



# Decoding Land Transitions across the Urban-Rural Continuums (URC)

## A Synthesis Study of Patterns, Drivers, and Socio-environmental Impacts in Southeast Asia

### Short title: Southeast Asia Land Transitions (SEAL)



PI: Peilei Fan (Tufts University)

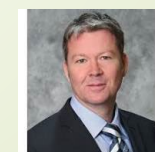
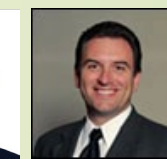
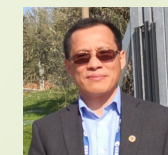
Co-Is: Jiquan Chen (MSU), Atul Jain (U. of Illinois-UC), Soe W. Myint (Texas St. U.), Jiaguo Qi (MSU), Karen Seto (Yale U.).

Southeast Asia Local Collaborators: Edvin Aldrian (IPCC, Indonesia), Heri Andreas (Institute of Technology Bandung, Indonesia), Putu Yastica (Universitas Mahasaraswati Denpasar, Indonesia), Mylene Cayetano (U. of Philippines), Tep Makathy (Cambodia Inst. of Urb. Std.), Zaw Naing (Mandalay Tech., Myanmar), Dinh Duong Nguyen (Vietnam Acad. of S&T.), Lam Dao Nguyen (HCMC Space Tech. App. Ctr.), Pat Yeh (Monash U., Malaysia)

GOFC-GOLD Southeast Asia Regional Network: Israr Alabar (Ministry of Env. & Forestry, Indonesia), Pariwate Vernakovida (King Mongkut's U. of Tech, Thailand)

International non-US collaborators: Naishen Liang & T Ohara (NIES, Japan), Peter Verburg (VMU Netherlands), Warren Jin (CSIRO, Australia)

US Collaborators: Chengquan Huang (U. Maryland), Joseph Messina (U. Alabama), Hogeun Park (World Bank), David Roy (MSU & GOFC-GOLD), David Skole (MSU & GOFC-GOLD), Stephen Leisz (Colorado St. U.), Steve Walsh (UNC)

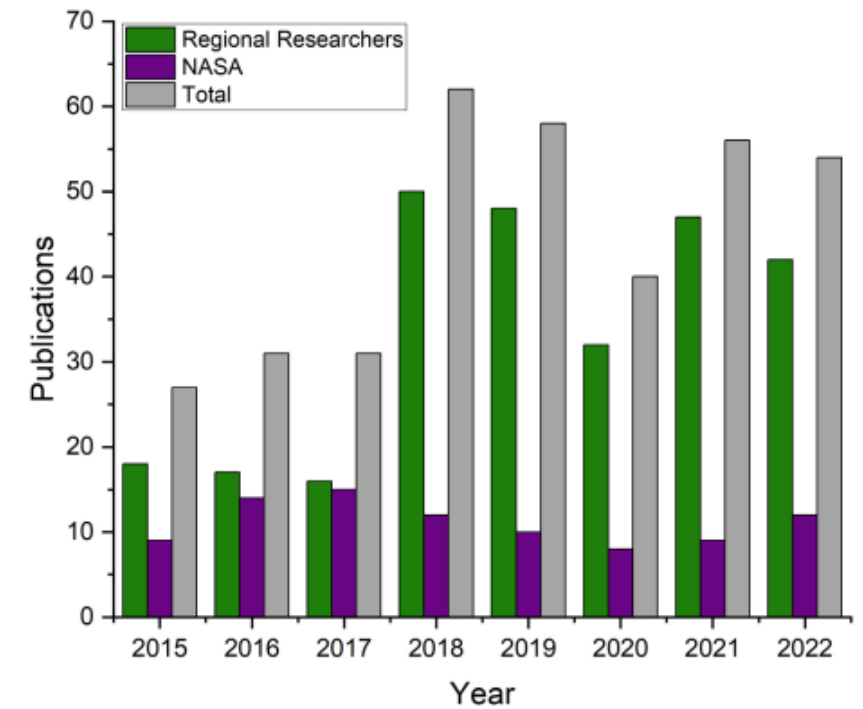


# Outline



# 1. Introduction

- ▶ Southeast Asia (SEA): a hotspot in global climate change, LCLUC, geopolitical conflicts, and societal changes since the end of World War II.
- ▶ 2022: 25th Anniversary of NASA's LCLUC program
  - ▶ SEARRIN
  - ▶ MAIRS-FE
  - ▶ SARI
- ▶ 25 research projects involving 300+ scientists in >200 institutions, ~350 publications (Fig. 1) by 2022
- ▶ significant knowledge in SEA
- ▶ few synthesis efforts



**Fig. 1.** Publications in peer reviewed journals and books from SARI (<https://lcluc.umd.edu>).

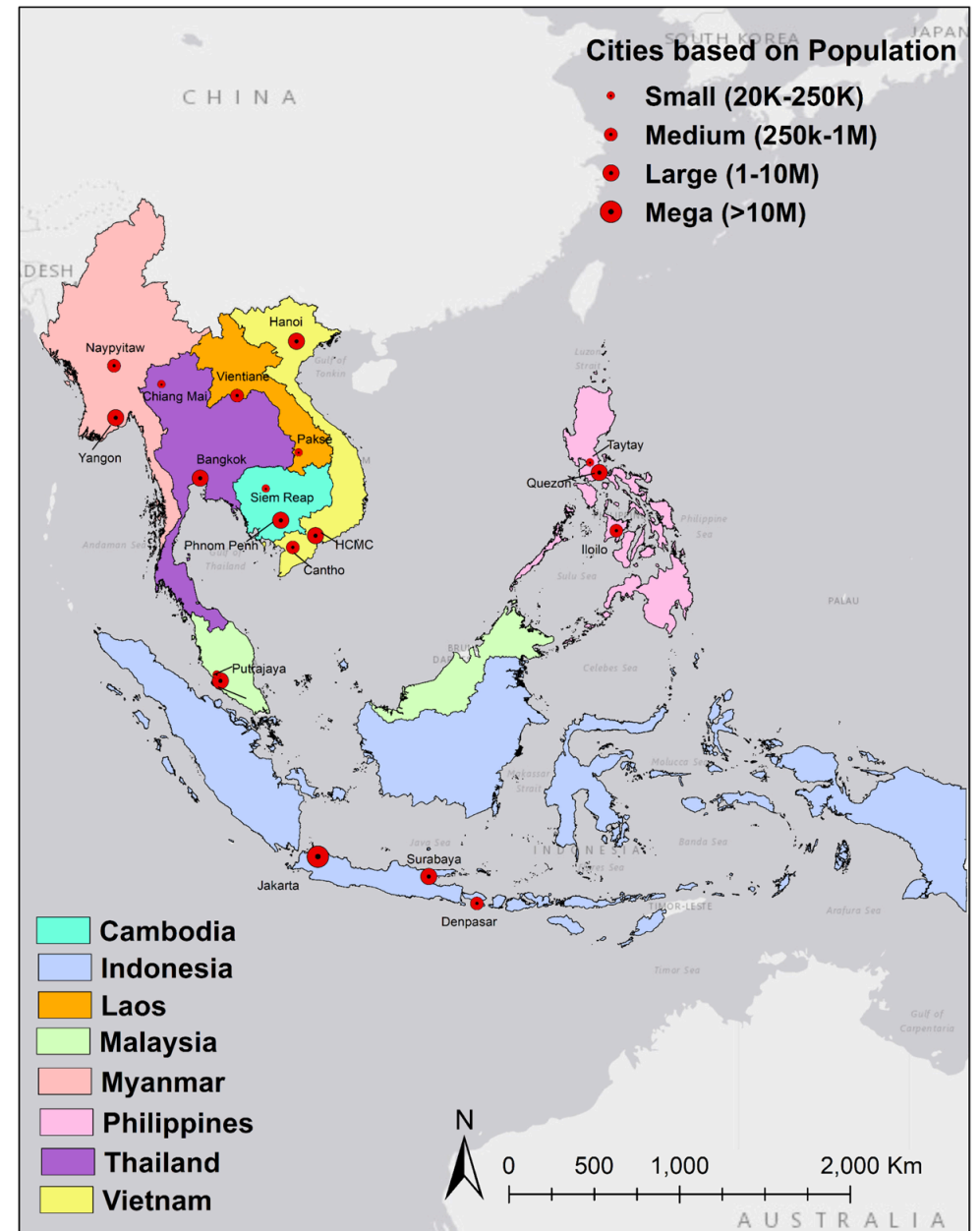


# Overarching goal:

- ▶ we established **an interdisciplinary team** of active scholars within the SARI Program to bring relevant efforts, with **LCLUC projects as the core**, toward a **synthesis of data, tools, models, and knowledge**
- ▶ **focus** not only on data, tools and models developed by the LCLUC community, but **on knowledge gaps and future needs and priorities** (e.g., **What have we not learned but need to know?**) in land use science and societal applications
- ▶ A series of **synthesis products and outcomes, such as open-access data, models and codes, journal publications, books**, and white papers will be developed in this proposed effort (including through collaborations with other SARI project teams)

# Our focus: Urban-rural continuums (URC) – an innovative concept adopted by this team

- **Fig. 2** Study area of **8 countries**, **19 cities** as urban centers of URC, with 1 mega city, 8 large cities, 5 medium cities and 5 small cities, population ranging from 88k in Pakse and 10.5 million in Jakarta.
- cities are considered a central element in land use science : (<2% in 2022), 57% of the global population



## 2. Study objectives

- (1) **synthesize existing projects and literature**
- (2) **identify knowledge gaps, challenges, opportunities, and pathways**
- (3) **examine/quantify drivers, patterns and processes** of land use transformation across the URC



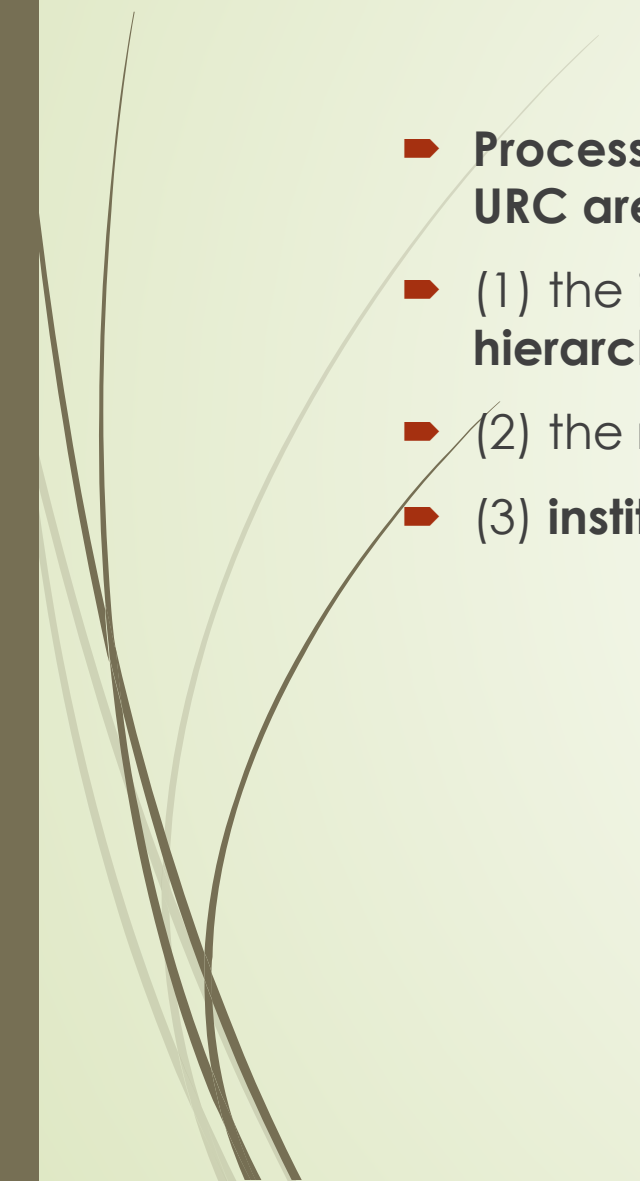
# Research questions:

- ▶ **RQ1 (Patterns): LCLUC along the urban-rural continuums (URC) in SEA** for large-, medium-, and small-size cities; **land transition patterns varied across URC 1990-2020**
- ▶ **RQ2 (Impacts)**
  - ▶ **ecosystem functions changed with LCLUC across the URC** (green & blue)
  - ▶ environmental problems: **GHG**, microclimate **extremes** and **air pollution**, especial
- ▶ **RQ3 (Drivers)**
  - ▶ **biophysical and socioeconomic drivers**
  - ▶ the roles of socioeconomic development level, global connection, and location in shaping URC



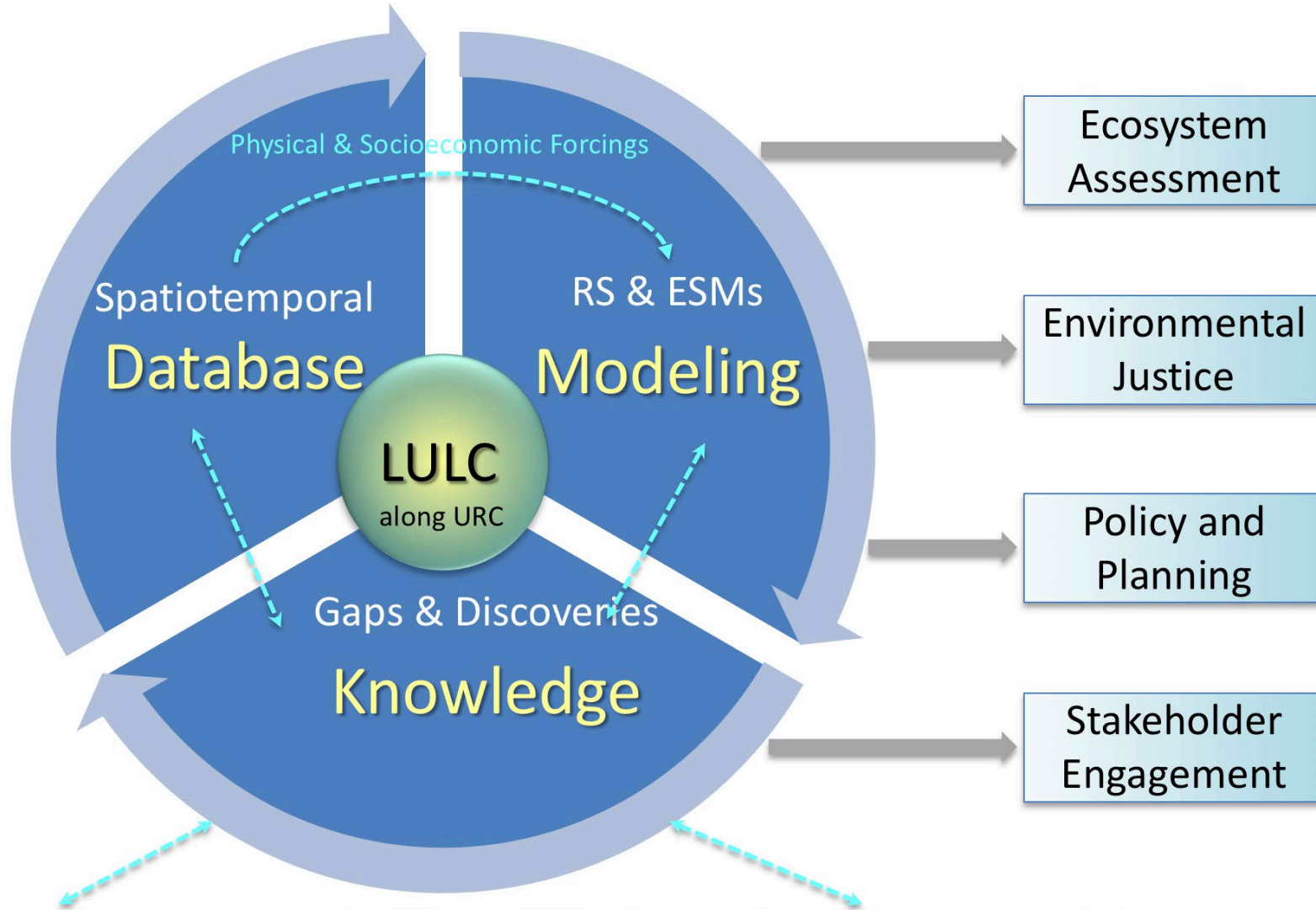


# Hypothesis

- ▶ **Process and outcome of land transitions and related ecosystem change across URC are jointly determined by:**
  - ▶ (1) the **importance of the attached urban center in global/regional city hierarchy,**
  - ▶ (2) the **relative location along the URC**
  - ▶ (3) **institutional policies**
- 



