UN GEONOW 2024
首届联合国地信周

Model construction and progress assessment for UN SDG 11.4

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International Centre on Space Technologies for Natural and Cultural Heritage under the Auspices of UNESCO

1. Objectives & Problems

☐ Heritage studies are essential for regional sustainable development

Cultural heritage represented by ancient ruins, ancient buildings, cultural landscapes, etc., is a landscape manifestation of human transformation and adaptation to nature, which is related to human sustainable development and civilization inheritance.

climate change, frequent disaser occurrence

Intensifying human activities

The speed of destruction and disappearance is accelerating, posing challenges to the sustainable protection and utilization of cultural heritage

- **Lack of timely provision of scientific data**
- **Insufficient overall monitoring awareness**
- **Scenario prediction assessment without prior preparation**

1. Objectives & Problems

☐ Facing bottlenecks for UN SDG 11.4

SDG 11.4 “Further efforts to protect and defend the world cultural and natural heritage”

The only indicator of 11.4.1 is: the “total per capita expenditure on the preservation, protection and conservation of all cultural and natural heritage, by source of funding (public, private), type of heritage (cultural, natural) and level of government (national, regional, and local/municipal)”

Currently in Tier II (lack of data, incomplete methods) status (United Nations, 2019):

According to survey data from 2020, less than 60% of countries have access to relevant statistical indicators (United Nations Statistics Division, 2021);

As of 2022, only 29 countries can provide reliable data (United Nations, 2022).

1. Objectives & Problems

☐ The era of remote sensing for cultural heritage

spaceborne

airborne

terrestial

landscape → sites → ontology

ancient site

ancient tomb

grotto temples/ stone carvings

historic building

modern & contemporary historical sites & representative buildings

Multi-scale

Phenomenon observation

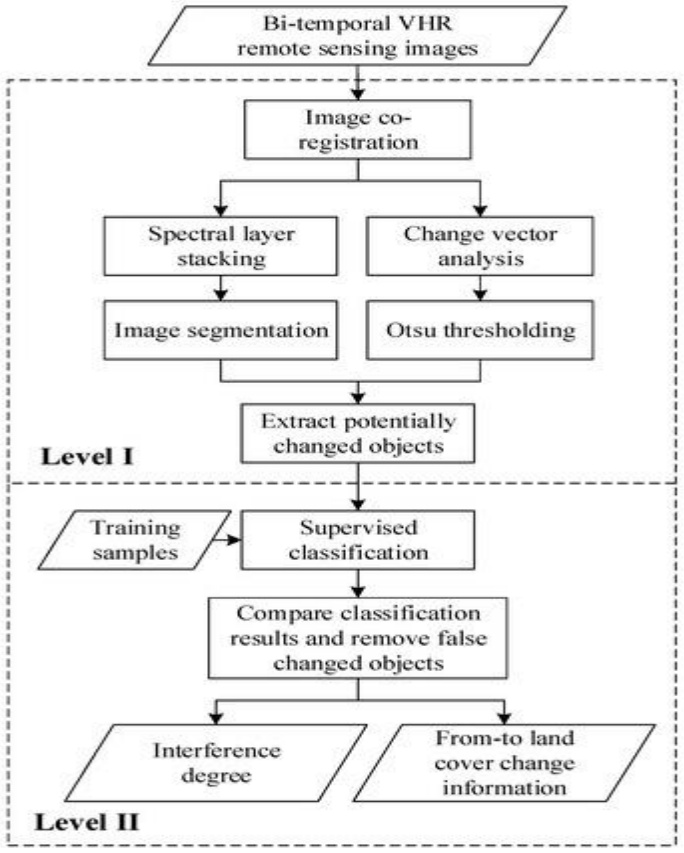
Process expresses

Value cognition

Fill in data → Provide indicators → Progress assessment

2. Methods and Technologies

☐ Extraction and dynamic monitoring of global change sensitive factors



$$V = \sqrt{\sum_{i=1}^{K}(p_i - q_i)^2}$$

CVA

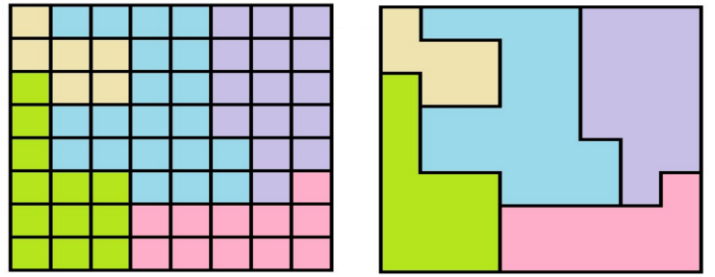
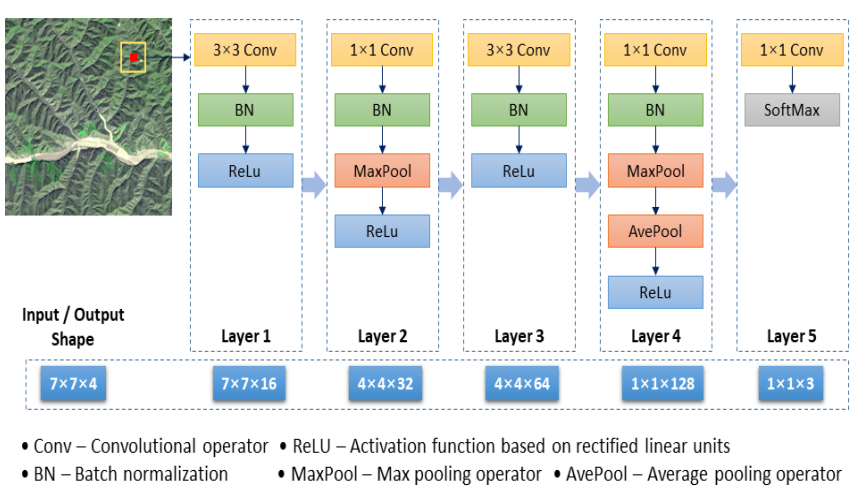
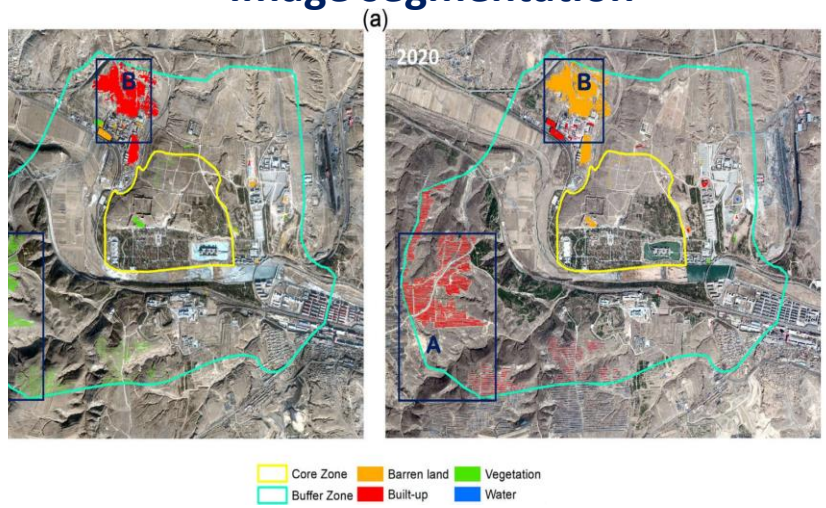


