National Central University
College of Earth Sciences

Seminar 111-2
Graduate Institute of Applied Geology

Spatiotemporal Variations in the Hydromechanical Property of Aquifers in Choushui River Alluvial Fan, Taiwan

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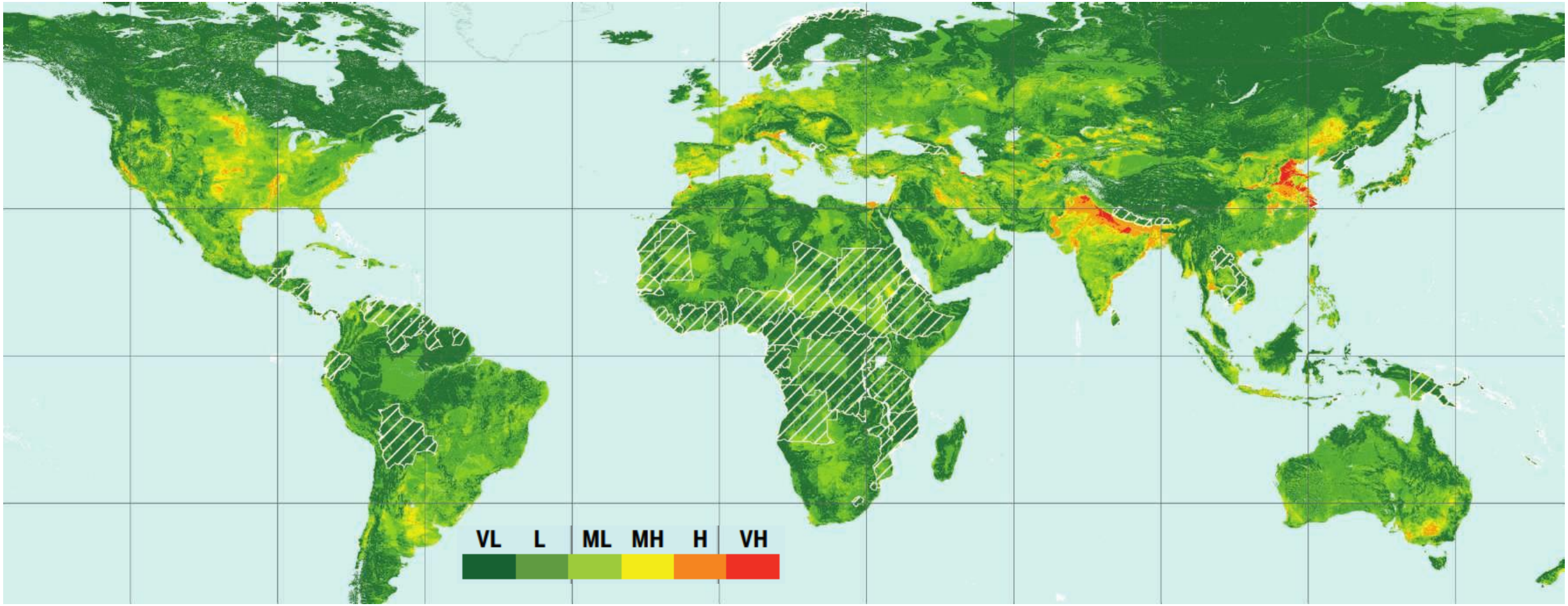
What is land subsidence?

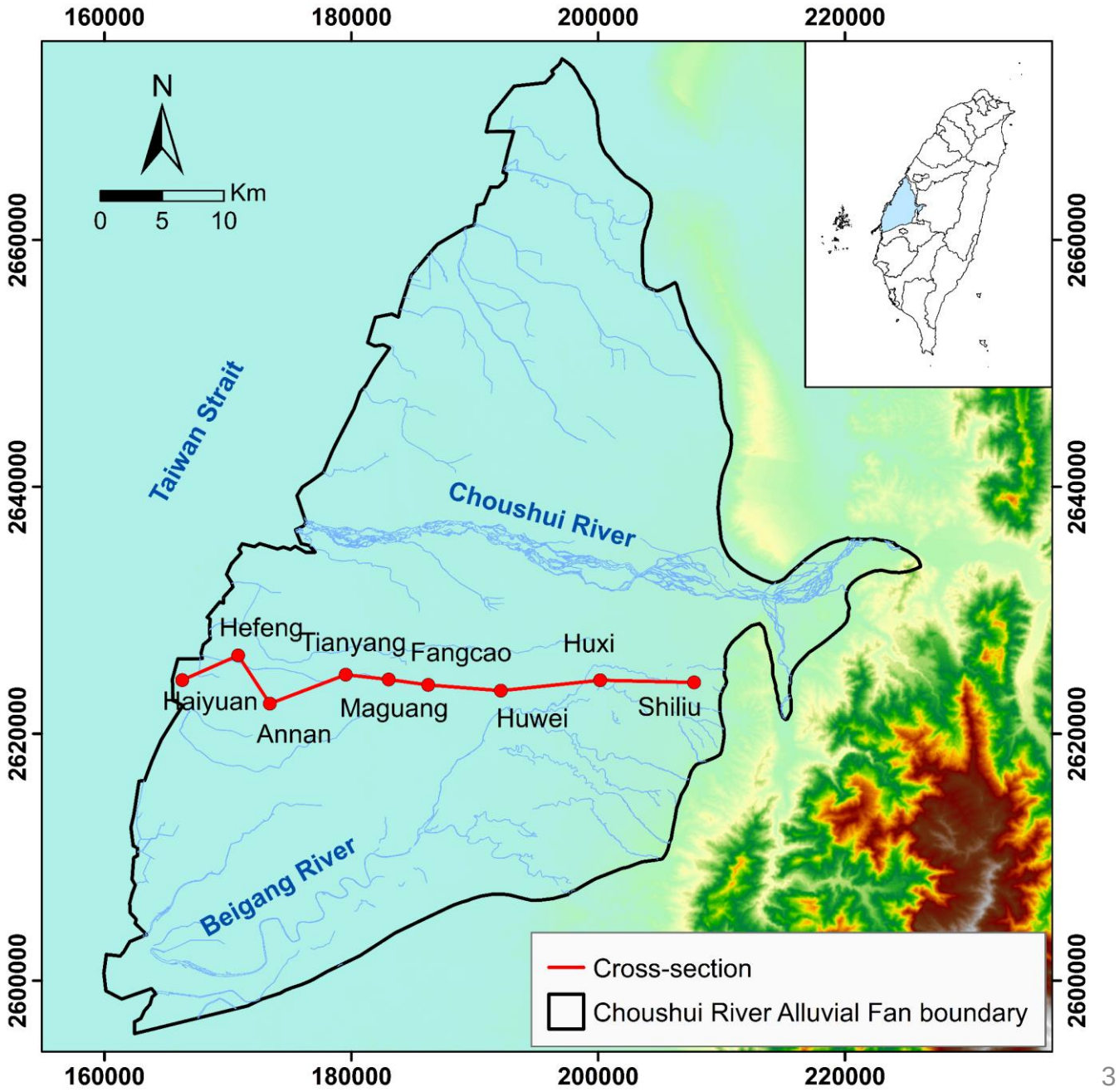
- Land surface sinking/settle-ment
- Vertical downward movement
- Not include landslides



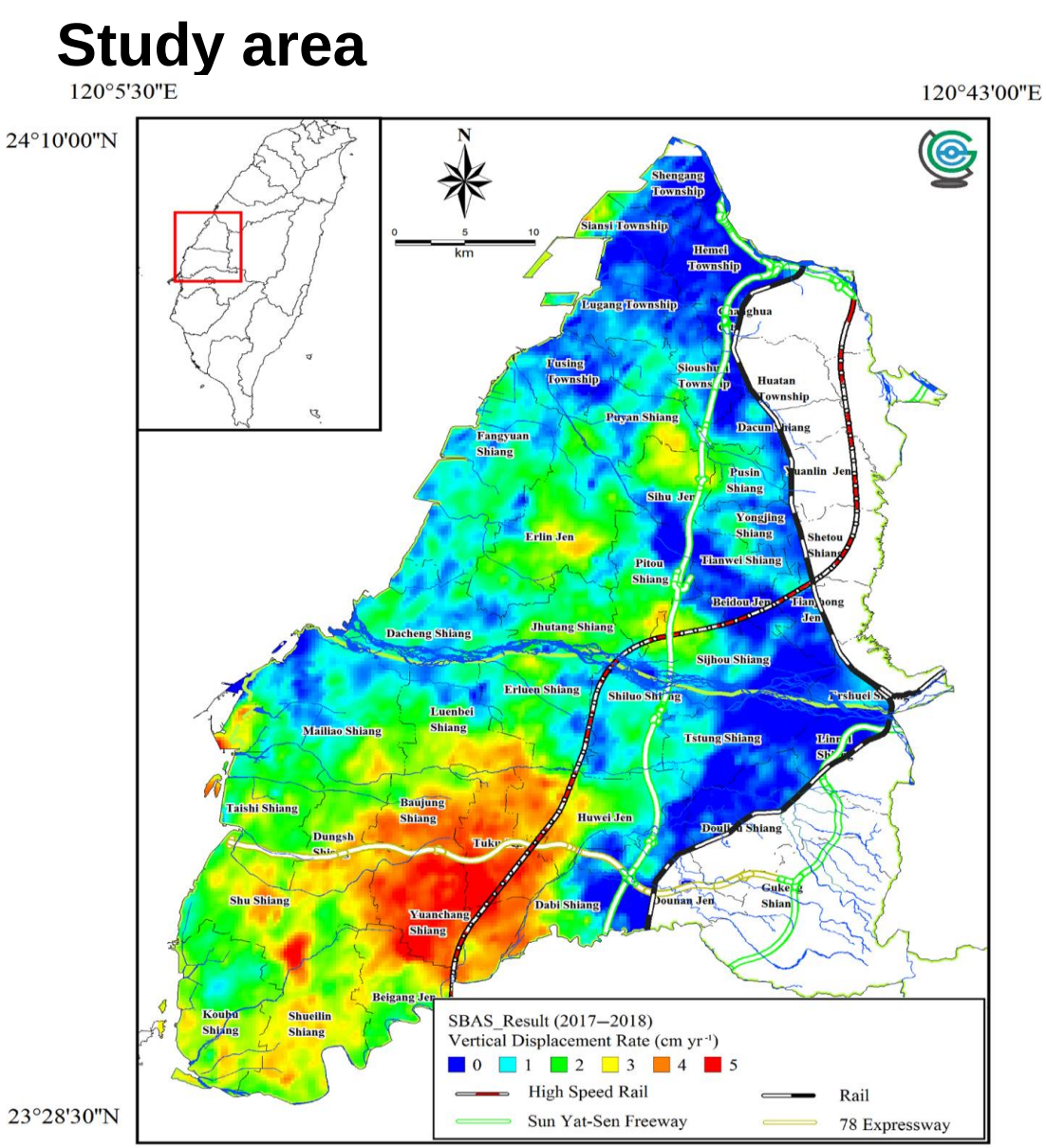
Mapping the global threat of land subsidence
(*Herrera-García, Ezquerro et al. 2021*)

