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

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

Short title: **S**outh**e**ast **A**sia **L**and Transitions (**SEAL**)

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Outline

1. Introduction

2. Objectives, research questions, & hypothesis

3. Key concepts & context

4. Study approaches

5. Expected outcomes

6. Recent highlights

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 (Southeast Asia Regional Research Information Network),
  - MAIRS-FE (Monsoon Asia Integrated Research in Sustainability-Future Earth),
  - South/Southeast Asian Research Initiative (SARI).

- 25 research projects involving 300+ scientists in >200 institutions, ~350 publications (Fig. 1) by 2022

- significant knowledge in SEA: massive amounts of data, RS images, & other geospatial products, research networks, many tools and models,

- few synthesis efforts:
  - holistically understand the current state of land use dynamics in SEA,
  - clearly identify bottleneck challenges and key knowledge gaps, and
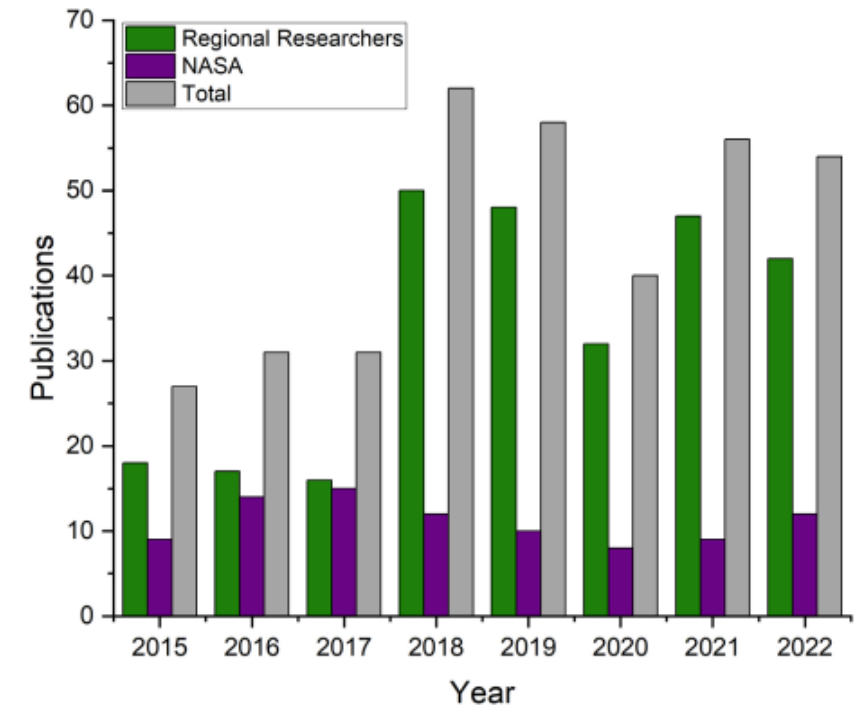 - pathways forward to programmatically address emergent sustainability challenges in the region

**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
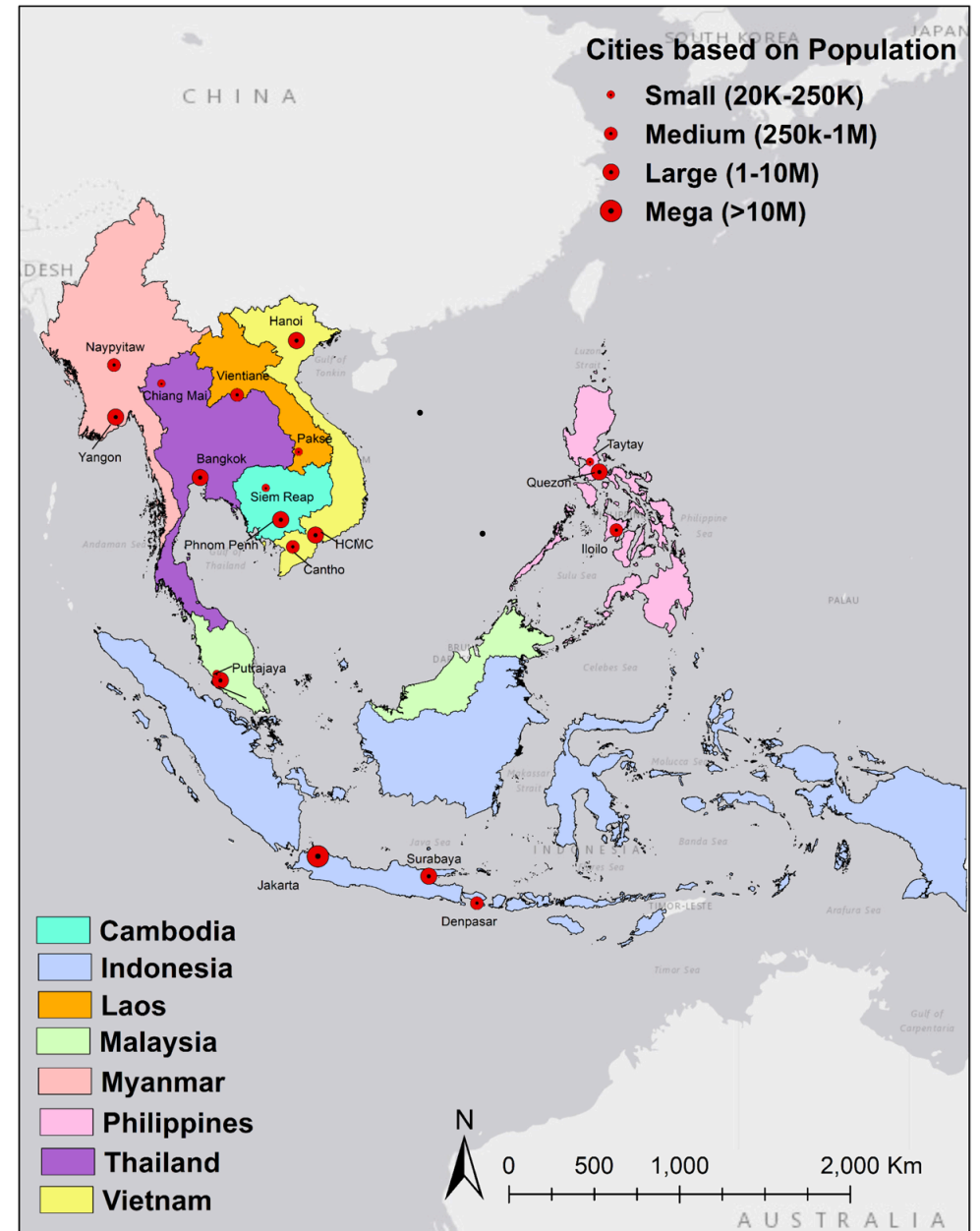
2. Study objectives

- (1) **synthesize existing projects and literature** relevant to URC to achieve a basic understanding of the current state of land use science in SEA

- (2) **identify knowledge gaps**, **challenges, opportunities, and pathways** in land use science related to URC in SEA,

- (3) examine/quantify **drivers, patterns and processes** of land use transformation across the URC to fill the gaps.

- the availability of multiple open-source, global spatial databases of meteorology and land cover and land use derived from remote sensing imageries and geospatial data of demographic, socioeconomic, and infrastructural measures available through our in-country collaborations.

Research questions:

- **RQ1 (Patterns).** What distinct **patterns of LCLUC** have occurred along **the urban-rural continuums (URC)** in SEA, and how have they differed for large-, medium-, and small-size cities? How have **land transition patterns variated across URC** (from the towering central business districts to the remote hinterlands) in the selected study sites in SEA between 1990 and 2020?

- **RQ2 (Impacts).** How have **ecosystem functions changed with LCLUC across the URC**, particularly in **green** infrastructure (vegetation and soils) and **blue** infrastructure (i.e., water quantity and quality and wetlands)? How have ecosystem changes induced environmental problems, such as greenhouse gas (**GHG**) emissions, microclimate **extremes** (drought, flood and heatwaves), and **air pollution**, especially for vulnerable communities?

- **RQ3 (Drivers).** What are the specific **biophysical and socioeconomic drivers** that created the observed spatiotemporal patterns (RQ1) and associated impacts (RQ2) across the URCs in SEA? What are the roles of socioeconomic development level, global connection, and location in shaping URC, including land governance, national policy, and local planning?

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**, reflected by population size, economic development level, and global connection,

- (2) the **relative location along the URC** (to the associated urban center) and its relevant features represented by connectivity (distance) to center/subcenters and access to major physical/social infrastructures, and

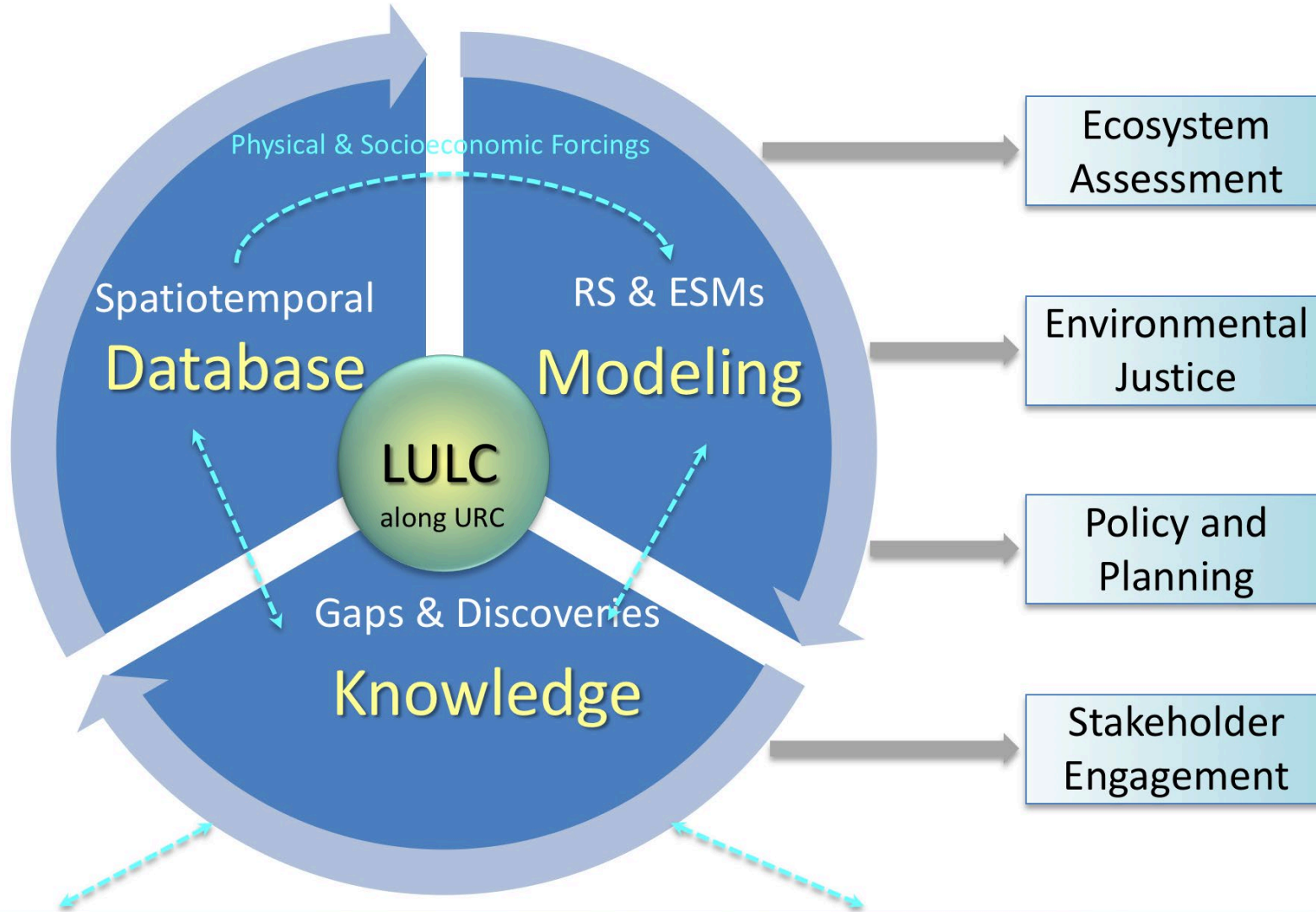- (3) **institutional policies** enforced by the national government and local urban planning.