Image segmentation



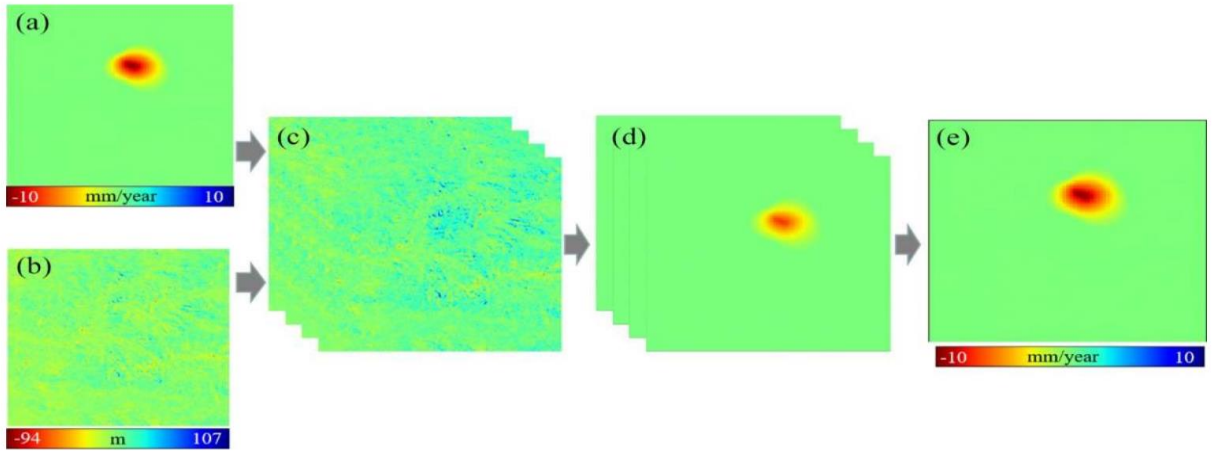
Deep-learning



change detection

Integrating multi-scale image segmentation, change vector analysis, and deep learning algorithms, a remote sensing accurate extraction and change tracing method for land cover has been proposed, with better than 0.1% accuracy

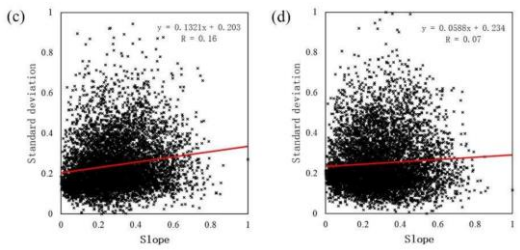
☐ Extraction and dynamic monitoring of global change sensitive factors

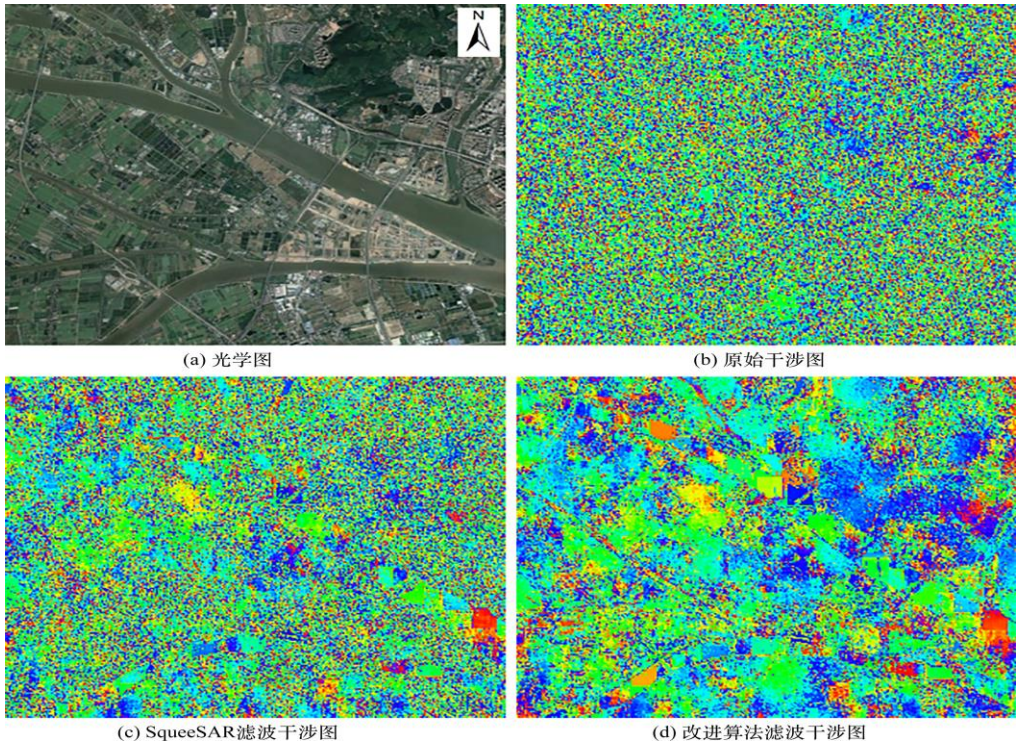


Integration of SBAS and PSInSAR

$$\phi_{pseudo} = -\frac{4\pi}{\lambda}\left(a\sum_{m=IS_m}^{IP_m} t_m v_m + \sum_{p=IS_p}^{IP_p} t_p v_p\right)$$

Pseudo-baseline time-series InSAR





(a) 光学图 (b) 原始干涉图

(c) SqueeSAR滤波干涉图 (d) 改进算法滤波干涉图

Target coherence homogeneous filtering

Overcoming technical bottlenecks such as image quantity constraints, terrain phase errors, and improving interferogram quality, the coherence quality of the target has been improved by over 30%

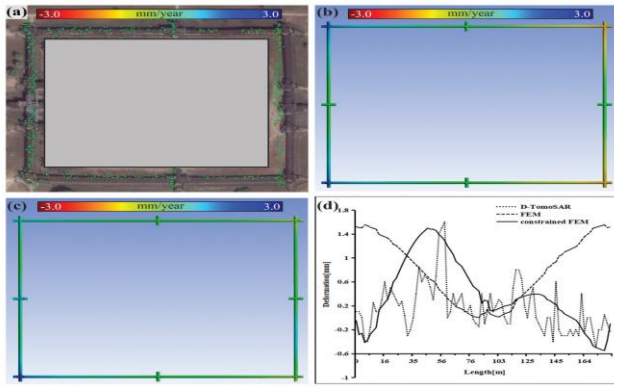
Remote Sens 2022; Geosc Rem Sen M, 2022

Extraction and dynamic monitoring of global change sensitive factors

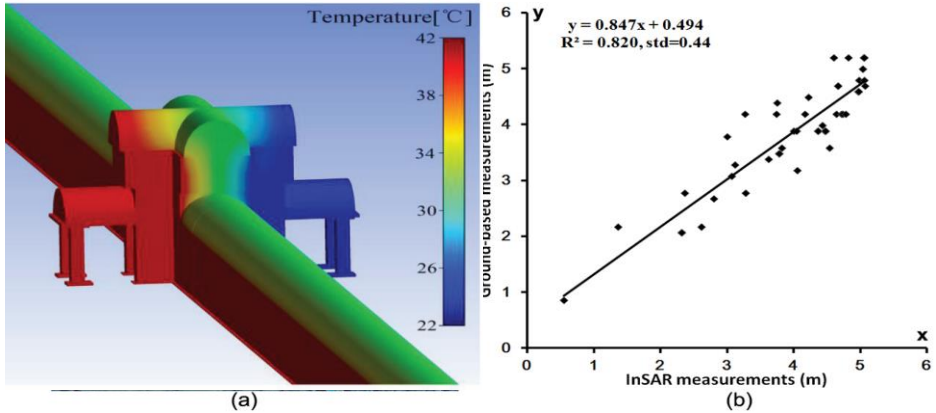
$$\hat{\gamma}(s,v,k)=\frac{\left|a(s,v,k)^H y\right|}{\|a(s,v,k)\|_2\|y\|_2}$$

$$a(s,v,k)=\begin{bmatrix}\exp(j2\pi(\xi_1 s+\eta_1 v+\zeta_1 k))\\ \vdots \\ \exp(j2\pi(\xi_N s+\eta_N v+\zeta_N k))\end{bmatrix}$$

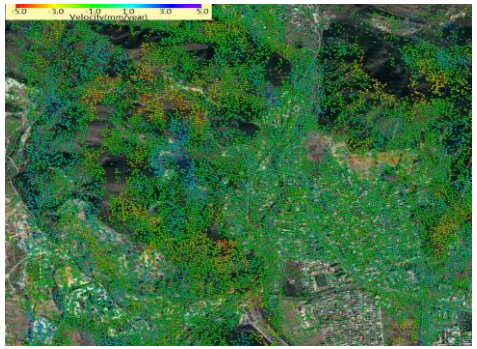
$$\{\varepsilon\}=[B]\{\delta\}^e \qquad \{\sigma\}=[S]\{\delta\}^e \qquad \{F\}^e=[k]\{\delta\}^e$$

