Fine-resolution Global Land Use/Cover Change Modeling under Four Representative Concentration Pathways by 2100

Xuecao Li

Iowa State University

11/8/2019

Outline

1. Background
2. Datasets and Method
3. Results
4. Discussion

Background

Rapid global urbanization process

World Urbanization Prospects

- More than half of the world's population residing in urban area
- By 2050, 66% of the world's population is projected to be urban

(United Nations, 2015)

Global Urban Land Expansion

- The global urban area increased about 1.3 times in 2013 compared to year 1992 *(Zhou et al., 2018)*
- The increment is even faster in developing countries such as China (more than doubled) *(Wang et al., 2012)*

Important of urban area for achieving the SDGs

Although globally the urban area occupied less than 1% of the total land surface, it accounts

- 90% of global economy; 50% of world population; 65% of world's energy; 70% of global greenhouse gas emissions

(Solecki et al., 2013; Schneider et al., 2012)

Urban growth modeling is of great importance to support global sustainable development

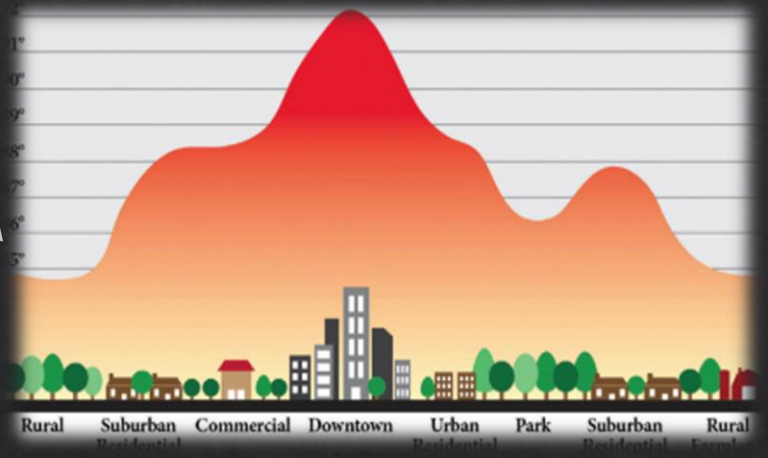
Importance of modeling future urban growth

Future urbanization scenarios

Flooding

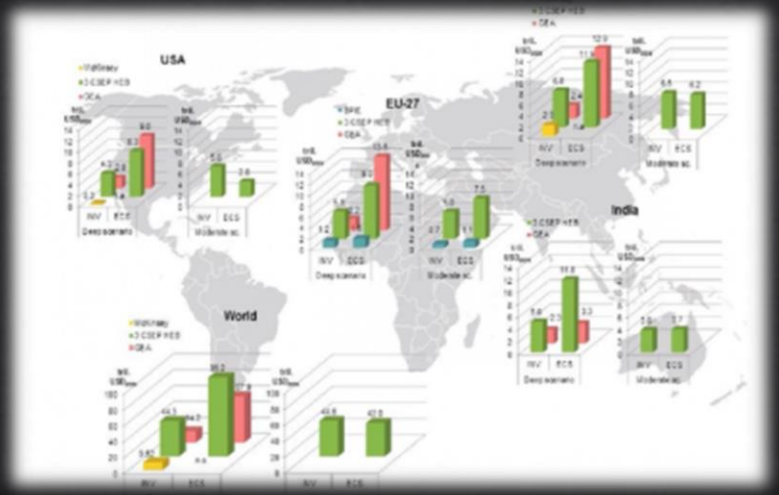
https://www.unisdr.org/archive/27965

Urban Heat Island



https://bayareamonitor.org/article/summer-in-the-city-seeking-relief-from-urban-heat-islands/

Building Energy Use



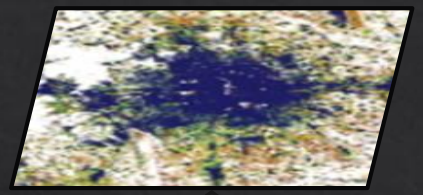
https://www.buildup.eu/en/practices/publications/monetary-benefits-ambitious-building-energy-policies

Agriculture System

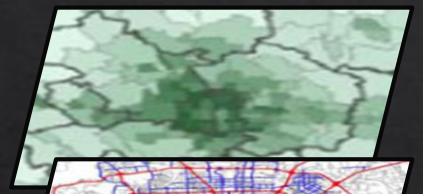
http://knowledge.ckgsb.edu.cn/2014/07/02/technology/the-business-of-urbanization-in-china/

Datasets and method

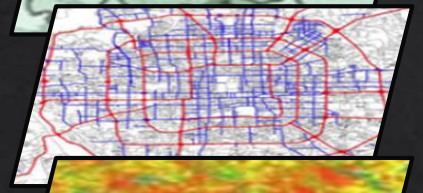
Overall framework



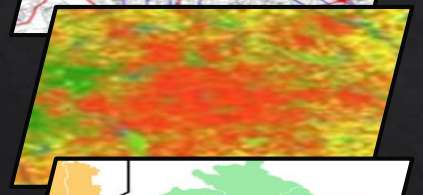
Urban Dynamics



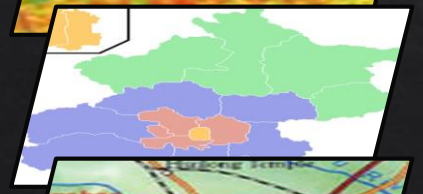
Population



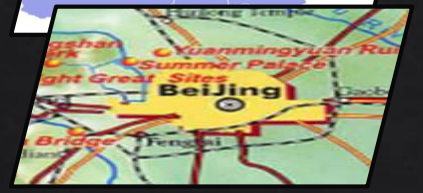
Transportation



Land cover



District



Terrain

Conceptual Model

How many?

Urban Demand

Up-down

Spatial Allocation

Bottom-up

Where?

Overall Structure

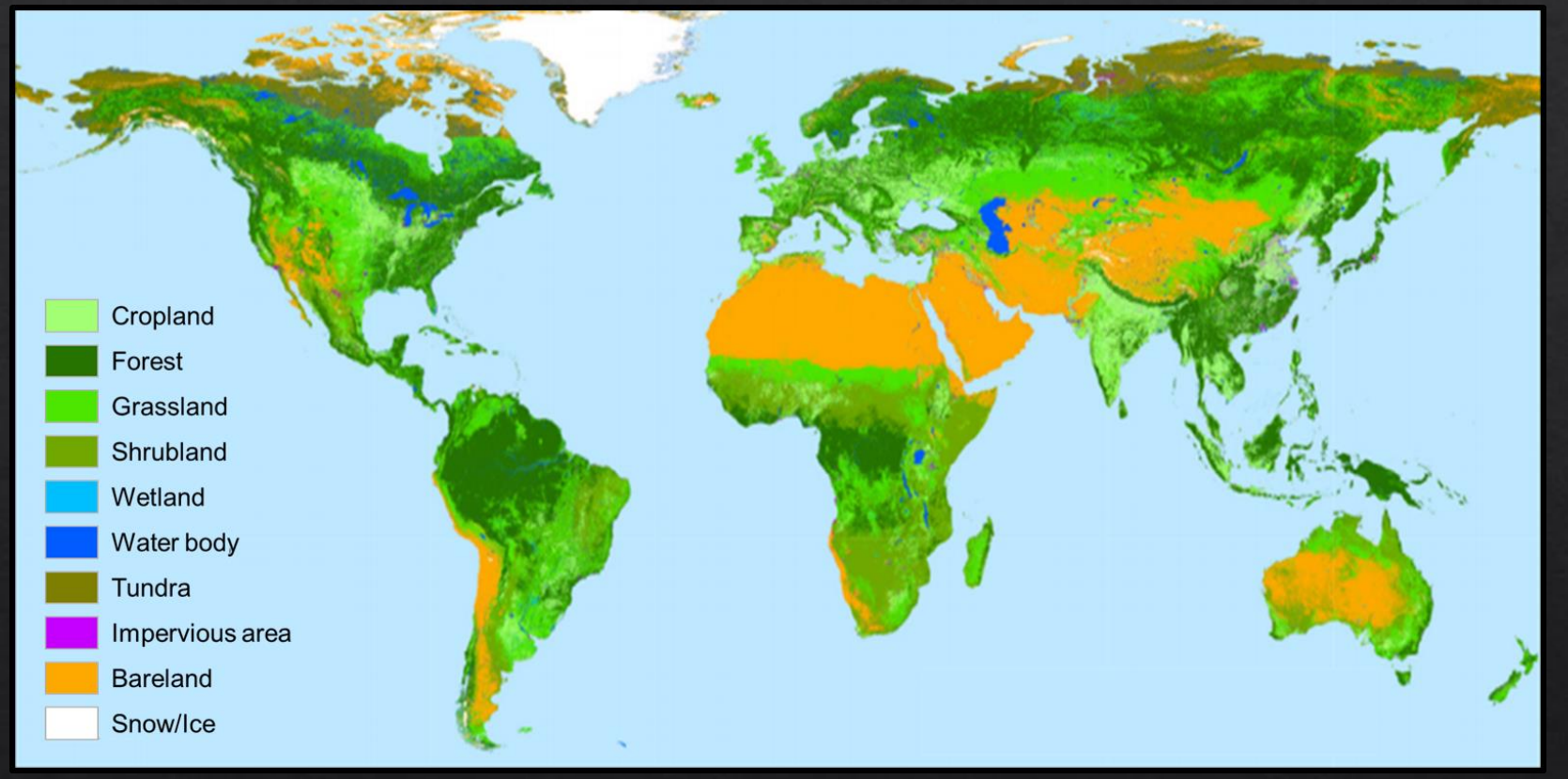
- Empirical approach
  - ❑ Population Vs. Urban
- Integrated Assessment Model
  - ❑ GCAM
  - ❑ System Dynamics
- Cellular Automata (CA)
  - ❑ Grid-based model
  - ❑ Self-adaption
- Multi-agent Model (ABM)
  - ❑ Multiple agents (e.g., residential, government, or estate)
  - ❑ Land price and market dynamics

