

**International Meeting on Land Cover/Land Use Change (LCLUC) in South/Southeast Asia and Synthesis – Hanoi, Vietnam – 31 January to 2 February 2024**

# **Synthesis Study of Land Cover, Land Use, and Demographic Change under Multi-Dimensional Developments and Climate Pressures in Southeast Asia**



National Aeronautics and  
Space Administration

**Jet Propulsion Laboratory**  
California Institute of Technology  
Pasadena, California

**Son V. Nghiem (PI)<sup>1</sup> and  
International Research Team**

**<sup>1</sup>NASA Jet Propulsion Laboratory  
California Institute of Technology  
Pasadena, California, USA**

# International Research Science Team

PI S. V. Nghiem, 6 Co-Is, and 52 collaborators from 15 countries

Full name *	First Name*	Last Name*	Role in the project*	Job Title	City*	State*	Zipcode*	Country*	Institution*	Professional Level*	Department *
Son Van Nghiem	Son	Nghiem	Principle Investigator	Senior Research Scientist	Pasadena	California	91109	United States	NASA Jet Propulsion Laboratory, California Institute of Technology	Program Manager	Earth Science
Deborah L. Balk	Deborah	Balk	Co-Investigator	Professor	New York	New York	10010	United States	Baruch College, City University of New York	Professor	Marx School of Public and International Affairs
Mark A. Cochrane	Mark	Cochrane	Co-Investigator	Professor	Frostburg	Maryland	21532	United States	Appalachian Laboratory, University of Maryland	Professor	Center for Environmental Science
Andrea E. Gaughan	Andrea	Gaughan	Co-Investigator	Associate Professor	Louisville	Kentucky	40292	United States	University of Louisville	Associate Professor	Department of Geographic and Environmental Sciences
Adam J. Mathews	Adam	Mathews	Co-Investigator	Associate Professor	Binghamton	New York	13902	United States	Binghamton University, State University of New York	Associate Professor	Department of Geography
Christopher Small	Christopher	Small	Co-Investigator	Research Professor	Palisades	New York	10964	United States	Columbia University	Research Professor	Lamont Doherty Earth Observatory
Forrest R. Stevens	Forrest	Stevens	Co-Investigator	Associate Professor	Louisville	Kentucky	40292	United States	University of Louisville	Associate Professor	Department of Geographic and Environmental Sciences
Thuy Le Toan	Thuy	Le	Collaborator	Senior Scientist	Toulouse	Cedex 9	31401	France	Centre d'Etudes Spatiales de la Biosphère	Senior Scientist	Centre d'Etudes Spatiales de la Biosphère
Lam Dao Nguyen	Lam	Nguyen	Collaborator	Director	Ho Chi Minh City	N/A	N/A	Vietnam	Vietnam National Space Center	Director	VNSC Space Technology Application Center
Khanh Quoc Nguyen	Khanh	Nguyen	Collaborator	Vice Director	Hanoi	N/A	N/A	Vietnam	Institute of Meteorology, Hydrology and Climate Change	Assistant Director	Institute of Meteorology, Hydrology and Climate Change
Nguyen Thi Kim Oanh	Oanh	Nguyen	Collaborator	Professor	Pathum Thani	N/A	N/A	Thailand	Asian Institute of Technology	Professor	Environmental Engineering and Management, Department of Energy
Somsanouk Pathoumvanh	Somsanouk	Pathoumvanh	Collaborator	Professor	Vietiane	N/A	N/A	Lao PDR	National University of Laos	Senior Scientist	Faculty of Engineering
Soriya Yin	Soriya	Yin	Collaborator	Associate Professor	Phnom Penh	N/A	N/A	Cambodia	American University of Phnom Penh	Chair & Professor	Tourism and Hospitality Management and General Education
Kasturi Devi Kanniah	Kasturi	Kanniah	Collaborator	Professor	Johor	N/A	N/A	Malaysia	Universiti Teknologi Malaysia	Professor	Faculty of Built Environment and Surveying
Vu Tuong Thuy	Thuy	Vu	Collaborator	Dean	Sarawak	N/A	N/A	Malaysia	Curtin University Malaysia	Dean & Professor	Faculty of Engineering and Science
Israr Albar	Israr	Albar	Collaborator	Deputy Director	Jakarta Timur	N/A	N/A	Indonesia	Ministry of Environment and Forestry	Deputy General Director	Directorate General of Climate Change, Land and Forest Fire Management
Bambang Hero Saharjo	Bambang	Saharjo	Collaborator	Professor	West Java	N/A	N/A	Indonesia	IPB University	Professor	Faculty of Forest and Environment
Asmadi Saad	Asmadi	Saad	Collaborator	Associate Professor	Jambi	N/A	N/A	Indonesia	Jambi University	Associate Professor	Department of Agroecotechnology
Andrea Taramelli	Andrea	Taramelli	Collaborator	Associate Professor	Pavia	N/A	N/A	Italy	Istituto Universitario di Studi Superiori	Associate Professor	School of Advanced Studies
Paola Rizzoli	Paola	Rizzoli	Collaborator	Senior Research Scientist	Weßling	N/A	N/A	Germany	German Aerospace Center	Senior Scientist	Microwaves and Radar Institute
Shinichi Sobue	Sobue	Shinichi	Collaborator	Mission Manager	Tsukuba	N/A	N/A	Japan	Japan Aerospace Exploration Agency	Program Manager	ALOS-2 Mission
Vu Anh Tuan	Tuan	Vu	Collaborator	Vice Director General	Hanoi	N/A	N/A	Vietnam	Vietnam National Space Center	Deputy General Director	VNSC Headquarters
Seung-Jae Lee	Seung-Jae	Lee	Collaborator	Senior Researcher	Daejeon	N/A	N/A	South Korea	Korea Aerospace Research Institute	Senior Scientist	National Satellite Operation & Application Center
Sun-Gu Lee	Sun-Gu	Lee	Collaborator	Principal Researcher	Daejeon	N/A	N/A	South Korea	Korea Aerospace Research Institute	Senior Scientist	National Satellite Operation & Application Center
Yenni Vetrita	Yenni	Vetrita	Collaborator	Senior Researcher	Jakarta Timur	N/A	N/A	Indonesia	Research and Innovation Agency	Senior Scientist	Research Organization of Aeronautics and Space
George Robert Brakenridge	Robert	Brakenridge	Collaborator	Professor	Boulder	Colorado	80303	United States	University of Colorado	Professor	Institute of Arctic and Alpine Research
Bui Quang Hung	Hung	Bui	Collaborator	Senior Research Scientist	Hanoi	N/A	N/A	Vietnam	Vietnam National University - University of Engineering and Technology	Director	Center for Interdisciplinary Integrated Technology Field Monitoring (FIMO)
