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Modeling forested wetland methane dynamics: insights from 5 flux towers and observations

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CONTEXT

Vegetation acts as an important emission pathway by providing an alternative route for methane (CH_4) that may otherwise be oxidized in surface waters and shallow soils.

Emerging science suggests that tree knees and stems in wetlands emit methane (Barba et al., 2019; New Phytologist; Covey & Megonigal, 2019, New Phytologist).

Experiments show that forested wetland systems will emit more methane under carbon dioxide (CO_2) enriched atmosphere (Vann & Megonigal, 2003, Biogeochemistry).

To accurately assess CH_4 emissions in a specific area, a comprehensive understanding of the plant community features is essential.(Bastviken et al., 2023, Aquatic Botany).

Our objective is to improve the representation of wetland CH_4 dynamics by incorporating emissions from temperate bald cypress (Taxodium distichum) trees and their knees (Figure 1, 2, 6) – woody structures that form above the root of the bald cypress – in a carbon modelling framework.

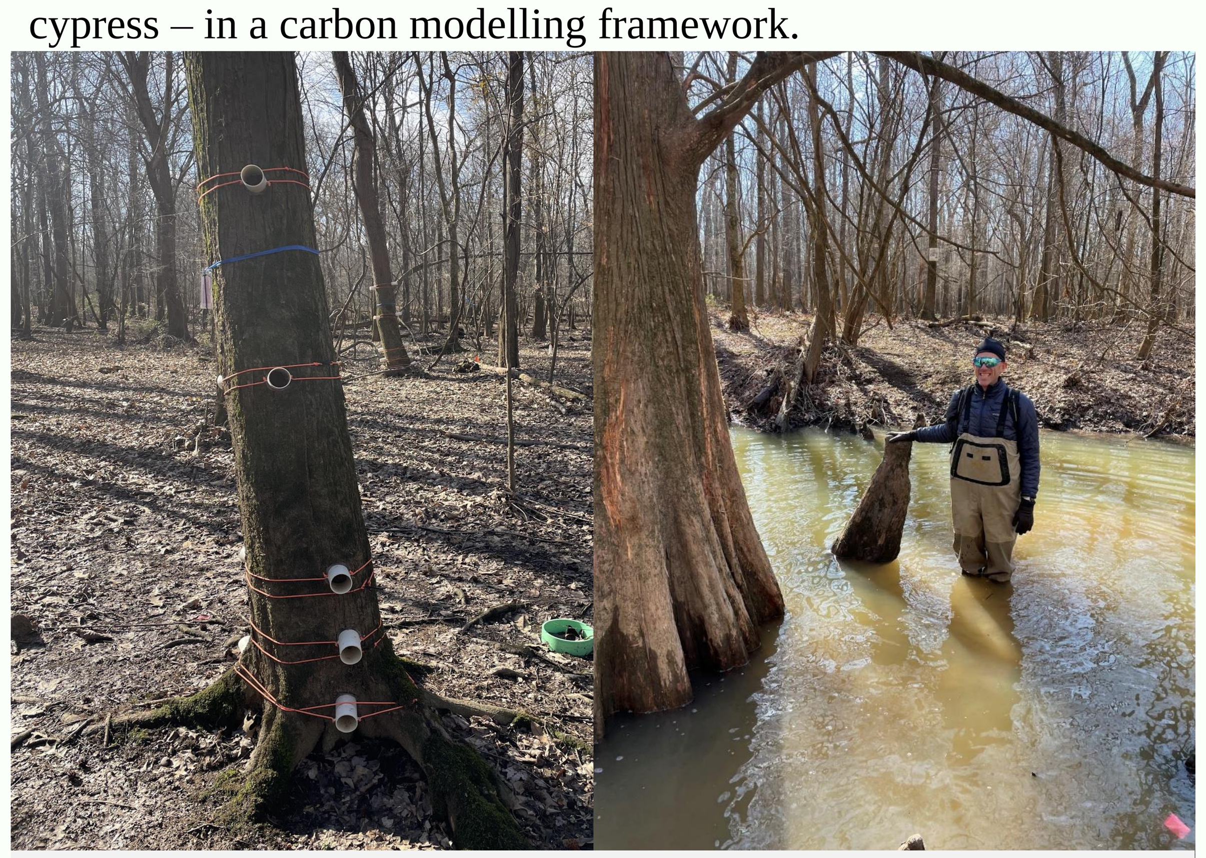

Figure 1: Chambers setup for tree stem methane flux measurement (left), knee height in the Clarks river, Kentucky (right).