Fig. 3 Conceptual framework

We will compare patterns of LCLUC across URC, assess ecosystem and socio-environmental impacts, and analyze physical and socioeconomic forcings/drivers.

The synthesis is based on the URC concept and key literature on land and environmental sciences. We will synthesize spatiotemporal data, tools, and models, as well as identifying knowledge gaps and future needs/priorities.

3. Key concepts & SEA context

Urban rural continuums (URC)

Land transitions

Ecosystem and socioenvironmental impacts from LCLUC

Forcing Mechanisms

Legend:
- Large city (>1 M)
- <1 hour to large city
- 1-2 hours to large city
- 2-3 hours to large city
- Medium city (250K - 1M)
- <1 hour to medium city
- 1-2 hours to medium city
- 2-3 hours to medium city
- Small cities and towns (20K - 250K)
- <1 hour to small city or town
- 1-2 hours to small city or town
- 2-3 hours to small city or town
- Dispersed/Hinterland

Urban-rural continuums (URC)
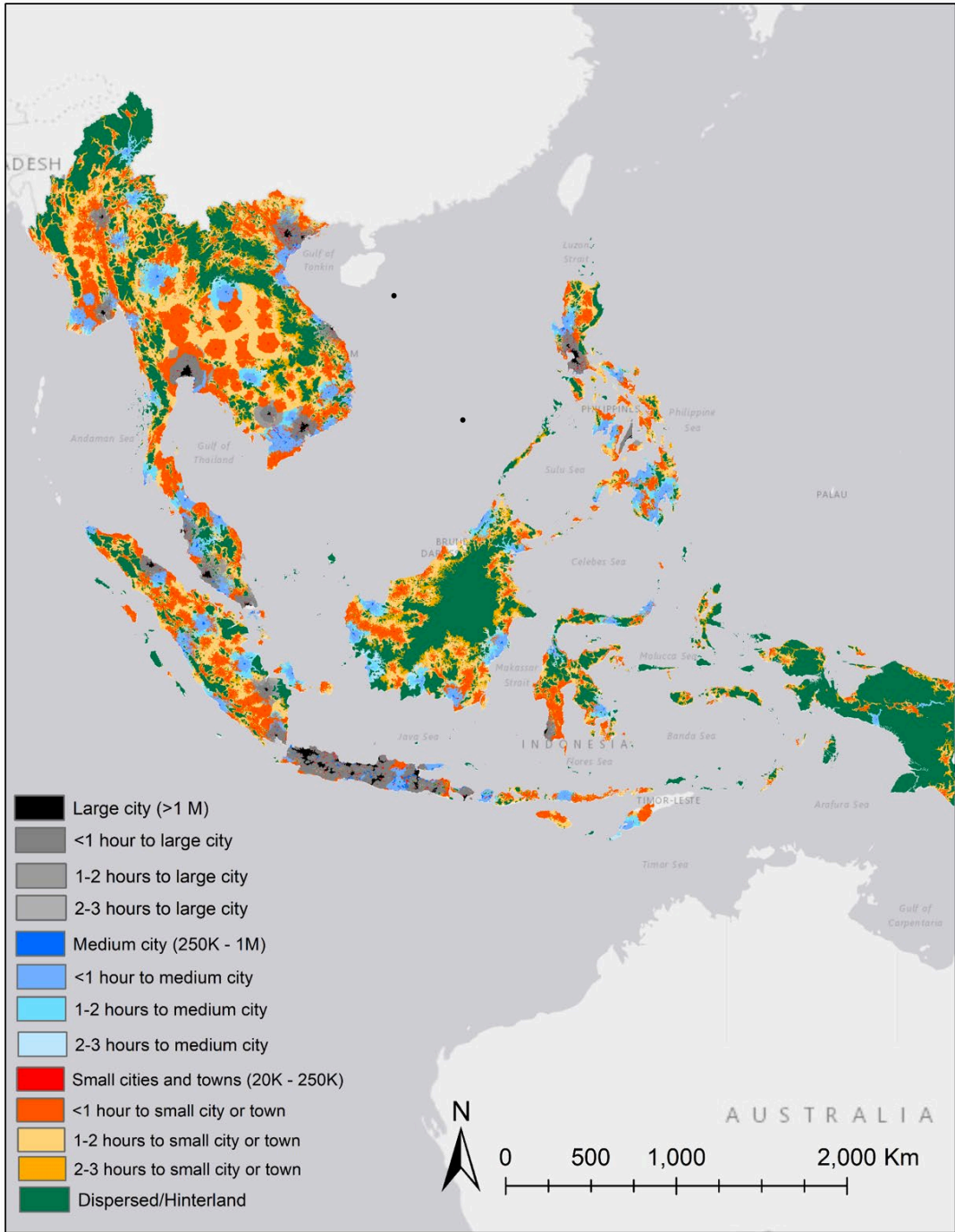
- To move **away from the urban-rural dichotomy**, a continuum from dense urban center to remote rural areas has been proposed, with its first implementations in 1974, where the rural-urban continuum code was devised by the U.S. Department of Agriculture (USDA) to classify all US counties and county-equivalents (ERS-USDA 2022).

- To operationalize **the urban-rural continuums**, URCA is defined by matching all rural locations to an urban center of reference based on the time needed to reach it, where a larger urban center dominates over a smaller one when a travel time category is the same (Cattaneo et al 2021).

- 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

a) Current Conceptualization
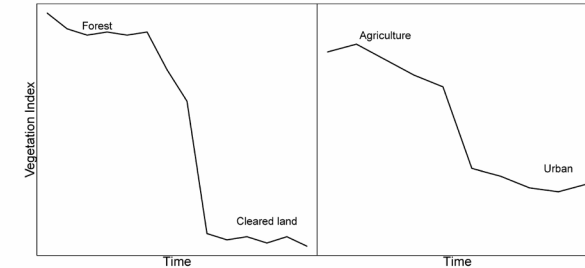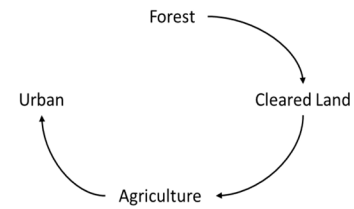
b) Proposed Conceptualization
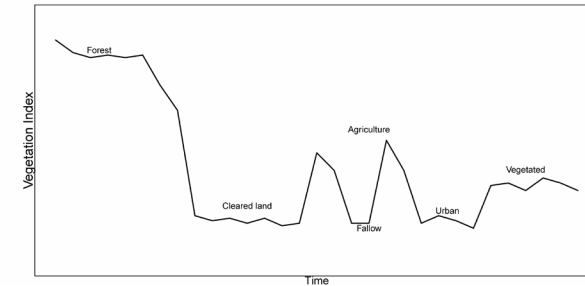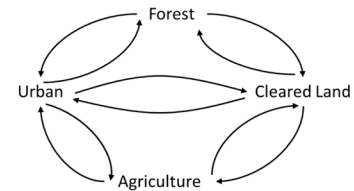
- Urban land transitions
    - urban land expansion: economic development/industrialization policy, and extreme events
- Agriculture land
    - agricultural land intensification, conversion of agricultural land to urban land, land use change to new types of plantation, and abandonment of some agricultural lands (Follmann 2021; Prabhakar 2021; Rudel et al 2009).
- 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

- Concepts: coupled human and natural systems, syndrome approach, Kuznets Environment Curve, urban environment transition

Forcing Mechanisms of LCLUC of URCs

- Biophysical drivers: Changes in biophysical conditions, such as climate, soil and water conditions, may result in land use change