Study area

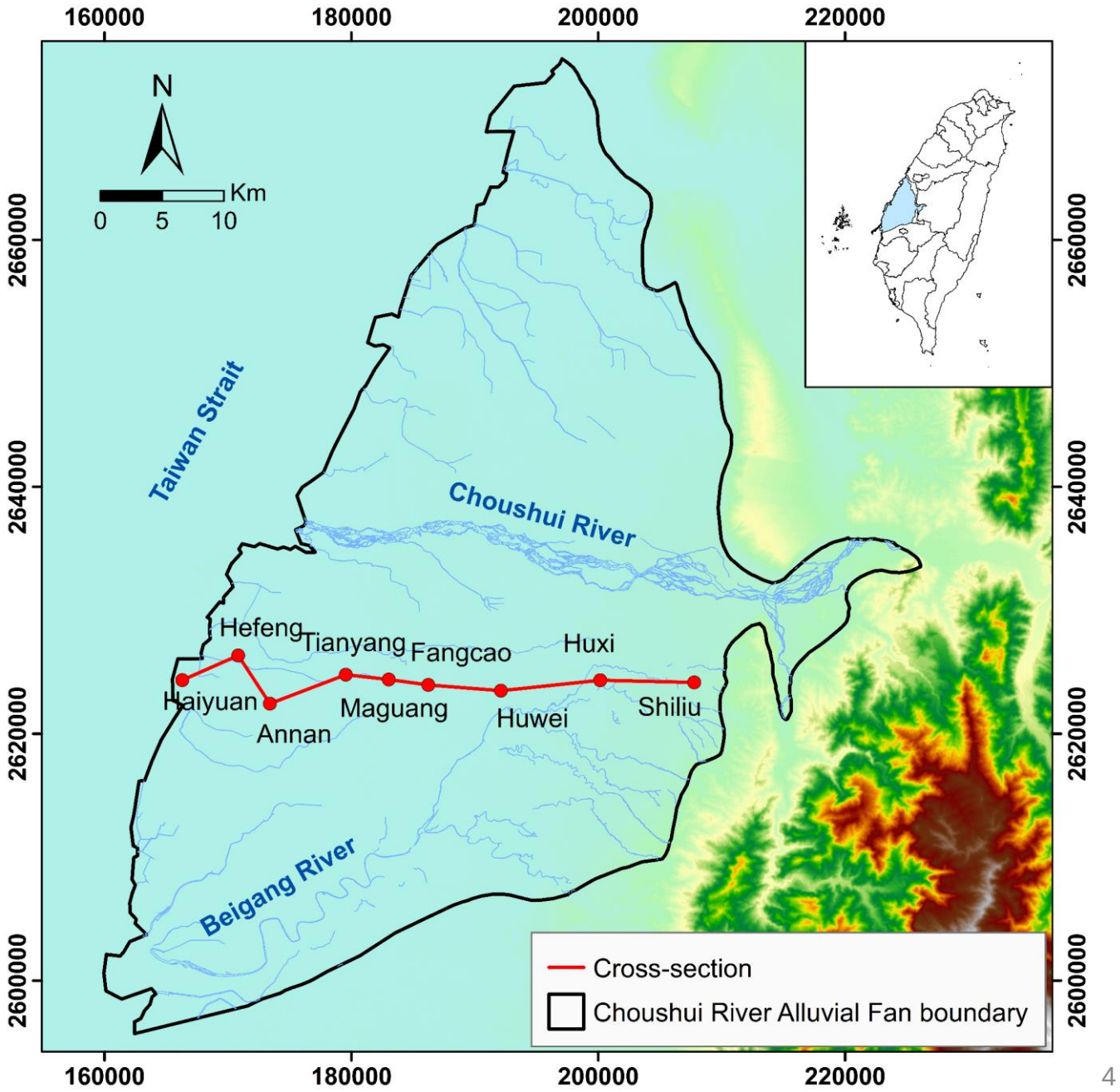
- Choushui River Alluvial Fan (CRAF) is located in the west-central of Taiwan.
- Important agriculture and aquaculture
- Groundwater for irrigation ➔ Overextraction
- Land subsidence ➔ Affect human lives, infrastructures and economic

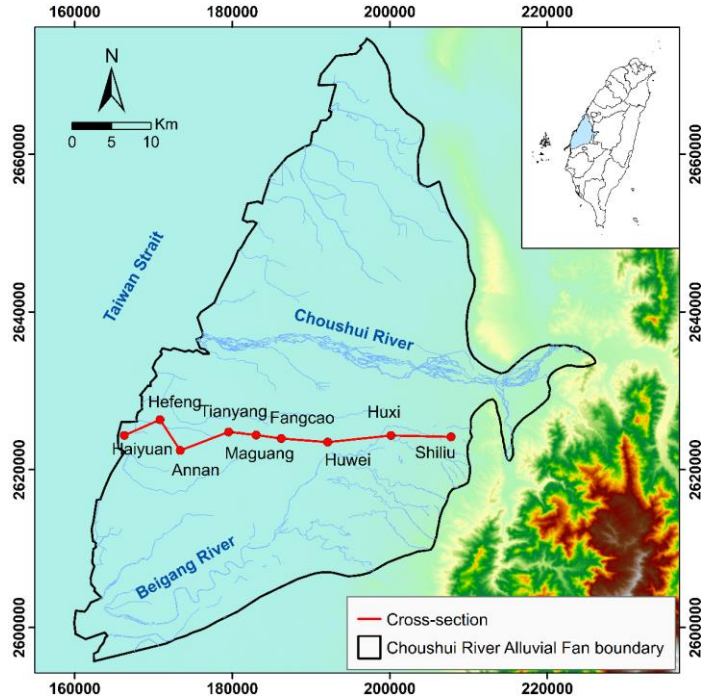


Study area



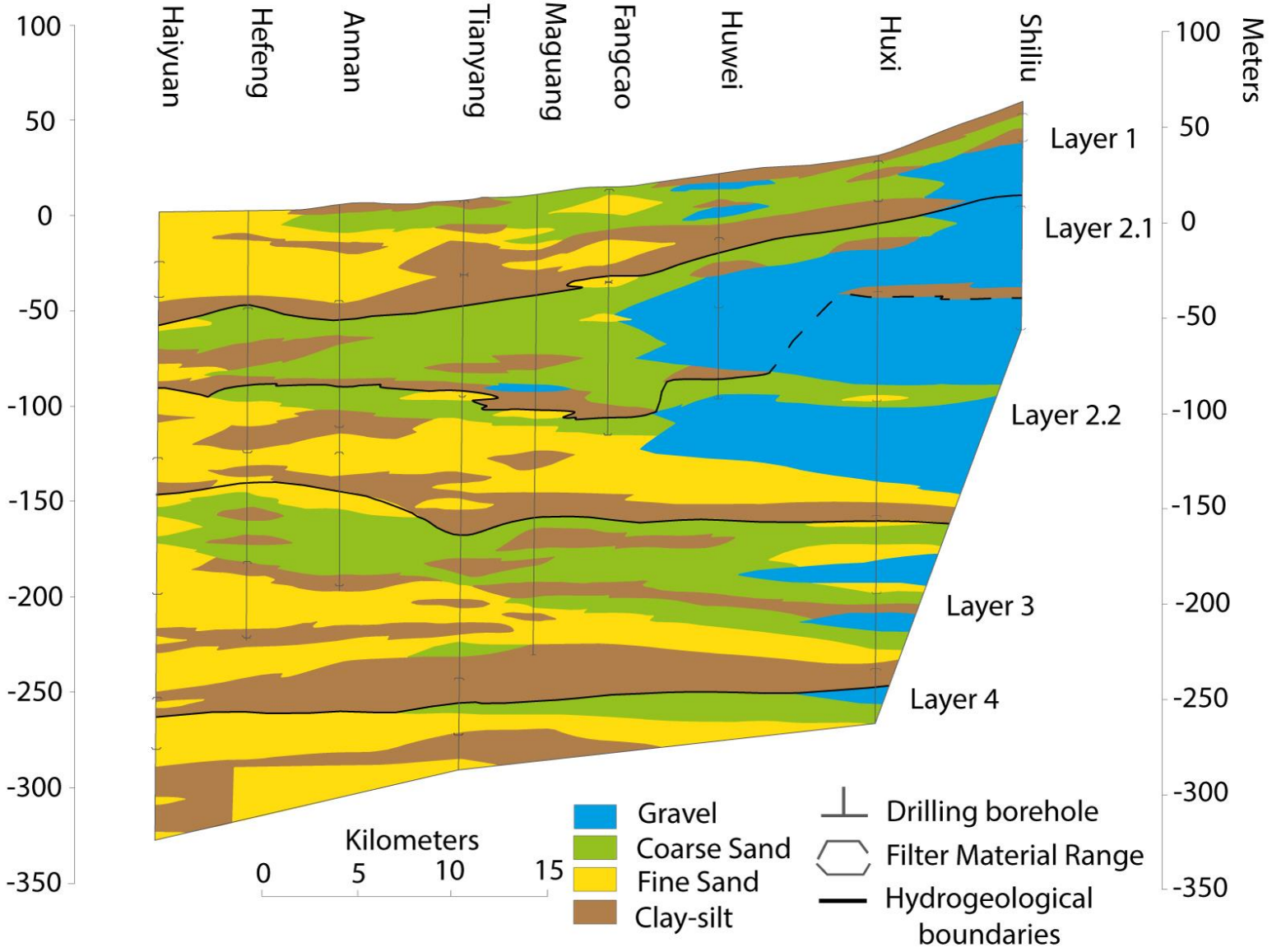
Vertical displacement rate over 2017-2018
(*Hung, Chen et al. 2020*)





The aquifer system in CRAF is divided into 5 layers as denoted Layers 1, 2.1, 2.2, 3, 4.

