Influence of Vegetation-Induced Roughness on the Morphodynamics of River-Dominated Deltas

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Intoduction

- **First-order delta morphology** is controlled by the dominant driver of sediment transport: river, waves, or tides (Galloway, 1975; Broaddus et al., 2022).
- **Vegetation affects sediment balance and morphology.** In turn, morphodynamic changes impact vegetation through a biogeomorphic feedback loop.
- **We examine how dynamic vegetation influences** vegetation-induced roughness distributions and the total volume of delta deposits.

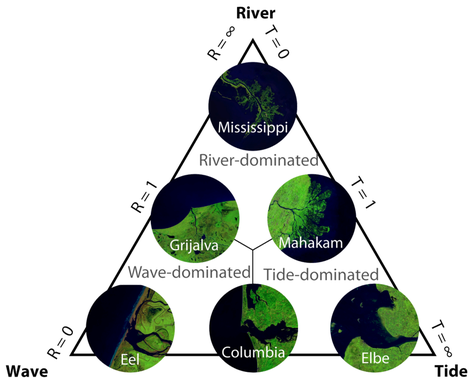

Figure 1: Galloway Ternary Diagram (Paniagua-Arroyave & Nienhuis, 2024).

Methods

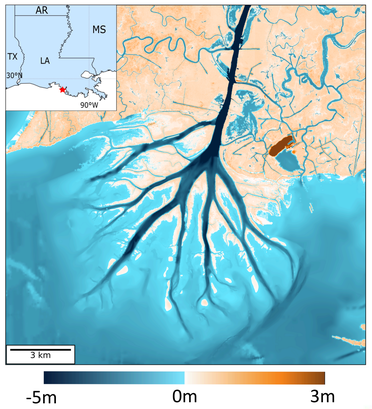

Figure 2: Digital Elevation Model (DEM) of the Wax Lake Delta (The Delta-X Project, 2021).

- **Modeling Tool:** We use Delft3D to simulate an idealized river-dominated delta under the influence of tides. We used parameters from Wax Lake Delta (WLD) in Louisiana, USA as a reference, including water discharge (2500 m^3/s), tidal range (35 cm) and its species distribution (*Salix nigra, Nelumbo lutea*, and *Sagittaria latifolia*).

Eco-morphodynamic Model

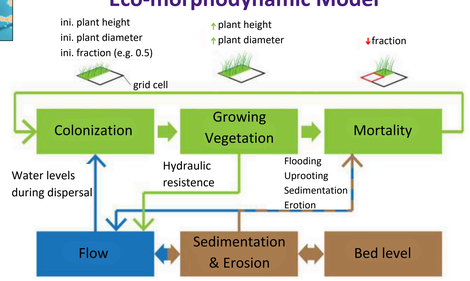

Figure 3: Overview of the feedback mechanisms in the Ecomorphodynamic Model (Brückner et al., 2019)

- **Eco-Morphodynamic Model:** We employ a dynamic eco-morphodynamic model coupled with Delft3D to simulate vegetation establishment, growth, and mortality.
- **Chézy Coefficient:** The hydraulic resistance due to vegetation is represented by the Chézy Coefficient, *C*, as:

$$C = \frac{1}{\sqrt{\frac{1}{C_b^2} + \frac{C_D\, n\, h_v}{2g}}} + \frac{\sqrt{g}}{\kappa} \ln\left(\frac{h}{h_v}\right) \quad (1) \qquad C = \frac{1}{\sqrt{\frac{1}{C_b^2} + \frac{C_D\, n\, h}{2g}}} \quad (2),$$

where C_b is the bed roughness coefficient, g is the gravitational acceleration, κ is the von Kármán constant, h is the water depth, h_v is the vegetation height, C_D is the drag coefficient, and n is the vegetation density. Equation (1) is for submerged vegetation, whereas equation (2) is for emerged vegetation. Note that lower values of C indicate higher roughness.