Selected Approaches in Demo

Detailed approaches

Datasets

FROM-GLC (2010)

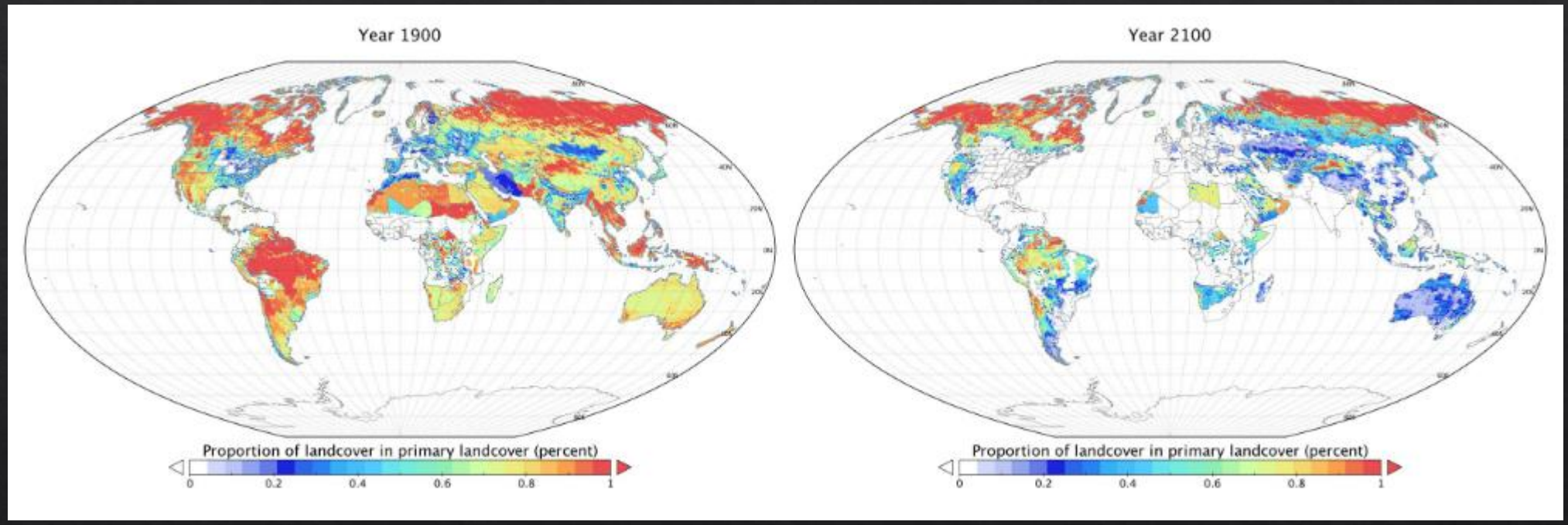


Resolution: 30m; 9 Level-1 land cove types

(Gong et al., 2013)

Datasets

Land Use Harmonization (LUH) Data



(Hurtt et al., 2011)

LUH

Historical Period (1500-2005) + *Future Scenarios (2006-2100)*

- *IMAGE*
- *GCAM*
- *AIM*
- *MESSAGE*

Variable	Description
Land Cover- Units=fraction (%) of each grid cell	
gcrop	cropland
gothr	primary land
gpast	pasture
gsecd	secondary land
gurbn	urban land