Synthesis across Urban-Rural Continuums .....> Actions & Policies



**Theoretical foundations**  
URC (concept and measurement), theories on urbanization, agricultural land changes, forest land changes, Syndrome, Kuznets Environment Curve, urban environment transition, environmental justice, forcing mechanisms (biophysical, market, institutional changes, globalization)

Fig. 3 Conceptual framework

### 3. Key concepts & SEA context



Urban rural continuums (URC)



Land transitions



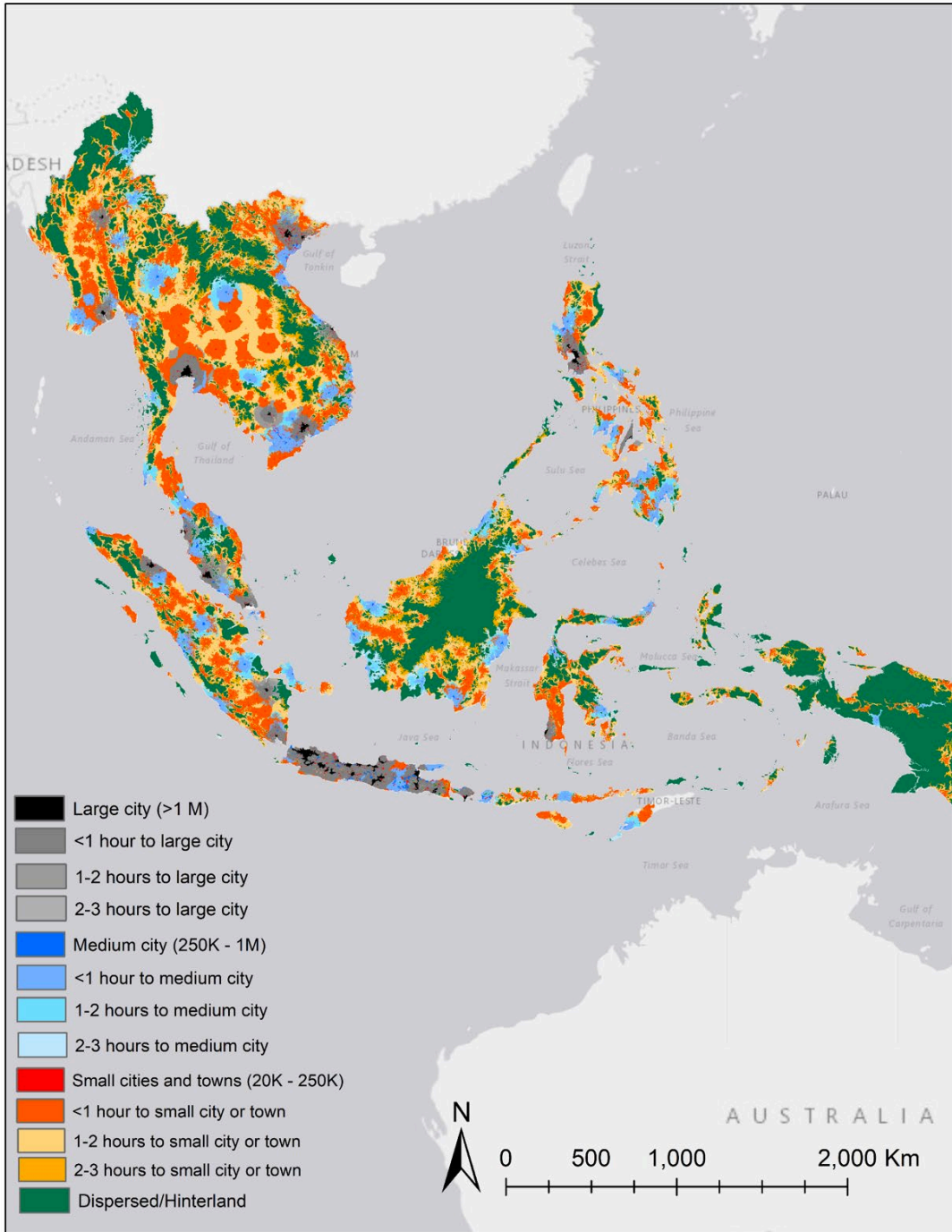
Ecosystem and socioenvironmental impacts from LCLUC



Forcing Mechanisms

## Urban-rural continuums (URC)

- The travel categories of **<1 hour, 1-2 hours, 2-3 hours, and >3 hours** travel time **correspond to peri-urban, peri-rural, rural, and hinterland**.
- In 2015 **<1%** of the global population lived in hinterland areas (i.e., **>3 hours** travel to any urban center **>20,000 pop**).
- SEA, **51%** of the population lived in **urban centers**, with **39%, 8%, and 1%** living in **peri-urban, peri-rural, and rural areas**, respectively, and only 1% in hinterlands (Fig. 4a).





# Land transitions in SEA

- Urban land transitions
- Agriculture land
- Forest land (reforestation vs. deforestation)
  - the Philippines, Thailand and Viet Nam: forest transition
  - Cambodia, Indonesia, Lao PDR, Malaysia, and Myanmar: forest loss



# Ecosystem and socioenvironmental impacts from LCLUC

- Carbon and nitrogen losses from and gains, soil degradation, the hydrological cycle (water quality and quantity), and coastal wetlands due to flooding and other extreme events in SEA
- Social environmental impacts: spatial distribution of air pollution, warming, drought condition

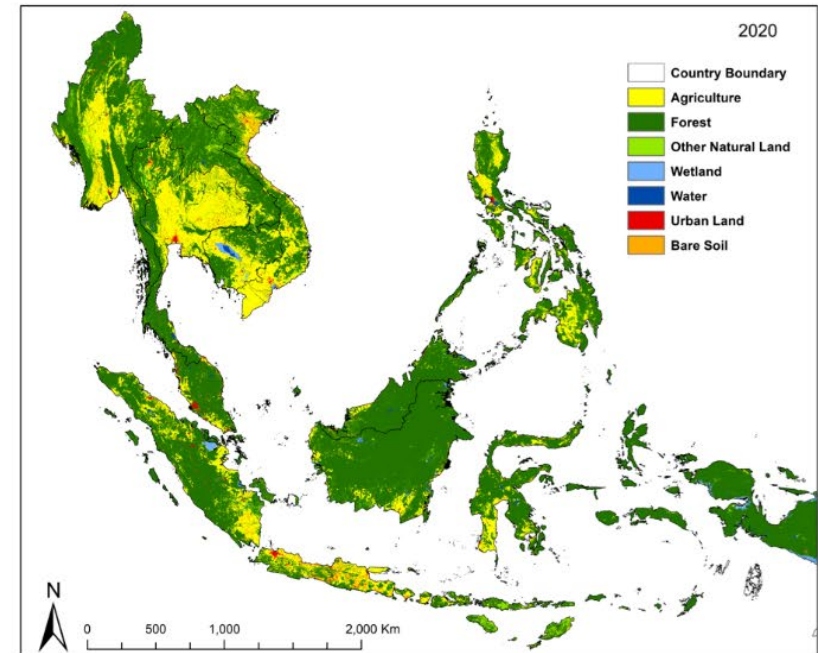
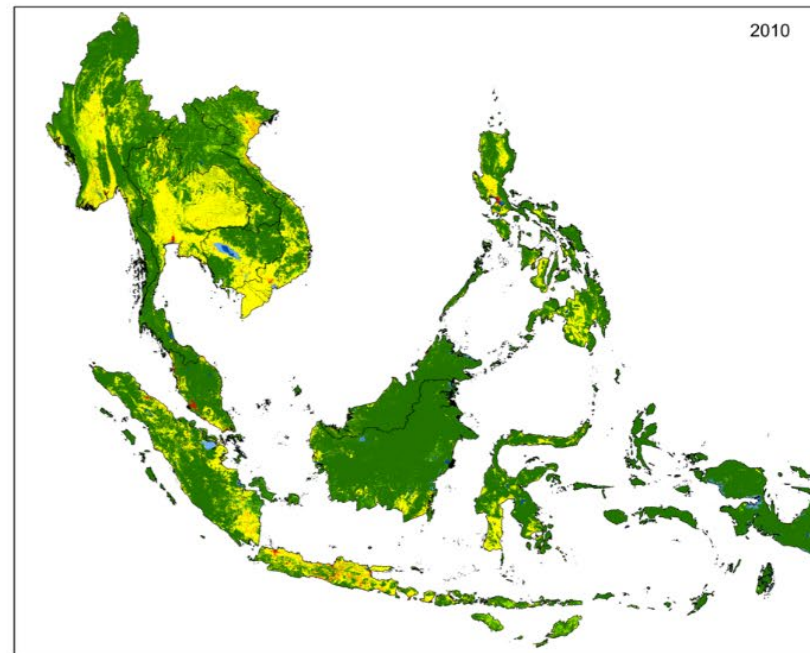
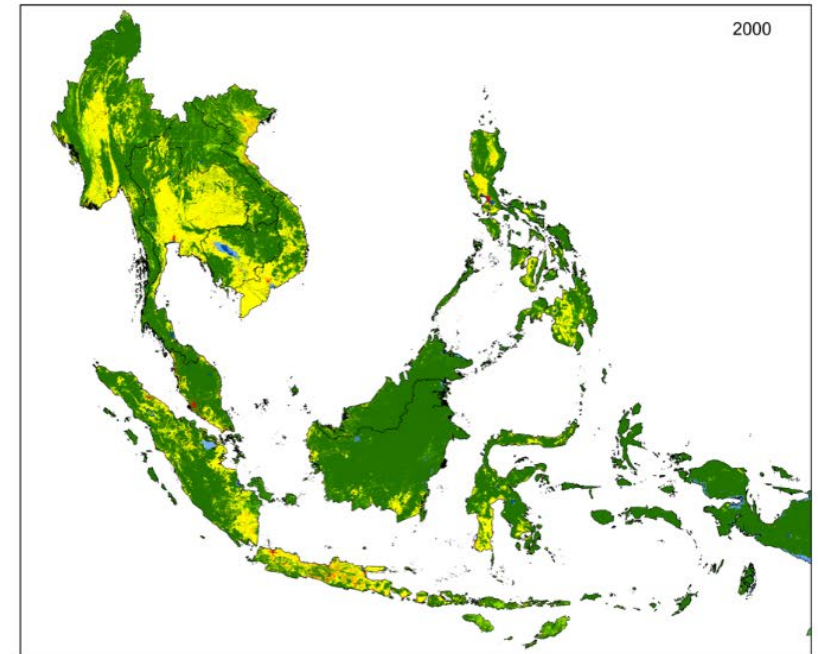
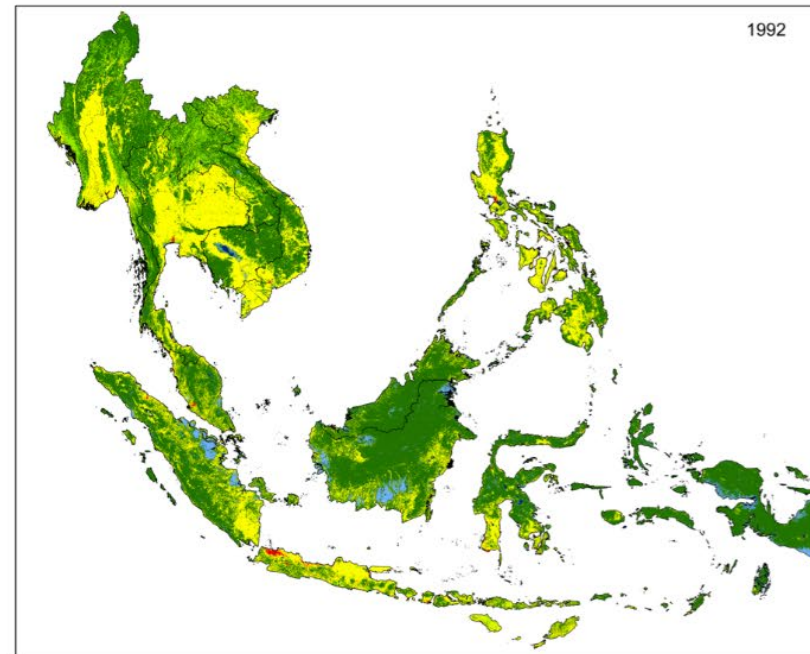
# Forcing Mechanisms of LCLUC of URCs

- ▶ Biophysical drivers:
  - ▶ SEA: climate change has been a major driver for the alteration of natural and human systems and land use transitions
- ▶ Socioeconomic drivers:
  - ▶ institutional change, policy and regulations, migration, and land governance, + economic development, globalization, + technological innovation.
  - ▶ Economic globalization



#### 4. Study approach: --Study Area

Major land cover/land use in the study area during 1992-2020.



