Land Cover/Land Use Change (LCLUC) Science Team Meeting
Gaithersburg, Maryland, April 4-6, 2024

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


**Son V. Nghiem (PI)[1] and International Research Team**

[1]NASA Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California, USA

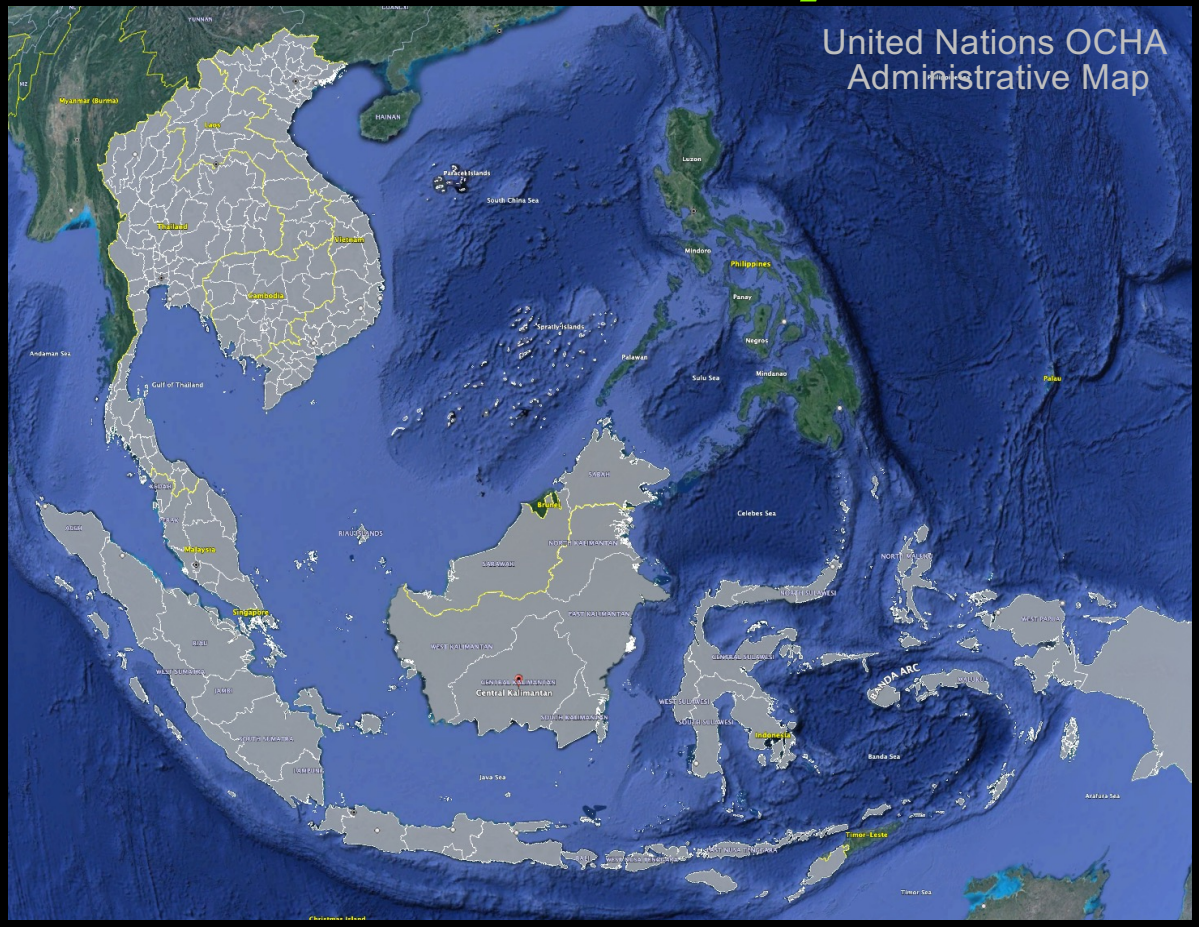
# International Research Science Team

## 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 Propulson 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 | Marxe 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 Enviornment 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 anf 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 | Assitant Professor | Seoul | N/A | N/A | South Korea | Kookmin University | Assistant Professor | College of General Education |
| Cathleen Linard | Cathleen | Linrar | Collaborator | Professor | Namur | N/A | N/A | Belgium | Universite 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 |

https://lcluc.umd.edu/projects/synthesis-study-land-cover-land-use-and-demographic-change-under-multi-dimensional

# Southeast Asia Synthesis Study Domain




The MPO Domain

Mainland: Cambodia, Lao PDR, Thailand, and Vietnam

Peninsular: Malaysia

Oceania: Indonesia

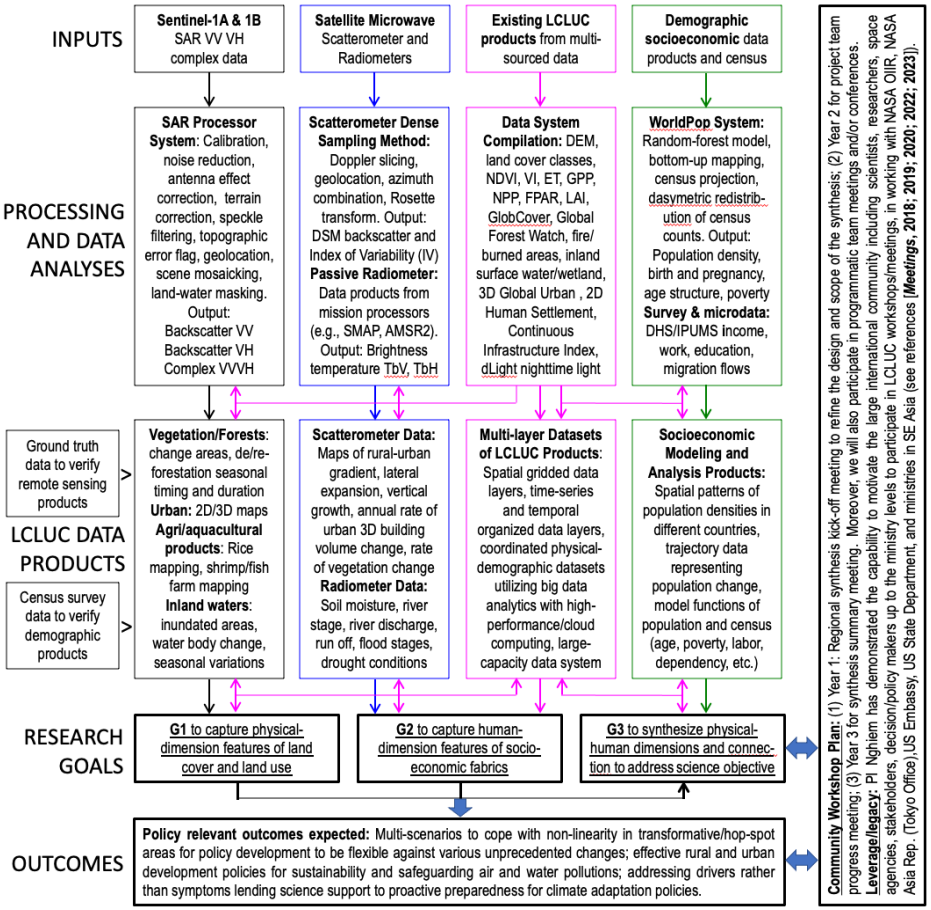
https://lcluc.umd.edu/projects/synthesis-study-land-cover-land-use-and-demographic-change-under-multi-dimensional

# 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



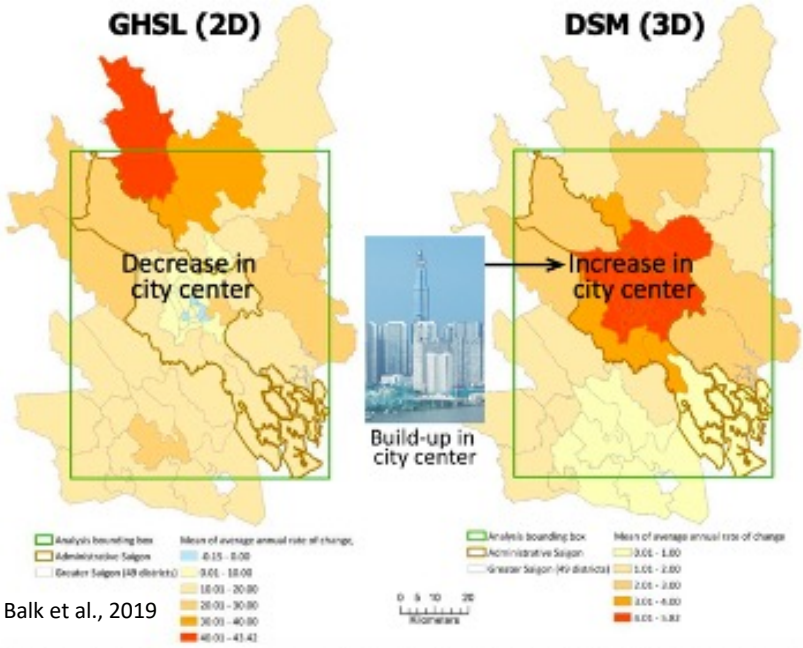

**Goal 1 (G1):** To capture physical-dimension features of the land cover (LC) and land use (LU) in the MPO. These will identify and quantify variations along the rural-urban continuum undergoing transitional, transformative, or hot-spot changes in time (1D) and in space (3D).

