UN GEONOW 2024
首届联合国地信周

11 SUSTAINABLE CITIES AND COMMUNITIES

Assessing Urban Sustainability using SDG11.3.1 Land Use Efficiency Indicator

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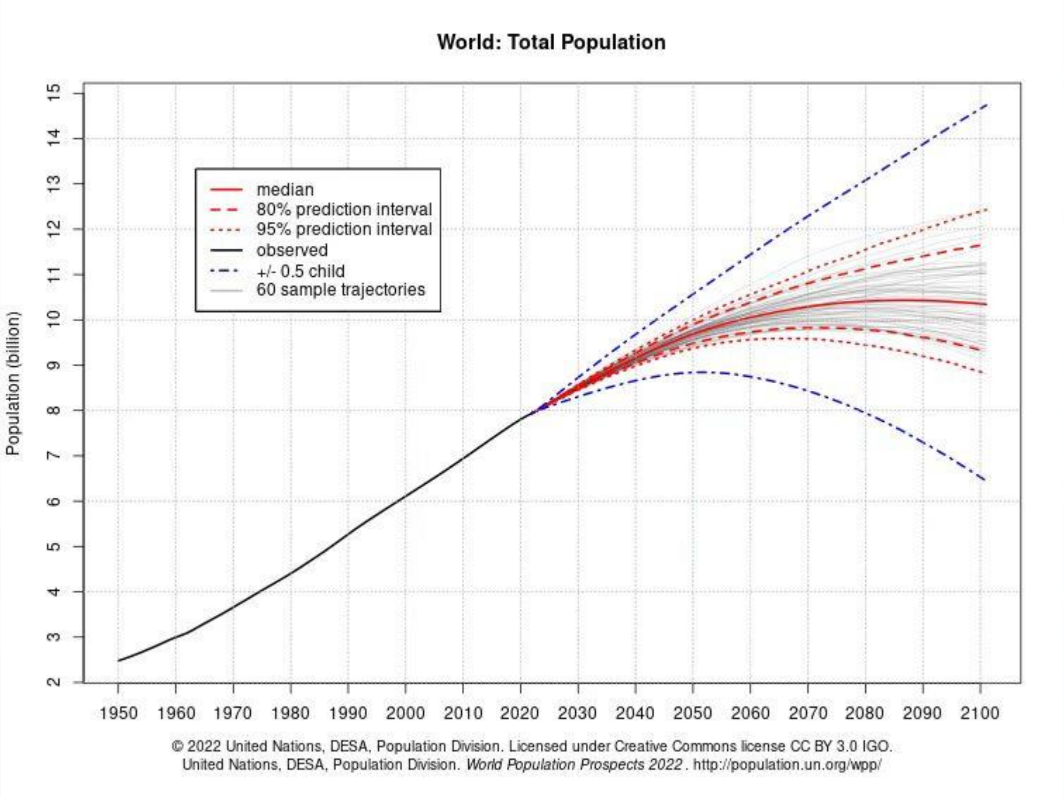
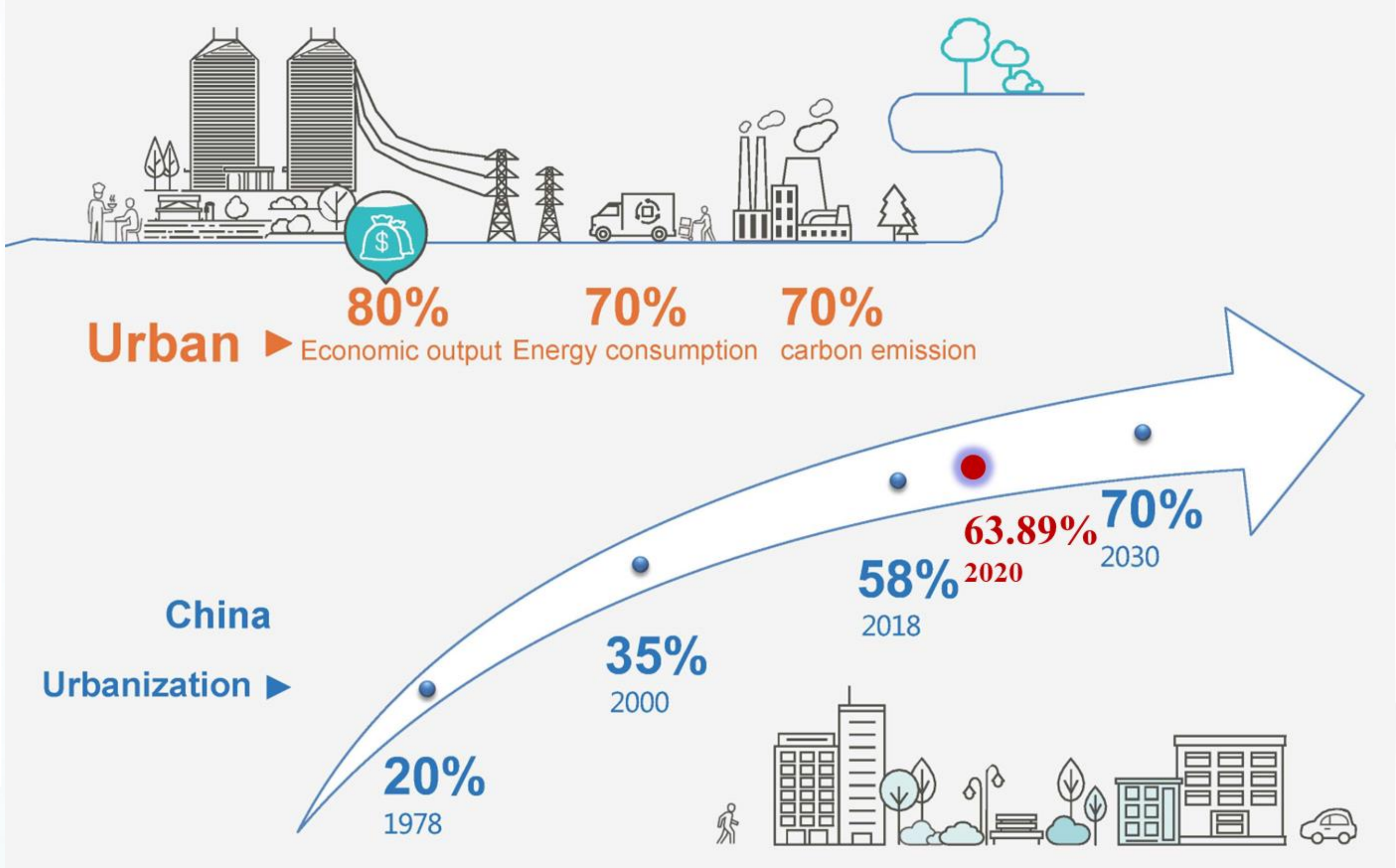
Outlines

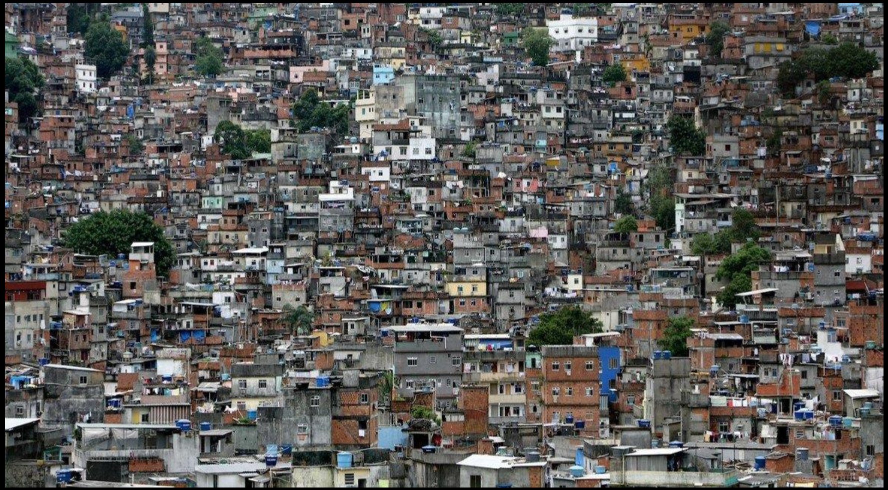
1. Background
2. Assessing Urban Sustainability using SDG11.3.1 Indicator
3. What we can do next for SDG 11

Background| Urbanization Prospect in China (1978 -2030)



World Urbanization Prospects, 2022





Slum

Traffic congestion

Urban expansion

Urban waterlogging

Air pollution

Inadequate freshwater supply

Background| The three actions proposed by the UN in 2015

Earth observation technology can play an important role in monitoring and evaluating SDGs

SUSTAINABLE DEVELOPMENT GOALS

Sustainable Development
UN SDGs

Measuring Status & Progress

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Climate Action
Paris Agreement

