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Defining morphological units from UAV images to study the evolution of bars in an active meandering gravel bed river

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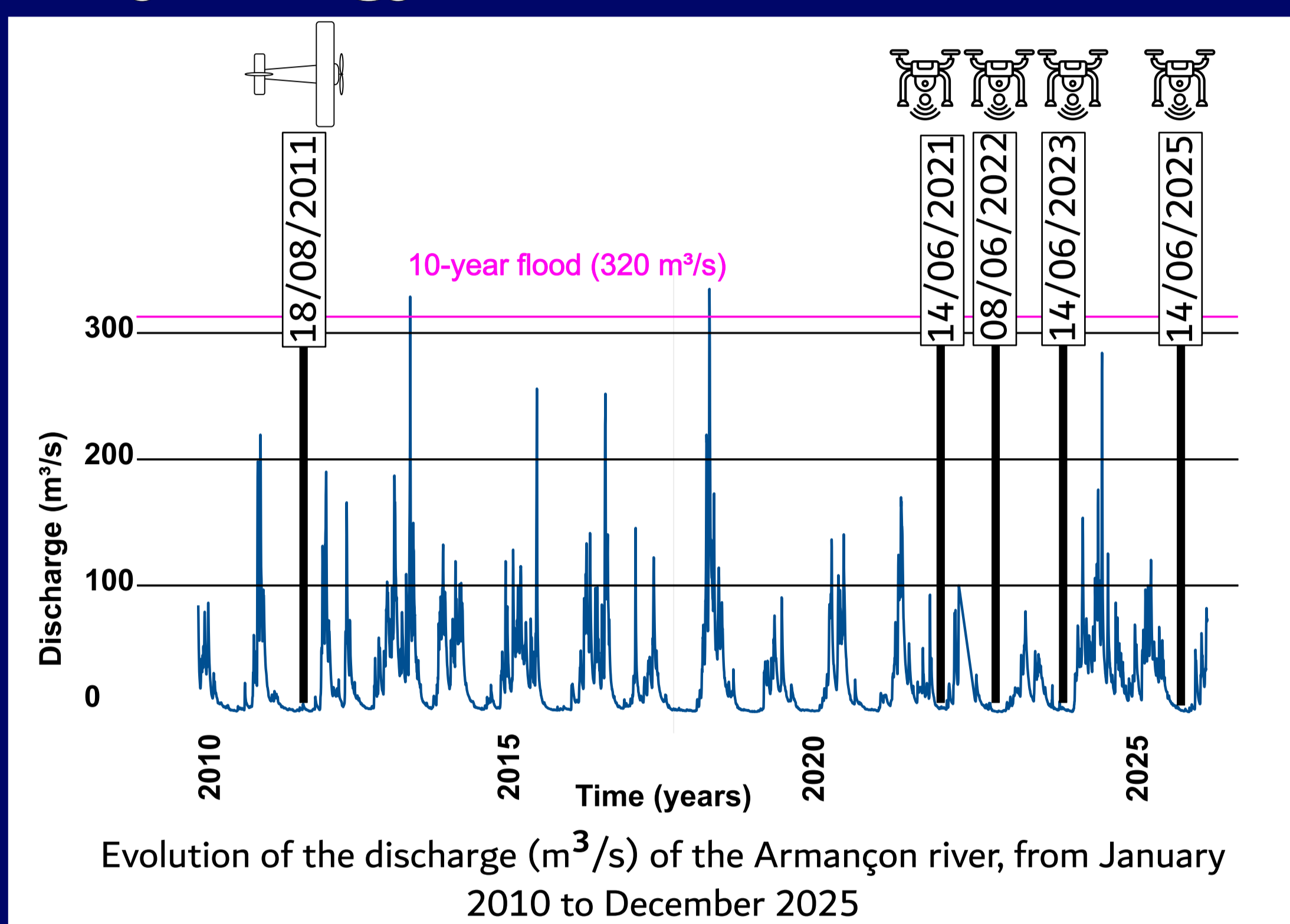
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Rémy Rivière^{1,2}, Frédéric Gob³, Manon Letourneur^{3,4}, Clément Virmoux⁵, Nathalie Thommeret⁶, Emmanuèle Gautier³, Thomas Dépret⁵

