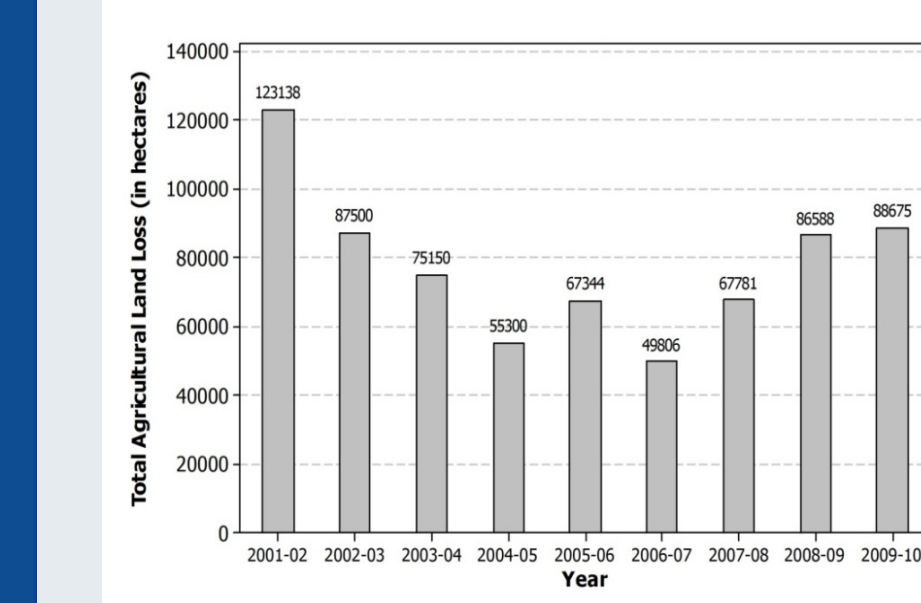
China's hotspots are concentrated around major urban regions and show greater inter-period variation



B. Analysis of urban land conversion

Loss of Indian agricultural land concentrated in areas most suited for cultivation

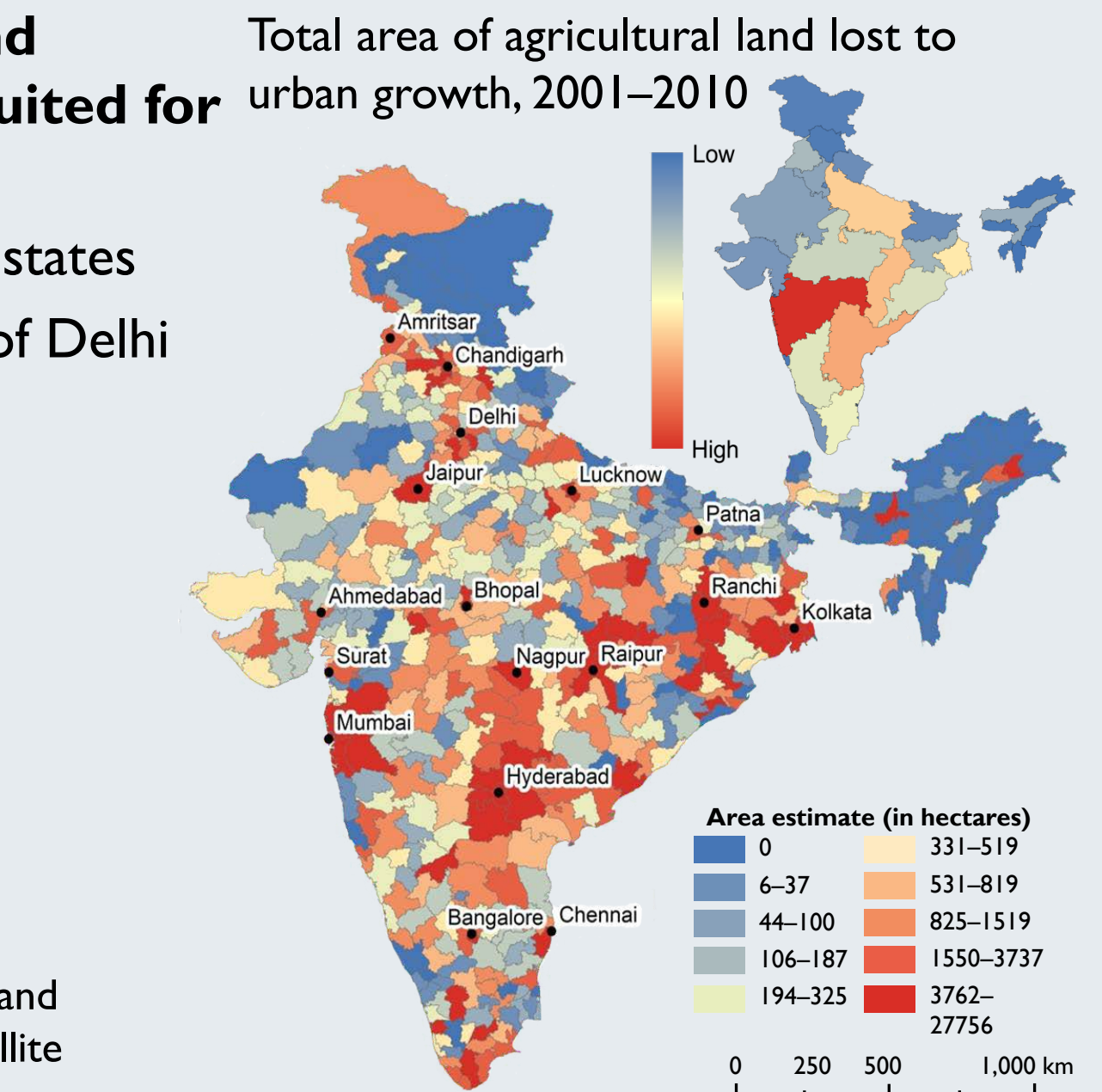
- Concentrated in industrialized states
- 0.7 million ha lost, 5x the size of Delhi