Spatial Resolution: 0.5 °

Temporal Resolution: annual

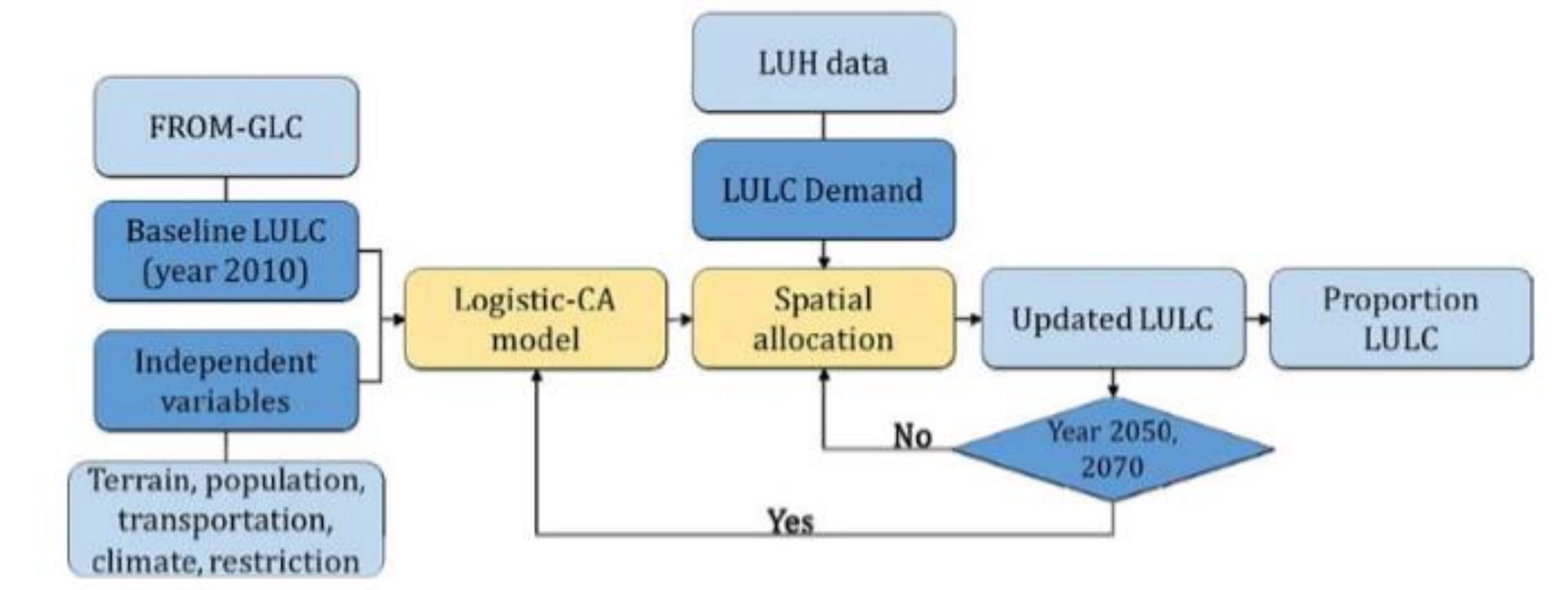
Spatial proxies

Table 1 Spatially explicit variables adopted for modeling

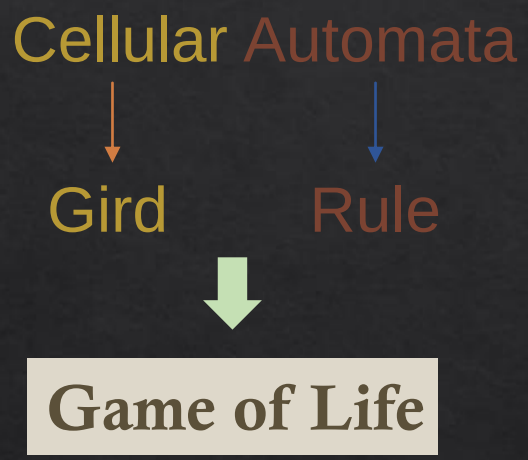
Variable	Description	Source	Resolution
Elevation	Digital elevation model (DEM)	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM[a]	30 m
Slope	Slope calculated from DEM		
Pop	Population	Gridded Population of the World[b]	5 km
$City_{dist}$	Distance to cities	ESRI World Cities layer (vector)[c]	Vector
$Road_{dist}$	Distance to roads	ESRI World Roads layer (vector)[d]	Vector
$Railway_{dist}$	Distance to railways	ESRI World Railroads layer (vector)[e]	Vector
$Soil_{d}$	Soil depth	World Harmonized Soil Database[f]	10 km
$Soil_{rh}$	Soil restriction (high inputs)		10 km
$Soil_{rl}$	Soil restriction (low inputs)		10 km
Temp	Mean temperature	WorldClim[g]	1 km
Pre	Mean precipitation		1 km
PA	Protected area	World Database of Protected Area[h]	Vector

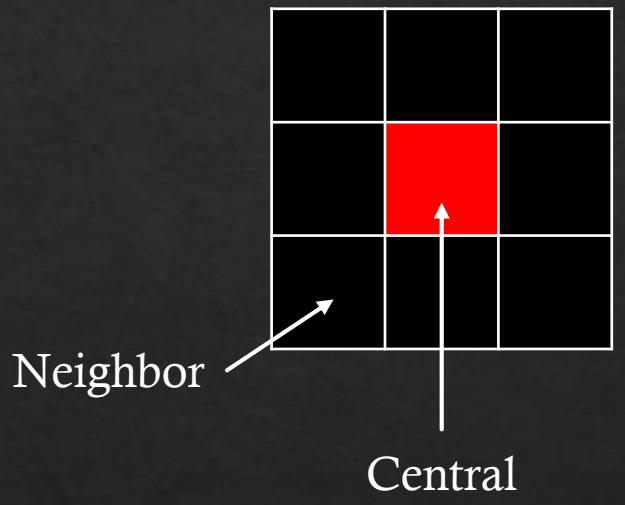
The links for these variables are as follows: [a] http://www.jspacesystems.or.jp/ersdac/GDEM/E/4.html; [b] http://sedac.ciesin.columbia.edu/data/collection/gpw-v3; [c] http://www.arcgis.com/home/item.html?id=dfab3b294ab24961899b2a98e9e8cd3d; [d] http://www.arcgis.com/home/item.html?id=83535020ce154bd5a498957c159e3a99; [e] http://www.arcgis.com/home/item.html?id=5ef3425348954c84a45860bcf86c78ab; [f] http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/; [g] http://www.worldclim.org/; [h] http://www.wdpa.org/

Technique workflow



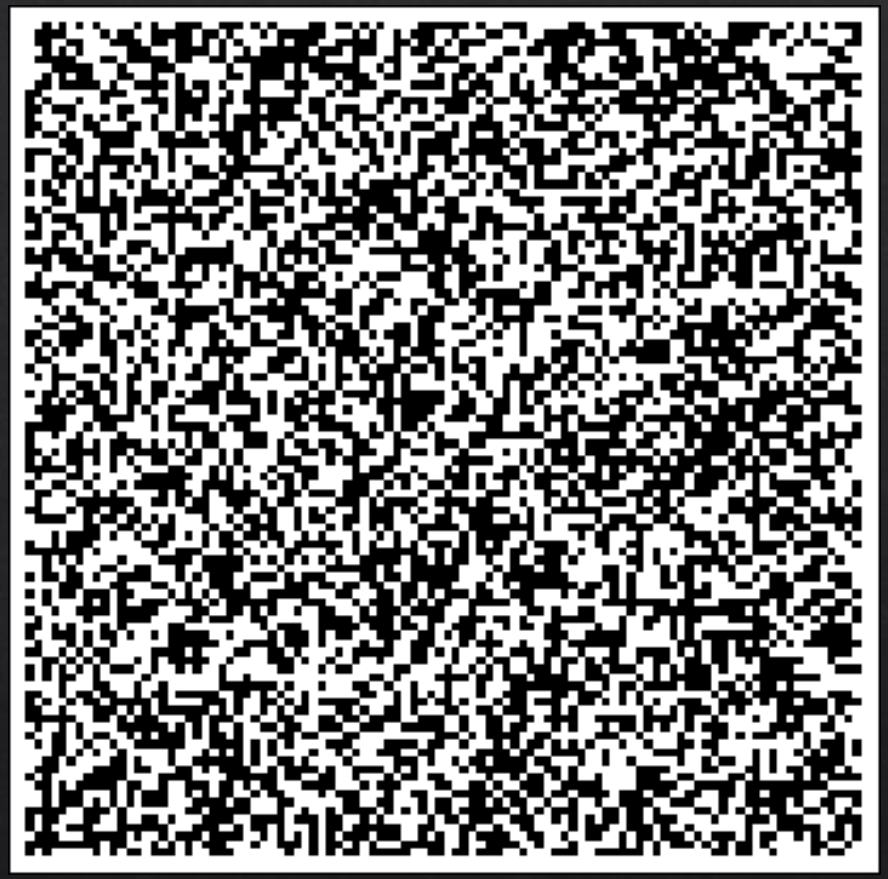
Cellular automata model



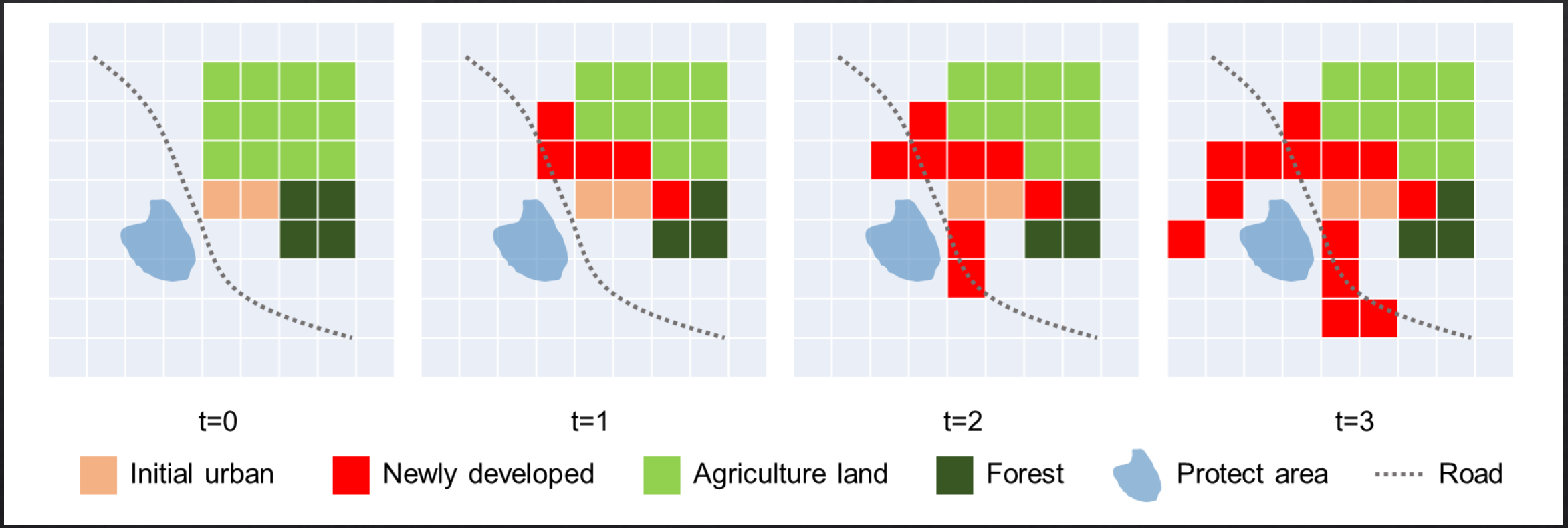


Rule1： **IF** central (live) & neighbor (2 or 3 live), **Then** die (competition)