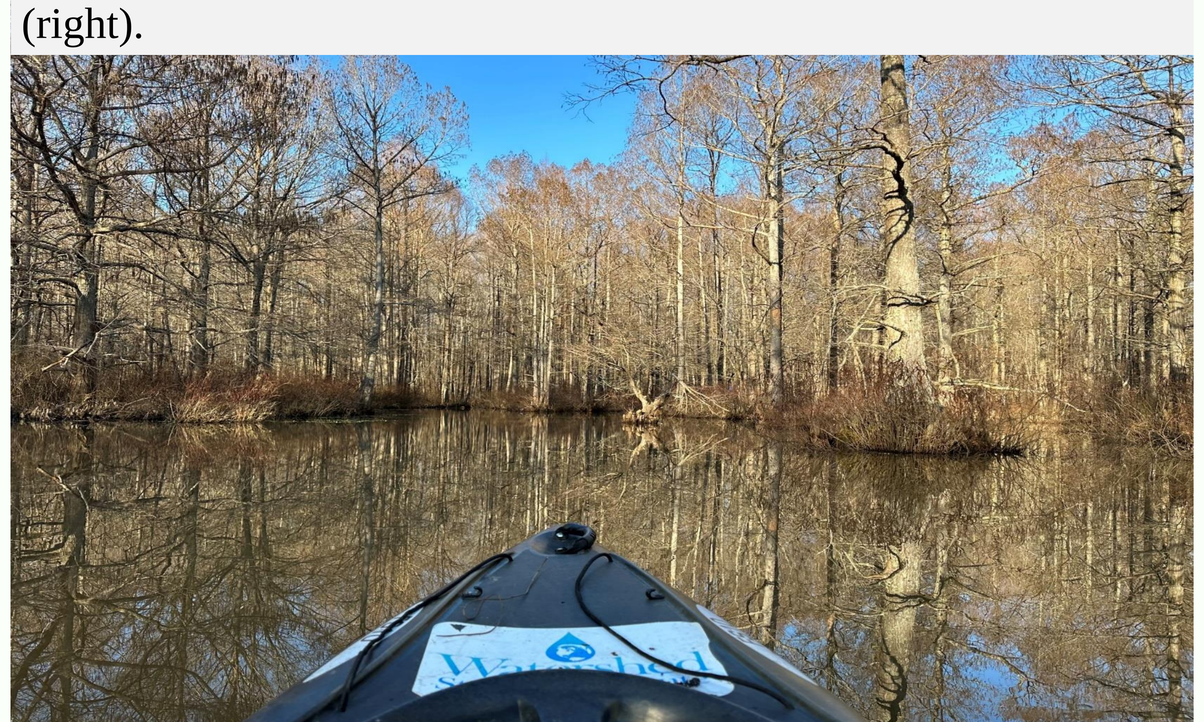

Figure 2: Murphy's pond, Kentucky

MODELING APPROACH

Peatland Ecosystem Photosynthesis Respiration and Methane Transport (PEPRMT) model (Oikawa et al., 2017, JGR: Biogeosciences) is a process-based biogeochemical model designed to estimate wetland CH_4 and CO_2 fluxes (Figure 3).

The model has shown promising results in rice paddies (Fertitta-Roberts et al., 2019, Science of the Total Environment). CH_4 transport will be improved in the model to represent forests.