Monitoring & Understanding

SENDAI FRAMEWORK
FOR DISASTER RISK REDUCTION 2015-2030

Disaster Risk Reduction
Sendai Framework

Supporting Resilient Infrastructure

GEO GROUP ON EARTH OBSERVATIONS

Engagement Priorities

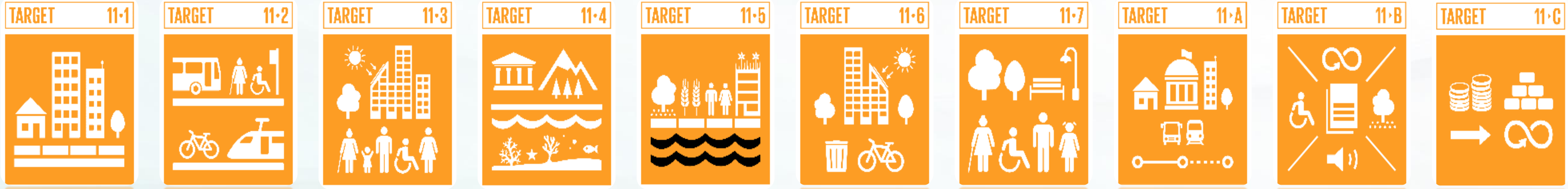
Resilient Cities & Human Settlements

Background| SDG11 Sustainable Cities and Communities

SUSTAINABLE DEVELOPMENT GOAL 11

Make cities and human settlements inclusive, safe, resilient and sustainable

SDG11 is central to achieving all 17 SDGs



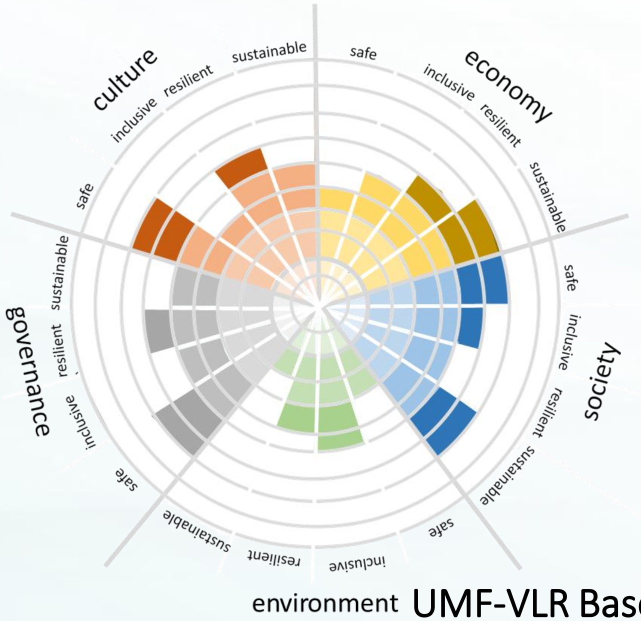
Tier I：11 indicators; Tier II：4 indicators; 1 indicator was deleted（2024.3）

Targets	Indicators	Lead Agency	Tier
11.1 Housing	11.1.1 Proportion of urban population living in slums, informal settlements, or inadequate housing	UN-Habitat	Tier I
11.2 Transport	11.2.1 Proportion of population that has convenient access to public transport	UN-Habitat	Tier I
11.3 Land Use and Planning	11.3.1 Ratio of land consumption rate to population growth rate	UN-Habitat	Tier I
	11.3.2 Proportion of cities with direct participation of civil society in urban planning and management	UN-Habitat	Tier II
11.4 Cultural and Natural Heritage	11.4.1 Total expenditure per capita on preservation, protection, and conservation of all cultural and natural heritage	UNESCO-UIS	Tier II
11.5 Disaster Risk and Prevention	11.5.1 Disaster mortality rate	UNDRR	Tier I
	11.5.2 Direct economic loss in relation to global GDP caused by disasters	UNDRR	Tier I
	11.5.3 (a) Damage to critical infrastructure and (b) disruption of basic services due to disasters	UNDRR	Tier I
11.6 Environmental Impact	11.6.1 Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated	UN-Habitat	Tier I
	11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities	WHO	Tier I
11.7 Public Space	11.7.1 Average share of the built-up area of cities that is open space for public use for all	UN-Habitat	Tier I
	11.7.2 Proportion of persons victimized by physical or sexual harassment in the previous 12 months	UNODC	Tier II
11.a Urban and Regional Development	11.a.1 Proportion of cities with urban and regional development plans integrating population projections and resource needs	UN-Habitat	Tier I
11.b Disaster Risk Reduction and Climate Change Adaptation	11.b.1 Number of countries that adopt and implement national disaster risk reduction strategies	UNDRR	Tier I
	11.b.2 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national strategies	UNDRR	Tier II
~~11.c Financial and Technical Assistance~~	~~11.c.1 Proportion of financial support to the least developed countries to construct and retrofit sustainable, resilient, and resource-efficient buildings utilizing local materials~~	~~UN-Habitat~~	~~Tier III~~

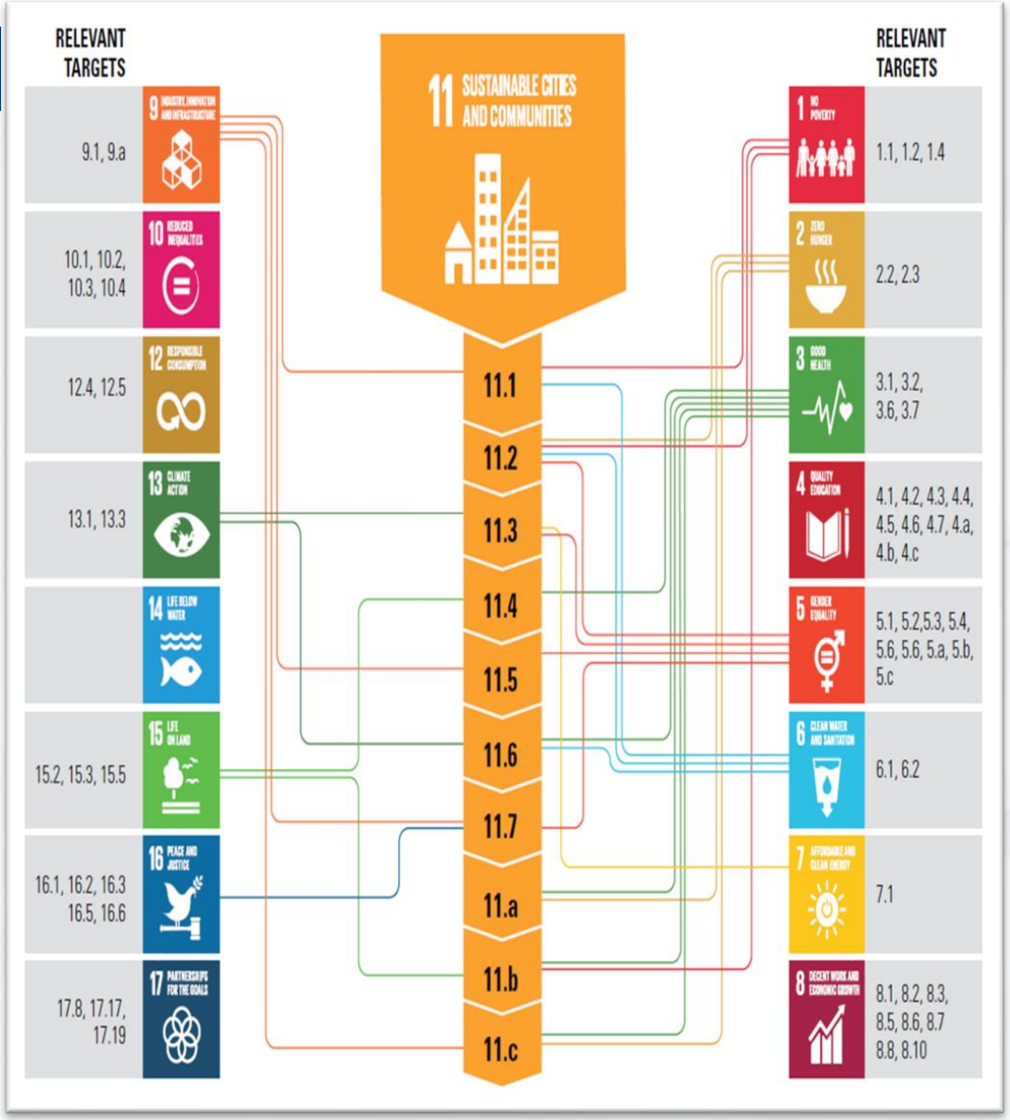
Background| SDG11 Sustainable Cities and Communities

Challenges in monitoring and evaluating SDG11 indicators

- SDG 11 indicator system incomplete and facing dynamic changes;
- Data gap still exists, Big Earth Data supporting SDG 11 space monitoring not fully utilized;
- Inter-linkage and inter-connectivity with other SDGs creating complex relationship;
- Individual indicator monitoring and single-scale evaluation are limited.



UMF-VLR Baseline



Interconnections between SDG11 and other SDGs

Outlines

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Background | SDG11.3.1 Urban Land Use Efficiency

TARGET 11·3

11.3：By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.3.1 ：Ratio of land consumption rate to population growth rate (Tier I)

1. Population Growth rate（*PGR*）

$$PGR = \frac{LN(Pop_{t+n}/Pop_t)}{(y)}$$

Pop_t is the total population within the urban area/city in the past/initial year

Pop_{t+n} is the total population within the urban area/city in the current/final year

y is the number of years between the two measurement periods

2. Land Consumption Rate（*LCR*）

$$LCR = \frac{LN(Urb_{t+n}/Urb_t)}{(y)}$$

Urb_t is total built up area in past year(unit: km^2)

Urb_{t+n} is total built up area in current year

y is the number of years between the two measurement periods

$$LCRPGR = \left(\frac{\text{Land Consumption rate}}{\text{Population growth rate}}\right) = \left(\frac{LCR}{PGR}\right)$$

UN-HABITAT

① This existing indicator has clear method but lacks data support (mainly urban built-up area), and it is difficult to solve the spatiotemporal coupling problem between built-up area and population data in urban areas

② The method only considers the relationship between the expansion of built-up area and population growth, and the dimension of economic growth is not included to describe the urbanization process comprehensively and accurately

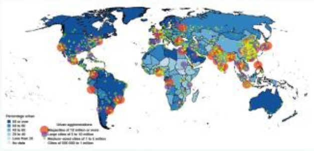
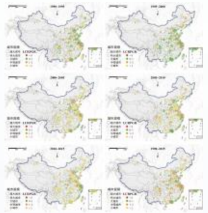
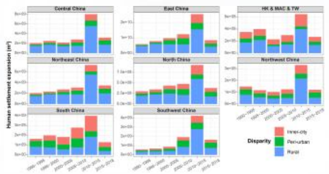
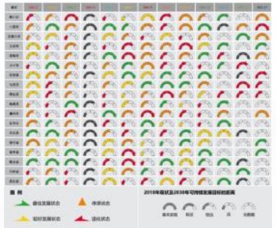
SDG11 | Research Framework for SDG11.3.1 indicator