# Scales of analysis



**8 countries**



**19 URC**

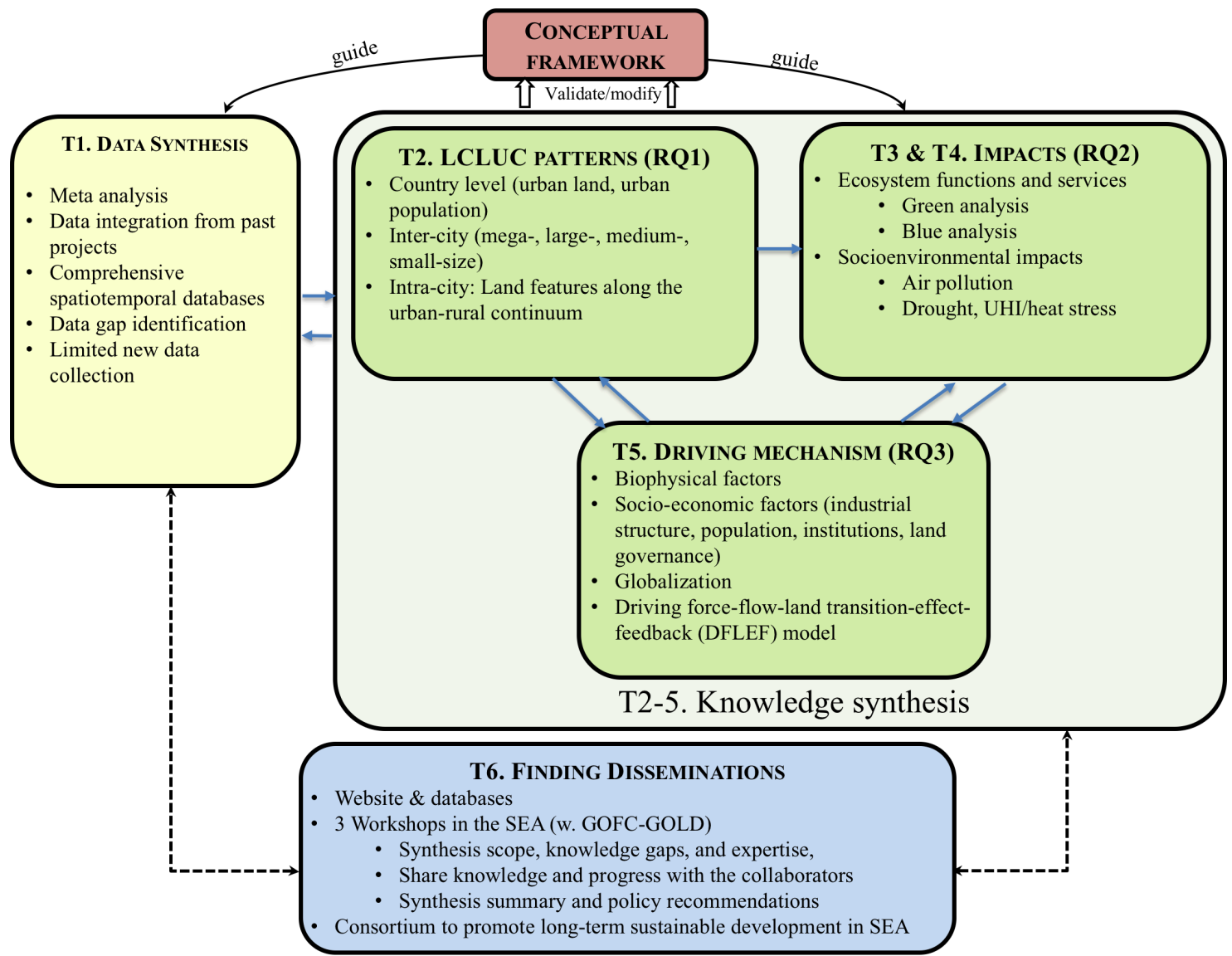
4 categories (i.e., urban center, peri-urban, peri-rural, and rural areas)



**Local (1kmx1km):**

local scale analysis on ecosystem and socio-environmental impacts





• Fig. 7 Tasks and connections for the proposed research.

## 5. EXPECTED OUTCOMES

advance the knowledge  
frontiers of

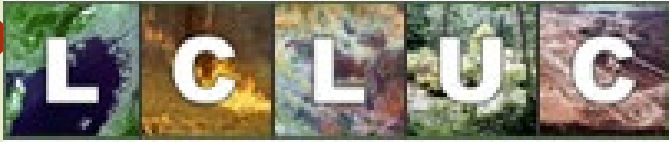
- theories and models for land transition and its socio-environmental impact across the URC at different temporal and spatial scales

Methodologically:

- integrates remotely sensed measurements with LCLUCs, climate models, ecological models, and socioeconomic analyses

enrich the public  
knowledge and will help  
decision-making of policy  
makers at different levels.

# Urbanization and sustainability under global change and transitional economies: Synthesis from Southeast, East, and North Asia (SENA)

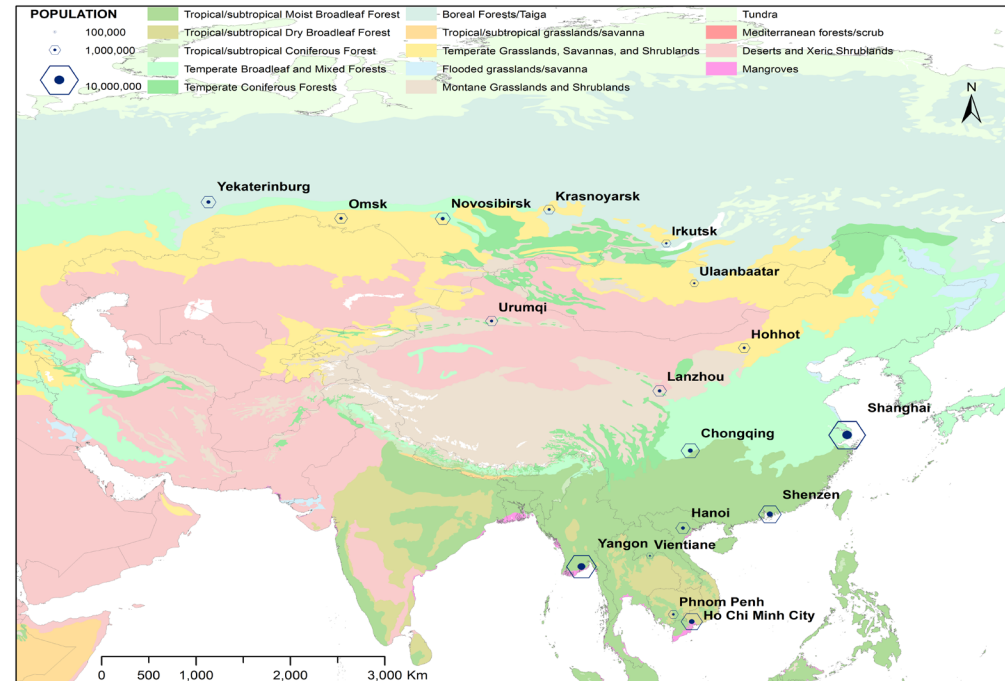


Grant #: NNX15AD51G  
web: [senacgc.org](http://senacgc.org)



## Study Context:

- SENA countries constitute a region that is significant in both natural and socioeconomic dimensions: a land area of 25.4 million km<sup>2</sup> population of 1.54 billion in 2010
- experienced liberalization, macroeconomic stabilization, restructuring and privatization, and legal and institutional reforms over the past three decades
- urbanization at various but mostly tenacious speeds, exert tremendous pressure on social, economic, and environmental sustainability, especially under the increasingly visible climate change.

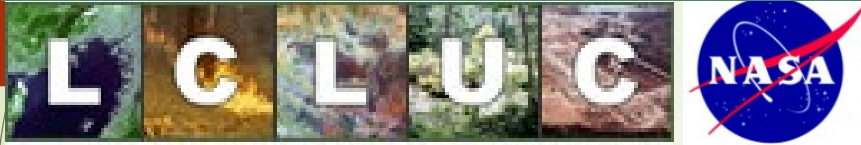


17 urban systems overlaid on the Ecoregion coverage (8 biomes in 7 countries)

## Research Questions:

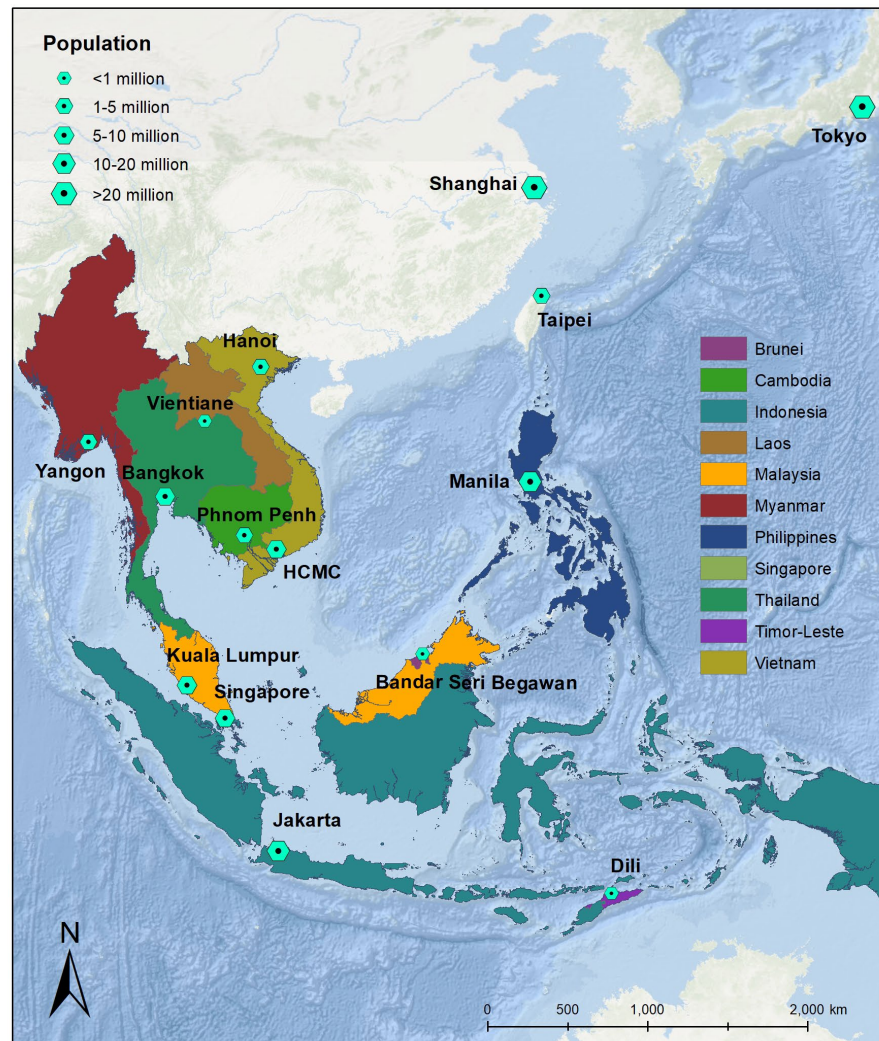
1. What are the spatiotemporal changes of urban expansion within transitional economies?
2. What are the key socioeconomic and biophysical drivers of urbanization and urban sustainability? More specifically, which institutional mechanism is unique and crucial? How well do our models and data explain these changes through the interactions and feedback mechanisms of human and natural systems?
3. How well can we predict the changes in urban LCLUCs and functions based on the derived structure and functions of LCLUC, human systems, and natural systems?
4. What socioeconomic and institutional adaptations have been implemented and how effective have they been? What policy recommendations can be offered to enhance urban sustainability in the near future?

# Divergent local responses to globalization: Urbanization, land transition, and environmental changes in Southeast Asia (SEAGUL)



Grant #: 80NSSC20K0740

Project publications:  
<http://seagul.info/>



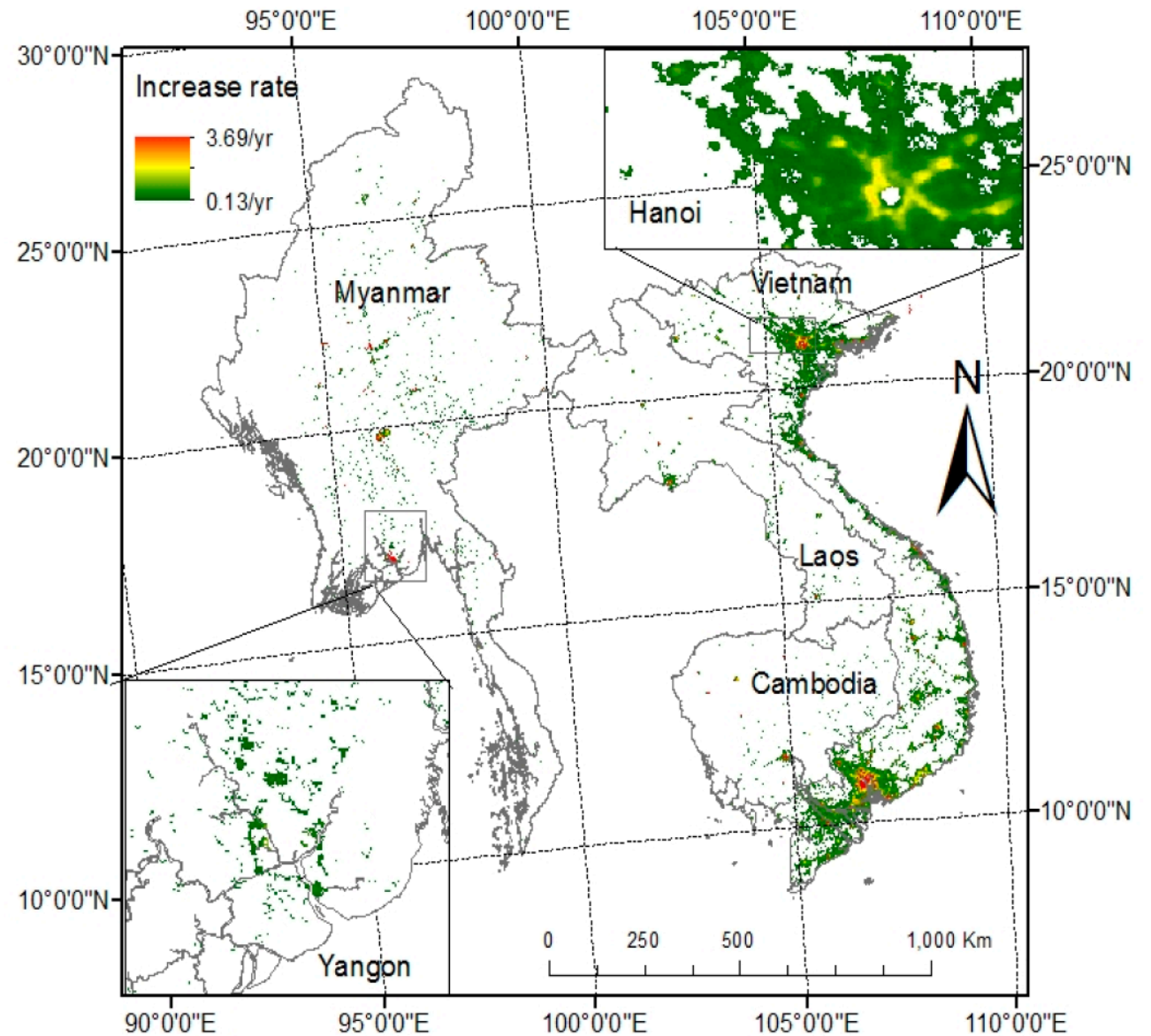
## Research Scope

- Examine urbanization, land transitions, and environmental changes under globalization in **7 SEA countries** through an innovative conceptual framework and related methods
  - developing **a theoretical framework** to examine one particular driver, globalization
  - integrating **quantitative and qualitative data and methods** to analyze system dynamics
  - offering **policy implications** on national development priorities, industrial structure, planning, land regulations and markets, and environment regulations.

