Flood dynamics monitoring in China's rural areas using multi-temporal Sentinel-1 SAR

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Background

1. Flooding affects more people than any other environmental hazard and hinders sustainable development, with enormous casualties, damaged croplands, and huge economic losses every year.

2. Under the background of climate change, extreme rainfall events are becoming more frequent in some region, increasing the risk of severe floods.

2022 Pakistan floods

2021 European floods

Two severe flood events in 2021

Flood location	Death toll	Economy losses
Pakistan	1717	$40 billion
Europe	229	$3 billion

What can we do for flood control?

Dam

Reservoir

Flood emergency

Fundamental for site selection ← Flood monitoring

Embankment

Drainage pipe/ Urban planning

Five approaches for direct flood monitoring

Method	Advantage	Disadvantage	Is it appropriate for large river basin?
Real-time field survey	Good to know where to rescue.	Dangerous.	no
Hydrological station data	Good to know water level and flood frequency; Real time.	Could not monitor flooded area; Density of hydrological station is sparse in rural area.	yes
UAV remote sensing	High spatial resolution and real time.	Could not monitor flood in entire large basin.	no
Optical Satellite remote sensing	Coverage of entire large basin.	Relatively low time resolution; Could not work under clouds.	yes
Radar satellite remote sensing	Coverage of entire large basin; Working regardless of clouds.	Relatively low time resolution	yes

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Large-scale flood monitoring: Hydrological station V.S Optical satellite V.S Rada satellite

Hydrological station

- Water level
- Flood frequency
- Flood flow
- Flood discharge

Optical satellite

- Flood frequency
- Flooded areas

Can not monitor floods under clouds

Radar satellite

- Flood frequency
- Flooded areas

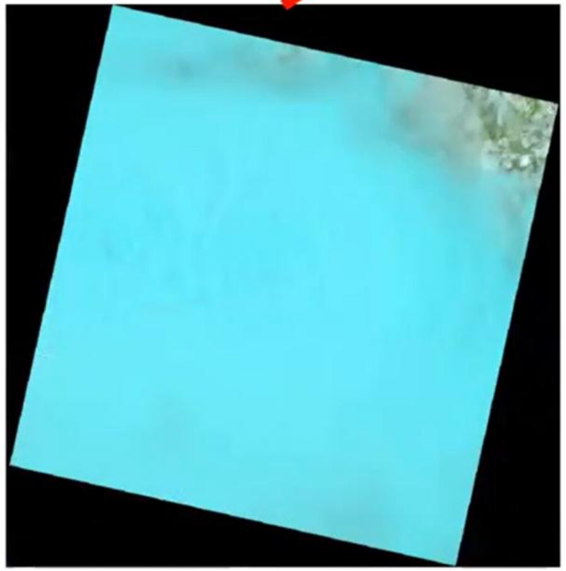
Can work regardless of clouds

Large-scale flood monitoring: Optical satellite V.S Rada satellite

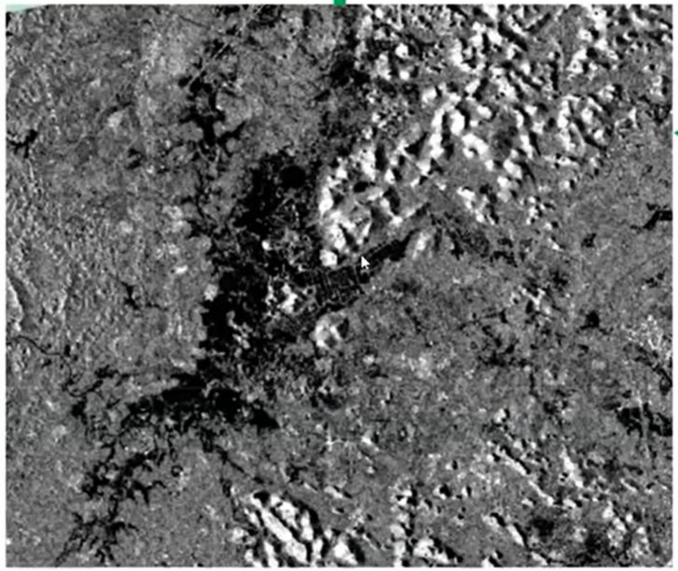
Flood event in Guilin, China
Flood peak: June 8, 2020