Pandey B, Seto KC. Accepted. Urbanization and agricultural land loss in India: comparing satellite estimates with census data. *J. Environ. Manage.*

China's agricultural land intensifying and spreading

- The net loss of cultivated land in developed provinces suggests intensification
- Additional land brought under cultivation offsets agricultural land loss due to urbanization



	Fixed Effects Model R ² , p-value, (t-statistic)	Random Effects Model R ² , p-value, (t-statistic)
Intercept	0.720, p<0.01 (14.94)	
Converted Land Area (000 ha)	-0.010, p<0.1 (-2.19)	-0.016, p<0.01 (-3.75)
Cultivated Land Area (000 ha)	-0.652, p<0.01 (-6.60)	-0.883, p<0.01 (-17.81)
Industrial GDP (billion ¥)	-0.010, p<0.01 (-3.99)	-0.011, p<0.01 (-5.61)
GDP per cap. (000 ¥)	0.004, p<0.01 (1.89)	0.006, p<0.01 (4.02)
Ag. investment per cap. (000 ¥)	0.706, p<0.05 (2.55)	0.671, p<0.01 (3.30)
Length of Highways (km)	0.0007, p<0.01 (6.91)	
Distance of county seat to province capital (km)		-0.0005, p<0.01 (-4.46)
Ratio of low-incline land (<8° grade)		0.369, p<0.01 (12.06)
Avg. elevation (km)		-0.077, p<0.01 (-4.80)
Avg. annual precipitation (mm)		0.0002, p<0.01 (7.45)
Avg. annual temperature (°C)		0.027, p<0.01 (8.62)
Observations	5010	5010
R-squared	0.21	0.31