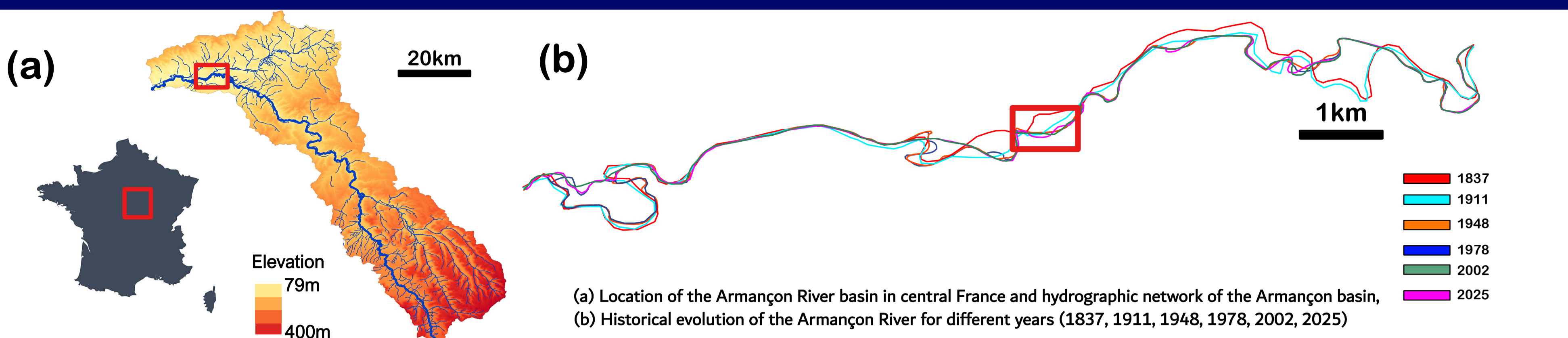
1. Introduction

The Armançon is a **low-energy river** (35 W/m²) located in central France. It has a **gravel bed and significant meandering activity**. As a result, the river exhibits strong lateral dynamics and the development of gravel bars. These **gravel bars** are essential for creating habitats for fauna and flora. This equilibrium is fragile due to **human activity**. It is therefore important to **study evidence of these dynamics**, such as gravel bars, at multiple spatial scales. These scales include the bank/bar sector, the bar scale, and the **determination of morphological units** within the bar. The latter scale allows observation of internal bar evolution at the finest resolution (5 cm pixels). We studied the evolution of four gravel bar areas, including Le Sureau. The analysis is based on **Phantom 4 RTK drone flyovers** conducted in 2021, 2022, 2023, and 2025. A 2011 digital terrain model (DTM) was also used.