**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.

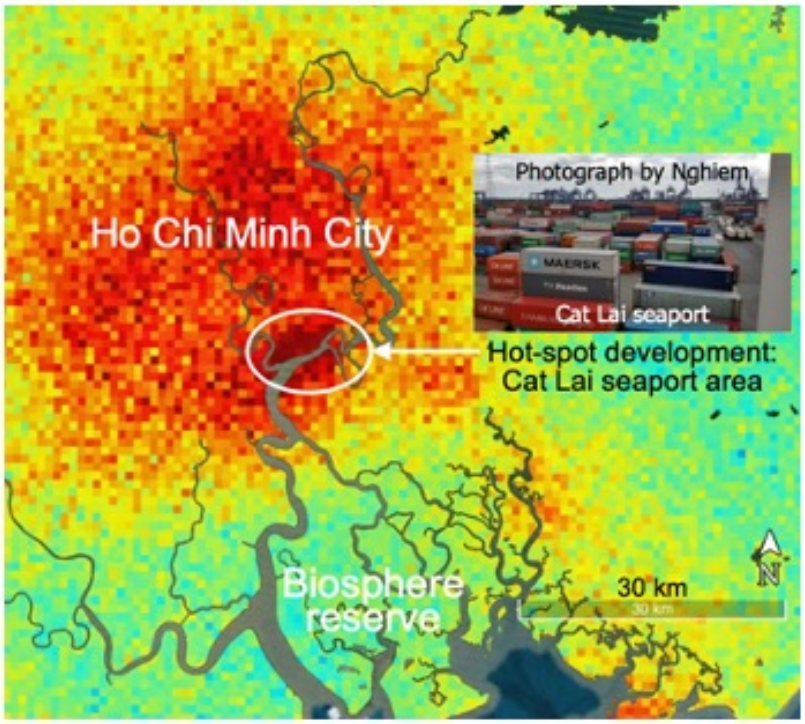
https://lcluc.umd.edu/projects/synthesis-study-land-cover-land-use-and-demographic-change-under-multi-dimensional

# Rural-Urban Continuum (RUC) in 3D



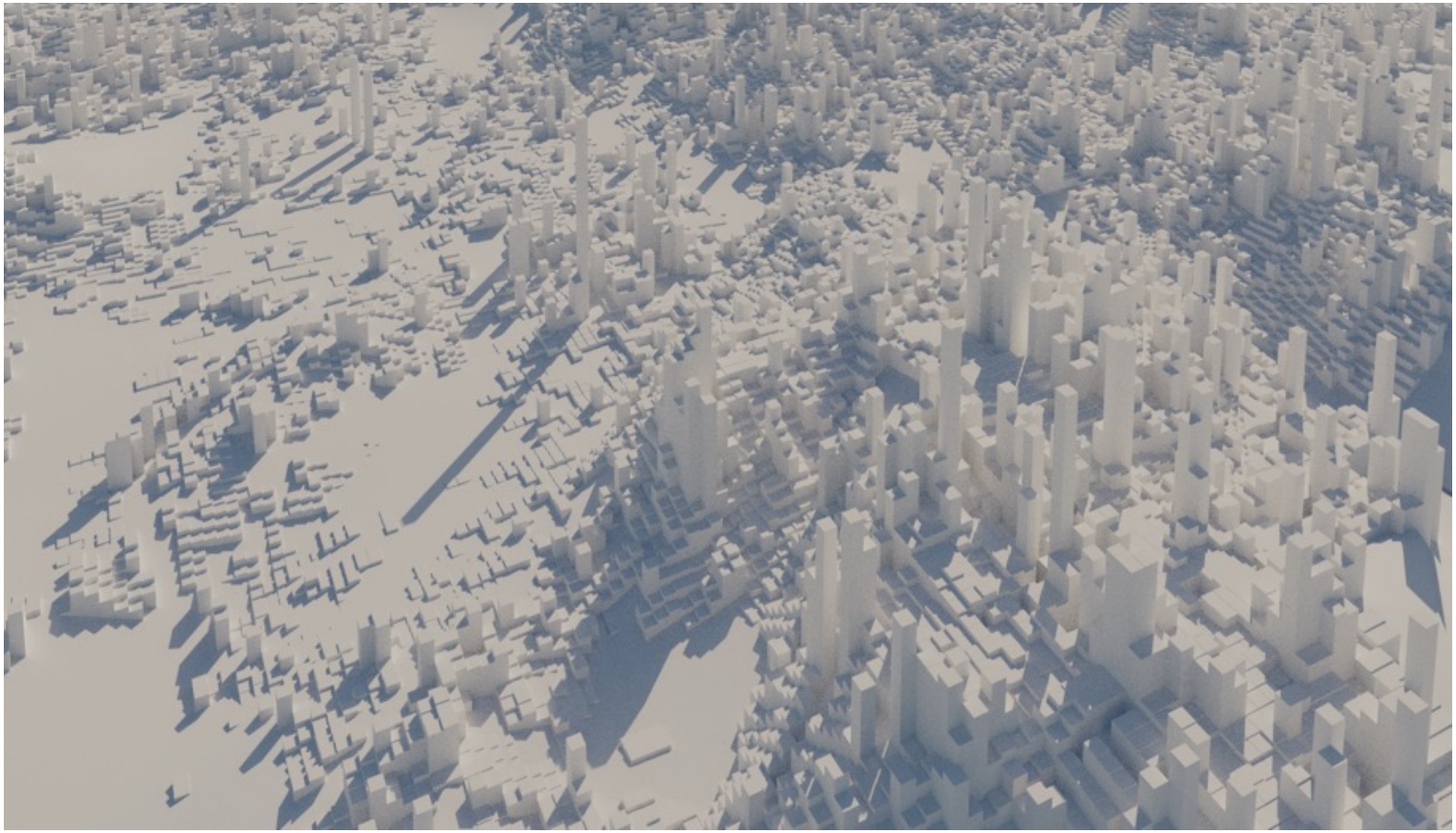

Balk et al., 2019

**Mean of annual rate of change at the district level** in the Greater Saigon from GSHL 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.



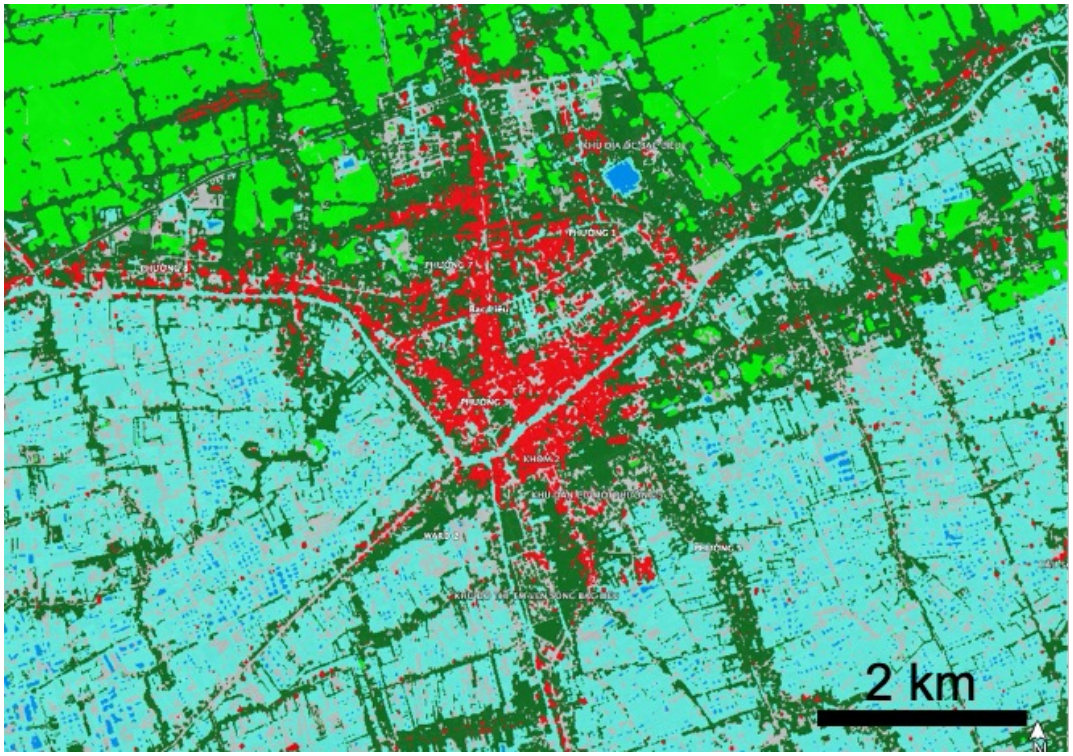

**DSM continuum product for rate of change of 3D** building volume from the Ho Chi Minh megacity to the UNESCO Cần Giờ Biosphere Reserve. The detected hot spot is the Cat Lai seaport area.