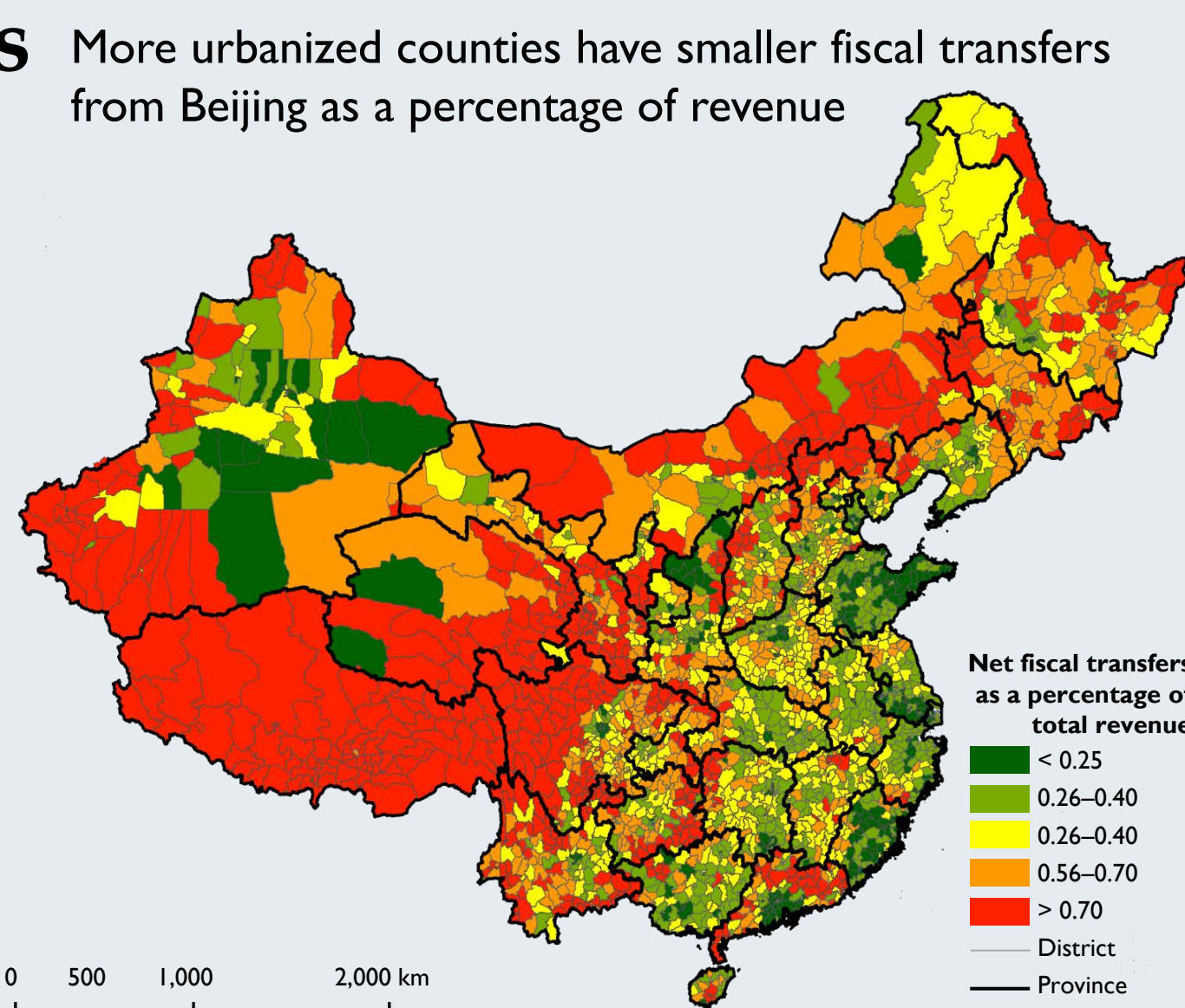
Jiang L, Deng X, Seto KC. The impact of urban expansion on agricultural land use intensity. *Land Use Policy* 35: 33–39

C. Drivers of urban cluster growth and land conversion

Fiscal Transfers

Local governments take a stronger role in urban expansion

- Area of urban land conversion greater in counties with lower central government transfers



Zhang, Qian, Wallace J, Deng X, Seto KC. 2014. Central versus local states: Which matters more in affecting China's urban growth? *Land Use Policy* 38: 487–496.

Higher Education

University establishments drive regional growth via infrastructure development, skilled labor training

- Contribution increases with the age of the university
- Diminishing returns on co-located universities suggest investments should focus on underdeveloped regions

Fragkias M, Seto KC. In revision. Do universities drive urban economic growth and regional development in India? Evidence from remote sensing and higher education data. *Urban Economics*.

Drivers of Urban Land Expansion

Primary predictors of urban land conversion in China are local, not regional factors

- Urban wages, agricultural investments per capita, and the ratio of agricultural to urban land rents are the dominant predictors of urban land conversion
- Agricultural investments driving farmland conversion suggest a policy failure

Decomposition analysis of determinants of China's land conversion, 1989–2000

	Estimated Parameter	% change in variable	Impact on converted land (%)	Contribution (%)
Agriculture/Urban Land Rent Ratio	-0.705	-0.11	0.078	0.137
Urban Wages	0.308	1.17	0.360	0.632
Agricultural Investment	0.063	0.59	0.037	0.065
Converted Land		0.57		1

