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Evapotranspiration effects on the accumulation of carbonate minerals in recreated Everglades' tree islands

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Introduction

In the south Florida Everglades, tree islands act as biogeochemical hotspots accounting for the oligotrophic conditions of the freshwater-wetland ecosystem. Moreover, hydrologic management in South Florida has resulted in a degradation (homogenization) of the interior Everglades landscape, which was originally composed sawgrass ridges, sloughs, and tree islands (**Fig. 1B**). The loss of the landscape bio-complexity has had negative ecological impacts and compromised the water quality of the freshwater ecosystem.

The **objective** of this study was to understand the water-rock interactions taking place in a set of constructed Everglades' tree islands (**Fig. 1A**) that result from seasonal-eco-hydrological processes under managed hydrologic conditions. This information will contribute to determining conditions capable of promoting tree-island resilience.

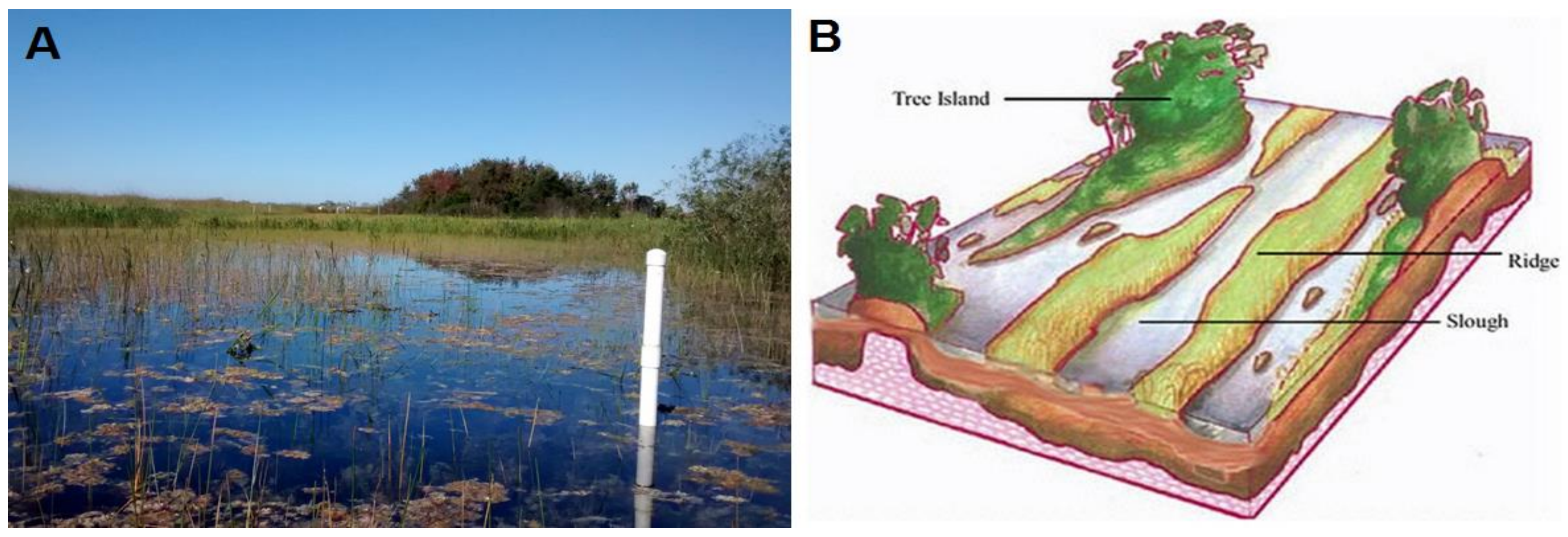

Figure 1. A) Recreated Everglades landscape and B) main features of the interior Everglades landscape.

Two main **hypotheses** were formulated: (a) seasonal tree evapotranspiration regulates the concentrations of dissolved major ions and nutrients, pCO_2, and S.I.'s with respect to calcite in the groundwater beneath the tree islands; and (b), $CaCO_3$ precipitates in the water-table capillary fringe during the dry season, forming a groundwater calcrete within the peat soils of the tree islands.

Methods

This project was conducted at the Loxahatchee Impoundment Landscape Assessment (LILA) facility, located at the Arthur R. Loxahatchee National Wildlife Refuge, in Boynton Beach, Florida. LILA consists of four macrocosms, each of which contains two tree islands: a peat-based island and a limestone-core island. The water within LILA is managed by a large electric pump, water control structures, and recording stage gauges.