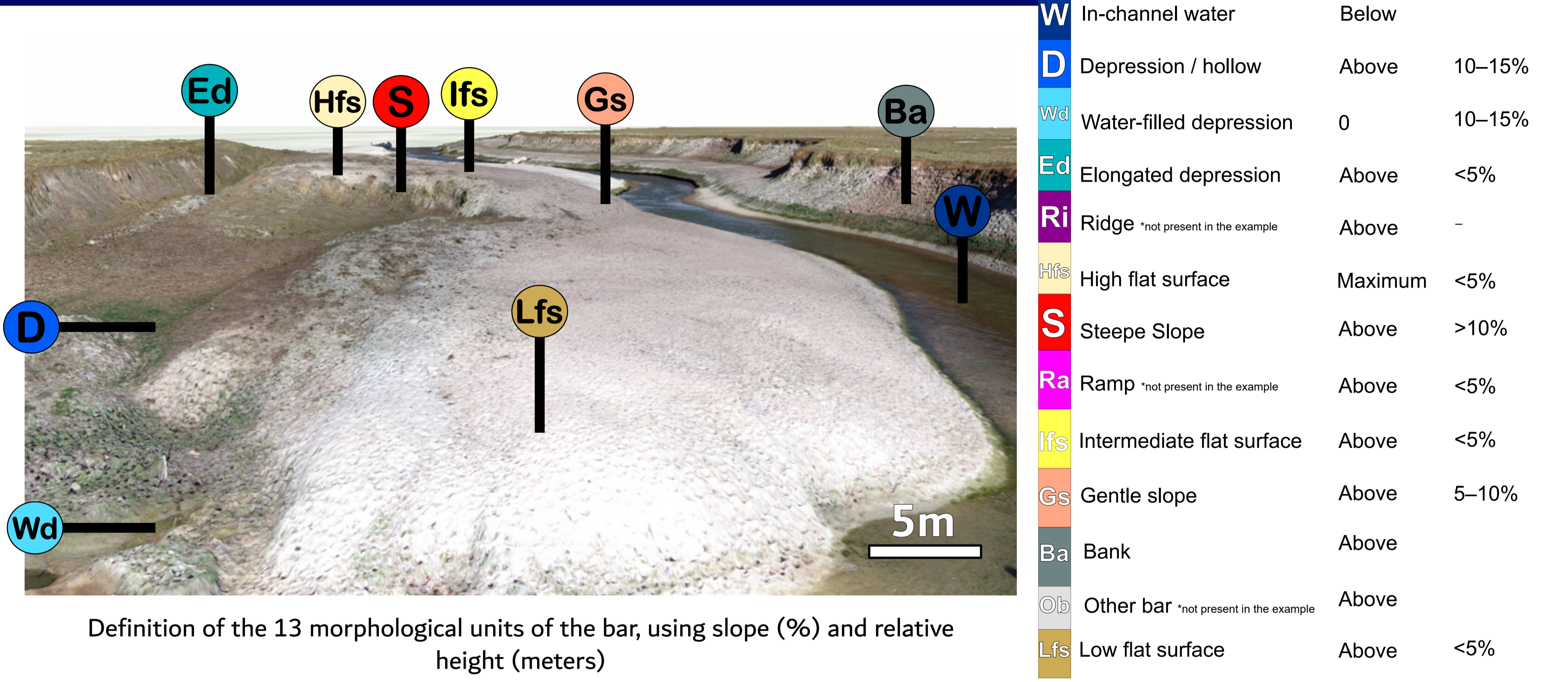
3. Hydrology



2. Location



4. Methods