  - 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

  - Concepts: urban land teleconnections and telecoupling, global-local response

4. Study approach: --Study Area

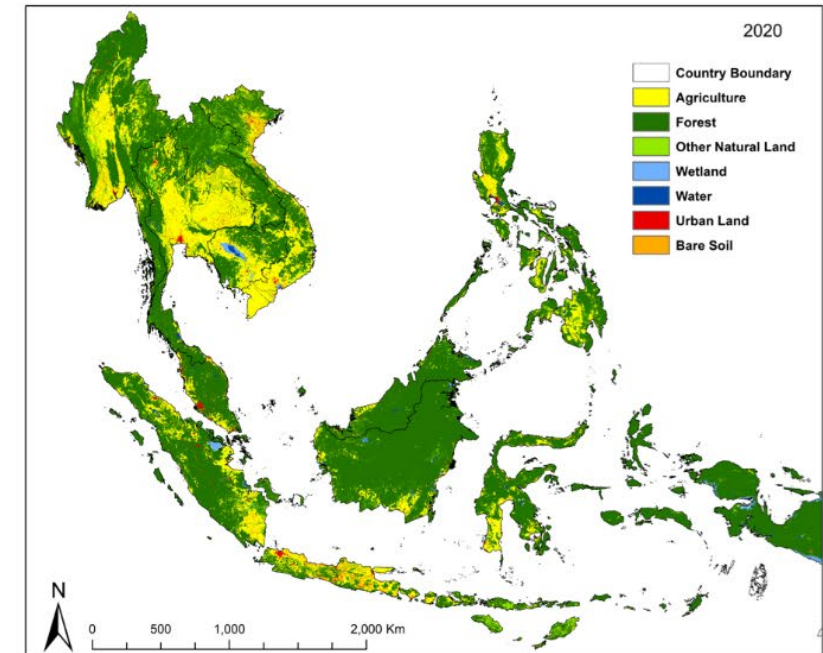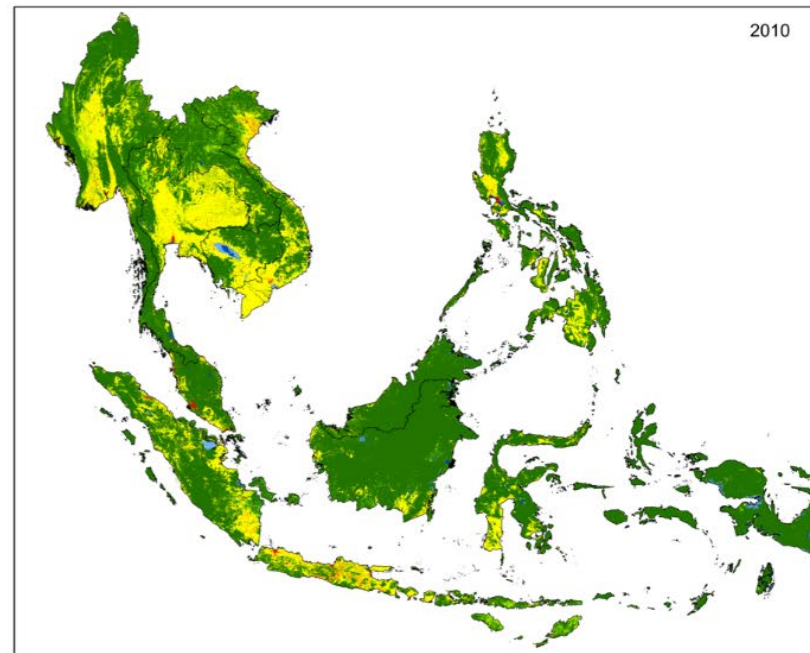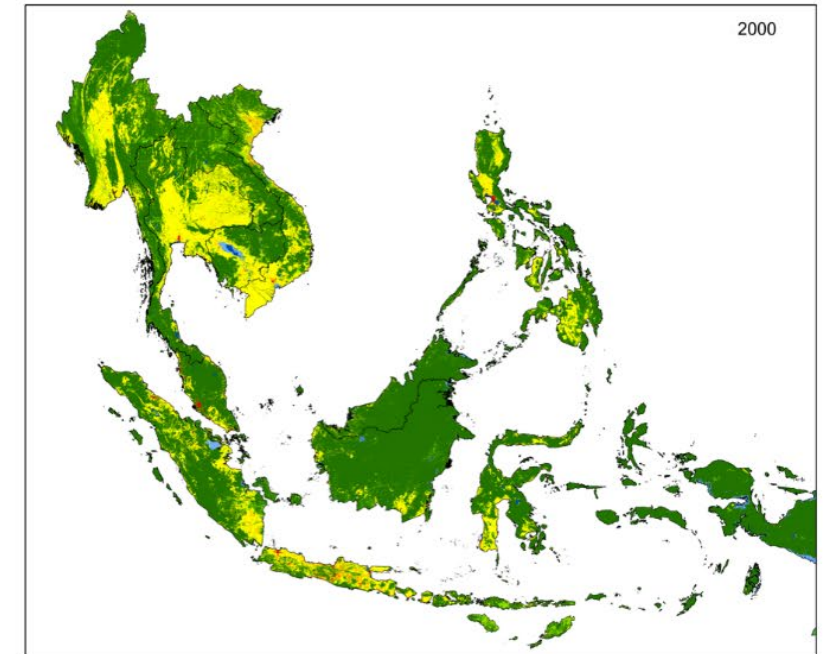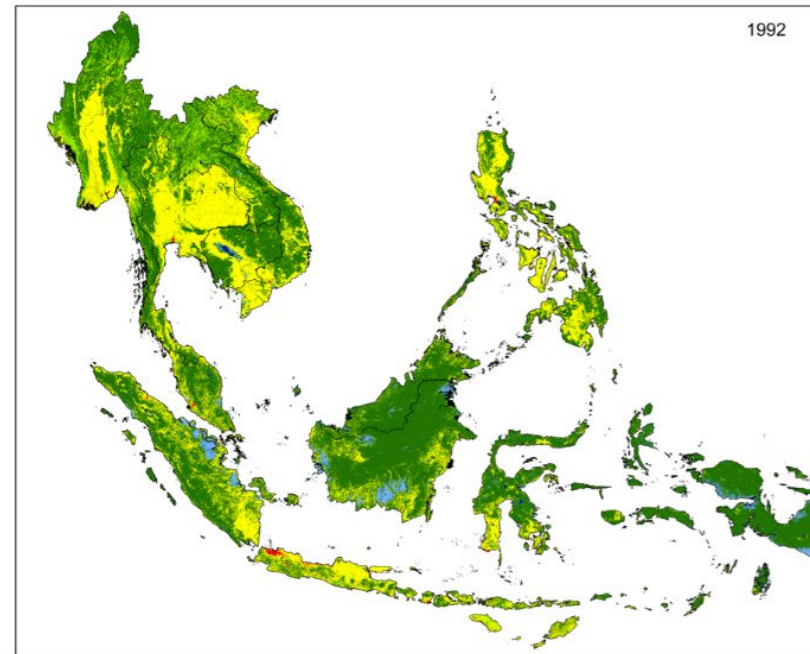Major land cover/land use in the study area during 1992-2020.

1992

2000

2010

2020

Legend:
- Country Boundary
- Agriculture
- Forest
- Other Natural Land
- Wetland
- Water
- Urban Land
- Bare Soil

N

0 500 1,000 2,000 Km

Table 1. Profile of 8 selected nations in SEA

Country	Land Area (km²)	Population (million)	Density (people/km²)	GDP (billion constant US$ 2015)	GDPpc (constant US$ 2015)	HDI	Urbanization (%)	
	2020	2020	2020	2020	2020	2013	1990	2020
Brunei	5270	0.4	83	13	30718	0.85	66	78
Cambodia	**176520**	**16.7**	**95**	**23**	**1375**	**0.58**	**16**	**24**
East Timor	14870	1.3	89	2	1286	0.62	21	31
Indonesia	**1877519**	**273.5**	**146**	**1028**	**3757**	**0.68**	**31**	**57**
Lao PDR	**230800**	**7.3**	**32**	**19**	**2546**	**0.57**	**15**	**36**
Malaysia	**328550**	**32.4**	**99**	**344**	**10617**	**0.77**	**50**	**77**
Myanmar	**652790**	**54.4**	**83**	**86**	**1218**	**0.52**	**25**	**31**
Philippines	**298170**	**109.5**	**368**	**358**	**3270**	**0.67**	**47**	**47**
Singapore	709	5.7	8019	330	58057	0.9	100	100
Thailand	**510890**	**69.8**	**137**	**433**	**6199**	**0.72**	**29**	**51**
Vietnam	**310070**	**97.3**	**314**	**259**	**2656**	**0.64**	**20**	**37**
Total SEA	4406158	668.3	152	2894	4331	0.67	33	52
selected nations	**4385309**	**660.9**	151	**2549**	3857	**0.66**	**28**	**50**

Scales of analysis

8 countries

19 URC

4 categories (i.e., urban center, peri-urban, peri-rural, and rural areas) the latter of which are within 40km, 40-80 km, and 80-120 km

Each grid cell (1 km^2) thus has both a URC type category and a distance variable to its associated urban center.

land change patterns for the three periods 1990-2000, 2000-10, and 2010-20

Local (1kmx1km):

local scale analysis on ecosystem and socio-environmental impacts,

randomly select 3~5 grid cells from each of the 4 categories of URC (stratified sampling), leading to a selection of 12~20 grid cells in the URC of each urban center (a total of 228~380 grid cells for 19 urban centers).

These grid cells will be used to characterize ecosystem functions or socio-environmental impacts, or to identify spatial determinants (drivers) for land transitions (RQ2&3).

Table 2. Selected urban centers for examining land transitions across URC

Country	Mega (>10M)	Large (1-10M)	Medium (250k-1M)	Small (20-250K)
Cambodia		Phnom Penh (2.3M)		Siem Reap (249K)
Indonesia	Jakarta (10.5M)	Surabaya (2.8M)	Denpasar (725K)	
Lao PDR			Vientiane (969K)	Pakse (88K)
Malaysia		KL (1.8M)		Putrajaya (109K)
Myanmar		Yangon (5.1M)	NPT (375K)	
Philippines		Quezon City (2.7M)	Iloilo (387K)	Taytay (231K)
Thailand		Bangkok (5.1M)		Chiang Rai (79k)
Vietnam		HCMC (9.0M), Hanoi (8M)	Cantho (812K)	
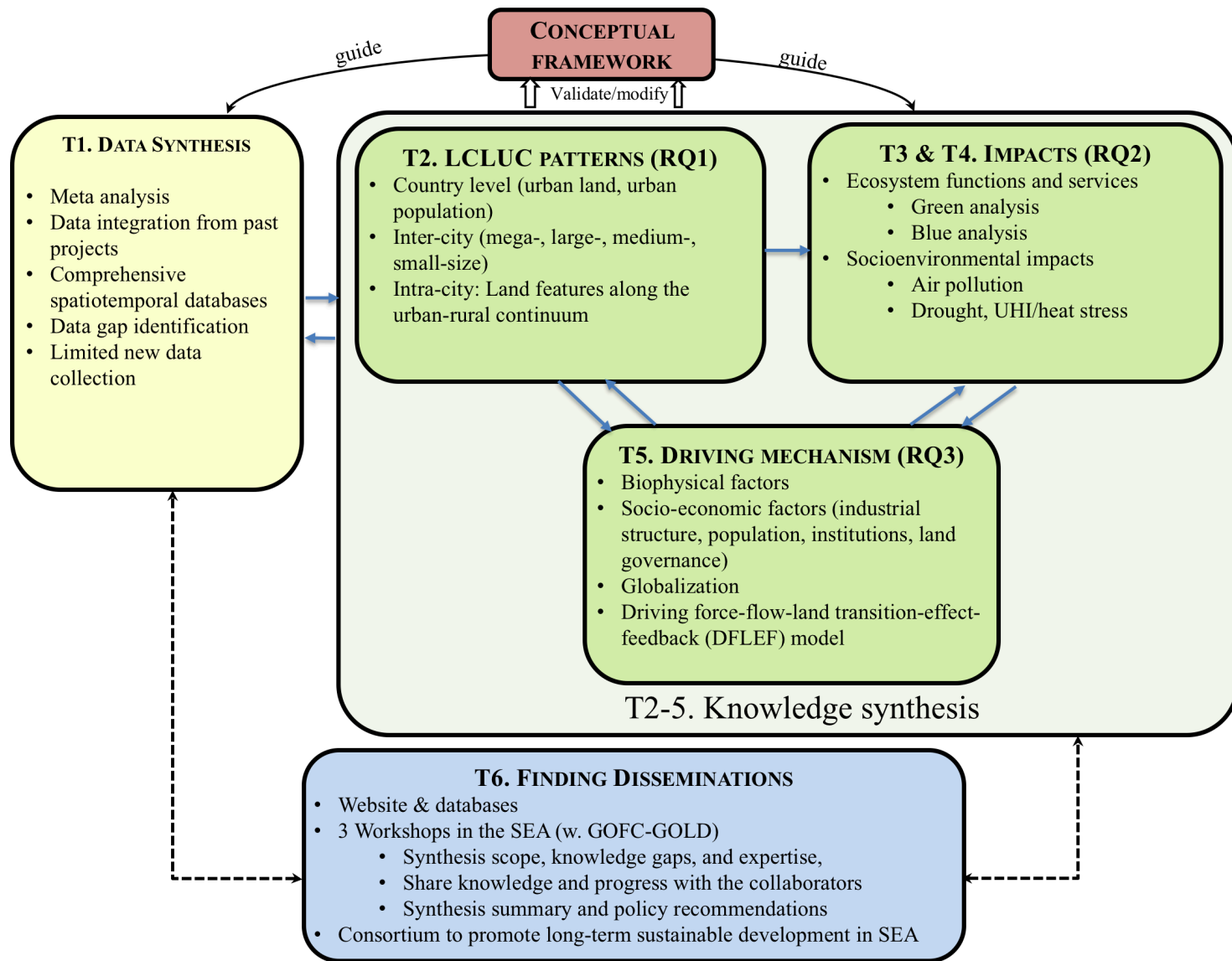
Fig. 7 **Tasks and connections for the proposed research**.