Bui Quang Thanh	Thanh	Bui	Collaborator	Dean	Hanoi	N/A	N/A	Vietnam	Vietnam National University - Hanoi University of Science	Dean	Faculty of Geography
Thomas Esch	Thomas	Esch	Collaborator	Senior Research Scientist	Weßling	N/A	N/A	Germany	German Aerospace Center	Senior Scientist	German Remote Sensing Data Center, Land Surface Dynamics
Paolo Gamba	Paolo	Gamba	Collaborator	Professor	Pavia	N/A	N/A	Italy	Università di Pavia	Professor	Dipartimento di Ingegneria Industriale e dell'Informazione
Mark Z. Jacobson	Mark	Jacobson	Collaborator	Professor	Stanford	California	94305	United States	Stanford University	Professor	Civil and Environmental Engineering
Menas C. Kafatos	Menas	Kafatos	Collaborator	Professor	Orange City	California	92866	United States	Chapman University	Director & Professor	Center of Excellence in Earth Systems Modeling and Observations (CEESMO)
Chang Ki Kim	Chang	Kim	Collaborator	Principal Researcher	Daejeon	N/A	N/A	South Korea	Korea Institute of Energy Research	Senior Scientist	New and Renewable Energy Resource Map Laboratory
Seung Hee Kim	Seung-Jae	Kim	Collaborator	Research Associate Professor	Orange City	California	92866	United States	Chapman University	Associate Professor	Center of Excellence in Earth Systems Modeling and Observations (CEESMO)
Zsofia Kugler	Zsofia	Kugler	Collaborator	Associate Professor	Budapest	N/A	N/A	Hungary	Budapest University of Technology and Economics	Associate Professor	Department of Photogrammetry and Geoinformatics
Le Trung Chon	Chon	Chon	Collaborator	Associate Professor	Ho Chi Minh City	N/A	N/A	Vietnam	Ho Chi Minh City (HCMC) University of Natural Resources and Environment	Dean & Professor	Institute for Sustainable Development Research
Le Van Trung	Trung	Le	Collaborator	Associate Professor	Ho Chi Minh City	N/A	N/A	Vietnam	Ho Chi Minh City (HCMC) University of Technology	Head	Department of Resources and Environmental Informatics
Alex M. Lechner	Alex	Lechner	Collaborator	Professor	Baten	N/A	N/A	Indonesia	Monash University	Professor	Landscape Ecology
Hanlim Lee	Hanlim	Lee	Collaborator	Professor	Busan	N/A	N/A	South Korea	Pukyong National University	Professor	Department of Spatial Information Engineering
Yun Gon Lee	Yun	Lee	Collaborator	Associate Professor	Daejeon	N/A	N/A	South Korea	Chungnam National University	Professor	Atmospheric Sciences, Department of Astronomy, Space Science and Geology
Chul-Hee Lim	Chul-Hee	Lim	Collaborator	Assistant Professor	Seoul	N/A	N/A	South Korea	Kookmin University	Assistant Professor	College of General Education
Cathleen Linard	Cathleen	Linard	Collaborator	Professor	Namur	N/A	N/A	Belgium	Université de Namur	Professor	Department of Geography
Marco Masetti	Marco	Masetti	Collaborator	Professor	Milan	N/A	N/A	Italy	Università degli Studi di Milano	Head	Dipartimento di Scienze della Terra
Anh Tuan Nguyen	Anh	Nguyen	Collaborator	Professor	Hanoi	N/A	N/A	Vietnam	VNU University of Social Sciences and Humanities	Professor	Faculty of Sociology
Nguyen Thi Thuy Hang	Hang	Nguyen	Collaborator	Lecturer	Hanoi	N/A	N/A	Vietnam	Vietnam National University	Research Scientist	Vietnam Japan University
Nguyen Thi Nhat Thanh	Thanh	Nguyen	Collaborator	Associate Professor	Hanoi	N/A	N/A	Vietnam	VNU University of Engineering and Technology	Associate Professor	University of Engineering and Technology
Simonetta Paloscia	Simonetta	Paloscia	Collaborator	Senior Scientist	Florence	N/A	N/A	Vietnam	National Research Council	Senior Scientist	Institute of Applied Physics
Simone Pettinato	Simone	Pettinato	Collaborator	Research Scientist	Florence	N/A	N/A	Vietnam	National Research Council	Research Scientist	Institute of Applied Physics
Pham Van Cu	Cu	Pham	Collaborator	Associate Professor	Montreal	N/A	N/A	Canada	University of Quebec in Montreal	Professor	Department of Geography
Pham Quy Nhan	Nhan	Pham	Collaborator	Associate Professor	Hanoi	N/A	N/A	Vietnam	Hanoi University of Natural Resources and Environment	Associate Professor	Faculty of Water Resources
Pham Thi Mai Thy	Thy	Pham	Collaborator	Senior Research Scientist	Ho Chi Minh City	N/A	N/A	Vietnam	Vietnam National Space Center	Senior Scientist	VNSC Space Technology Application Center
Phan Hien Vu	Vu	Phan	Collaborator	Senior Lecturer	Thu Duc City	N/A	N/A	Vietnam	VNU International University	Senior Scientist	Department of Physics
Michele Romolini	Michele	Romolini	Collaborator	Managing Director	Los Angeles	California	90045	United States	Loyola Marymount University	Director	Center for Urban Resilience
Emanuele Santi	Emanuele	Santi	Collaborator	Research Scientist	Florence	N/A	N/A	Vietnam	National Research Council	Research Scientist	Institute of Applied Physics
Alessandro Sorichetta	Alessandro	Sorichetta	Collaborator	Associate Professor	Milan	N/A	N/A	Italy	Università degli Studi di Milano	Associate Professor	Dipartimento di Scienze della Terra
Eric G. Strauss	Eric	Strauss	Collaborator	Professor	Los Angeles	California	90045	United States	Loyola Marymount University	Director & Professor	Center for Urban Resilience
Ta Quoc Dũng	Dũng	Ta	Collaborator	Senior Lecturer	Ho Chi Minh City	N/A	N/A	Vietnam	Ho Chi Minh City University of Technology	Dean	Faculty of Geology and Petroleum
Tong Si Son	Son	Tong	Collaborator	Lecturer	Hanoi	N/A	N/A	Vietnam	University of Science and Technology of Hanoi	Research Scientist	Space and Applications Department
Cuong Quoc Tran	Cuong	Tran	Collaborator	Research Scientist	Hanoi	N/A	N/A	Vietnam	Vietnam Academy of Science and Technology	Research Scientist	Institute of Geological Science
Lenny H. E. Winkel	Lenny	Winkel	Collaborator	Associate Professor	Zurich	Switzerland	N/A	Switzerland	ETH Zurich	Associate Professor	Department of Environmental System