- **Research Framework**

Full Chain + Systematization

Resolving the insufficient data for long time series monitoring

Resolving the multidimensional and comprehensive assessment

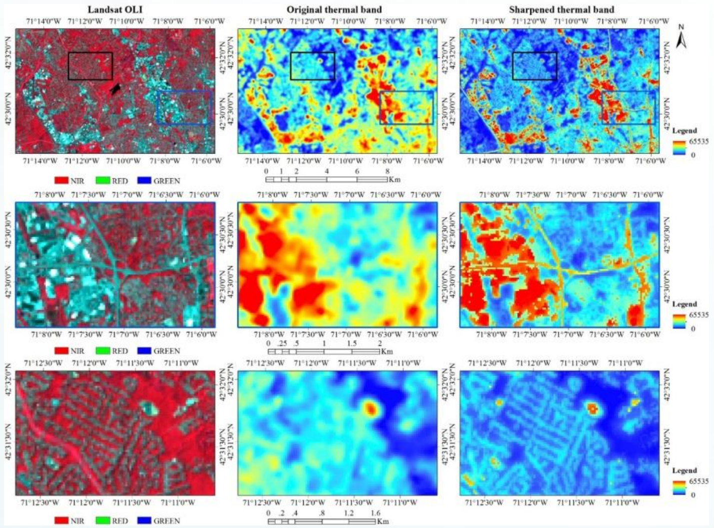
Method model	Datasets	Monitoring & Evaluation	Simulation & Prediction	Interactions among SDGs	Comprehensive Assessment
 High-resolution ISA mapping method	 Urban built-up areas datasets	 Urban land use efficiency	 Predict ULUE sustainability	 Carbon stock & urban rural expansion	 SDG progress in Hainan province
1	2	3	4	5	6

- In order to resolve the lack of data and lack of multidimensional assessment results of SDG11.3.1, we have carried out systematic and full-chain research works, including remote sensing monitoring methodologies, data products, single indicator monitoring and projection, as well as interaction and comprehensive assessment of SDG11 indicators

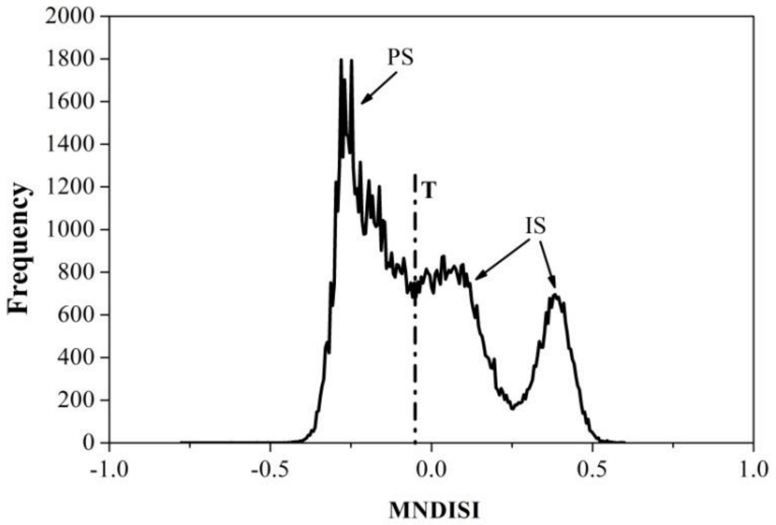
- Methods models
- Data products
- Indicator monitoring
- Scenario forecast
- Indicator interaction
- Compre. Eval. decision support

□ Propose a Modified Normalized Difference Impervious Surface Index (MNDISI)

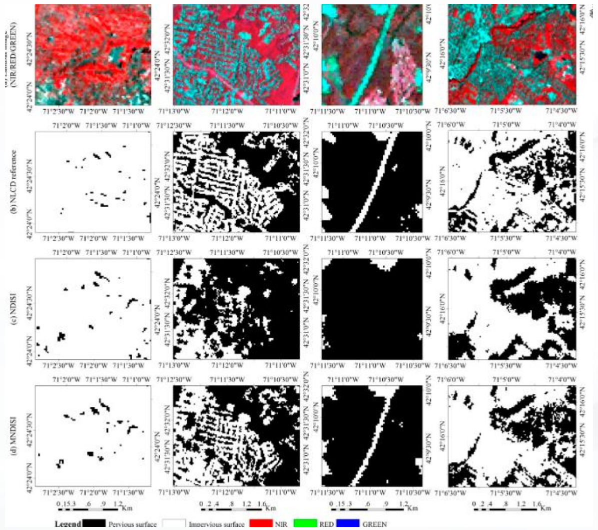
- MNDISI is proposed based on Landsat imagery by sharping of TIR band, which can effectively solve the problem of spectral similarity between impervious surface and bare soil, as well as improve the accuracy of impervious surface extraction and spatial details in low-density areas.
- A generalized Gaussian-based automatic threshold selection method is proposed to automatically identify the optimal threshold to segment impervious surfaces from other land covers in the MNDISI image.



Sharpening of TIR band



Automatic threshold selection



Comparison of Extraction Results

Sun Zhongchang, Wang Cuizhen, Guo Huadong, Shang Ranran. A modified normalized difference impervious surface index (MNDISI) for automatic urban mapping from Landsat imagery, ***Remote Sensing***, 2017, 9(9), 942.

SDG11 | Devised Extraction Methods for Urban Environmental Factors for SDG

Methods models

Data products

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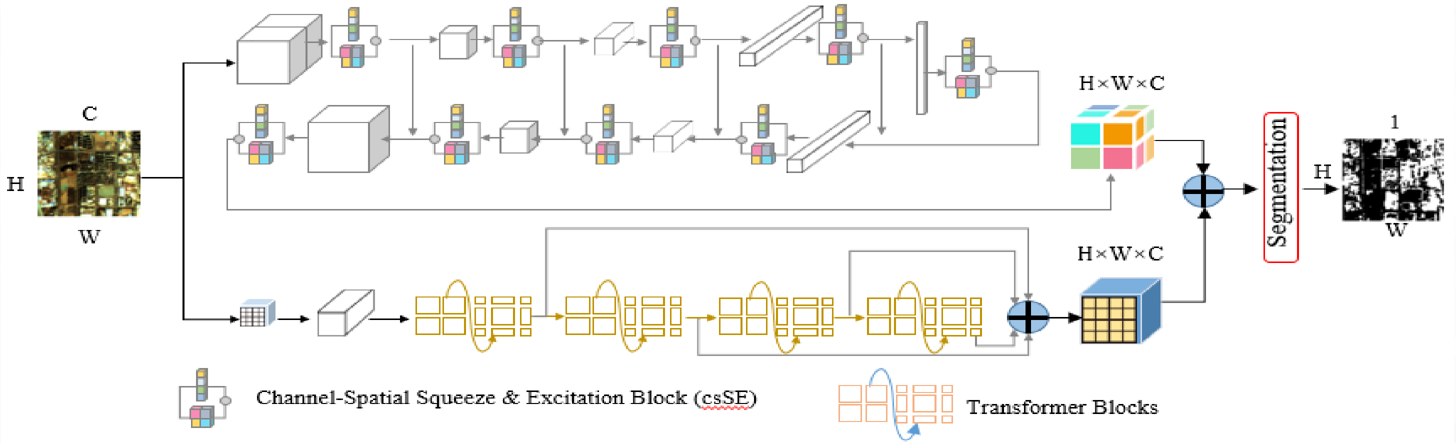
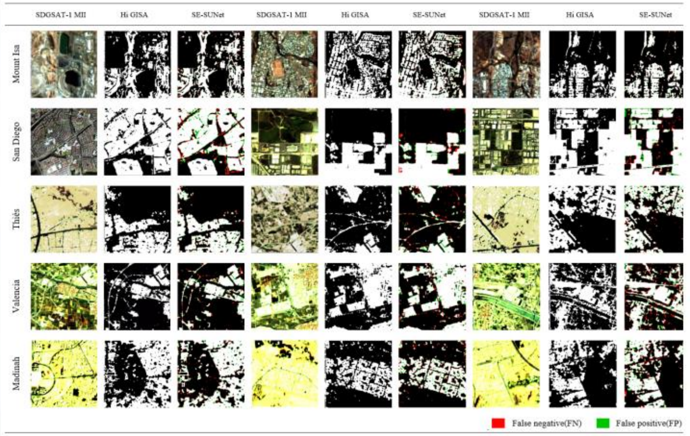
☐ Constructing Deep Learning model for impervious surface extraction

- In our studies, some deep learning models (ResNet+SPP-net, SE-SUNet et al.) were improved and applied for the extraction of urban environmental elements such as impervious surfaces and public open spaces.
- For example, we proposed a novel dual-branch network model, the Multi-stage Competitive Attention Integrated Hierarchical Network (SE-SUNet) to extract impervious surfaces from SDGSAT-1 imagery. SE-SUNet demonstrates a robust capability in accurately segmenting extensive bare land and scattered impervious surfaces in arid and semi-arid areas.

Building SE-SUNet deep learning model to extract urban impervious surface from SDGSAT-1 imagery





- Sijia Li, **Zhongchang Sun***, Zongqiang Liu et al. SE-SUNet: A Multi-Stage Competitive Attention Network for Impervious Surface Extraction in Arid and Semi-Arid Regions Based on SDGSAT-1 Imagery. ***Remote Sensing of Environment***, 2024. (Under review)
- Wu Mengfan, Zhao Xiangwei, **Sun Zhongchang***, and Guo Huadong. A Hierarchical Multiscale Super-Pixel-Based Classification Method for Extracting Urban Impervious Surface Using Deep Residual Network from WorldView-2 and LiDAR Data. ***IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing***, 2019, 12(1), 210-222.