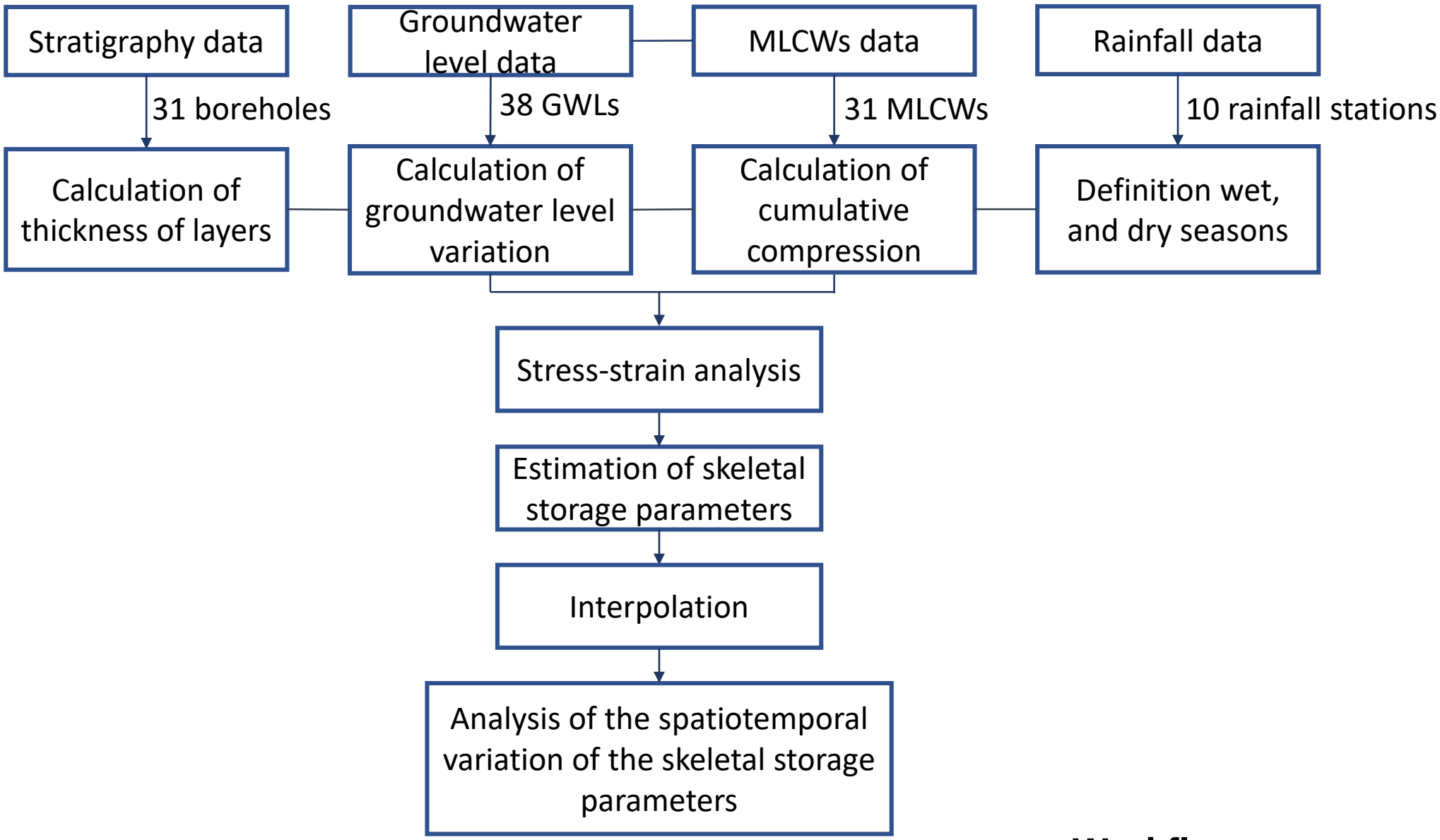
Primary materials: gravel, coarse sand, fine sand, and clay-silt.



Representative Cross-section from Haiyuan to Shiliu *(modified from Central Geological Survey of Taiwan)*

Objective

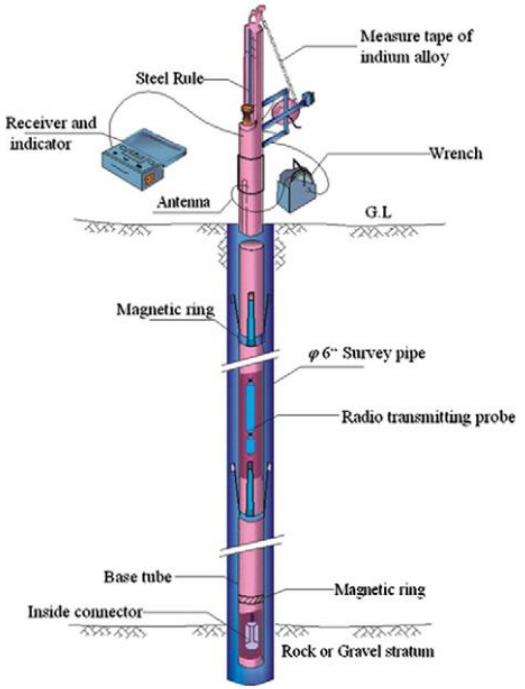
- Investigation of the variability of the skeletal storage values (depth, time).
- Analysis of the relationship between groundwater level changes and land subsidence.



Workflow summary

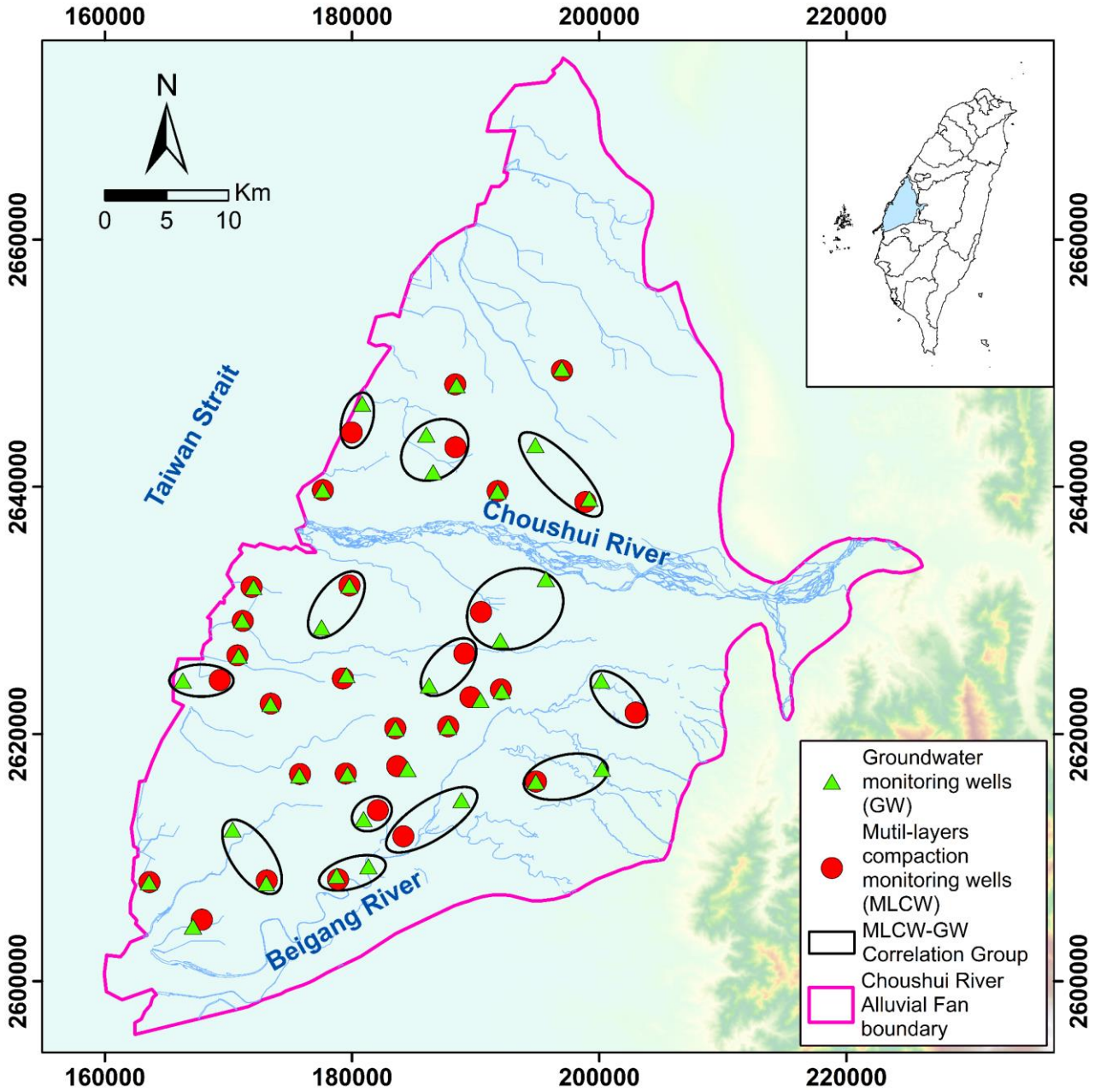
1. Collecting Data

- 38 Groundwater level monitoring wells
- 31 Multi-layers compaction monitoring wells
- 10 Rainfall stations to define wet and dry seasons