T1 is data synthesis whereas T2-5 focus on knowledge synthesis. T6 shares outcomes with stakeholders.

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)
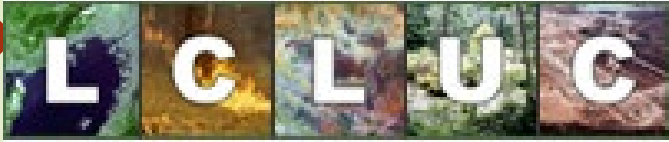
Grant #: NNX15AD51G
web: senacgc.org

Study Context:

- SENA countries constitute a region that is significant in both natural and socioeconomic dimensions: a land area of 25.4 million km^2 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.
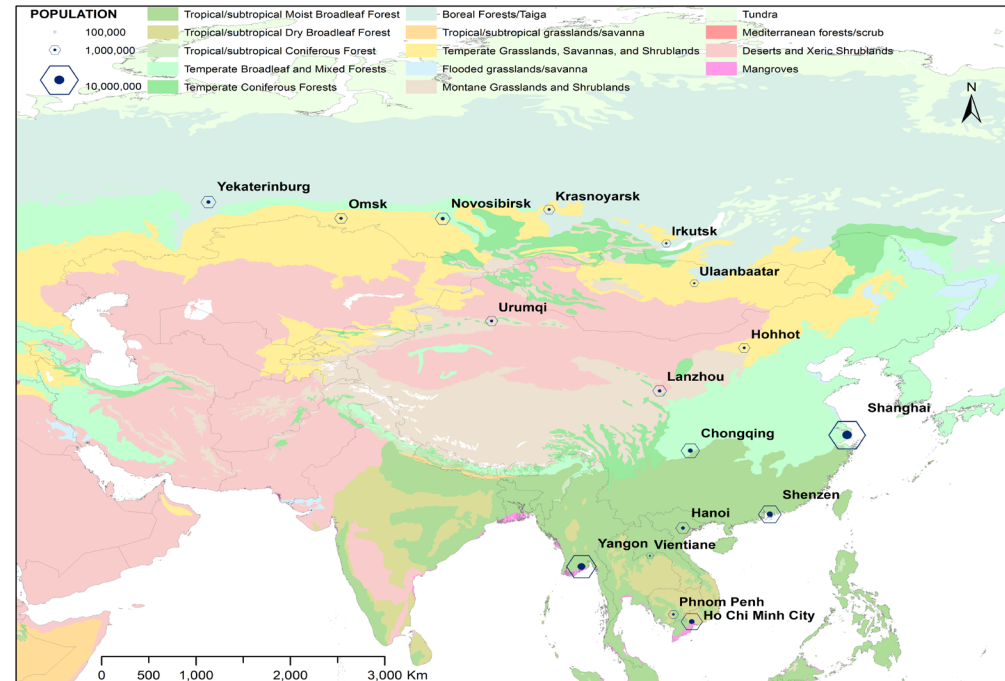

17 urban systems overlaid on the Ecoregion coverage (8 biomes in 7 countries)

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)
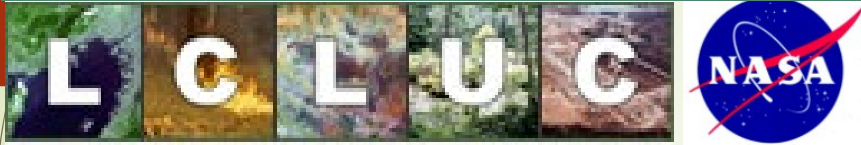
Grant #: 80NSSC20K0740

Project publications:

http://seagul.info/
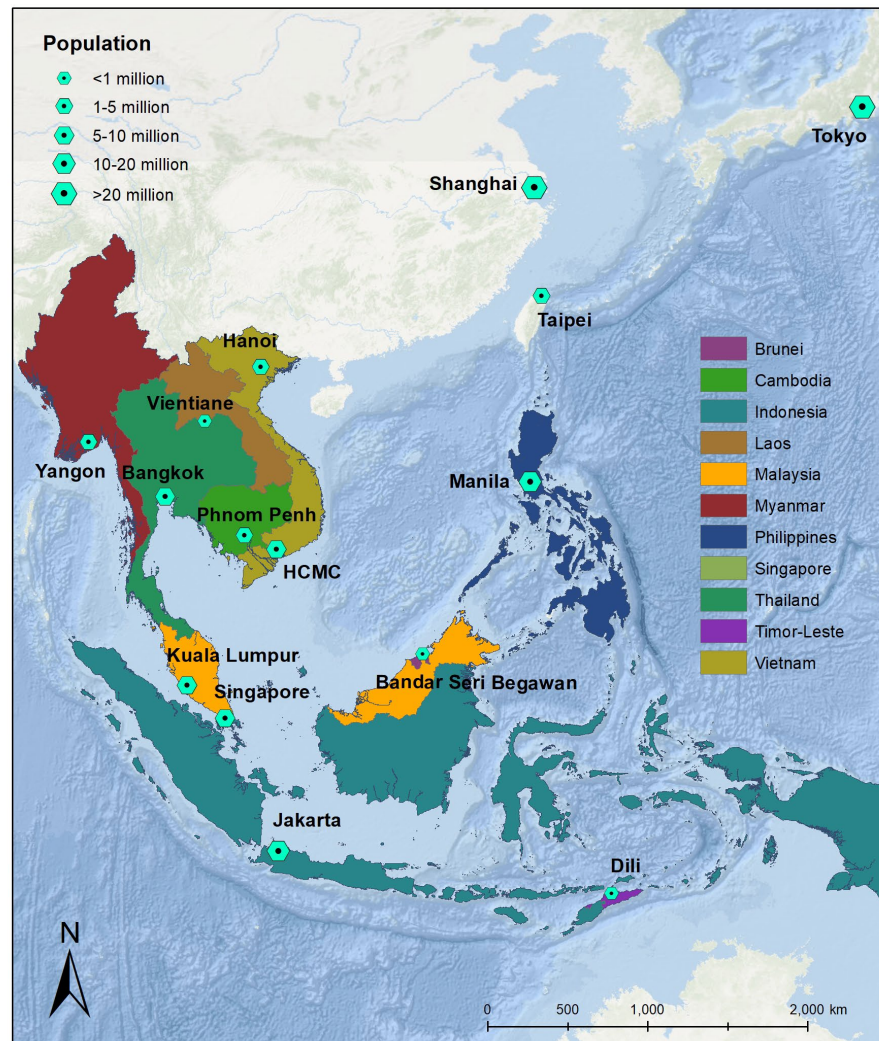
Research Scope

- Examine urbanization, land transitions, and environmental changes under globalization in **7 SEA countries** through an innovative conceptual framework and related methods

  1. developing **a theoretical framework** to examine one particular driver, globalization

  2. integrating **quantitative and qualitative data and methods** to analyze system dynamics

  3. 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),
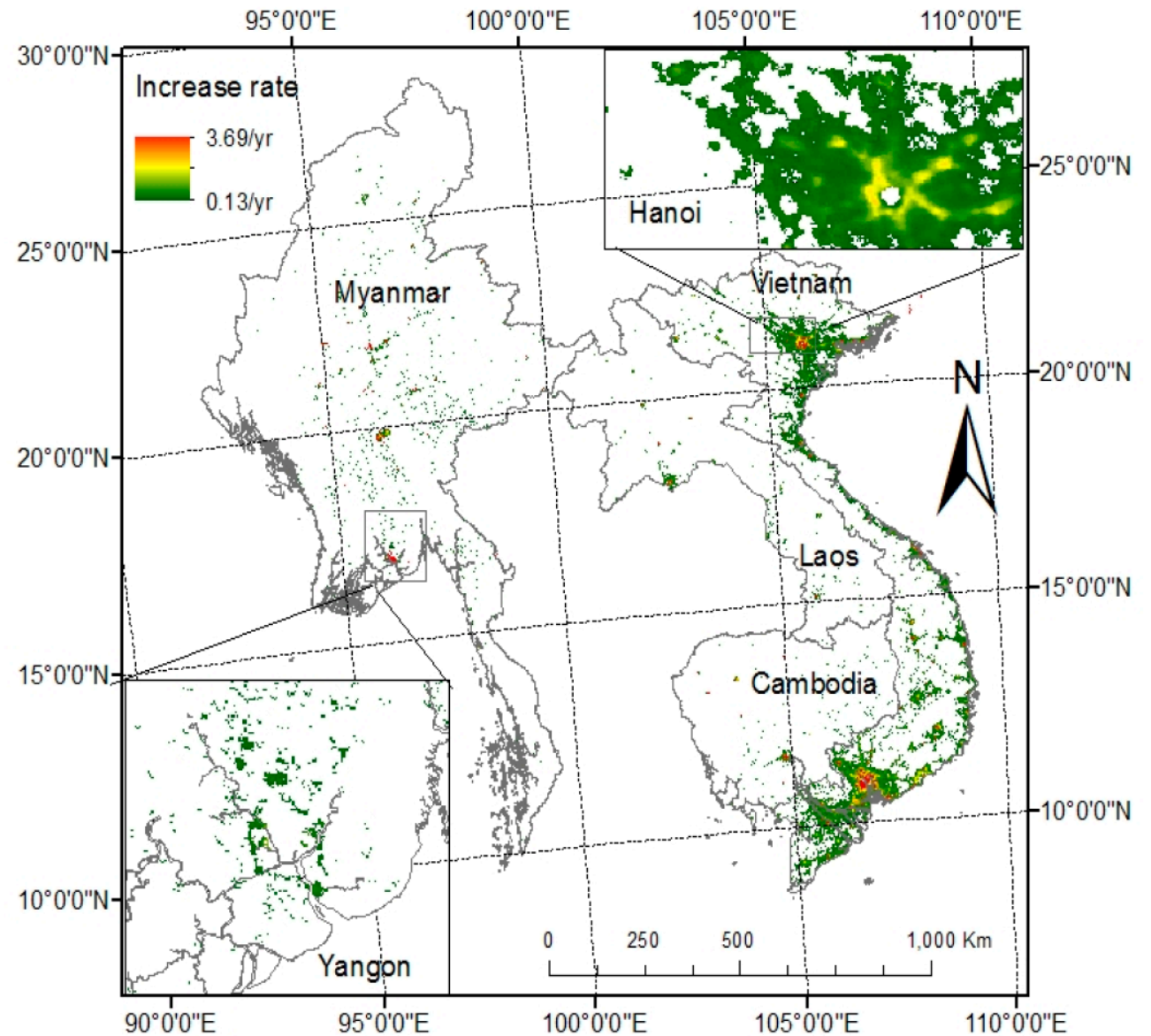 - followed by Laos, Cambodia and Myanmar, which increased at 6.0-, 3.6- and 0.24-times, respectively.

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.

