National Central University
College of Earth Sciences

Seminar 112-1
Graduate Institute of Applied Geology

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

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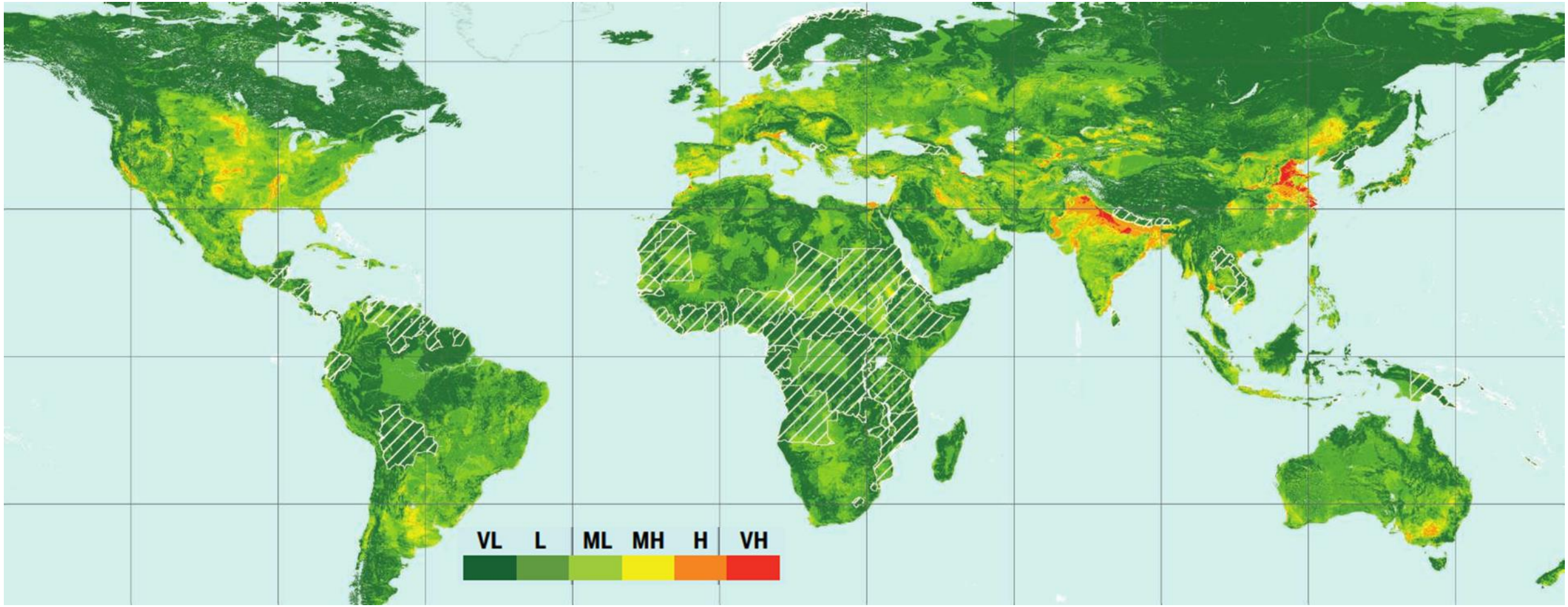
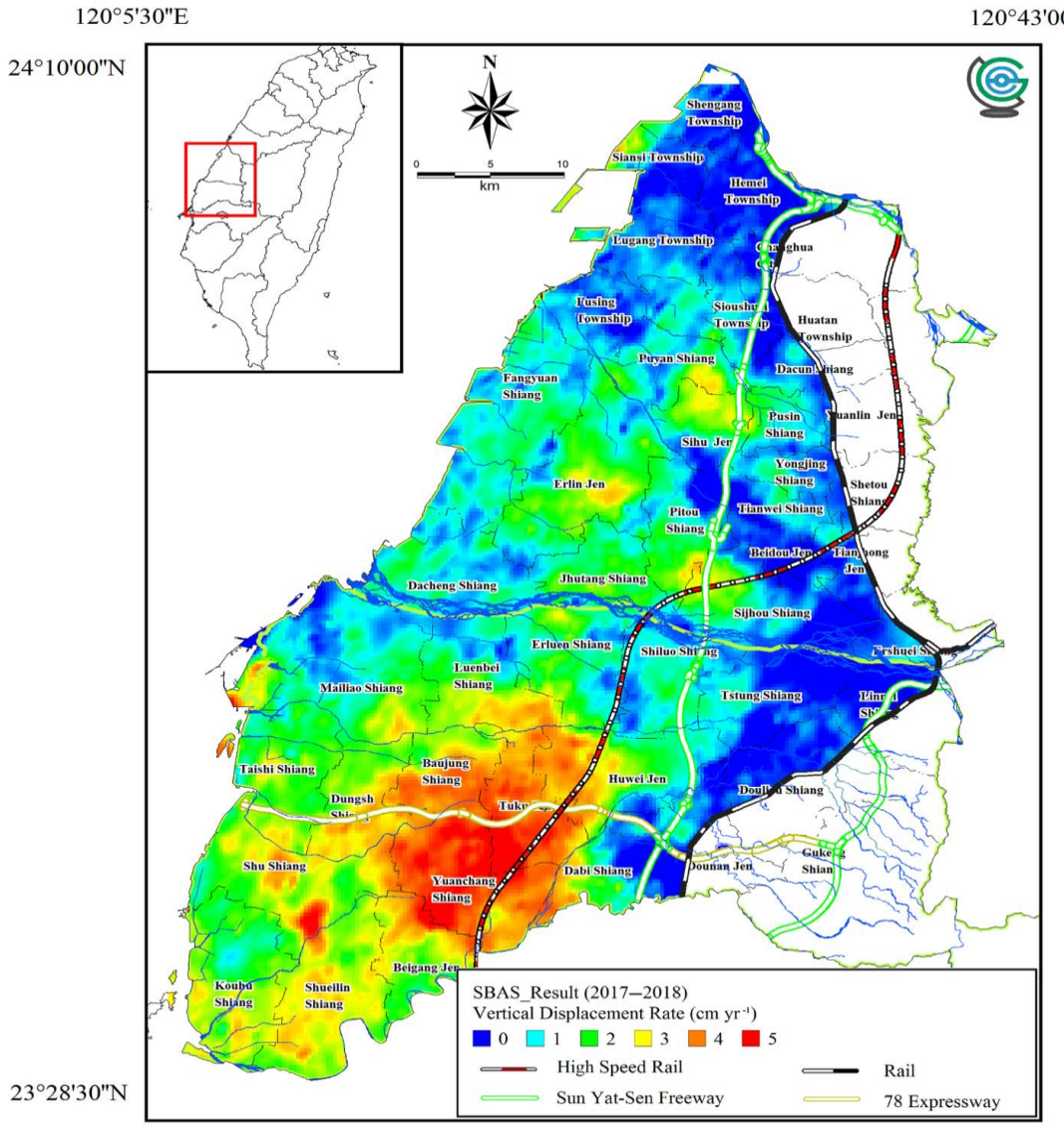
Date: 2023/10/06



Mapping the global threat of land subsidence

(Gerardo et al., 2021)

Motivation



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

- Due to lack of sufficient surface water, massive amount of groundwater has been extracted, resulting in severe land subsidence (Hung et al., 2012).
- When land subsidence occurs, it affects the safety of buildings and other infrastructures.
- Land subsidence occurs quickly, with a maximum rate of up to 5 cm per year.
- Land subsidence is a consequence of stratum compaction, which may vary with different seasons and can be affected by groundwater levels (Amelung et al., 1999; Hung et al., 2012; etc).

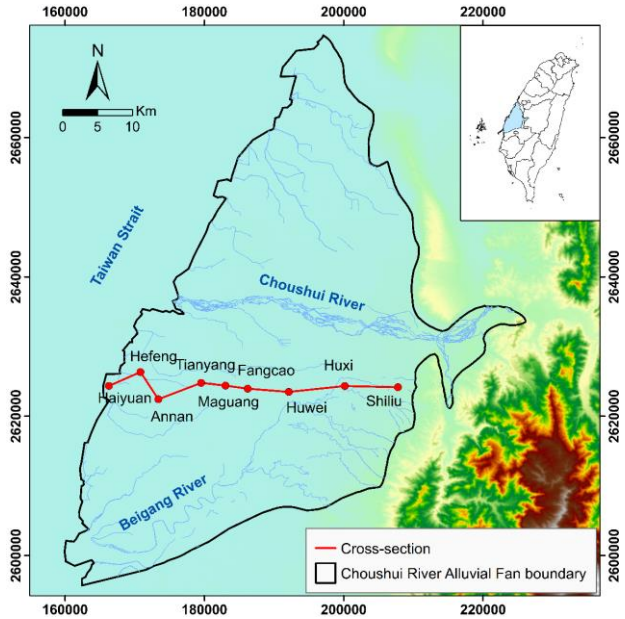
Objective:

- Estimate the skeletal-specific storage (S_{sk}) in the Choushui River Alluvial Fan (CRAF).
- Investigate the spatiotemporal variation of the S_{sk}.
- Evaluate the land subsidence potential.

Key terminology:

- **Skeletal-specific storage** – refers to the hydrogeological parameter that quantifies the deformability of the material within a fine-grained or coarse-grained sediment layer.