<=Southeast Asia, its major cities, and bench mark cities of Tokyo, Taipei, and Shanghai in East Asia

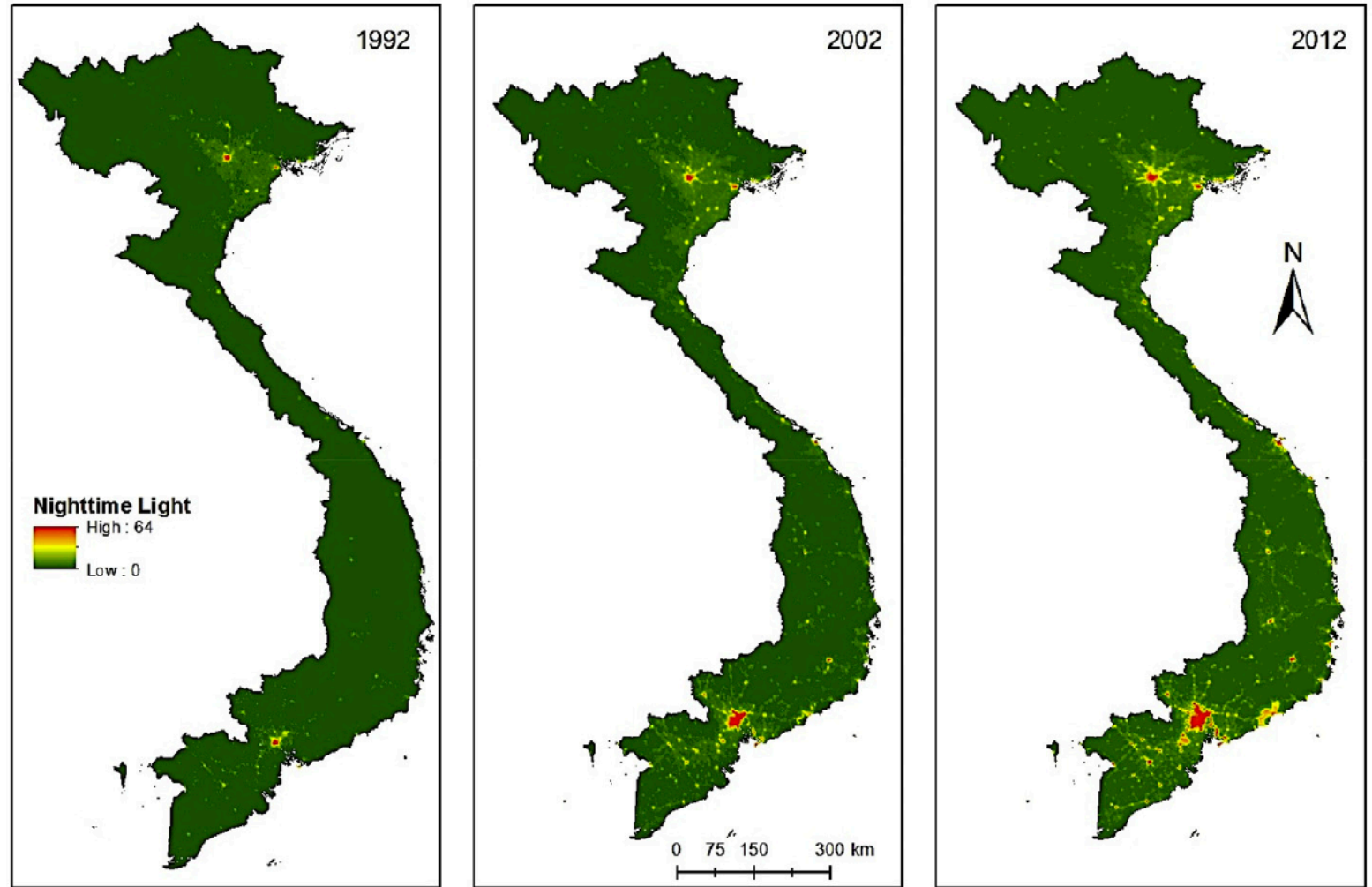
## Examples from the past projects:

- Vietnam had the highest proportion of urban built-up area (0.91%),
  - followed by Myanmar (0.15%), Cambodia (0.12%) and Laos (0.09%).
- Vietnam was also the fastest in new built-up development (increased ~8.8-times during the 18-year study period),
  - followed by Laos, Cambodia and Myanmar, which increased at 6.0-, 3.6- and 0.24-times, respectively.



**Figure 7.** The increasing trends of DMSP/OLS NTL brightness in 1992 to 2010. Areas for Yangon and Hanoi were enlarged to illustrate the slow and fast change.

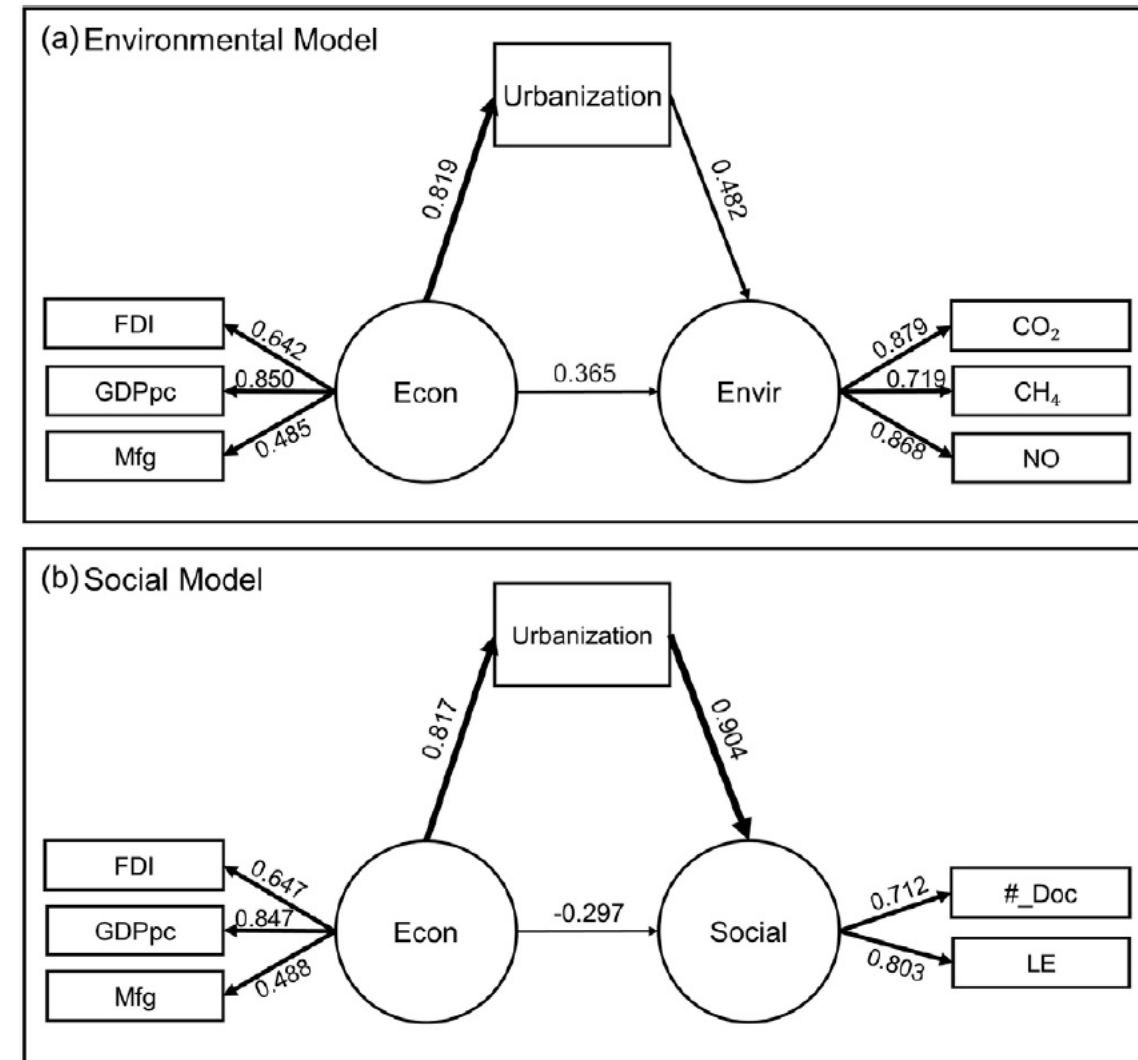
## Examples from the past projects:



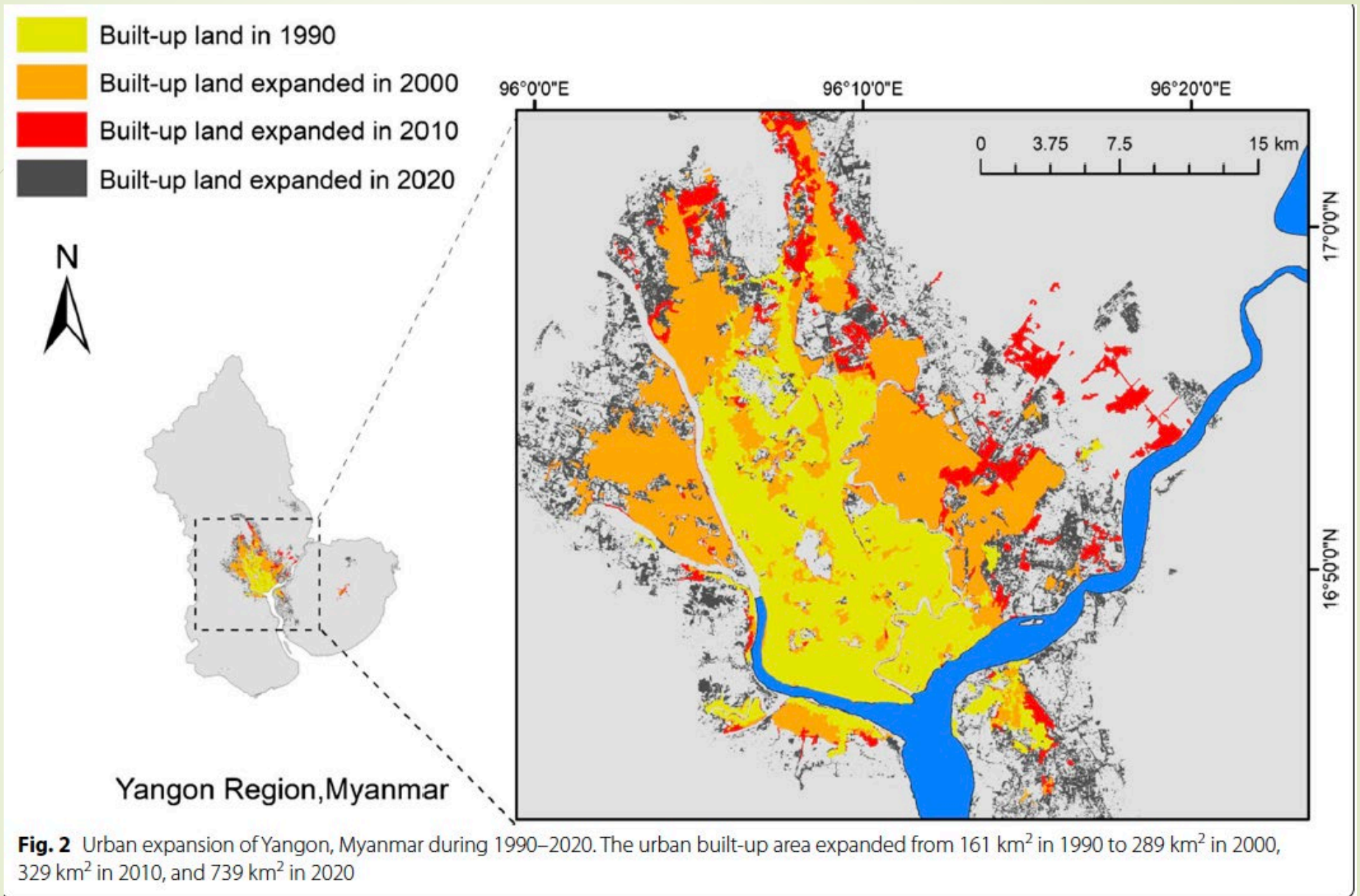
**Fig. 2.** The spatial distribution of nighttime light (NTL) in original DN Values in Vietnam in 1992, 2002, and 2012. The higher the value of NTL, the higher the density of urban land. The figure shows the emergence of three main urban clusters in Vietnam over the years.

## Examples from the past projects:

**Fig. 7.** Partial least squared structural equation modeling (PLS-SEM) of economic development (Econ), urbanization, environmental (Envir), and social conditions in Vietnam (1980–2015). Circles indicate the latent variables and the squares refer to measured variables. The path coefficients describe the relationships between variables and are located on the path. The measured variables are GDPpc, the percentage of the manufacturing value added in GDP (Mfg), the percentage of foreign direct investment in GDP (FDI), CO<sub>2</sub> emissions per capita (CO<sub>2</sub>), CH<sub>4</sub> emissions per capita (CH<sub>4</sub>), and NO emissions per capita (NO), number of doctors per capita (#\_Doc), and life expectancy (LE).