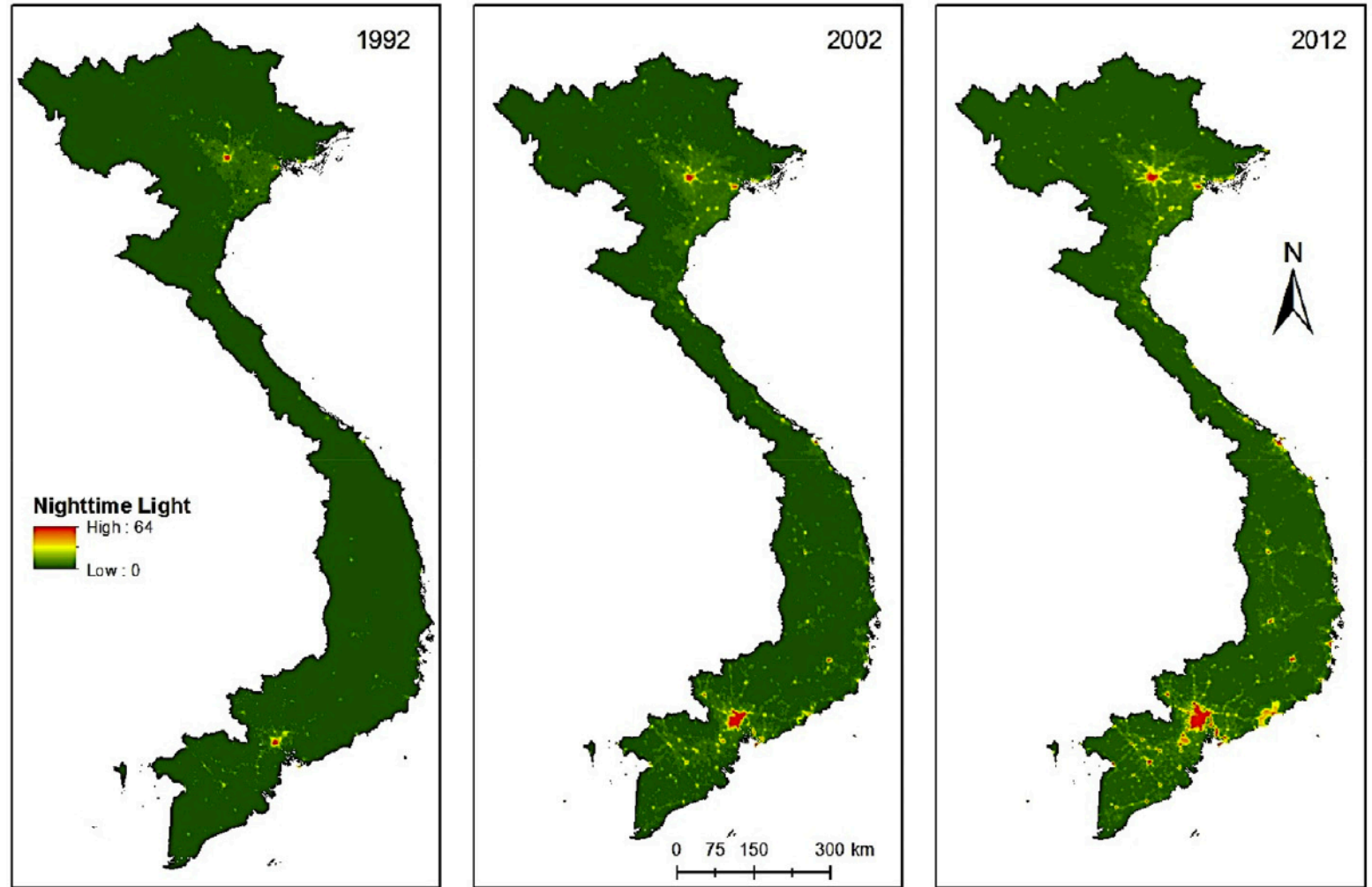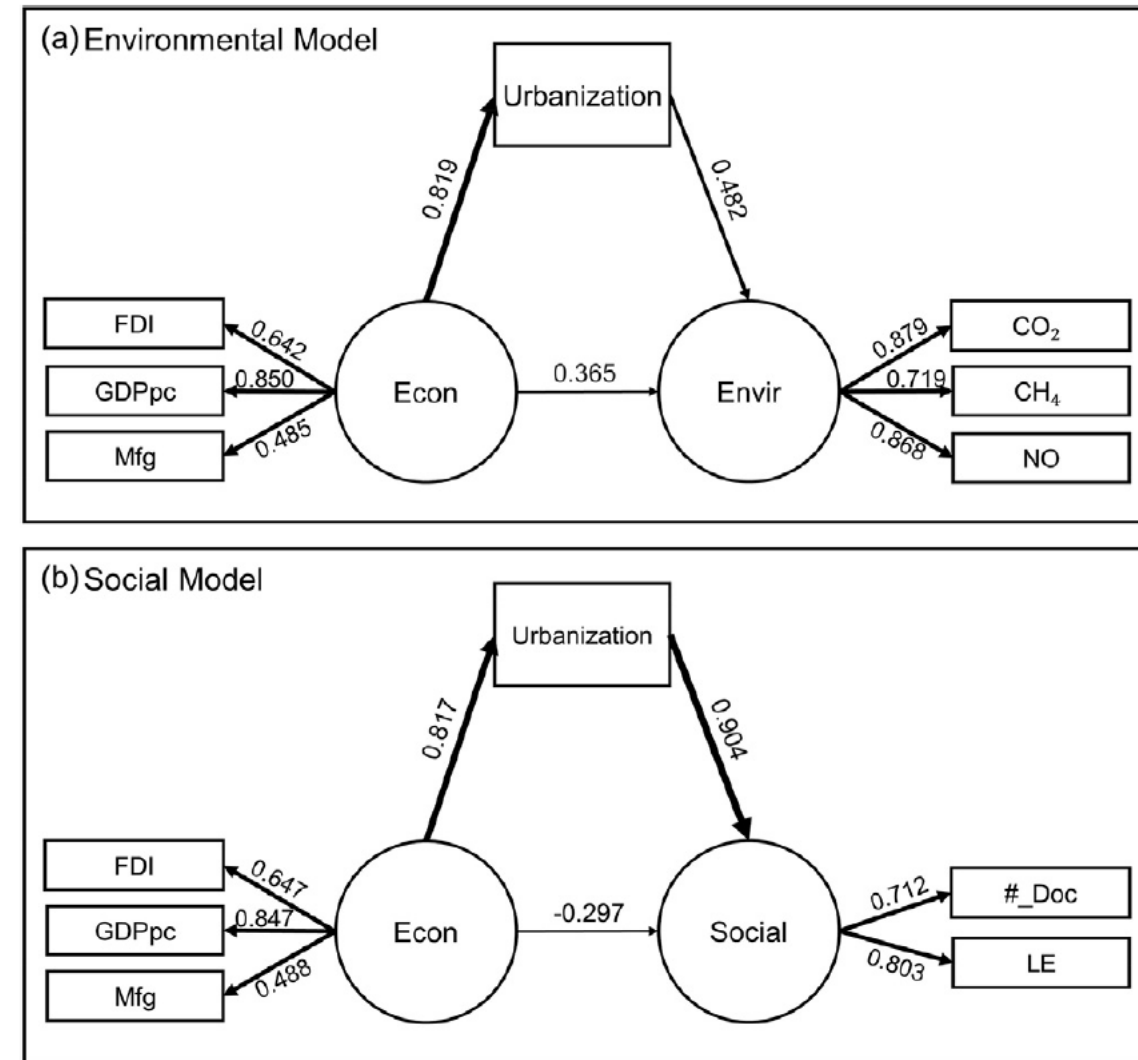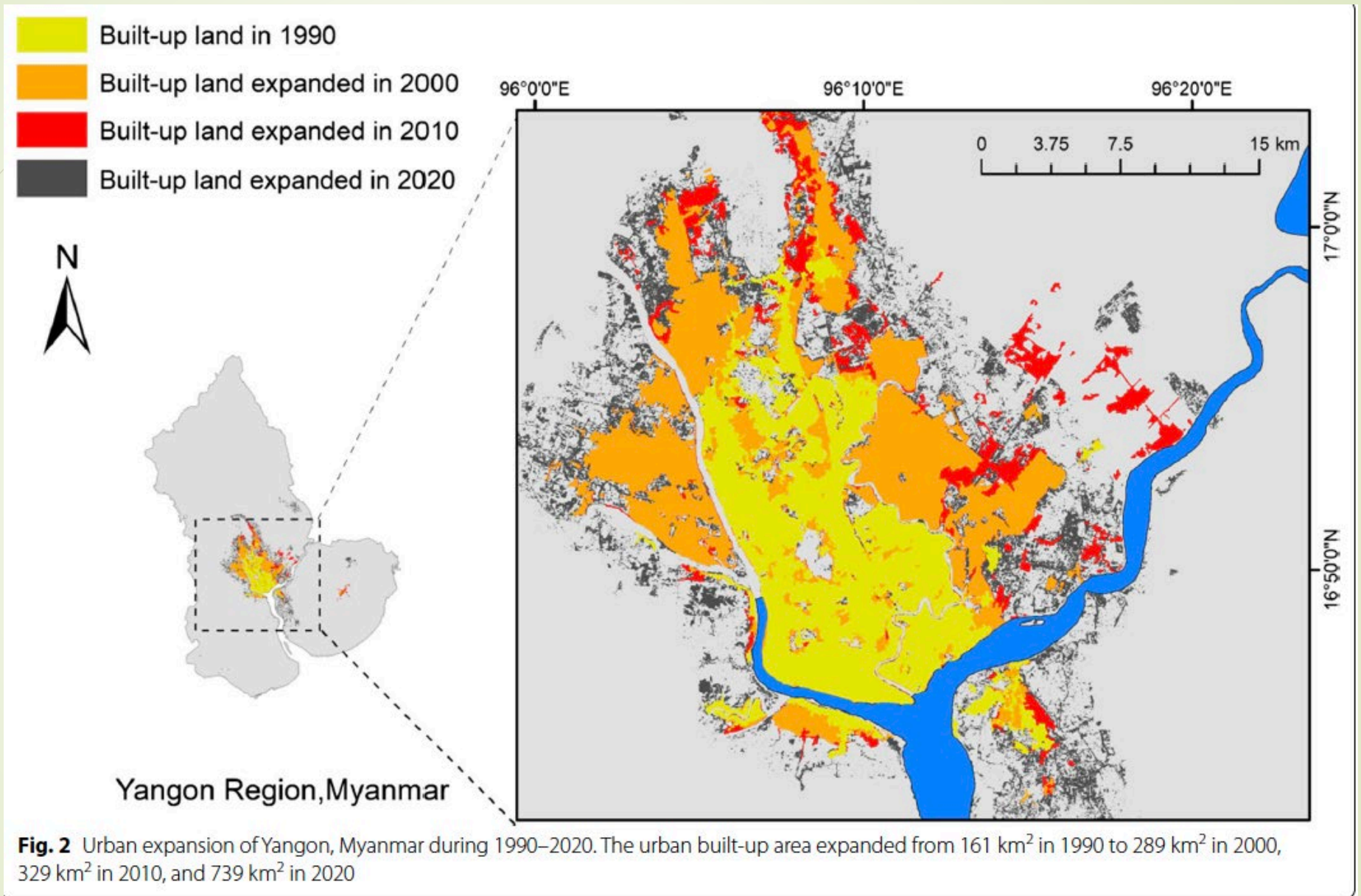## Examples from the past projects:

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.

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.