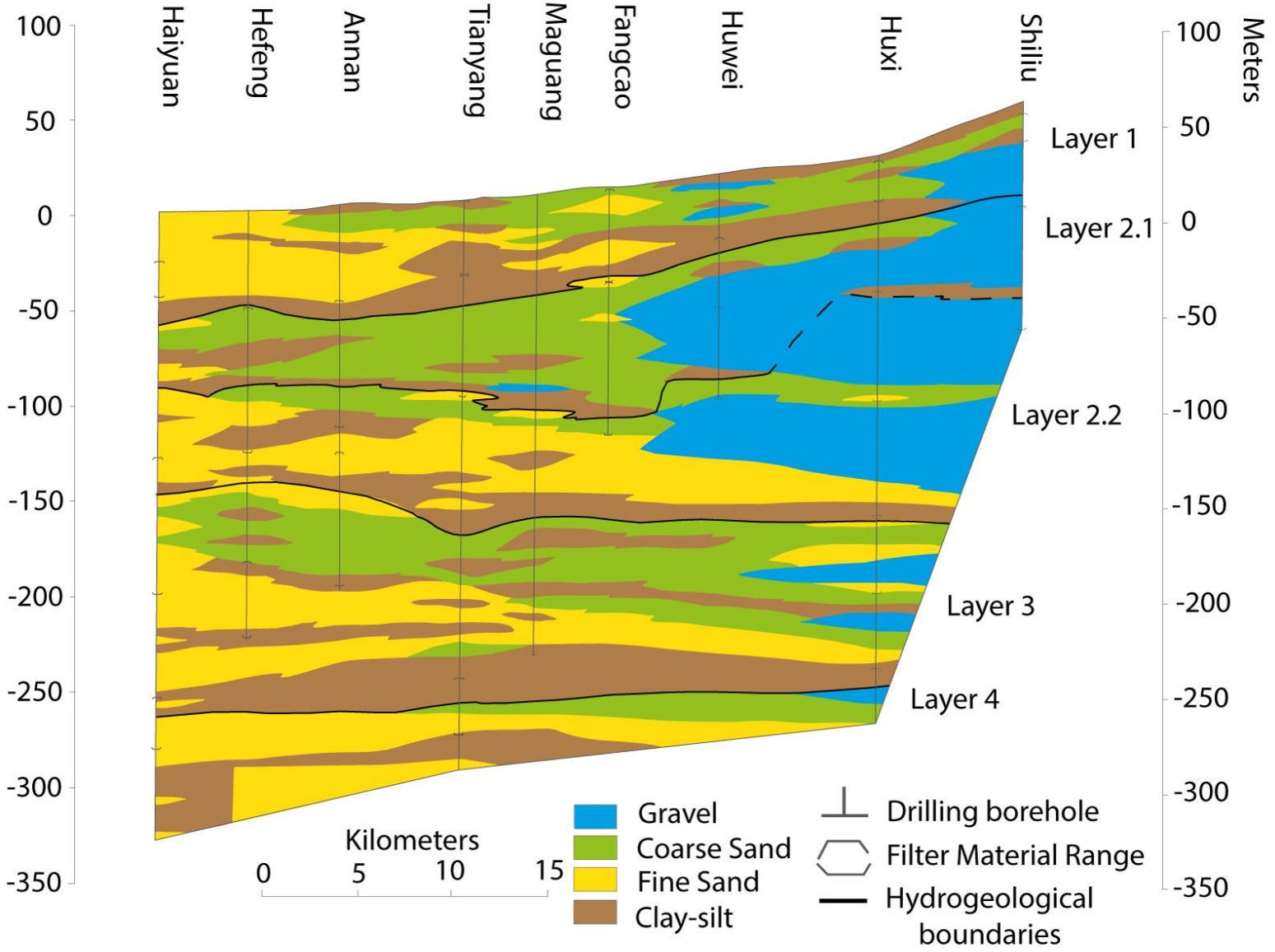
Study background



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

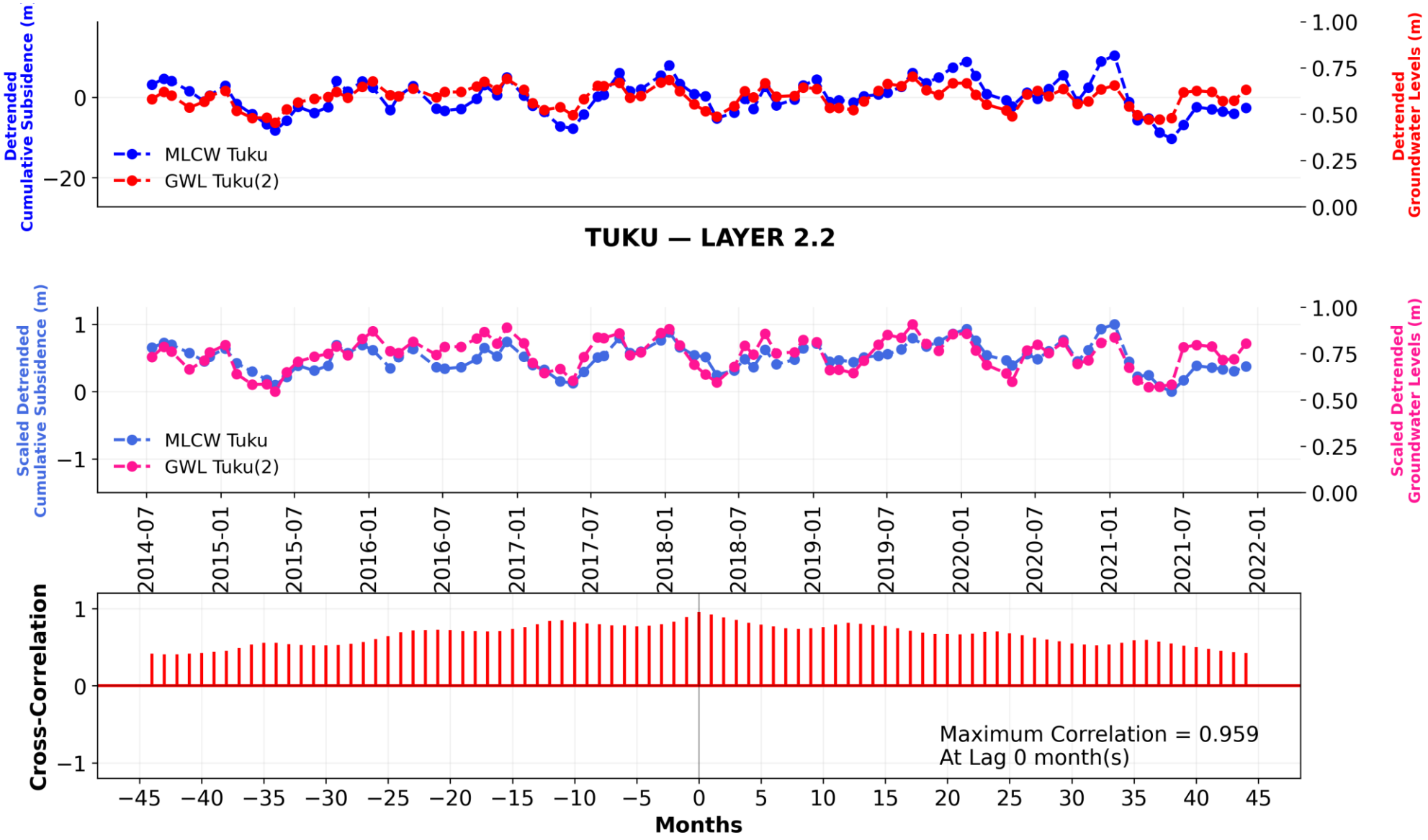
The term “layer” refers to a complex set of aquifers and aquitards.

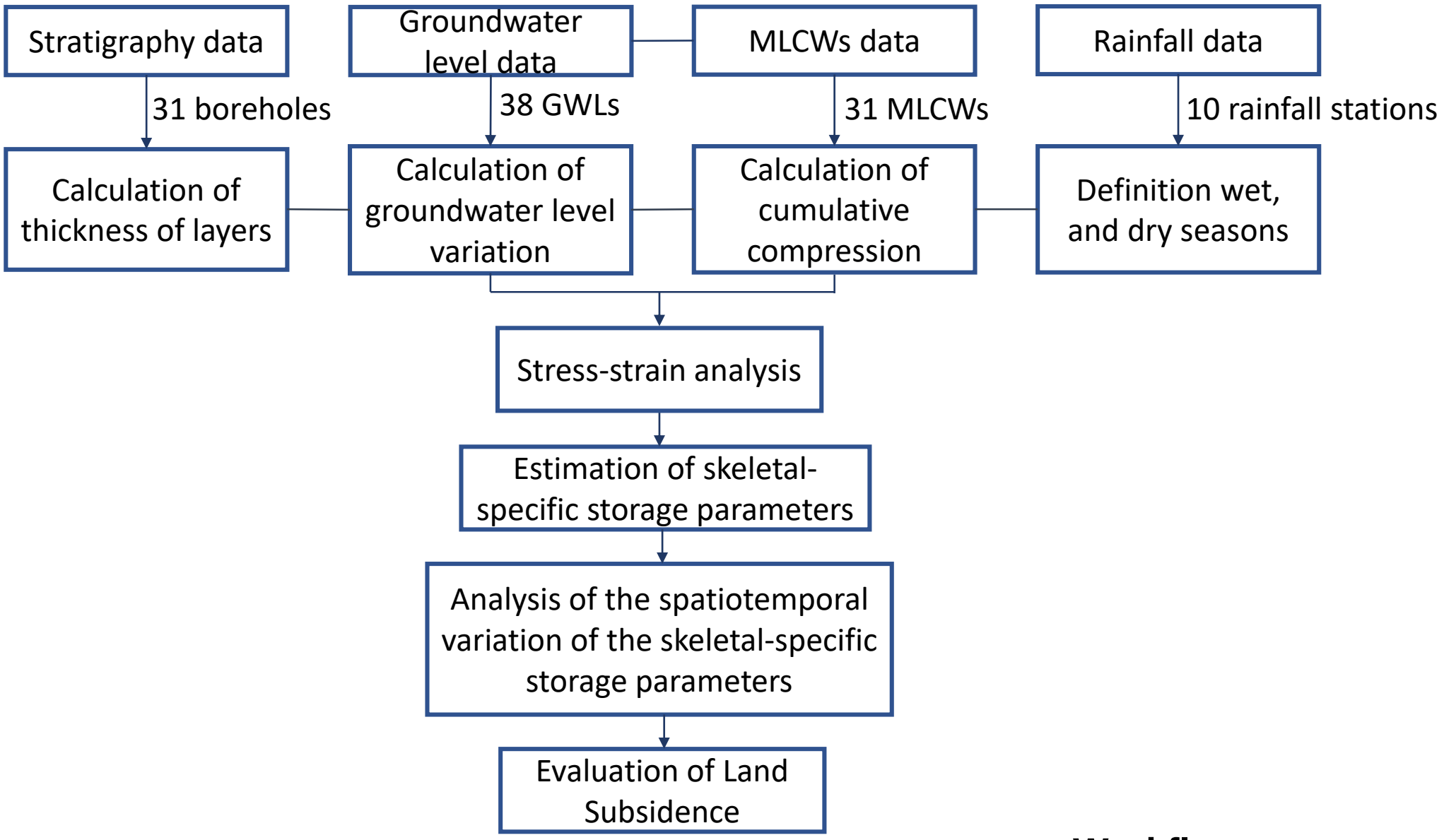
Primary materials: gravel, coarse sand, fine sand, and clay-silt.



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

Cross-Correlation between GWLs and Deformation

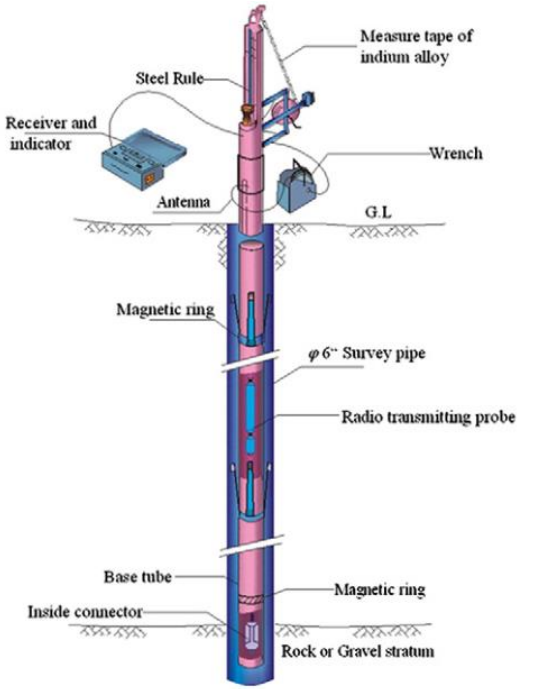




Workflow summary

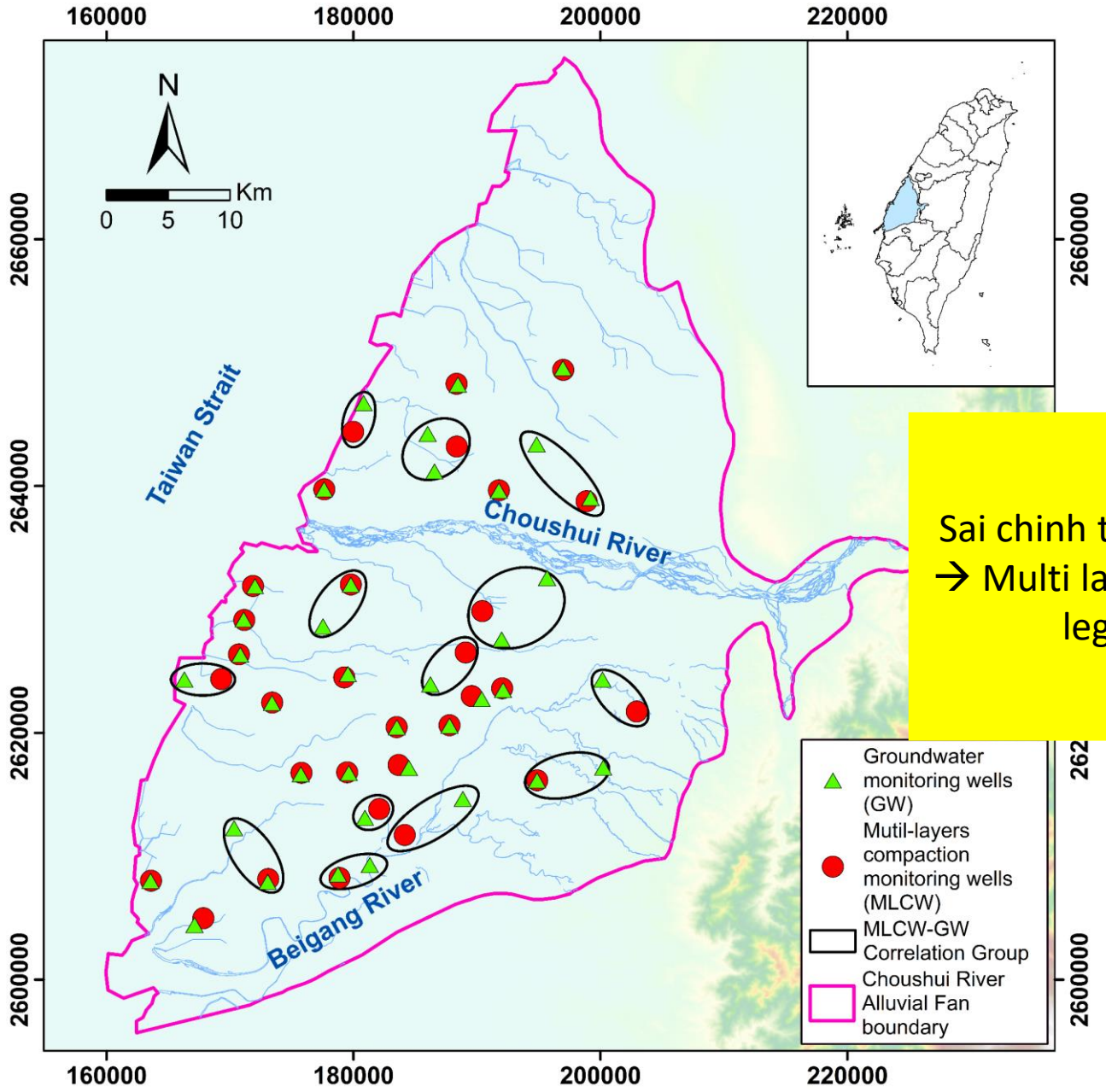
1. Data Collection

- 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 et al., 2012)