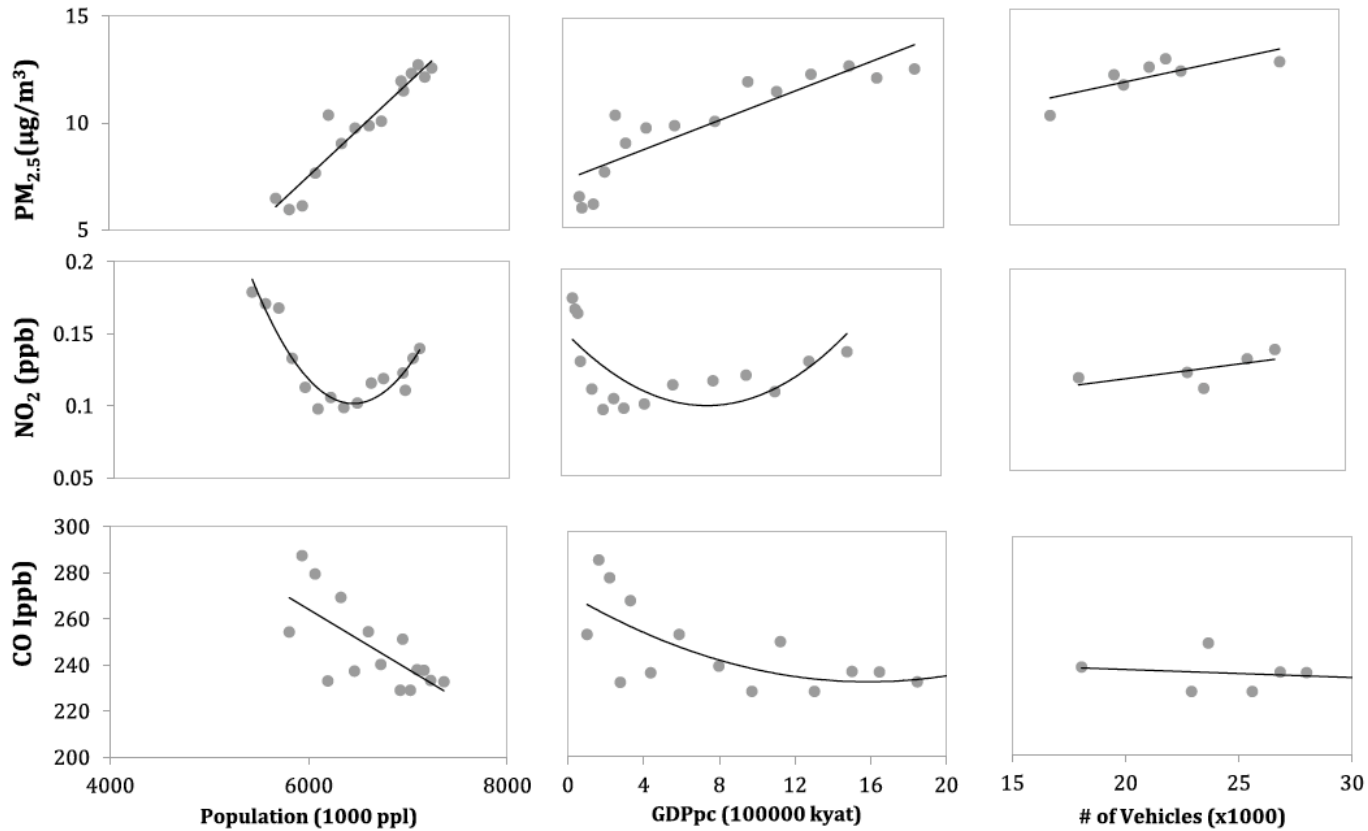


## Examples from the past projects:

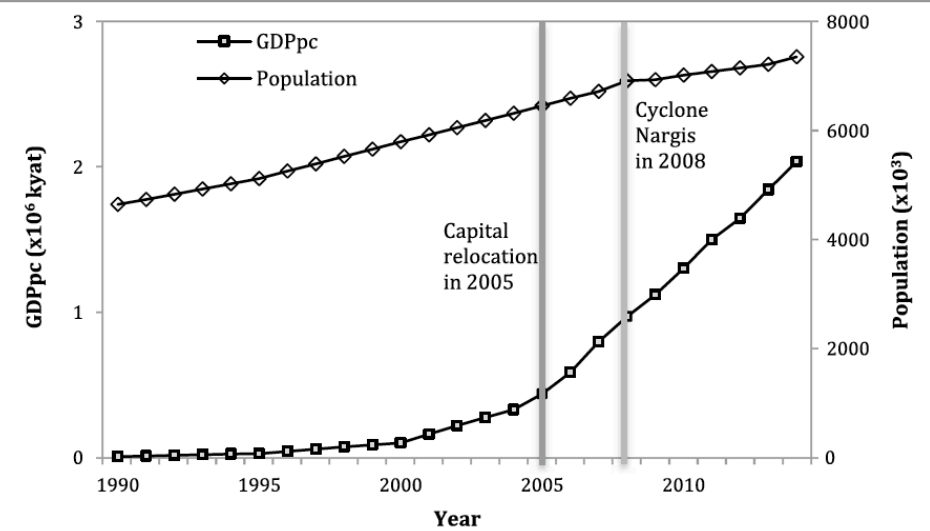




## Examples from the past projects:




**Fig. 5** Changes in concentrations of three air pollutants (PM<sub>2.5</sub>, NO<sub>2</sub>, and CO) with three socioeconomic variables (population, GDPpc, and # of vehicles) in Yangon. PM<sub>2.5</sub> was positively associated with all three socioeconomic variables; NO<sub>2</sub> decreased and increased with population and GDPpc, respectively; and CO declined with population and GDPpc

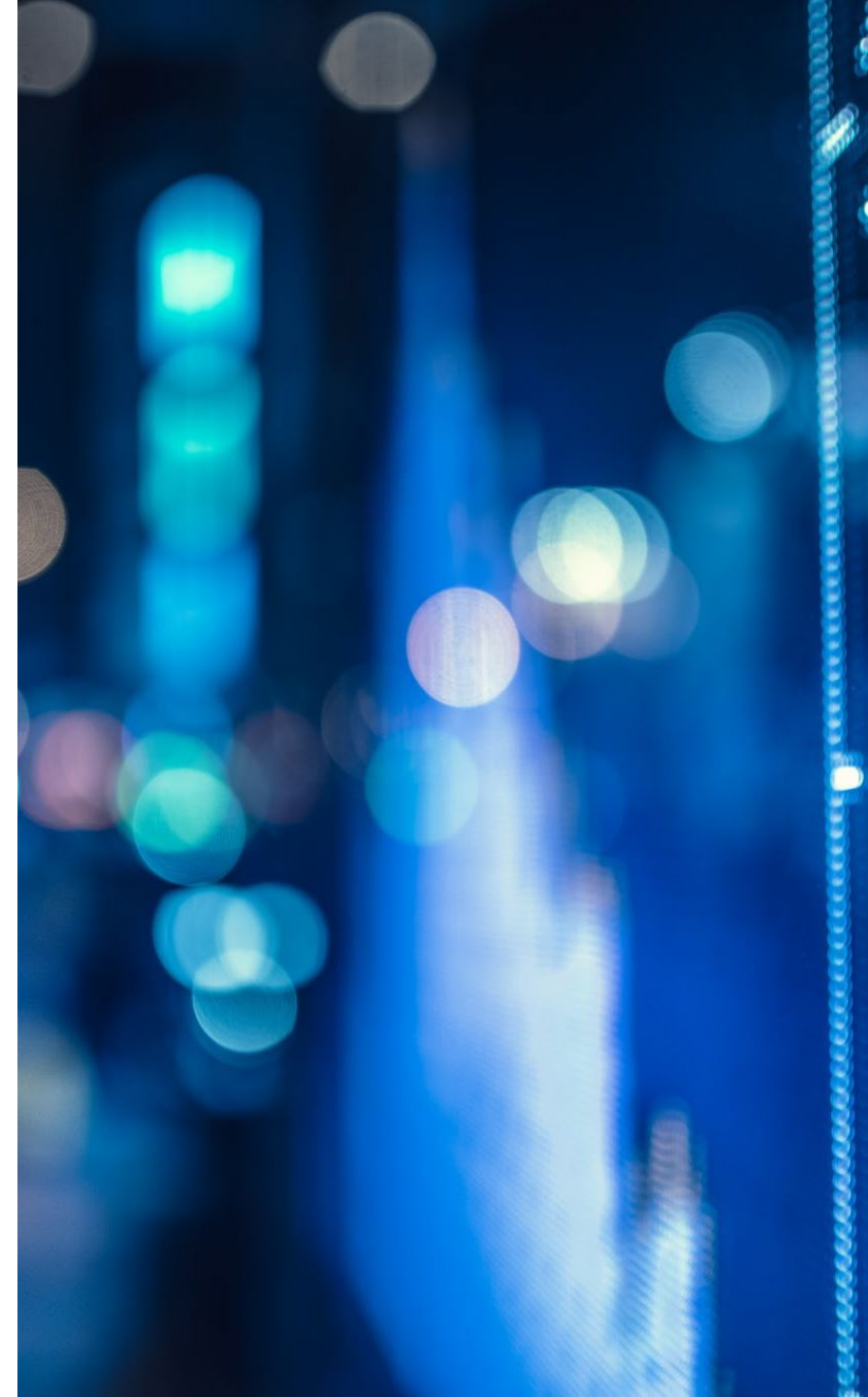


**Fig. 4** Changes in population and GDP per capita (GDPpc) in Yangon from 1990 to 2014. Note: Two external events and the growth of population and GDPpc of Yangon, capital relocation in 2005 and Cyclone Nargis in 2008. These two events seem do not have obvious impacts on city's population or economic development level

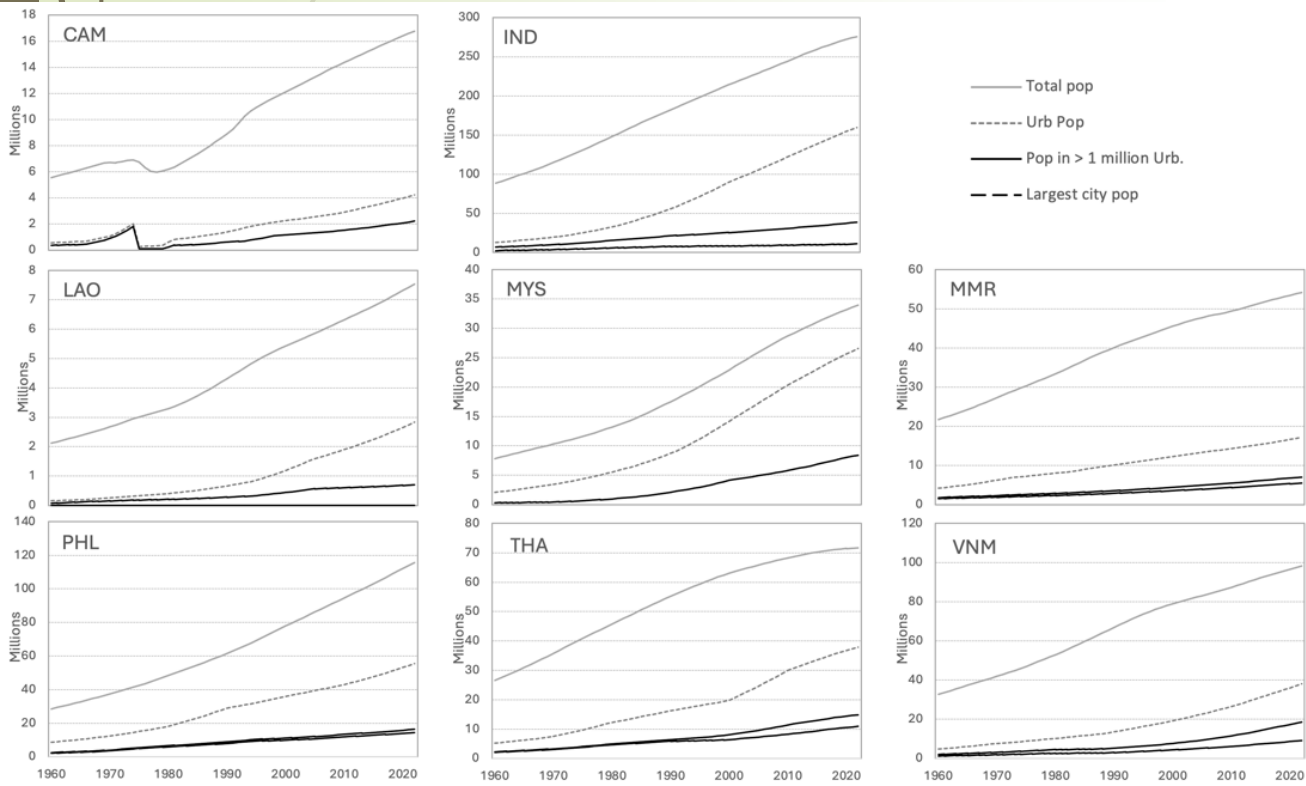
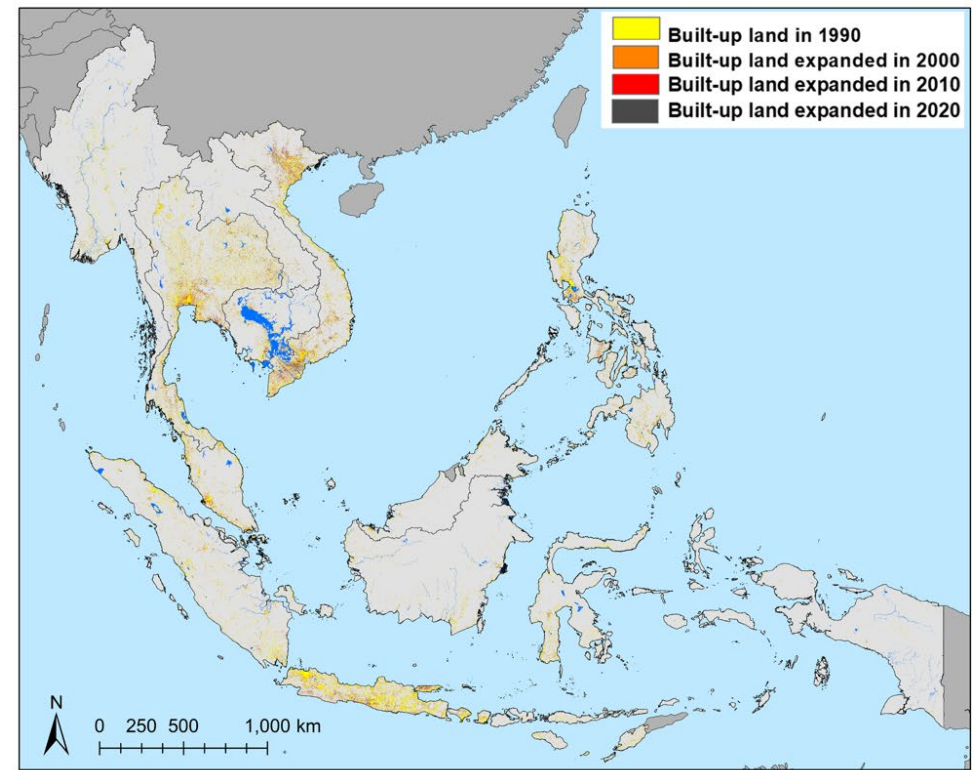