Jiang L, Deng X, Seto KC. 2012. Multi-level modeling of urban expansion and cultivated land conversion for urban hotspot counties in China. *Landsc. Urban Plan.* 108(2–4): 131–139

D. New remote sensing methods for characterizing urbanization

3D Urban Structure

Novel dataset, SeaWinds, adds new dimension to urban form

- SeaWinds backscatter used to derive coarse-resolution urban form and joined with NTL-derived urban extent to characterize changes in 3D structure over time
- Data show Chinese cities growing more vertically than Indian cities, mirroring real estate and investment patterns

Frolking S, Milliman T, Seto KC, & Friedl MA. 2013. A global fingerprint of macro-scale changes in urban structure from 1999 to 2009. *Environ. Res. Lett.* 8(2), 024004.

Reducing DMSP/OLS NTL Saturation

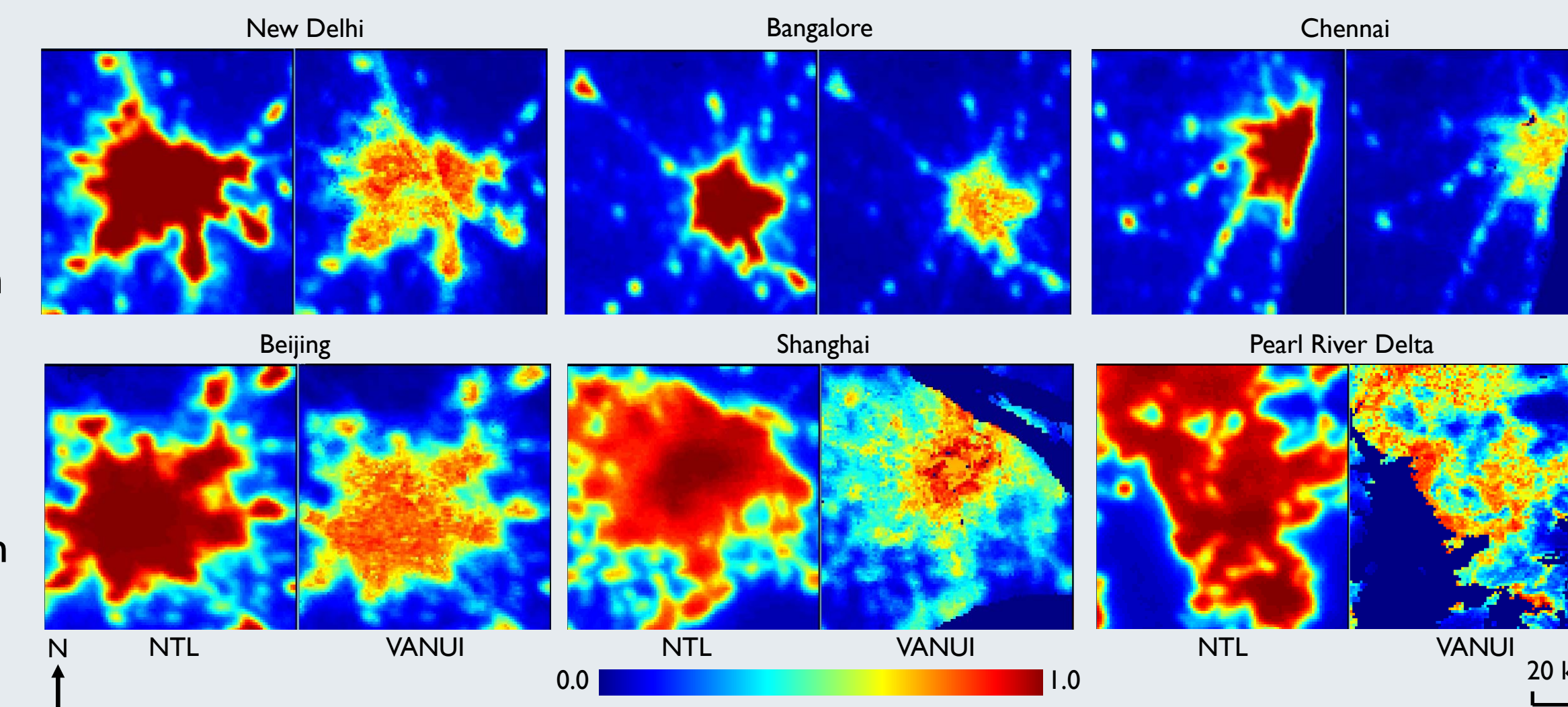
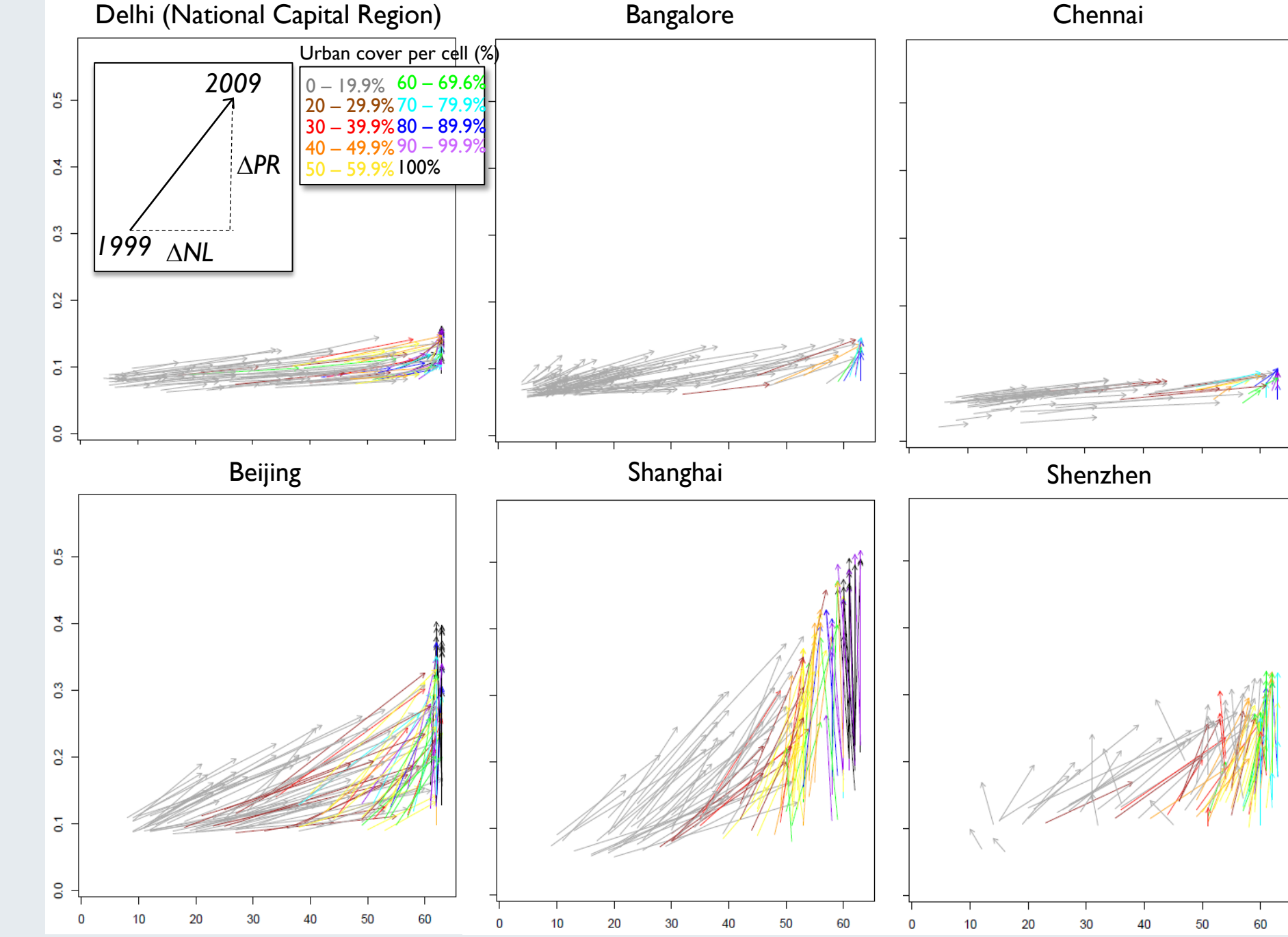
Leveraging NDVI to correct urban NTL saturation

- The Vegetation Adjusted NTL Urban Index (VANUI) increases inter-urban variability using underlying biophysical and urban characteristics

Zhang, Qingling, Schaaf C, Seto KC. The Vegetation Adjusted NTL Urban Index: A new approach to reduce saturation and increase variation in nighttime luminosity. *Remote Sens. Environ.* 129, 32–41