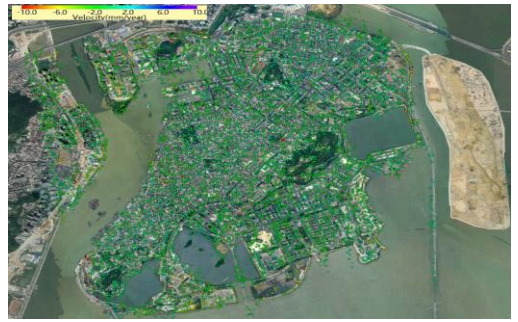


PS+DS for enhancement of measurements



4D+InSAR for the health diagnosis of architectural heritage



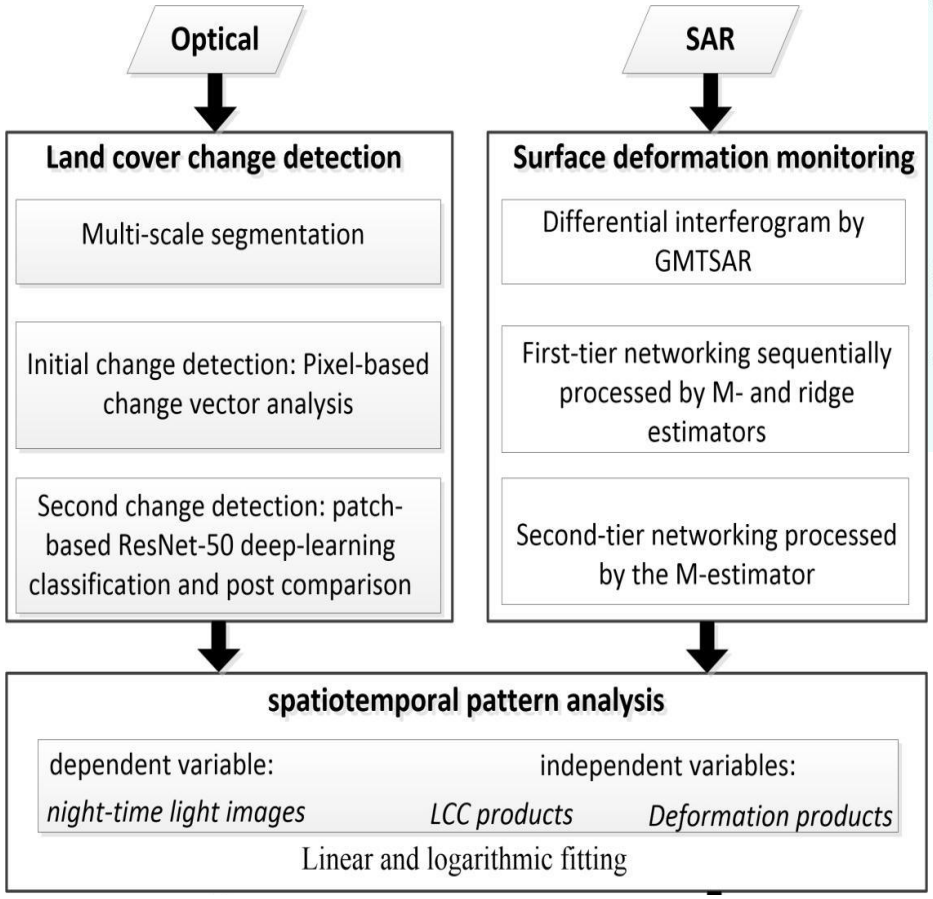


A 4D+InSAR deformation model, parameter robust estimation (M-H ridge estimation), and finite element numerical simulation method for health diagnosis of architectural heritage have been proposed. The overall accuracy improved to 1-2mm/year, and the density of InSAR measurements in complex scenes increased by 5 times

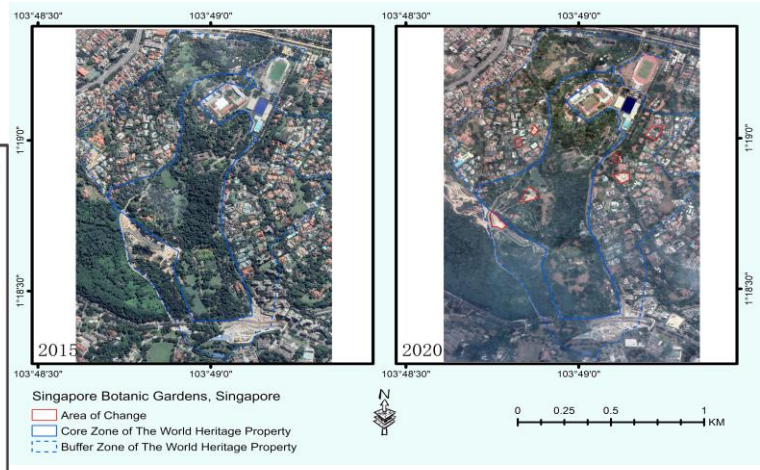
IEEE J-STARS, 2020; GISci Remote Sens,2021; IEEE Geosc Rem Sen M, 2022;Remote Sens Environ, 2023

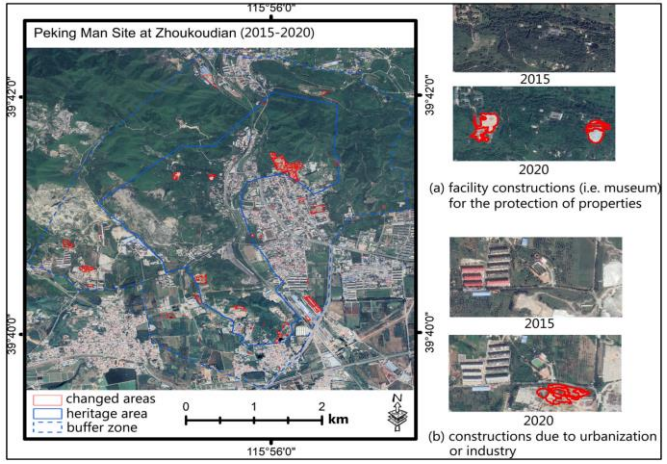
2. Methods and Technologies

☐ Constructing RS information indicators and progress evaluation models for UN SDG11.4

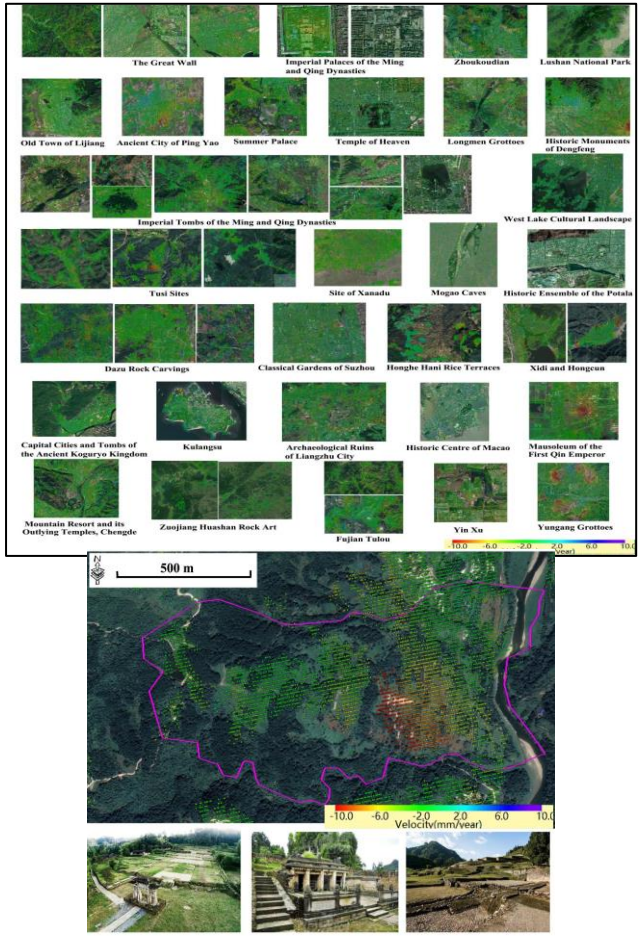


combined factors and indicators：





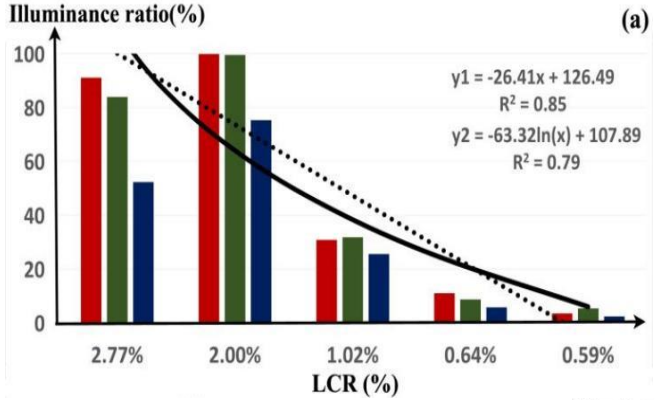
land cover change ratio(LCR)