# City in Three Dimensions from Radar Data



Mapping Product of 3D Building in Ho Chi Minh City (DLR)

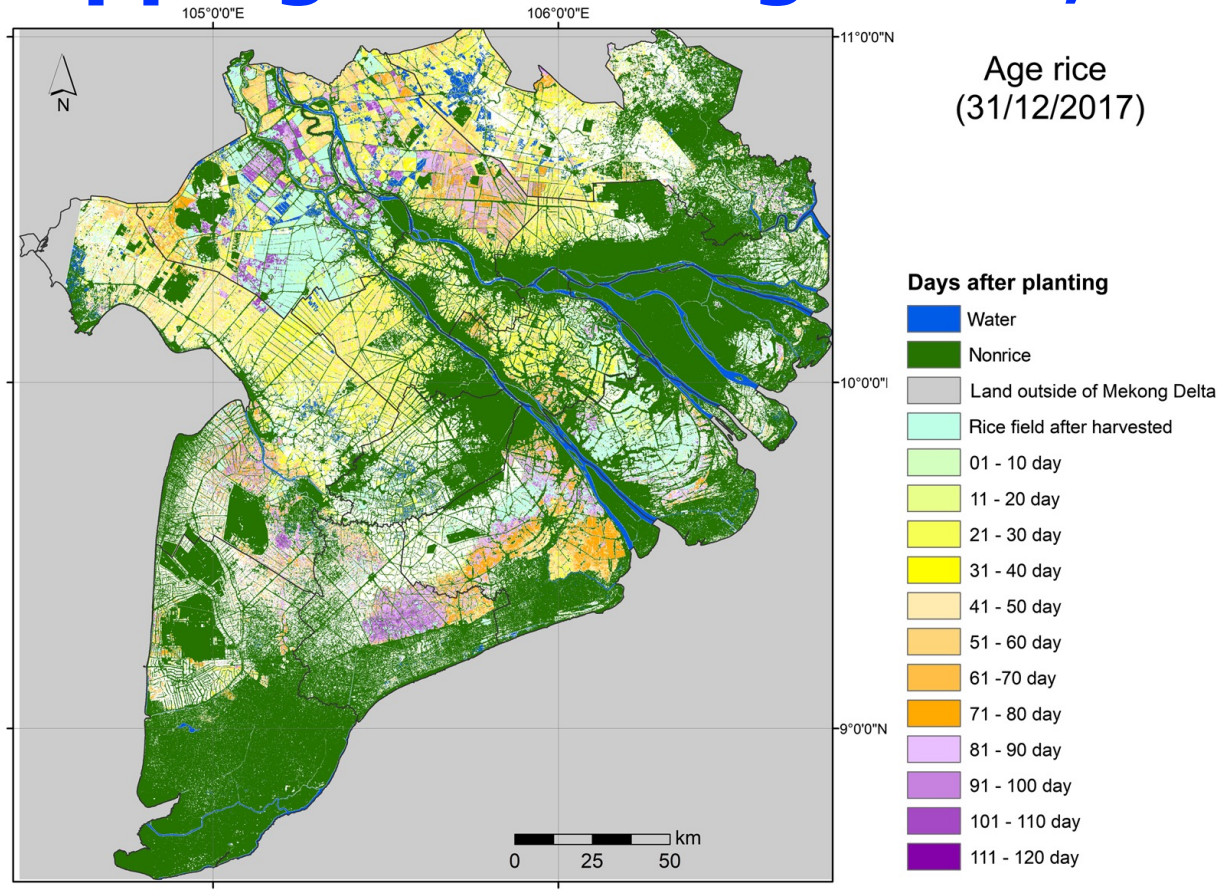
# RUC in High Resolution from Radar Data




Ngo et al., 2024

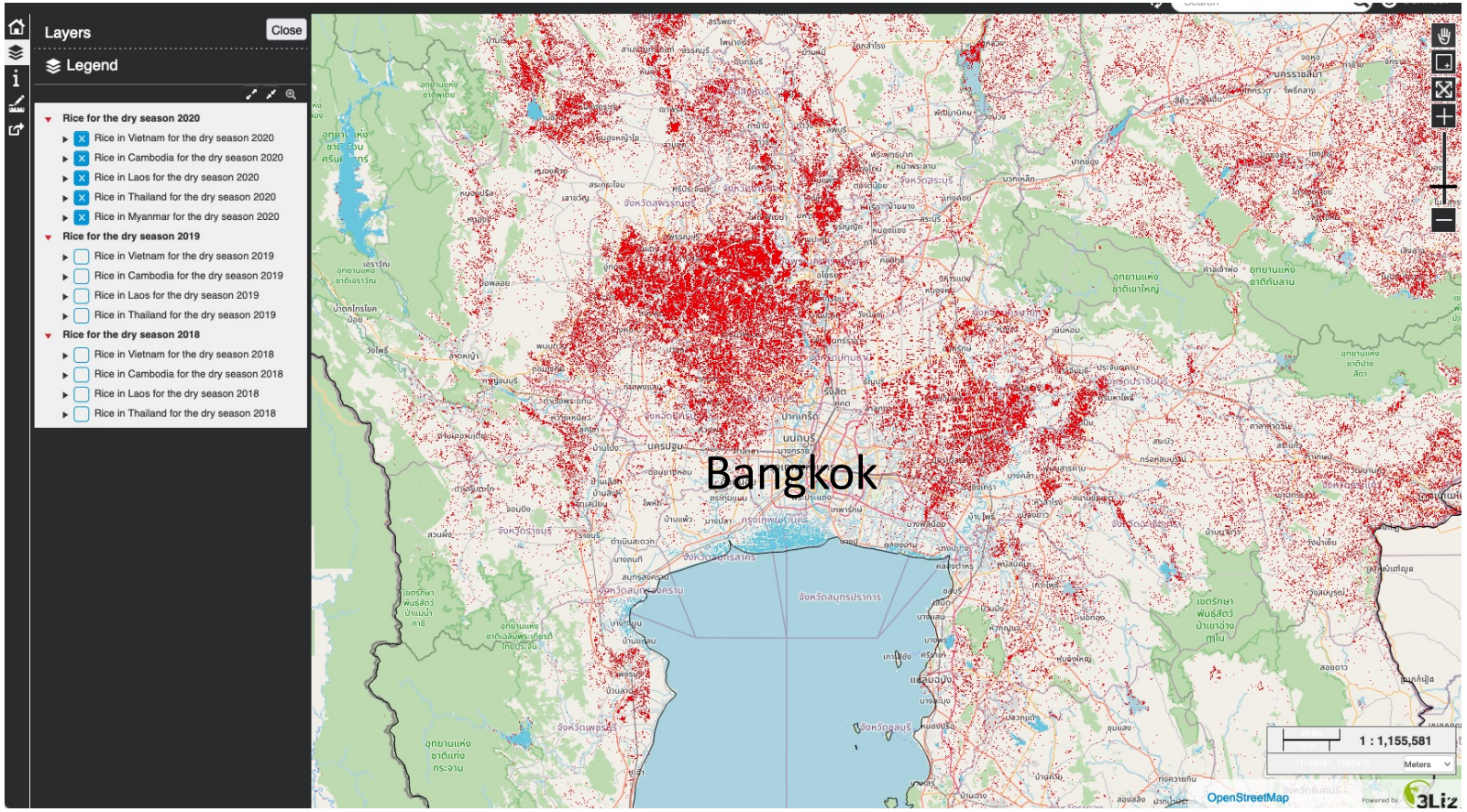
Products of LU classes from Sentinel-1 SAR in the RUC around Bạc Liêu city in Vietnam including persistent building structures (red), agricultural areas (light green), aquacultural areas (light blue), tree cover (dark green), and persistent surface water (dark blue).

# Rice Mapping in Mekong Delta, Vietnam



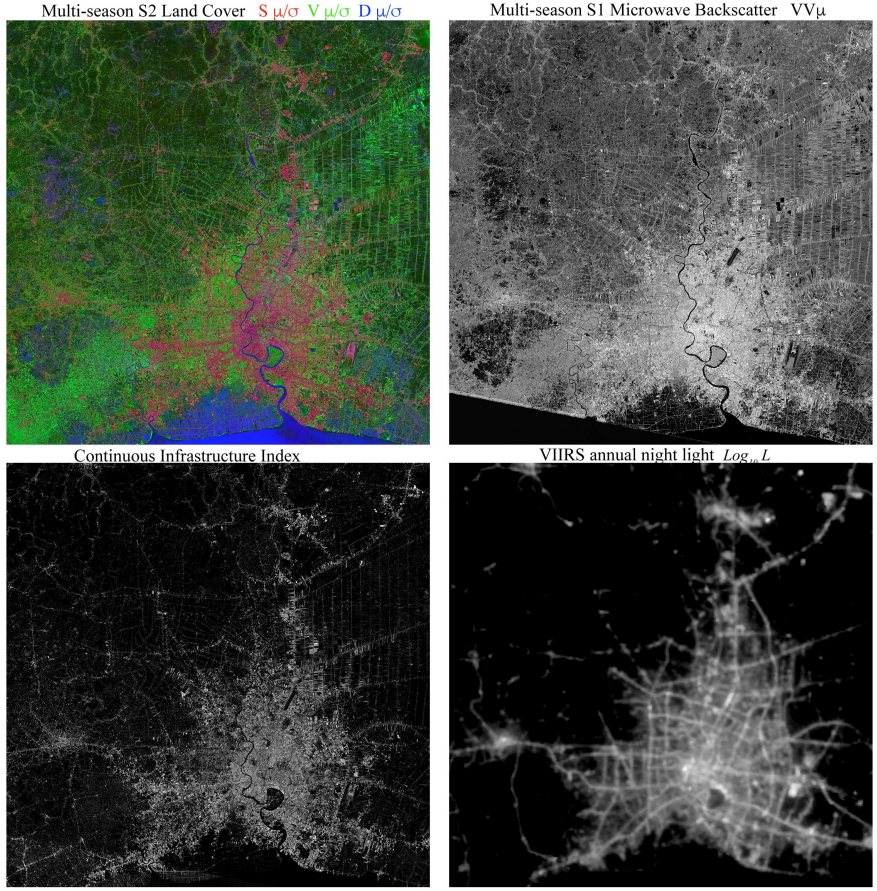

Rice age map on 12/31/2017 from Sentinel-1 SAR data (Phung et al., 2020)