SDG11 | Devised Extraction Methods for Urban Environmental Factors for SDG

Methods models → **Data products** → **Indicator monitoring** → **Scenario forecast** → **Indicator interaction** → **Compre. Eval. decision support**

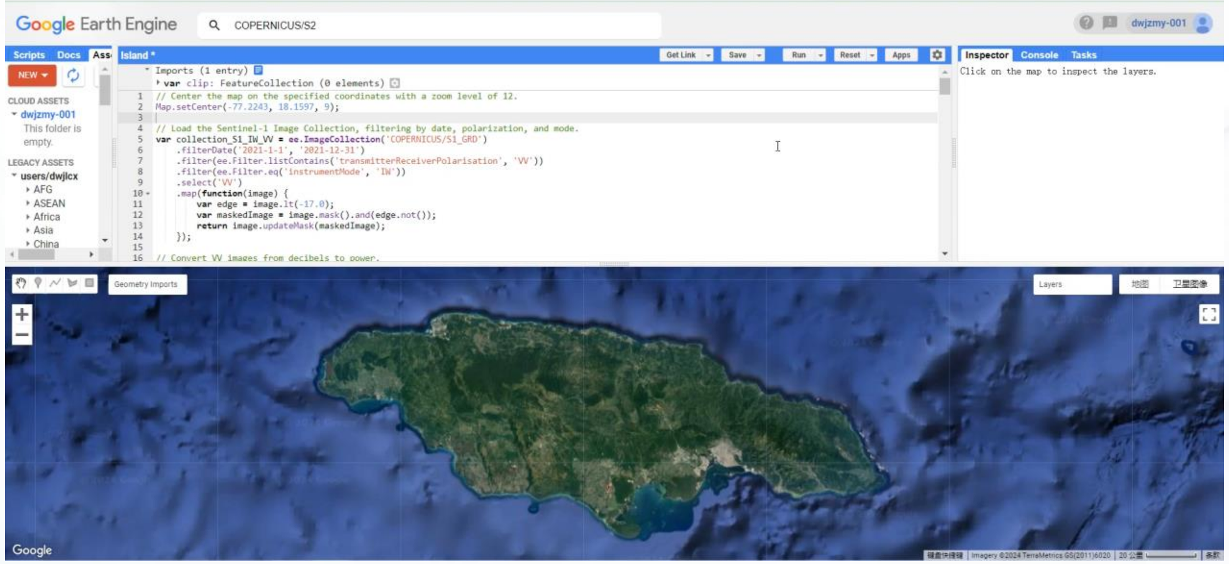
☐ Global impervious surface mapping and rapid updating method

- **Data Sources:** Primarily used Sentinel-1 (S1) and Sentinel-2A (S2A) imagery.

- **Threshold Setting:**
Histogram statistical analyses were performed on the Google Earth Engine (GEE) platform to determine the thresholds for backscatter values and normalized vegetation index (NDVI).

- **Multi-temporal phase change detection**
Independent supervised classification of S1 and S2A data for the year 2021 was performed using the Support Vector Machine (SVM) algorithm. Dynamic Time Warping (DTW) technique was introduced to analyze the time series patterns of different years and detect regions of significant changes.

- **Accuracy Assessment**
Confusion matrix analysis; block-level validation.



- **Sun, Z.**, Du, W., Li, S., Yang, M., Ouyang, X., & Guo, H. A Rapidly Update Mapping Method for High-Resolution Global Impervious Surface Area (Hi-GISA) Product. ***Science Bulletin***, 2024 (2nd Under Review).
- **Zhongchang Sun**, Du Wenjie, Huiping Jiang, et al. Global 10-m impervious surface area mapping: A big earth data-based extraction and updating approach. ***International Journal of Applied Earth Observation and Geoinformation***, 2022, 109: 102800.

SDG11 | Developed Data Products that Target the Demand of SDG11

- Methods models
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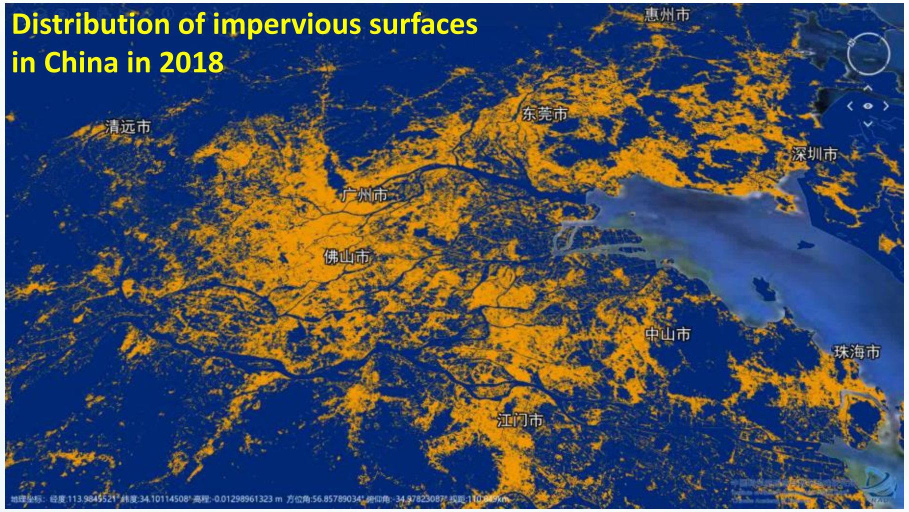
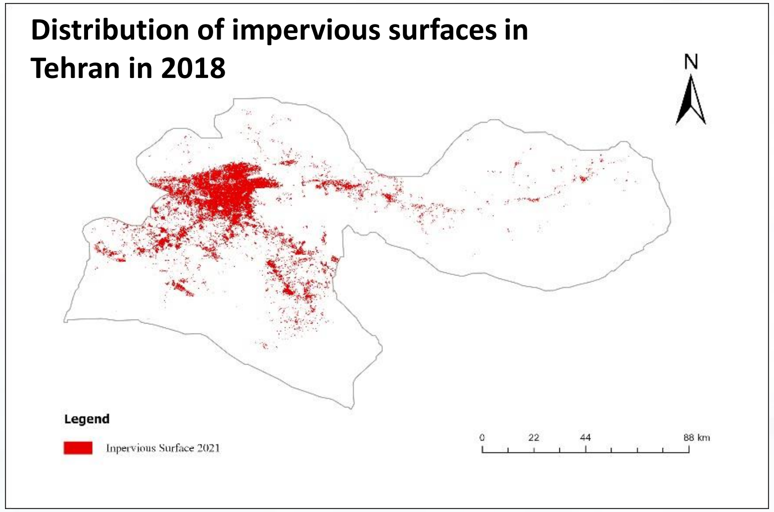
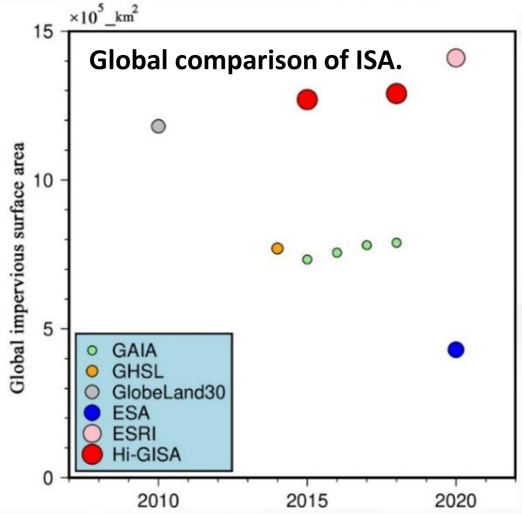
□ Hi-resolution Global Impervious Surface Area (Hi-GISA) products

- Hi-GISA products from 2015 to 2021 (updated every three years) with 10-meter spatial resolution were produced. The overall accuracy of our products are great than 86.00%.
- Using our data products, an online calculation tool for SDG 11.3.1 land use efficiency indicator has been developed based on the Big Earth Data Cloud Service Platform, providing data and technological support for monitoring and evaluating SDG 11.3.1.







- **Zhongchang Sun**, Du Wenjie, Huiping Jiang, et al. Global 10-m impervious surface area mapping: A big earth data-based extraction and updating approach. ***International Journal of Applied Earth Observation and Geoinformation***, 2022, 109: 102800.