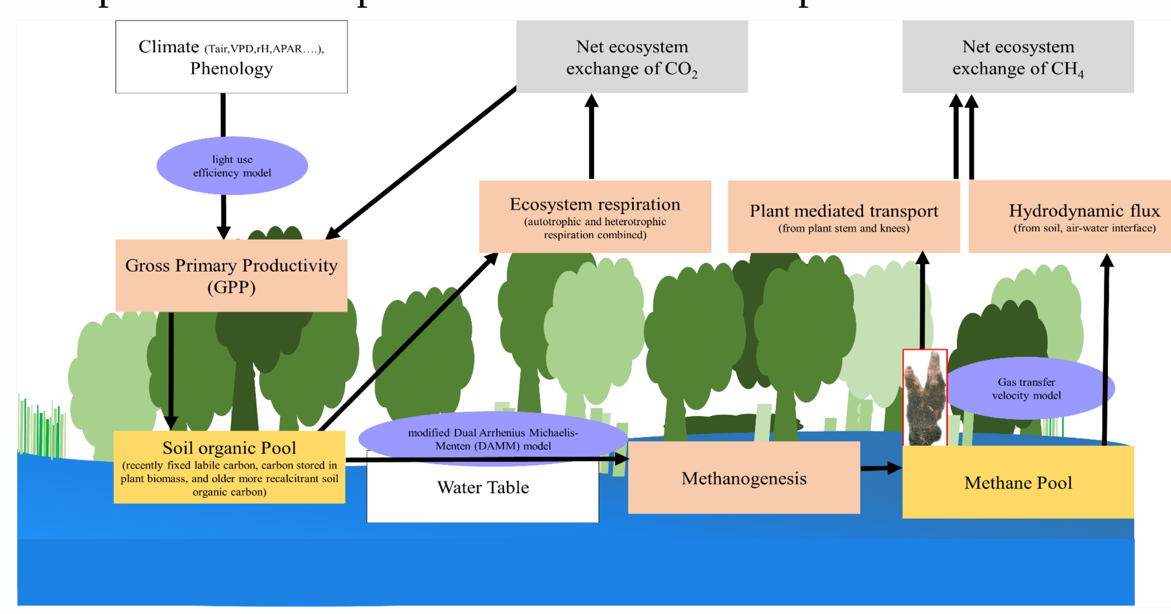

Figure 3: Schematic diagram of PEPRMT model.
Inputs are shown in white, outputs in grey, processes in orange, equations/model in purple, and pools are yellow boxes.
(Modified from Oikawa et al., 2017, JGR: Biogeosciences)

LOCATIONS

Data from five eddy covariance flux towers (AmeriFlux stations) representing upland, bottomland hardwood, and forested wetland sites from different parts of the United States (Figure 4) are being analyzed to model the total methane flux estimate.

The five sites are:

1) US-HO1: Howland Forest (main tower), ME
2) US-LA1: Pointe-aux-Chenes Brackish Marsh, LA
3) US-Myb: Mayberry Wetland, CA
4) US-NC4: Alligator River, NC
5) US-PFa: Park Falls/WLEF, WI