# Highlights: recent activities of the SEAL project

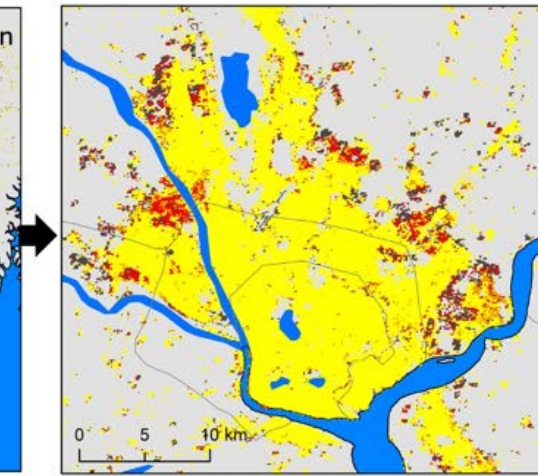
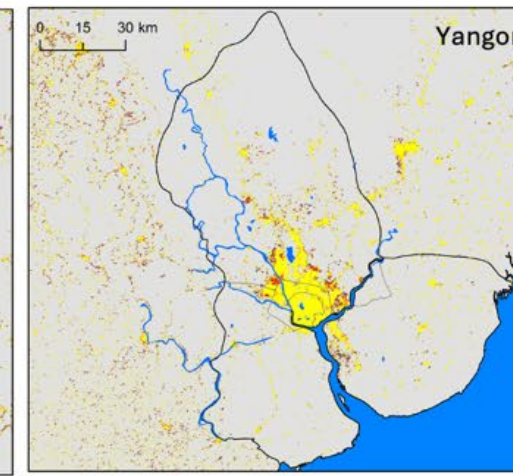
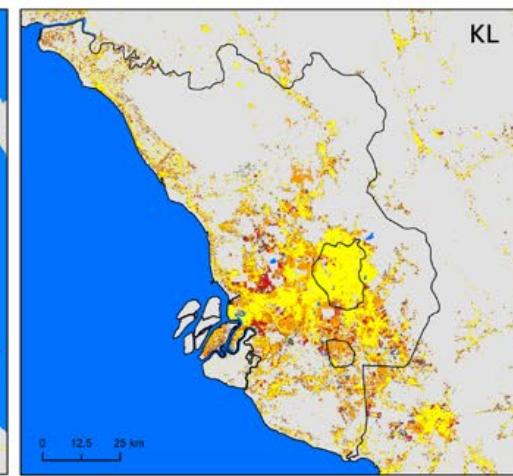
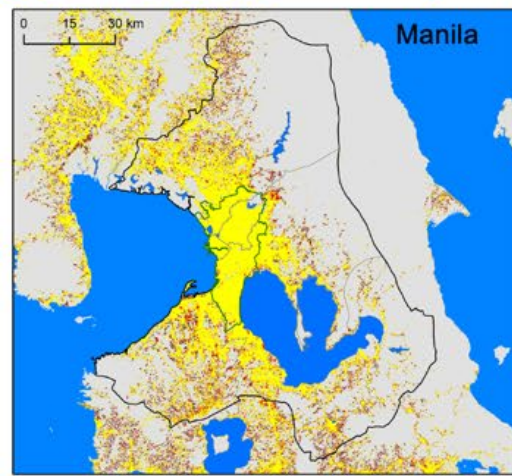
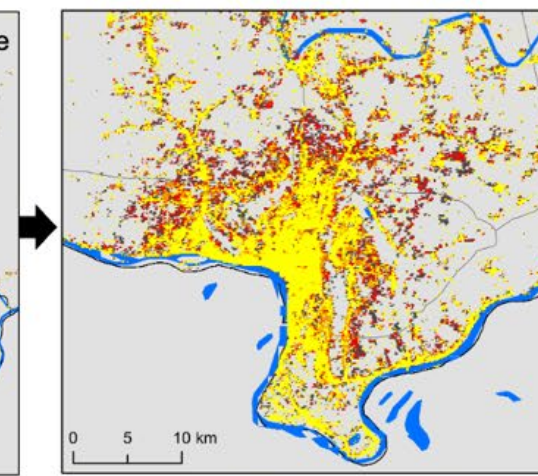
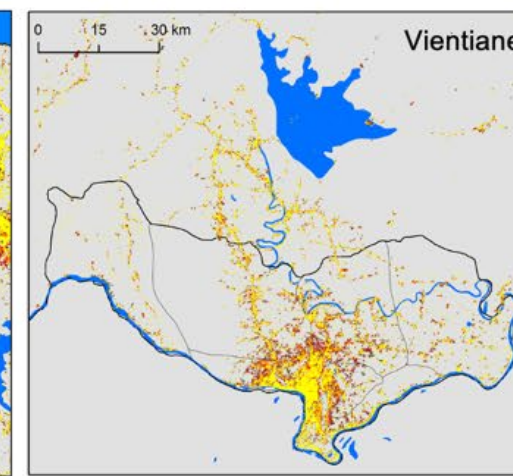
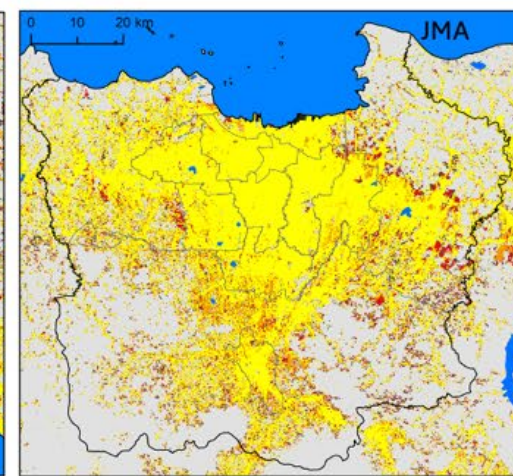
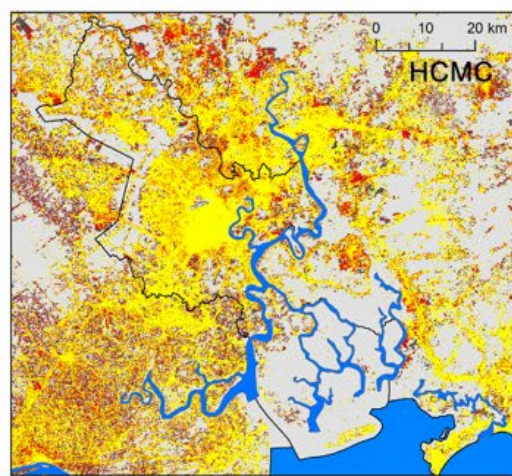
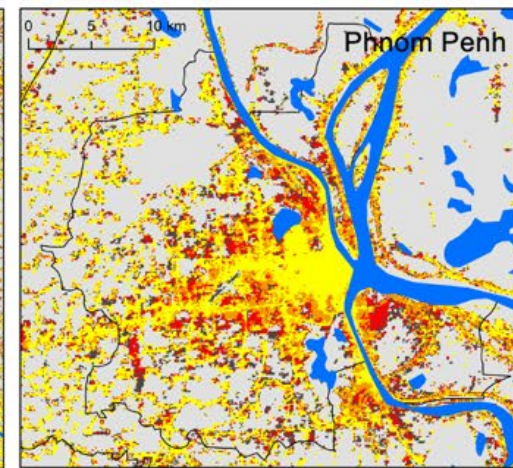
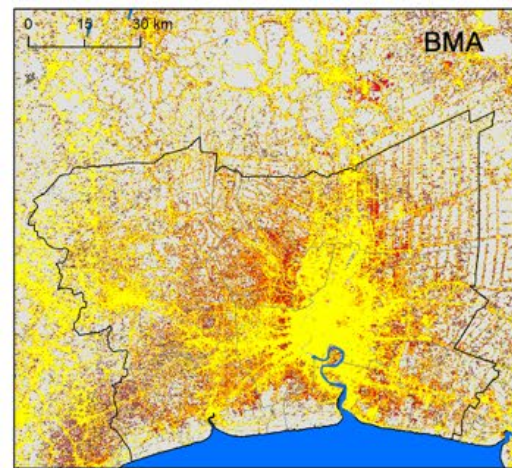
- Synthesis: Urban built-up land & population (country vs. cities)
  - Spatial pattern: Urban built-up area and volume along the URC
  - The interrelated relationship between spatial pattern and socioenvironmental impacts along URC
  - The visible hand of the state along the URC: institutions, governance, planning
- 



# Highlight 1: Urban built-up land & population (country vs. cities)



Source: Fan, P., T Sarker, J. Messina, J Chen, A Jain, S Myint, & J Qi. (in preparation) "Urban land transition and population dynamics across Southeast Asia", in K. Vandrevu, C Justice, G Gutman. (eds) *Remote Sensing of Land-Use/Cover Changes in South/Southeast Asia*. CRC Press



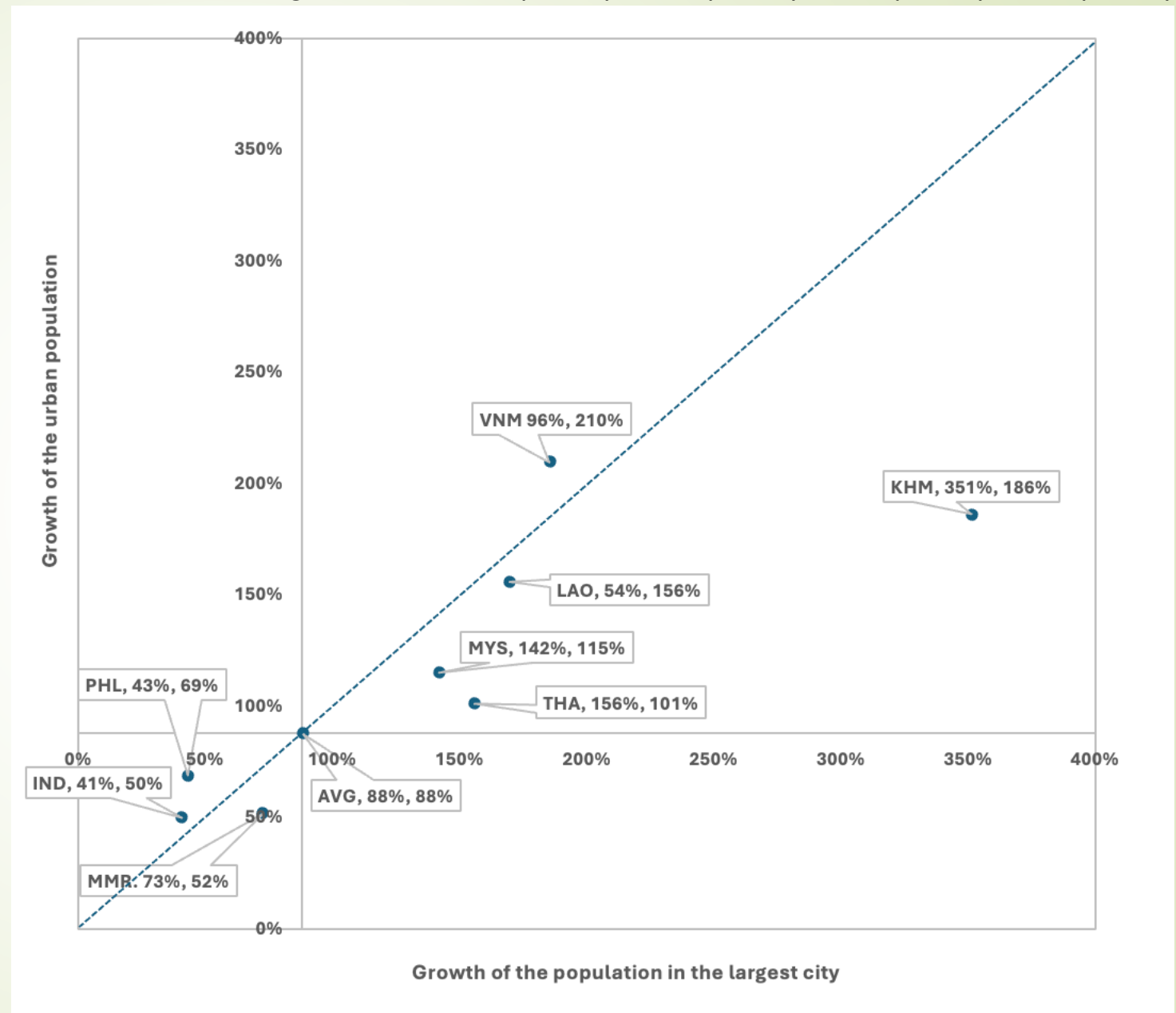
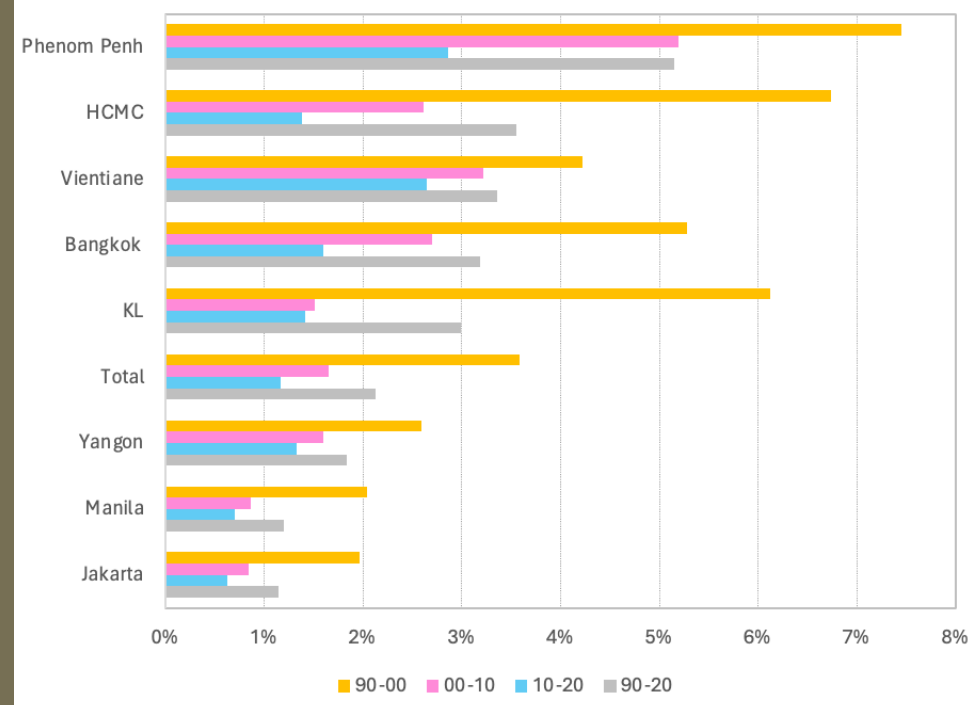
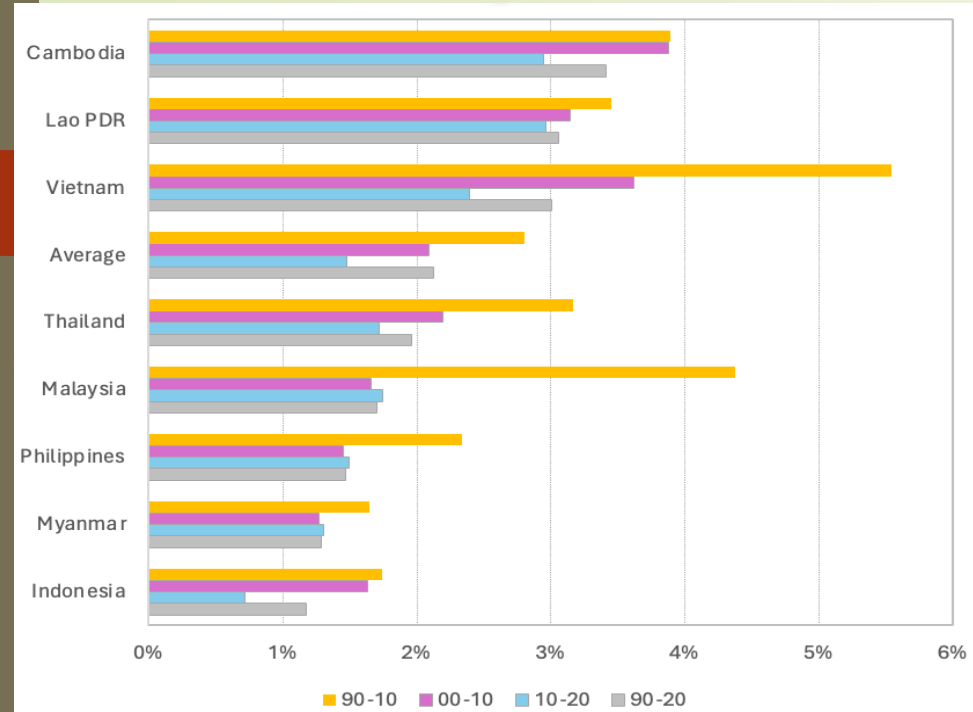
- Built-up land in 1990
- Built-up land expanded in 2000
- Built-up land expanded in 2010
- Built-up land expanded in 2020