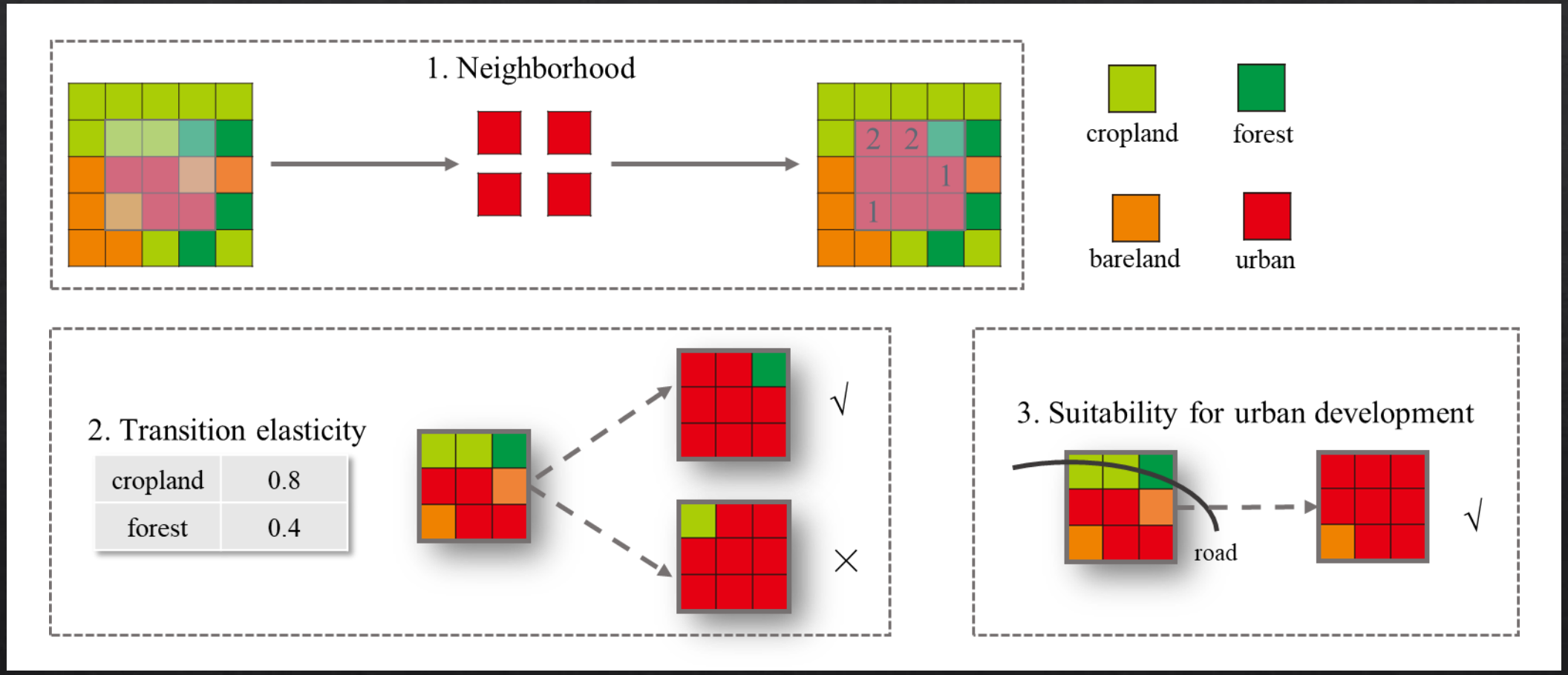
Rule2 ： **IF** central (die) & neighbor (3 live), **Then** live (reproduce)