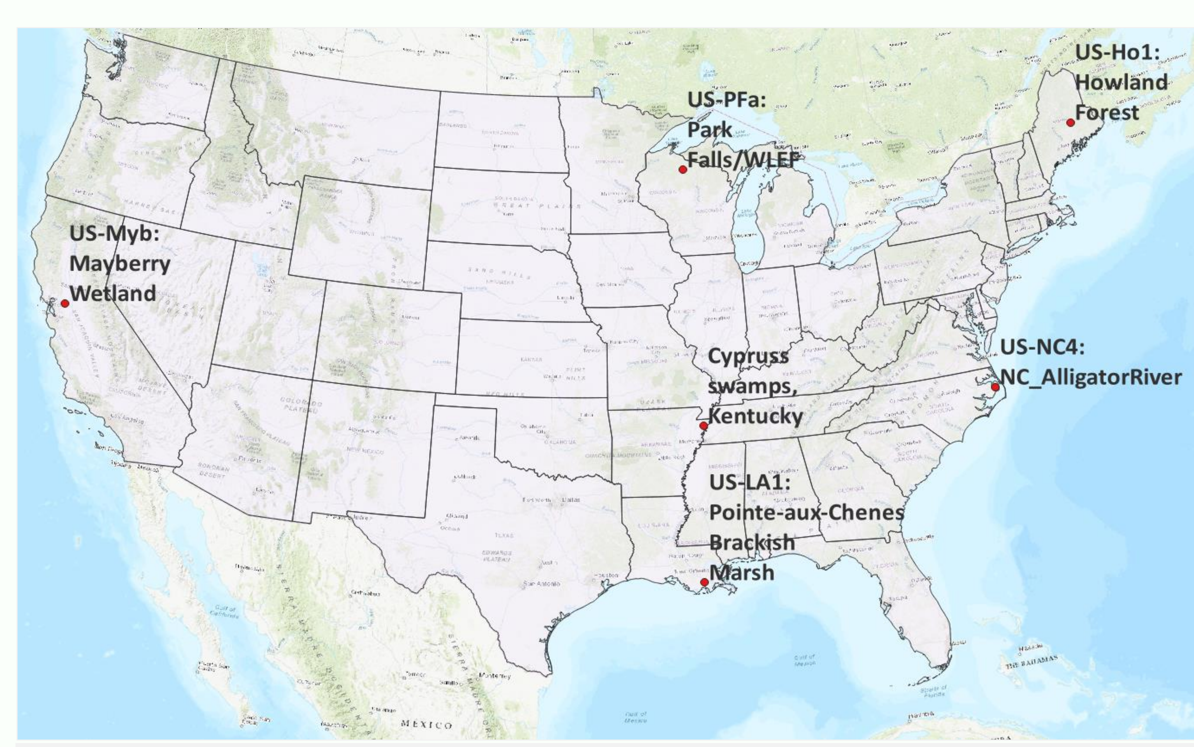

Figure 4: Study area: 5 flux tower sites and field site

Colleagues at Murray State University in Kentucky are conducting emissions measurements at Clarks River (Figure 1) and Murphy's Pond (Figure 2), focusing on emissions from the knees and stems within wetlands.