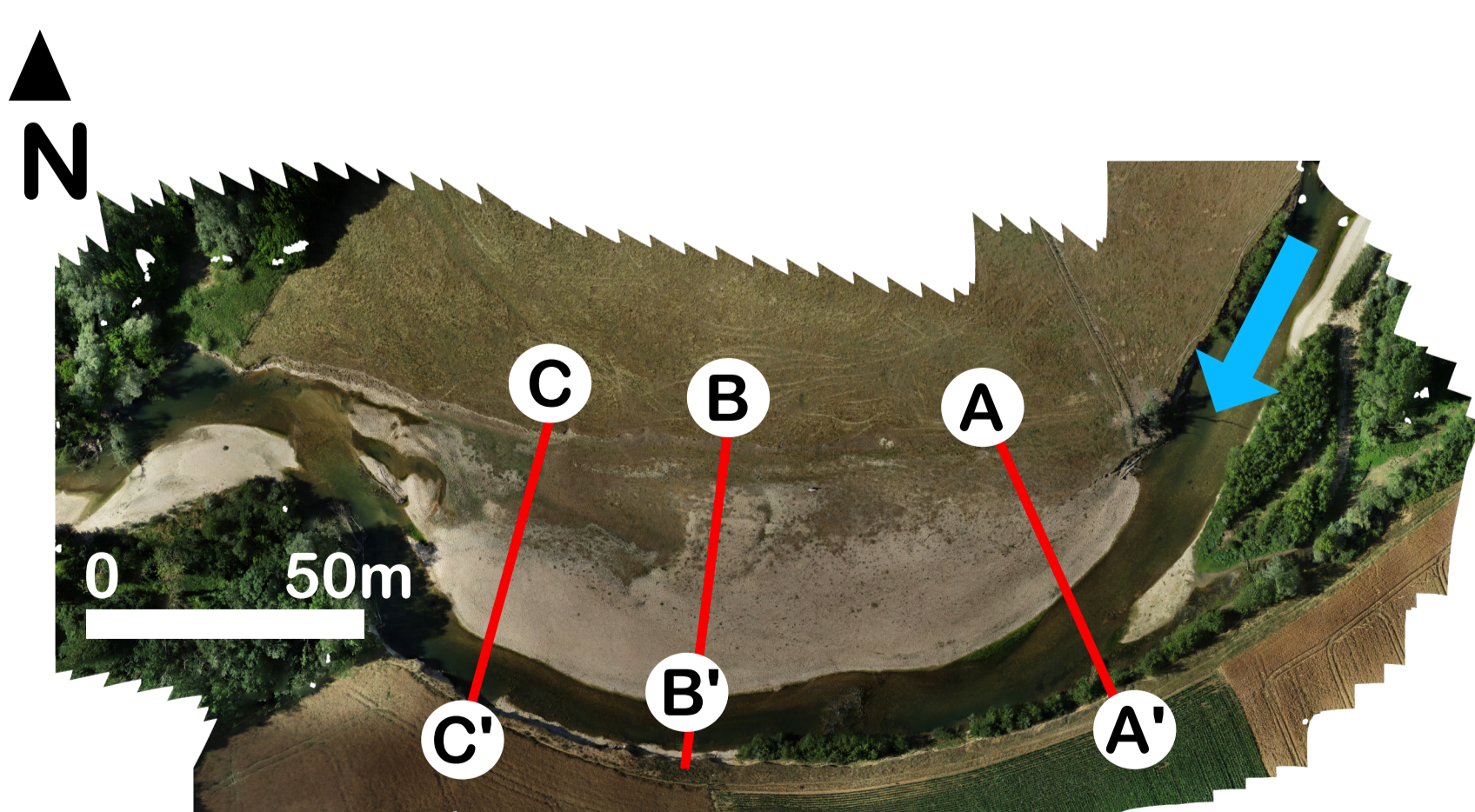
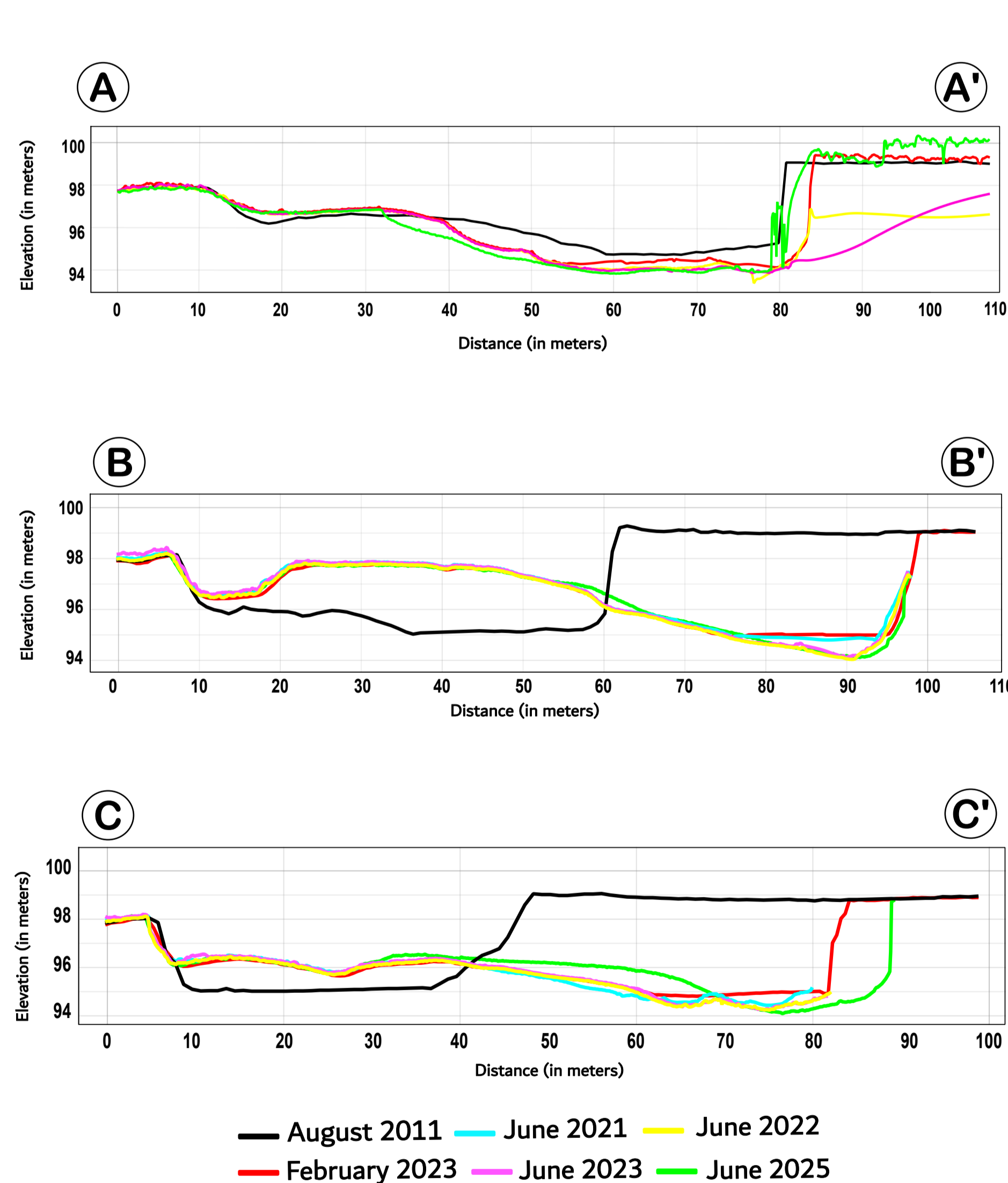