Multi-layer compaction monitoring well

(*Hung, Hwang et al. 2012*)



Distributions of GW and MLCW monitoring wells

2. Analysis stress-strain

Groundwater levels change ➔ Land subsidence through the stress-strain relationship (considers elastic or inelastic skeletal specific storage) (*Hung, Hwang et al. 2012*)

Using Terzaghi's theory

$$\delta_e = \delta_T - P_w$$

δ_T : total stress

δ_e : effective stress

P_w: fluid or pore water pressure

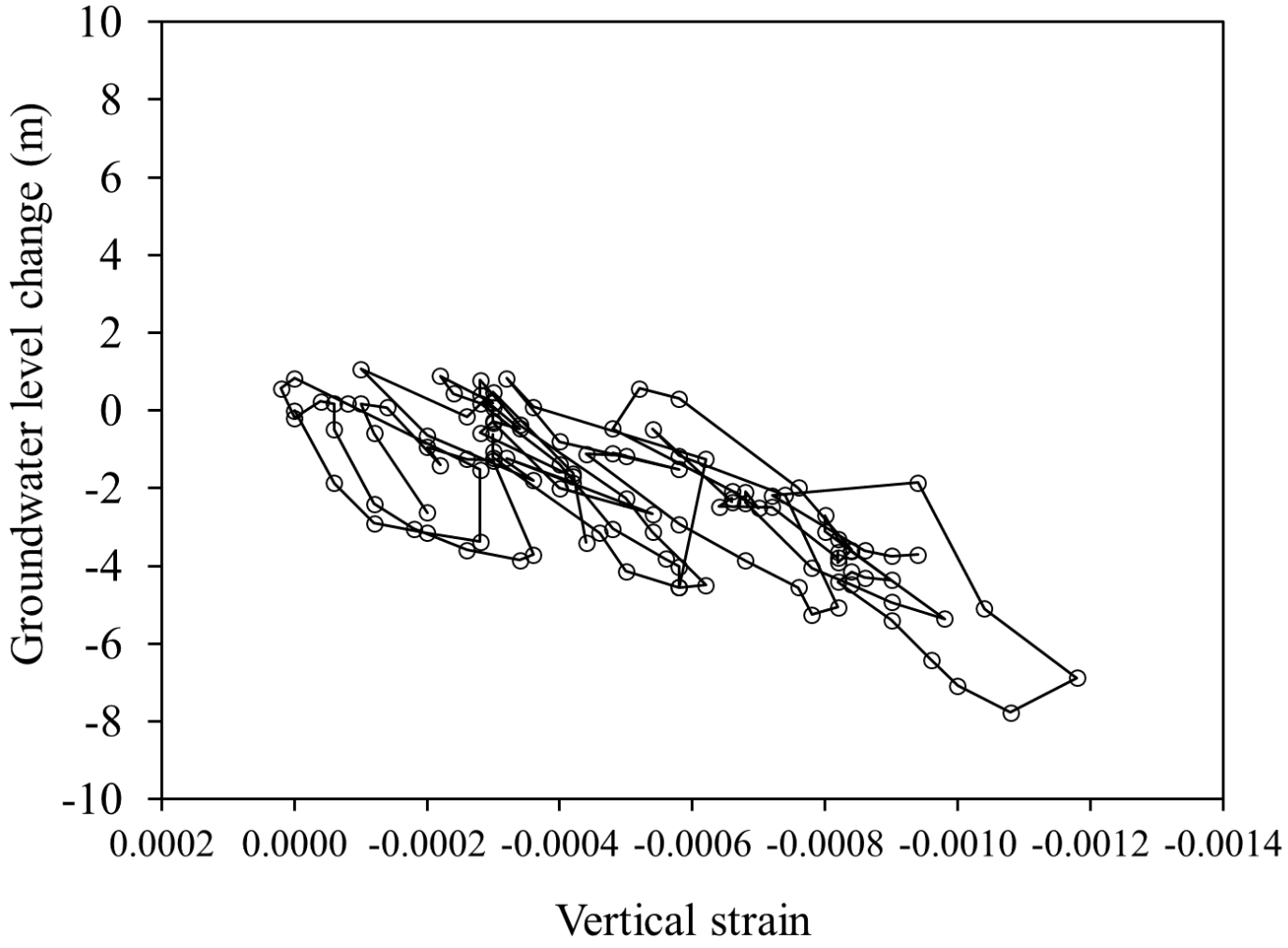
$$\Delta\delta_e = -\Delta P_w$$

$$\Delta P_w = \rho_w g \Delta h$$

ρ_w : water density

g : gravity

Δh : groundwater level change



The pattern between strain and groundwater level from 2010-2020

2. Analysis stress-strain

One−dimensional compressibility is related to skeletal−specific storage (*Hung, Hwang et al. 2012*)

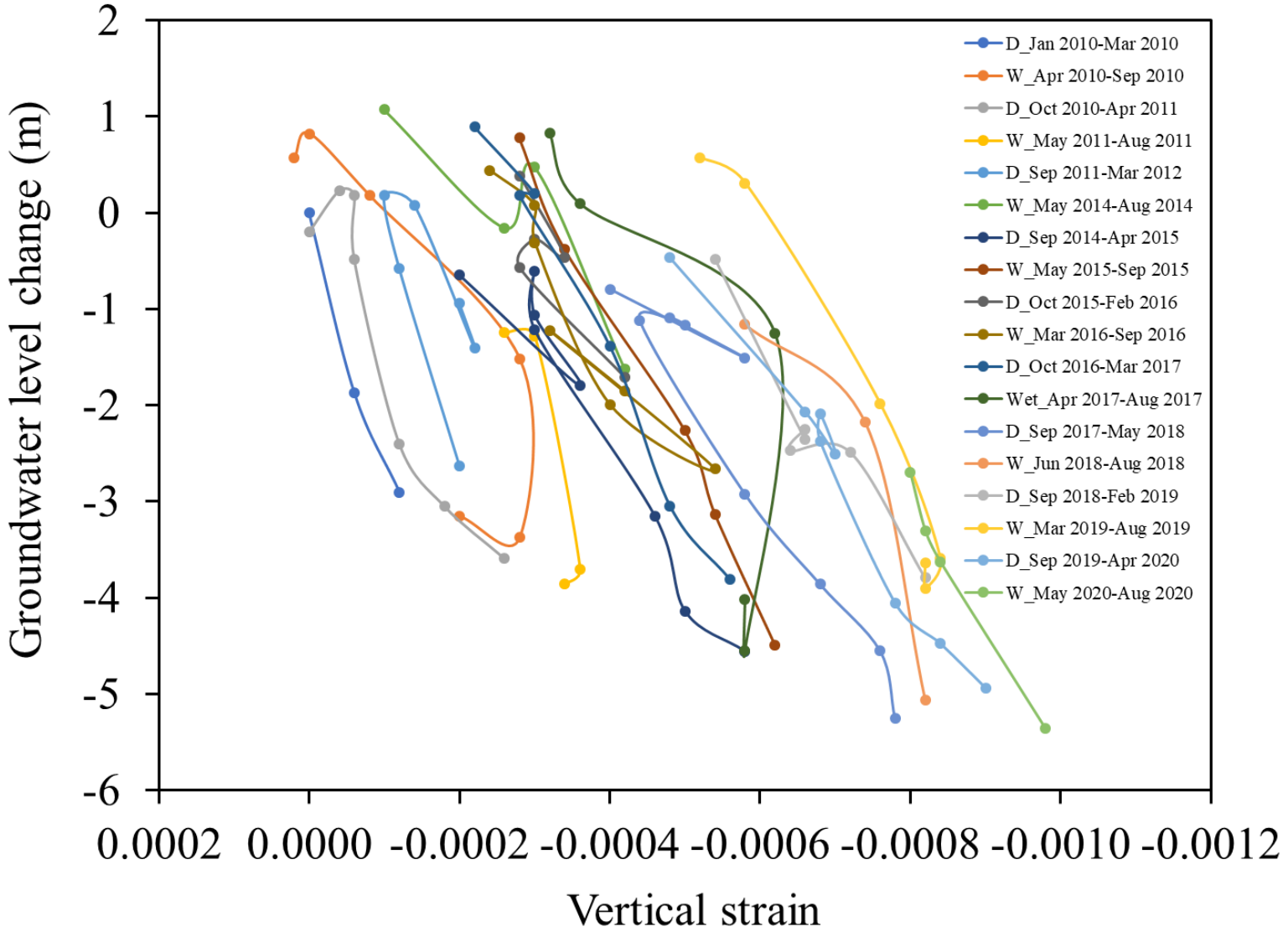
$$S_{sk} = \frac{-\Delta B / B_0}{\Delta h}$$

S_{sk} : skeletal specific storage

ΔB : compression

B_0 : thickness of layer

Δh : Groundwater level change



The seasonal and annual pattern between strain and groundwater level

3. Estimation storage parameters

Skeletal Storage Coefficient

$$S_{ke} = \frac{\Delta B_e}{\Delta h_e}$$

$$S_{kv} = \frac{\Delta B_v}{\Delta h_v}$$

(*Abolfazl, Zahra et al. 2020*)

S_{ke} , S_{kv} : elastic/ inelastic skeletal storage coefficient

ΔB_e , ΔB_v : elastic/inelastic deformation

Δh_e , Δh_v : groundwater level change (elastic/inelastic)

- 31 positions (Yunlin & Changhua)
- 5 layers
- 11 years (2010-2020)
- Wet and dry seasons