Source: Fan, P., T Sarker, J. Messina, J Chen, A Jain, S Myint, & J Qi. (in preparation) "Urban land transition and population dynamics across Southeast Asia", in K. Vandrevu, C Justice, G Gutman. (eds) *Remote Sensing of Land-Use/Cover Changes in South/Southeast Asia*. CRC Press



Country-level: 2.1% (90-20); 2.8% (90-00), 2.1% (00-10), 1.5% (10-20)  
 8 Largest cities: 2.1% (90-20); 3.6% (90-00), 1.7% (00-10), 1.2% (10-20)



Source: Fan, P., T Sarker, J. Messina, J Chen, A Jain, S Myint, & J Qi. (in preparation) "Urban land transition and population dynamics across Southeast Asia", in K. Vandrevu, C Justice, G Gutman. (eds) *Remote Sensing of Land-Use/Cover Changes in South/Southeast Asia*. CRC Press

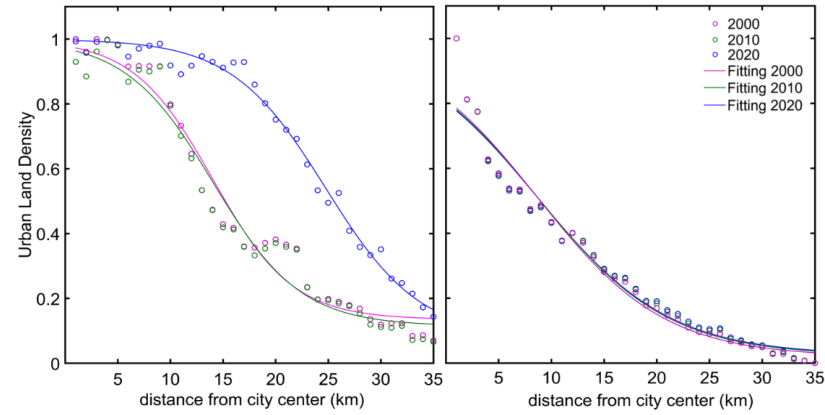
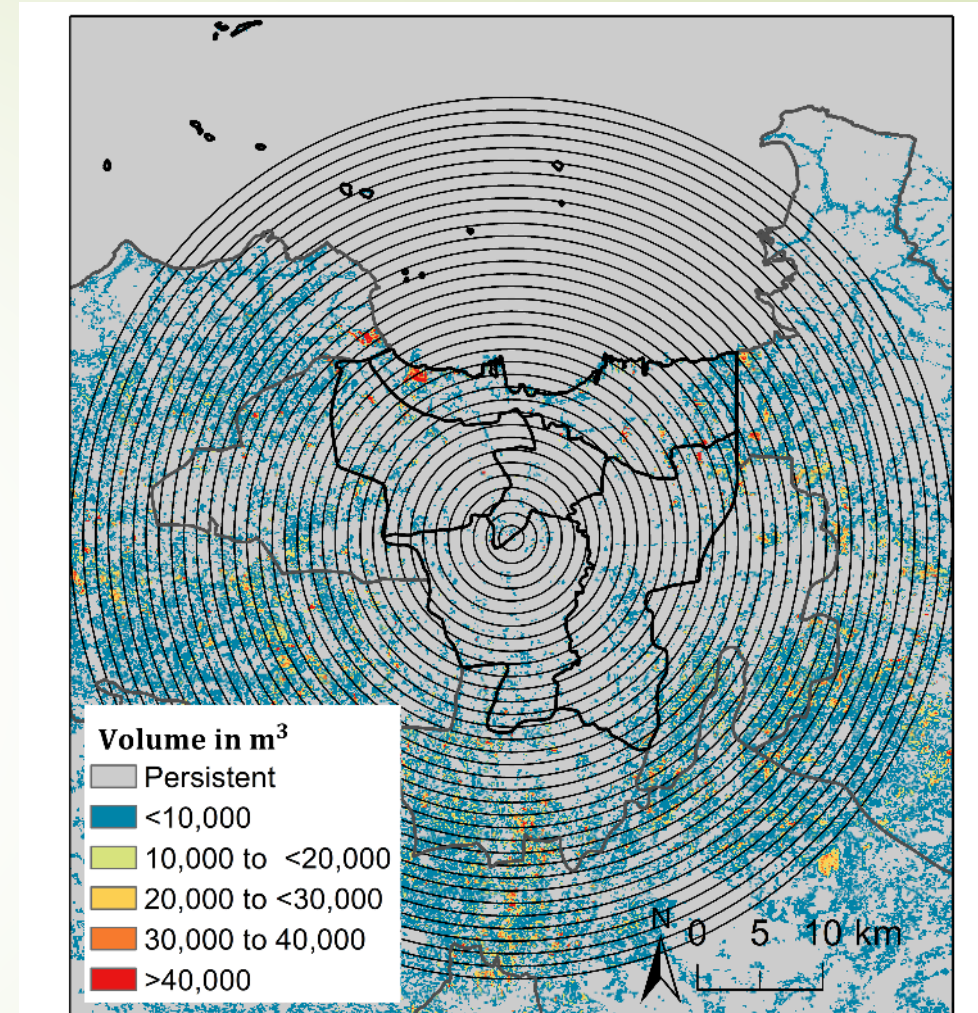


Figure 5. Changes in urban land density with distance from the city center to the suburban area in Jakarta based on  $ULD_{2D}$  (left), and  $ULD'_{3D}$  (right).

## Highlight 2: Urban built-up volume & its environmental impact

(b)



(a)

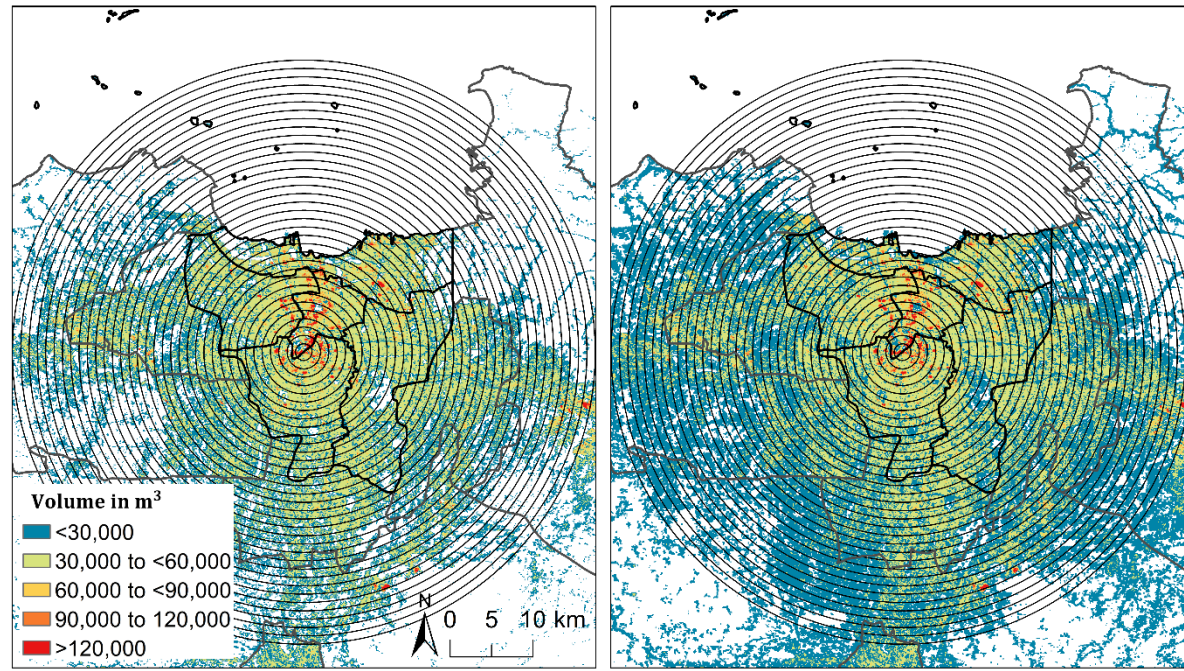
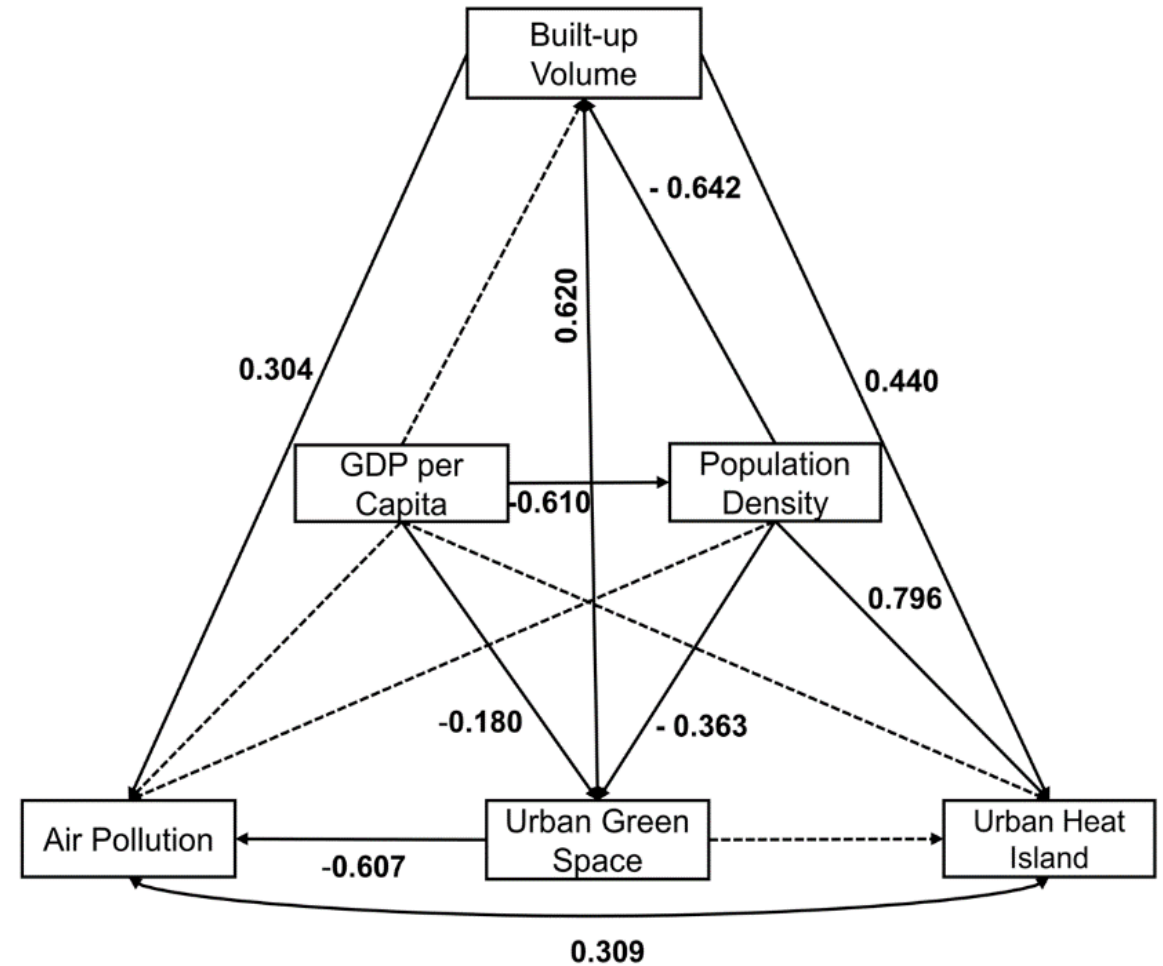


Figure 4. Distribution of urban built-up volume in Jakarta: (a) in 2000 and in 2020 and (b) the increase from 2000 to 2020.

- Figure 6. PLS-SEM of built-up volume and various aspects of urban environment. Note: The significance level ( $p < 0.05$ ) is indicated by solid lines and insignificant ( $p > 0.05$ ) is indicated by dotted lines.



Source of the Figure: Sarker T., #Fan P., Messina, J.P., Mujahid N., Aldrian E., Chen, J. (2024). Impact of Urban Built-up Volume on Urban Environment: A Case of Jakarta. *Sustainable Cities and Society*. 105 (2024): 105364



# Highlight 3: interlinked relationship and transboundary influence between UHI & air pollution

*Figure 1: Study Area of Bangkok Metropolis Region (BMR), Thailand.*

Source of the Figure: Sarker, T., Fan, P., Messina, J., Macatangay, R., Varnakovida, P., Chen, J. Land Surface Temperature and Transboundary Air Pollution: A Case of Bangkok Metropolitan Region. Revision Submitted.