# South East Asia Synthesis Study Domain



The MPO Domain

Mainland:  
Cambodia, Lao PDR, Thailand, and Vietnam

Peninsular:  
Malaysia

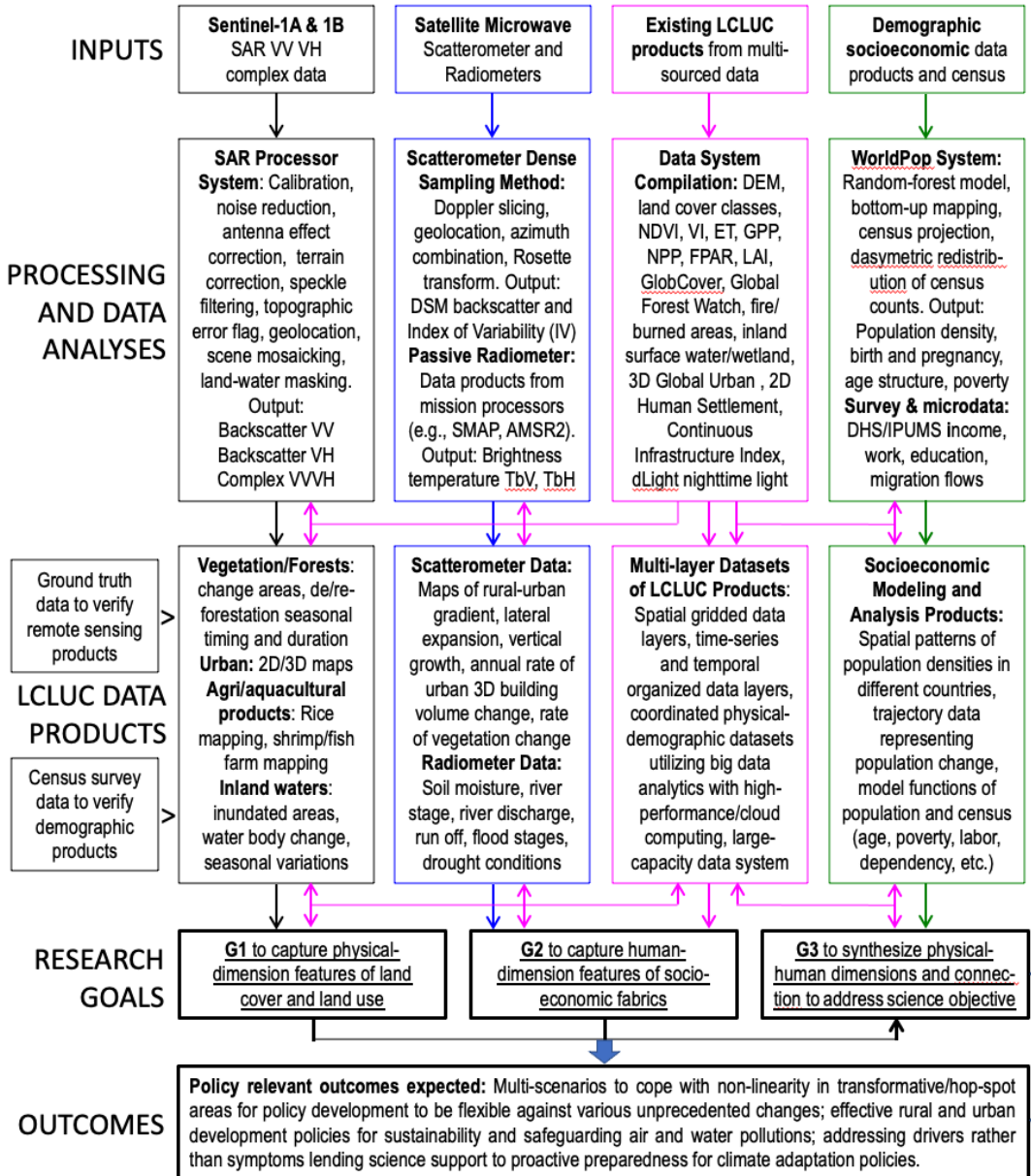
Oceania:  
Indonesia

# Research Science and Hypotheses

Overarching Science Question: How land cover (LC), land use (LU), and demography (DG) evolve and interact in this highly dynamic and vulnerable setting along the entire **3D rural to urban continuum (RUC)**.

Hypotheses: (1) Physical-human feedback processes are exacerbated by urbanization, agriculture conversion, and climate factors forcing **LC, LU, and DG processes to become non-stationary**, thereby causing unprecedented impacts that are not predictable from past observable trends in transformative regions and in anomalous hot-spot areas where multi-scenario flexibility must be considered in policy development. (2) **In contrast, for transitional regions undergoing weak or gradual changes**, we hypothesize that trajectories are associated with continual environmental trends and sociodemographic drivers so that past reference of the LC, LU, and DG changes can be used to plan for effective future policies .

# Research Approach and Structure



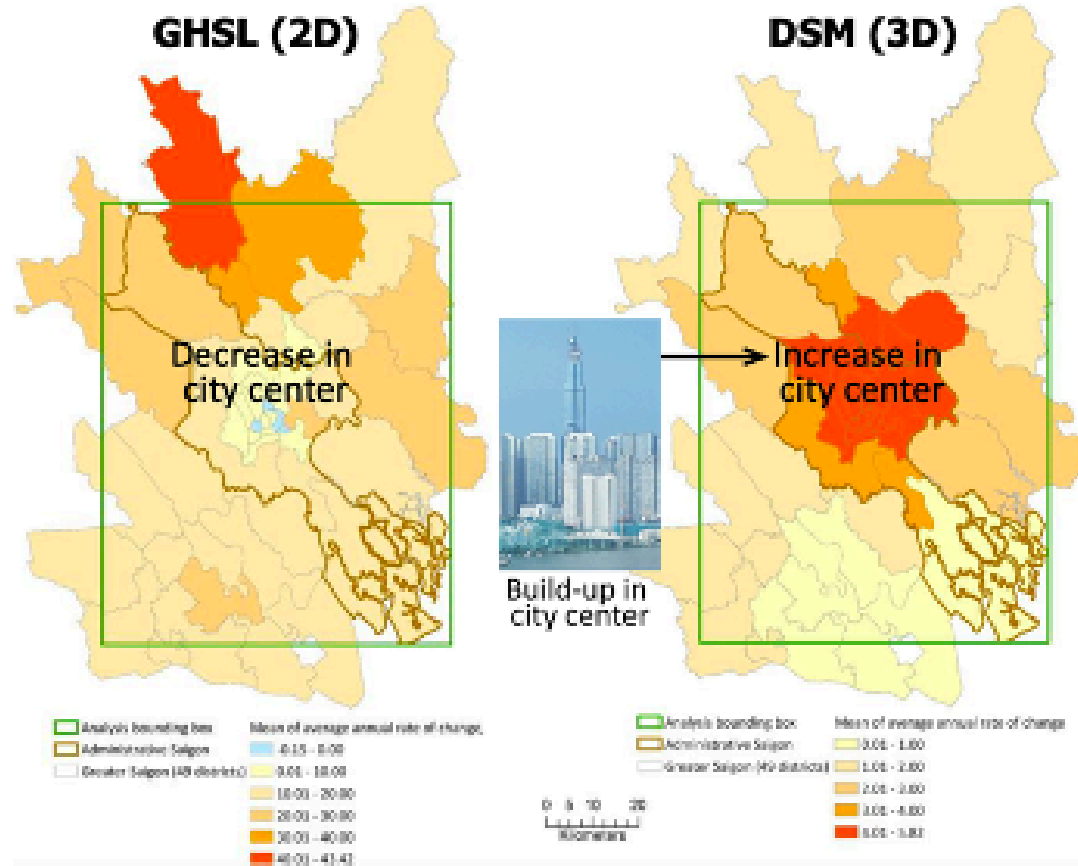
**Community Workshop Plan:** (1) Year 1: Regional synthesis kick-off meeting to refine the design and scope of the synthesis; (2) Year 2 for project team progress meeting; (3) Year 3 for synthesis summary meeting. Moreover, we will also participate in programmatic team meetings and/or conferences. **Leverage/legacy:** PI Nghiem has demonstrated the capability to motivate the large international community including scientists, researchers, space agencies, stakeholders, decision/policy makers up to the ministry levels to participate in LCLUC workshops/meetings, in working with NASA OIR, NASA Asia Rep. (Tokyo Office), US Embassy, US State Department, and ministries in SE Asia (see references [Meetings, 2018; 2019; 2020; 2022; 2023]).

**Goal 1 (G1):** To capture physical-dimension features of the land cover (LC) and land use (LU) in the MPO. These will identify and quantify variations along the rural-urban continuum undergoing transitional, transformative, or hot-spot changes in time (1D) and in space (3D).