Changes in structural backscatter (PR) and nighttime lights (NL), 1999–2009

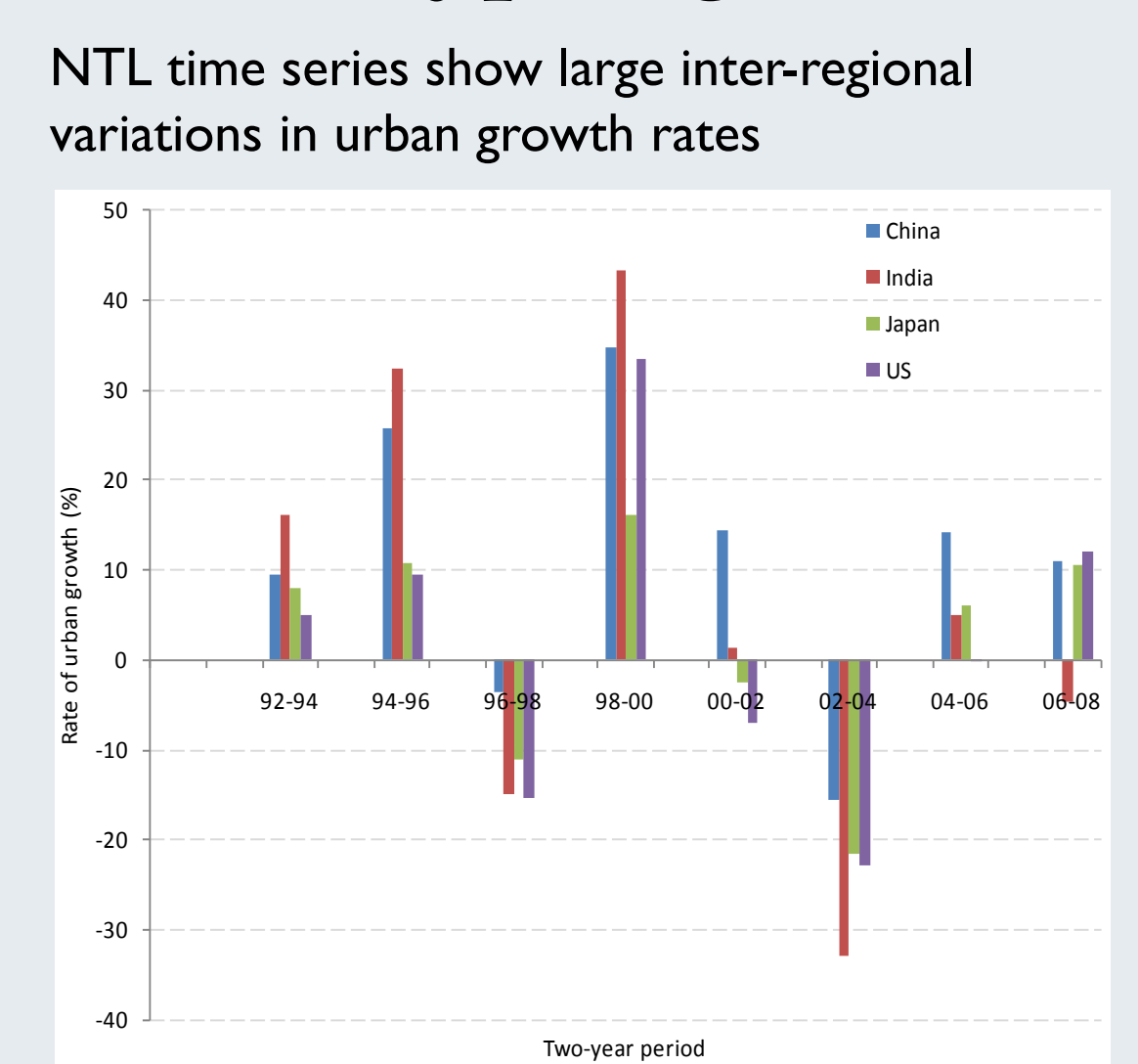
Arrows represent non-water, 0.05° cells in a 11x11 grid around each urban center; tail and head are at 1999 and 2009 coordinates of cell PR and NL