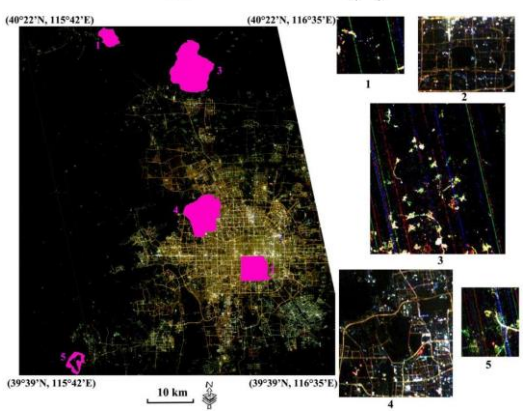


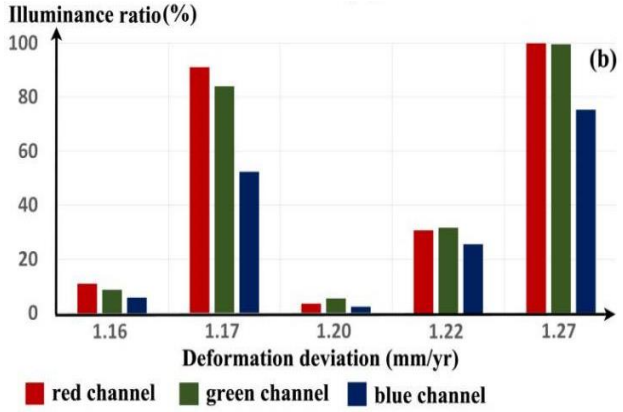
surface deformation anormaly ratio (LDR)

2. Methods and Technologies

☐ Constructing RS information indicators and progress evaluation models for UN SDG11.4







Correlation analysis and modeling between economic indicators (SDGSAT-1 light data) and LCR/deformation

Percentile scores for baseline-year:

$$percentile - benchmark_{2015} = 16.46\ln(GDP\ per\ capita_{2015}) - 96.98$$

$$S_{site} = \mathrm{sign} \times \frac{LCR_b}{3.0} \qquad S_{nation} = \sum_{i=1}^{N} \frac{S_{site}}{N}$$

Model 1:

Updated score=benchmark score+relative SI

Model 2:

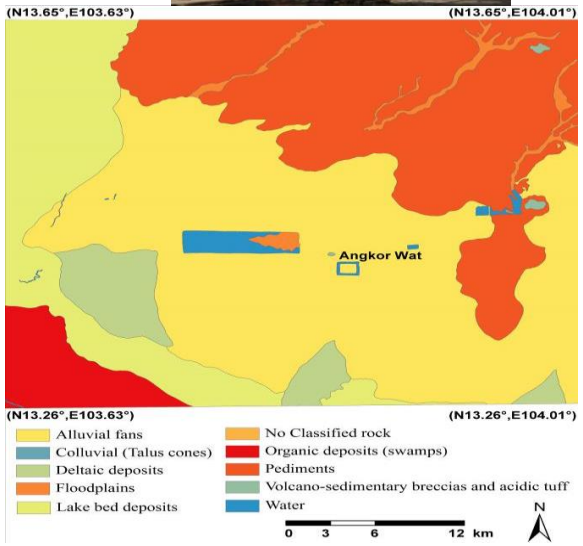
$$R_p = 100\left(1 - \lambda L_p/3.0 - (1-\lambda)V_p/10.0\right)$$

We proposed the indicators of LCR and LDR. We constructed two models for the SDG 11.4 progress assessment, 1) a weighted regression model linking remote sensing information and funding investment, 2) a percentile scoring model for assessing the disturbances from natural and anthropogenic factors.

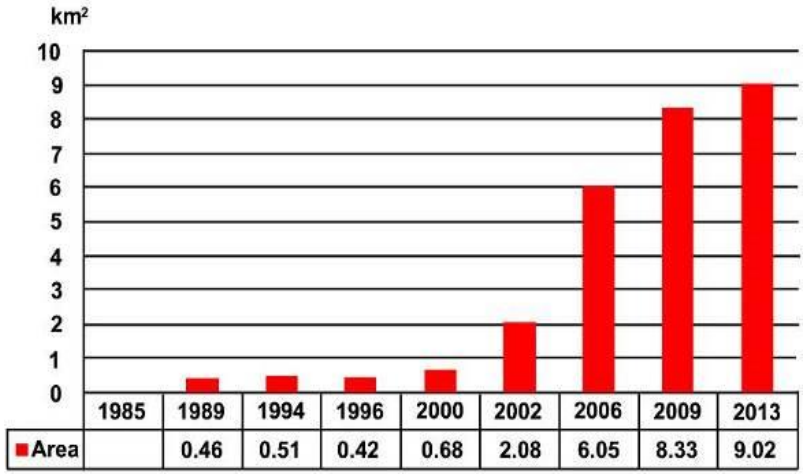
Remote Sens Environ,2023; The Innovation, 2023

3. Multi-scale Application Scenarios

☐ Angkor site from heritage site perspective



Angkor site



	1985	1989	1994	1996	2000	2002	2006	2009	2013
Area		0.46	0.51	0.42	0.68	2.08	6.05	8.33	9.02

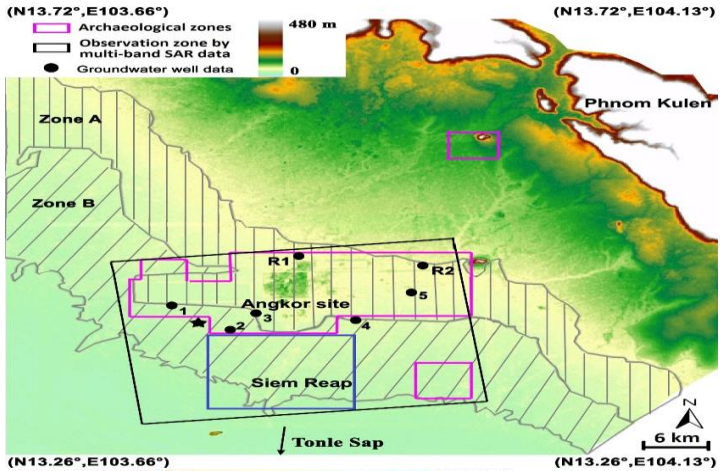
Urbanization in recent 30 years

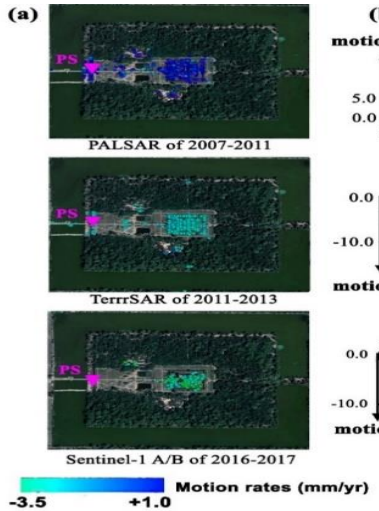
(a) (b)