5. Results

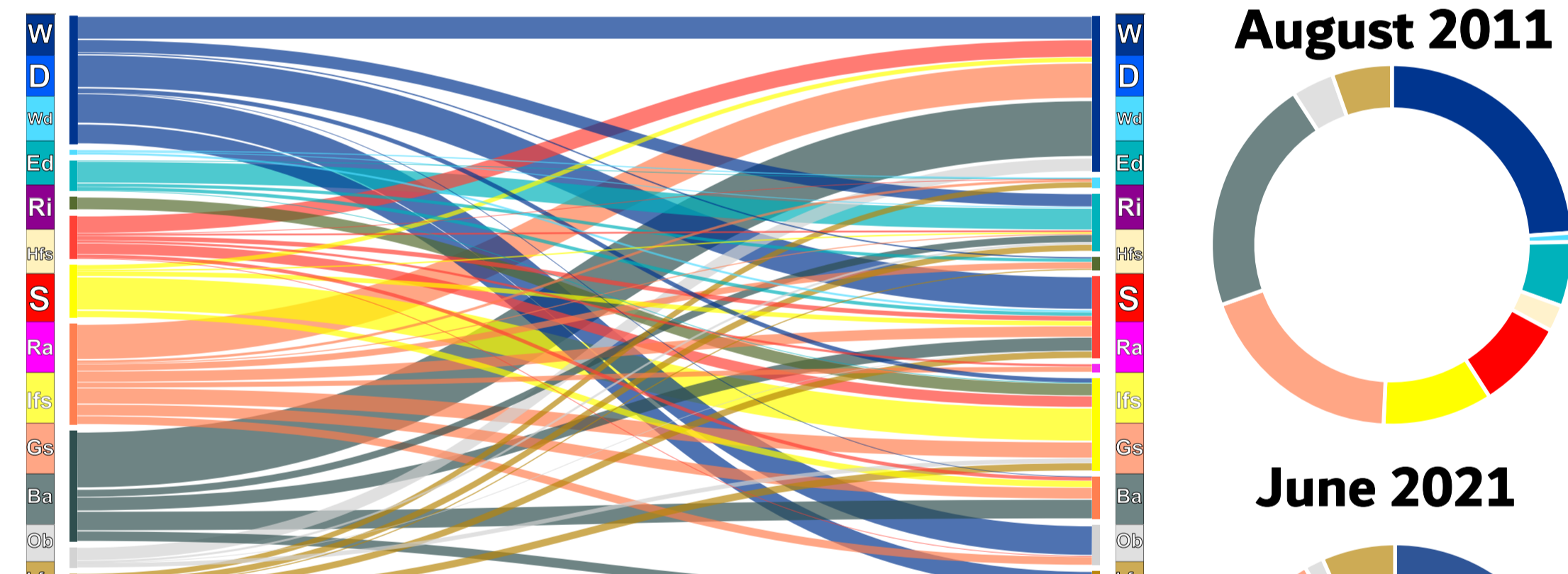
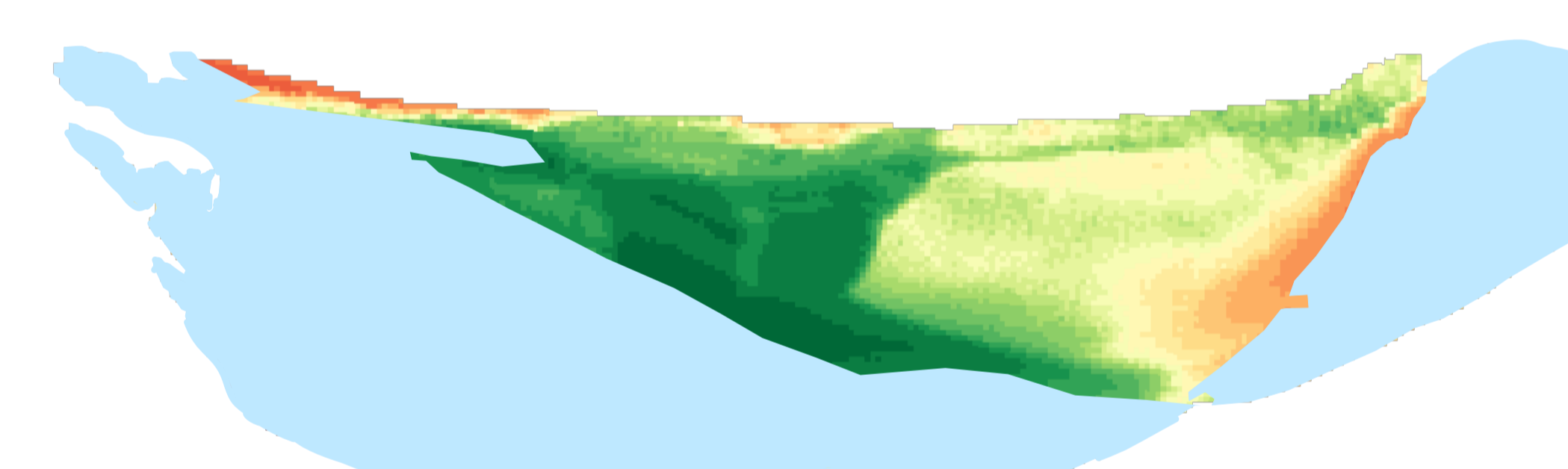
Three morphological zones are identified across the Sureau area. At the **bar head**, **erosion** reaches several tens of centimetres and was enhanced by the 2024 floods. Bank retreat remains limited (<5 m over 15 years). The **central bar sector** formed through **gravel accumulation up to 3 m thick** since the 2010s. Bank retreat reached ~35 m over 12 years. Morphological changes have been limited since 2021. At the **bar tail** (profile CC'), **net gravel accretion** reached several tens of centimetres between 2011 and 2021. A further 0.5 to 1 m of aggradation occurred between 2023 and 2025 following the 2024 floods. **Bank retreat reached 40 m over 12 years**, plus 5 m in 1.5 years.

Sankey diagrams show strong morphological change between 2011 and 2021. Bank pixels decreased from 21.5% to 0% and mainly converted to water (24% to 30%). Several units (Ed, S, lfs, Gs) **doubled** in proportion due to **bar accretion**. Between **2021 and 2023**, morphology was **relatively stable**. Water pixels decreased from 30% to 21%. Steep (+1%) and gentle slopes (+5%) increased slightly. **After 2023, major pixel transfers occurred**. Steep slopes increased by 7.2%, gentle slopes by 2.1%, and intermediate flat surfaces by 4.5%. Elongated depressions decreased by 5% between 2021 and 2025, indicating progressive infilling.