Preliminary results

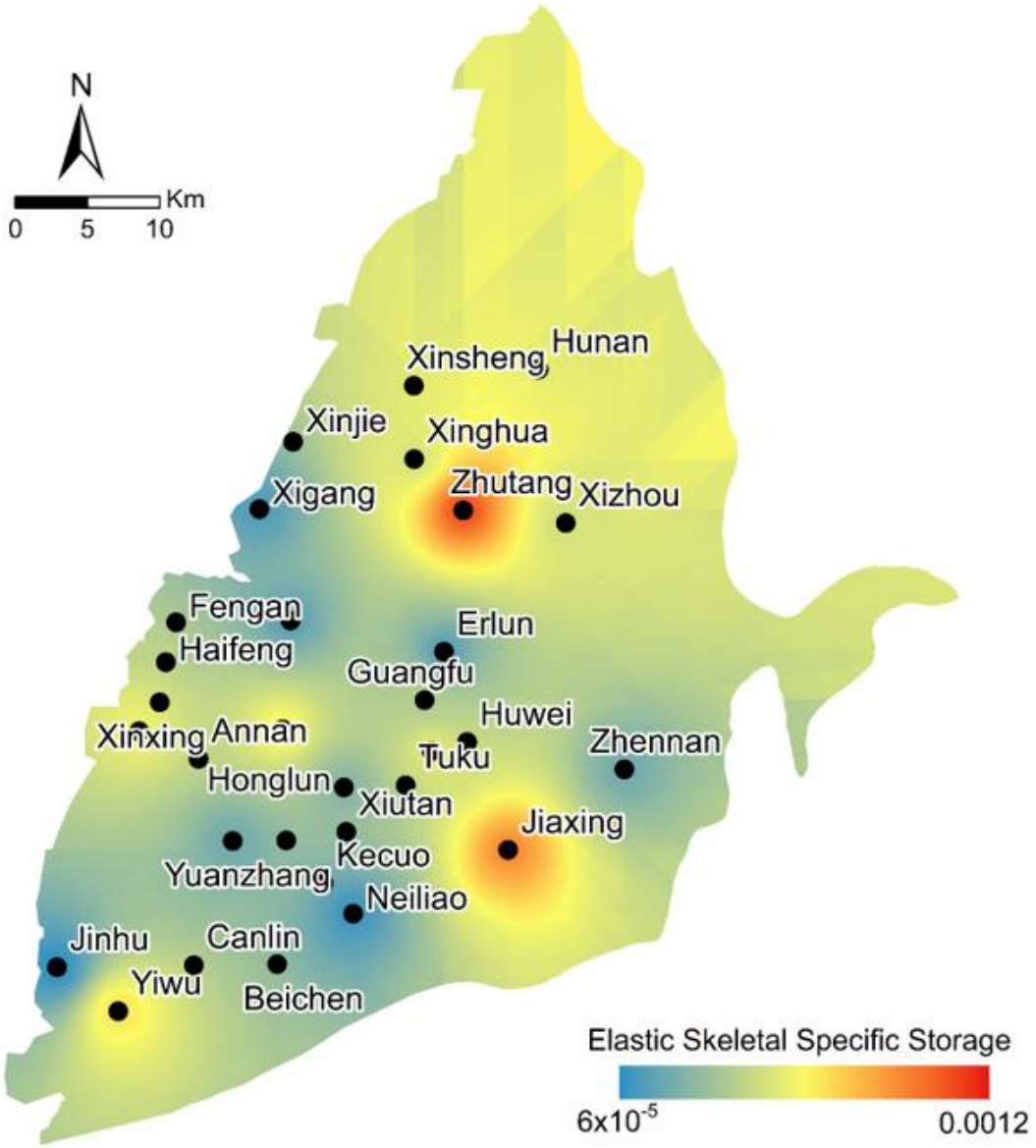
The **elastic skeletal storage coefficient** of 31 wells from 2010-2020

Layer (depth range)	Wet season			Dry season		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Layer 1 (0-57 m)	8.43E-04	4.28E-01	2.26E-02	6.27E-04	2.41E-01	2.47E-02
Layer 2.1 (57-96 m)	3.48E-04	4.93E-01	1.71E-02	2.47E-04	7.05E-01	1.71E-02
Layer 2.2 (96-166 m)	5.69E-04	6.80E-01	3.10E-02	1.96E-04	7.97E-01	3.68E-02
Layer 3 (166-262 m)	3.71E-04	5.32E-01	4.36E-02	1.58E-04	3.91E-01	3.88E-02
Layer 4 (262-300 m)	2.31E-04	9.58E-01	3.42E-02	2.73E-04	7.26E-01	3.74E-02

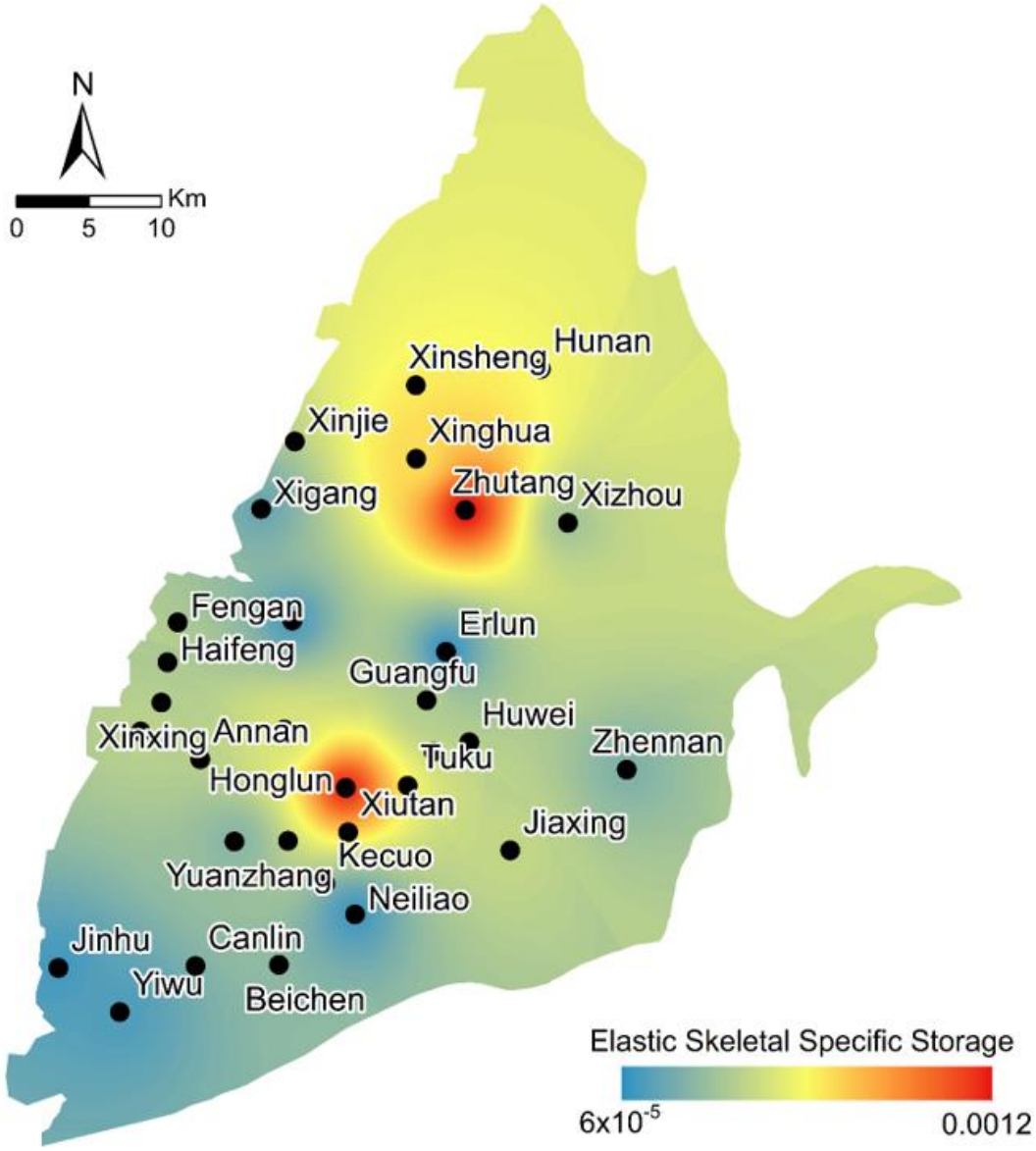
Layer (depth range)	**Inelastic skeletal storage coefficient**		
	Minimum	Maximum	Average
Layer 1 (0-57 m)	4.56E-04	2.26E-02	9.50E-03
Layer 2.1 (57-96 m)	2.13E-03	8.83E-02	2.34E-02
Layer 2.2 (96-166 m)	1.01E-03	2.13E-01	4.14E-02
Layer 3 (166-262 m)	4.25E-04	6.11E-02	2.70E-02
Layer 4 (262-300 m)	5.36E-03	1.28E-02	9.39E-03