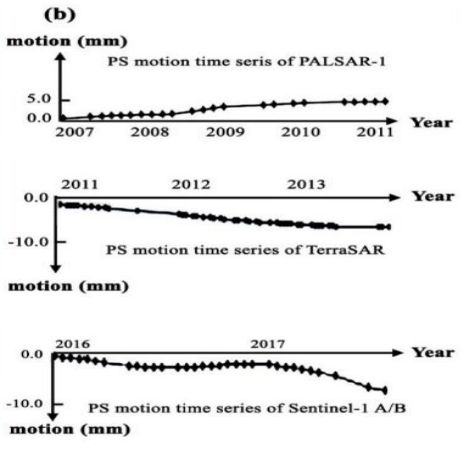
The widely popular view: groundwater extraction causes surface subsidence, which in turn exacerbates the instability and even collapse of ancient temples. *Awaiting to be validated*

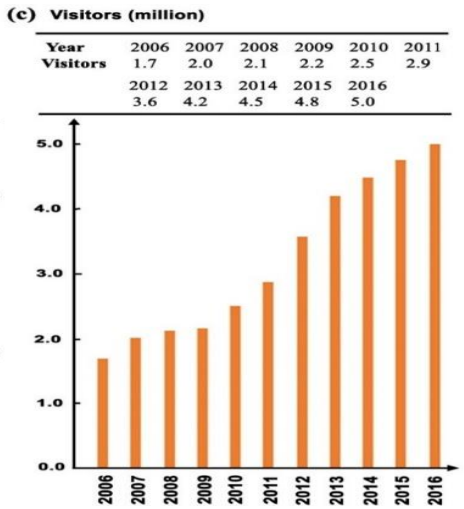
3. Multi-scale Application Scenarios

☐ Angkor site from heritage site perspective





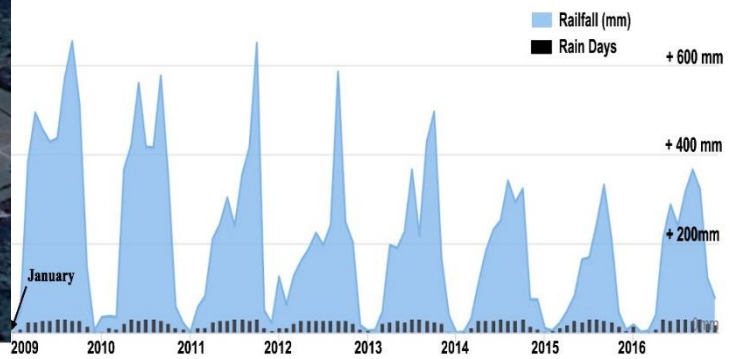


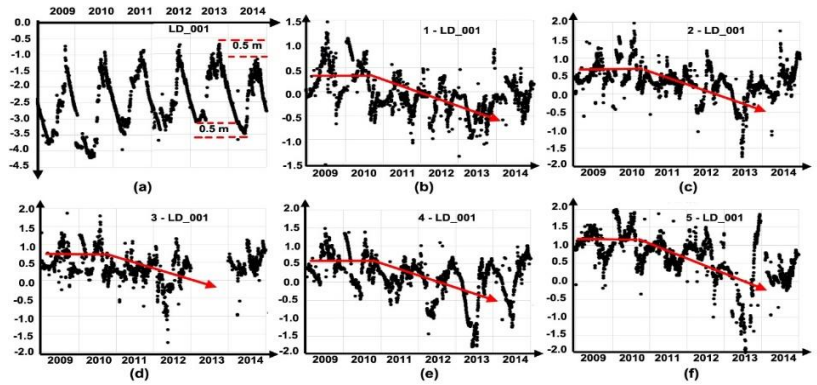


+0.5 mm/a

-1.5 mm/a

-3.5 mm/a



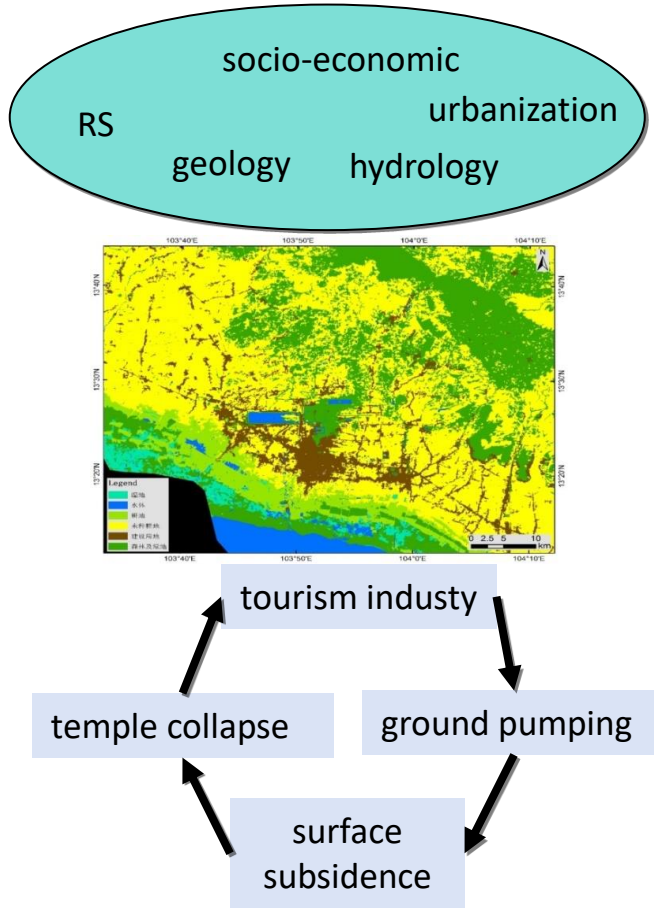


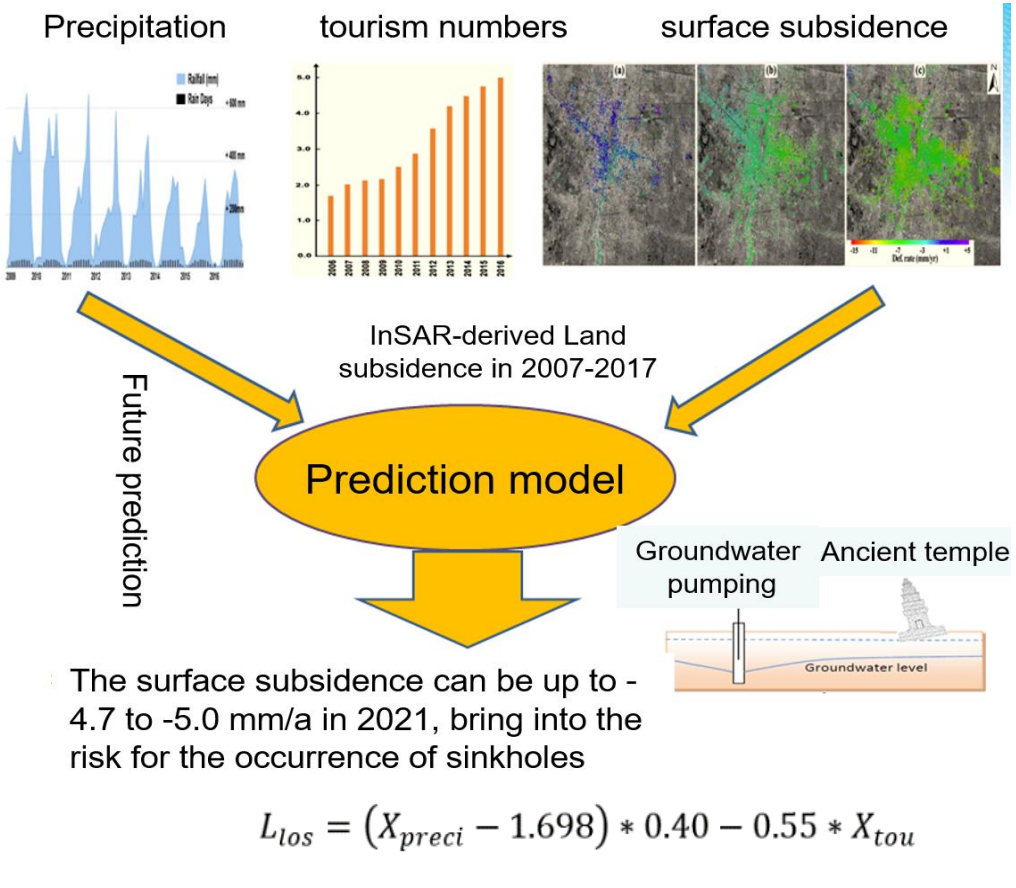
Scientific findings: 1) Seasonal changes in groundwater and thermodynamic differential deformation (≈ 2 mm) caused by different ancient building materials can exacerbate natural degradation processes and even lead to temple collapse; 2) The trend of surface subsidence is intensifying, and the heritage site shows signs of groundwater degradation.