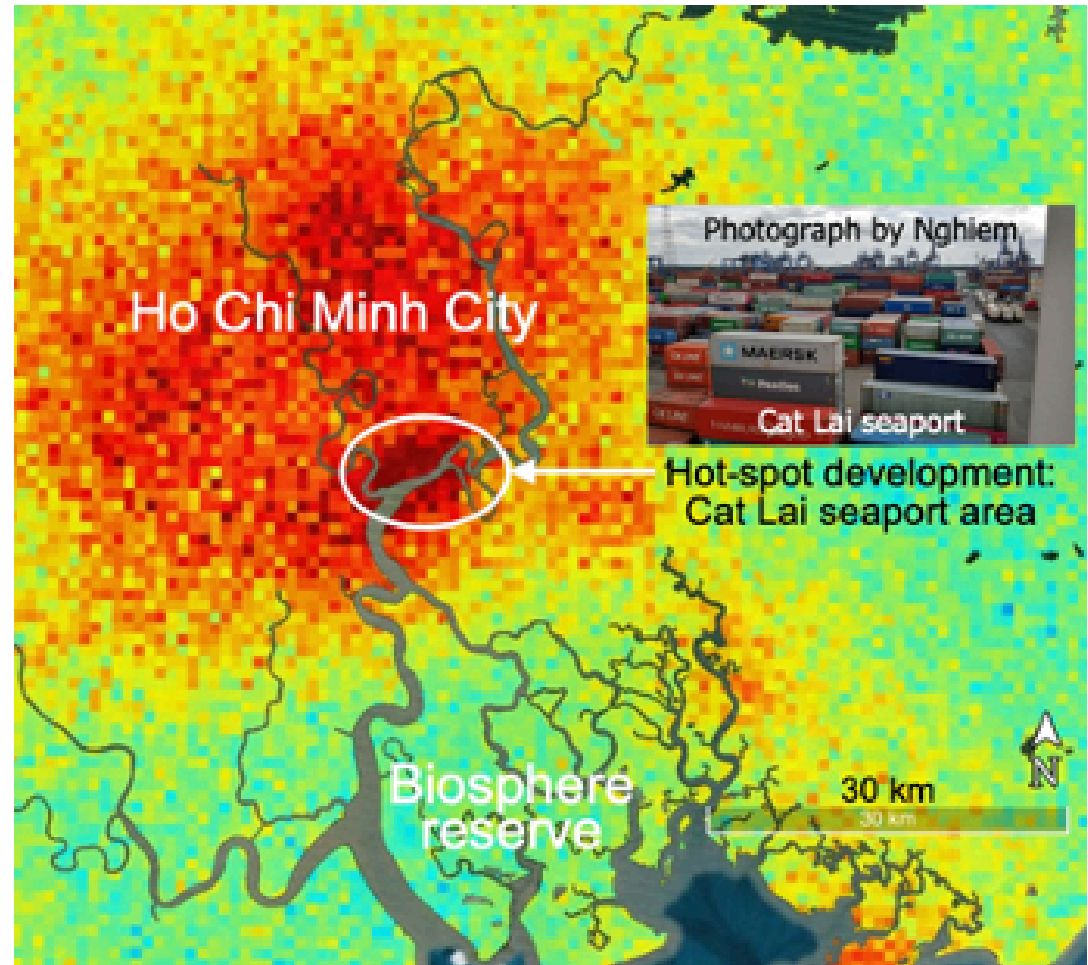
**Goal 2 (G2):** To capture human-dimension features of the socioeconomic fabrics in the MPO. These are crucial to address both land use at risk (LUR) and population at risk (PAR) under deteriorated ecoservice values.

**Goal 3 (G3):** To combine (G1+G2) within a synthesis framework of integrations, interactions, and linkages (left panel). These are to test the stationarity versus non-stationarity hypotheses. The outcomes from the synthesis are intended to lend scientific support to the strategic development of proactive policies that are regionally relevant and effective.

# Rural-Urban Continuum (RUC) in 3D

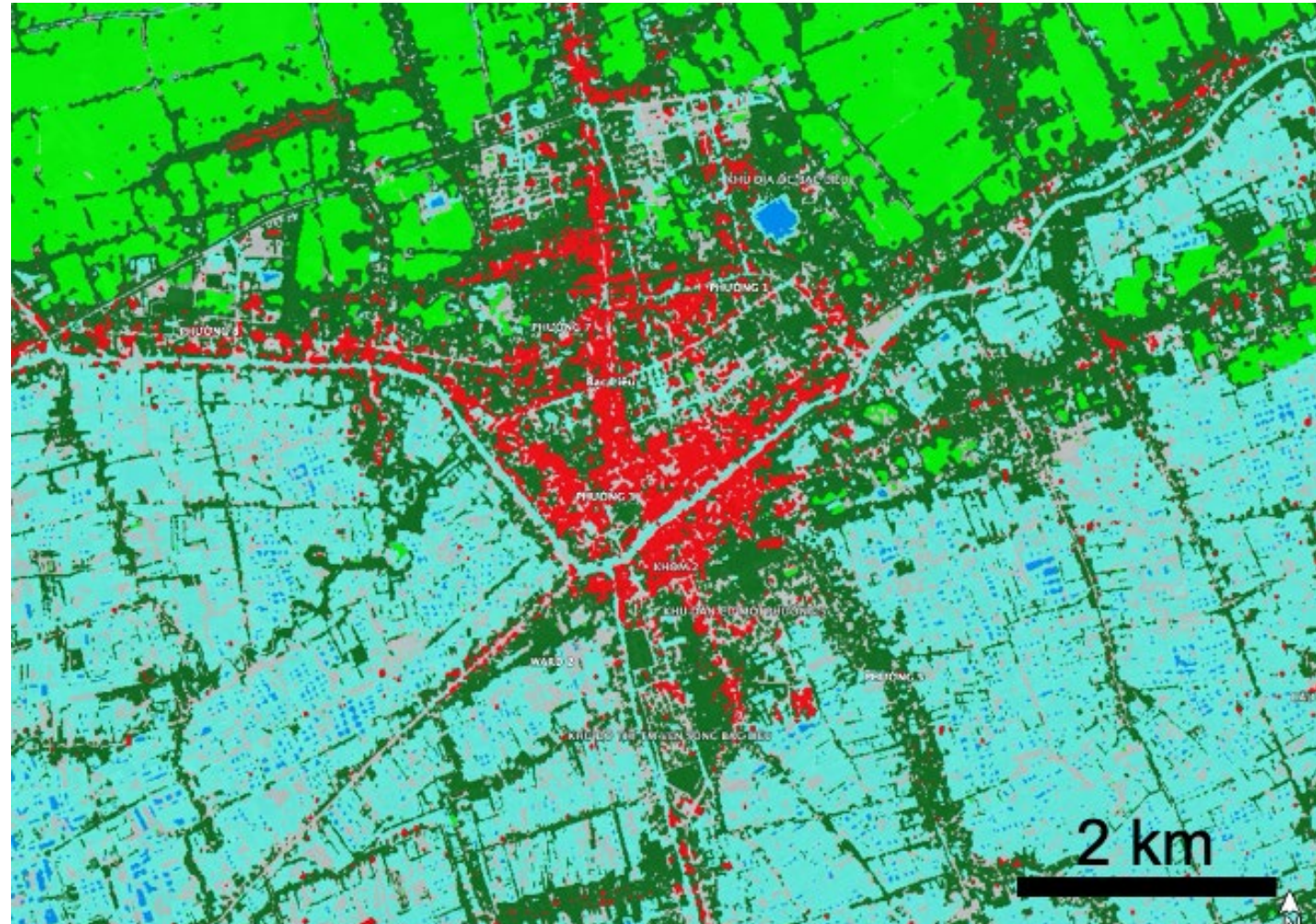


**Mean of annual rate of change at the district level** in the Greater Saigon from GHSL for 2D urban fraction (left) and from DSM for 3D building volume (right) in the 2000s, see details in [Balk et al., 2018]. The inset photo shows the strong vertical build-up in the city center consistent with DSM observation.