S_{ke} values of range 10^{-4} to 10^{-1}

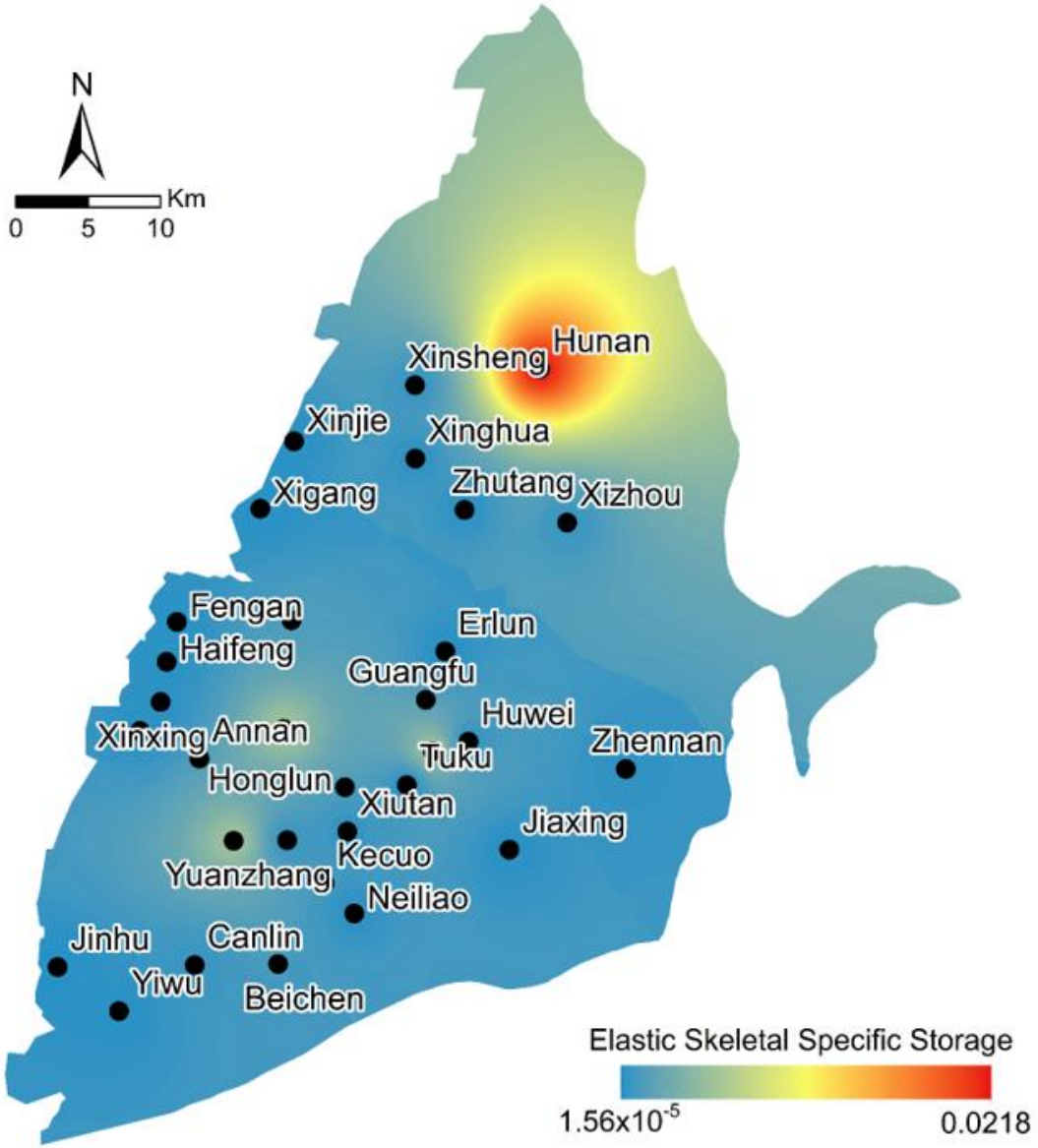
S_{kv} values exhibit a consistent average of approximately 10^{-2}