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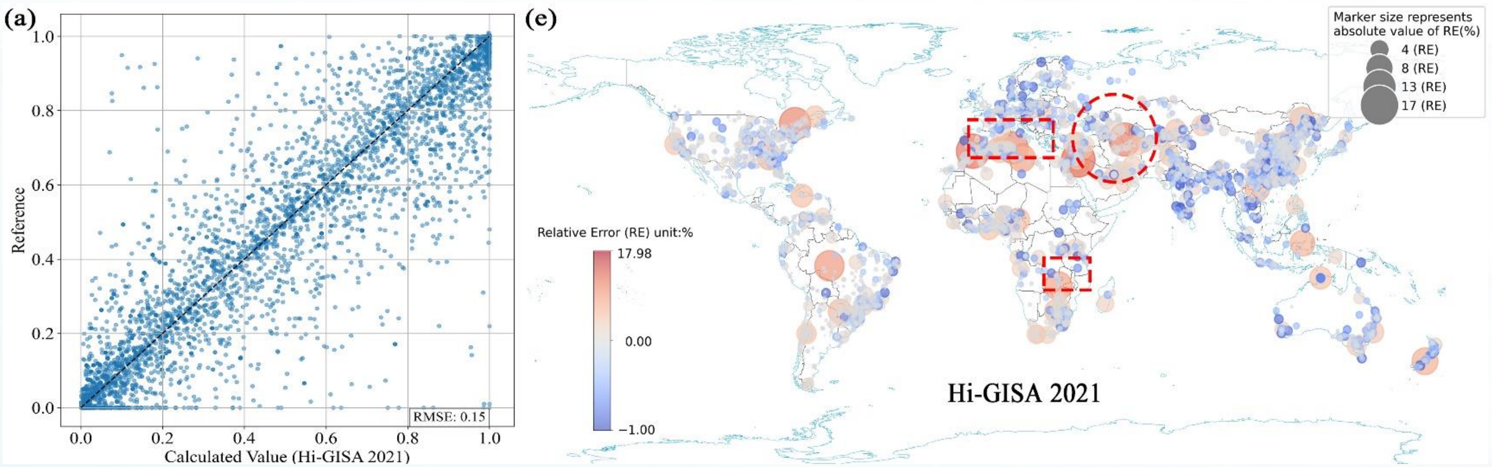
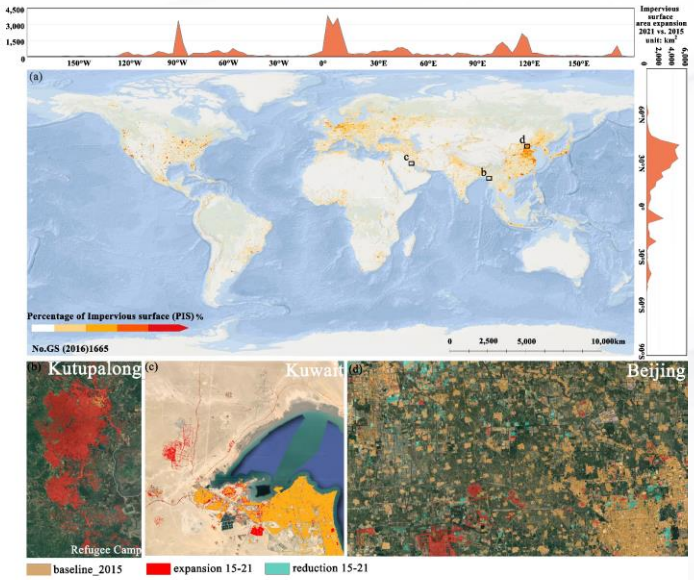
☐ Hi-resolution Global Impervious Surface Area (Hi-GISA) products

- The global impervious surface area is 1.32 million km² in 2021, an increase of about 50,000 km² from 2015;
- This study significantly improves the precision and data accuracy of urban change monitoring by integrating data from multiple sources, optimises the validation process, improves the accuracy of spatial distributions and the consistency of the time series, and enhances the usefulness of Hi-GISA in SDG monitoring and analysis.



Block-Level Validation and Spatial Error of Impervious Surface Area Product



- **Sun, Z.**, Du, W., Li, S., Yang, M., Ouyang, X., & Guo, H. A Rapidly Update Mapping Method for High-Resolution Global Impervious Surface Area (Hi-GISA) Product. ***Science Bulletin***, 2024 (2nd Under Review).

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☐ Built-up areas dataset of global major cities

Data conversion (UN-Habitat, 2019)

① We first linked areas of urban patches that had an area of 200,000 square meters or more and that were less than 200 meters apart to form a continuous main urban area

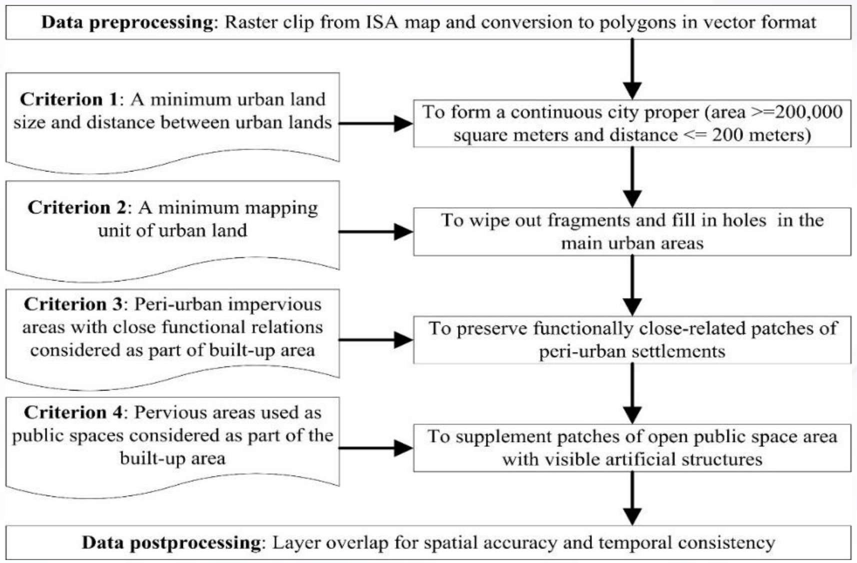
② Any polygons with an area of less than 57,600 square meters were eliminated from the vector products derived from the UISA map and 'holes' with areas of less than 200,000 square meters lying inside the main urban area were filled to preserve the continuous distribution pattern

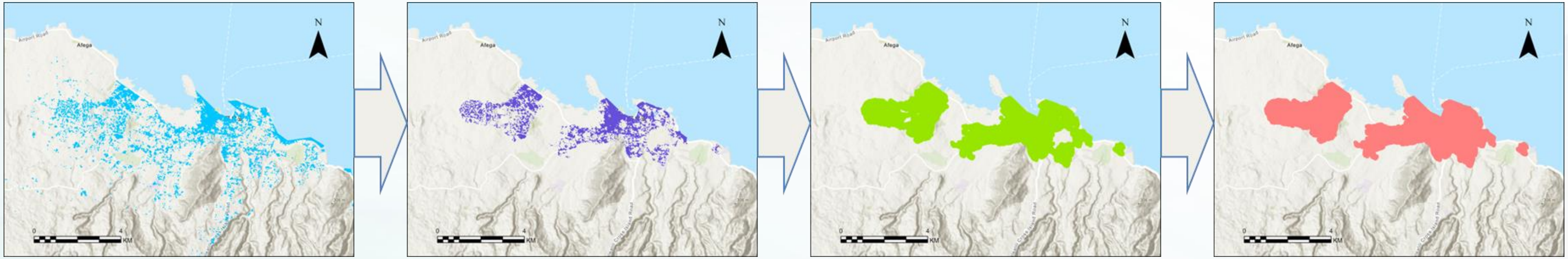
③ We also preserved the peri-urban patches that had close functional relations with the main urban area to improve the accuracy of the extent of built-up area

④ Aided by the high-resolution Google Earth images, we chose to locate manually the park and greenbelt patches that contained visible artificial structures and merged these newly added polygons into the main urban area to generate a built-up area that satisfied certain criteria

A GUIDE TO ASSIST NATIONAL AND LOCAL GOVERNMENTS TO MONITOR AND REPORT ON SDG GOAL 11+ INDICATORS

MONITORING FRAMEWORK - DEFINITIONS - METADATA - UN-HABITAT TECHNICAL SUPPORT





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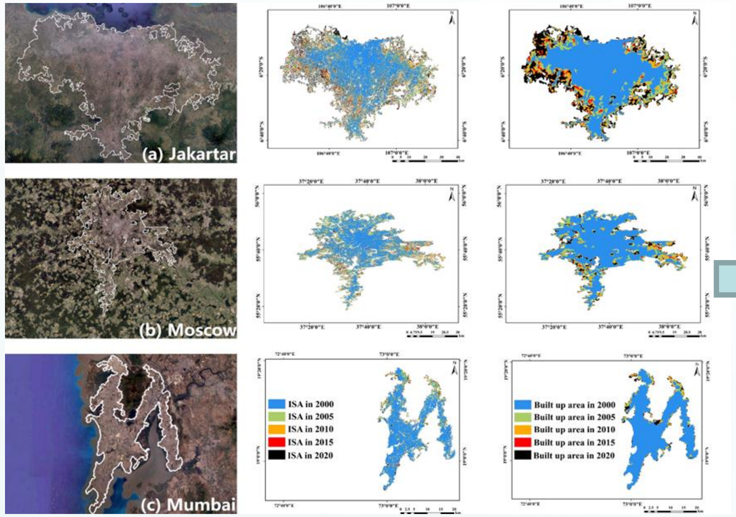
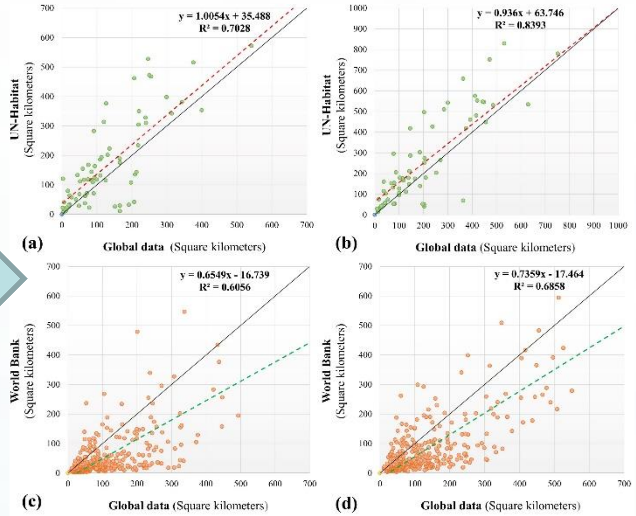
Built-up areas dataset of global major cities

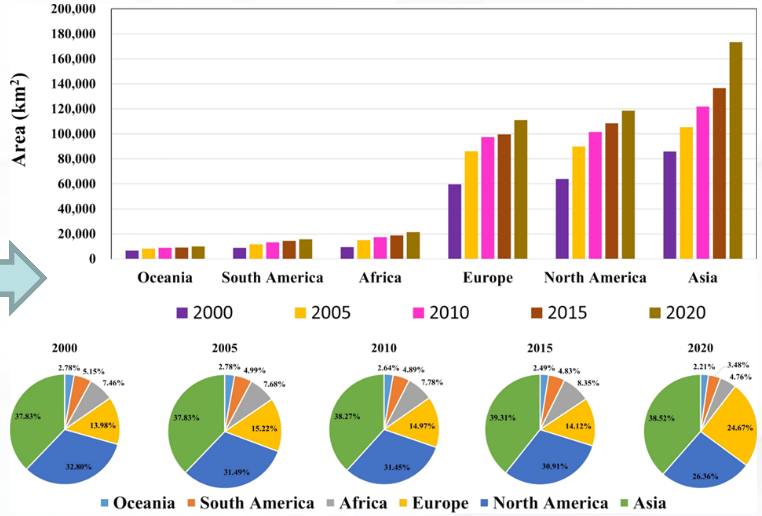
- With reference to the UN-Habitat standard, the automatic conversion from urban impervious surfaces to built-up areas has been realized.
- A built-up areas dataset of more than 1,700 global major cities (population greater than 300,000) from 1990 to 2020 (interval of 5 years) has been produced.