Flood monitoring? **No**

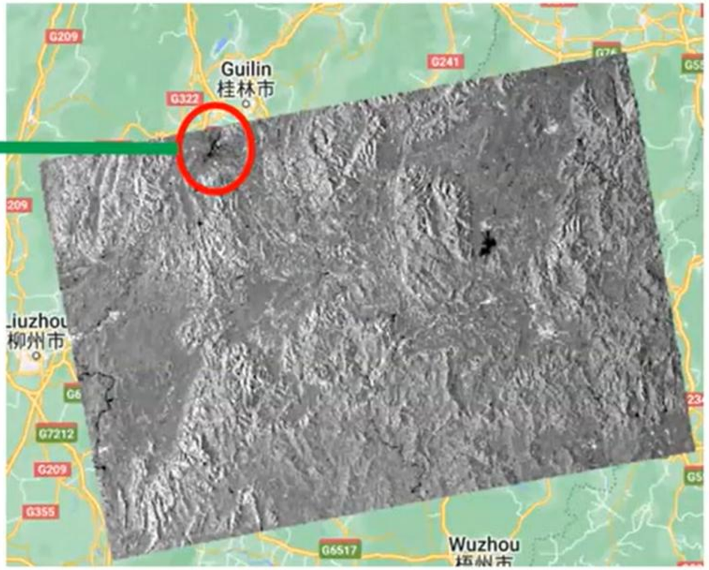
Flood monitoring? **Yes**



Optical satellite images of Landsat 8
Sensing date: June 7, 2020

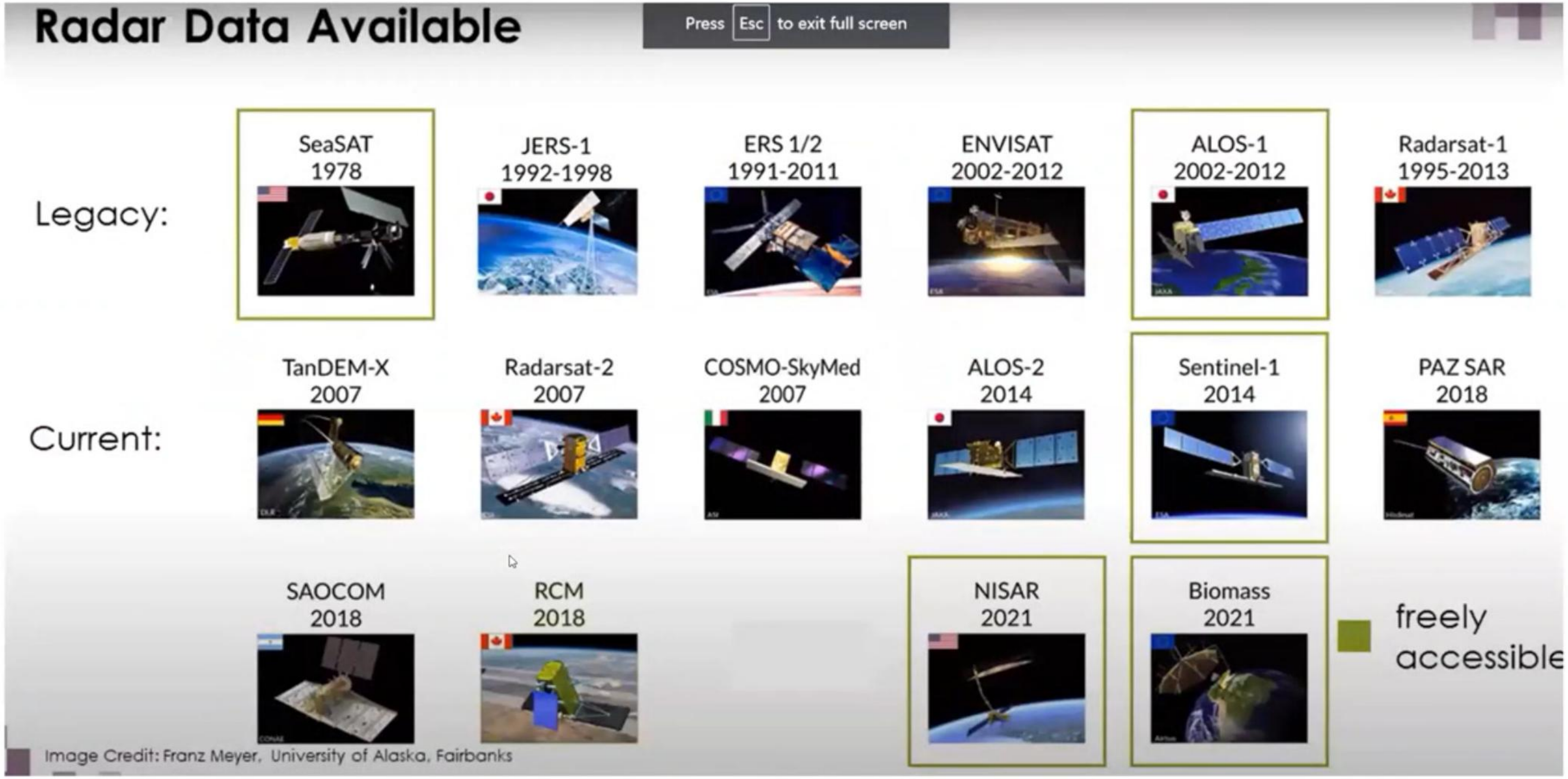


Flood regions in Sentinel-1image

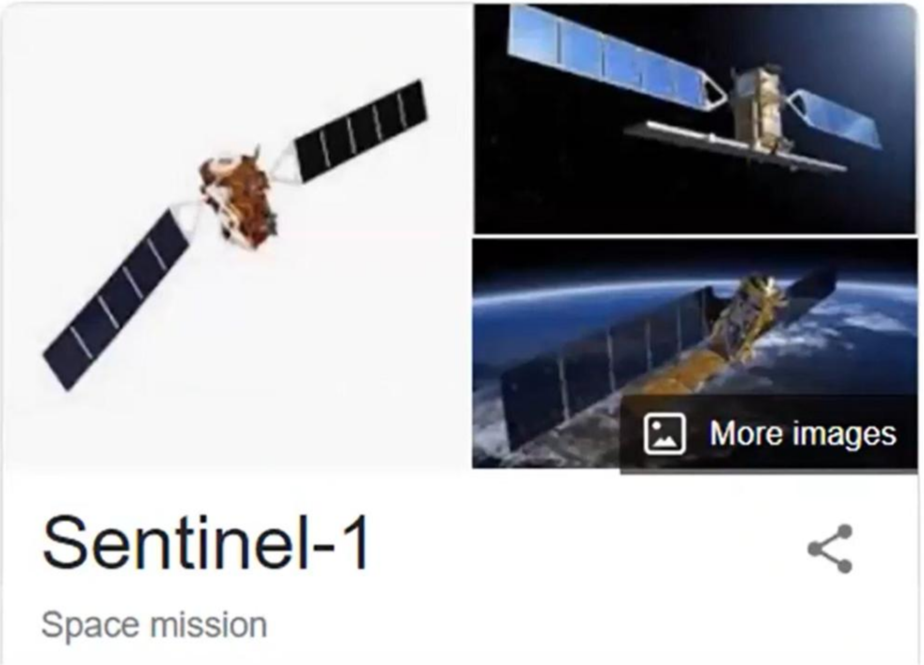


Radar satellite images of Sentinel-1
Sensing date: June 5, 2020

Rada satellites



- Advantages of Sentinel-1 SAR data



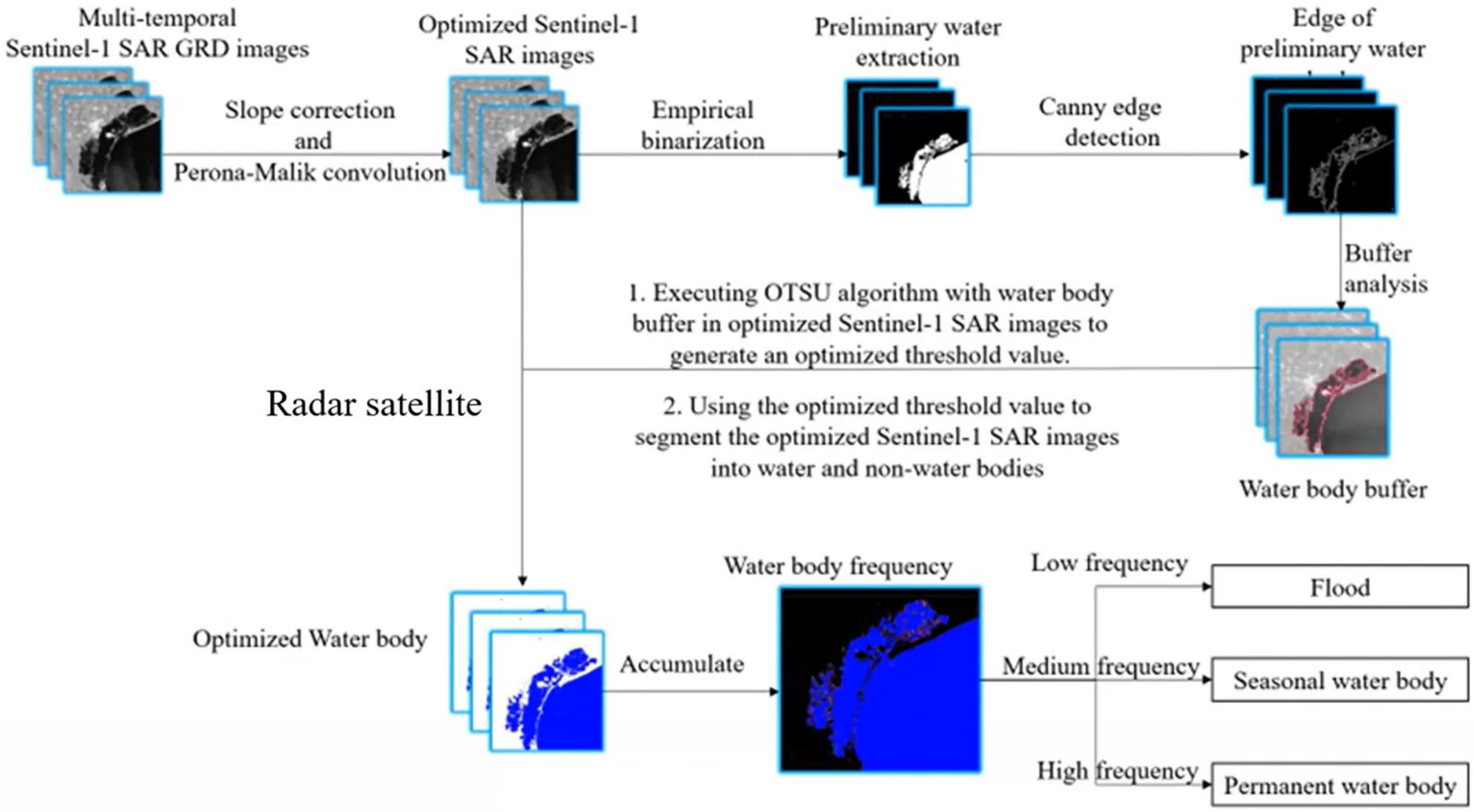
High spatial-resolution of 10 meters

Wide swath of 400 km

Short return period (6~12 days)