Examples from the past projects:

(a) Environmental Model

(b) Social Model

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), CO2 emissions per capita (CO2), CH4 emissions per capita (CH4), and NO emissions per capita (NO), number of doctors per capita (#_Doc), and life expectancy (LE).

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.

Examples from the past projects:

Fig. 2 Urban expansion of Yangon, Myanmar during 1990–2020. The urban built-up area expanded from 161 km² in 1990 to 289 km² in 2000, 329 km² in 2010, and 739 km² in 2020

Source: Fan, P., Chen, J., Fung, C., Naing, Z., Ouyang, Z., Nyunt, K.M., Myint, Z.N., Qi, J., Messina, J.P., Myint, S.W., Peter, B.G. (2022). Urbanization, economic development, and environmental changes in transitional economies in the Global South: A case of Yangon. *Ecological Processes. 11:65*
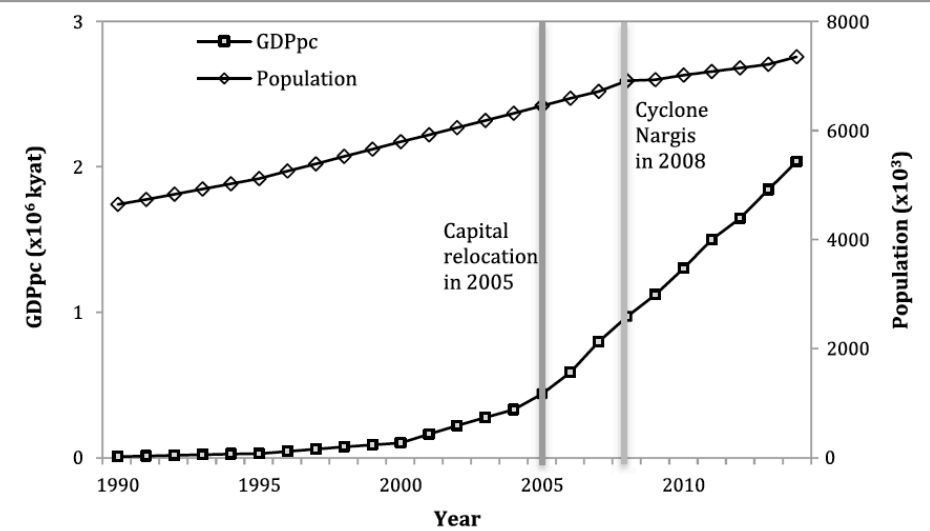
Examples from the past projects:

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

Fig. 5 Changes in concentrations of three air pollutants ($PM_{2.5}$, NO_2, and CO) with three socioeconomic variables (population, GDPpc, and # of vehicles) in Yangon. $PM_{2.5}$ was positively associated with all three socioeconomic variables; NO_2 decreased and increased with population and GDPpc, respectively; and CO declined with population and GDPpc

Source: Fan, P., Chen, J., Fung, C., Naing, Z., Ouyang, Z., Nyunt, K.M., Myint, Z.N., Qi, J., Messina, J.P., Myint, S.W., Peter, B.G. (2022). Urbanization, economic development, and environmental changes in transitional economies in the Global South: A case of Yangon. *Ecological Processes. 11:65*

Highlights: recent activities of the SEAL project

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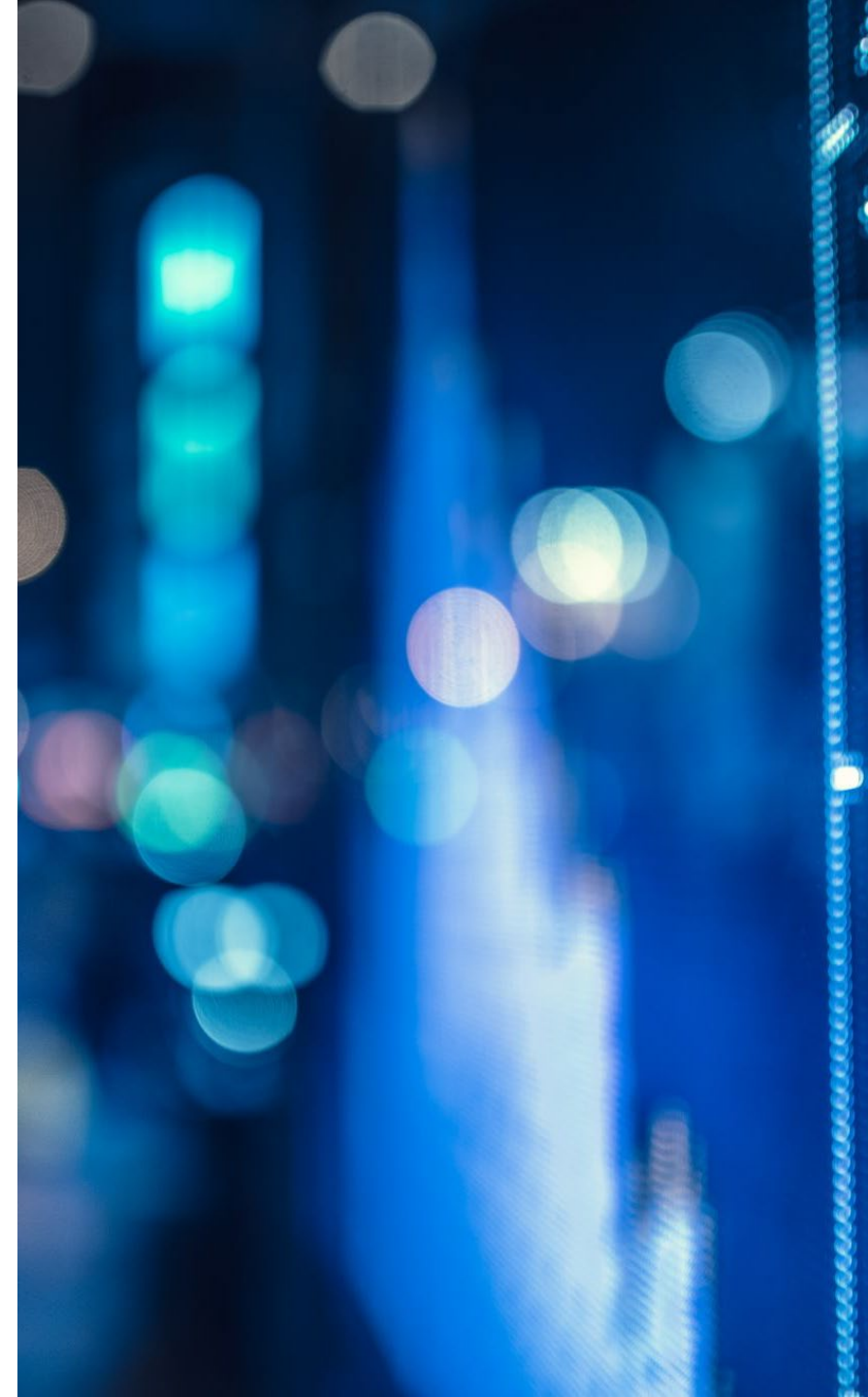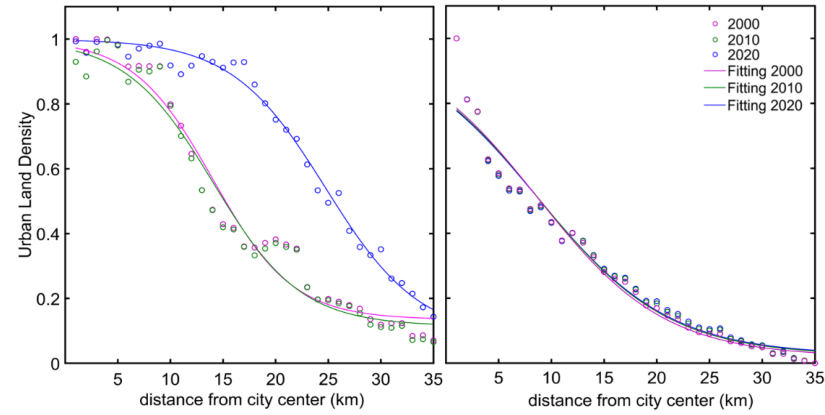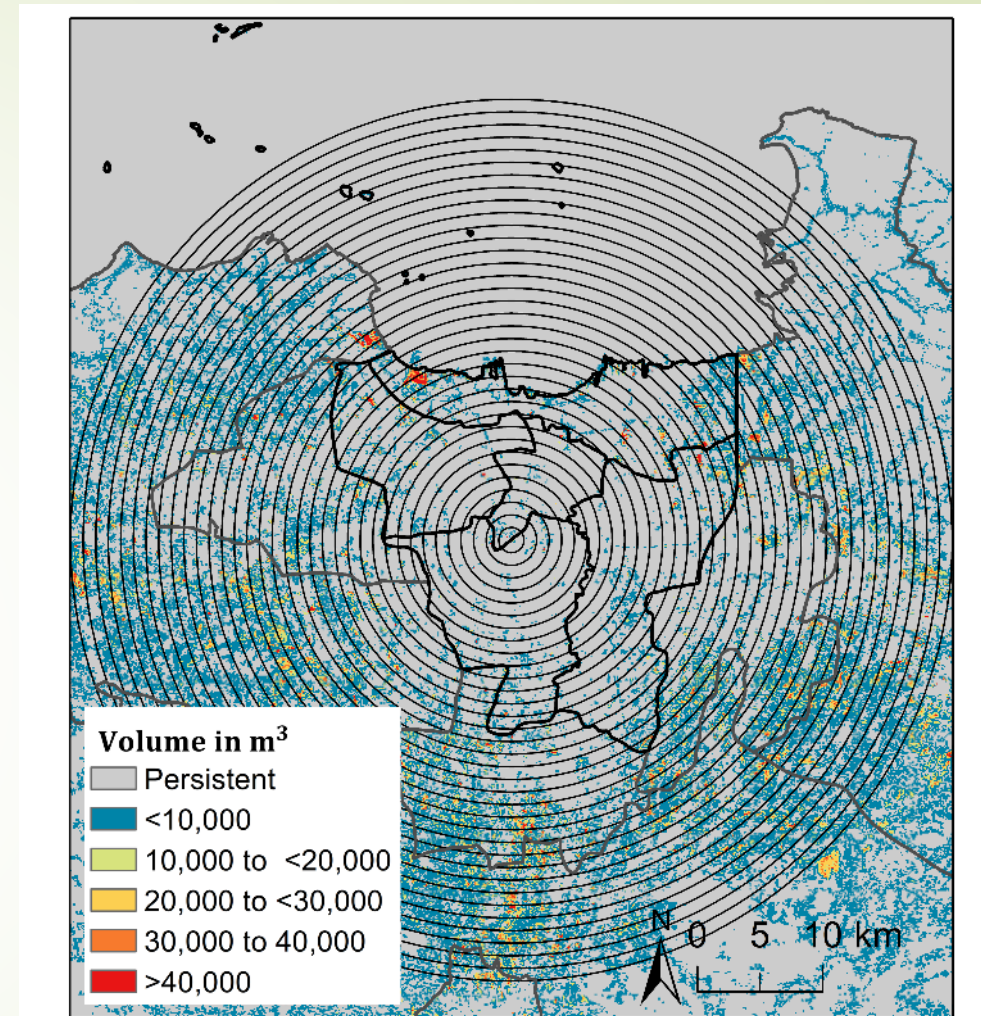
Figure 5. Changes in urban land density with distance from the city center to the suburban area in Jakarta based on ULD_{2D} (left), and ULD'_{3D} (right).