# Rice Mapping in 2020 in Thailand




Rice Map in Dry Season (Georice/GlobeEO, Thuy Le Toan et al, 2024)

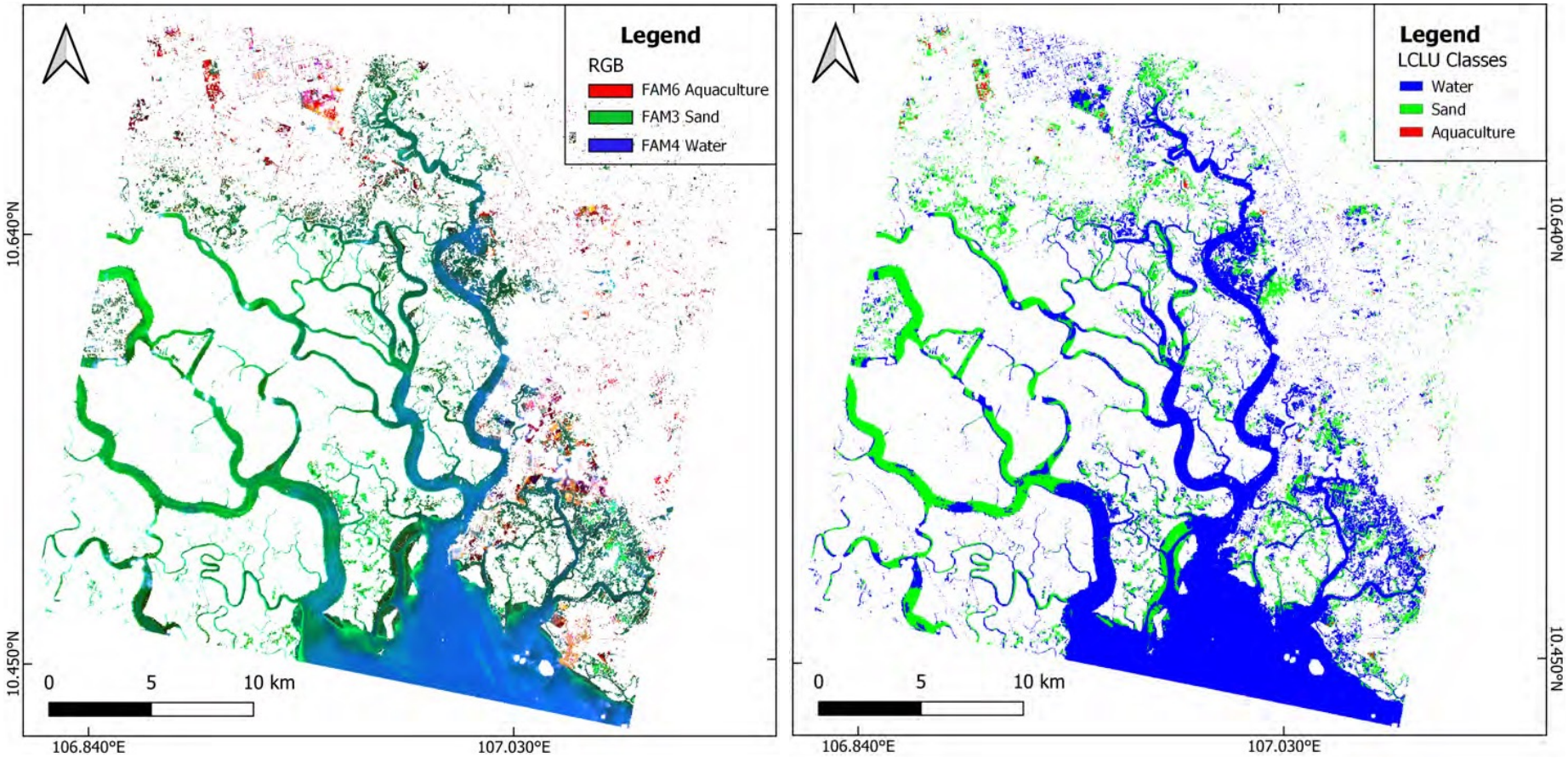
# Multi Sourced Observations over the RUC




Small et al., 2019

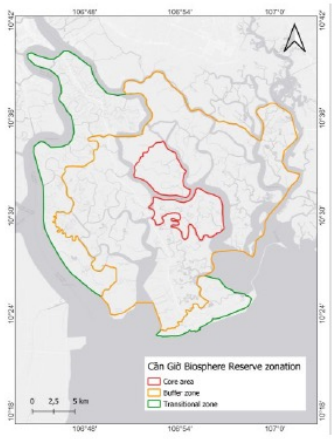
Multi-sourced, multi-season, and multi-scale composite images around Bangkok, Thailand.

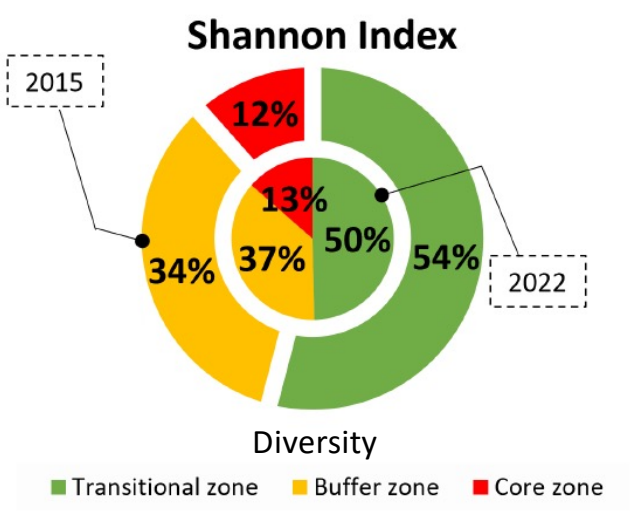
# Hyperspectral Data Products over the RUC

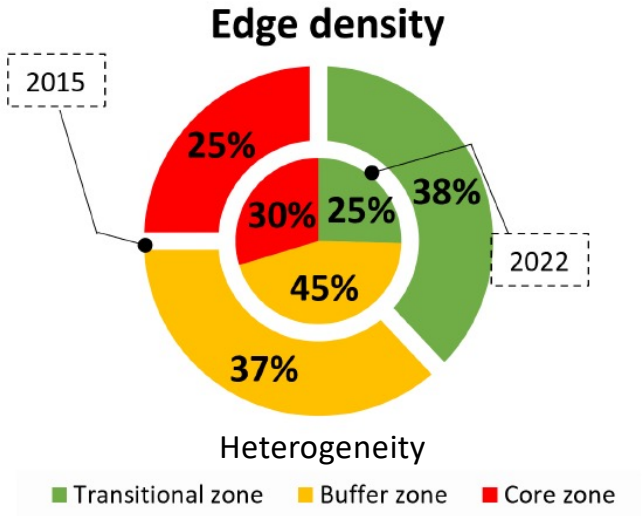



Data products from PRISMA data in Saigon-Dong Nai Delta (Taramelli et al., 2022).