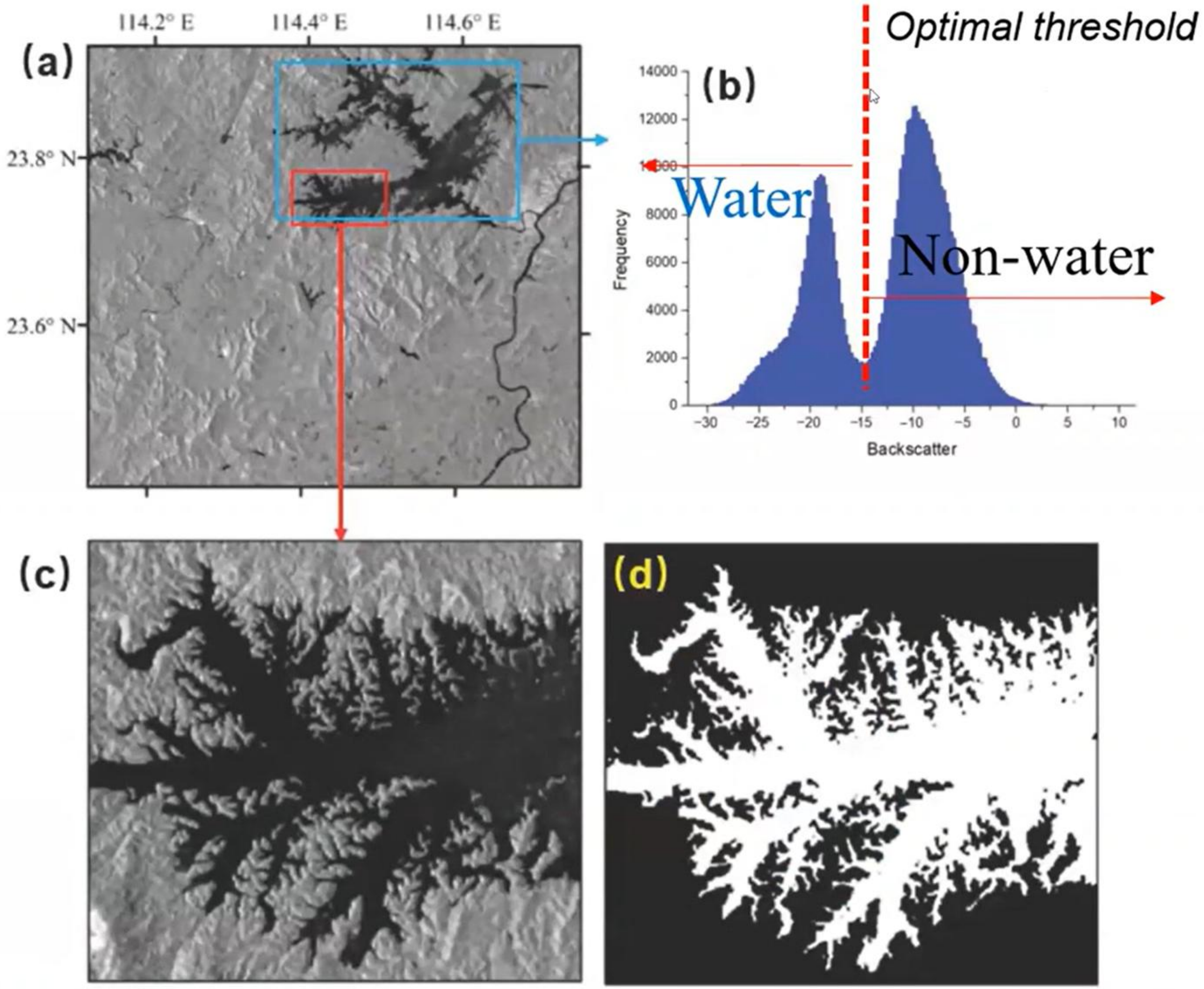
Full coverage of earth land

- Flood monitoring method (Edge-based OTSU) using Google Earth Engine



Otsu, N. A threshold selection method from gray-level histograms. *IEEE Trans. Syst. Man Cybern* **1979**, *9*, 62–66.

• Flood monitoring method (Edge-based OTSU)

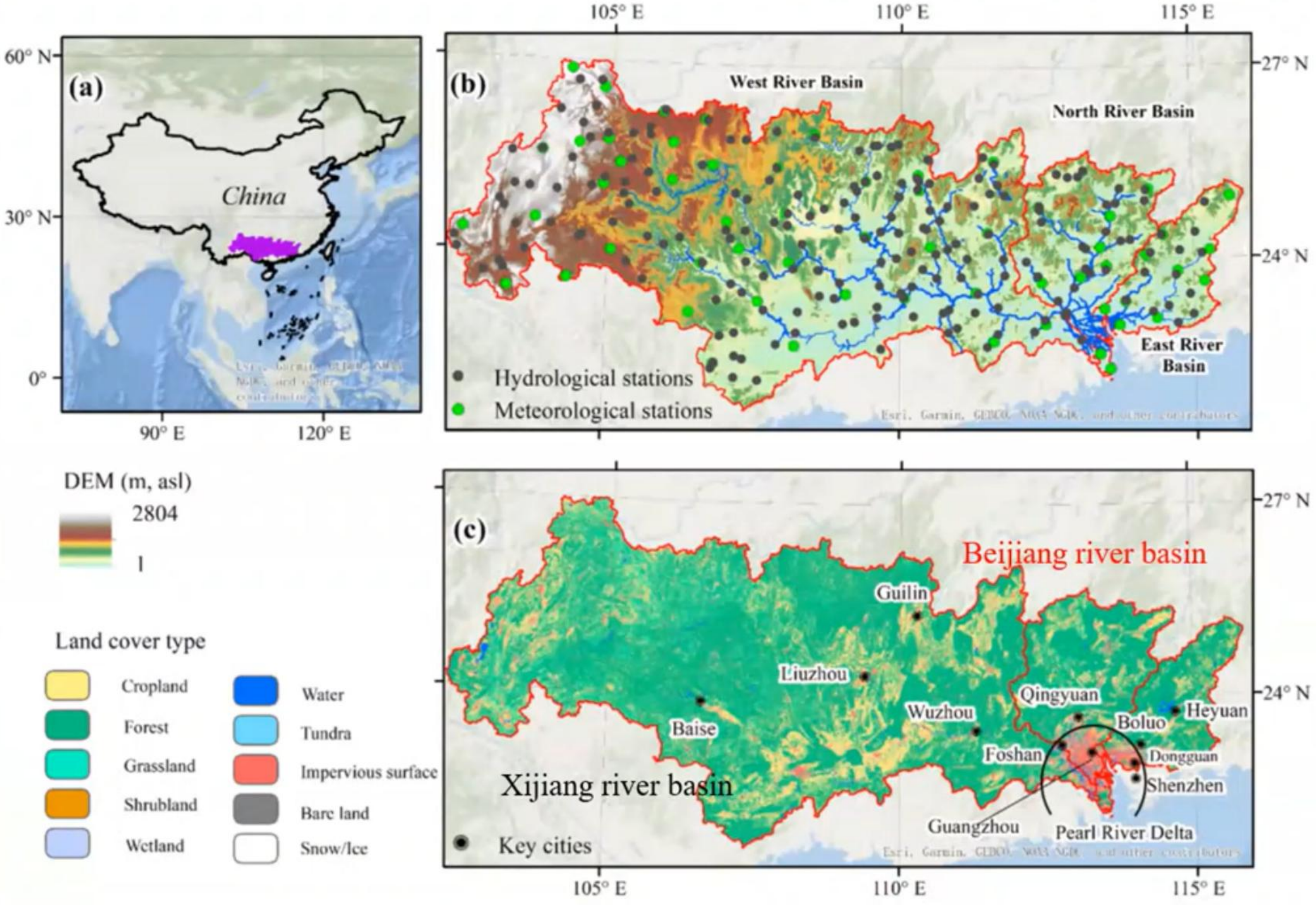


Sentinel-1 image. Date: October 29, 2020

Water body extraction based on Sentinel -1 image and Otsu's method

Study area

Why Pearl River Basin?