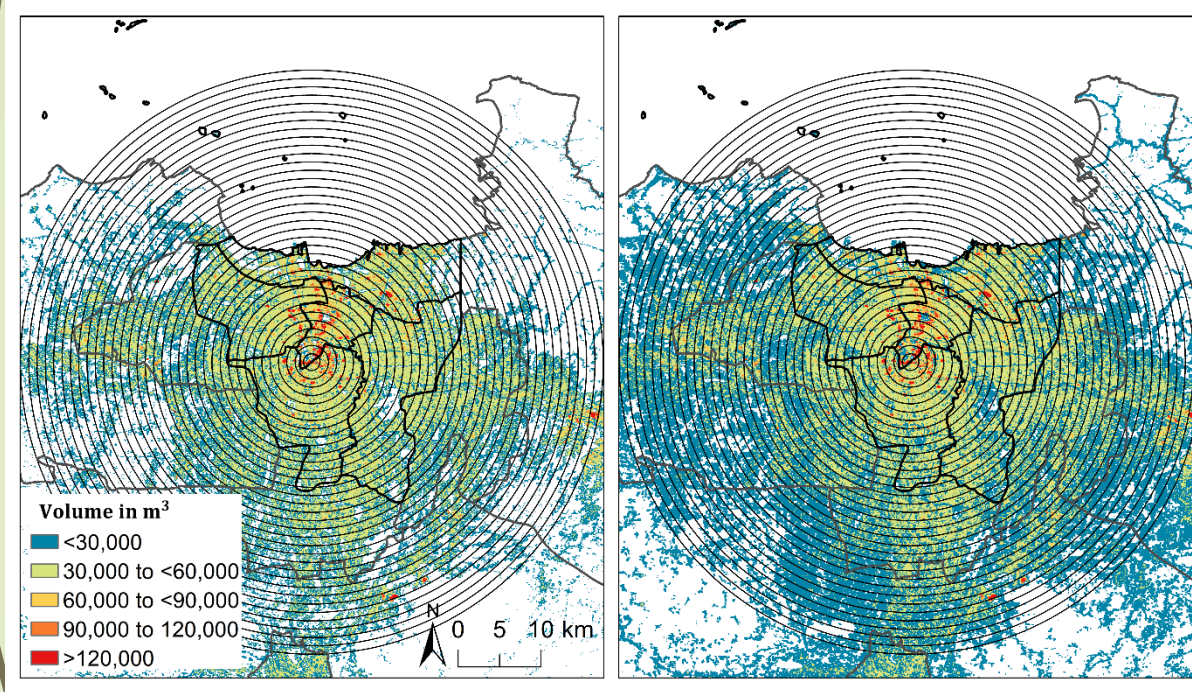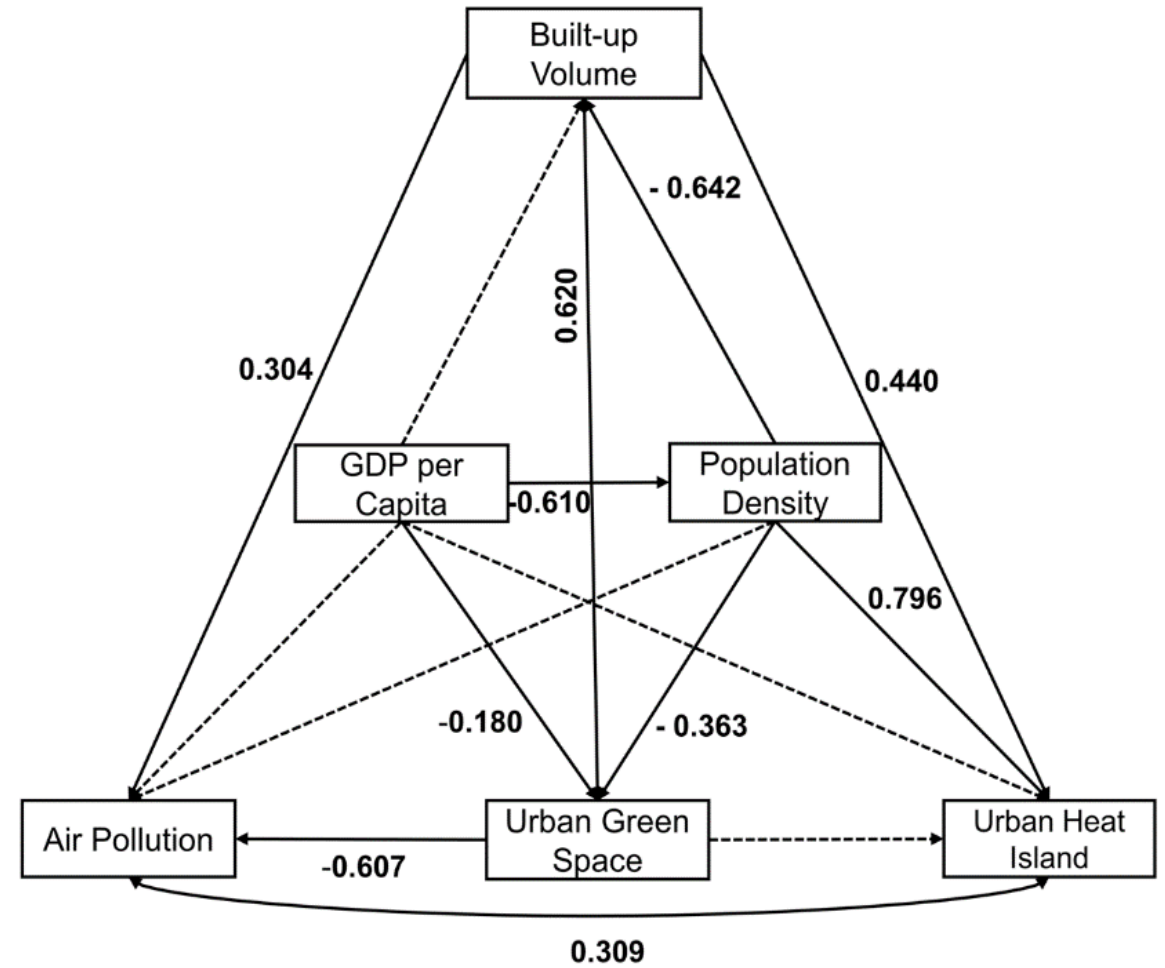# Highlight 1: Urban built-up volume & its environmental impact

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. Revision Submitted.

Highlight 2: interlinked relationship and transboundary influence between UHI & air pollution

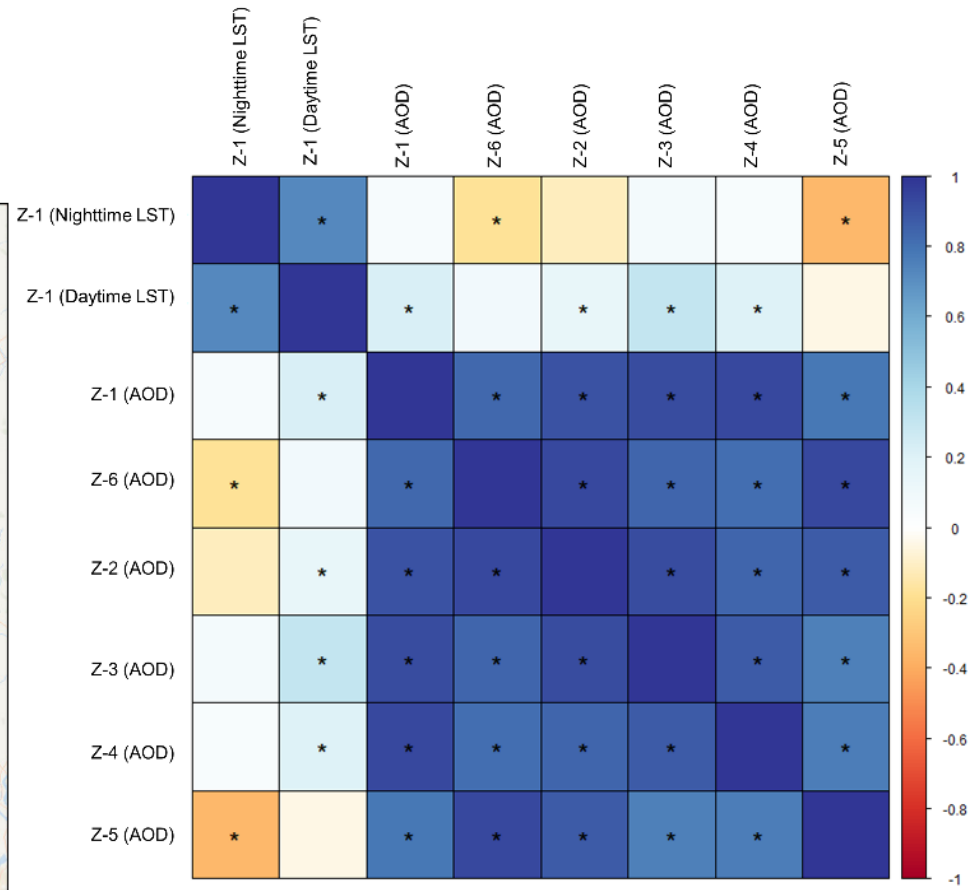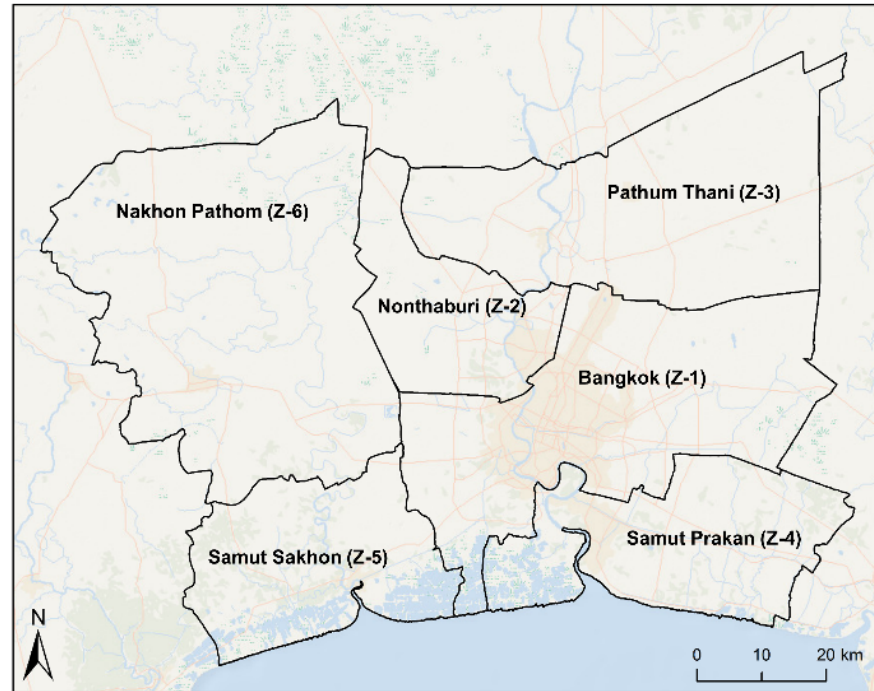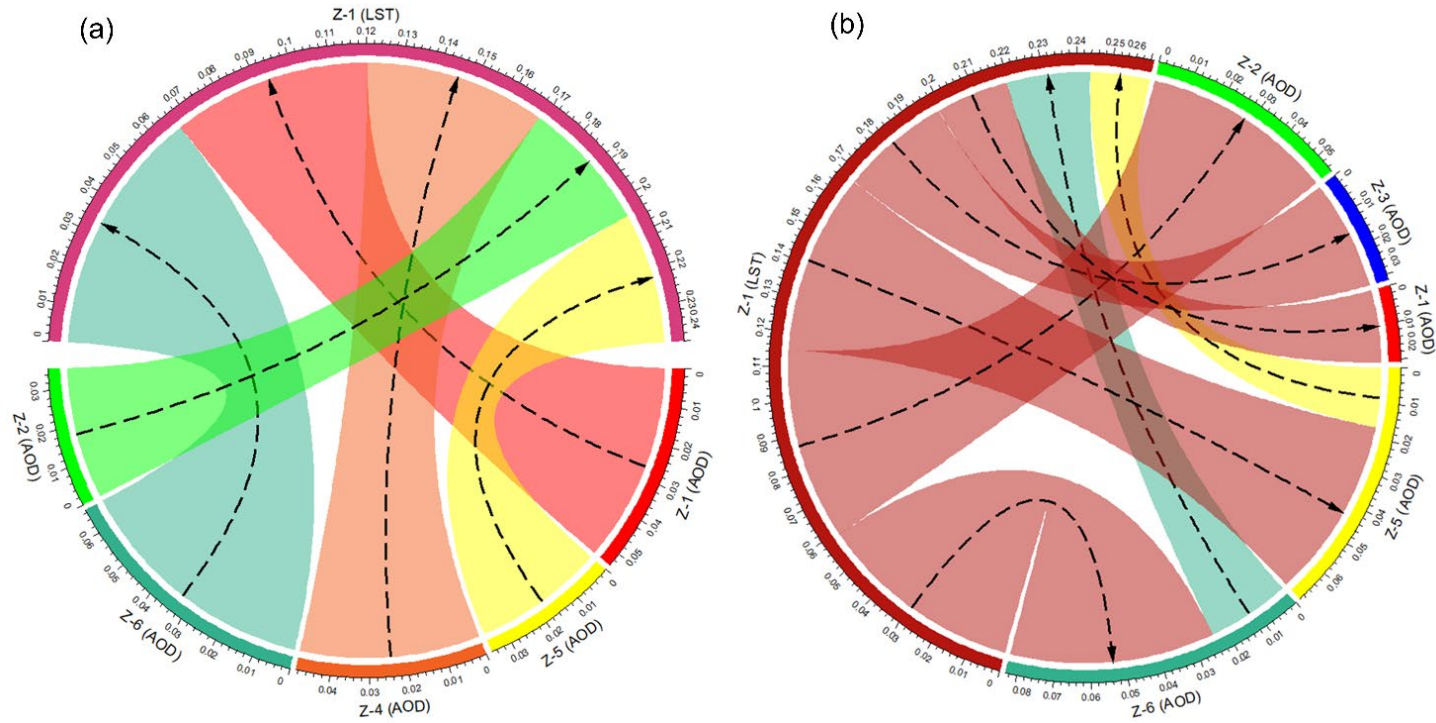*Figure 1: Study Area of Bangkok Metropolis Region (BMR), Thailand.*