**DSM continuum product for rate of change of 3D building volume** from the Ho Chi Minh megacity to the UNESCO Cần Giờ Biosphere Reserve. The detected hot spot is the Cat Lai seaport area.

# RUC in High Resolution from Radar Data



Products of LU classes from Sentinel-1 SAR in the RUC around Bạc Liêu city in Vietnam including **persistent building structures (red)**, **agricultural areas (light green)**, **aquacultural areas (light blue)**, **tree cover (dark green)**, and **persistent surface water (dark blue)**.

# City in Three Dimensions from Radar Data

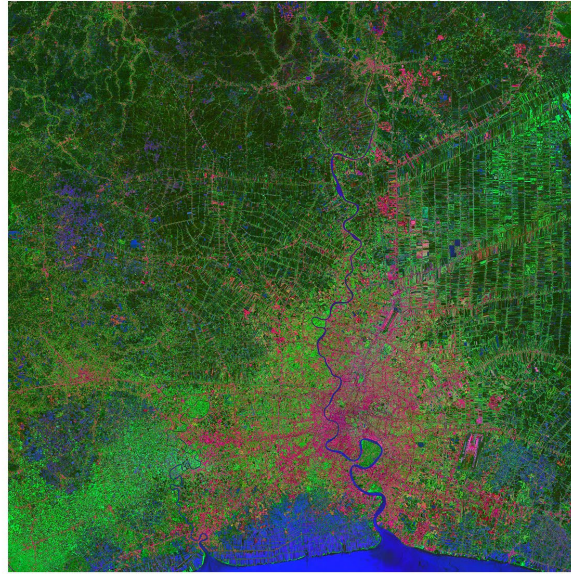


Mapping Product of 3D Building in Ho Chi Minh City

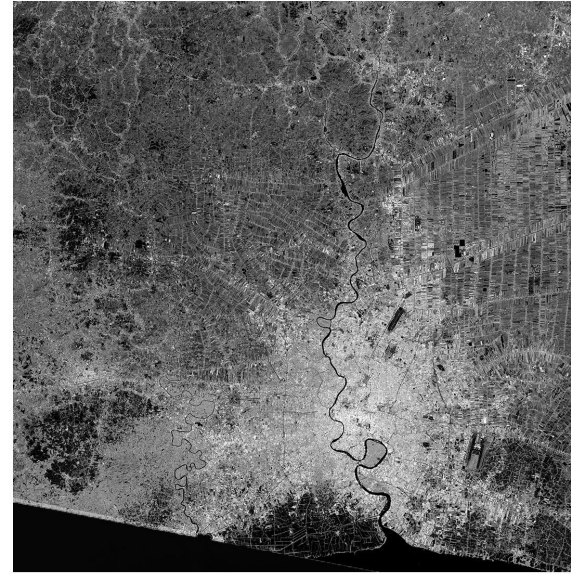


# Multi Sourced Observations over the RUC

Multi-season S2 Land Cover  $S \mu/\sigma$   $V \mu/\sigma$   $D \mu/\sigma$



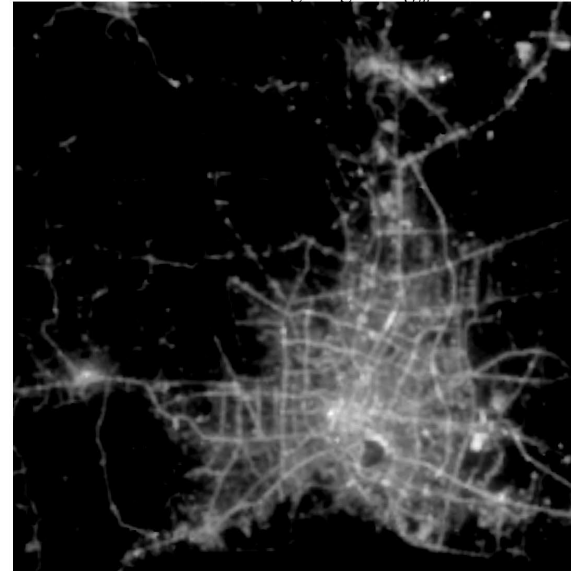
Multi-season S1 Microwave Backscatter  $VV\mu$