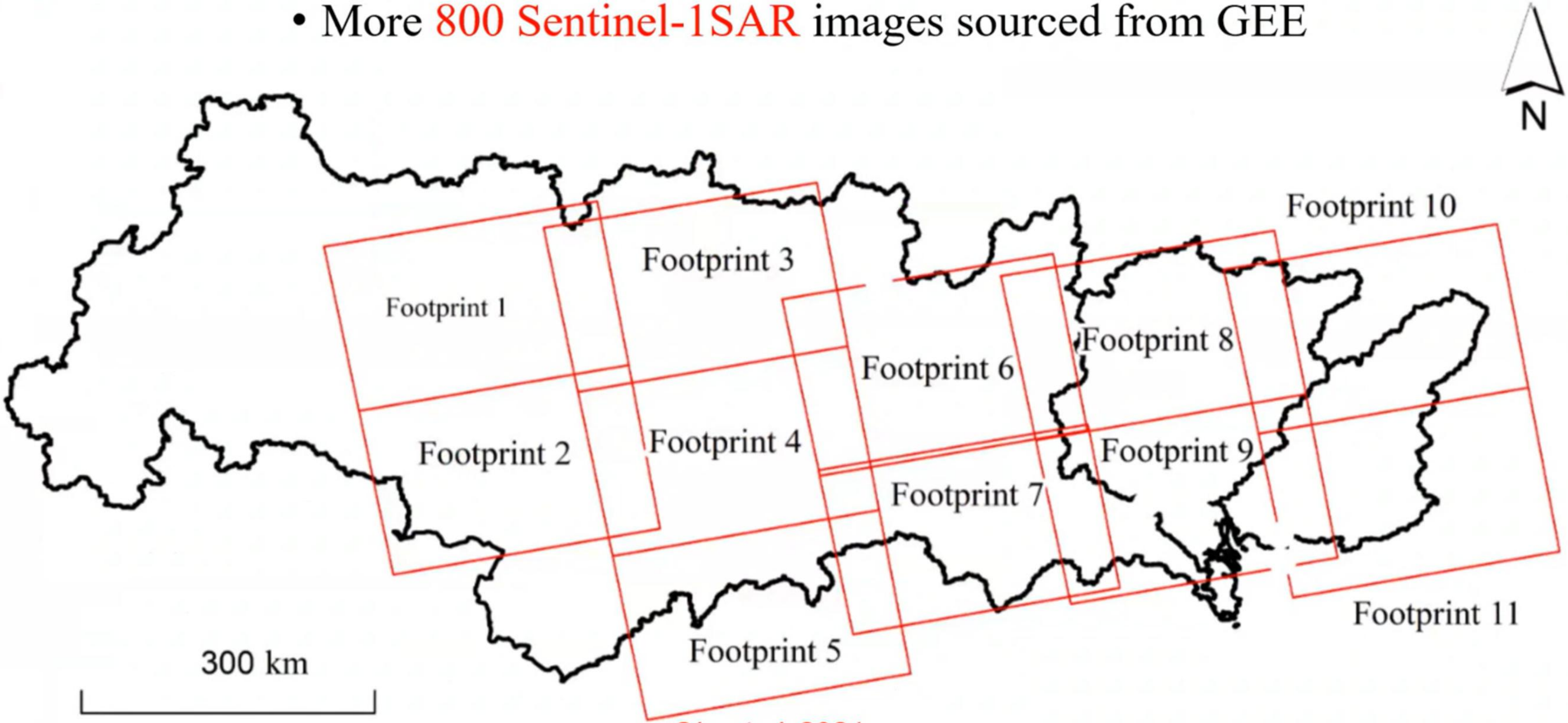


Location and hydrological station of the Pearl River Basin (PRB) in China;

1. Flood-prone area.
2. Densely populated areas and economically developed areas.
3. Suffering economy losses caused by flood every year.
4. Pearl River Basin is food barn in South China. **Its food security is under threat by floods.**
5. Previous studies did not quantitatively analyze the spatial pattern of flood area in this basin.
6. Previous studies did not focus on the floods in rural area in Pearl River Basin.

Qiu, J et al. Flood Monitoring in Rural Areas of the Pearl River Basin (China) Using Sentinel-1 SAR. Remote Sensing, 2021.

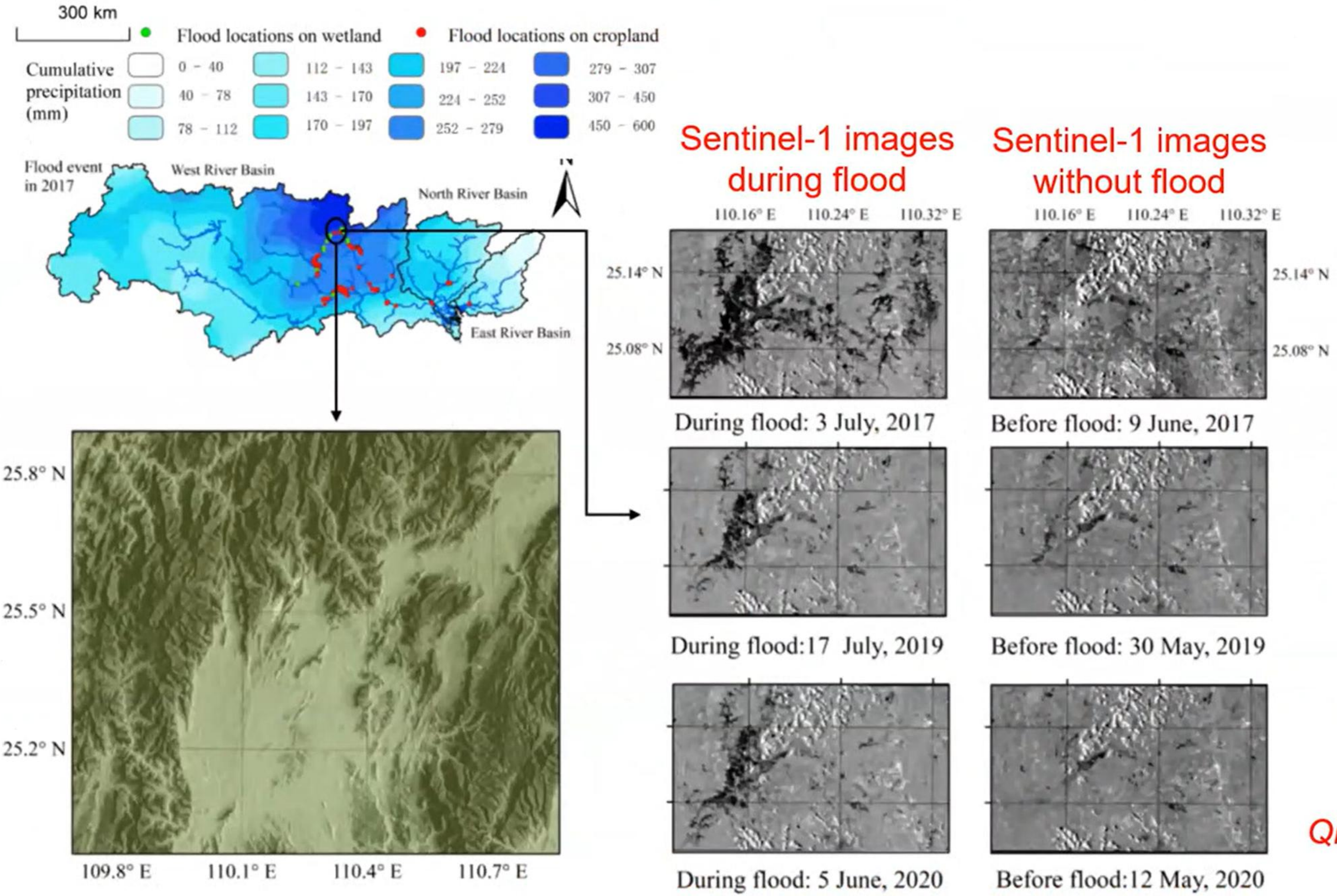
- Footprints of Sentinel-1 images in Pearl River Basin
- More 800 Sentinel-1SAR images sourced from GEE