Science Advances,2017

3. Multi-scale Application Scenarios

☐ Angkor site from heritage site perspective





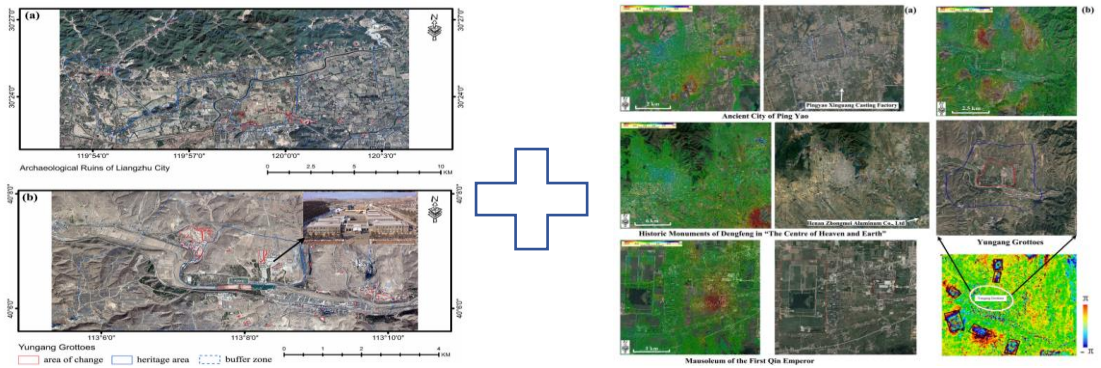
$$L_{los} = (X_{preci} - 1.698) * 0.40 - 0.55 * X_{tou}$$

The annual tourist carrying capacity of Angkor Wat in Cambodia was calculated to be 2.5 million per year; the correlation between excessive tourism development and groundwater head degradation in heritage sites has been empirically verified, scientifically addressing the international community's concerns about the "water crisis".

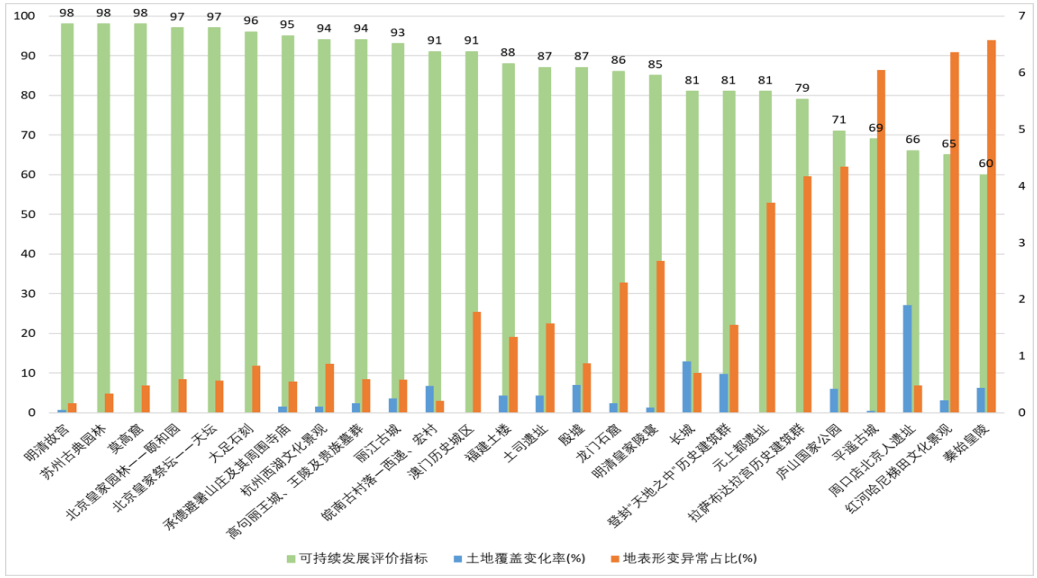
Remote Sens Environ,2019

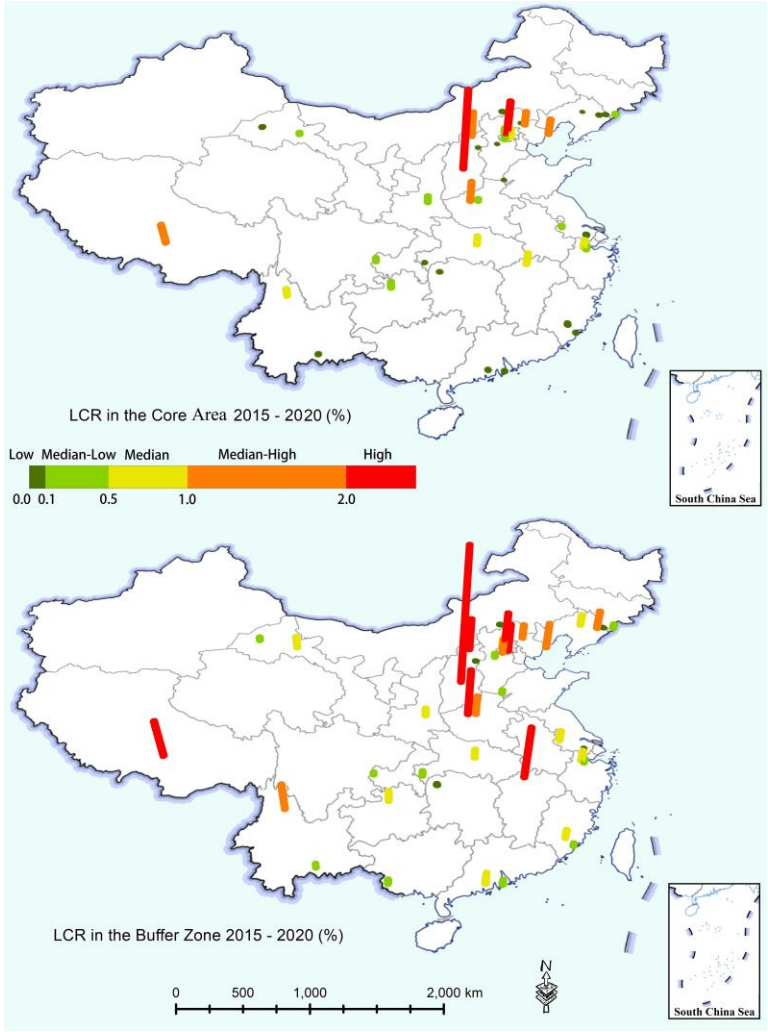
3. Multi-scale Application Scenarios

China from national perspective



LCR LDR





From 2015 to 2020, over 96% of China's world cultural heritage sites were in qualified protection condition

Remote Sens Environ,2023

3. Multi-scale Application Scenarios

Global World Cultural Heritage

589 world cultural heritage sites worldwide

we proposed technical diagrams from extracting heritage boundaries, classifying heritage attributes, calculating LCRs, linking LCRs with socio-economic factors, to evaluating the progress of sustainable development

Natural disasters

Anthropogenic disturbances

Adopted SDG Target 11.4 for the progress assessment of WHL property sustainability