Sai chinh ta
→ Multi lay
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Distributions of GW and MLCW monitoring wells

2. Stress-Strain Analyses

Groundwater levels change ➔ Land subsidence through the stress-strain relationship (considers elastic or inelastic skeletal specific storage)
(Hung 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

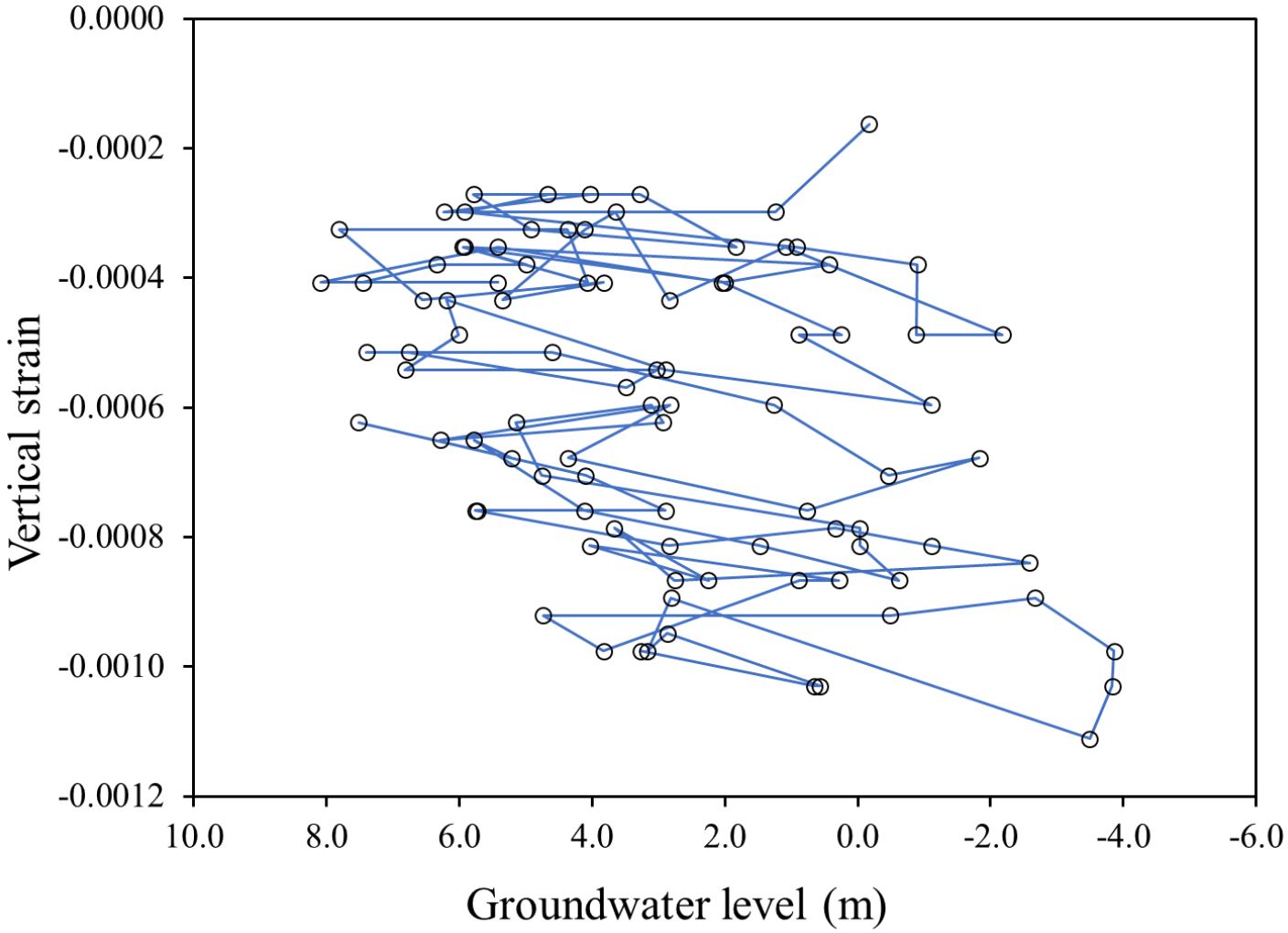
$$\Delta\delta_e = -\Delta P_w$$

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

ρ_w : water density

g : gravity

Δh : groundwater level change



The pattern between strain and groundwater level from 2014-2021 at Tuku

2. Stress-Strain Analyses

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

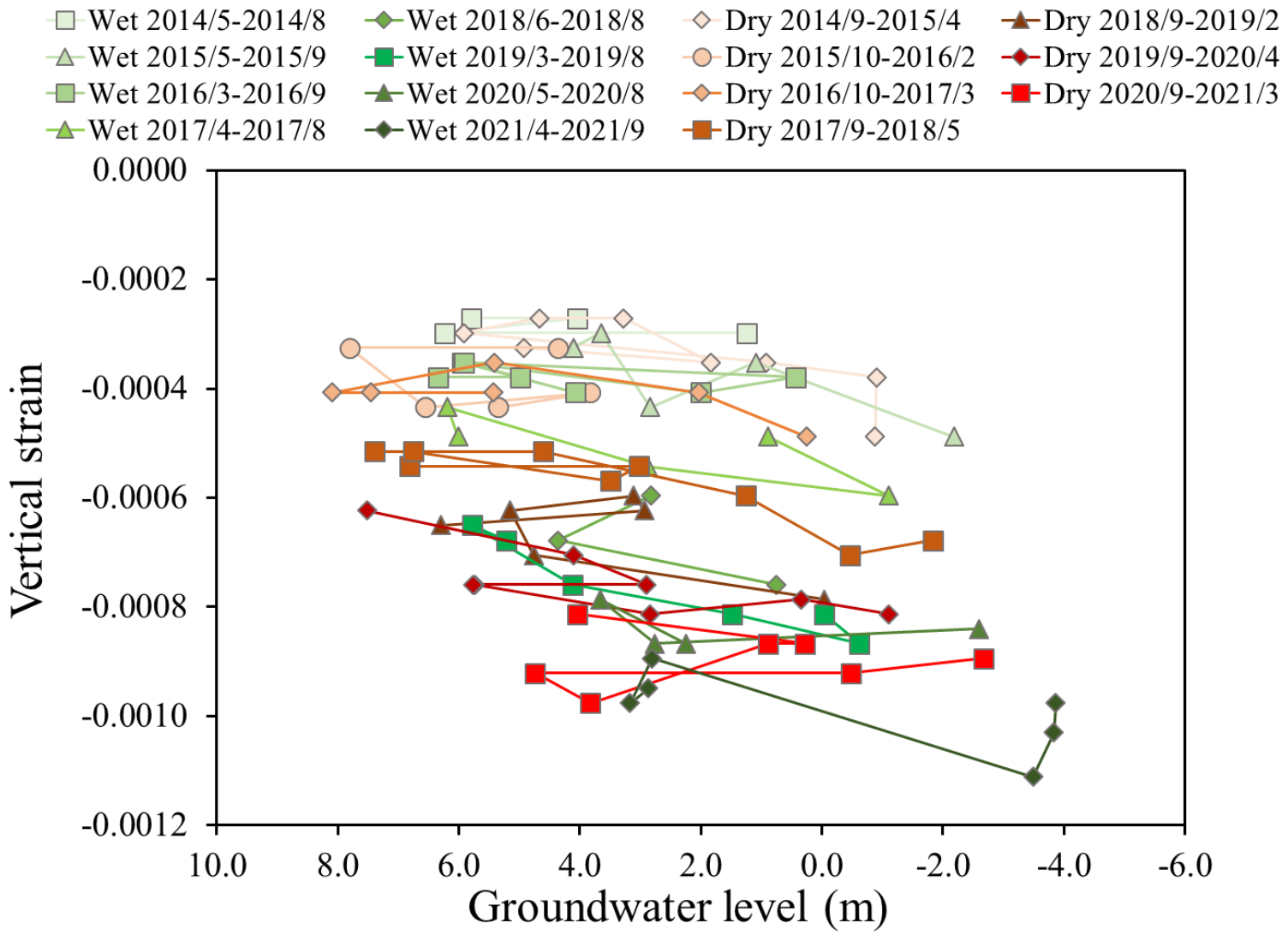
$$S_{sk} = \frac{-\Delta B / B_0}{\Delta h}$$

S_{sk} : skeletal-specific storage

ΔB : compression

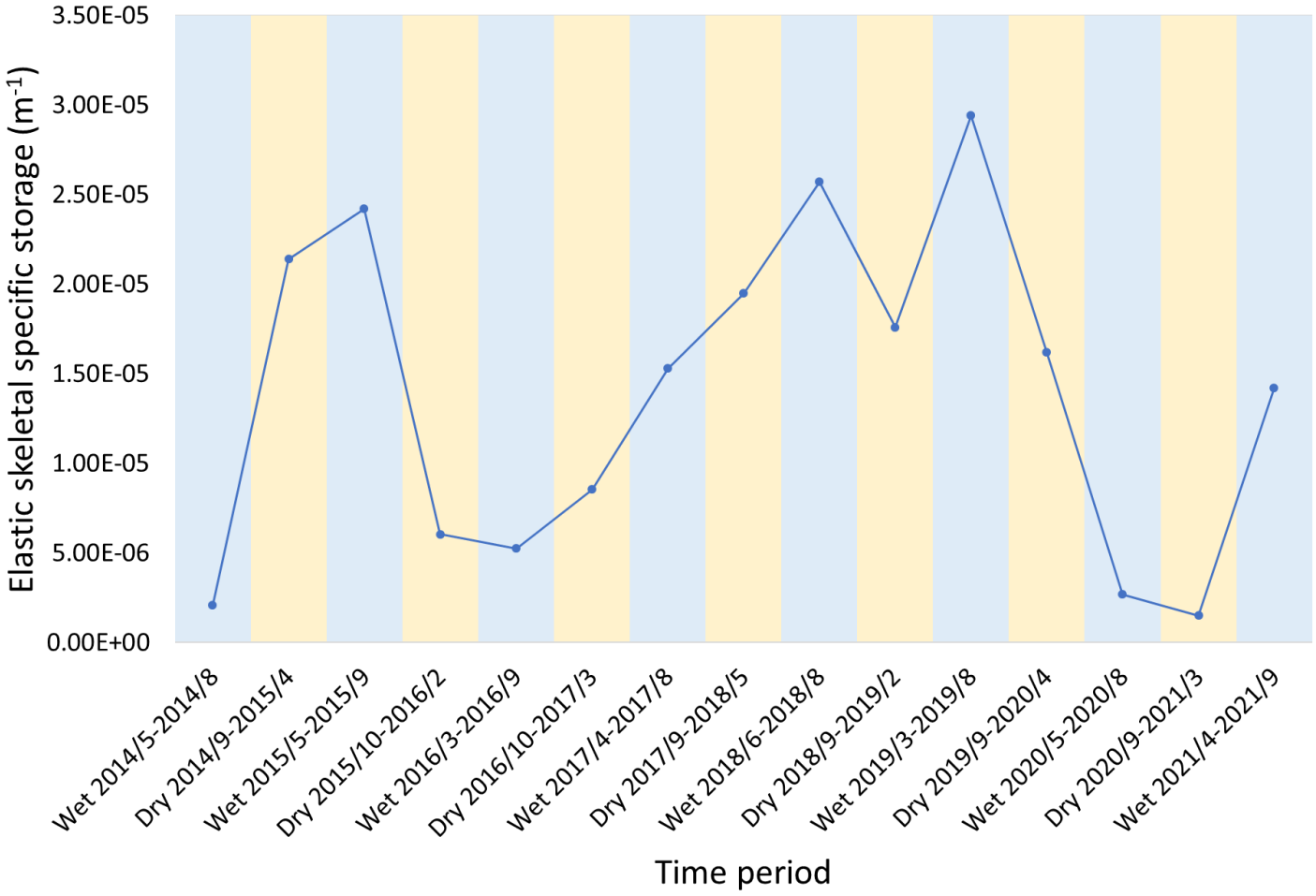
B_0 : thickness of layer

Δh : Groundwater level change

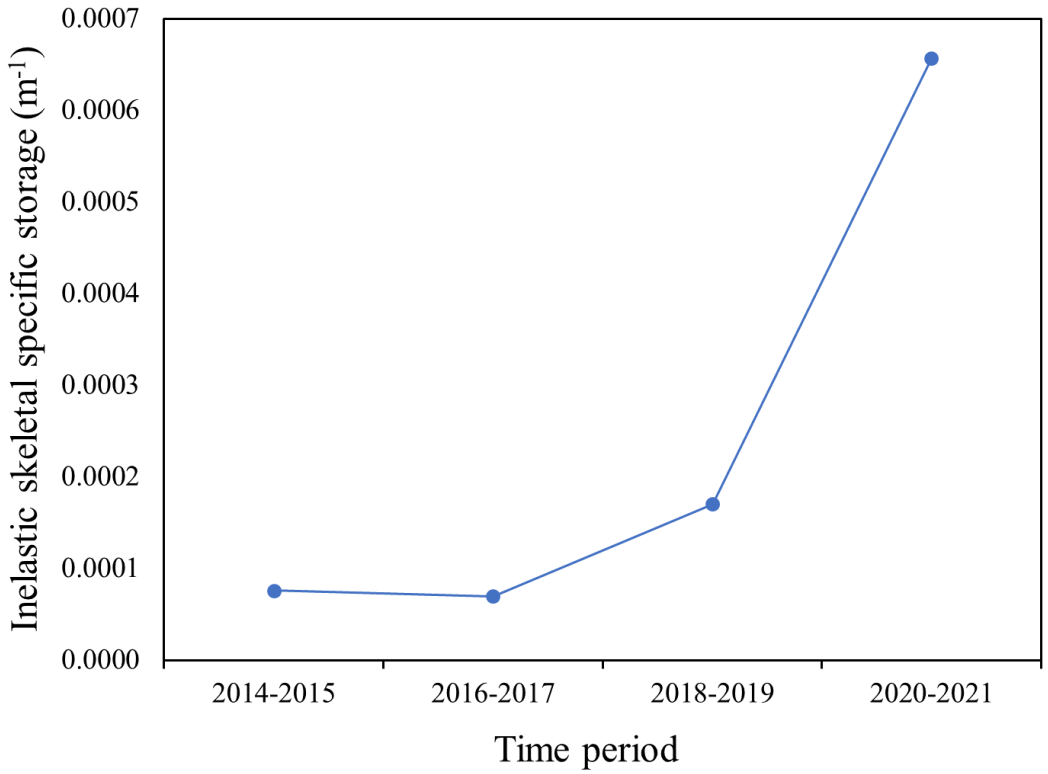


The relationship between vertical strain and groundwater level by seasonal at Tuku