Qiu et al.,2021

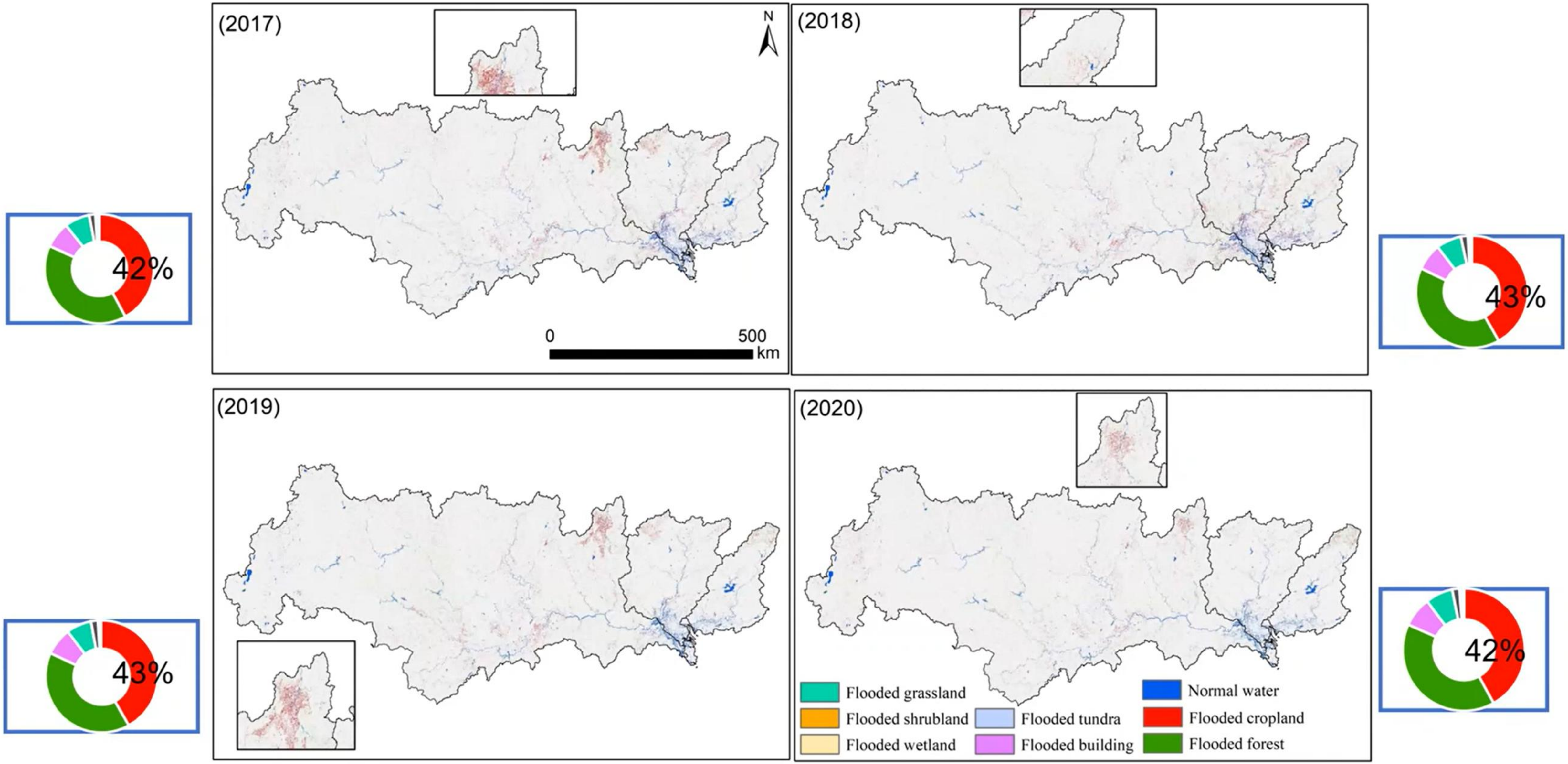
Result

• Location with high flood frequencies



Qiu et al.,2021

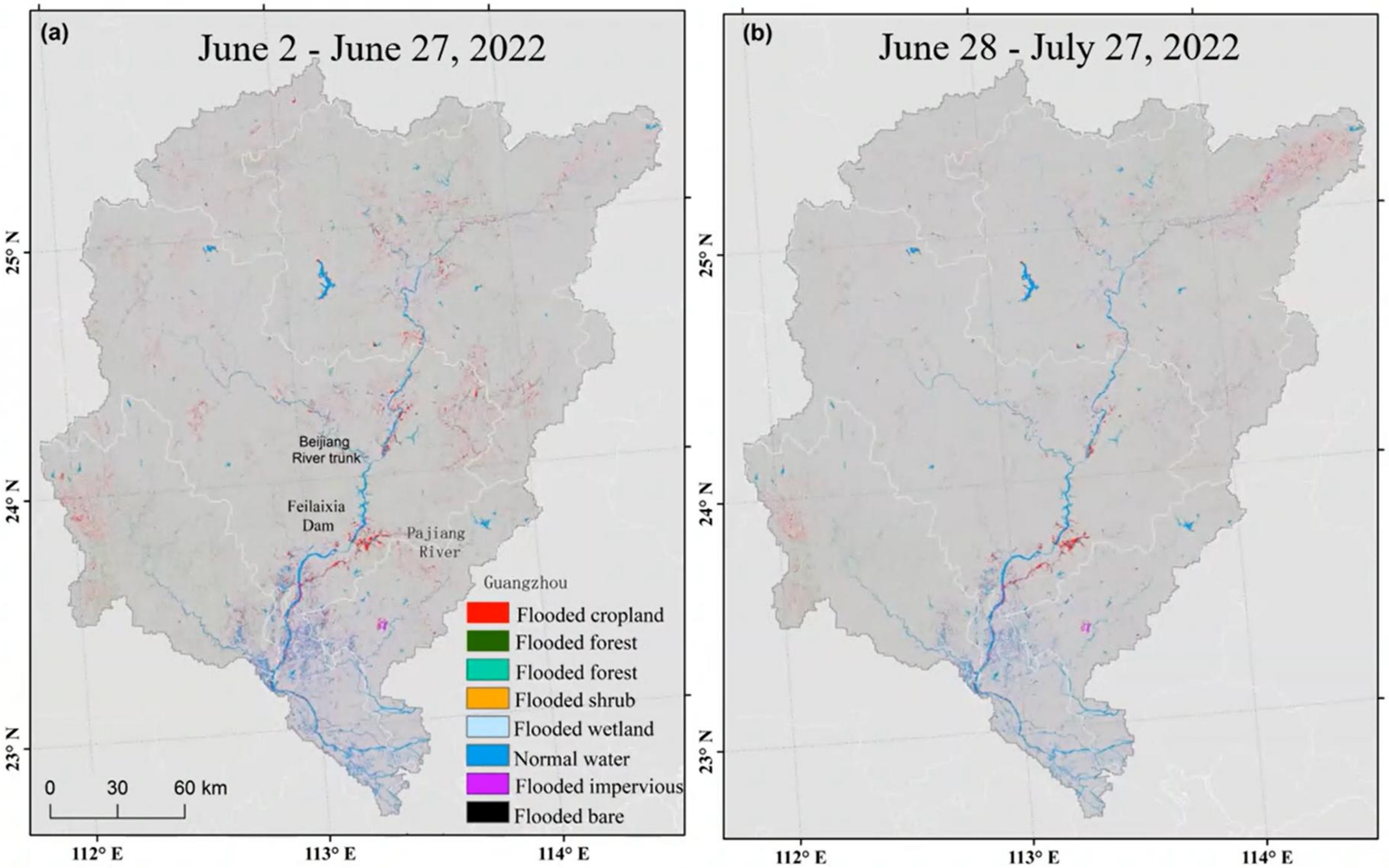
• Flooded land cover maps

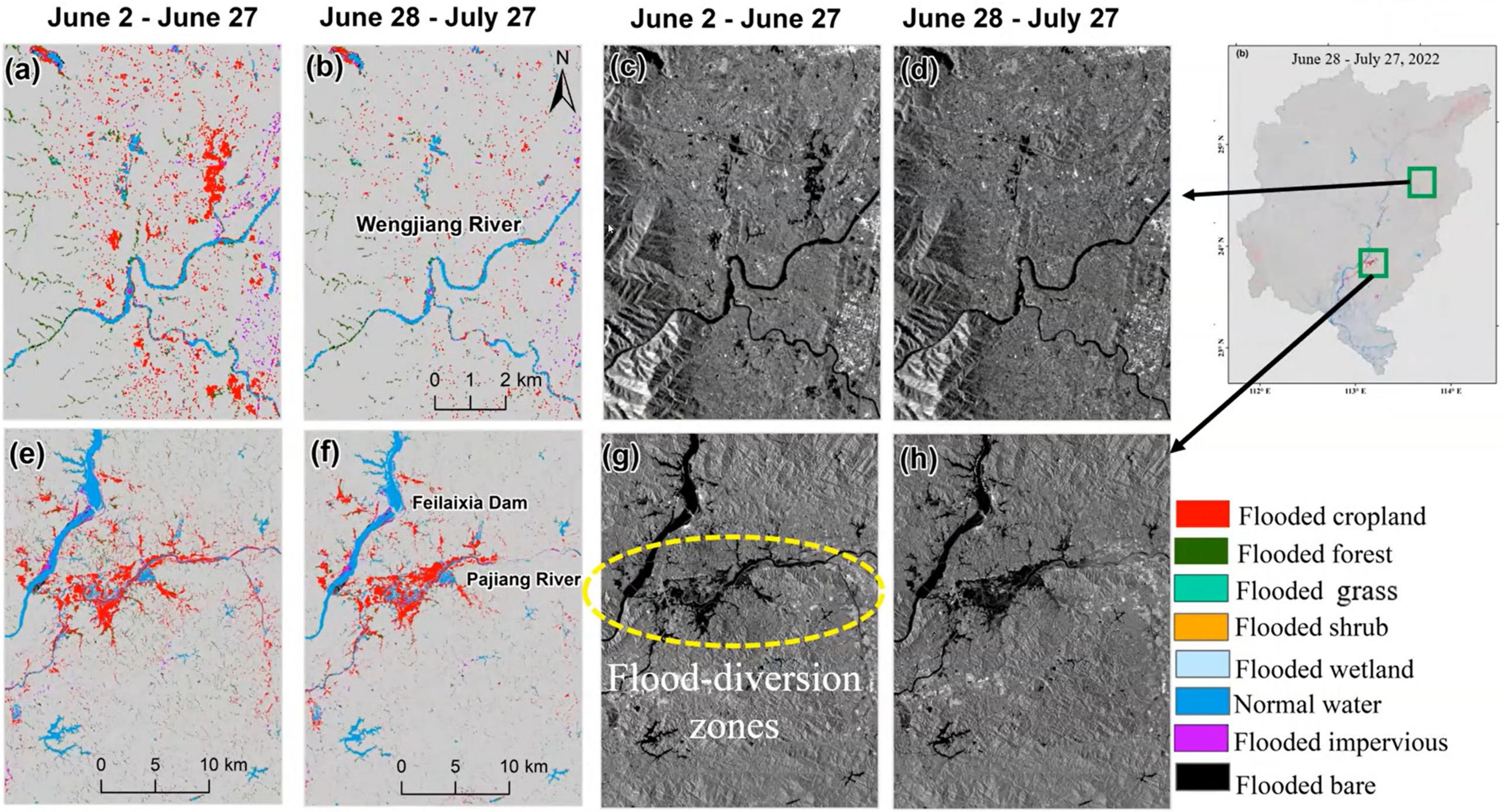


Result

- Dynamic mapping of flooded croplands for a long-duration flood event, in Beijiang River Basin, 2022

Red part is Beijing River Basin




June 2 - June 27
June 28 - July 27
June 2 - June 27
June 28 - July 27
(a)
(b)
(c)
(d)
N
Wengjiang River
0 1 2 km
(b) June 28 - July 27, 2022
25° N
24° N
23° N
112° E
113° E
114° E
(e)
(f)
(g)
(h)
Feilaixia Dam
Pajiang River
Flood-diversion zones
0 5 10 km
0 5 10 km
Flooded cropland
Flooded forest
Flooded grass
Flooded shrub
Flooded wetland
Normal water
Flooded impervious
Flooded bare

Result

- Quantification of flooded areas (accuracy :74%~83%)

Flood areas in Beijiang River Basin, 2022 (unit:km^2)

Flood period	Flooded cropland	Flooded forest	Flooded grassland	Flooded shrub	Flooded shrub	Flooded imperious	Flooded bare
June.2-June.27	814.12	855.32	121.95	13.05	24.53	281.90	23.40
June.28-July.17	529.39	572.30	83.62	8.02	17.57	179.49	17.27