Impervious surface to built-up area



Validation against other data products



The proportion and change of the built-up area in each continent from 2000 to 2020

- The report named ***Big Earth Data in support of Sustainable Development Goals*** (2022).
- Jiang, H., **Sun, Z.***, Guo, H., Xing, Q., Du, W., & Cai, G. A Standardized Dataset of Built-up Areas of China's Cities with Populations over 300,000 for the Period 1990–2015. ***Big Earth Data***, 2021, 6(1), 103-126.

SDG11 | Monitoring, Assessment, and Projection of SDG 11.3.1 Indicator

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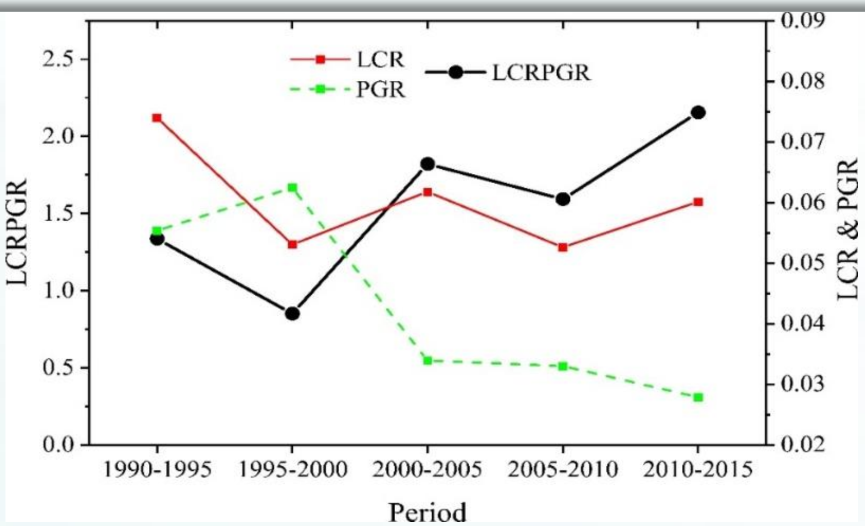
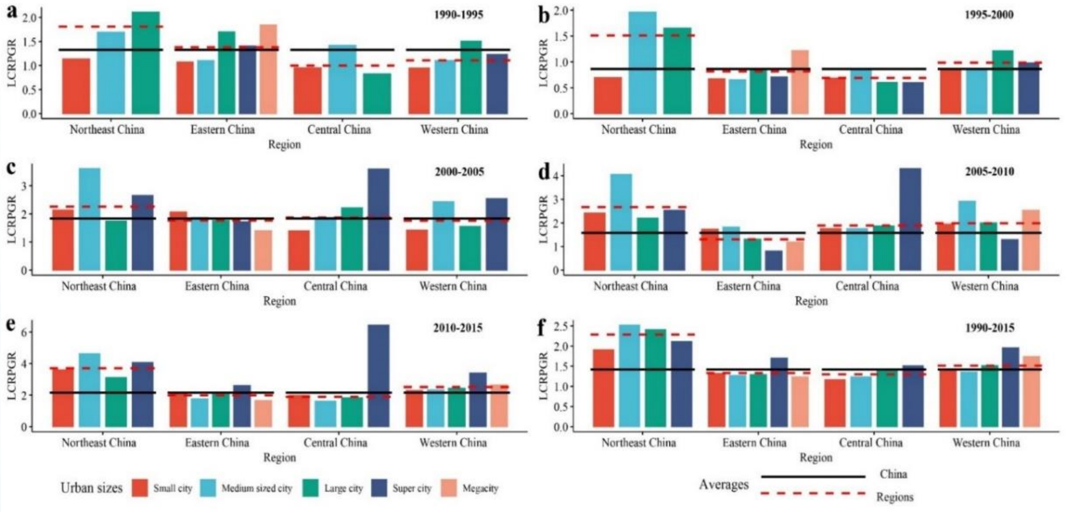
☐ An assessment of urbanization sustainability in China using land use efficiency indicators

- A new evaluation indicator of "the ratio between economic growth rate and land use rate (EGRLCR)" is proposed. Combined with LCRPGR, the dynamics and the process of urbanization in China is conducted from 1990 to 2015 from the three dimensions of economy, society and environment.
- Since 1990, the value of LCRPGR rose from 1.33 between 1990 to 1995 to 2.15 between 2010 to 2015; after 2015, the expansion of urban built-up areas has been slowing down; but coordinated development of urbanization still faces challenges.



Changes in LCRPGR for Chinese cities from 1990 to 2015



Changes in LCRPGR of different regions and sizes in China for the period 1990-2015

- Huiping Jiang#, **Zhongchang Sun#**, Huadong Guo, Qihao Weng, et al. An assessment of urbanization sustainability in China between 1990 and 2015 using land use efficiency indicators. *npj Urban Sustainability*, 2021, 1:34. DOI: 10.1038/s42949-021-00032-y.
- Huadong Guo, Dong Liang, **Zhongchang Sun**, et al. Measuring and Evaluating SDG Indicators with Big Earth Data. ***Science Bulletin***, 2022.

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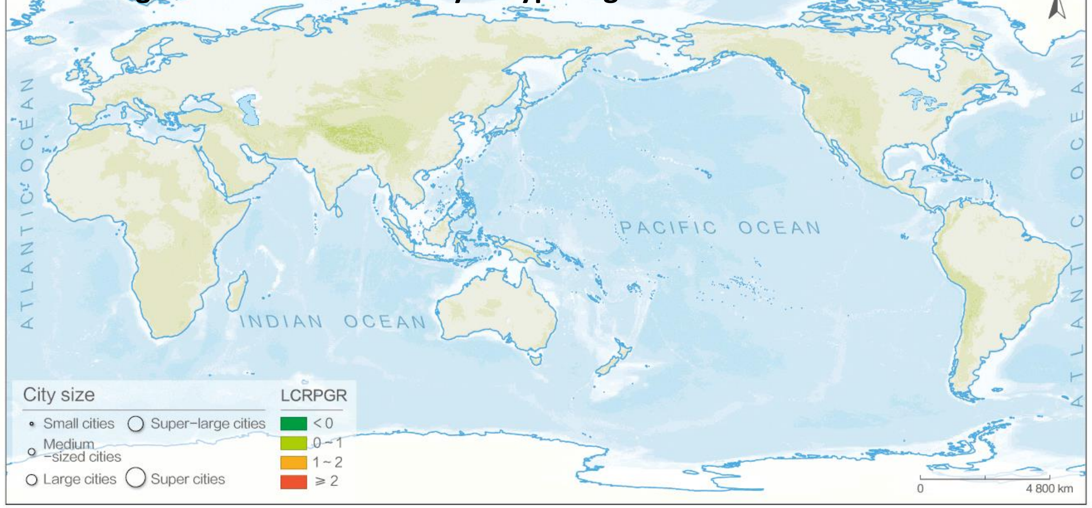
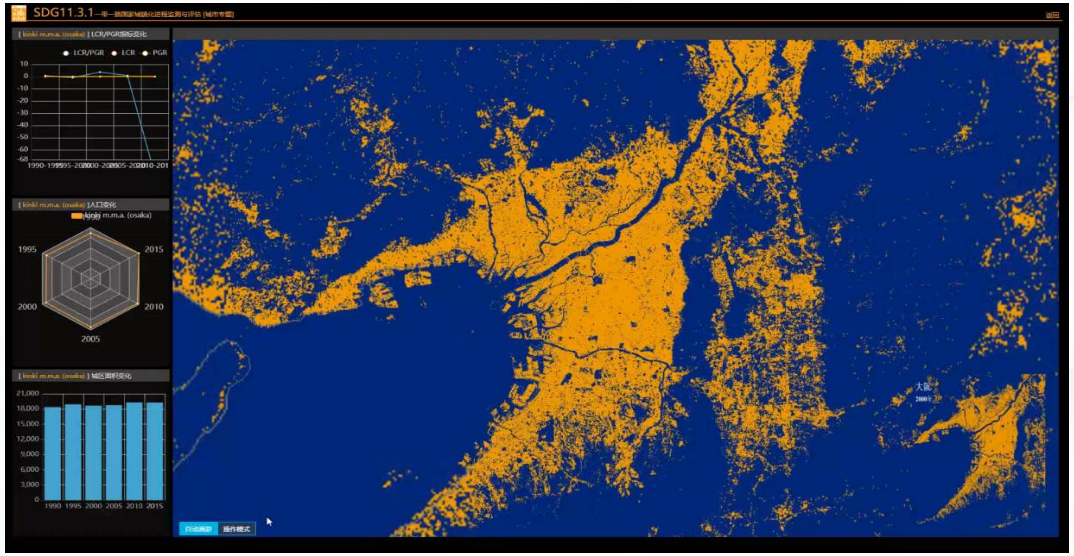
☐ Comprehensive assessment of global urban land use efficiency from 2000 to 2020

- The overall coordination of global urbanization development has improved. The urban land use efficiency indicator for global cities has decreased from 1.65 between 2000 and 2005 to 1.31 between 2015 and 2020. However, the rate of urban land expansion still exceeds the rate of urban population growth.
- There is a significant regional disparity in global urbanization, with the land urbanization rate in Europe being significantly faster than the urban population growth rate.