# Synthesis of Radar/Spectral Products for Fragmentation Analysis



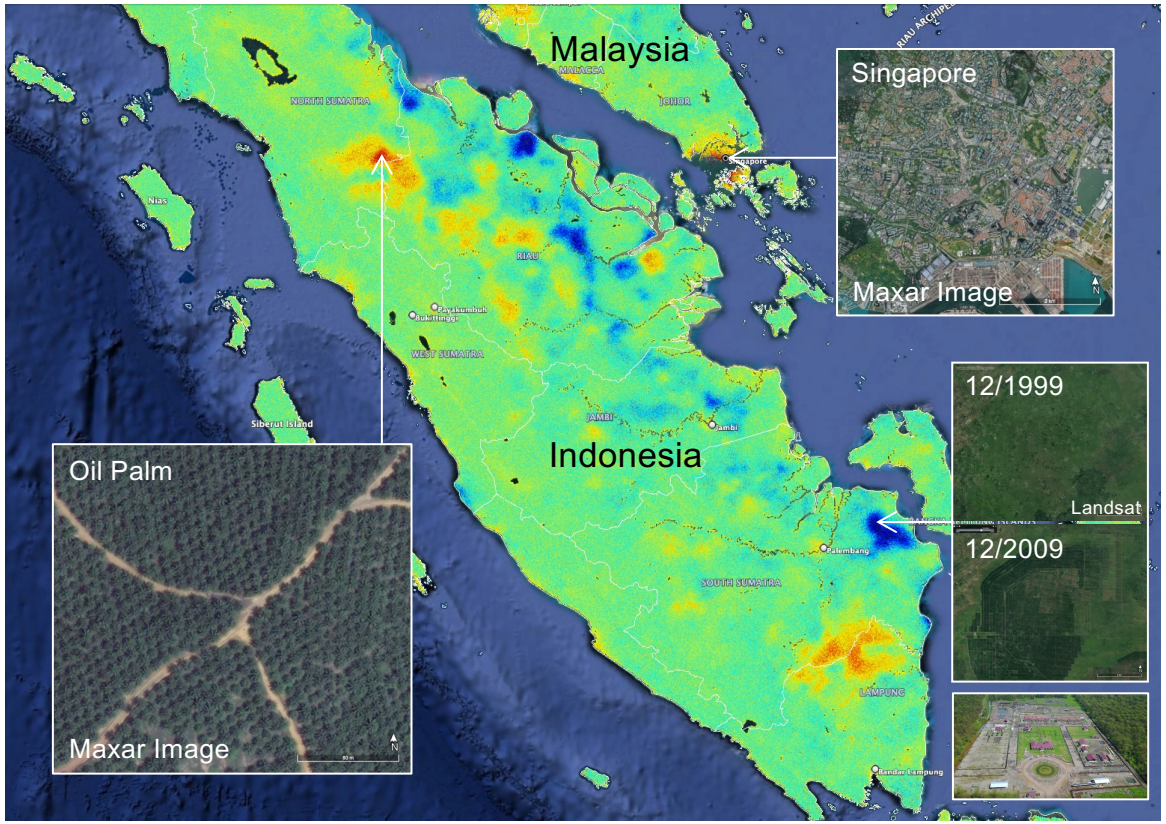




**Core and buffer**
similar trends. Small increase in the heterogeneity of the landscape, fragmentation stable or slightly increased

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

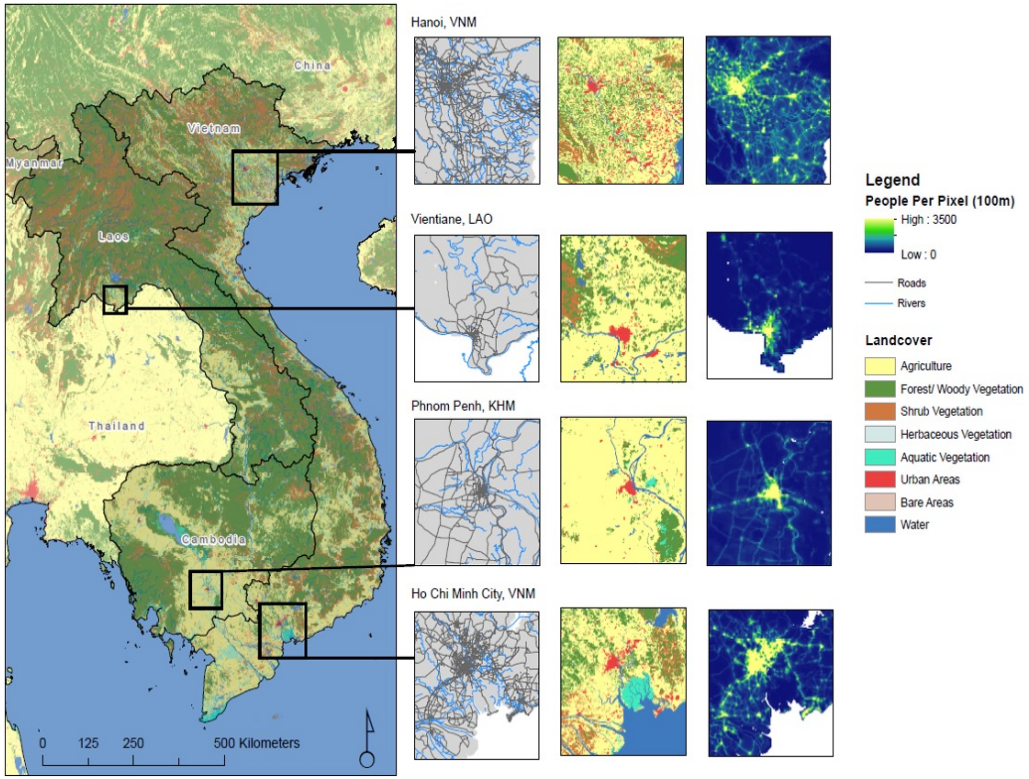
E. Valentini, M. Righini, S. Sapio, S. Liburdi, V. Cima, S. V. Nghiem, and A. Taramelli, 2023.

# 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

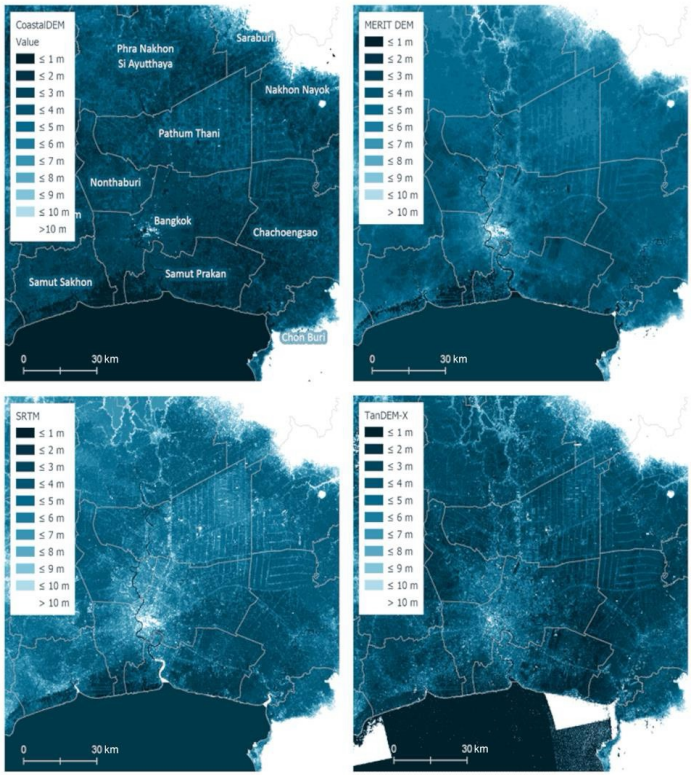
# Demography: Cambodia, Lao PDR, Vietnam




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).

# Estimating Population and Urban Areas at Risk of Coastal Hazards: How Data Choice Matter in in Synthesis Study:

K. MacManus, D. Balk, H. Engin, G. McGranahan, and R. Inman



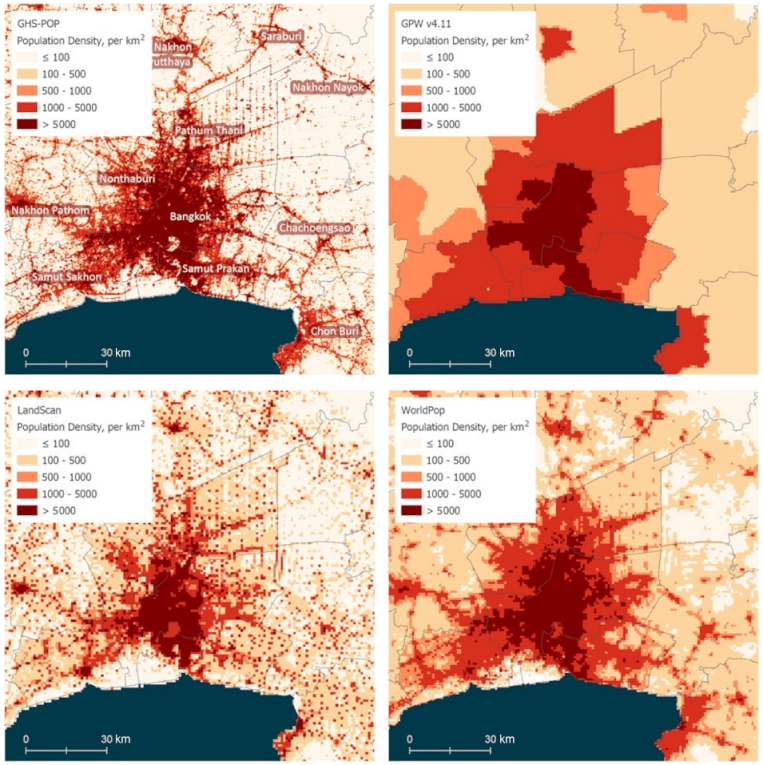

Bangkok

<< 4 Elevation data sets --> LECZ

4 gridded pop >> data sets

4 urban data sets (not shown)