Sampling approach, laboratory and data analyses/modeling

- Biannual surface/ground-water sampling (October 2013 – October 2015).
- Temperature, salinity, pH, conductivity, and DO were measured in situ.
- Pressure transducers recorded ground/surface-water depth (**Fig. 2**).
- Soil samples were collected from three peat-based islands using a soil auger

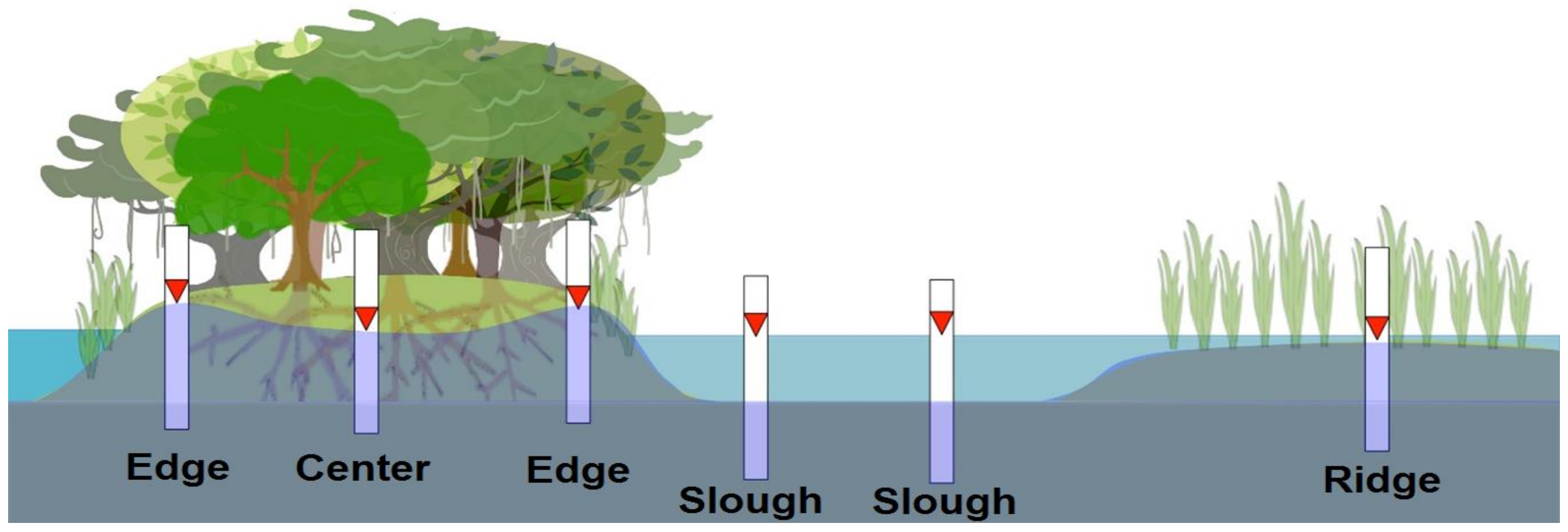

Figure 2. Schematic cartoon showing the pressure-transducer locations across the LILA macrocosms.

- Water alkalinity, major ions, and stable isotopes of H and O (FIU's Hydrogeology lab).
- Water TOC, TN, and TP (SERC nutrient lab).
- Water PO_4^-, NH_4^+, NO_2^-, and NO_3^- (FIU's Soil/Sediment Biogeochemistry lab).
- Soil TC and TIC (FIU's Soil/Sediment Biogeochemistry lab).
- Soil samples were analyzed with a binocular and a petrographic microscope (FIU's Stratigraphy lab).
- Speciation-solubility modeling and inverse mass-balance modeling (AquaChem-PHREEQC).
- Pearson correlations of water constituents (IBM SPSS statistics).