Continuous Infrastructure Index

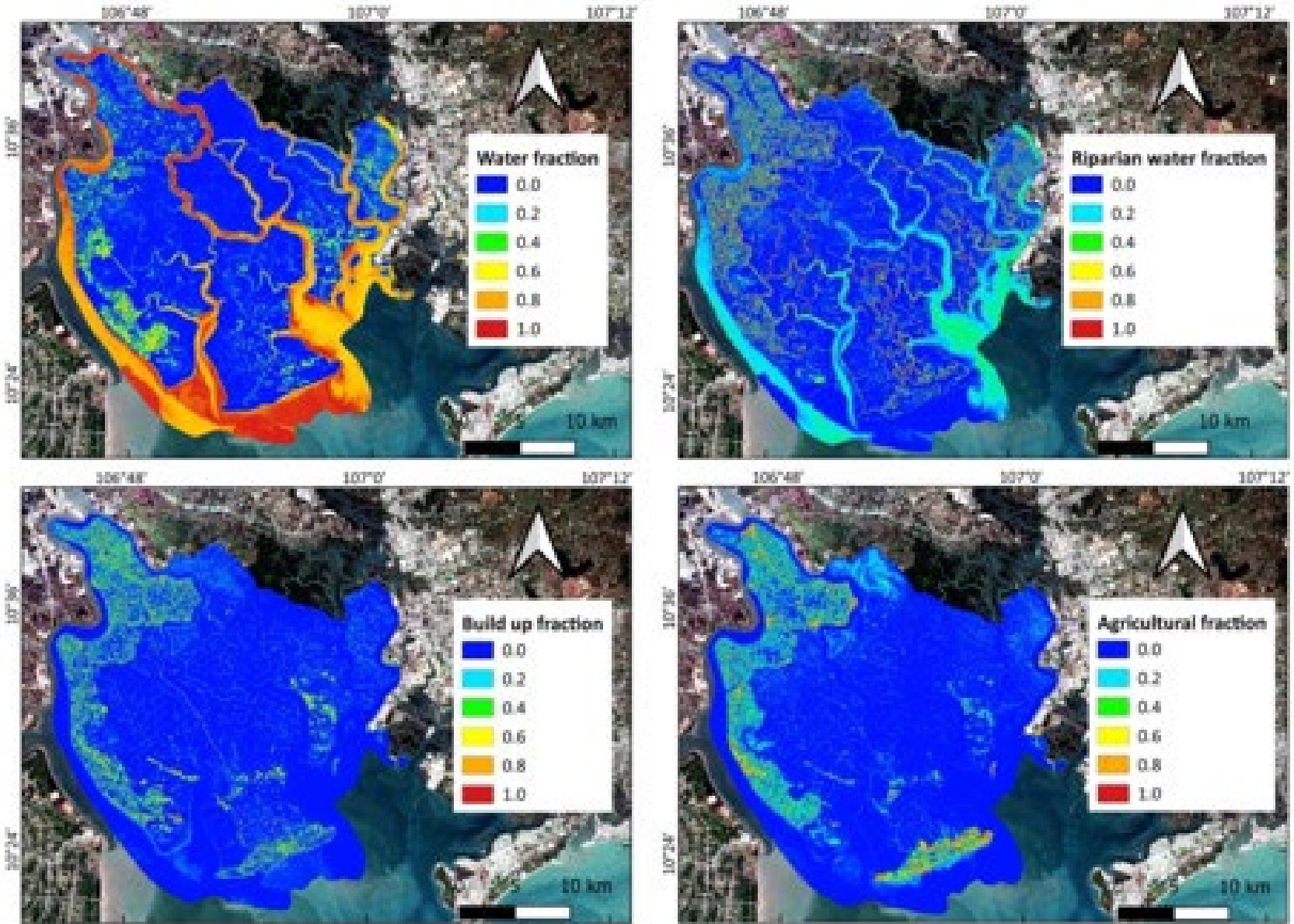


VIIRS annual night light  $\log_{10} L$



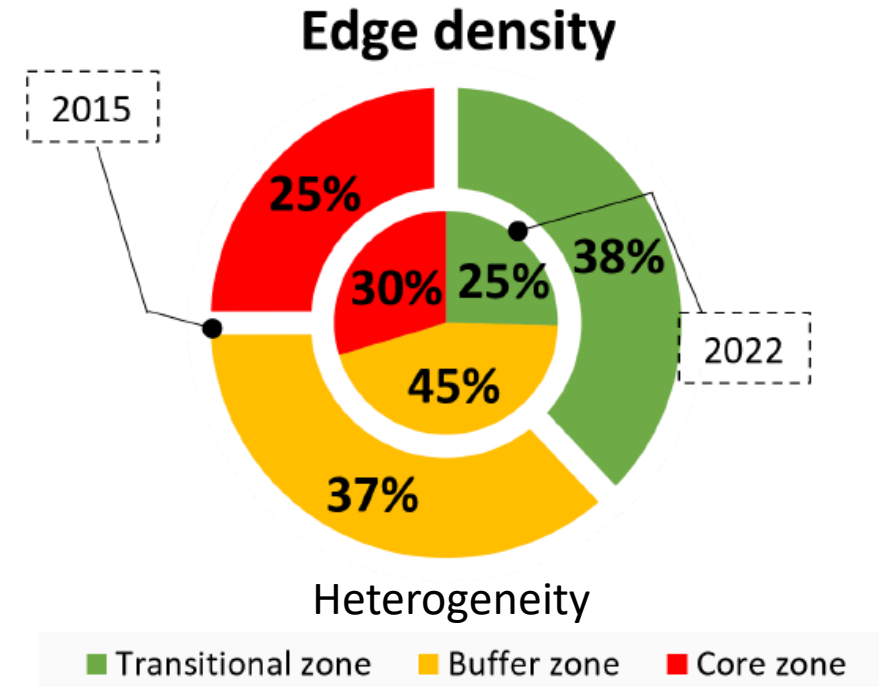
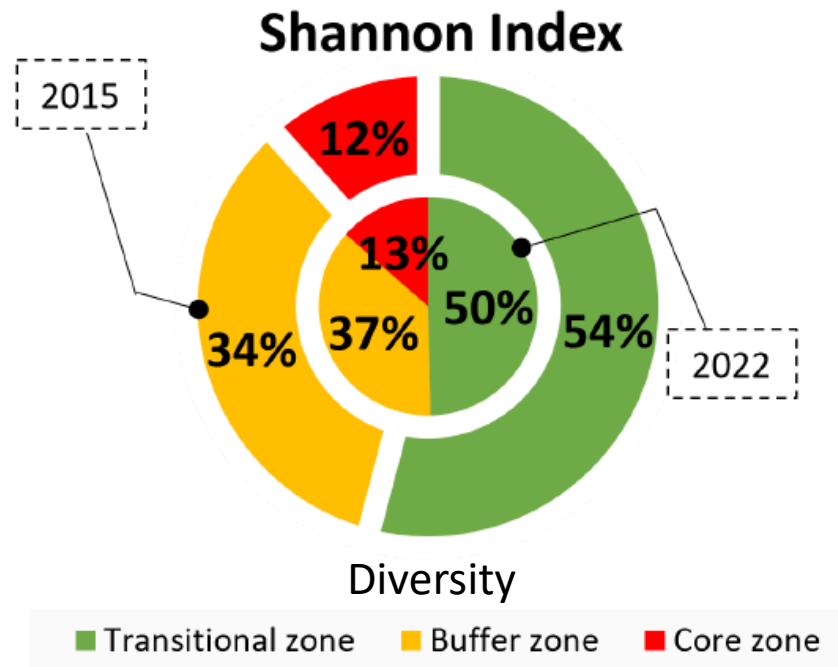
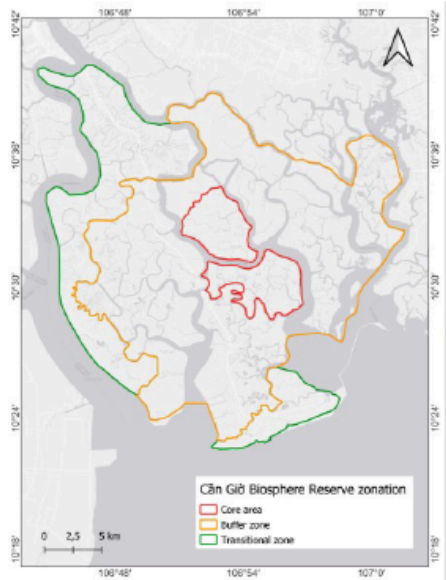
Multi-sourced, multi-season, and multi-scale composite images around Bangkok, Thailand.

# Hyperspectral Data Products over the RUC



Data products from PRISMA data in Saigon-Dong Nai Delta and surrounding environments.