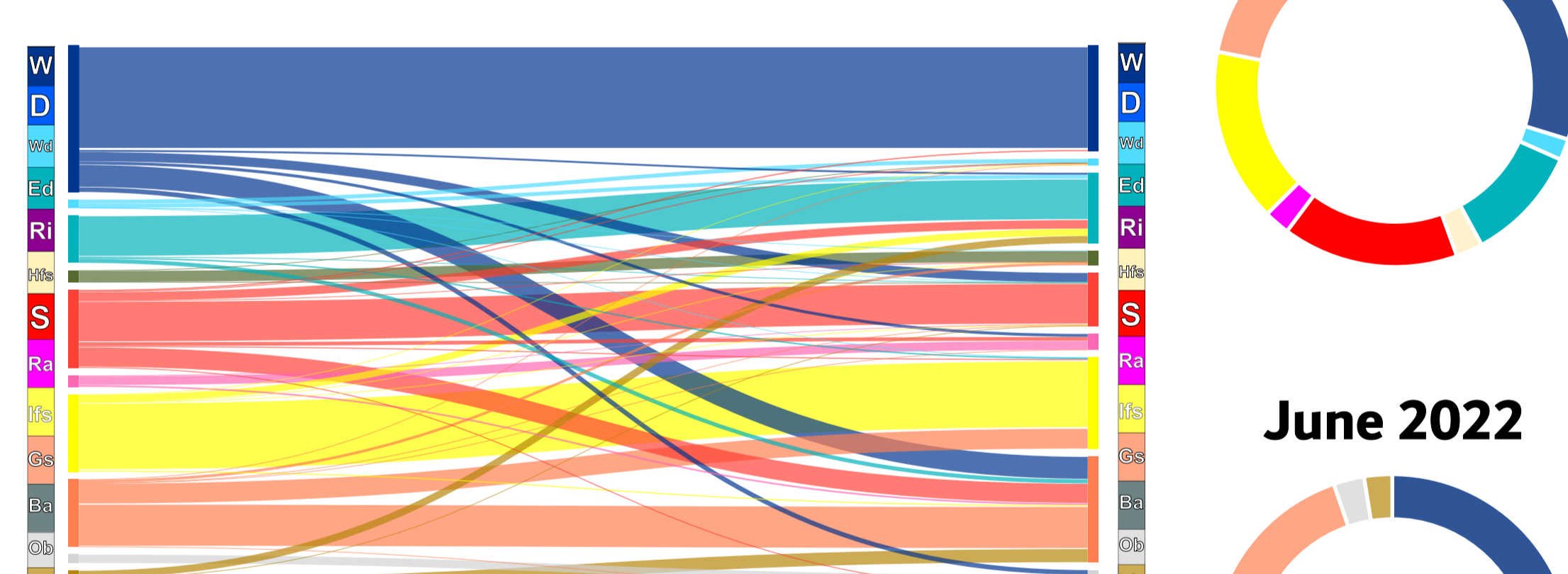
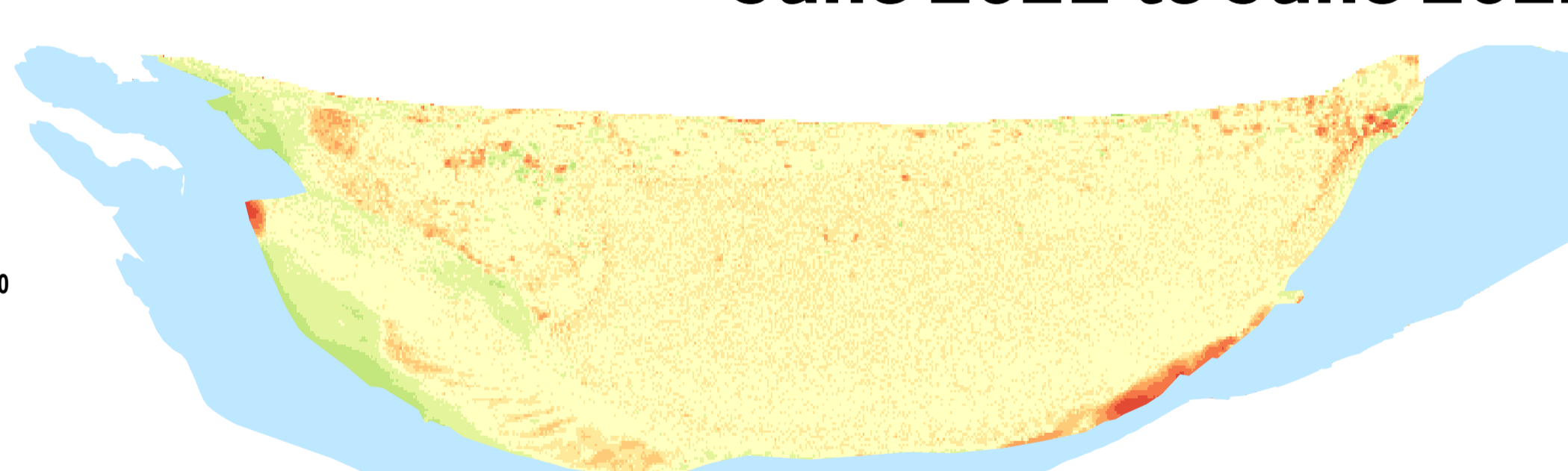
Cross sectional profiles