Results

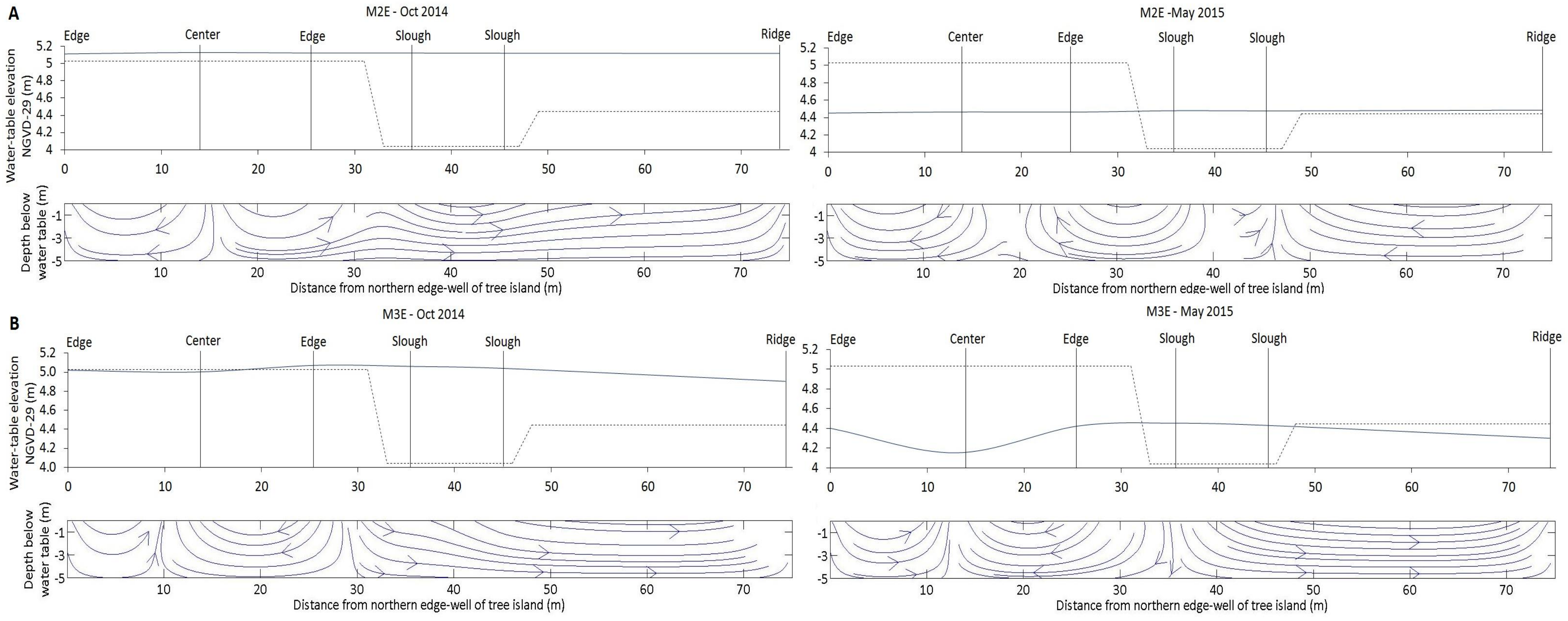

Figure 3. Seasonal groundwater-flow directions across two LILA macrocosms containing peat-based tree islands: A) M2E and B) M3E.