Tuku location - Results

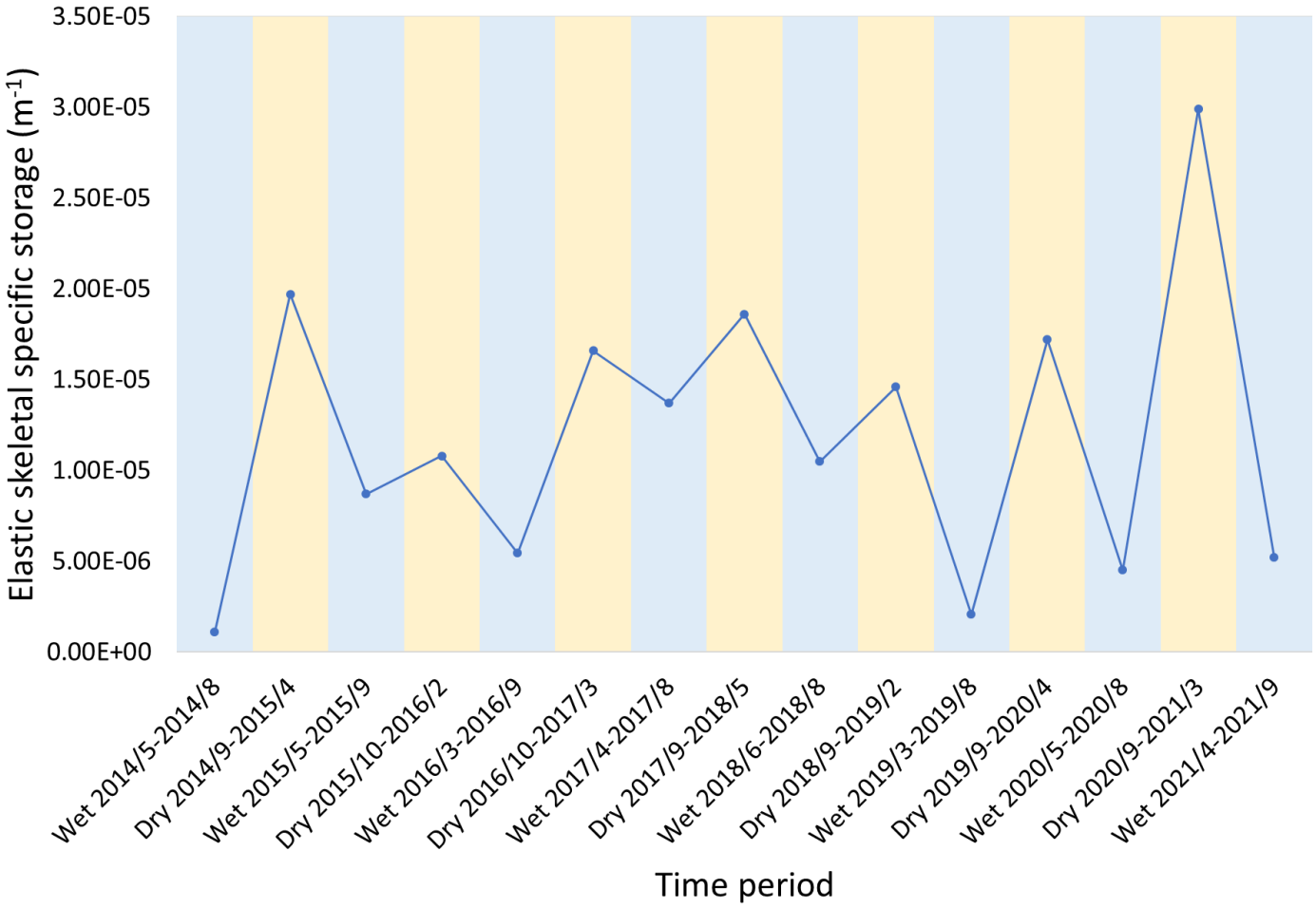


S_{ske} versus time at Tuku (Layer 2.1)

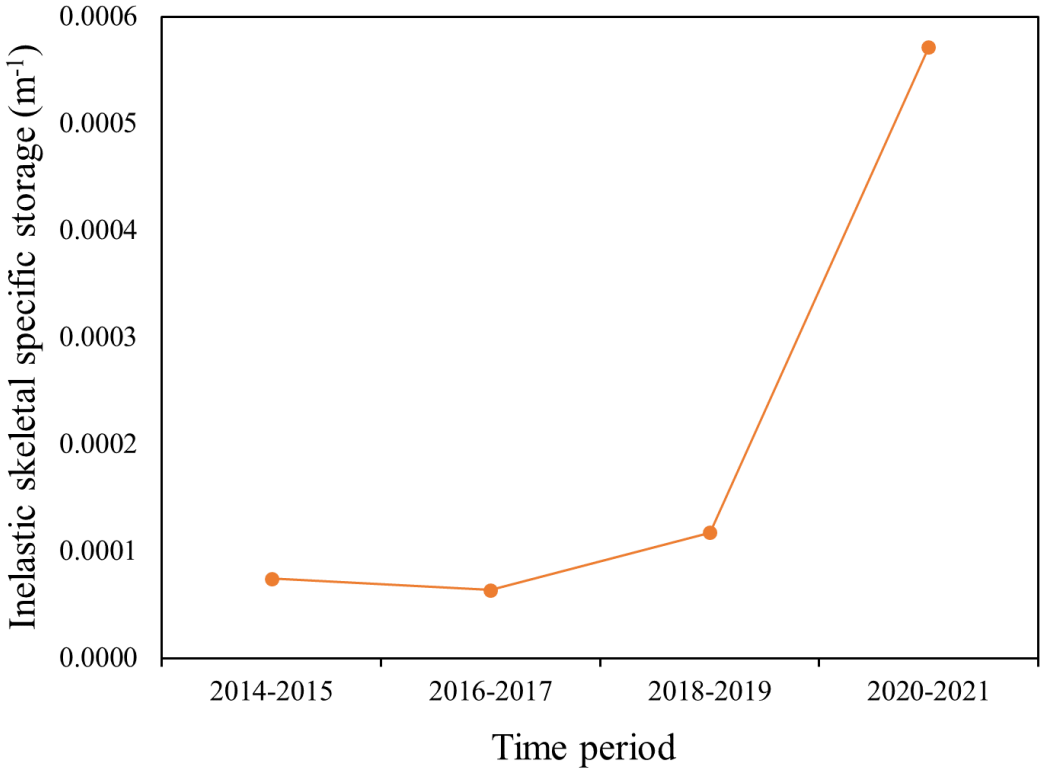


S_{skv} versus time at Tuku (Layer 2.1)

Tuku location - Results

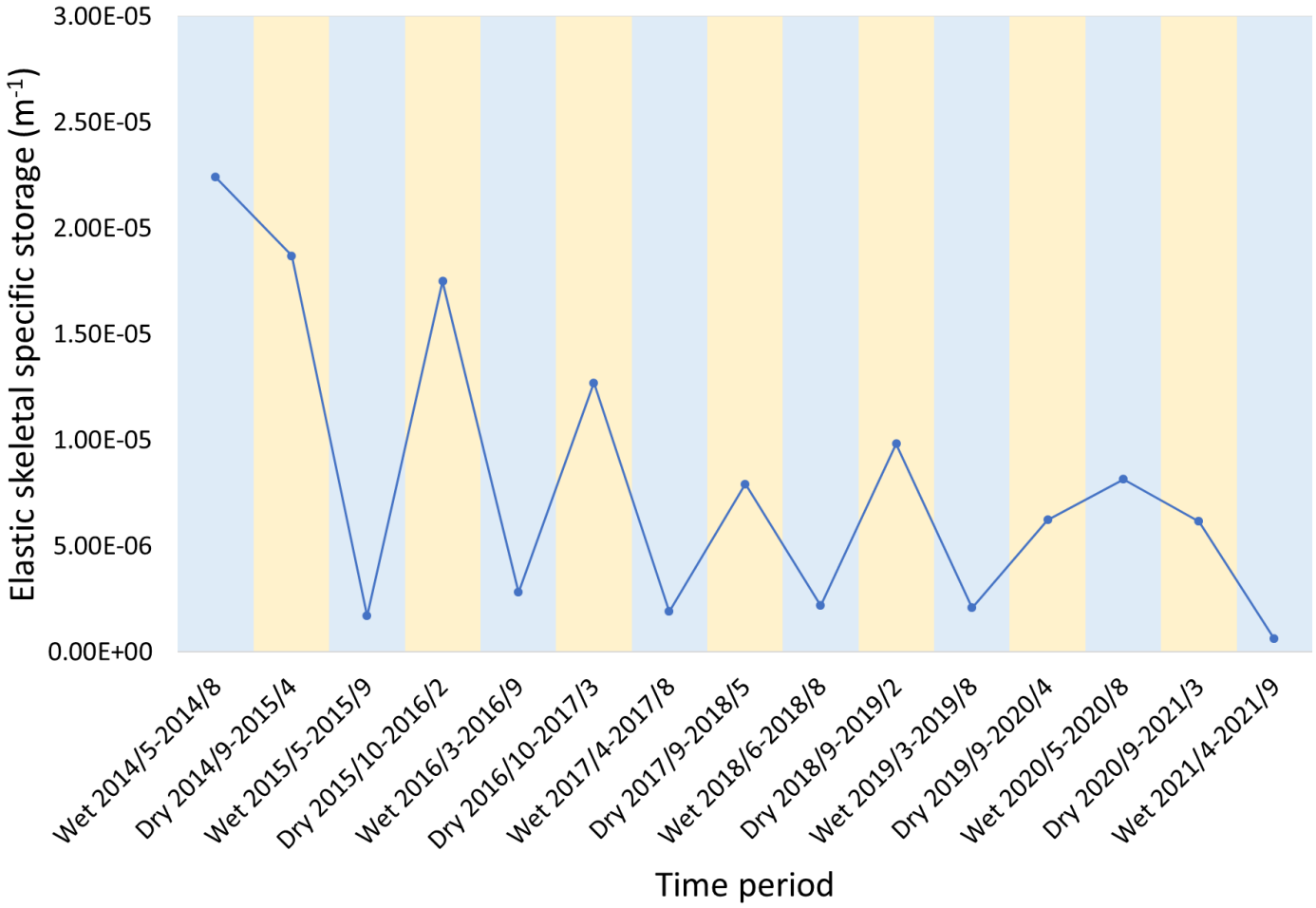


S_{ske} versus time at Tuku (Layer 2.2)