# Synthesis of Radar/Spectral Products for Fragmentation Analysis



## Core and buffer



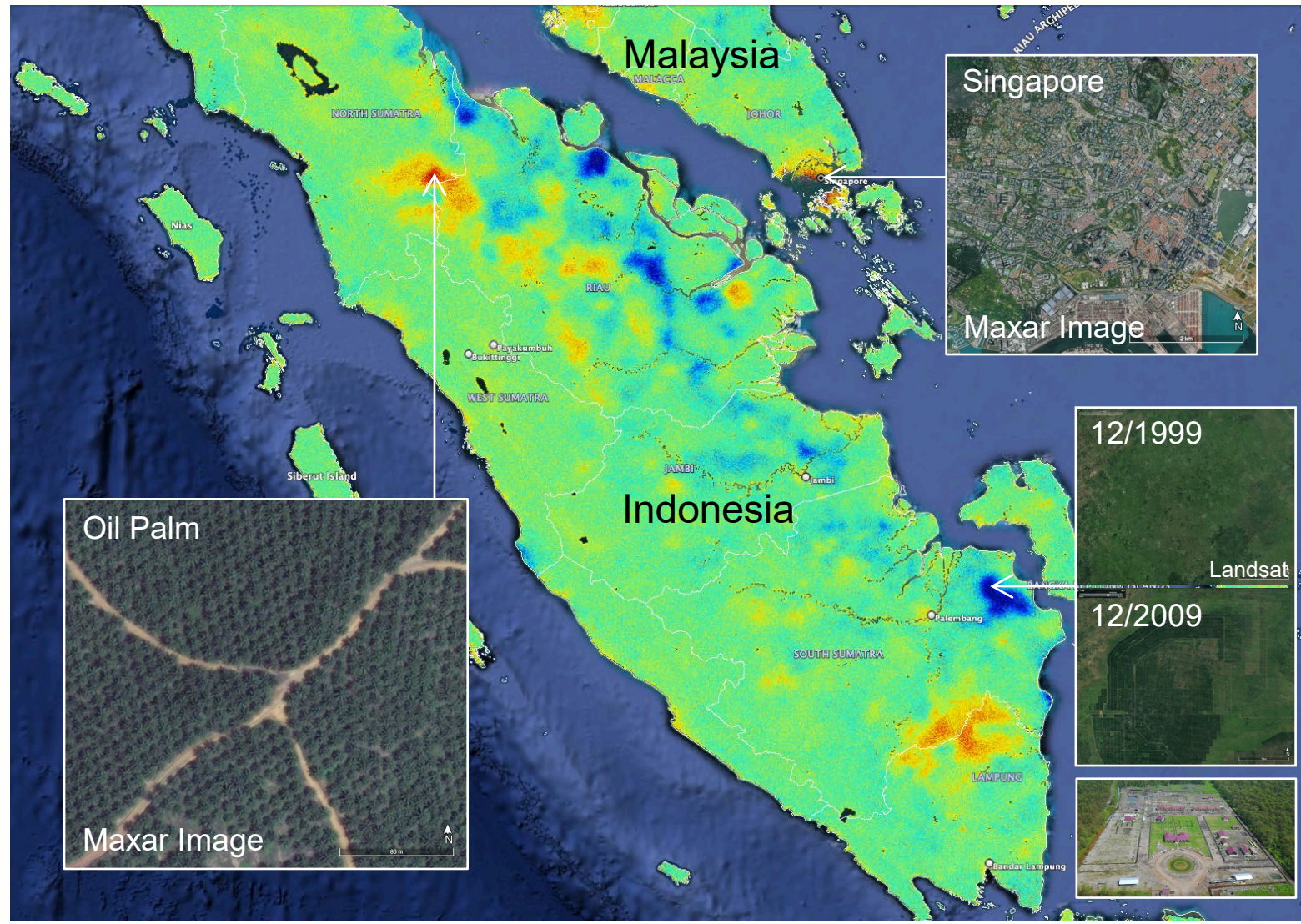
similar trends. Small increase in the heterogeneity of the landscape, fragmentation stable or slightly increased

## Transitional



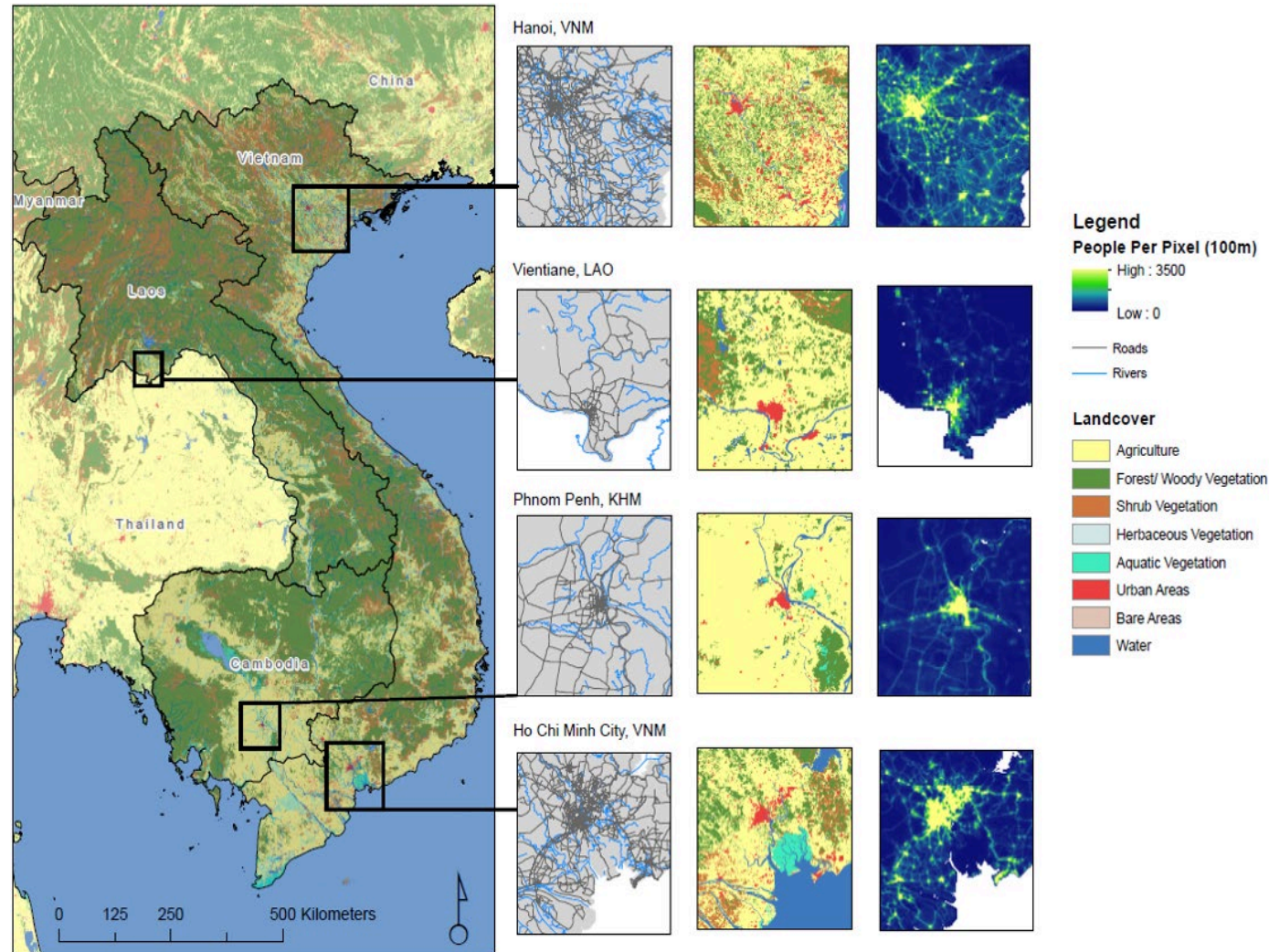
reduction of diversity, stable fragmentation. Aquaculture becomes an increasingly dominant class in an already fragmented area