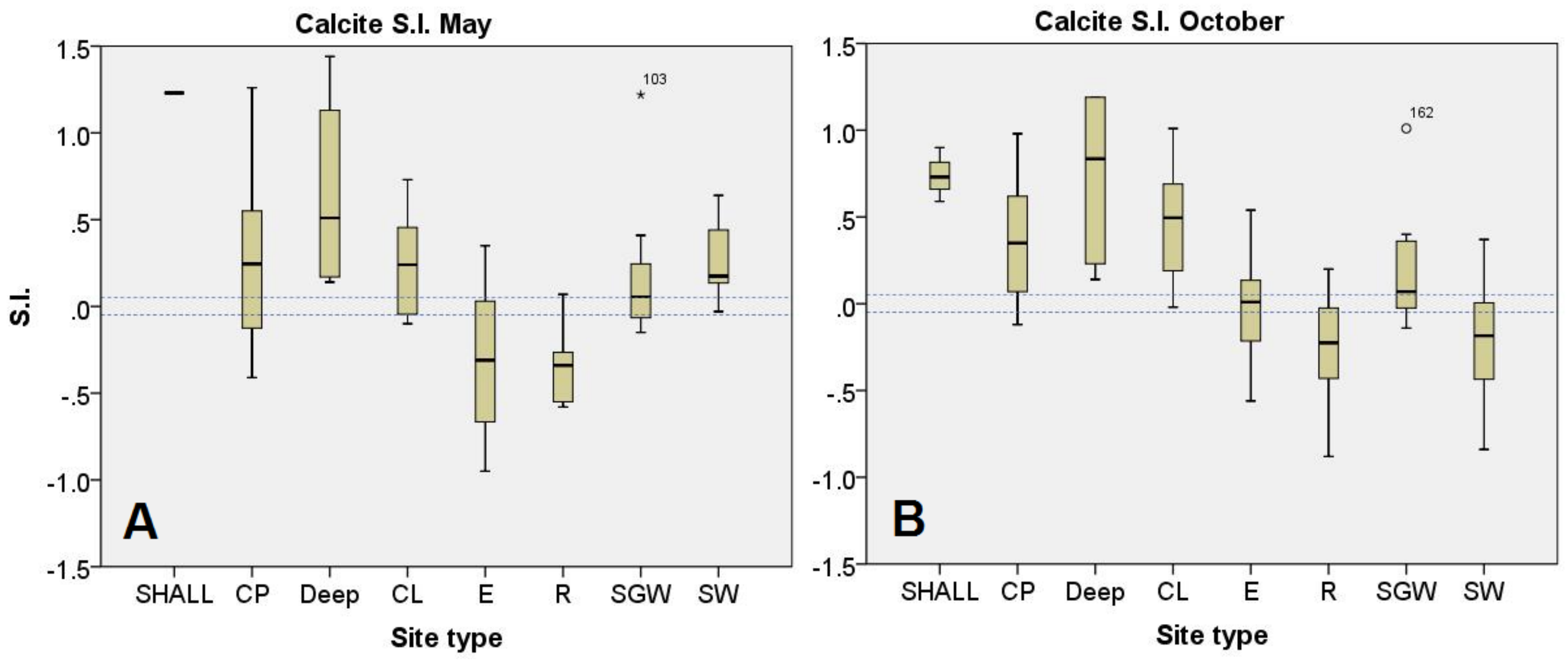

Figure 4. Average saturation indices with respect to calcite of water samples collected at different sites at LILA . A) May (dry season) and B) October (wet season).