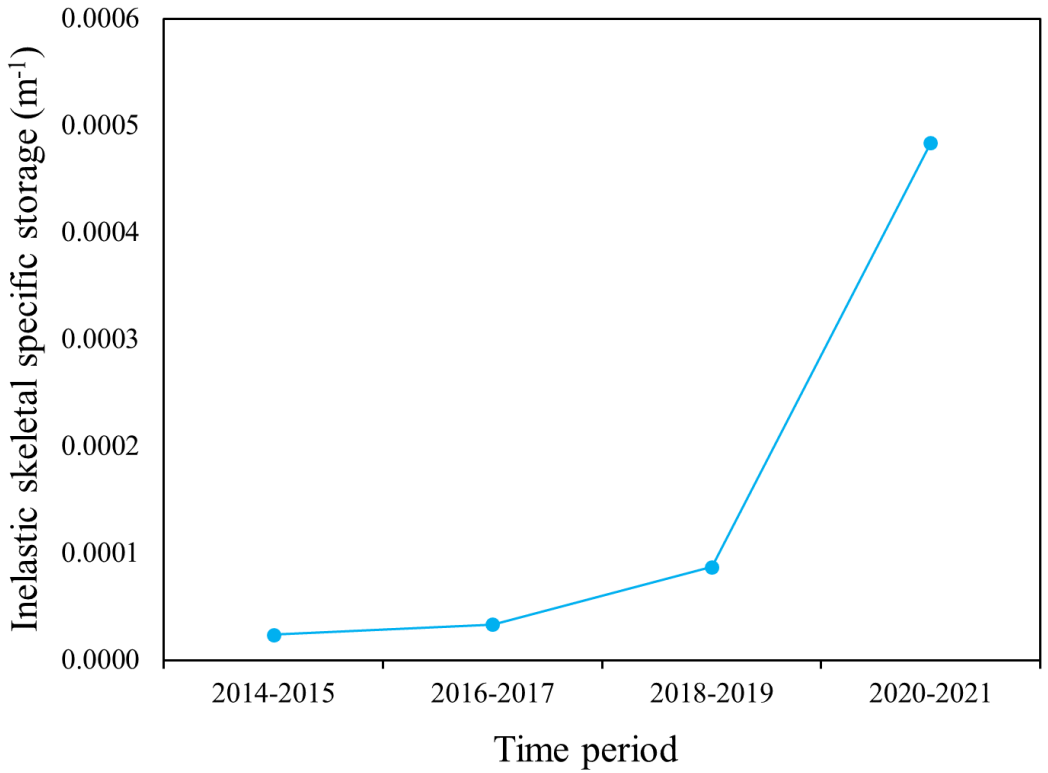


S_{skv} versus time at Tuku (Layer 2.2)

Tuku location - Results

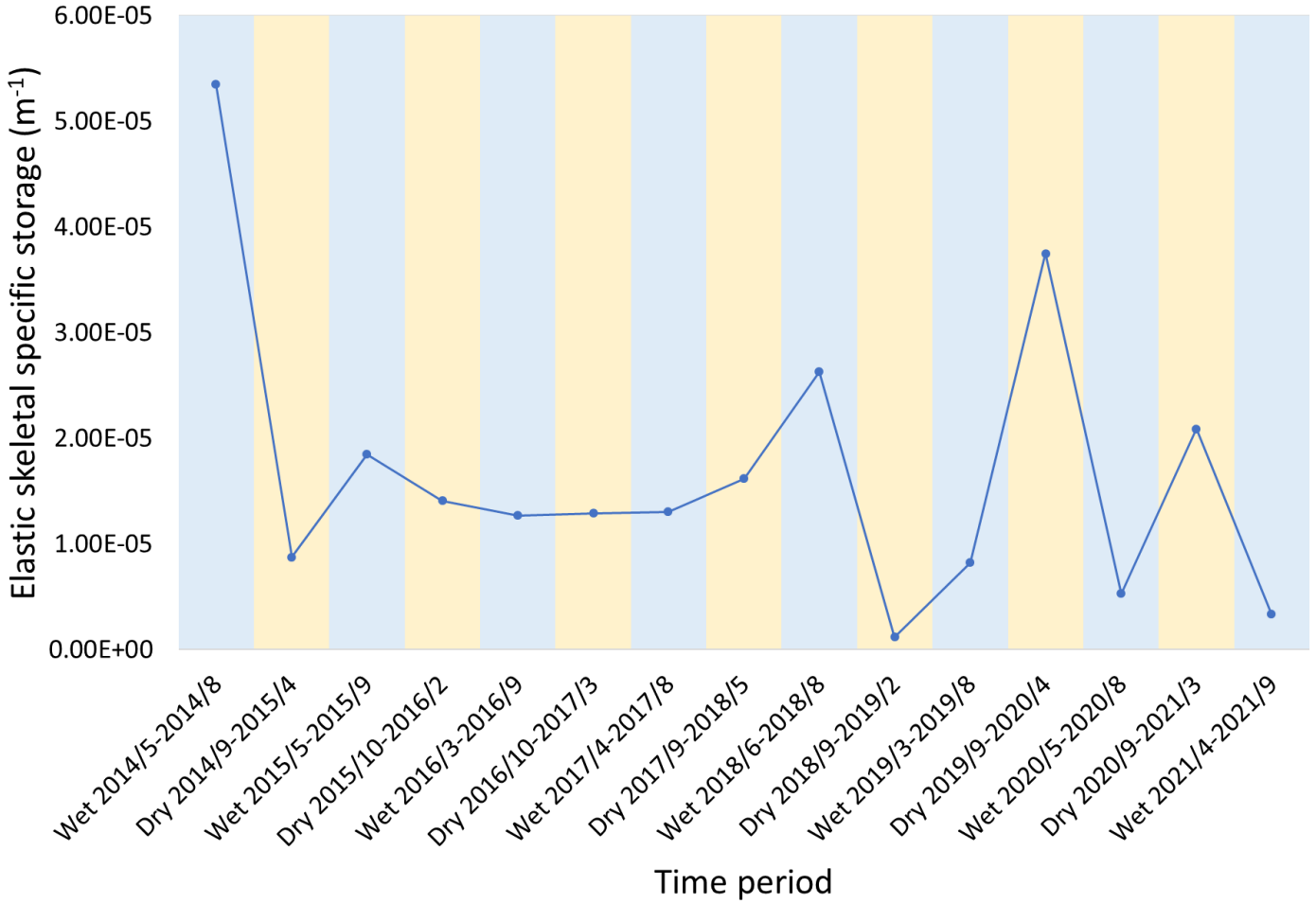


S_{ske} versus time at Tuku (Layer 3)

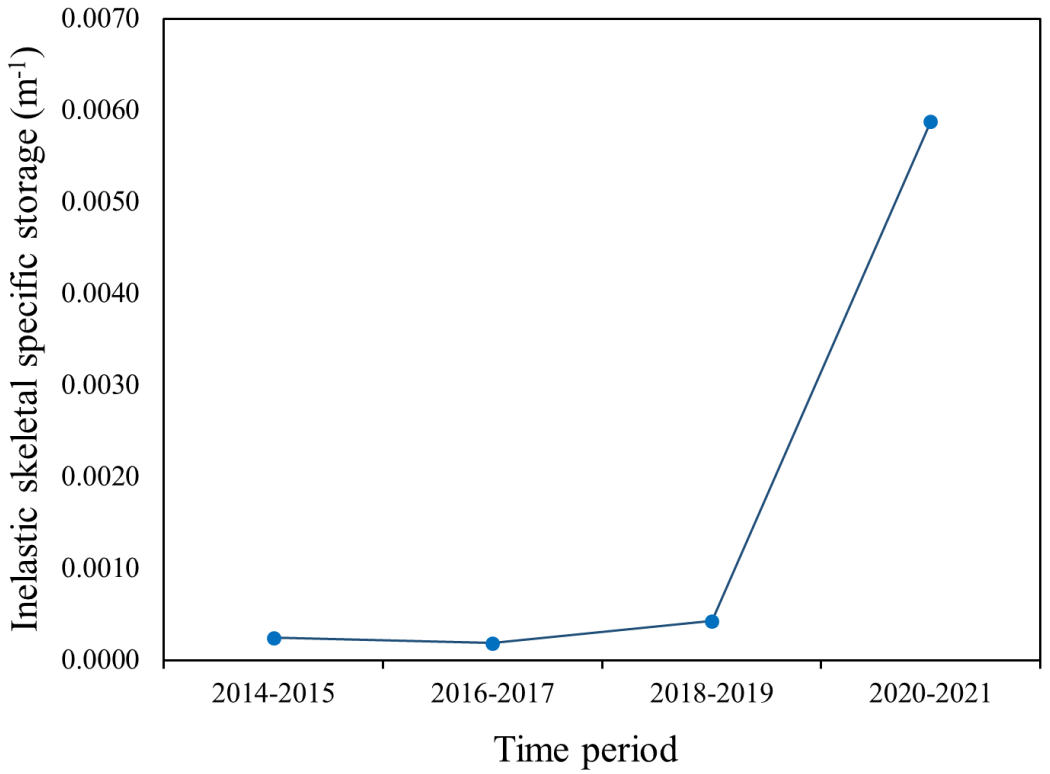


S_{skv} versus time at Tuku (Layer 3)

Tuku location - Results

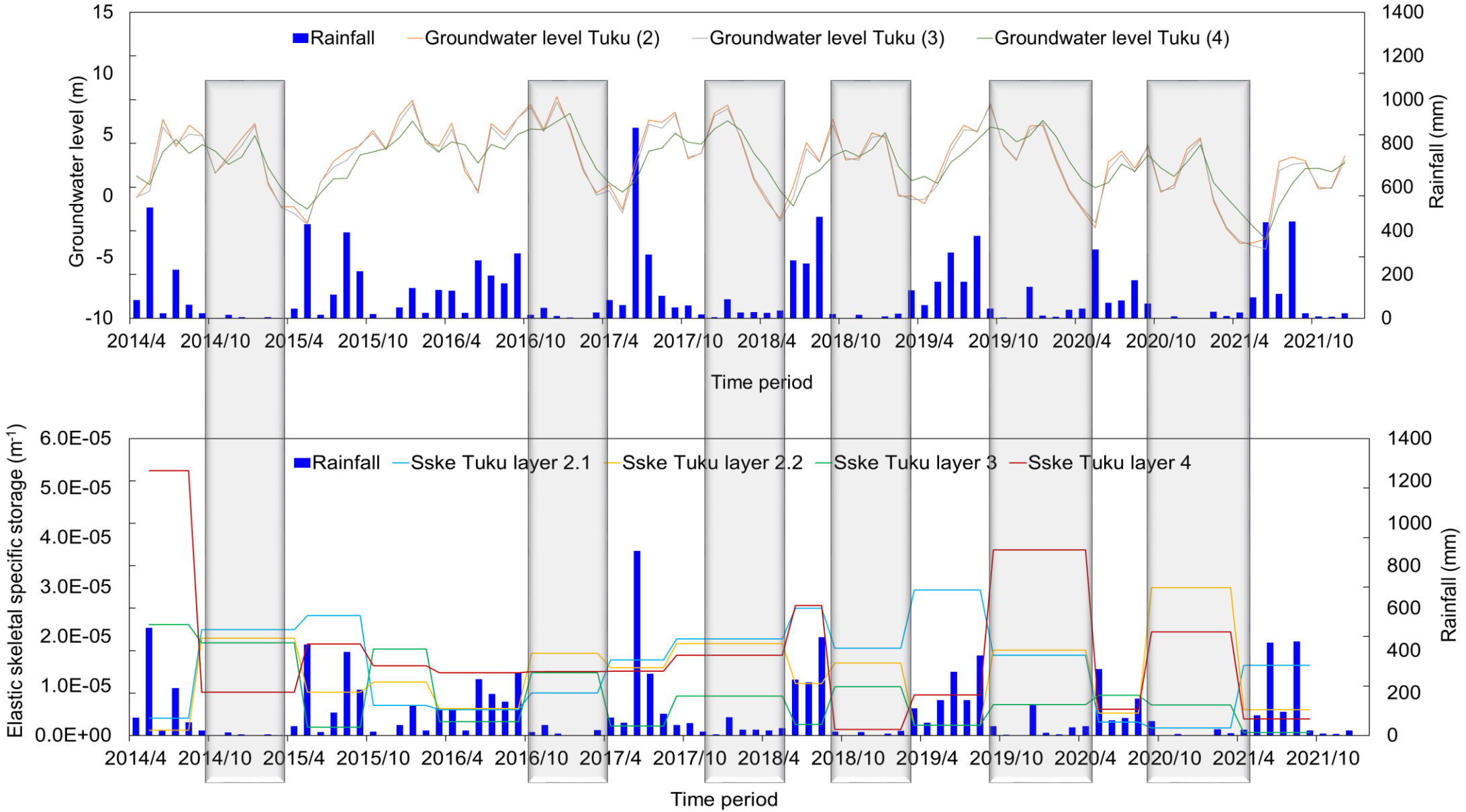


S_{ske} versus time at Tuku (Layer 4)



S_{skv} versus time at Tuku (Layer 4)