The changes in land use efficiency of typical global cities from 2000 to 2020.





- **Zhongchang Sun**, Sisi Yu, Huadong Guo, Cuizhen Wang, Zengxiang Zhang, and Ru Xu. Assessing 40 years of spatial dynamics and patterns in megacities along the Belt and Road region using satellite imagery. ***International Journal of Digital Earth***, 2021, 14(1):71-87.
- Huadong Guo, Fang Chen, **Zhongchang Sun**, et al. Big Earth Data: a practice of sustainability science to achieve the Sustainable Development Goals, ***Science Bulletin***, 2021, 66:1050-1053.

SDG11 | Monitoring, Assessment, and Projection of SDG 11.3.1 Indicator

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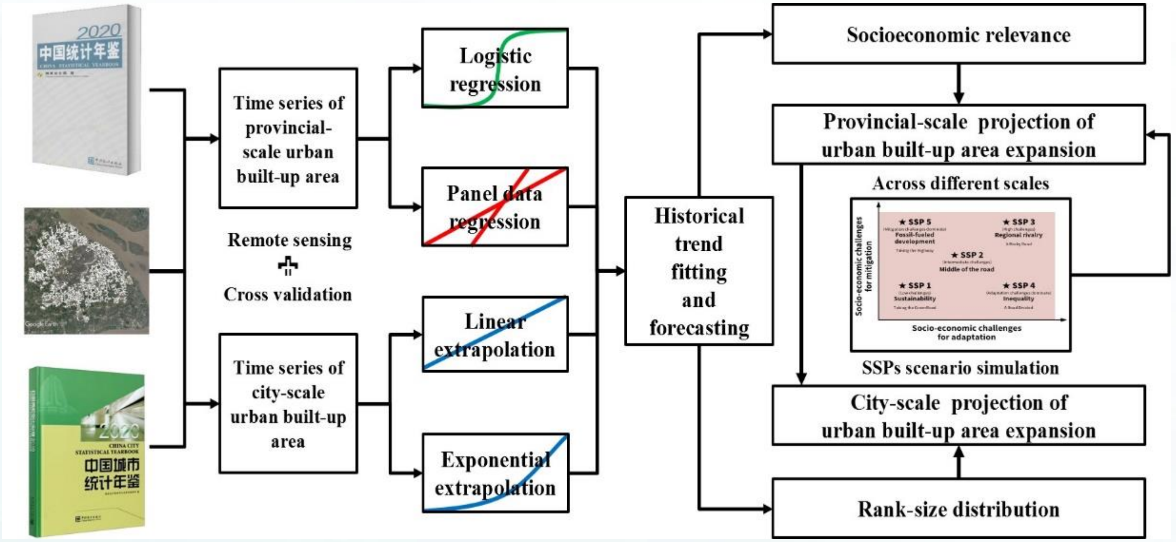
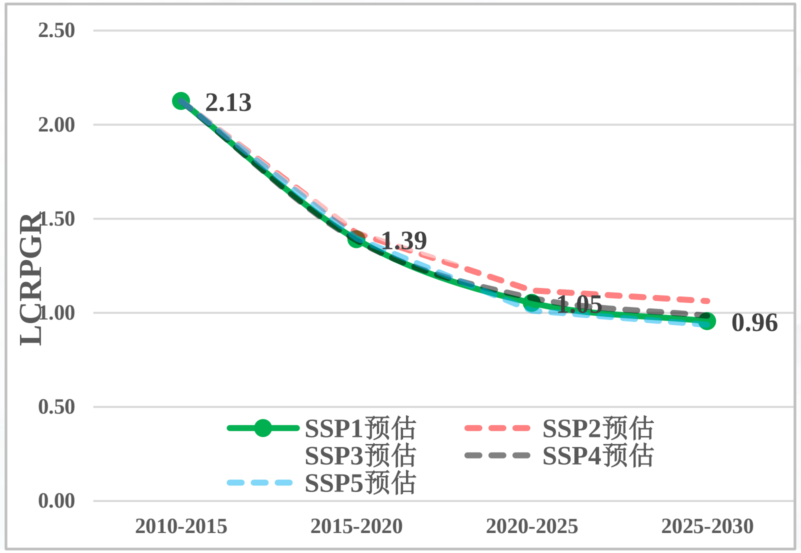
☐ Urbanization sustainability projection in China's cities through 2030

- Through logistic and panel data regression, as well as linear and exponential extrapolation, multi-scale projections of urban growth were generated based on the Shared Socioeconomic Pathways (SSPs) data, then it is used to evaluated and forecasted China's urbanization sustainability through 2030 using the land use efficiency indicator.
- Our results shown that the land use efficiency indicator in China is likely to decline as the logistic regression result indicates, and China's urbanization can achieve a more sustainable future under feasible scenarios.





- Jiang H, Guo H, **Sun Z***, Xing Q, Zhang H, Ma Y, Li S. Projections of urban built-up area expansion and urbanization sustainability in China's cities through 2030. ***Journal of Cleaner Production***, 2022, 367: 133086.

SDG11 | Interactions between SDG 11.3.1 Indicators and the other SDGs

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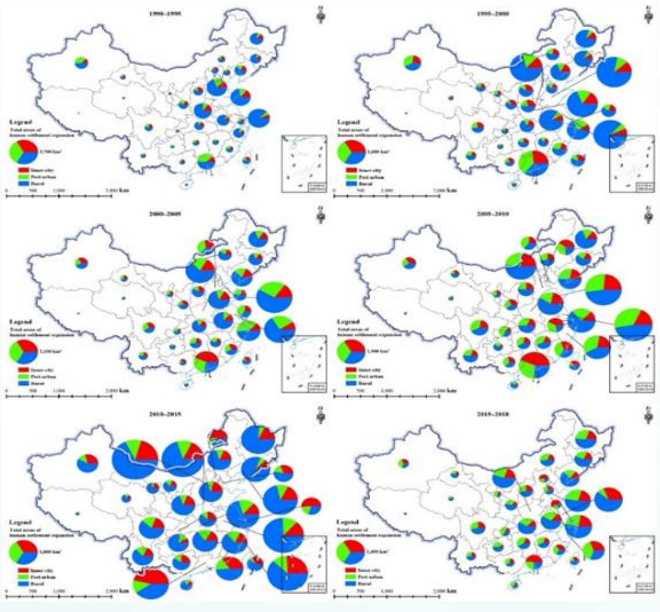
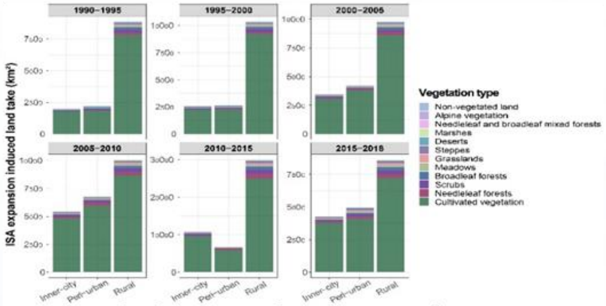
☐ Urban-rural disparities of carbon storage dynamics in China's human settlements

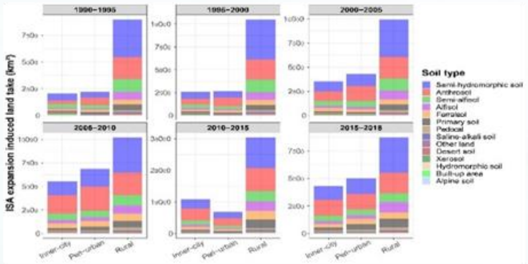
- To uncover urban-rural disparities of impervious surface area (ISA) growth and its direct impacts on carbon storage change, a unified assessment framework by incorporating satellite-derived products, soil sampling data, and official statistics was utilized
- To inform regional policy making for well-planned and eco-friendly human settlement expansion, the driving forces of urban-rural human settlement expansion disparities were also explored with correlation and regression models



Urban-rural composition of impervious surface area expansion at the provincial level



Land take along the urban-rural gradient caused by the conversion of different vegetation and soil types



Pearson's correlation between urban-rural human settlement growth and socioeconomic changes

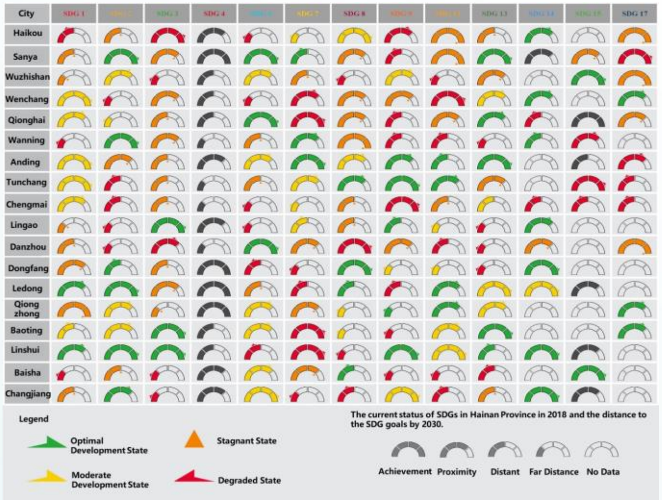
Period		UR	Pop_total	Pop_urban	Pop_rural	GDP	PI	SI	TI	FAI	CL
2000–2005	ISA_total	0.35	0.31	0.77***	−0.65***	0.86***	0.69***	0.88***	0.74***	0.91***	−0.01
	ISA_urban	0.28	0.47**	0.75***	−0.52**	0.93***	0.6***	0.93***	0.88***	0.89***	0.02
	ISA_rural	0.37*	0.17	0.72***	−0.68***	0.74***	0.69***	0.78***	0.58***	0.85***	−0.02
2005–2010	ISA_total	0.22	0.49**	0.76***	−0.4*	0.89***	0.69***	0.87***	0.82***	0.83***	−0.11
	ISA_urban	0.19	0.68***	0.86***	−0.28	0.95***	0.6***	0.91***	0.93***	0.76***	−0.23
	ISA_rural	0.22	0.23	0.58***	−0.49**	0.73***	0.71***	0.75***	0.63***	0.83***	0.04
2010–2015	ISA_total	0.11	0.29	0.66***	−0.65***	0.79***	0.66***	0.74***	0.76***	0.8***	−0.31
	ISA_urban	−0.03	0.42*	0.6***	−0.52**	0.9***	0.59***	0.83***	0.89***	0.78***	−0.14
	ISA_rural	0.19	0.2	0.66***	−0.69***	0.68***	0.66***	0.65***	0.63***	0.76***	−0.39*
2015–2018	ISA_total	0.05	0.27	0.56**	−0.63***	0.54**	−0.13	0.48**	0.57***	0.3	−0.11
	ISA_urban	0.01	0.42*	0.61***	−0.58***	0.62***	−0.07	0.52**	0.67***	0.35	−0.12
	ISA_rural	0.08	0.14	0.48**	−0.63***	0.44*	−0.17	0.41*	0.45*	0.24	−0.09