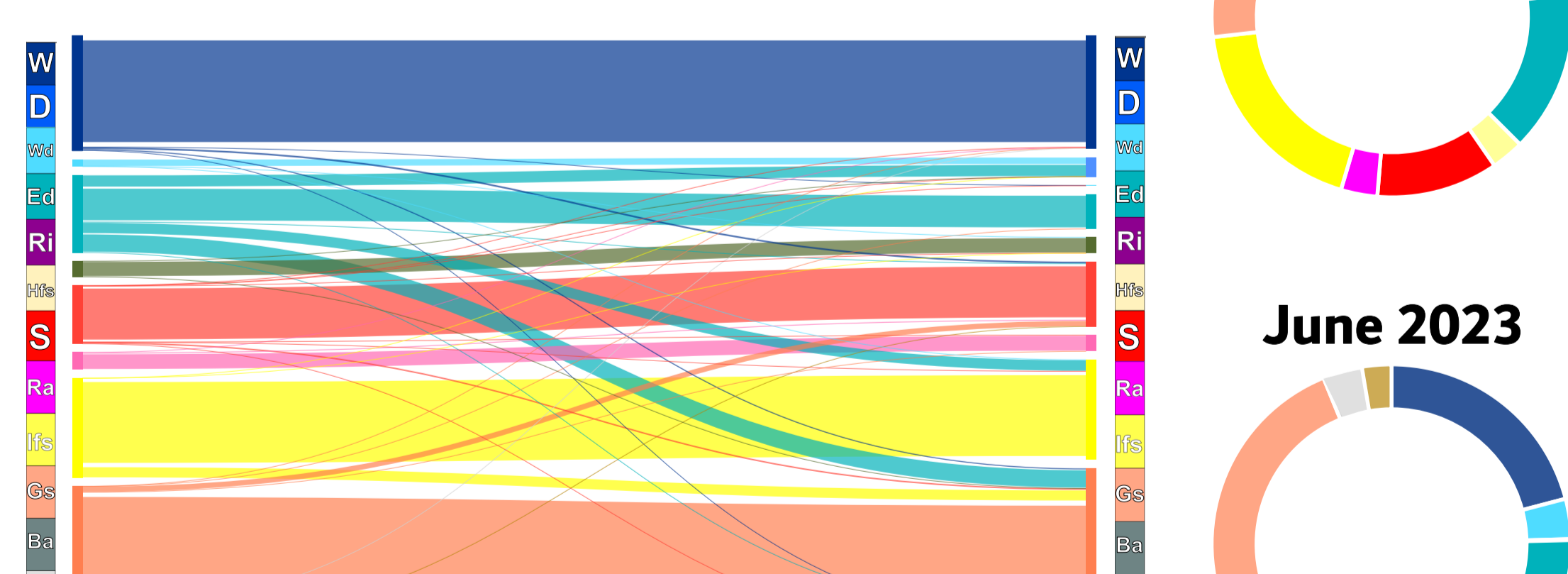
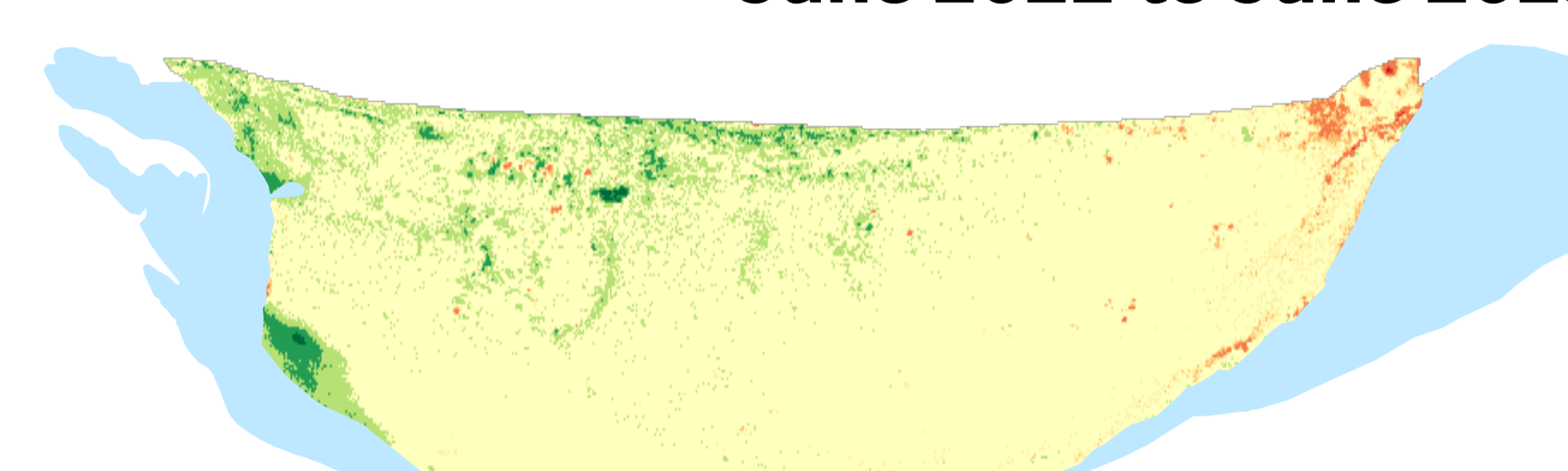
August 2011 to June 2021