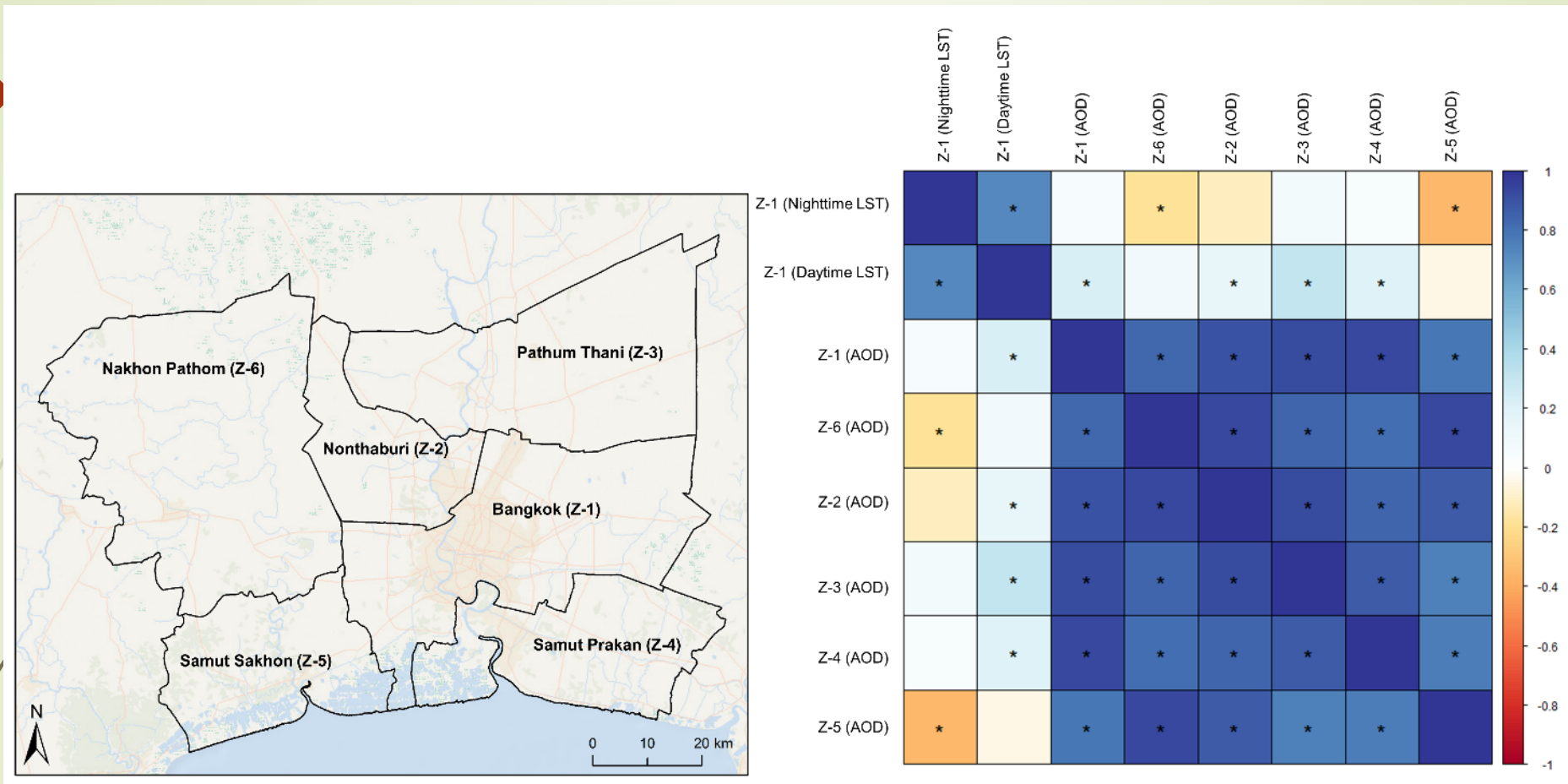
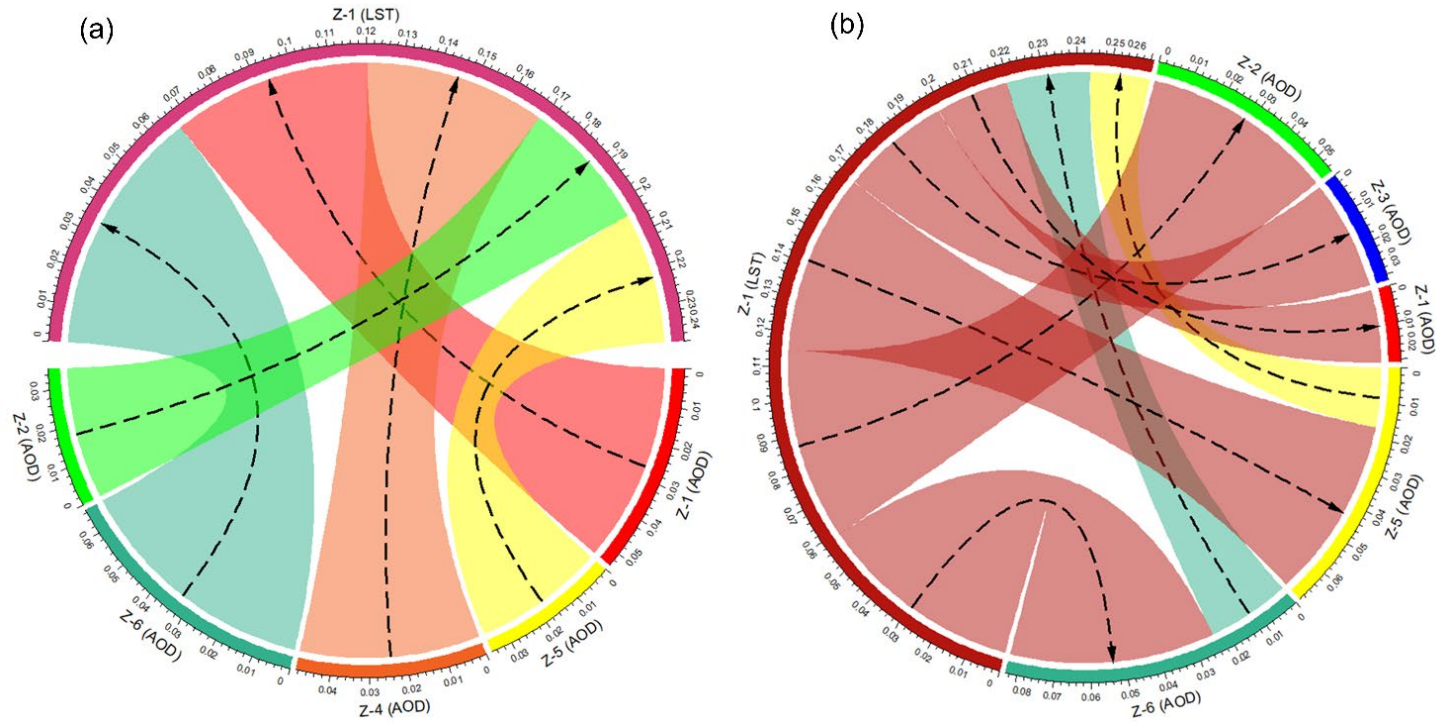


Figure 4: The heat map of the Pearson correlation coefficient of Aerosol loading (AOD) loadings of each province and with land surface temperature (LST) (daytime and nighttime) of BMR.

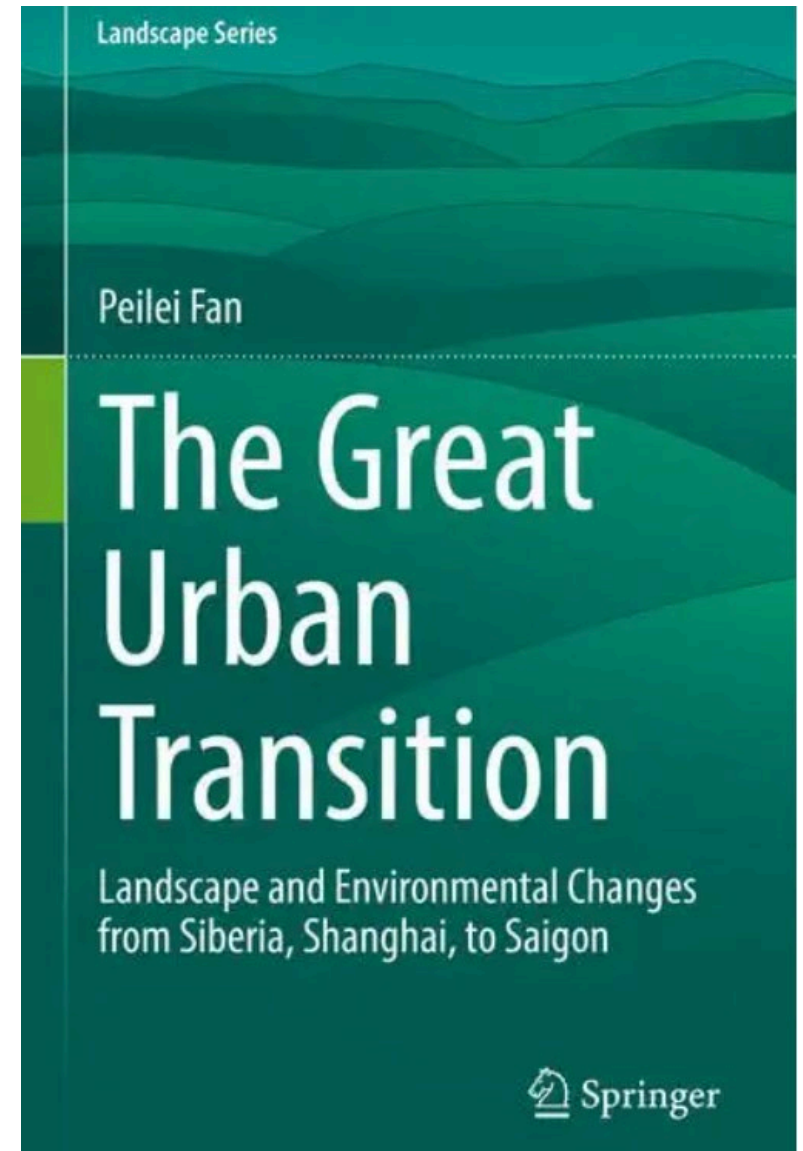


- Figure 5: Chord diagram showing statistically significant transfer entropy between LST and AOD during 2003-2020 (a) daytime (left) and (b) nighttime (right).



## Highlight 4: The Visible Hand of the State

- *land governance*
- *Transformed planning*
- *The role of planning in guiding land use*



Fan, P. (2022). *Great Urban Transition: Landscape and Environmental Changes from Siberia, Shanghai, to Saigon*. Springer Nature.

# Ch. 7. Governing the Land

- ▶ Changing institutions: from central to local, from global to regional
  - ▶ *Household registration*
  - ▶ *Development policies at different spatial levels*
  - ▶ *The rise of the local government*
- ▶ From state to private land ownership: Russia, Mongolia, and Cambodia
- ▶ An upper hand in land use rights: China and Vietnam
- ▶ Land concessions: Laos and Myanmar

Fan, P. (2022). *Great Urban Transition: Landscape and Environmental Changes from Siberia, Shanghai, to Saigon*. Springer Nature.



# Ch. 8. Transforming Urban Planning

Weakened role of  
planning: Russia  
and Mongolia

Strengthened role  
of planning: China  
and Vietnam

Foreign-assisted  
Planning:  
Cambodia, Laos  
PDR, and Myanmar



*Urban Planning Exhibition Hall, Bangkok Metropolitan Area*



Fig. 8.2 Boeung Kak (Lake) has been significantly filled: most part of the lake has been converted to land fill to make space for urban built-up land





## Ch. 9. From Planning to the Change of Urban Landscape

- Planning effectiveness: a quantitative measurement
- Planning through center (re)development
- Planning through setting up transportation lines
- Planning through administrative area changes
- Planning through the evolving role of industry

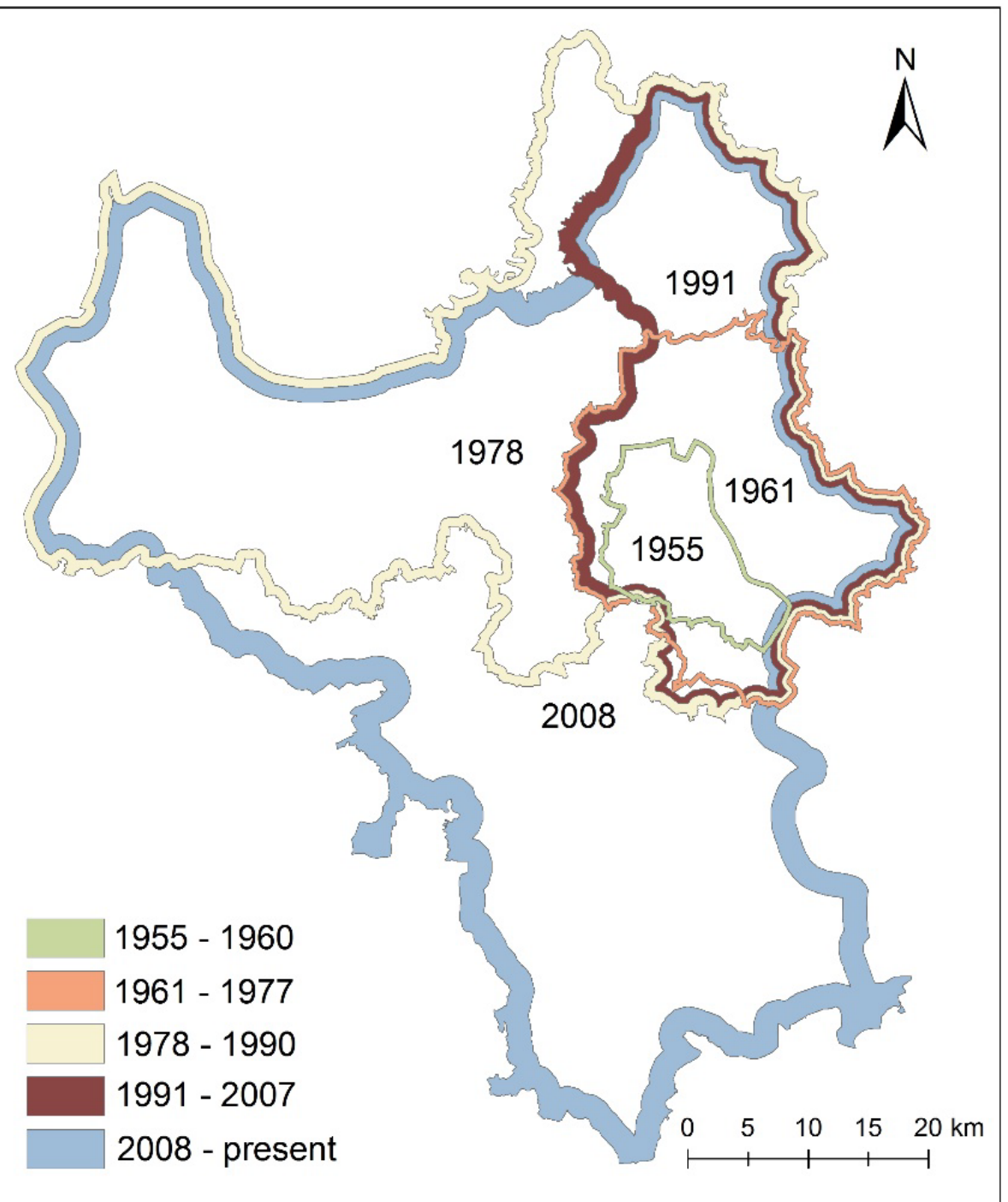


**Figure 9.1** Historic city center of Irkutsk, Russia.

**Planning through center (re)development**

*Source: Photo taken by Peilei Fan, May 28, 2015.*

## Planning through administrative area changes



Source: Fan, P., Ouyang, Z., Nguyen, D. D., Nguyen, T. T. H., Park, H., & Chen, J. (2019). Urbanization, economic development, environmental and social changes in transitional economies: Vietnam after Doimoi. *Landscape and urban planning*, 187, 145-155.



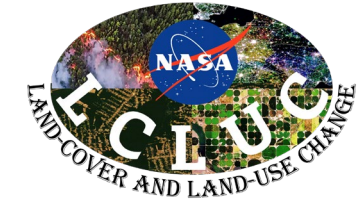
**Figure 4.6** Borey Angkor Phnom Penh, a gated community in suburb Phnom Penh (top photo: Gate of Borey Angkor Phnom Penh; bottom photo: inside the gated community)





# Ecopark City of Hanoi

Photos taken by Peilei Fan, Jan. 30, 2024



**Thank you!**



*Photo was taken by Peilei Fan in Hanoi in Nov. 2015*