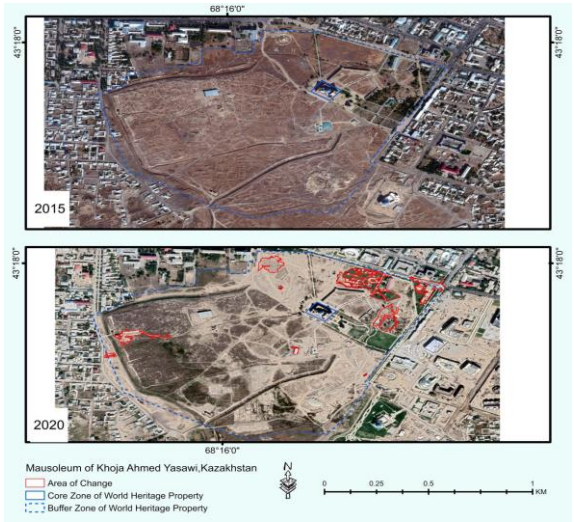
Earth observations & emerging technologies for the monitoring & quantification

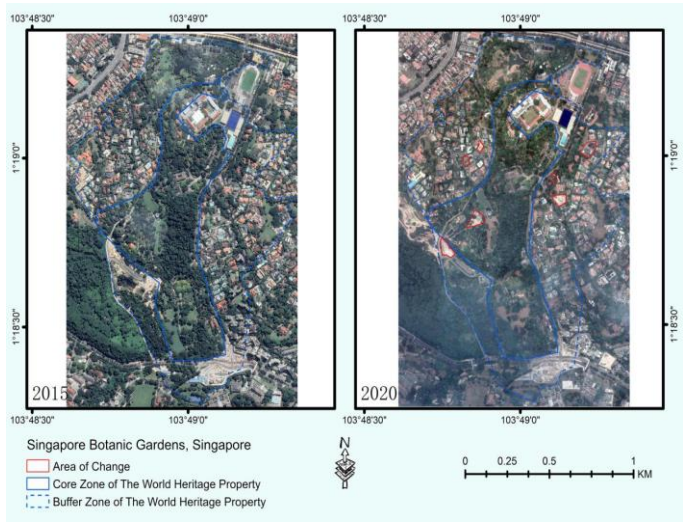
Multi-source satellite images available via GEE

AI and Big data for knowledge discovery

Procedures:

1. Boundary digitalization	*Shapefiles of core & buffer zones for per WHL property*
2. Grouping of WHL properties	*WHL properties grouped into three categories of MB, ST, and CL*
3. Land cover change ratio (LCR) calculation & mapping	*Changes detected by remotely sensed images for calculating LCR indicators*
4. Global LCR patterns & socioeconomic development	*Exploitation the linkage between measured LCRs & social developmental trajectories*
5. Sustainability index (SI) calculation 6. National SI metrics for the SDG target 11.4 progress assessment	*SI calculation for WHL properties & their hosting countries (regions) to assess the progress toward SDGs*

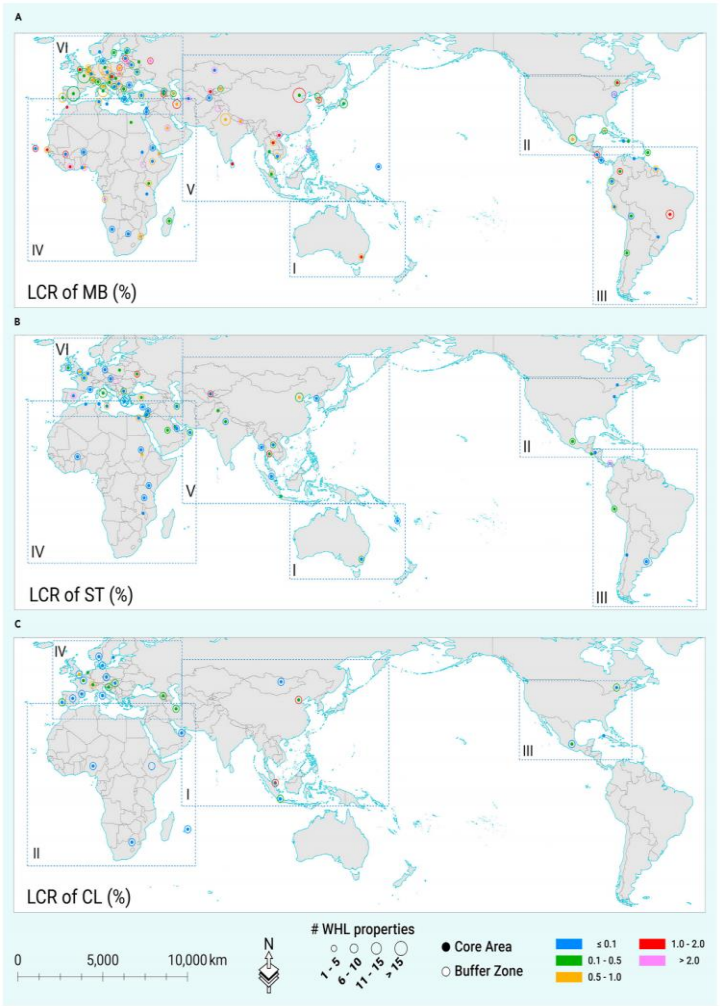


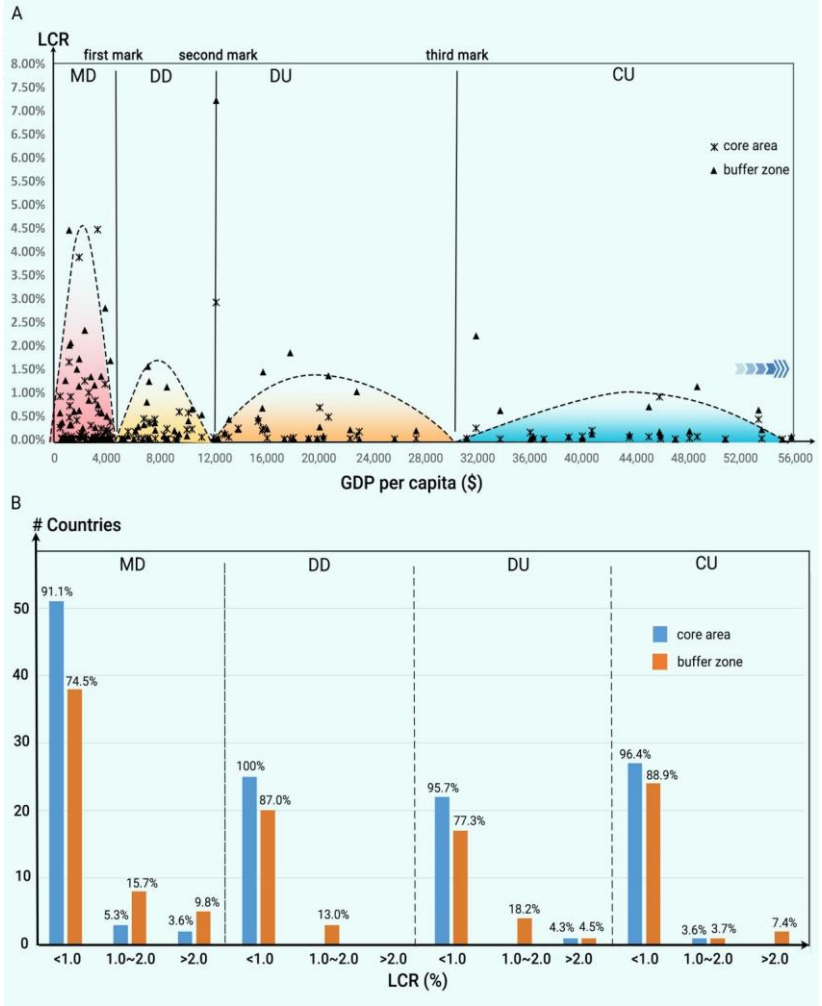


environment renovation **development encroachment**

3. Multi-scale Application Scenarios

☐ Global World Cultural Heritage





➢The LCR indicator can be used to quantitatively describe the impact of complex factors such as socio-economic and policy orientation on the sustainable development of world cultural heritage. The LCRs of world cultural heritage with different attributes show significant spatial diversity.