# LCLU Change in the 2000s across 3D RUC



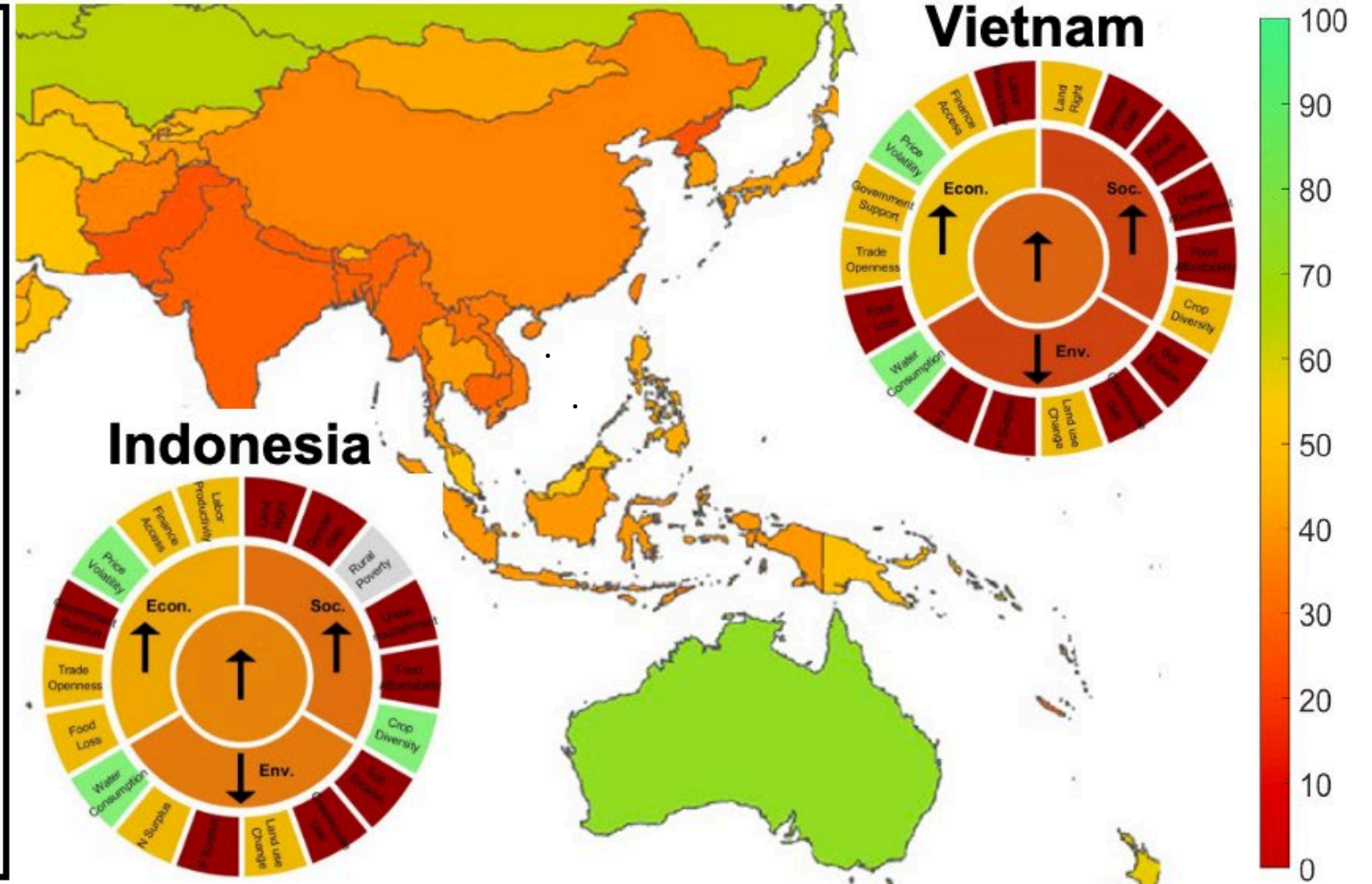
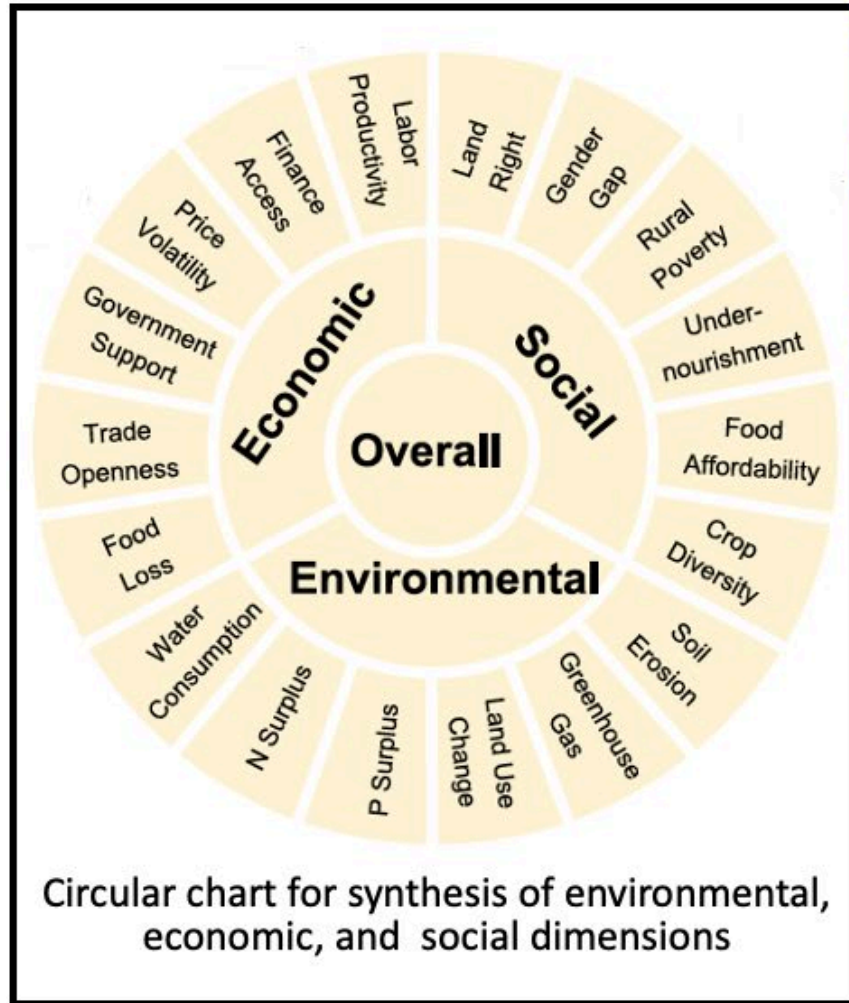
Mapping Product of LCLU Change in Indonesia, Malaysia, and Singapore from Radar Data:  
Red for positive hot spots/areas, Blue for negative hot spots/areas, Green for small/no change

# Demography: Cambodia, Lao PDR, Vietnam



Data products of rivers, roads and land cover in the nonparametric, ensemble model with sub-panels for 4 cities. Roads (black) and rivers (blue) noted are in the first column panel, land cover in the second and the 2010 gridded population in the third [Gaughan et al., 2019].

# Synthesis in Physical-Human Dimensions



Sustainable Agriculture Matrix (SAM) method synthesizing multiple data products to quantify the impacts of agriculture on sustainability considering environmental, economic, and social dimensions across the RUC in 2000-2014. Examples including Indonesia and Vietnam.

# Synthesis in Physical-Human Dimensions

## Sendai Framework for United Nations Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)

**Risk = Combination of Hazard, Exposure, and Vulnerability**

- **Hazard**: Process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
- **Exposure**: Situation of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas.
- **Vulnerability**: Conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

# Contact



National Aeronautics and  
Space Administration

**Jet Propulsion Laboratory**  
California Institute of Technology  
Pasadena, California

**PI: [Son.V.Nghiem@jpl.nasa.gov](mailto:Son.V.Nghiem@jpl.nasa.gov)**

**Acknowledgements:** The research carried out at the JPL California Institute of Technology, was supported by the Land Cover/Land Use Change (LCLUC) Program, under a contract with the National Aeronautics and Space Administration (80NM0018D0004).