Urban CA model

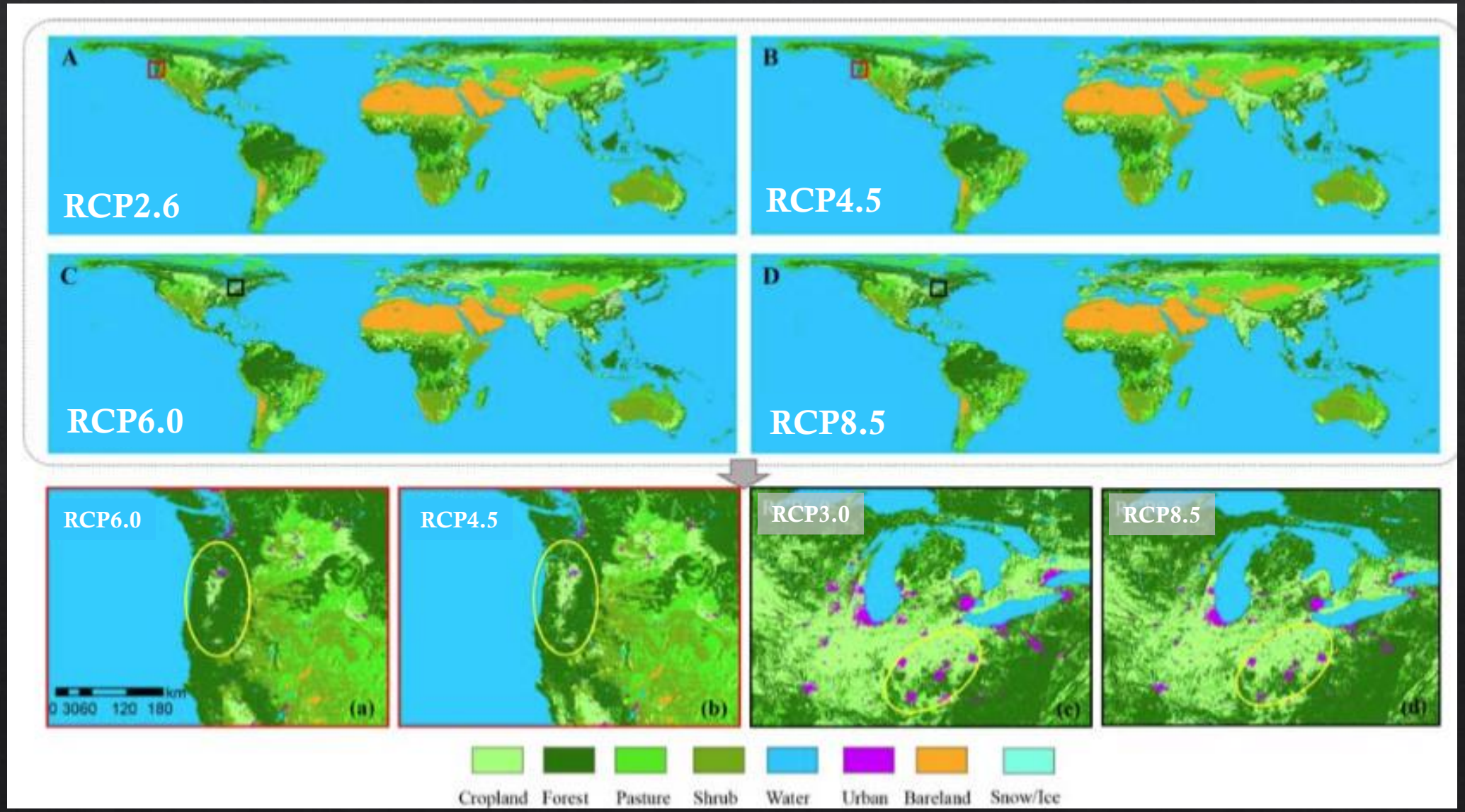


Deal with multi-types

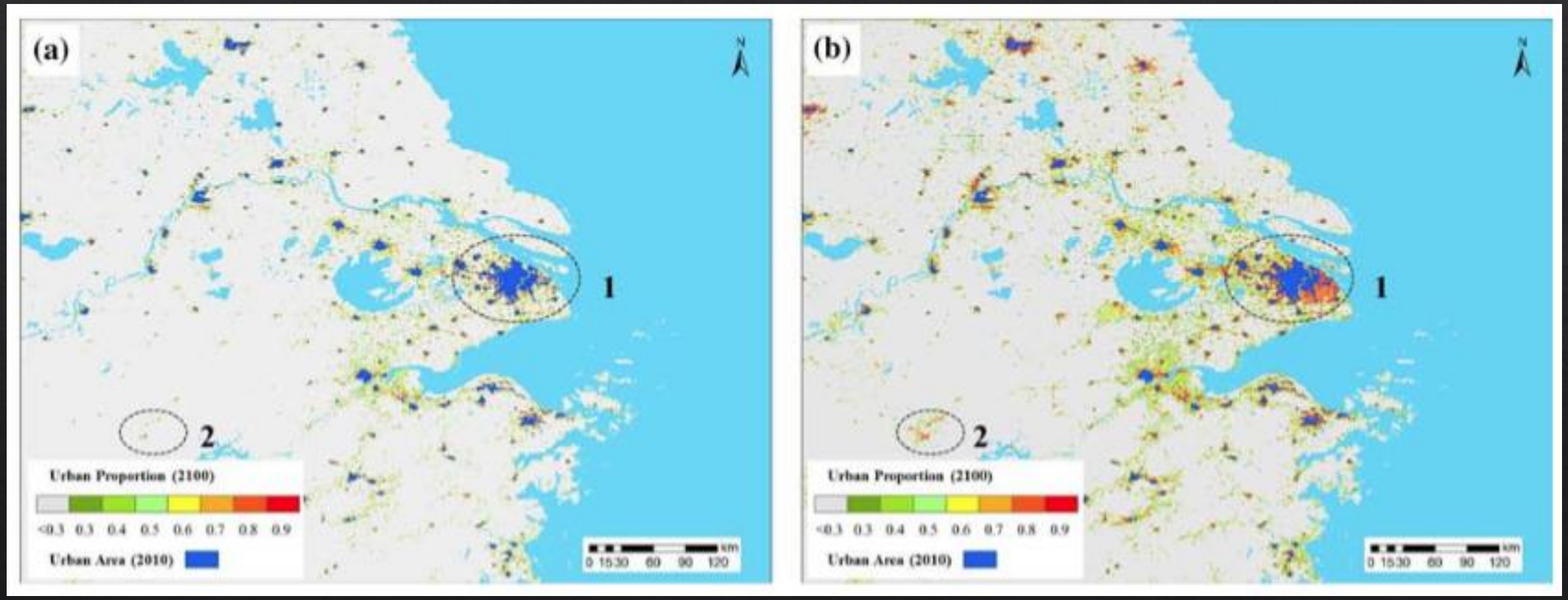


Results

Global pattern of LULC in 2100

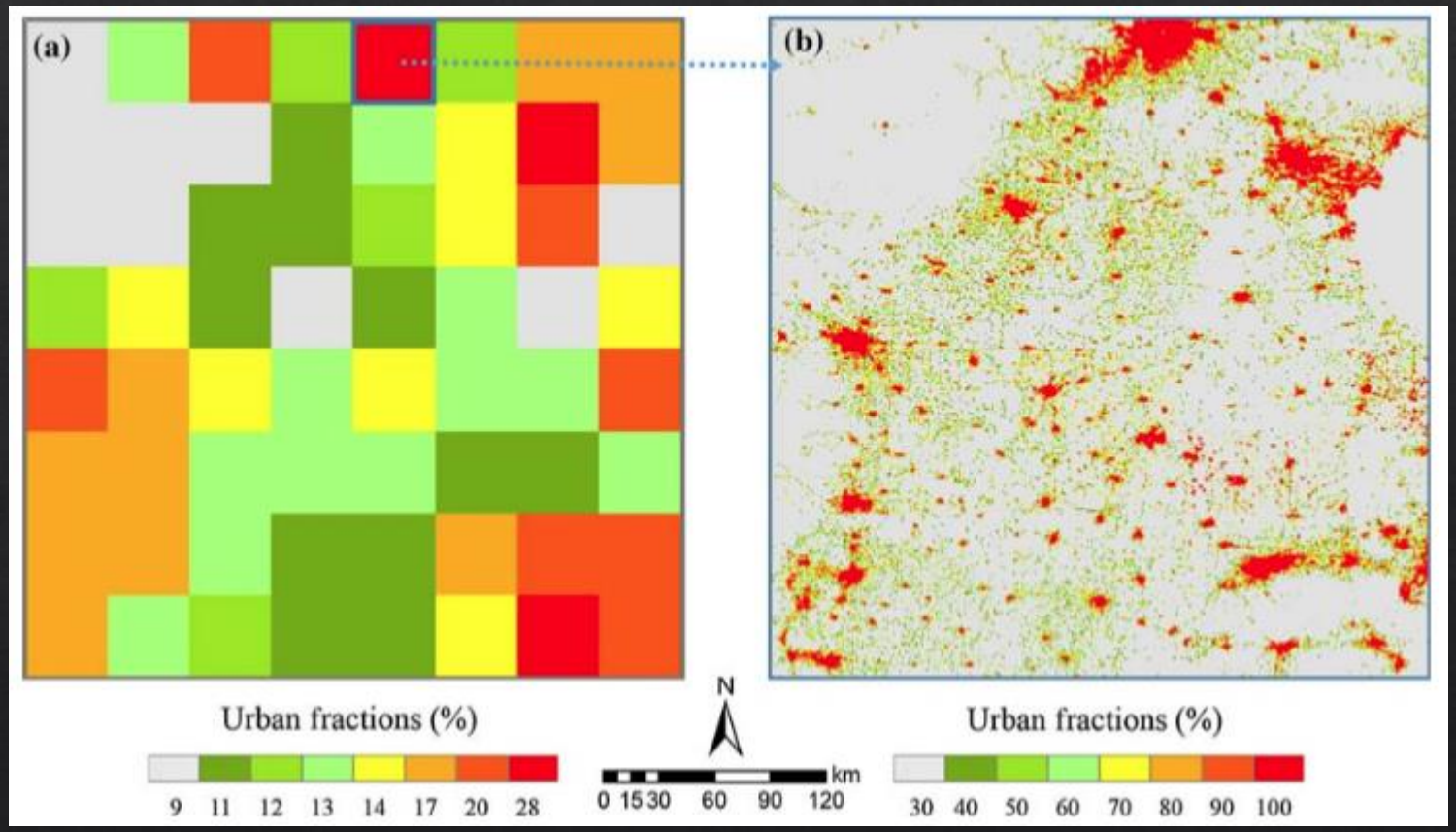


Future urbanization in Eastern China



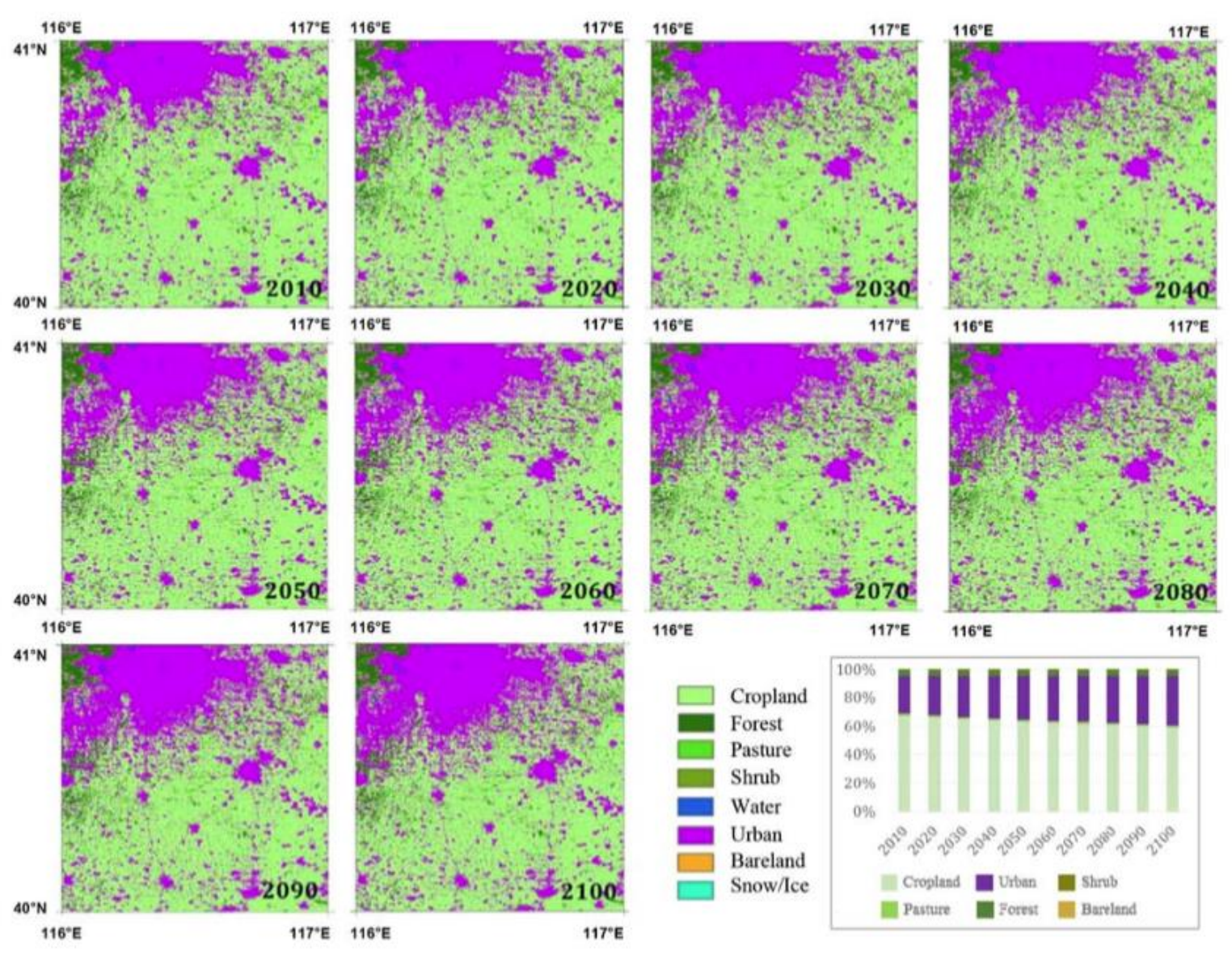