Tuku location - Results



The relationship between rainfall, GWLs and S_{ske} from 2014-2021

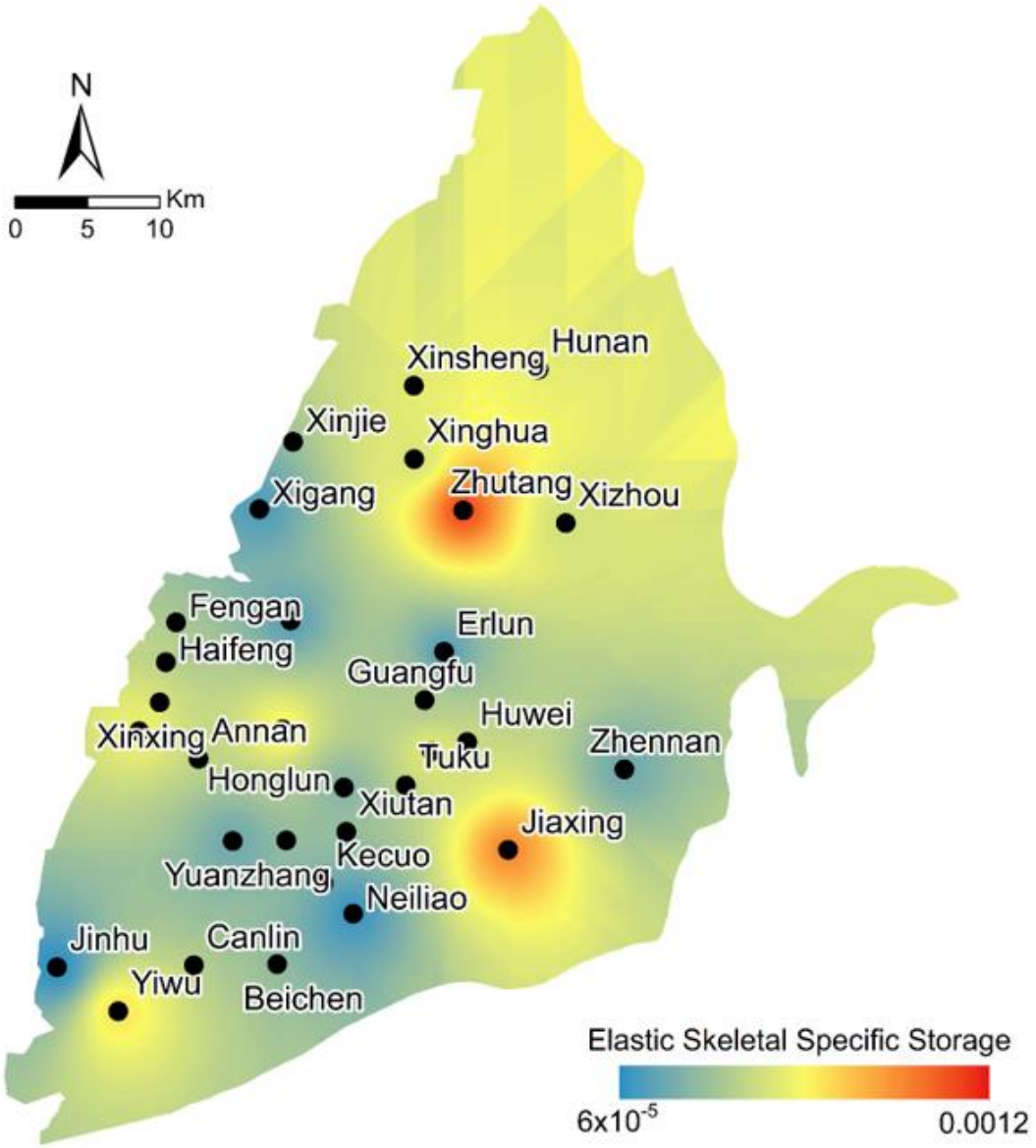
The **elastic skeletal storage coefficient** of 31 wells from 2010-2021

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

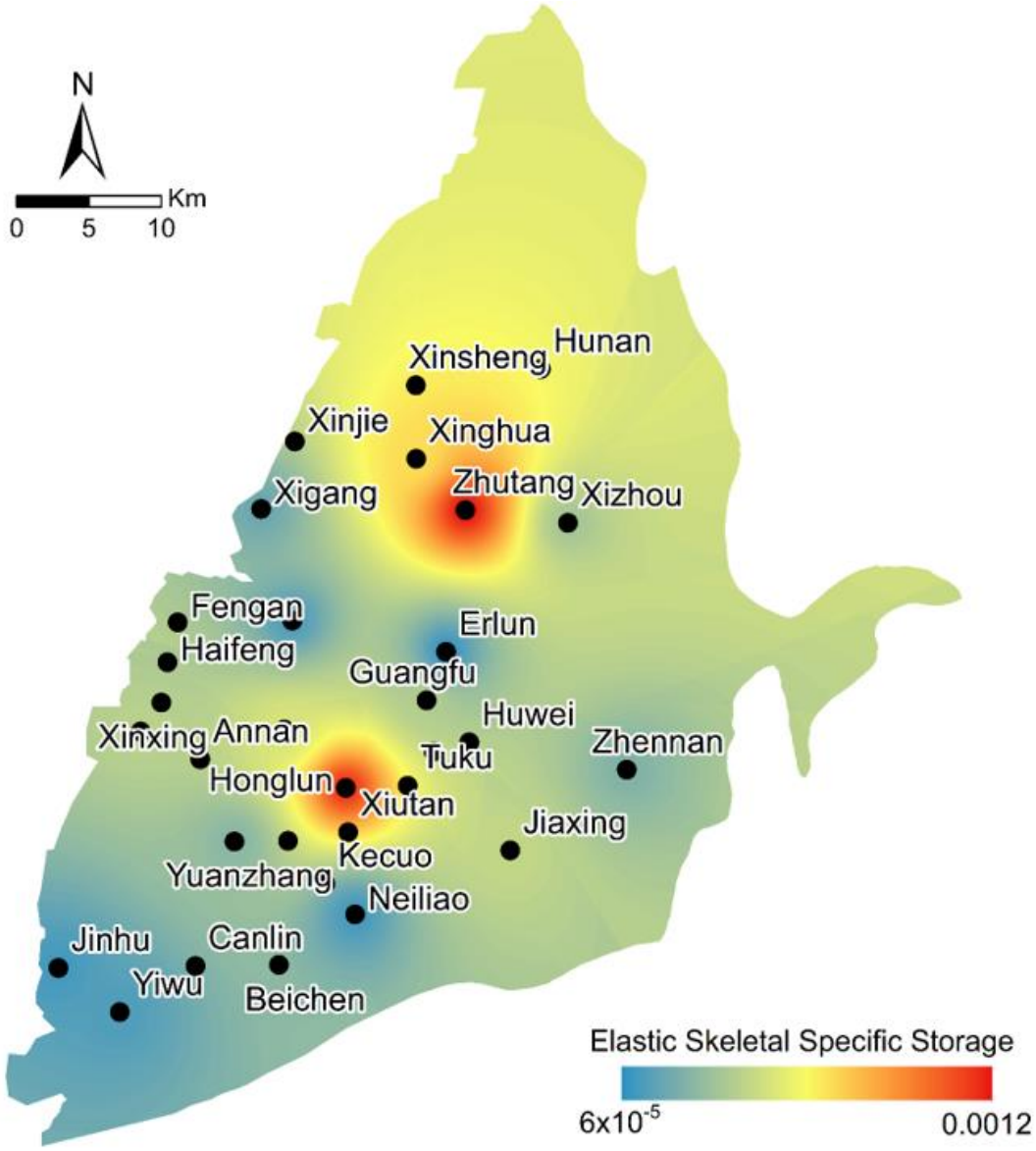
Layer (depth range)	**Inelastic skeletal storage coefficient**		
	Minimum	Maximum	Average
Layer 1 (0-57 m)	4.56E-04	2.26E-02	9.50E-03
Layer 2.1 (57-96 m)	2.13E-03	8.83E-02	2.34E-02
Layer 2.2 (96-166 m)	1.01E-03	2.13E-01	4.14E-02
Layer 3 (166-262 m)	4.25E-04	6.11E-02	2.70E-02
Layer 4 (262-300 m)	5.36E-03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

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

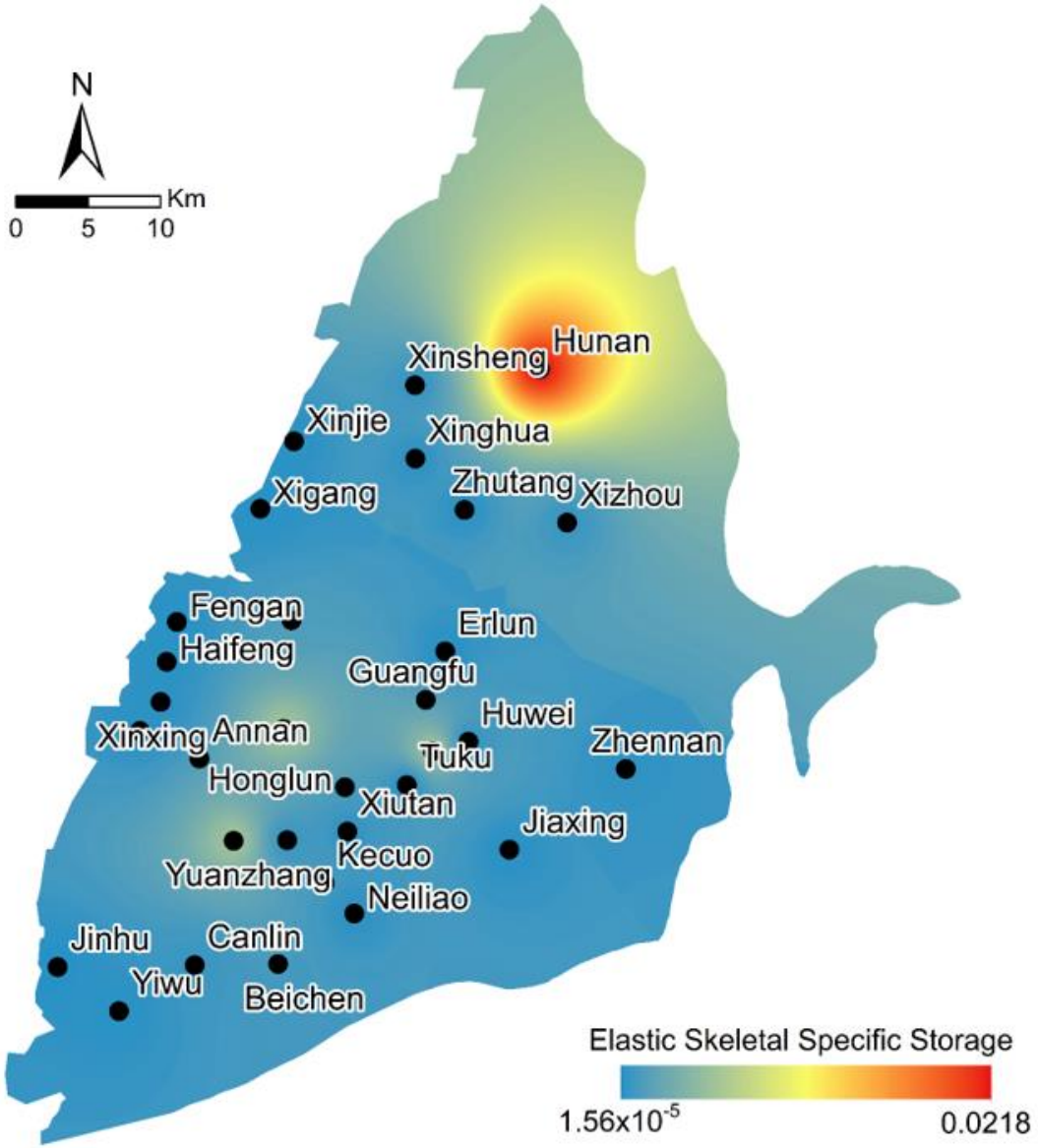
S_{kv} values exhibit a consistent average of approximately 10^{-2}