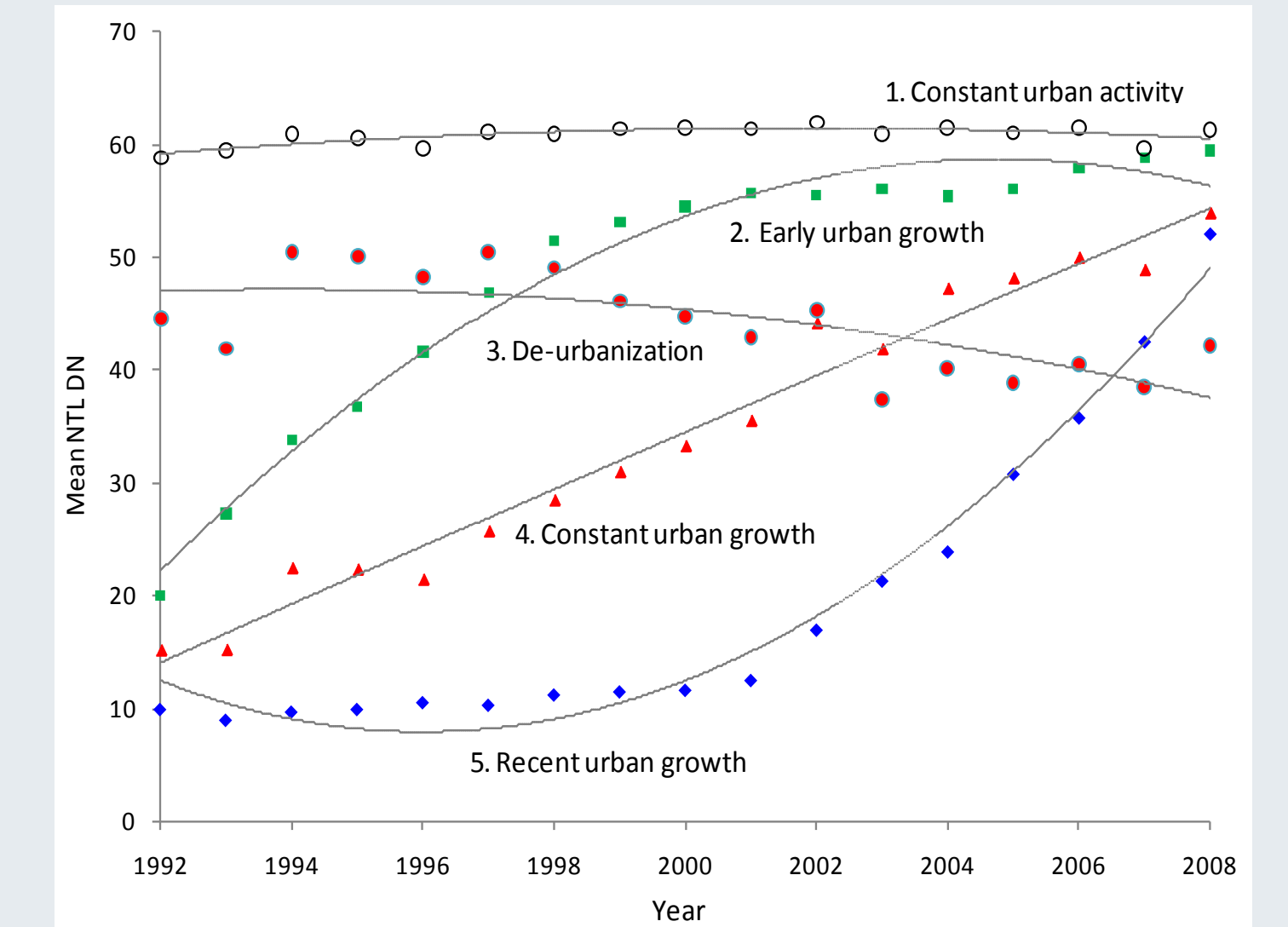
Identifying Urbanization Typologies

NTL temporal profiles can detect urban growth rates and underlying processes

- Rates of urban growth in China and India were higher than the developed world in most two-year periods from 1992 to 2008
- Urban growth accelerated more in 1990s than 2000s in both countries
- Less accurate in less-developed and low-lit regions



NTL temporal profiles identify distinct urbanization typologies



Zhang, Qingling, Seto KC. 2011. Mapping urbanization dynamics at regional and global scales using multi-temporal DMSP/OLS nighttime light data. *Remote Sens. Environ.* 115(9), 2320–2329.

Zhang, Qian, Seto KC. 2013. Can night-time light data identify typologies of urbanization? A global assessment of successes and failures. *Remote Sens.* 5(7), 3476–3494.