Yield different estimates of population exposures to coastal flooding

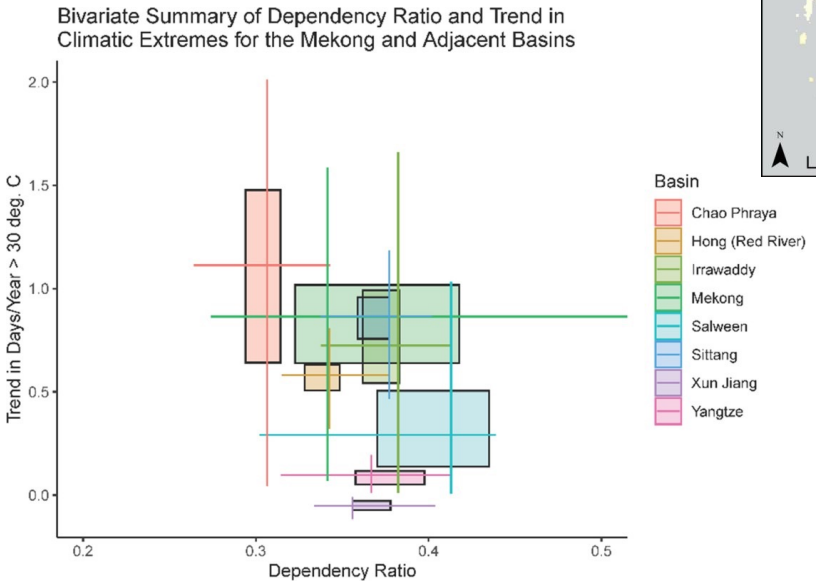


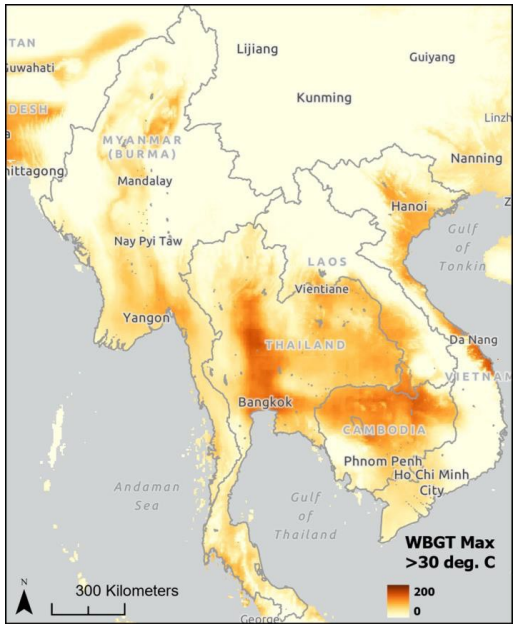

Data available from: https://doi.org/10.7927/d1x1-d702; paper from https://doi.org/10.5194/essd-13-5747-2021

# The Greater Mekong Region: Human Population and Heat Exposure

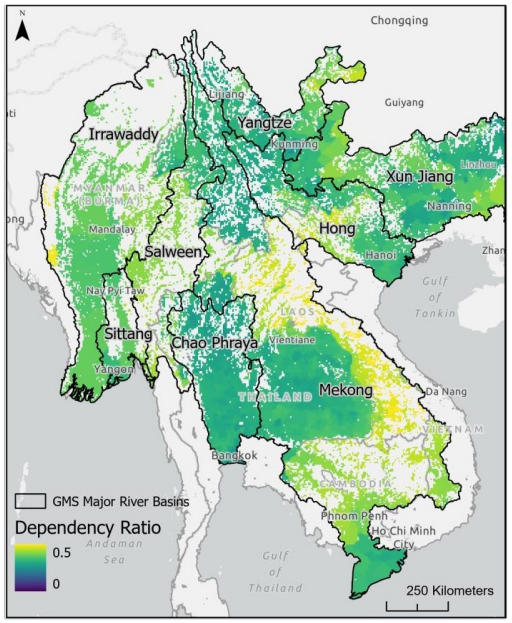
An application of leveraging Google Earth Engine and gridded data of demographic patterns to illustrate heat exposure for the Lower Mekong Region.

Steven et al., 2024



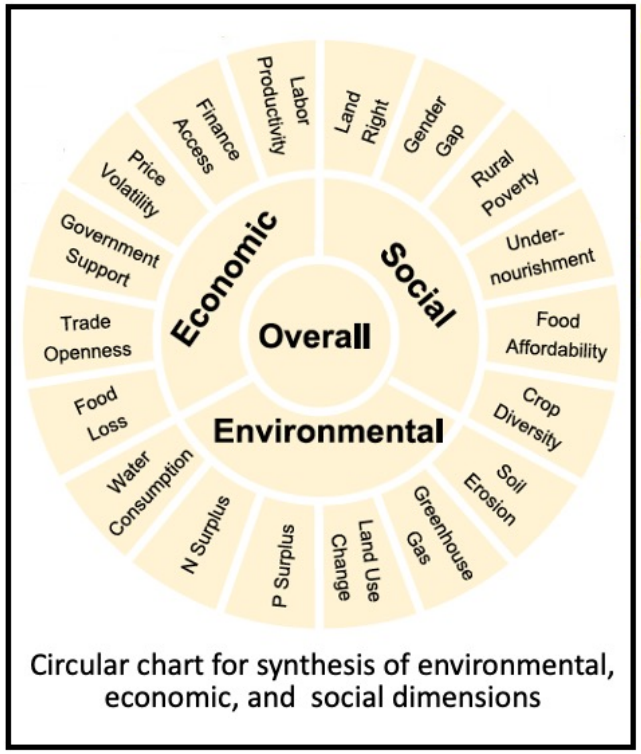

Gridded annual counts of the number of days where the maximum WBGTmax exceeded > 30°C for 2016.



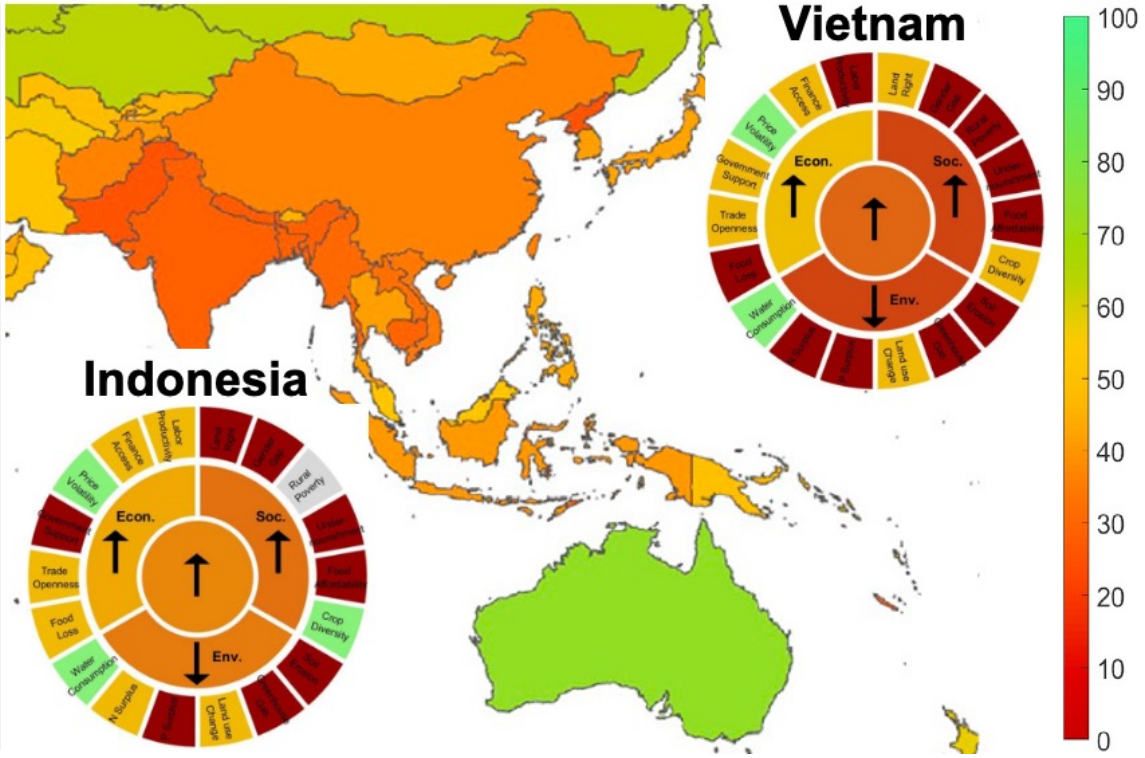

Dependency ratio (2020) across the Greater Mekong Subregion river basins

The Mekong and Chao Phraya basins have the most notable impact of heat stress on key demographic populations of young and old, but also have the highest range of dependency ratios.