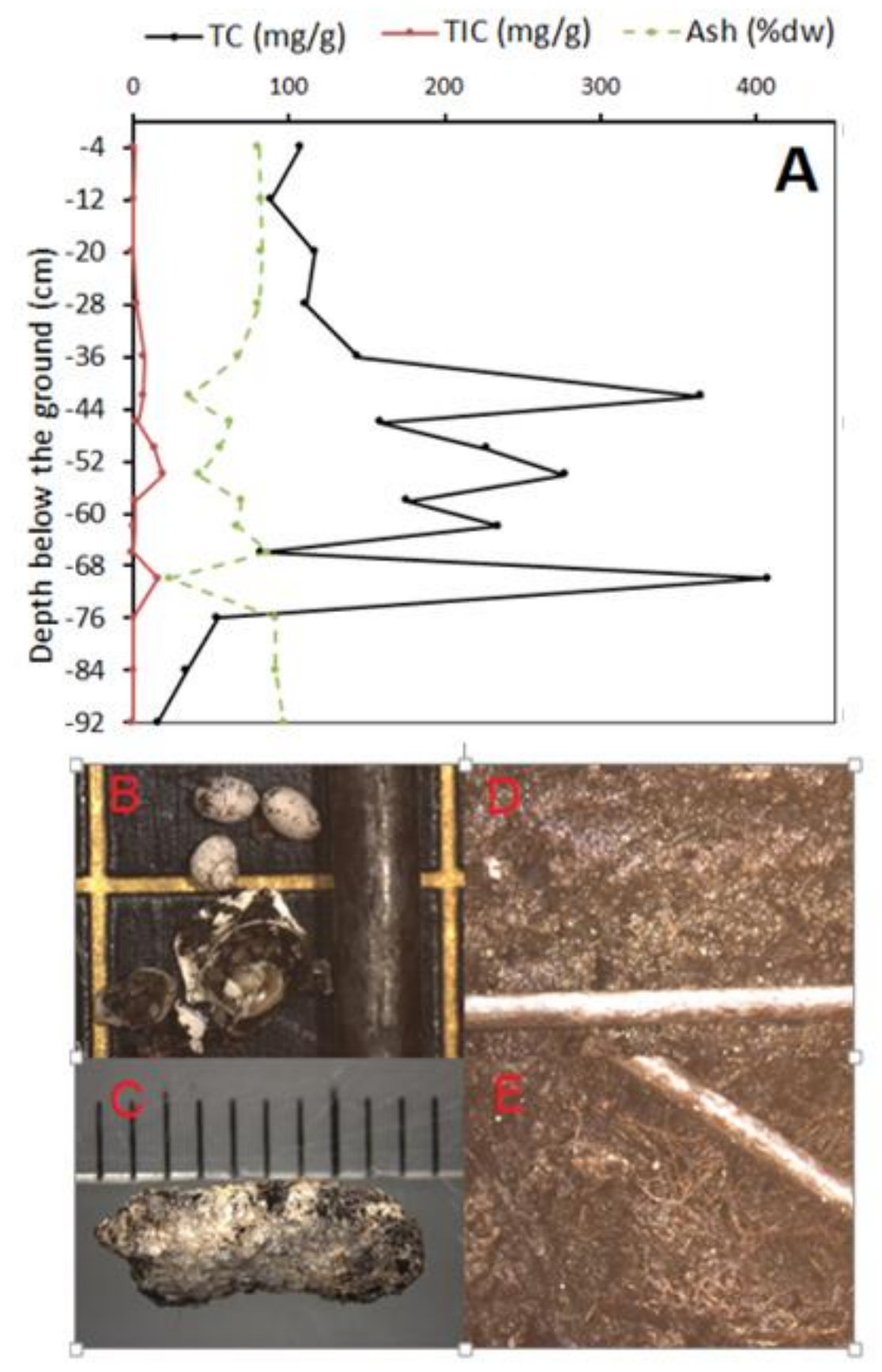

Figure 5. A) TC/TIC content of a soil core obtained from a peat-based tree island at LILA. B) Shells of freshwater gastropods. C) Micrite ($CaCO_3$)-cemented quartz grains (lines are 1mm apart). D) Loxahatchee peat with high quartz content. E) Loxahatchee peat with low quartz content (the metal bar is 1mm wide).

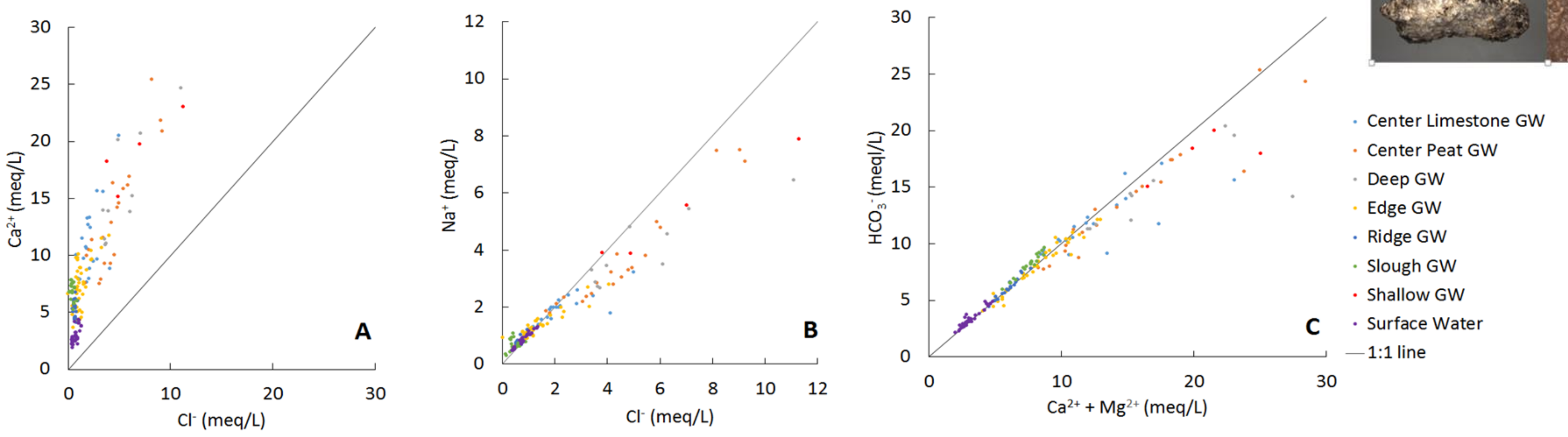

Figure 5. A) Excess calcium concentrations with respect to chloride indicating calcite dissolution at LILA. B) Sodium depletion with respect to chloride suggesting cation exchange processes. C) 1:1 relation between bicarbonate and calcium + magnesium concentrations indicating carbonate-mineral dissolution at LILA.

Conclusions

- There is no evidence indicating calcite precipitation in the water-table capillary fringe of the peat-based tree islands. However, inverse-mass balance modeling results suggest thermodynamic feasibility for calcite precipitation below the water table only in islands with elevated sand content, where greater inputs of solutes from adjacent sloughs (**Fig. 3B**) are likely to result in calcite precipitation in response to ion exclusion during root water uptake.

- Geochemical modeling indicates calcite dissolution in peat-based islands with lower hydraulic conductivity (**Fig. 3A**). Seasonal cycles of precipitation and dissolution of $CaCO_3$ in limestone-core islands indicate no long-term accumulation of carbonate minerals under current climatic conditions.

- Collecting and analyzing soil samples from a sawgrass ridge will help to characterize the sand-shell layer that underlies the peat at LILA, interpreted as the Pamlico Formation. This can serve to better assess the origin/composition of the observed micrite-cemented quartz grains (**Fig. 5C**) found in the upper part of some of the peat-based islands.

Acknowledgments

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