Results

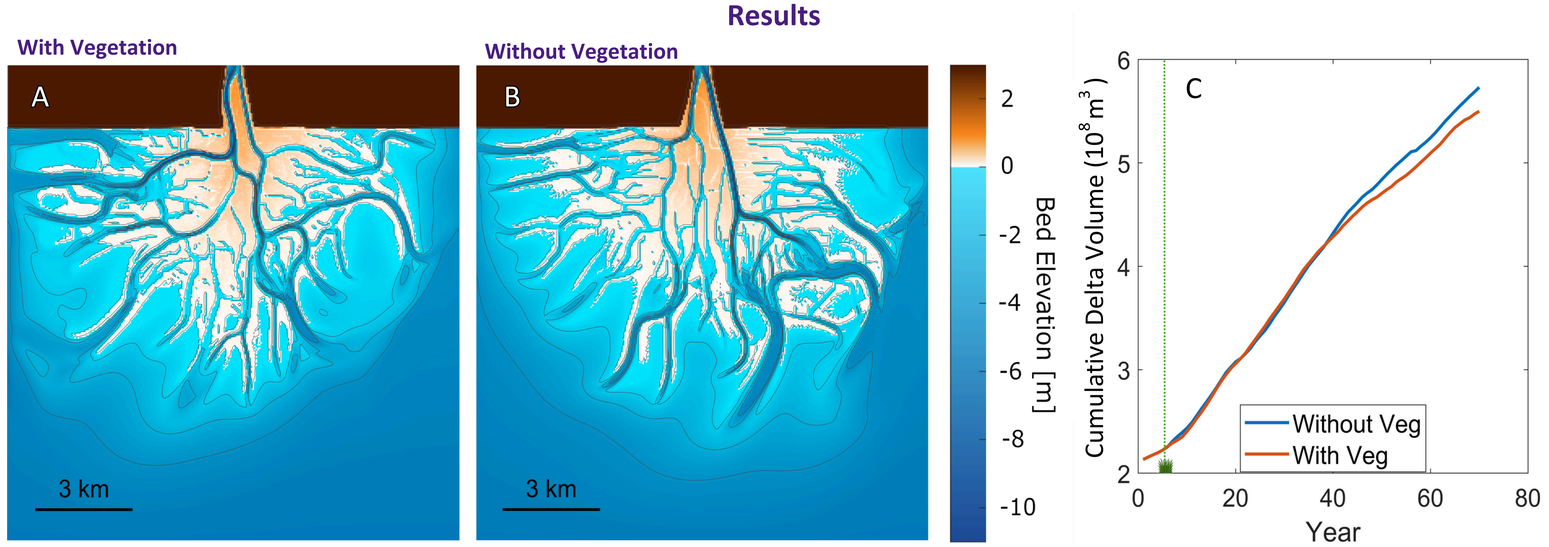

Figure 4: Delta morphology and sediment deposition comparison: (A) Final morphology with vegetation for year 70. (B) Final morphology without vegetation for year 70. (C) Annual deposited sediment volume up to year 70 for both scenarios.

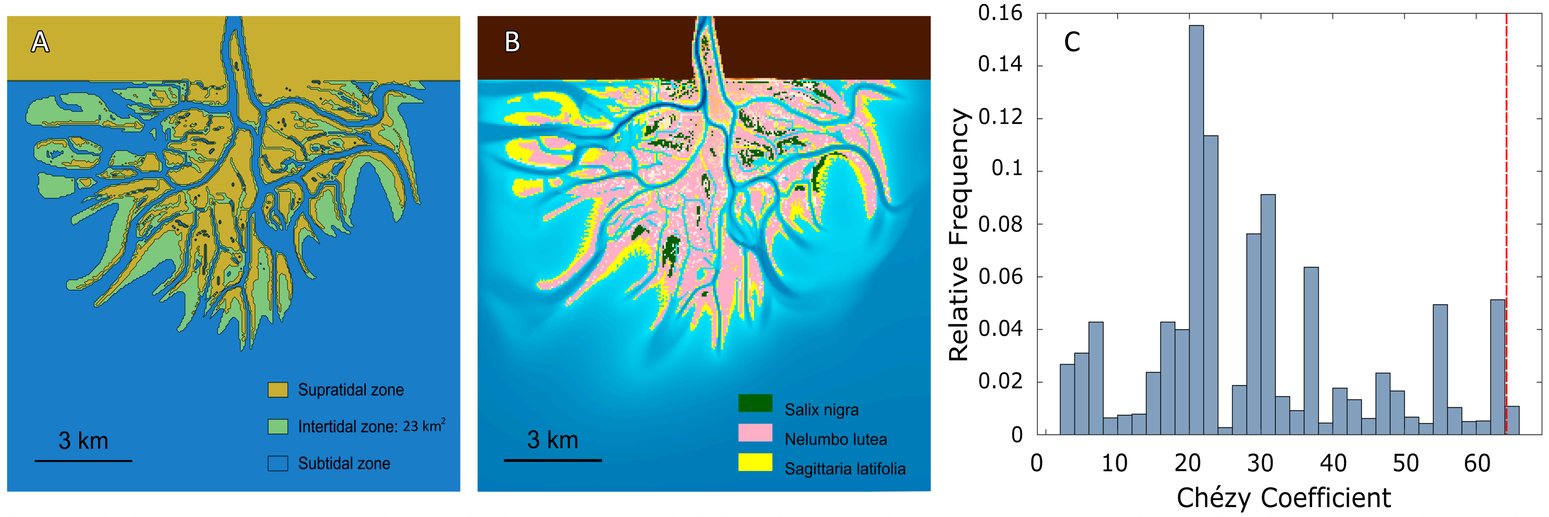

Figure 5. Model with vegetation at year 70: (A) Tidal zonation over the final delta morphology. (B) Spatial distribution of vegetation species. (C) Relative-frequency histogram of Chézy coefficients for all vegetated grid cells, computed from equations (1) and (2). Red dashed line marks the Chézy value for bare soil (65)

Conclusions

- Vegetation increases hydraulic roughness heterogeneously throughout the delta, as demonstrated by spatial variations in Chézy coefficients. Lower Chézy values represent areas of greater roughness, linked to plant presence.
- The ecomorphodynamic model realistically predicts spatial distributions of dominant vegetation species (*Salix nigra, Nelumbo lutea,* and *Sagittaria latifolia*), resembling patterns observed in the natural environment at Wax Lake Delta (Jansen et al., 2021).
- Vegetation modifies local hydrodynamics and sediment deposition patterns, which in turn influence vegetation distribution, and drive the morphological evolution of the delta.

Future Efforts

We will finalize the coupled vegetation–morphology variables test. We will then run scenarios with different vegetation types and density and quantify key delta metrics (distributary mouth count, channel width and depth, volume, etc) to identify statistical correlations between vegetation and delta morphodynamic.

References

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