# Synthesis in Physical-Human Dimensions



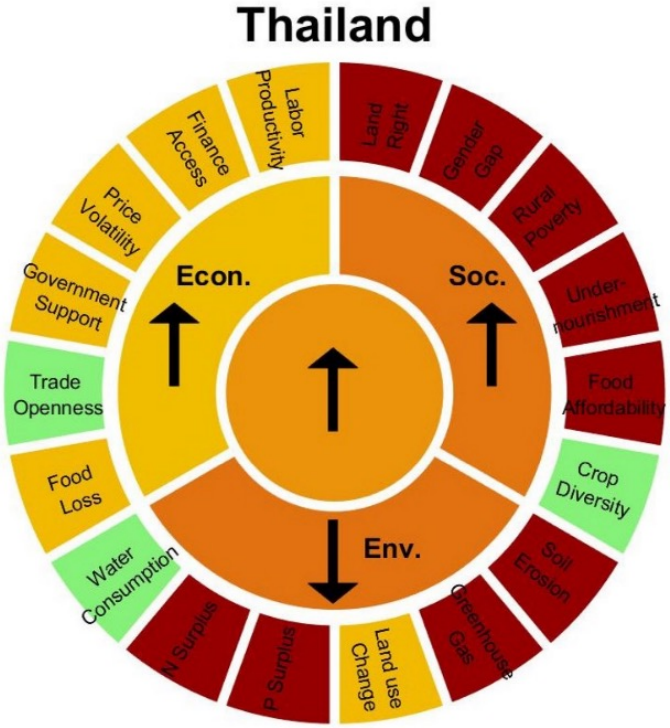

Circular chart for synthesis of environmental, economic, and social dimensions



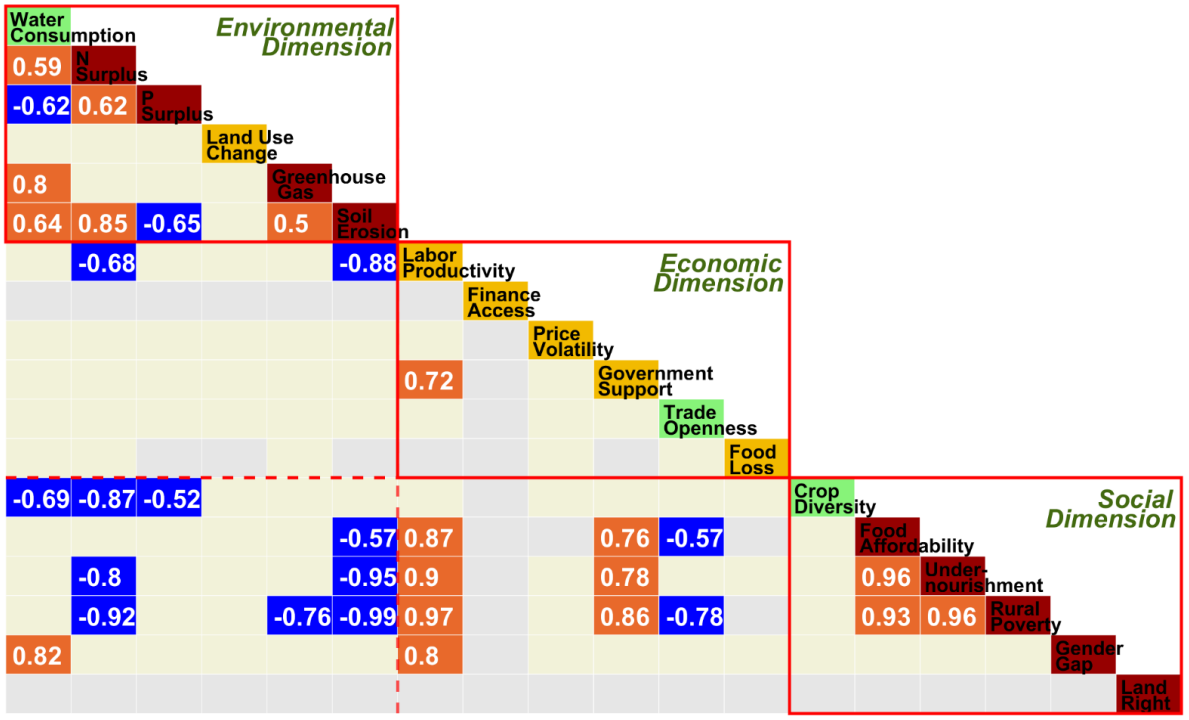

Sustainable Agriculture Matrix (SAM) method synthesizing multiple data products to quantify the impacts of agriculture on sustainability considering environmental, economic, and social dimensions across the RUC in 2000-2014. Examples for Indonesia and Vietnam (UMCES).

# Synthesis in Physical-Human Dimensions

## Sustainable Agriculture Matrix Example for Thailand in 2010-2014




**Report Card**




**Trade-offs and Synergies**

UMCES, 2024

# Synthesis in Physical-Human Dimensions

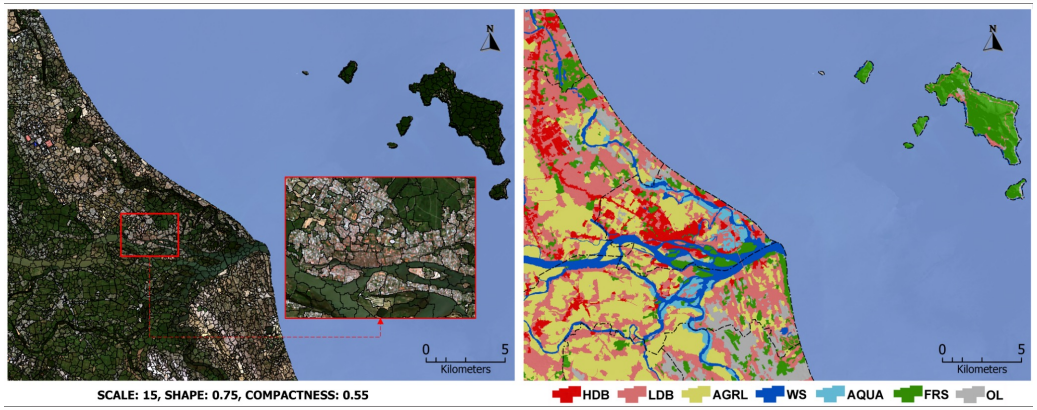
**Sendai Framework for United Nations Space-based Information for Disaster Management and Emergency Response (UN-SPIDER)**

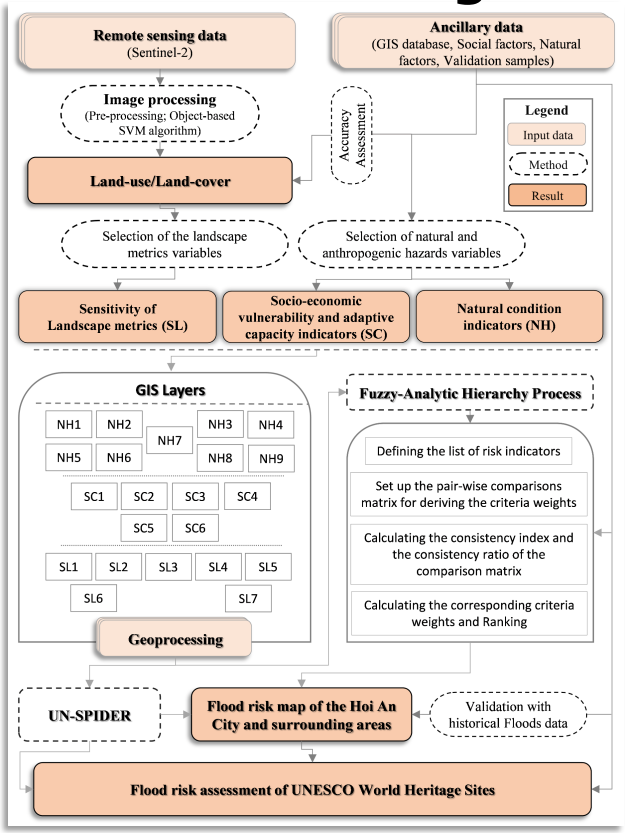
Risk = Combination of Hazard, Exposure, and Vulnerability

- **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.

# UN-SPIDER Synthesis for Flood Risk at Hoi An World Heritage Sites

METHOD: The research framework is formulated to assess flood risk in heritage areas based on the Sendai Framework Terminology used in the UN-SPIDER definition of risk as a combination of hazard, exposure, and vulnerability.