➢We classify the heritage management levels of the 115 UNESCO member countries where World Heritage sites are located: management disorder (MD), development priority (DD), equal emphasis on development and utilization (DU), and protection and utilization (CU); a high correlation between country-scale LCRs and socio-economic development levels

3. Multi-scale Application Scenarios

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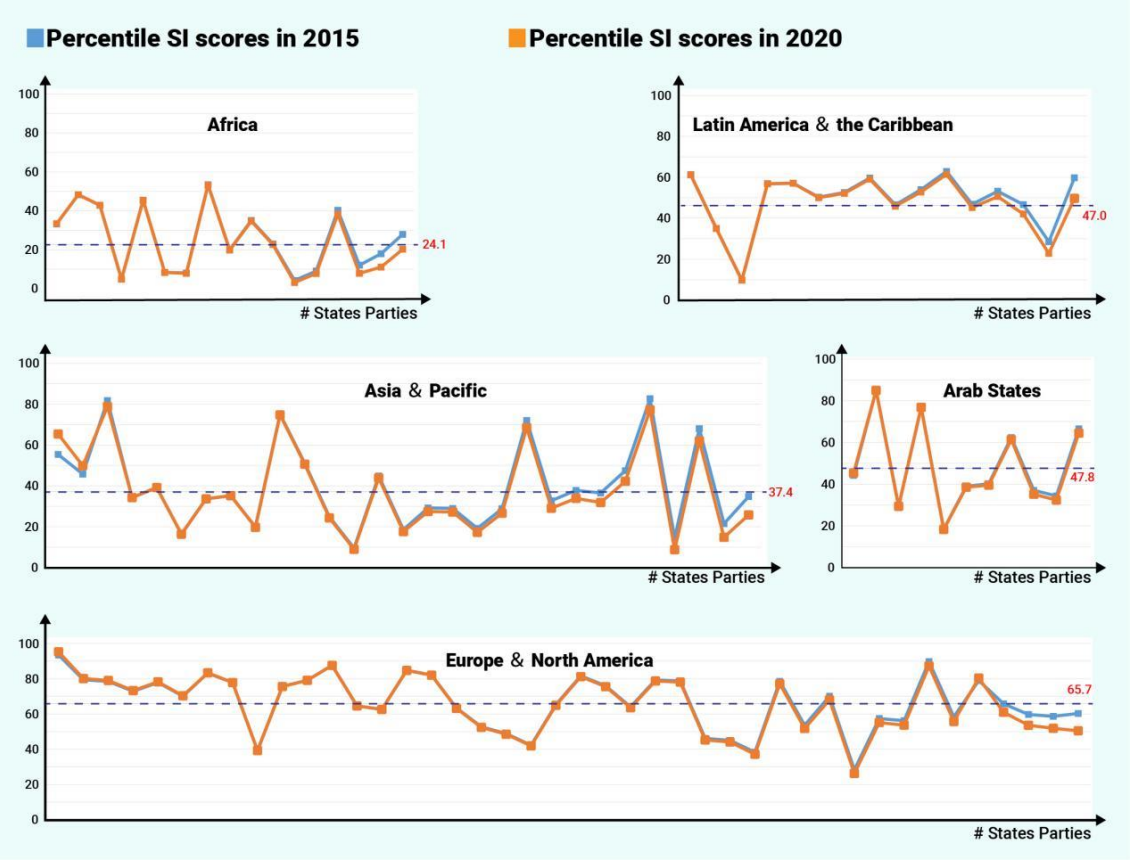
☐ Global World Cultural Heritage



Only 10.4% of UNESCO member states have shown a positive development trend in the protection of world cultural heritage, which verifies the leading and promoting role of socio-economic development in the protection of world heritage, as well as the feasibility of sensing world heritage protection situations using RS big data technologies.

The Innovation,2023

Summary

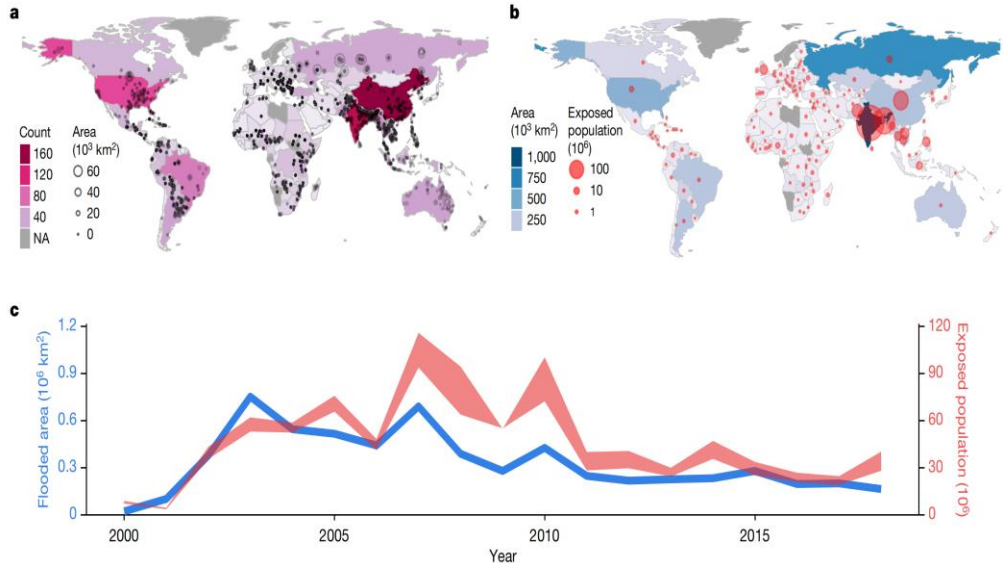
- We proposed remote sensing information indicators of LCR and LDR for SDG 11.4 progress evaluation: compared with the random occurrence of LDR, LCR is highly correlated with the economic development level of adjacent communities;

- We developed two models for the SDG 11.4 progress assessment, including a percentile scoring model based on weighted regression of capital investment and a percentile scoring model for assessing the disturbances from natural and anthropogenic factors; Taking the sustainable tourism of Angkor Wat in Cambodia and the sustainable assessment of world cultural heritage sites in China and globally as examples, the assessment of SDG 11.4 progress across heritage sites, countries, and the world was achieved by addressing the gaps in data and incomplete methods for this specific application.

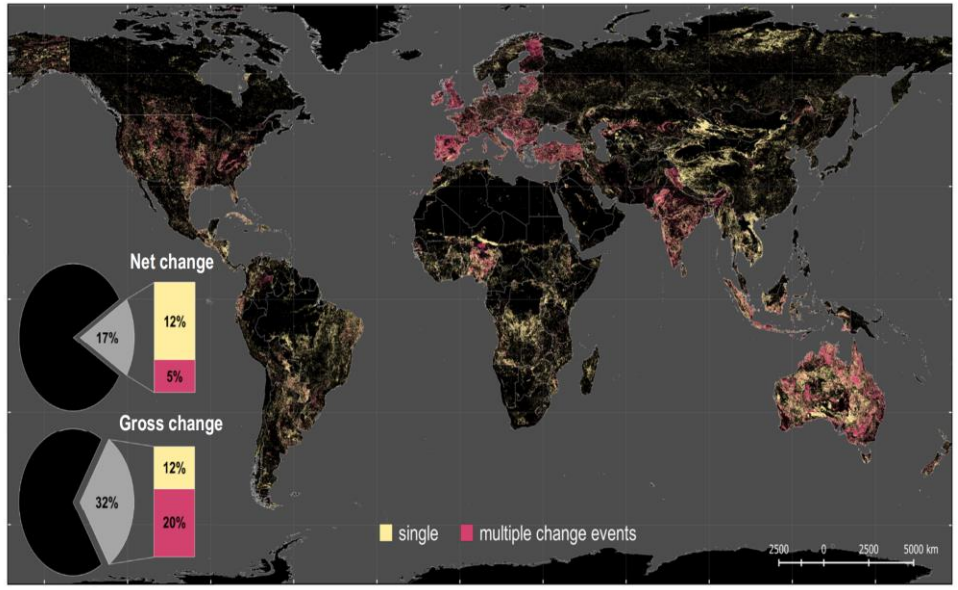
Perspectives

The impact of global changes on Cultural Heritage for the regional sustainable development

The proportion of global population affected by floods has increased by 20-24%(Nature, 2021)



1/3 of global land has changed in just 60 years (NC, 2021)



Scientific issues

- **Spatiotemporal cognition and quantitative expression of global change impacts for CH**
- **SDG indicator synergy - trade-off for the regional sustainable development**

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THANK YOU