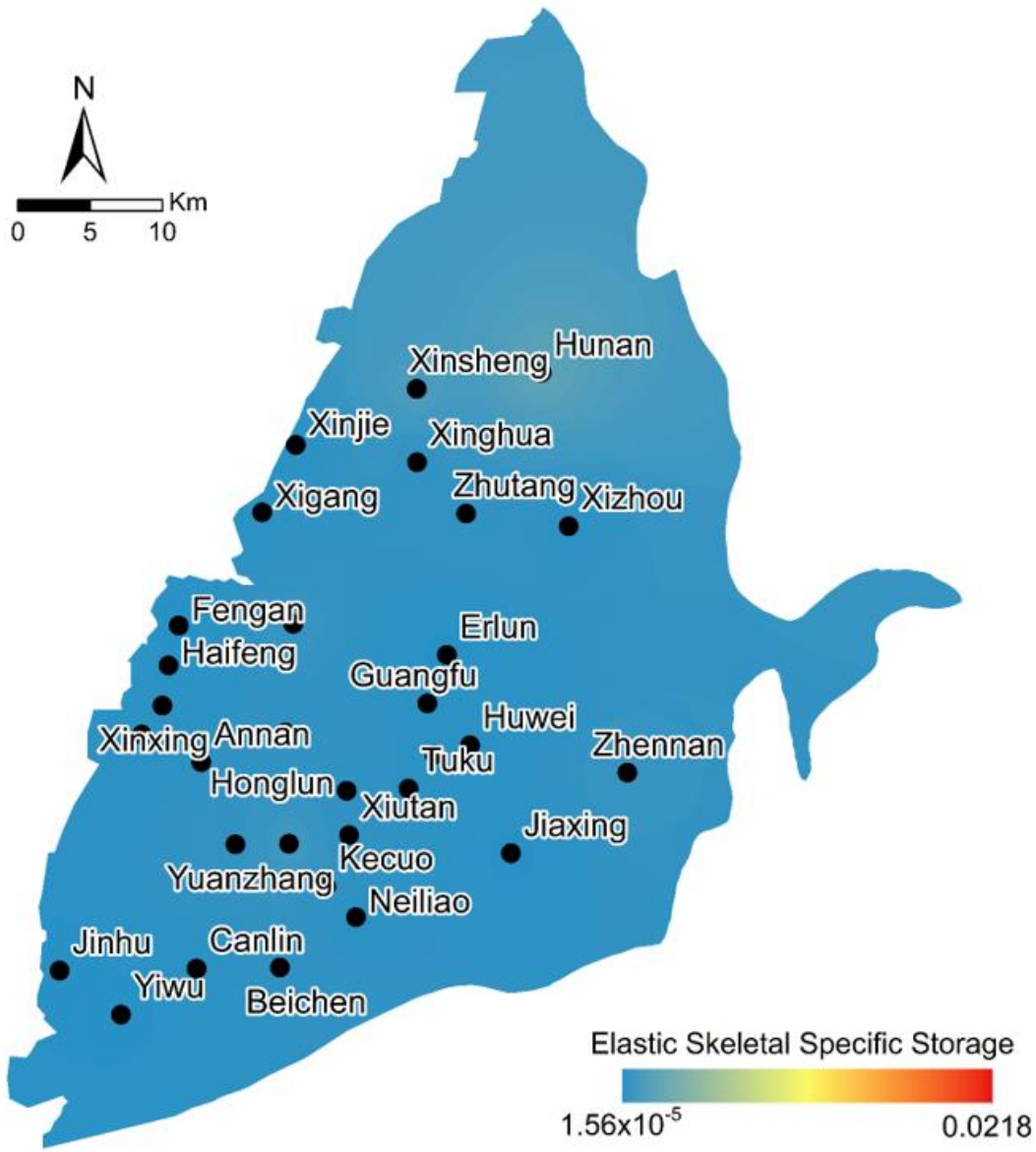
Dry season
Layer 1



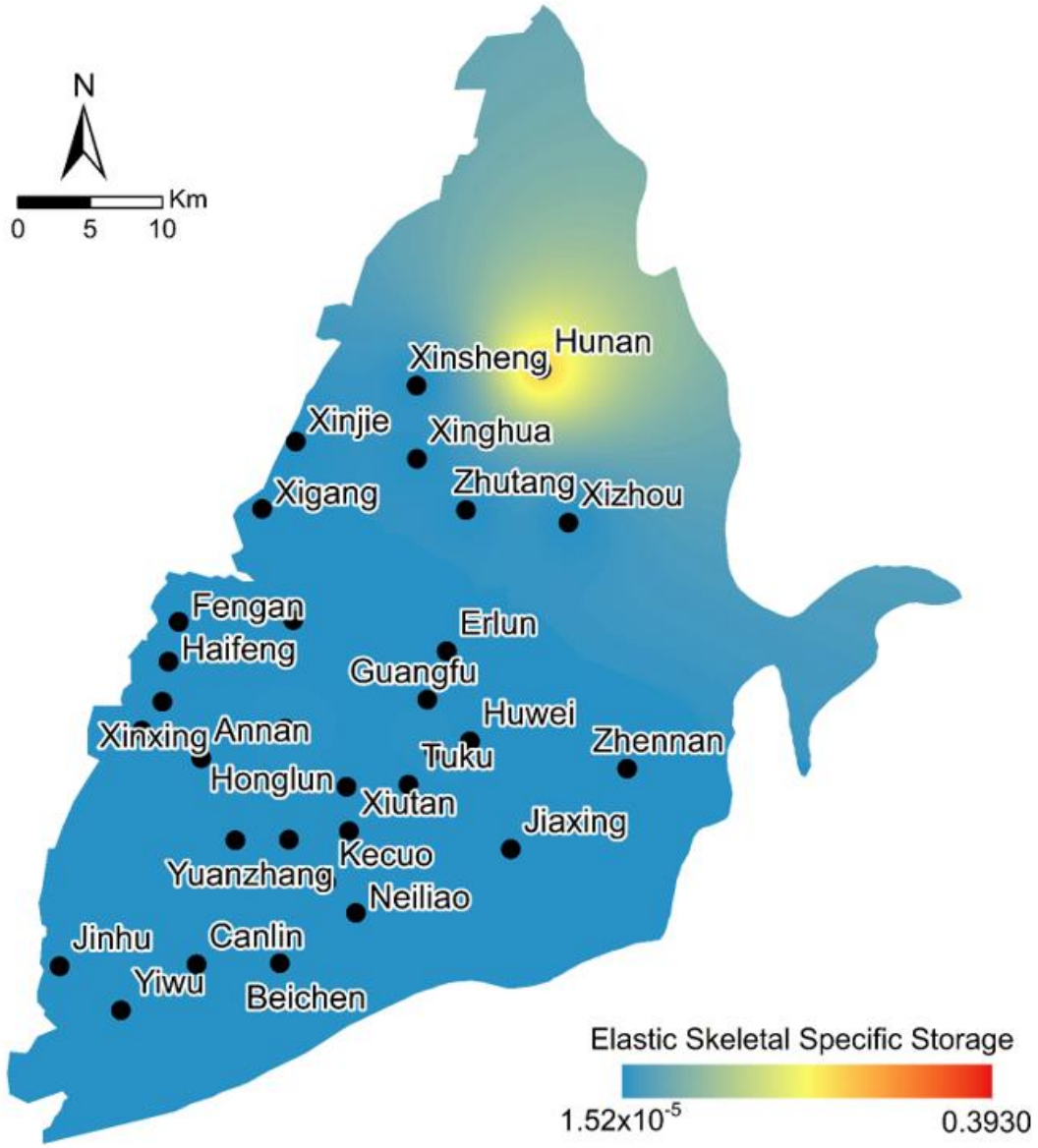
Wet season
Layer 1



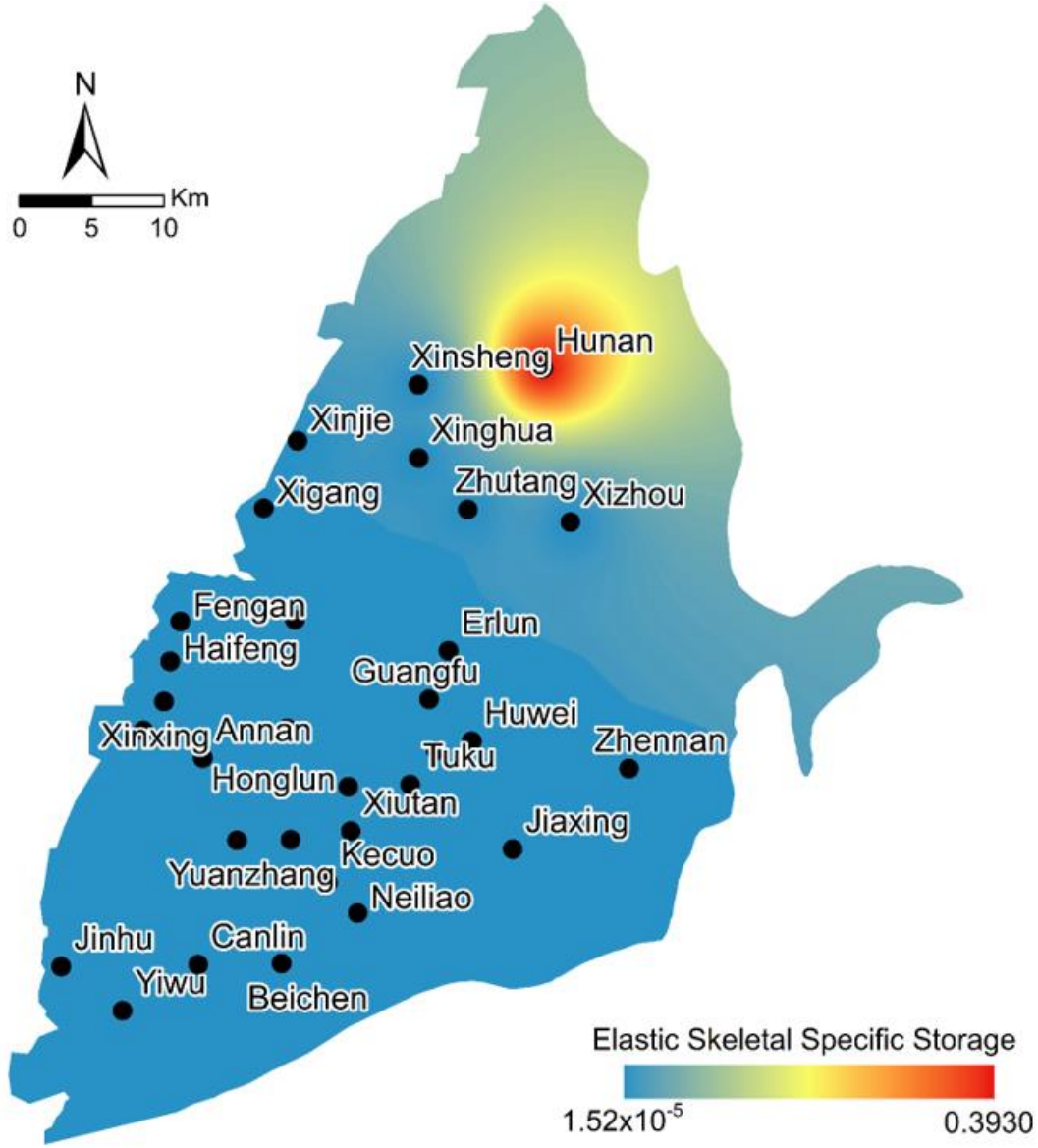
Dry season
Layer 2.1



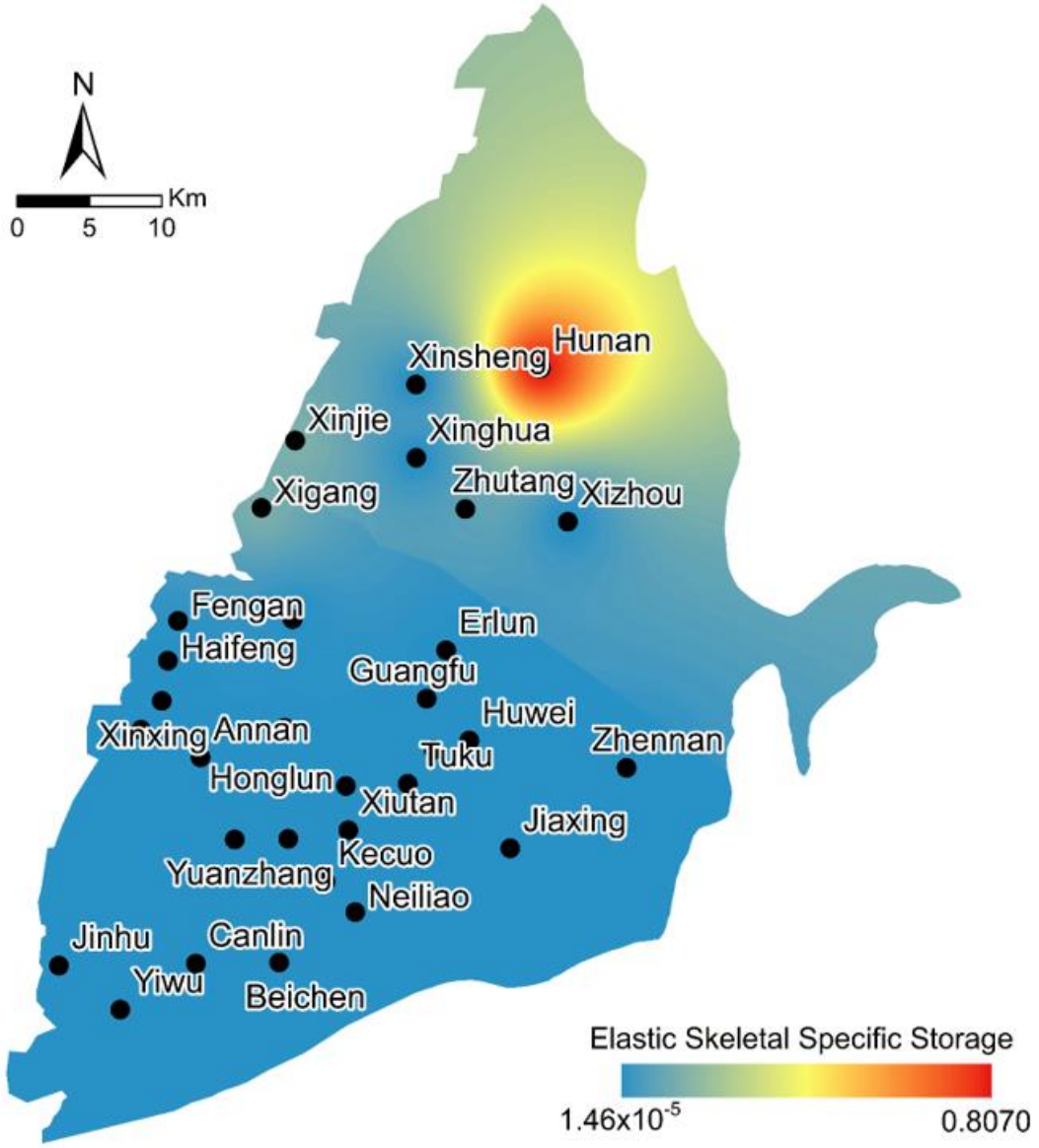
Wet season
Layer 2.1



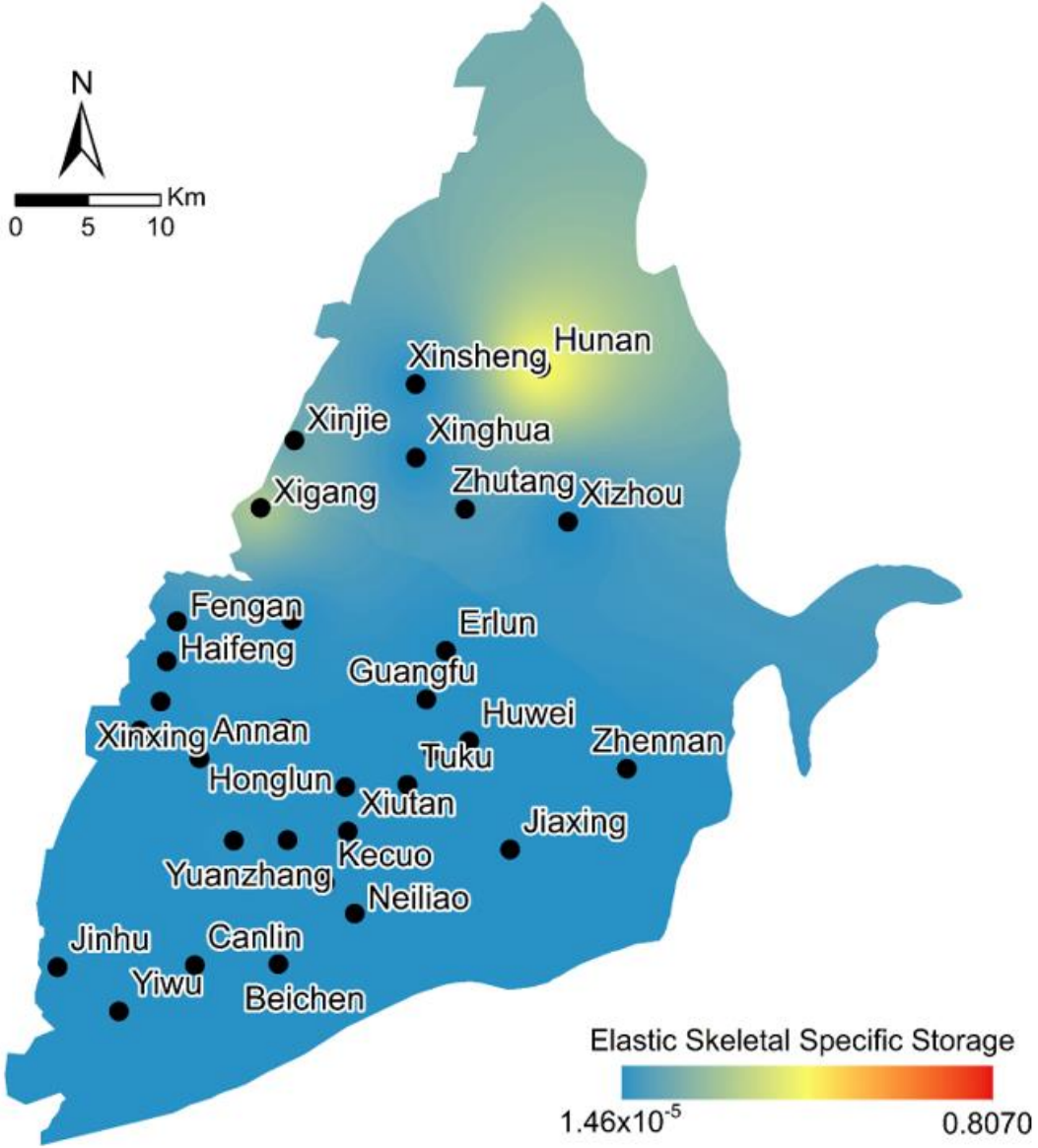
Dry season
Layer 2.2



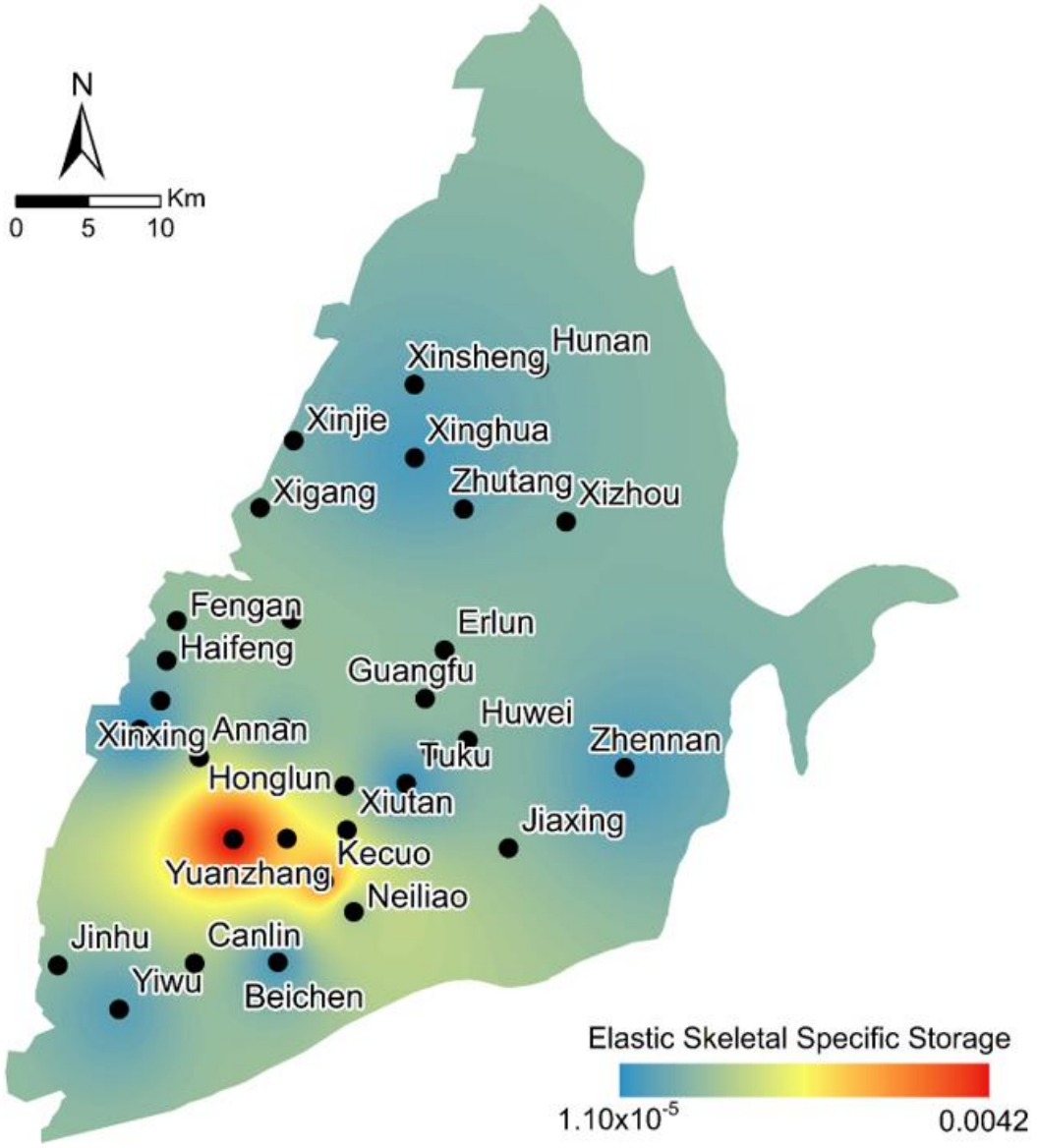
Wet season
Layer 2.2



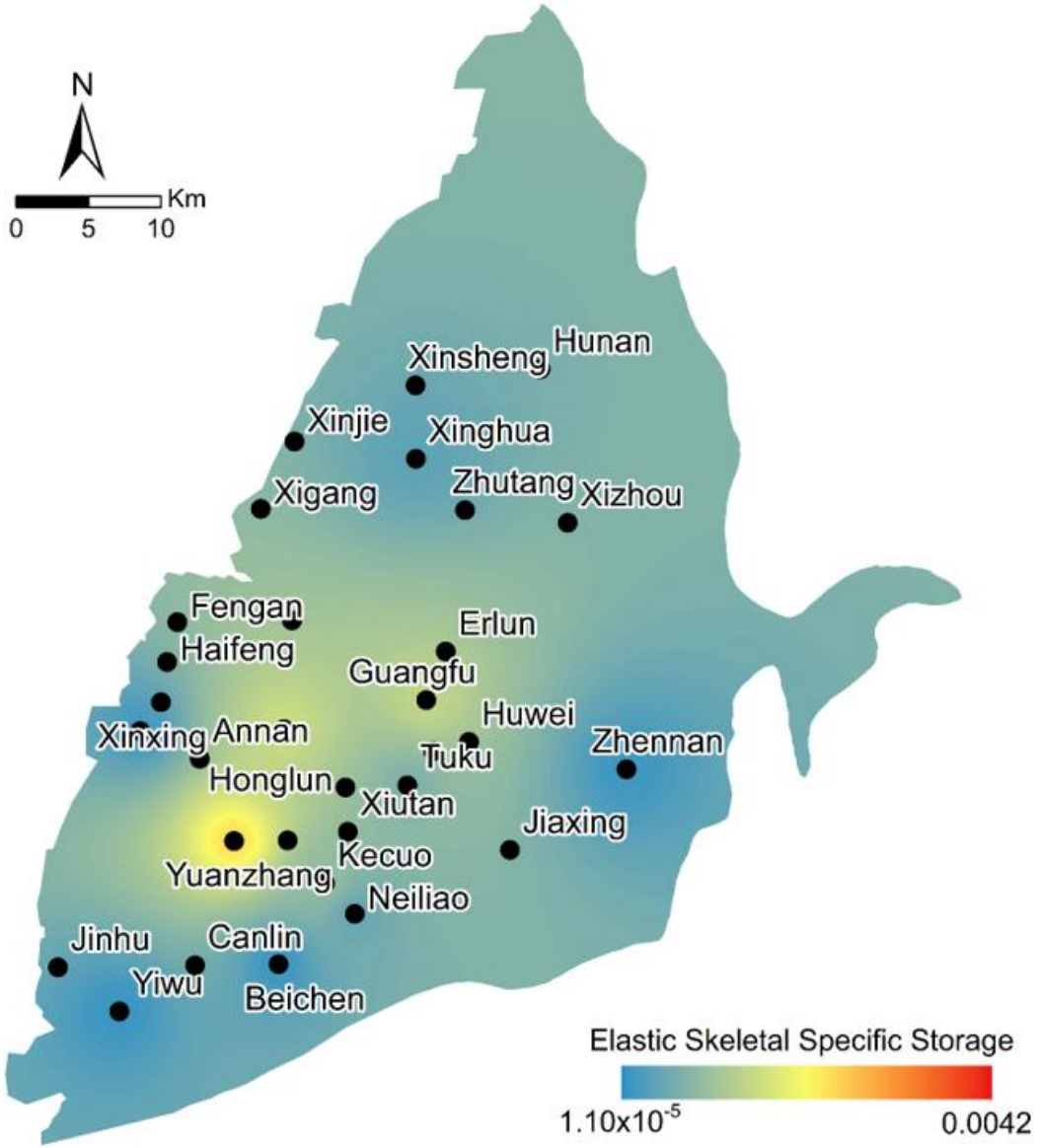
Dry season
Layer 3



Wet season
Layer 3



Dry season
Layer 4



Wet season
Layer 4

From preliminary results:

- The skeletal elastic storage coefficient between dry and wet seasons is not much different.
- The skeletal inelastic storage coefficient varies with depth.
- The skeletal storage parameters vary spatiotemporally.

- Interpolation of the skeletal storage parameters on a seasonal basic per year
- Analysis of the relationship between skeletal storage parameters and lithology (materials)
- Comparison of the skeletal storage values (my results to literature results)

Thank you for your attention