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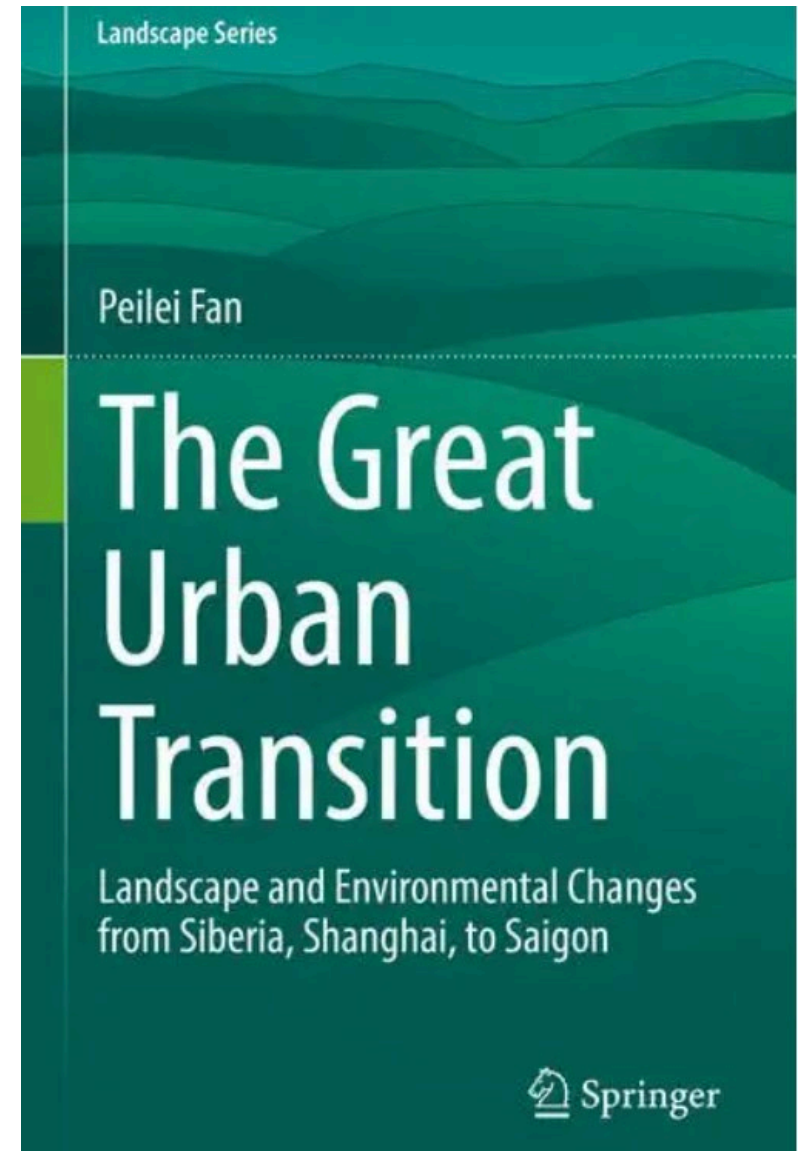
- *Figure 5: Chord diagram showing statistically significant transfer entropy between LST and AOD during 2003-2020 (a) daytime (left) and (b) nighttime (right).*

Highlight 3:
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.

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

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

Figure 8.1. Urban Planning Exhibition Hall, Shanghai.

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

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

Figure 9.2 Viewing the futuristic landscape of Pudong, from the bund, the waterfront area of the west of Huangpu River, Shanghai.

Planning through center (re)development

Photos taken by Peilei Fan, August 2018.

Figure 9.3 Supertall trio in the clouds, Lujiazui Finance and Trade Zone, Pudong New Area, Shanghai.

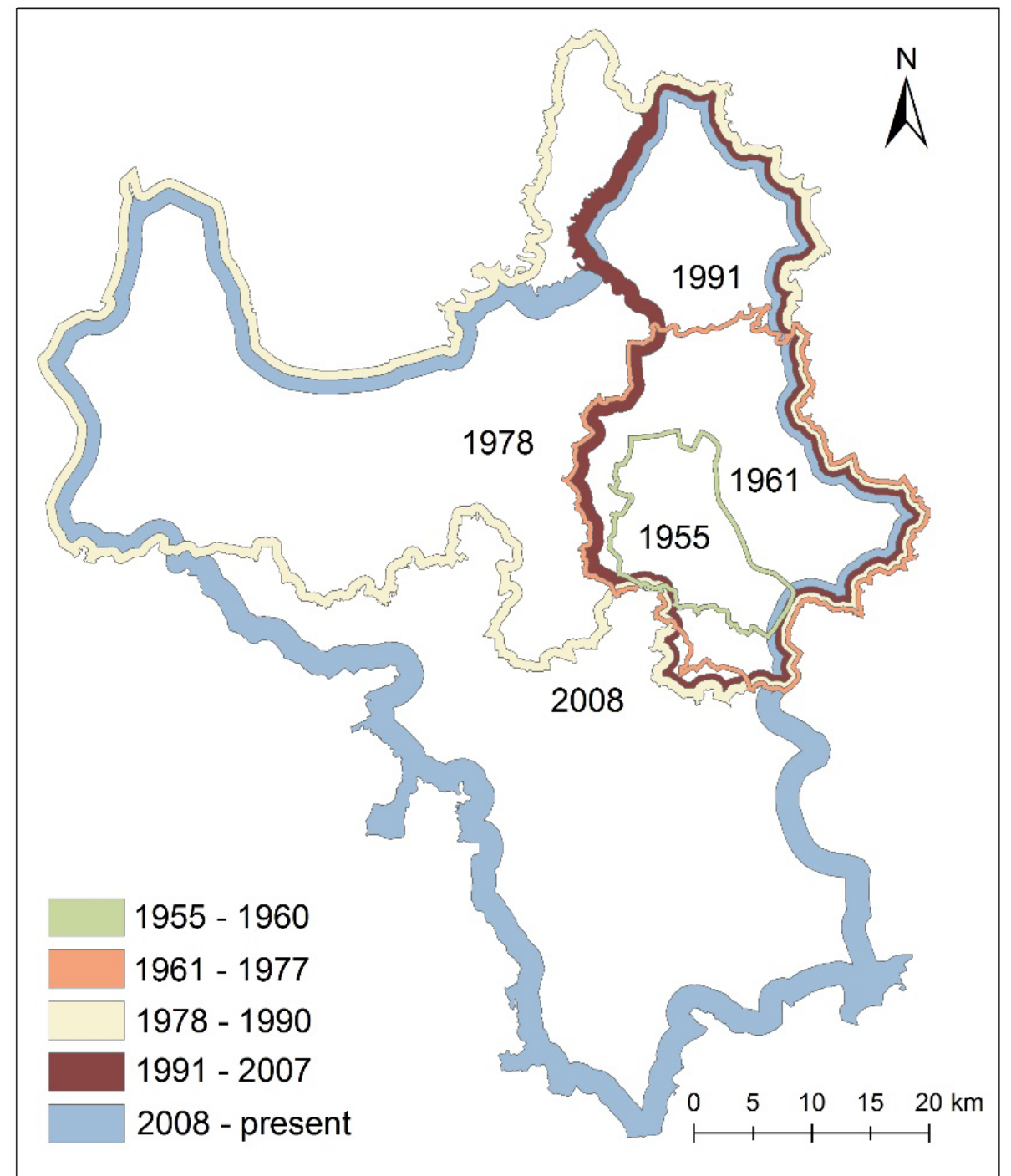**Planning through administrative area changes**

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)

Source: Photos taken by Peilei Fan in Phnom Penh on June 14, 2015.

Ecopark City of Hanoi

Photos taken by Peilei Fan, Jan. 30, 2024

Thank you!
Cảm ơn!

Looking forward to collaborating with you!

- Data sharing
- Insights/idea sharing
- workshops

Contact: Peilei.Fan@tufts.edu

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