First wave of flood

Second wave of flood

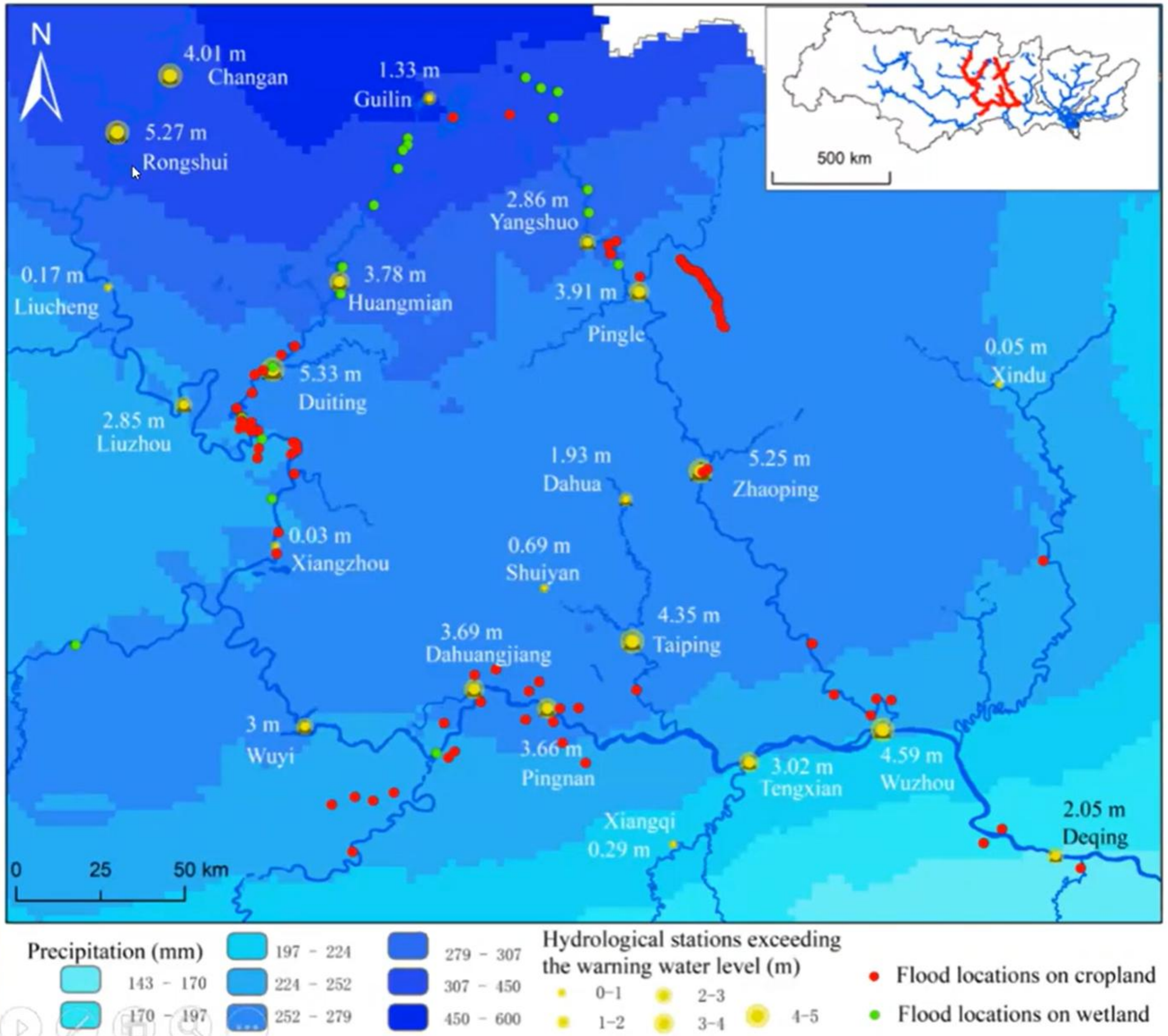
Sentinel-2 images time-series

2022 05 04 2022 06 23 2022 06 28 2022 07 08

Images are from Remote Sensing 董

Discussion

Sentinel-1 images V.S hydrological station data

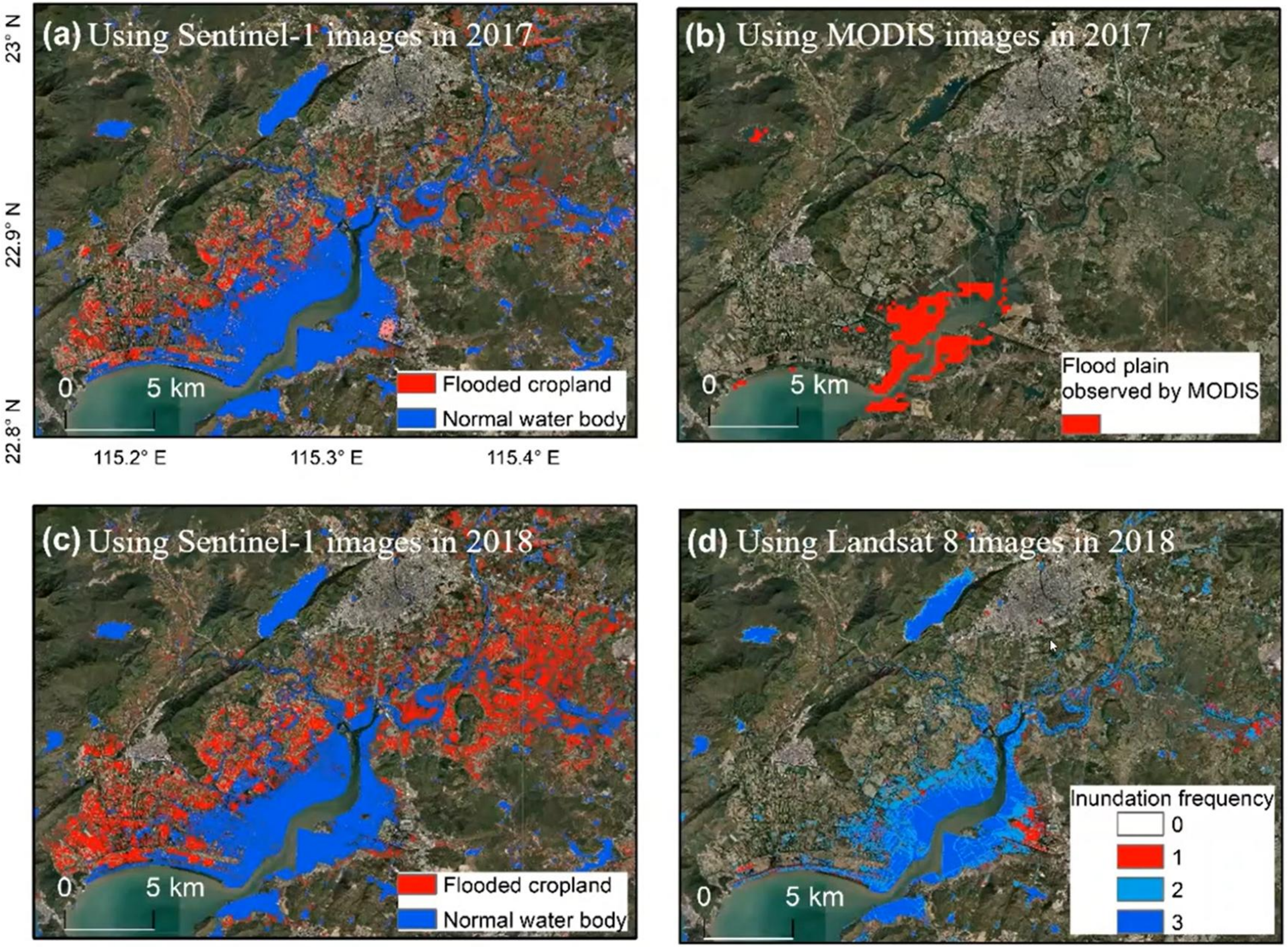


Flood monitoring results derived from Sentinel-1 images and hydrological data.

Red and green points are flood location monitored by Sentinel-1 images. Yellow points are flood location monitored by hydrological station.

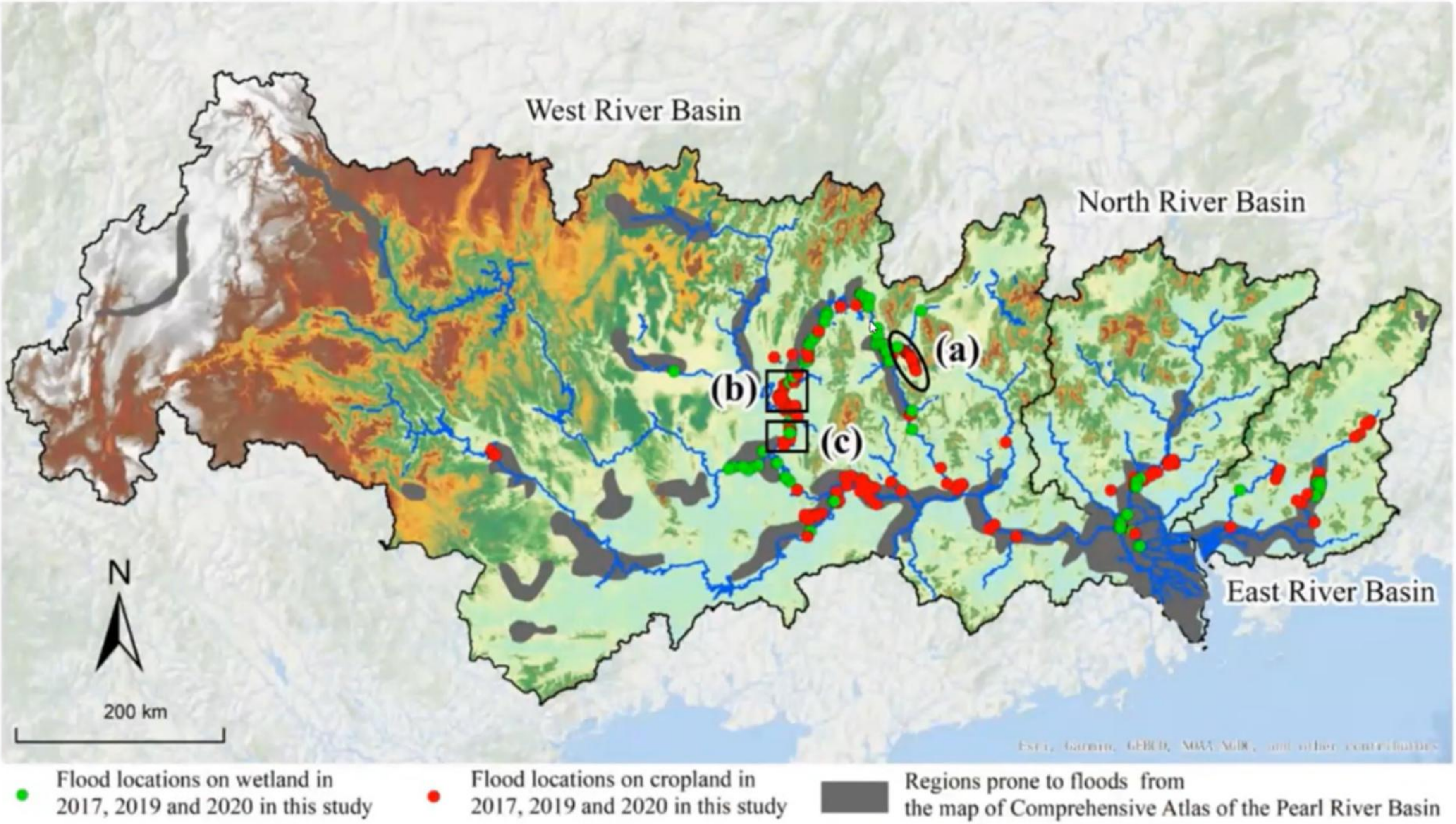
Flood monitoring results only based on hydrological data would undoubtedly cause deviation in such regions or river sections with sparse or without hydrological stations