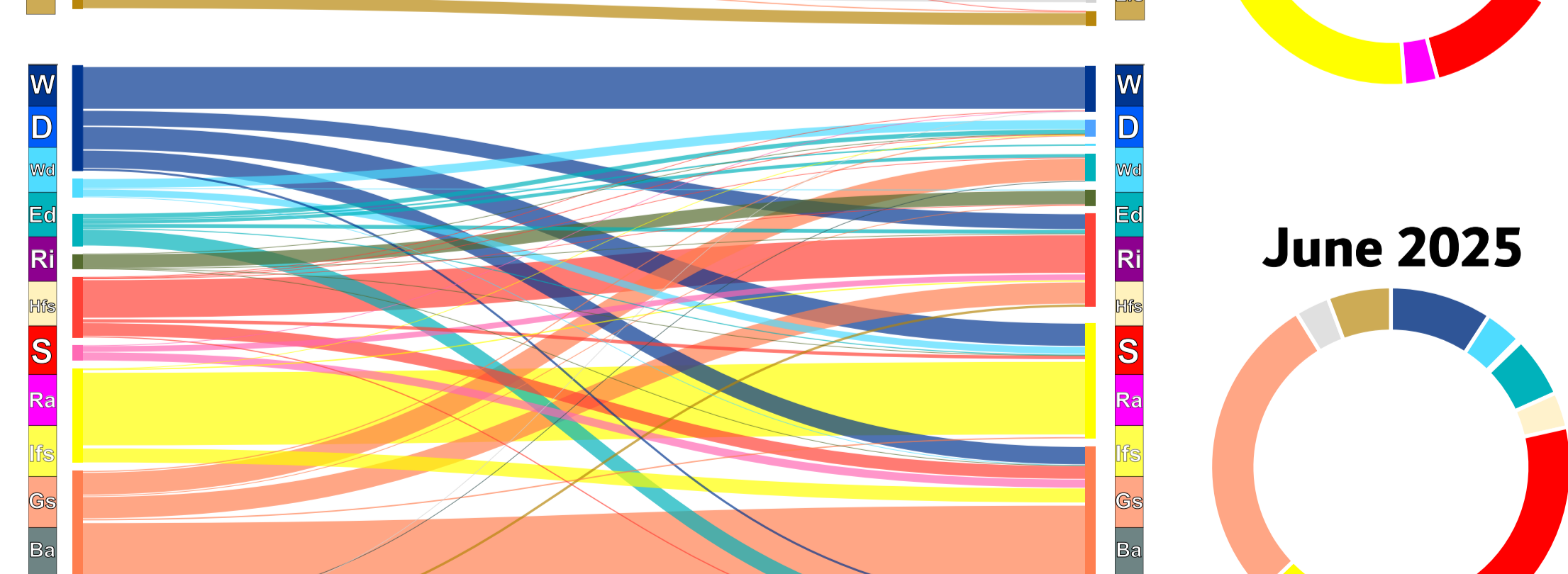
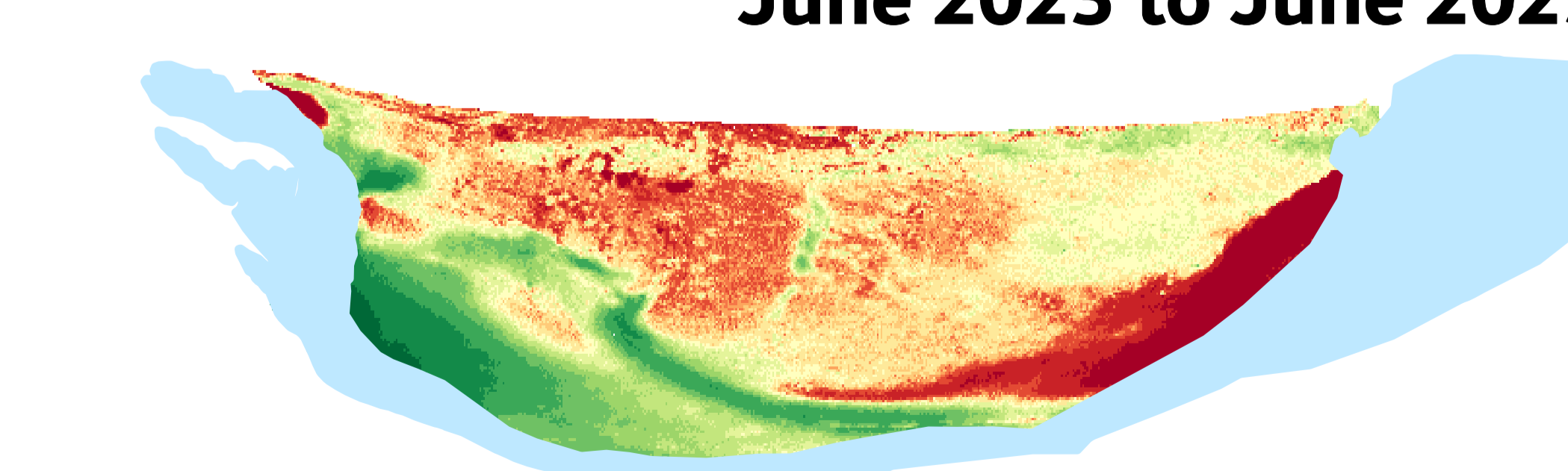
June 2021 to June 2022



June 2022 to June 2023



June 2023 to June 2025



W = In-channel water, D = Depression / hollow, Wd = Water-filled depression, Ed = Elongated depression, Ri = Ridge, Hfs = High flat surface, S = Steepe Slope, Ra = Ramp, lfs = Intermediate flat surface, Gs = Gentle slope, Ba = Bank, Ob = Other bar, Lfs = Low flat surface

6. Conclusion

In this study, longitudinal profiles and sediment balances provide evidence of the **natural downstream migration** of a **gravel bar**. **High-resolution drone imagery** enables precise **quantification and interpretation** of changes to the bar's morphology and the surrounding area. This study will be published as a paper covering four sites along the same section of river. The **results** will improve our **understanding of the dynamics** of this low-energy yet highly dynamic gravel-bed river.

7. Bibliography

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