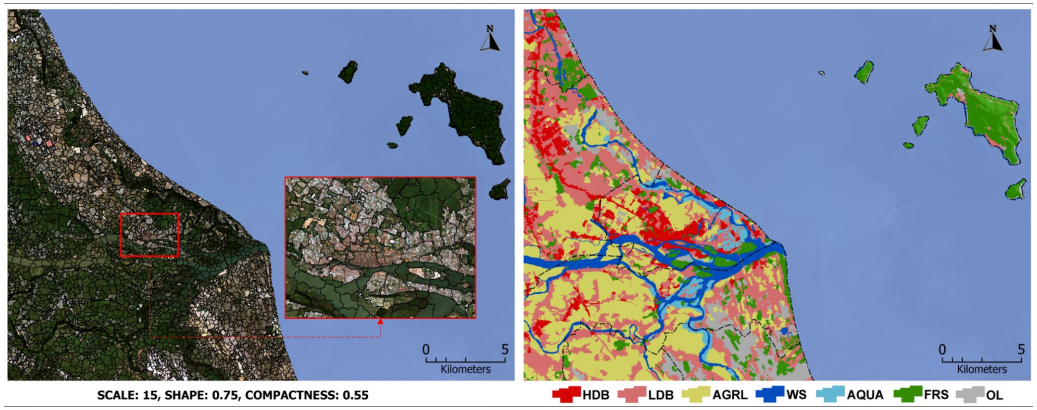

Based on the UN-SPIDER definitions, the 22 indicators can be assigned into the hazard set = {NH4, NH5, NH6, NH7, NH9}, exposure set = {SC1, SC2, SC3, SC4}, and vulnerability set = {NH1, NH2, NH3, NH8, SC5, SC6, SL1 to SL7}

$$FRI = \{W_{NH} \sum_{i\in\{4,5,6,7,9\}} W_{NHi} ( \sum_{i\in\{4,5,6,7,9\}} W_{NHi} L_{NHi} )\} \times \{W_{SC} \sum_{j=1}^{4} W_{SCj} ( \sum_{j=1}^{4} W_{SCj} L_{SCj} )\} \times \{W_{NH} \sum_{i\in\{1,2,3,8\}} W_{NHi} ( \sum_{i\in\{1,2,3,8\}} W_{NHi} L_{NHi} ) + W_{SC} \sum_{j=5}^{6} W_{SCj} ( \sum_{j=5}^{6} W_{SCj} L_{SCj} ) + W_{SL} ( \sum_{k=1}^{7} L_{SLk} W_{SLk} )\}$$

D. T. Nguyen, T. N. Do, S. V. Nghiem, J. Ghimire, K. B. Dang, V. T. Giang, K. C. Vu, and V. M. Pham, 2024

# UN-SPIDER Synthesis for Flood Risk at Hoi An World Heritage Sites

METHOD: The research framework is formulated to assess flood risk in heritage areas based on the Sendai Framework Terminology used in the UN-SPIDER definition of risk as a combination of hazard, exposure, and vulnerability.




Based on the UN-SPIDER definitions, the 22 indicators can be assigned into the hazard set = {NH4, NH5, NH6, NH7, NH9}, exposure set = {SC1, SC2, SC3, SC4}, and vulnerability set = {NH1, NH2, NH3, NH8, SC5, SC6, SL1 to SL7}

**Natural Indicators:**
NH1 = Slope, NH2 =Altitude, NH3 = Topography Wetness Index, NH4 = Stream Power Index, NH5 = Sediment Transport Index, NH6 = Geomorphology Index, NH7 = Distance to River, NH8 = Drainage Density, NH9 = Rainfall.

**Socioeconomic Indicators:**
SC1 = Population Density, SC2 = Distance between Hoi An and Modern Transportation Network, SC3 = Road Density, SC4 = Number of Businesses, SC5 = Per Capita Income, SC6 = Heath Sector Workforce.

**Landscape Indicators:**
SL1 = Largest Patch Index, SL2 = Fractal Dimension Area-weighted Mean, SL3 = Number of Disjunct Core Areas, SL4 = Total edge contrast index, SL5 = Landscape Division index, SL6 = Landscape Shape Index, SL7 = Shannon Diversity Index.

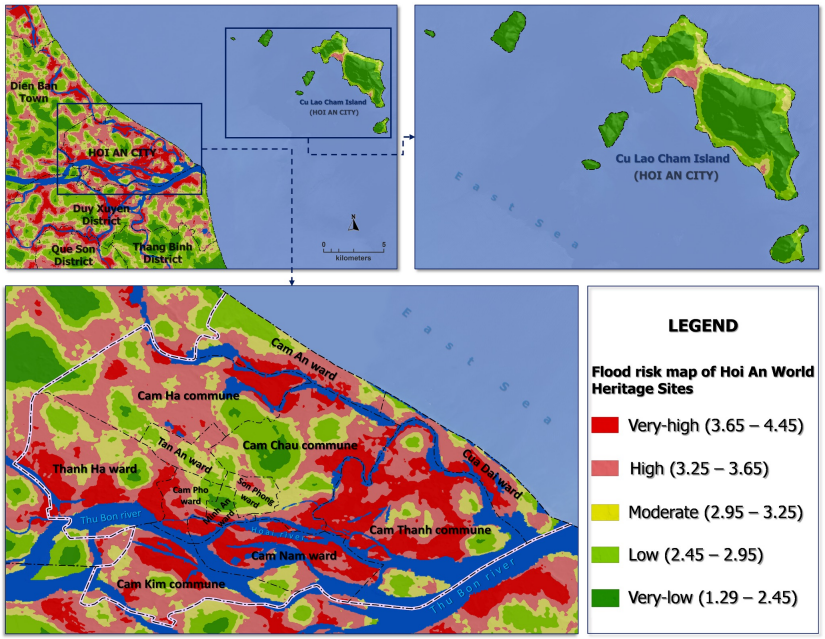
$$FRI = \{W_{NH} \sum_{i\in\{4,5,6,7,9\}} W_{NHi}\left(\sum_{i\in\{4,5,6,7,9\}} W_{NHi}L_{NHi}\right)\} \times \{W_{SC}\sum_{j=1}^{4} W_{SCj}\left(\sum_{j=1}^{4} W_{SCj}L_{SCj}\right)\} \times \{W_{NH} \sum_{i\in\{1,2,3,8\}} W_{NHi}\left(\sum_{i\in\{1,2,3,8\}} W_{NHi}L_{NHi}\right) + W_{SC}\sum_{j=5}^{6} W_{SCj}\left(\sum_{j=5}^{6} W_{SCj}L_{SCj}\right) + W_{SL}\left(\sum_{k=1}^{7} L_{SLk}W_{SLk}\right)\}$$

D. T. Nguyen, T. N. Do, S. V. Nghiem, J. Ghimire, K. B. Dang, V. T. Giang, K. C. Vu, and V. M. Pham, 2024

# UN-SPIDER Synthesis Results for Flood Risk at Hoi An UNESCO Site

The synthesis approach in this research can be used to analyze flood risk, as defined by UN-SPIDER, for UNESCO World Heritage Sites

The integration of elements of natural conditions, socio-economic characteristics, and landscape characteristics in the synthesis approach allows for a quantitative and unambiguous assessment of potential flood impacts on individual World Heritage Site as well as on the city and surrounding areas




The adaptive capability can also account for the dynamics of physical, demographic, and socioeconomic changes by using updated remote sensing and surface data for long-term monitoring of flood risk that can be exacerbated by climate change. Policy Relevance: Proactive planning for flood preparedness and response.

Nguyen et al., 2024

# UN-SPIDER Synthesis Results for Flood Risk at Hoi An UNESCO Site

The synthesis approach in this research can be used to analyze flood risk, as defined by UN-SPIDER, for UNESCO World Heritage Sites

The integration of elements of natural conditions, socio-economic characteristics, and landscape characteristics in the synthesis approach allows for a quantitative and unambiguous assessment of potential flood impacts on individual World Heritage Site as well as on the city and surrounding areas

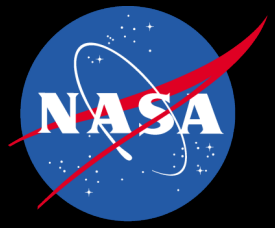
## UNESCO World Heritage Sites

**Cambodia:** Angkor (1992), Koh Ker Archaeological Site of Ancient Lingapura or Chok Gargyar (2023), Temple of Preah Vihear (2008), Temple Zone of Sambor Prei Kuk, Ancient Ishanapura (2017).
**Indonesia:** Borobudur Temple Compounds (1991), Cosmological Axis of Yogyakarta and its Historic Landmarks (2023), Cultural Landscape of Bali Province (2012), Komodo National Park (1991), Lorentz National Park (1991), Ombilin Coal Mining Heritage of Sawahlunto (2019), Sangiran Early Man Site (2004), Ujung Kulon National Park (1991).
**Lao PDR:** Town of Luang Prabang (1995), Vat Phou and Associated Ancient Settlements within the Champasak Cultural Landscape (2001), Megalithic Jar Sites in Xiengkhuang Plain of Jars (2019).
**Malaysia:** Kinabalu Park (2000), Gunung Mulu National Park (2000), Melaka and George Town (2008), Lenggong Valley (2012)
**Thailand:** Town of Sukhothai (1991), City of Ayutthaya (1991), Thungyai–Huai Kha Khaeng Wildlife Sanctuaries (1991), Ban Chiang Archaeological Site (1992), Dong Phayayen–Khao Yai Forest Complex (2005), Kaeng Krachan Forest Complex (2021), The Ancient Town of Si Thep (2023).
**Vietnam:** Central Sector of Imperial Citadel of Thăng Long (2010), Citadel of the Hồ Dynasty (2011), Complex of Huế Monuments (1993), Hạ Long Bay–Cát Bà Archipelago (1994), Hội An Ancient Town (1999), Mỹ Sơn Sanctuary (1999), Phong Nha – Kẻ Bàng National Park (2003), Tràng An Landscape Complex (2016).

The adaptive capability can also account for the dynamics of physical, demographic, and socioeconomic changes by using updated remote sensing and surface data for long-term monitoring of flood risk that can be exacerbated by climate change. Policy Relevance: Proactive planning for flood preparedness and response.

Nguyen et al., 2024

# Contact




National Aeronautics and
Space Administration

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

**PI: 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).