Sentinel-1 images V.S MODIS images and Landsat images

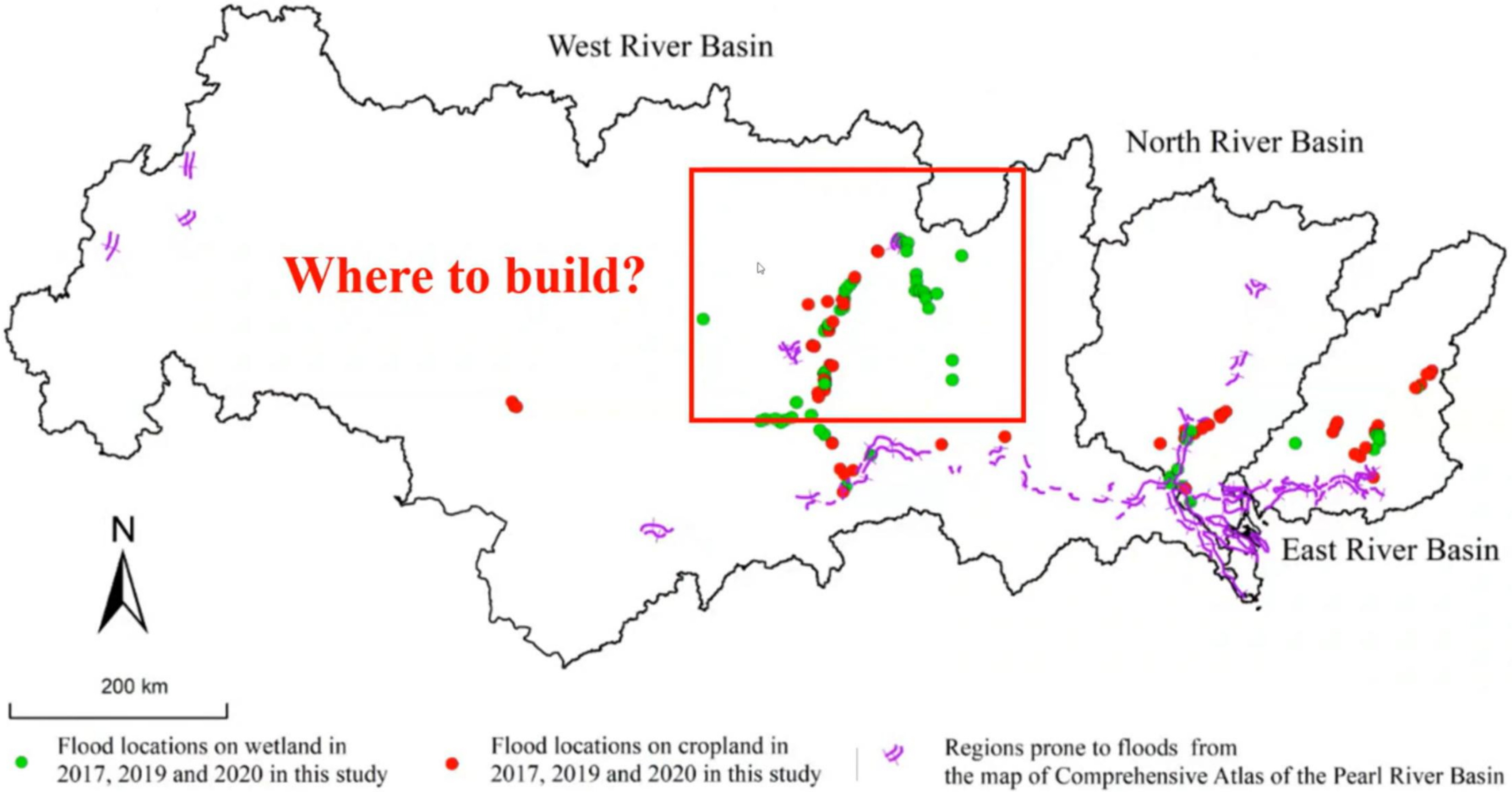


Flood monitoring in the coastal region of Shanwei City

Comparison between the flood locations obtained in this study and the flood-prone area delineated by government in 2012.

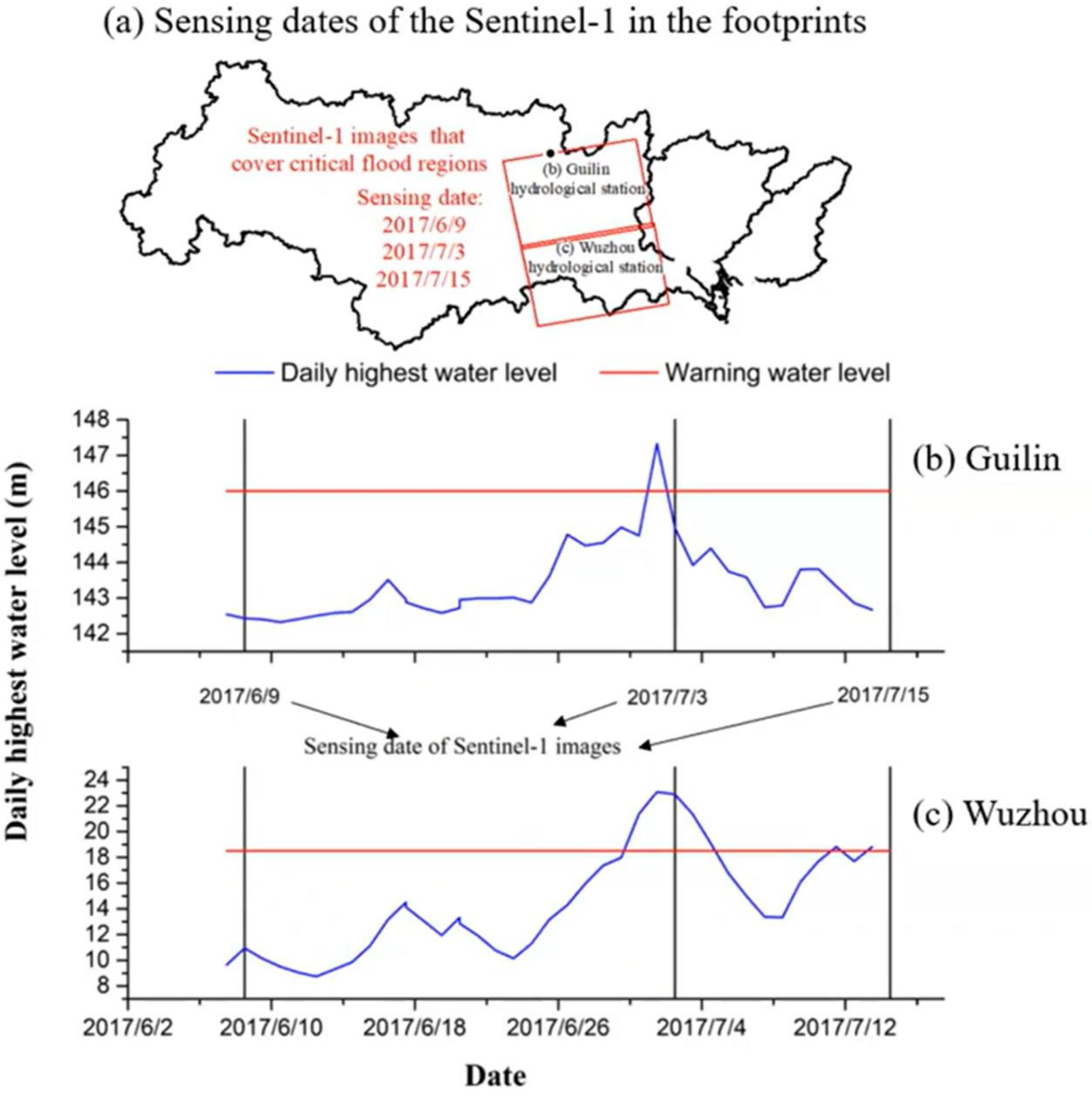


Implication for the construction of water conservancy facilities



Comparison of the flood locations obtained in this study and the distribution of embankments

What is the probability of Sentinel 1 successfully detecting floods?



Guilin is in a steep region, where flood peak duration is generally about 2 or 3 days. Comparing with the 12 days return period of Sentinel-1 images, we can know that there is about 20% for Sentinel-1 images to catch a flood event during flood peak in this region.

Wuzhou is in a flat region, where flood peak duration is generally about 5 or 6 days. Comparing with the 12 days return period of Sentinel-1 images, we can know that there is about 50% for Sentinel-1 images to catch a flood event during flood peak in this region.

Future perspective

Sentinel-1 SAR satellite

Identification of flood location

Estimation of flooded croplands to support flood damage on food security.

High-resolution flood map can be the calibration data to improve the hydrological flood model

Thank you for your time!

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remote sensing

MDPI

Article

Flood Monitoring in Rural Areas of the Pearl River Basin (China) Using Sentinel-1 SAR

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Abstract: Flood hazards result in enormous casualties and huge economic losses every year in the Pearl River Basin (PRB), China. It is, therefore, crucial to monitor floods in PRB for a better understanding of the flooding patterns and characteristics of the PRB. Previous studies, which utilized hydrological data were not successful in identifying flooding patterns in the rural and remote regions in PRB. Such regions are the key supplier of agricultural products and water resources for the entire PRB. Thus, an analysis of the impacts of floods could provide a useful tool to support mitigation strategies. Using 66 Sentinel-1 images, this study employed Otsu's method to investigate floods and explore flood patterns across the PRB from 2017 to 2020. The results indicated that floods are mainly located in the central West River Basin (WRB), middle reaches of the North River (NR) and middle reaches of the East River (ER). WRB is more prone to flood hazards. In 2017, 94.0% flood-impacted croplands were located in WRB; 95.0% of inundated croplands (~9480 hectares) were also in WRB. The most vulnerable areas to flooding are sections of the Yijiang, Luoqingjiang, Qianjiang, and Xunjiang tributaries and the lower reaches of Liujiang. Our results highlight the severity of flood hazards in a rural region of the PRB and emphasize the need for policy overhaul to enhance flood control in rural regions in the PRB to ensure food safety.