Modeled urban dynamic in 2100 under scenarios of RCP 2.6 and RCP 8.5 in eastern China.

Improved spatial details (compare to LUH)

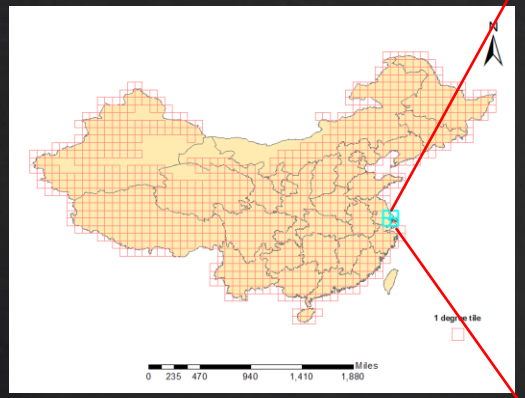


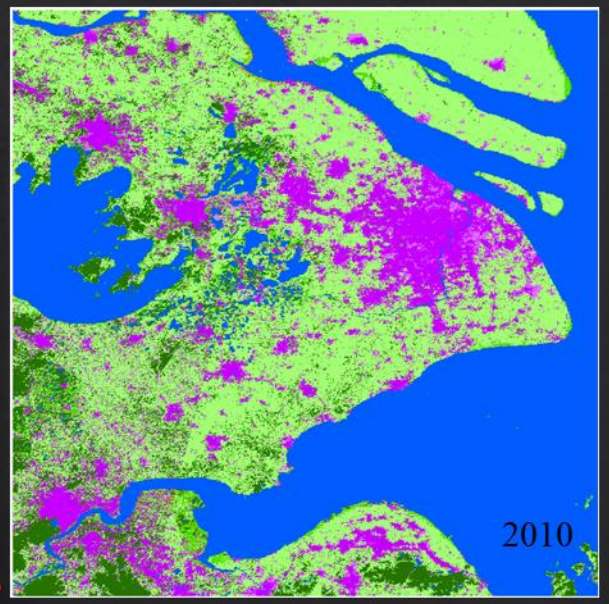
Urban fraction in 2100 under RCP 8.5 (left: 0.5 ° ; right: modeled)

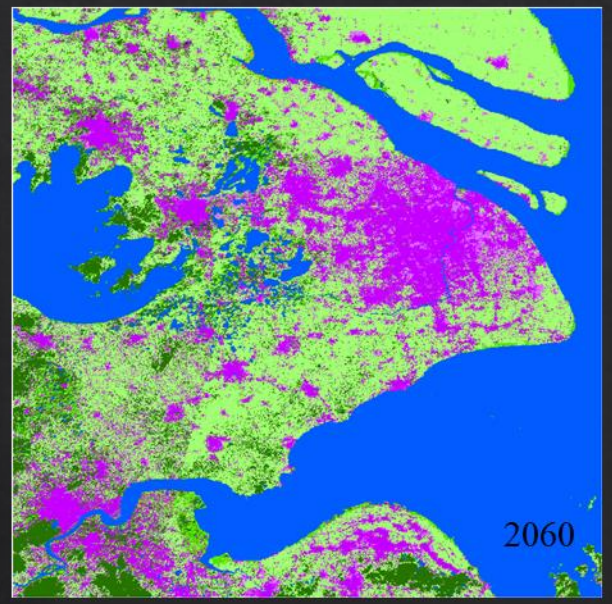
Temporal dynamics (case study)