- Jiang H, Guo H, **Sun Z***, Yan X, Zha J, Zhang H, Li S. Urban-rural disparities of carbon storage dynamics in China's human settlements driven by population and economic growth. ***Science of the Total Environment***, 2023, 871, 162092.

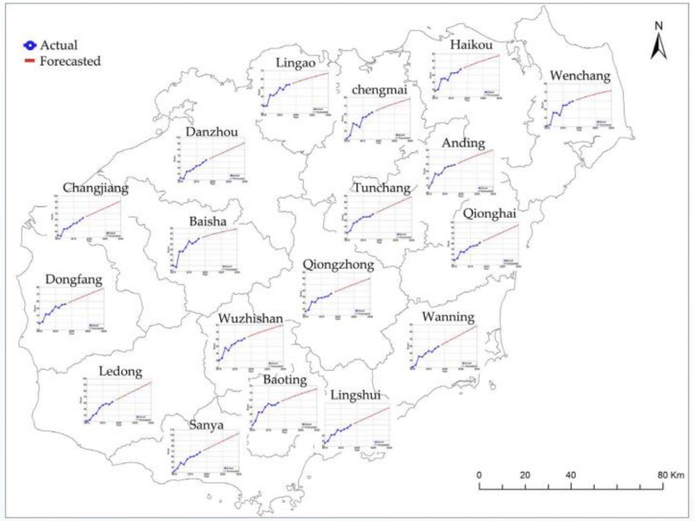
Methods models → Data products → Indicator monitoring → Scenario forecast → Indicator interaction → Compre. Eval. decision support

Integrated evaluation of urban sustainable development in Hainan Island

- Under the framework of SDG and UMF, SDG 11 indicator system was constructed at the county scale in Hainan Province, and a comprehensive assessment of 13 SDGs in 18 cities and counties was carried out.
- Our results showed that the overall urban sustainable development of Hainan Province was on the rise, and the average score increased from 55.59 in 2010 to 79.14 in 2018; the sustainable development of Hainan Province was characterized by "high in the north and low in the middle".



Status and progress table of SDG targets in Hainan Province in 2018



Predicted comprehensive score for 18 cities in Hainan province from 2019 to 2030.

Results incorporated into UN Habitat's "Cities of the Future and the New Economy: Green Innovation Drives Carbon Neutrality" report

- Sijia Li, **Zhongchang Sun**, Huadong Guo, Xiaoying Ouyang, Zongqiang Liu ,Huiping Jiang and Hongwei Li. Localizing Urban SDGs Indicators for an Integrated Assessment of Urban Sustainability : A Case Study of Hainan Province, ***International Journal of Digital Earth***, 2024, 17(1):2336059.

SDG11 | SDG 11 Integrated Assessment and Decision Support

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Writing and releasing Big Earth Data in Support of SDGs Reports

- The theory, method and science and technology innovation practice of monitoring and evaluation of urban sustainable development indicators supported by big earth data are constructed.
- The Big Earth Data in Support of SDGs Reports have been released by the Chinese Government for 5 consecutive years.

- Huadong Guo, Fang Chen, **Zhongchang Sun**, et al. Big Earth Data: a practice of sustainability science to achieve the Sustainable Development Goals, ***Science Bulletin***, 2021, 66:1050-1053.
- Huadong Guo, Dong Liang, **Zhongchang Sun**, et al. Measuring and Evaluating SDG Indicators with Big Earth Data. ***Science Bulletin***, 2022.
- Chunlin Huang, **Zhongchang Sun** *, Huiping Jiang , et al. Big Data for Sustainable Cities and Communities: Progress and Challenges. ***Proceedings of the Chinese Academy of Sciences***, 2021, 36 (8), 914-922.

Big Earth Data in Support of SDGs
(2019, 2020, 2021, 2022, 2023)

SDG11 | Data sharing and indicator online computing tool

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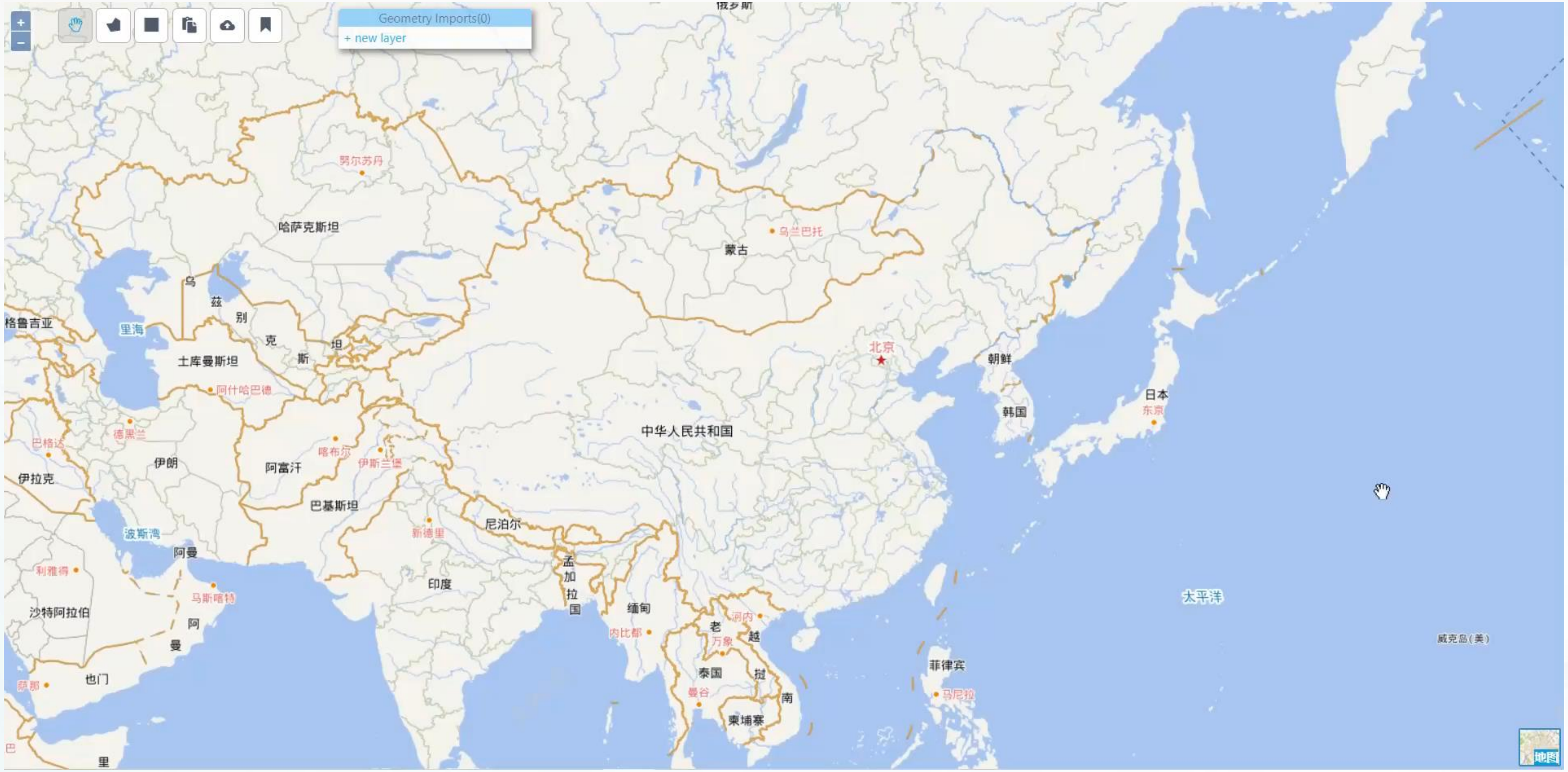

Developed online computing and processing toolkit for SDG11.3.1 based on SDG big data platform (http://earthdataminer.casearth.cn/app/sdg11.3.1indicator_en)

Outlines

1. Background
2. Assessing Urban Sustainability using SDG11.3.1 Indicator
3. What we can do next for SDG 11

What we can do next for SDG 11

We can address the Data Gap challenge with:

- Utilization of **earth-observation technology** working in solidarity with the global scientific communities through a global alliance on earth observation.

We can address the Incompatible Indicators challenge with:

- Construction of **localized SDG 11 indicator systems** under the framework of SDG and UMF to take proper account of the uneven development among different urban regions.

We can accelerate the SDG 11 implementation with:

- Development and application of **pioneering digital technologies** like big earth data, cloud computing, deep learning, and digital twins.

We can make transformative impact by:

- Integrating the SDG 11 implementation solutions driven by STI into the **urban management and policy-making process**.

THANKS

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