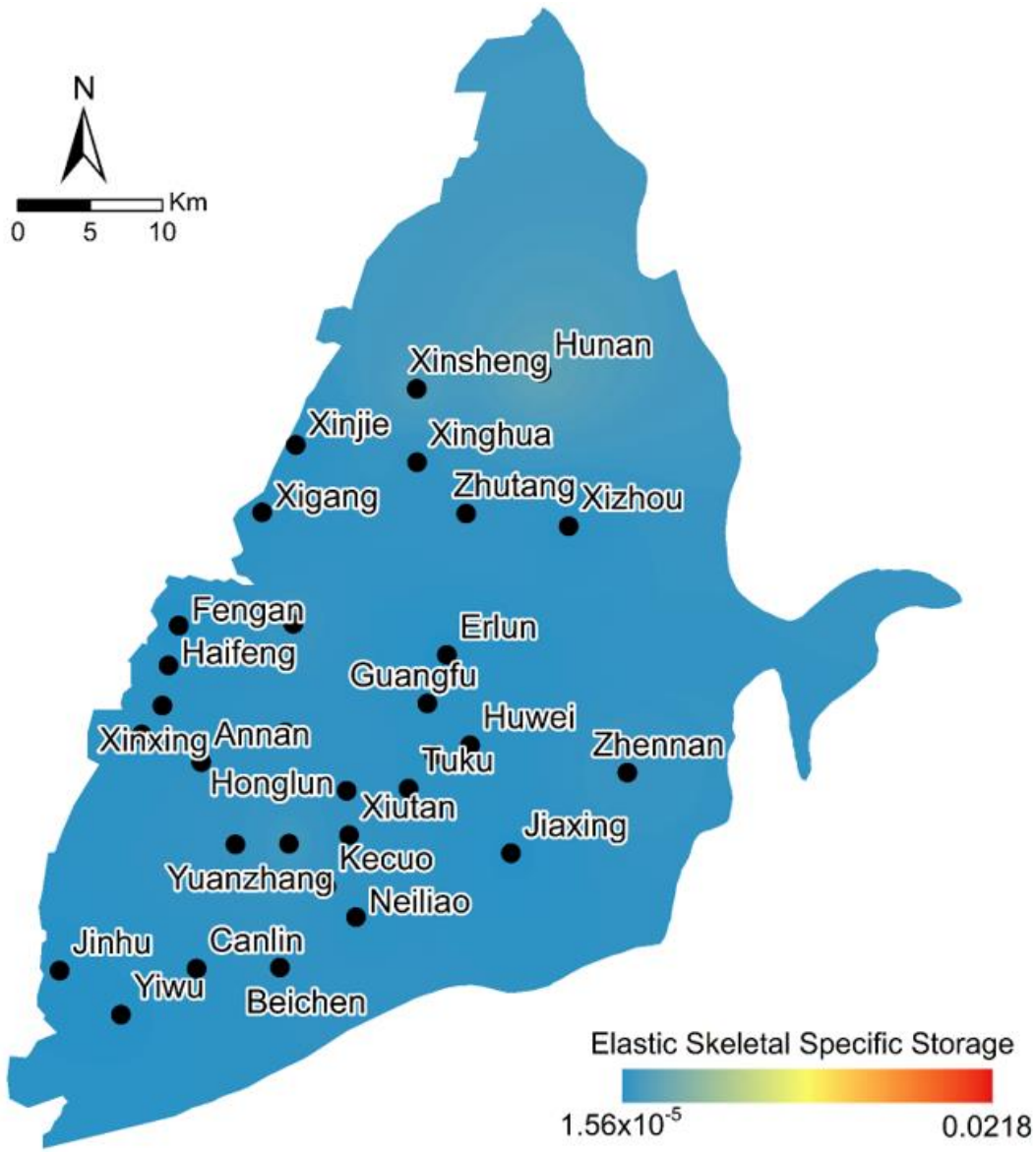
Dry season
Layer 1



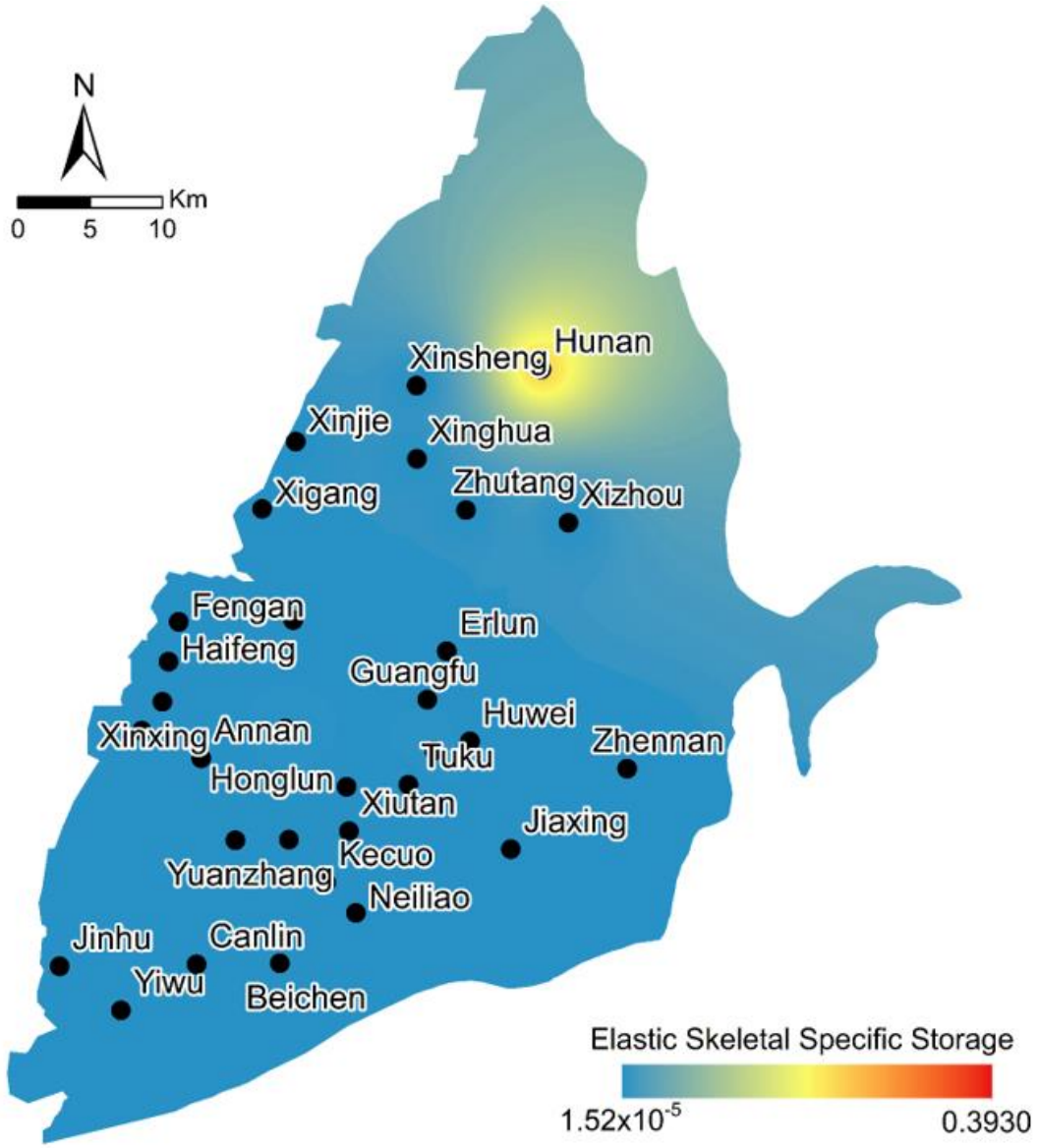
Wet season
Layer 1



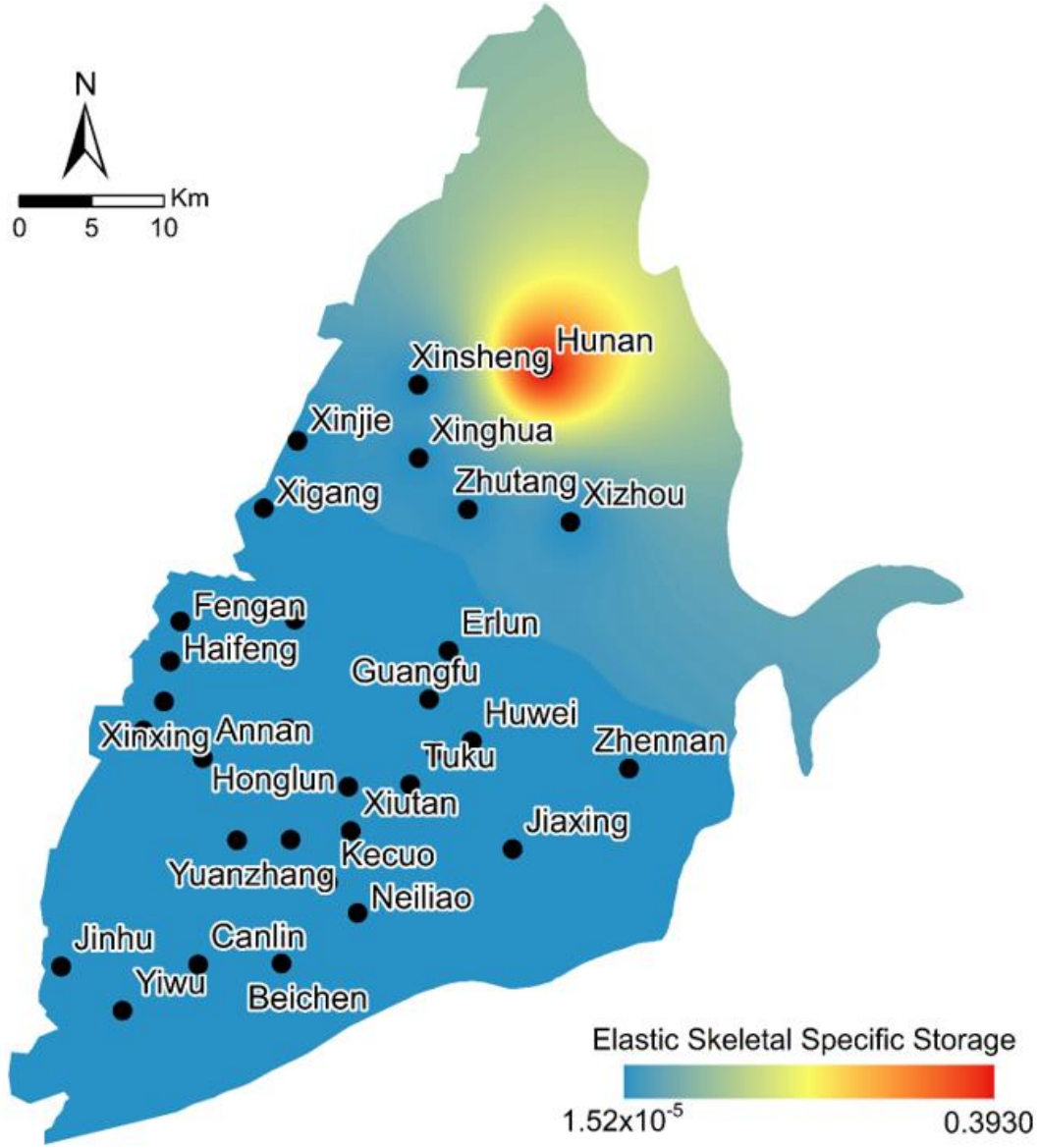
Dry season
Layer 2.1



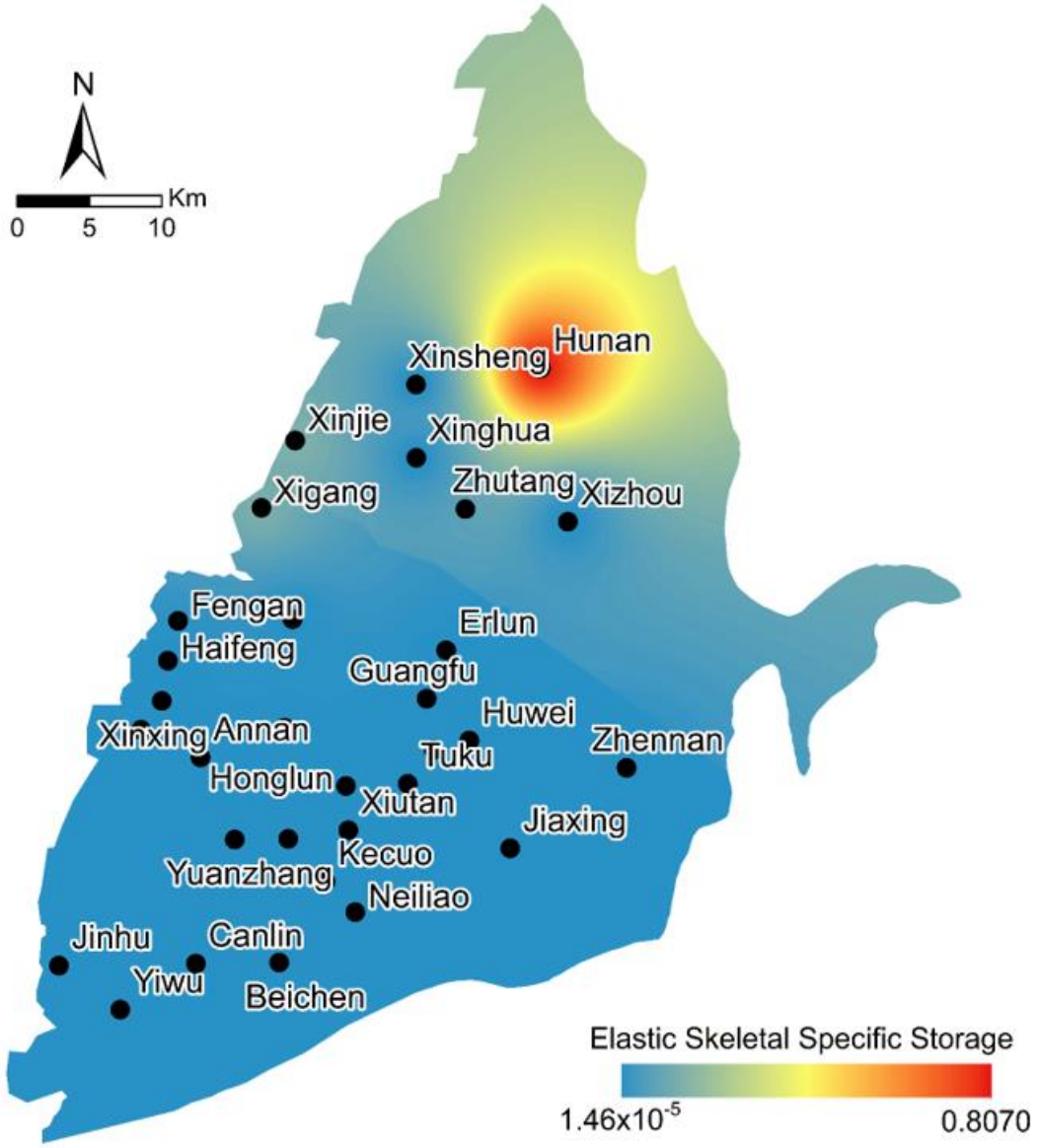
Wet season
Layer 2.1



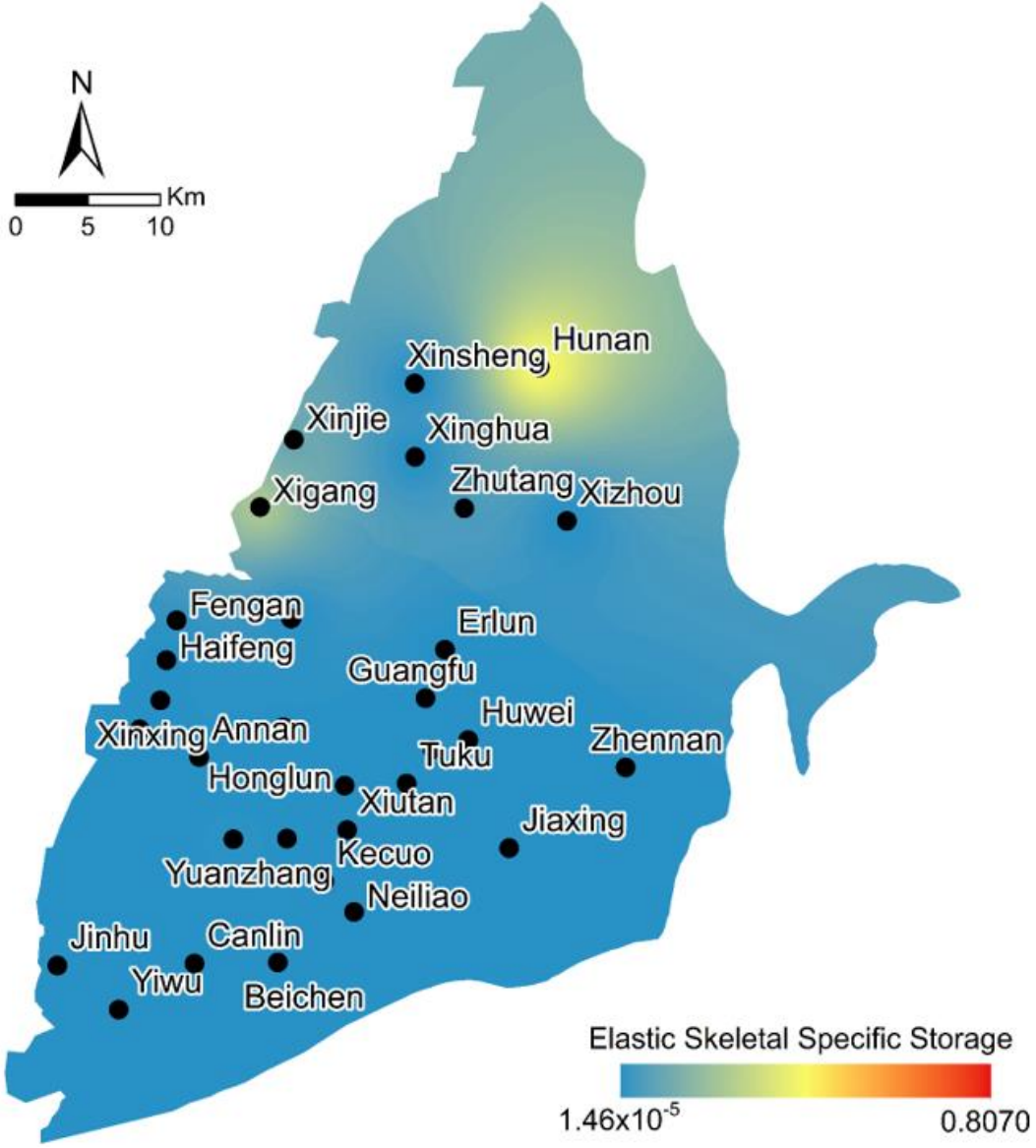
Dry season
Layer 2.2



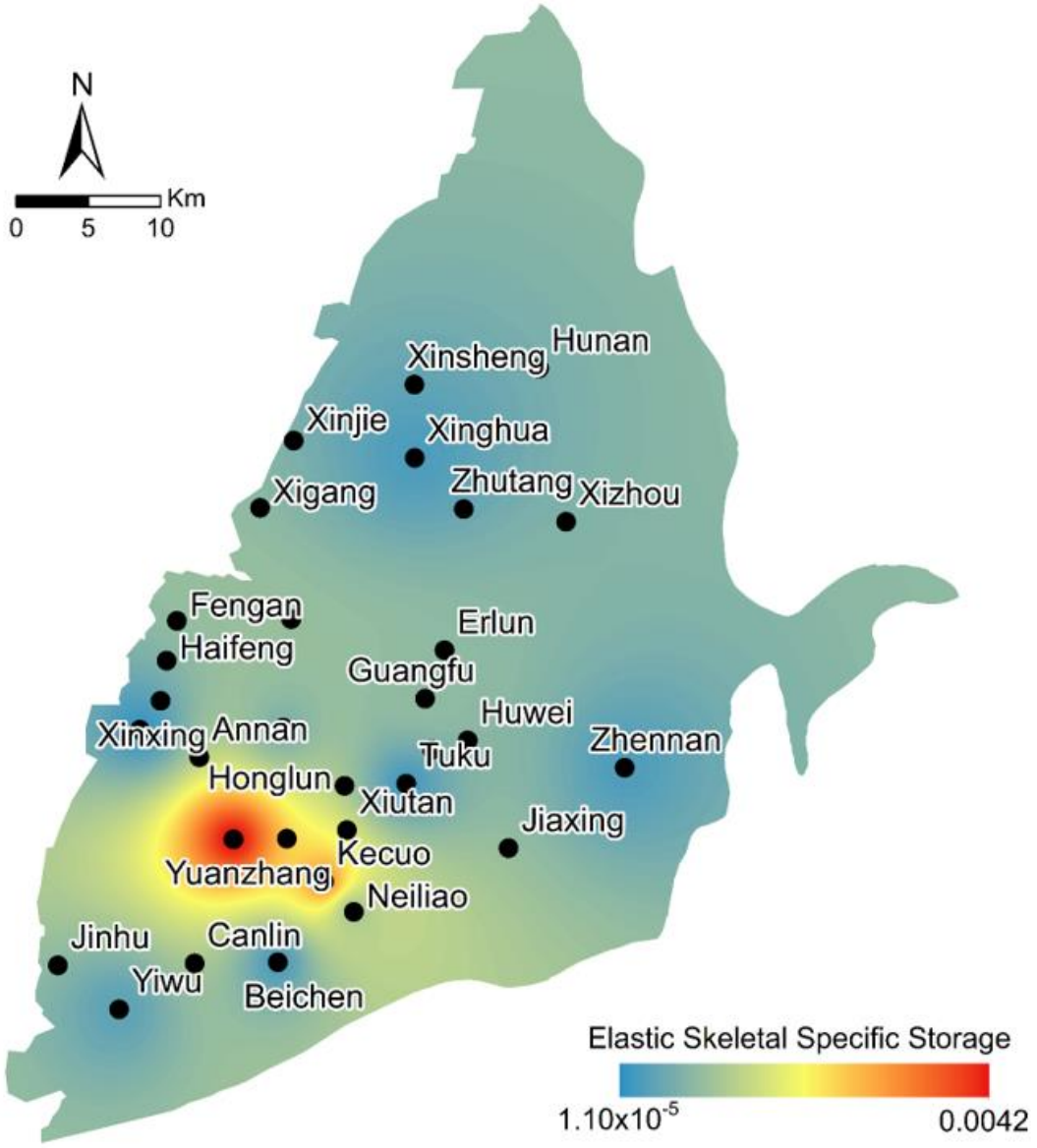
Wet season
Layer 2.2



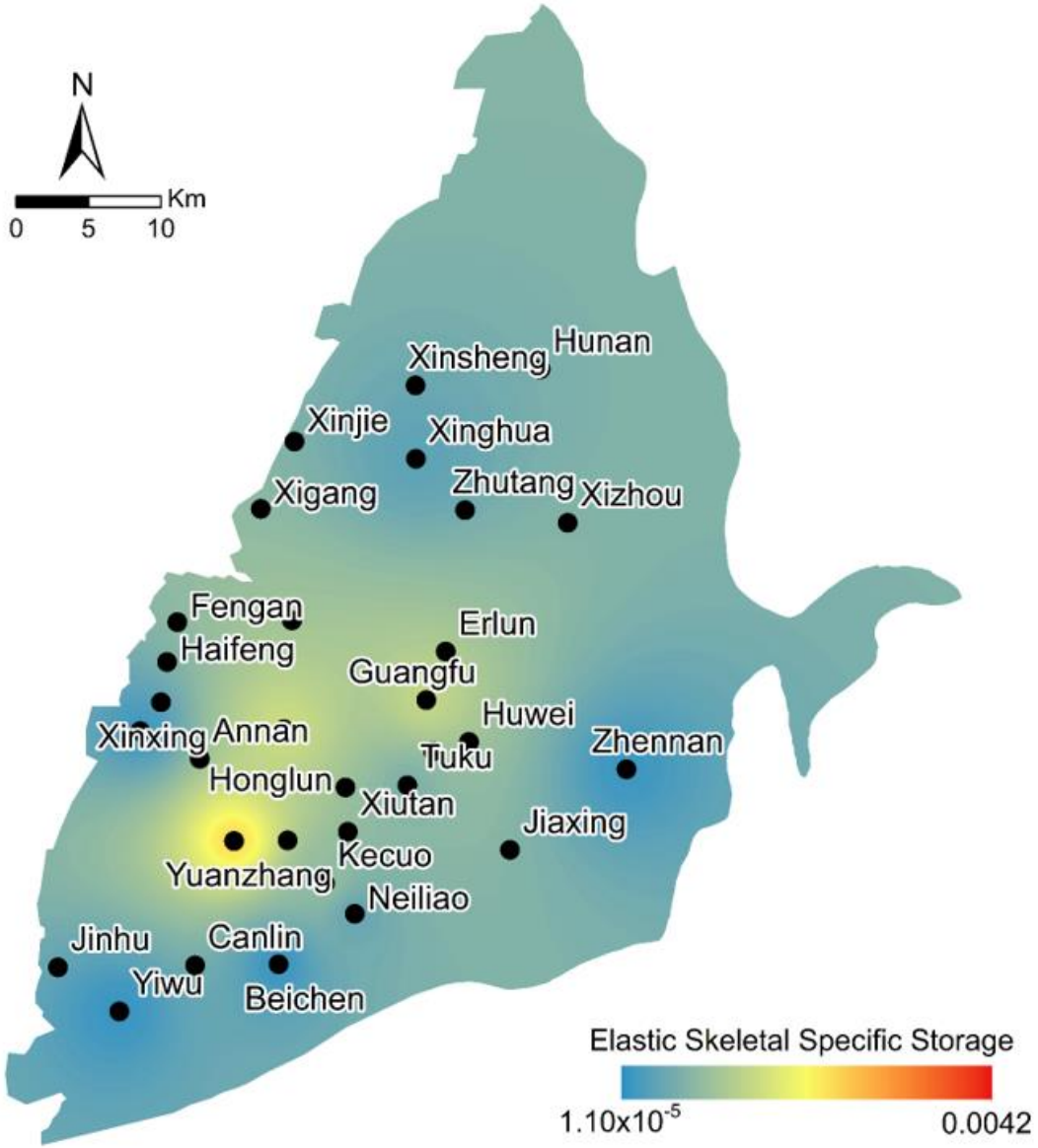
Dry season
Layer 3



Wet season
Layer 3



Dry season
Layer 4



Wet season
Layer 4

- We can estimate the skeletal-specific storage based on observation data to evaluate the land subsidence potential.
- The observations illustrate seasonal fluctuations of aquifer-system-specific storage and corresponding uplift associated with groundwater level variations.
- Skeletal-specific storage at different locations and layers is different, meaning it varies spatially.
- The skeletal-specific storage is high in the dry season and low in the wet season, which means it is not constant with time.

- Update the distribution of skeletal-specific storage in the study area.
- Evaluate the land subsidence potential.

Thanks for your attention!

謝謝!