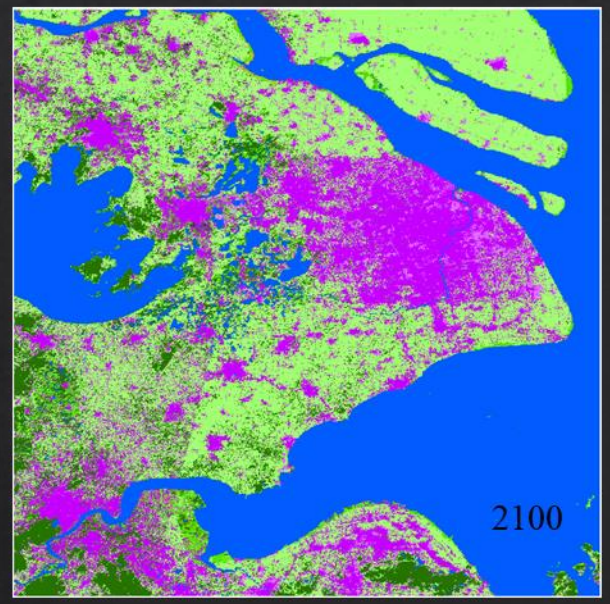


Urban sprawl in Shanghai



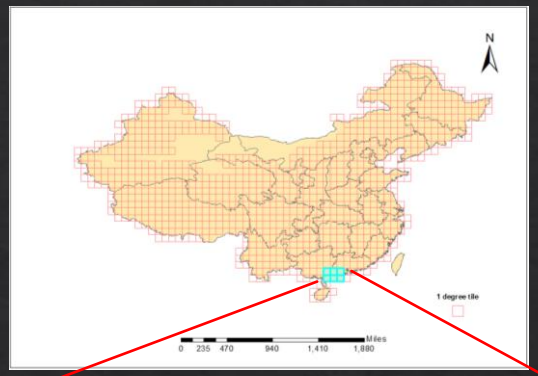


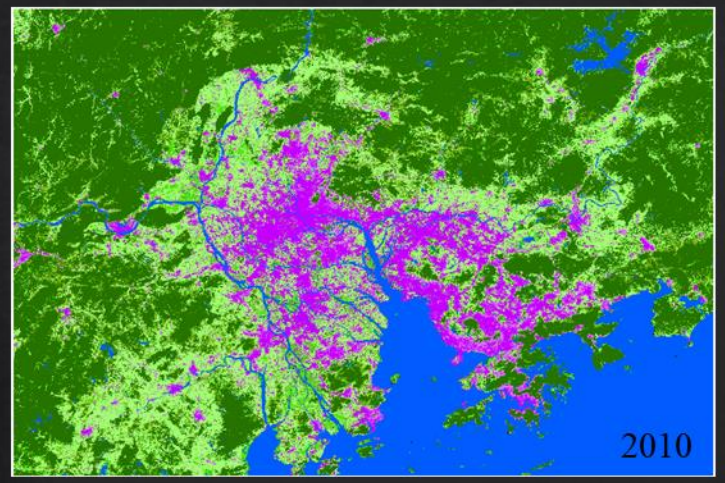


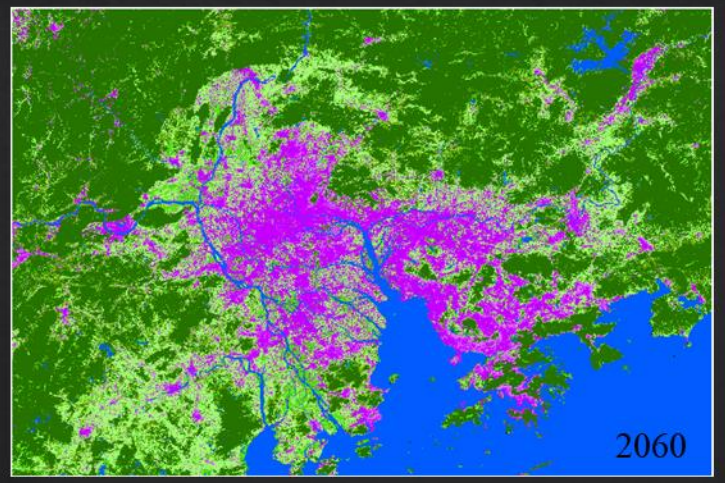


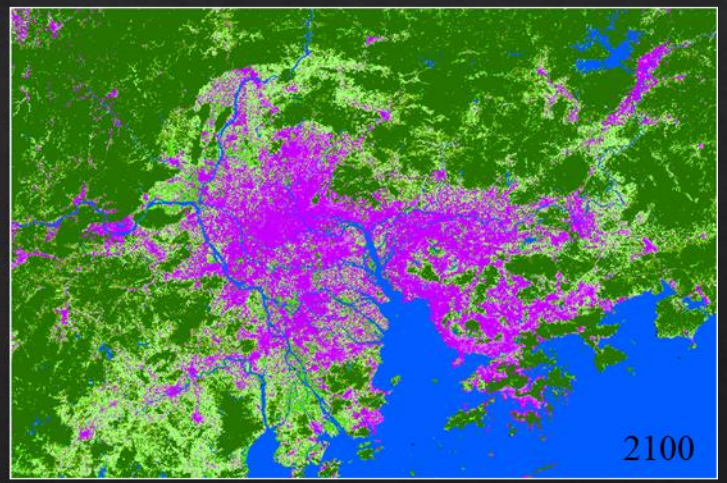
RCP: 8.5

Urban sprawl in Shanghai



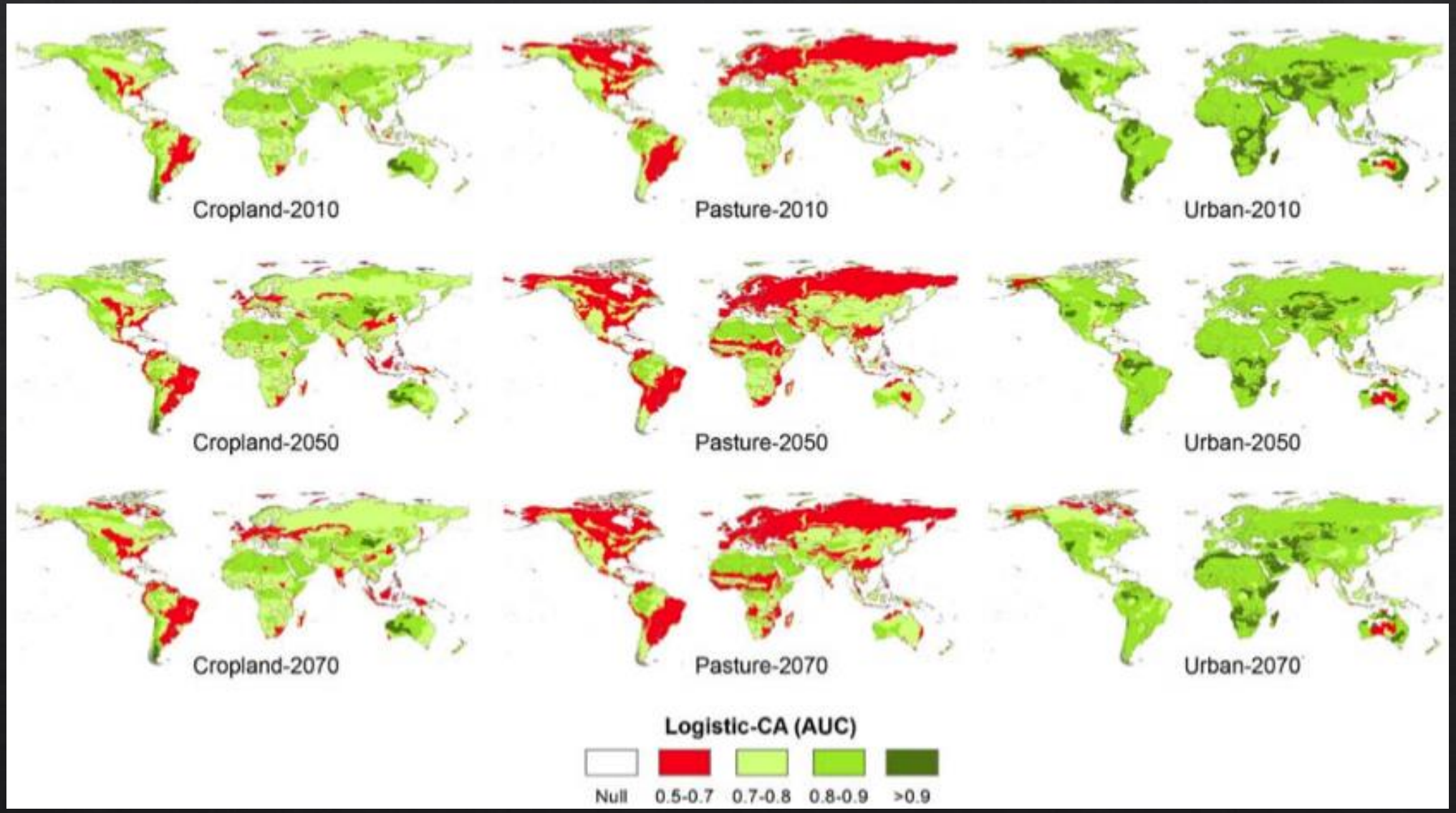




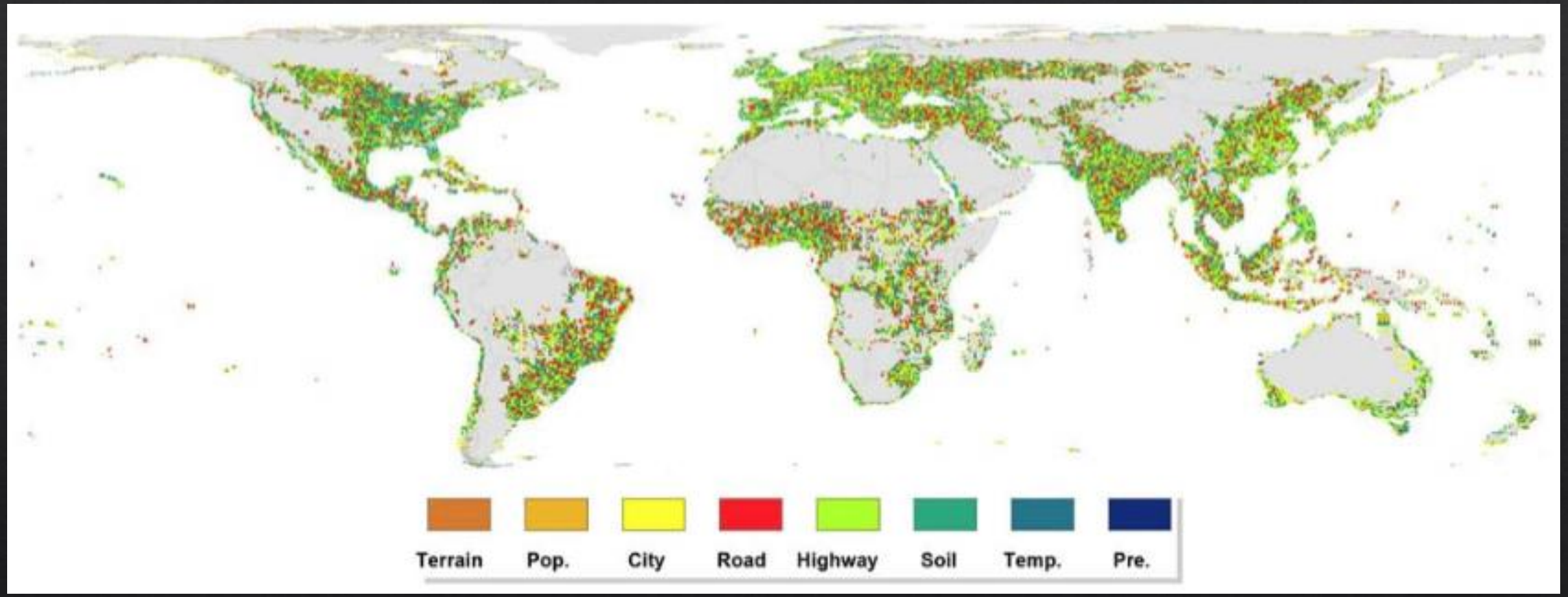


RCP: 8.5

Model performance for primary types



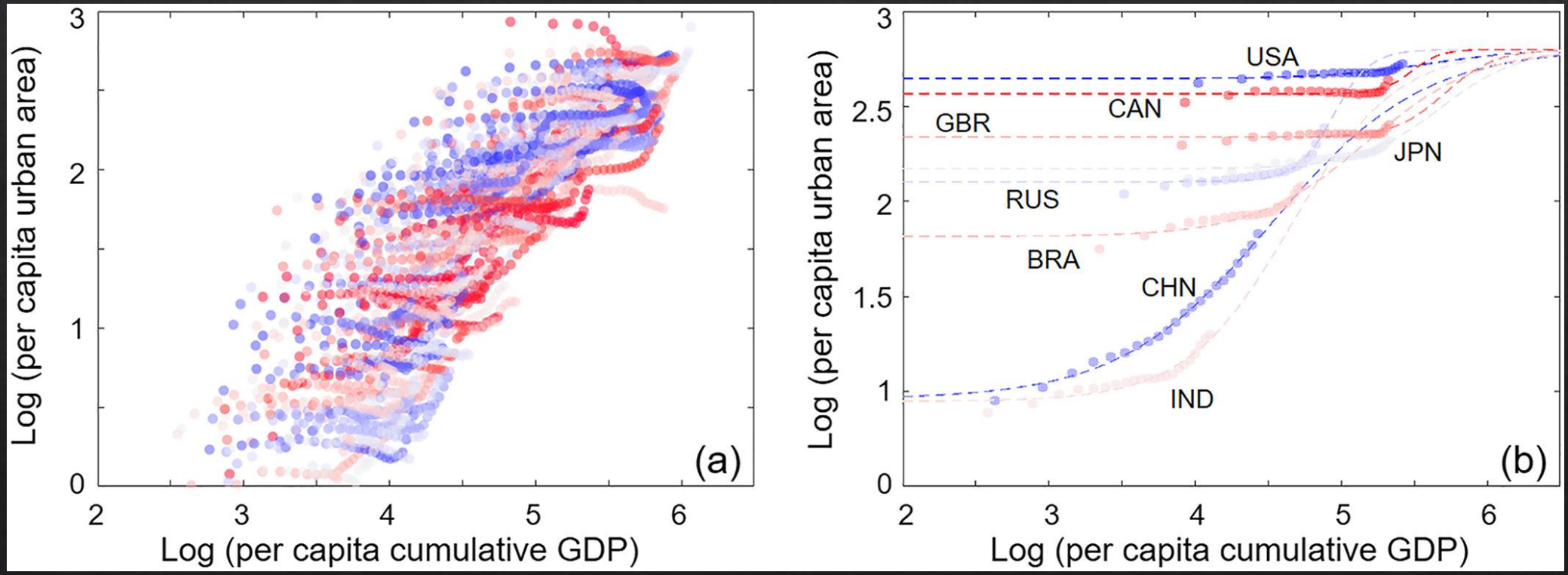
Analysis of spatial variables in each 0.5 ˚ extent



- The most important variable in each 0.5 ° extent
- Traffic is the most important variables to explain the spatial pattern of urban

A recent work of urban area projection

- Use more than 20 years continuous observations of urban extent (from NTL)

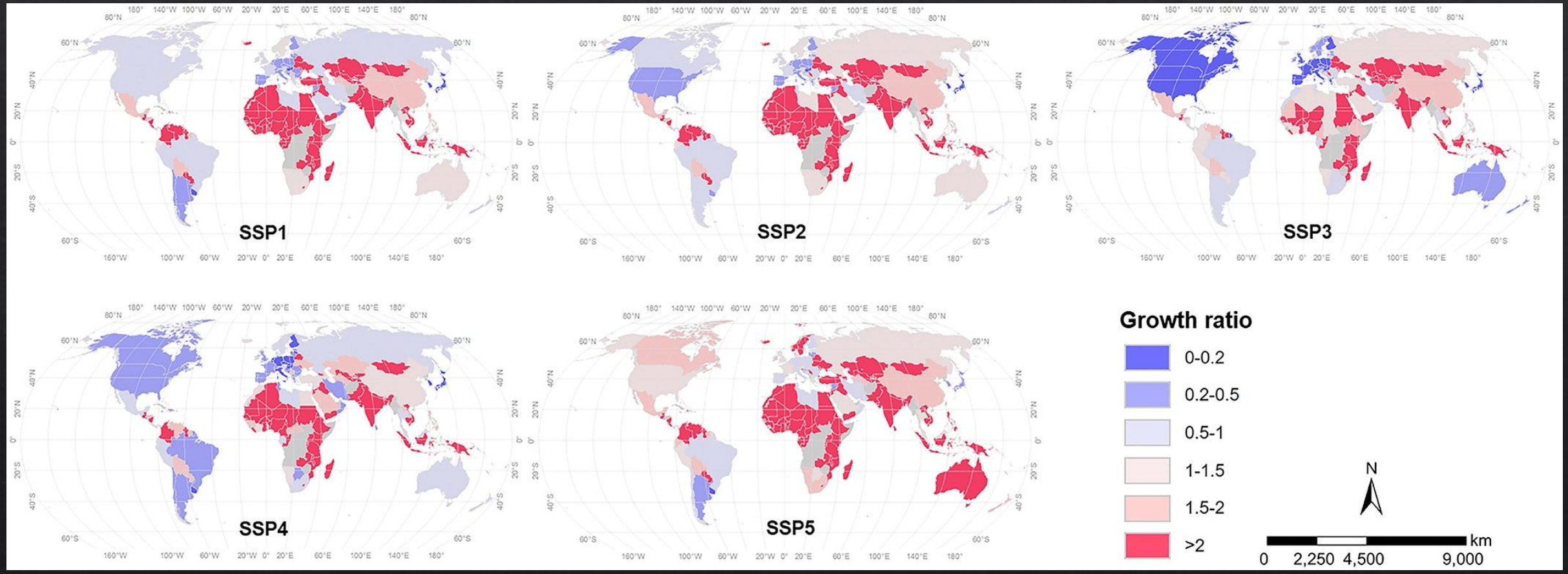


The relationship between per capita urban areas and per capita cumulative gross domestic product (GDP) for all countries in the world (a) and for representative countries that rank high regarding the urban area in 2013 (b).

Li et al., 2019

A recent work of urban area projection

Download link: https://figshare.com/articles/Global_urban_area_projection_under_five_SSPs/7817624/1



Urban area growth ratio (compare to 2013) at the country level by 2100 under five Shared Socioeconomic Pathways (SSPs).

Discussion

- ❖ Built the fine-scale modeling framework for global scale application
- ❖ The mapped datasets can be potentially used in future climate studies
- ❖ More and more high-spatial and temporal resolution urban extent data are available to support future modeling of urban extent

Download link:
https://figshare.com/articles/A_cellular_automata_downscaling_based_1_km_global_land_use_datasets_2010_2100_/9943688