INITIAL RESULTS

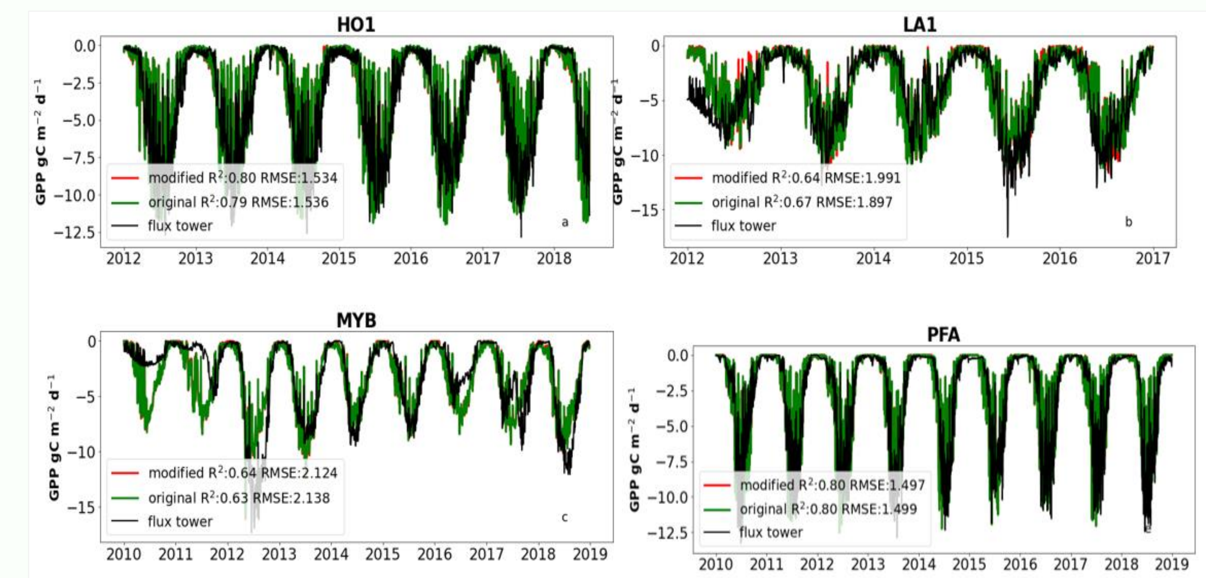

Figure 5: Calibration of Gross primary productivity (GPP) using FLUXNET data

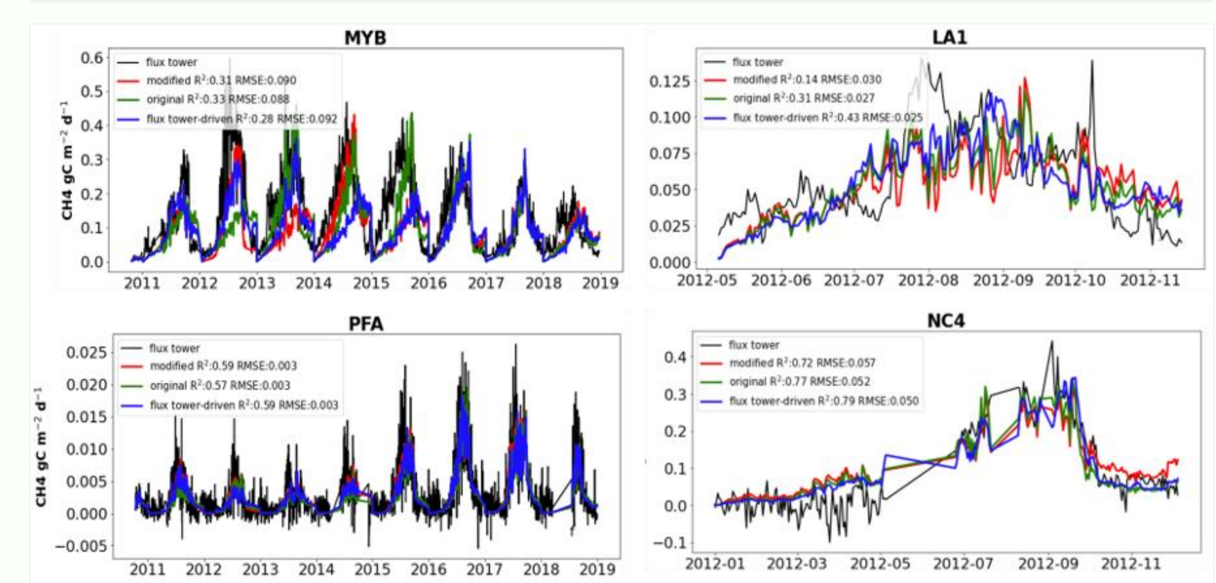

Figure 6: Calibration of methane (CH_4) flux using FLUXNET data

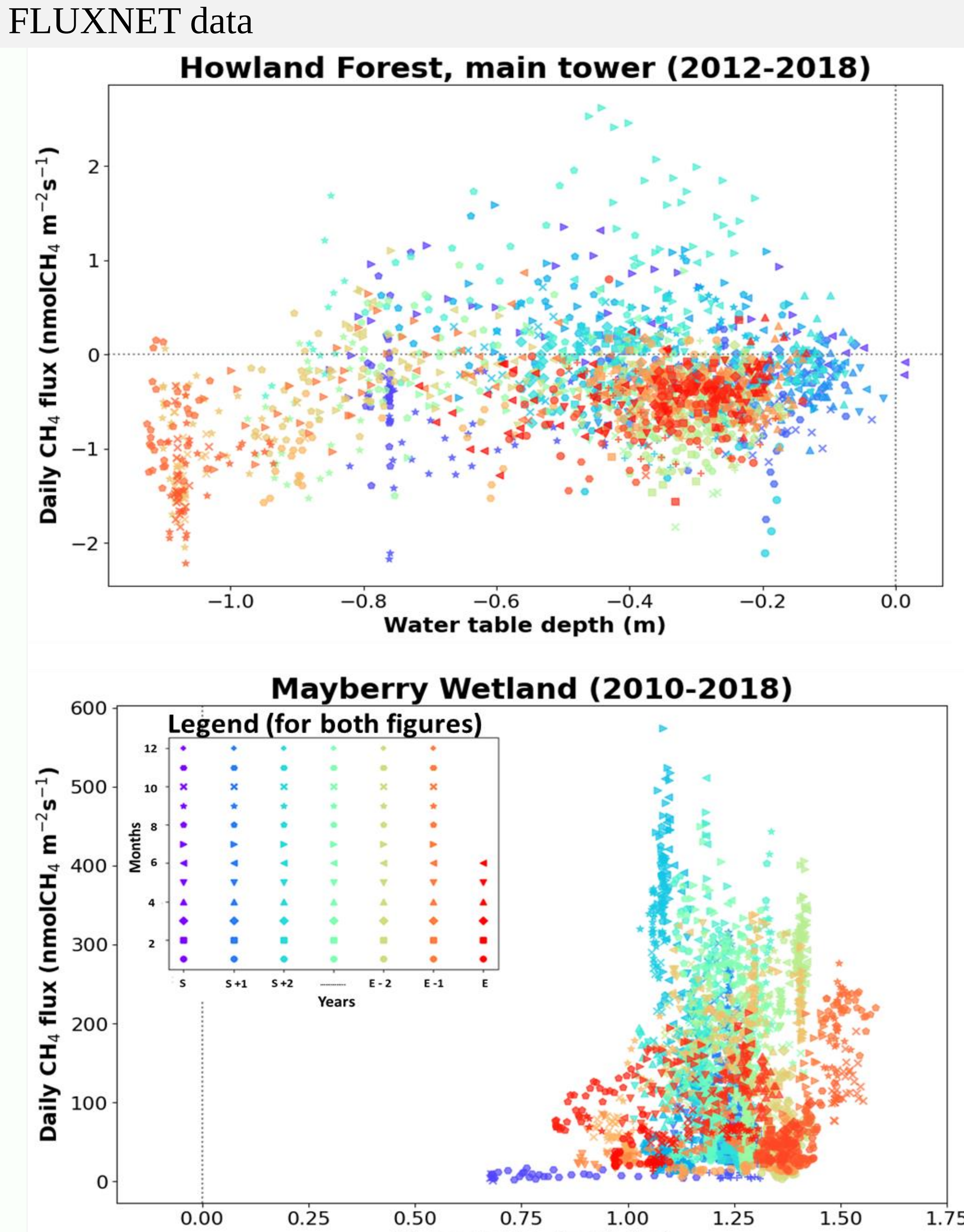

Figure 7: Dynamic nature of methane (CH_4) flux at different water table depth at two sites.
(Each month is represented by a unique shape, and for each year, a distinct color is employed. Here, 'S' denotes the start year of the data, and 'E' represents the end year.)

WAY FORWARD

The PEPRMT model is able to replicate the Gross Primary Productivity (GPP) in most of the stations, and in all stations, the R^2 value is greater than 0.6 and RMSE is 1 gCm^{-2}s^{-1} in most of the stations (Figure 5). The next step involves assessing how various methods of calculating GPP impact the overall results.

The model is being modified to represent CH_4 and CO_2 emissions from bottomland hardwood forests and forested wetland swamps.

The model does display patterns of CH_4 release (Figure 6); however, it still requires further calibration to enhance its accuracy. The next step involves integrating plant-mediated CH_4 transport into PEPRMT model and incorporate knees as a functional unit of gas exchange. Transpiration and diffusion driven mechanisms for CH_4 transport will be used.

Different seasons play a major role in CH_4 flux (Figure 7). Next step is to unlock the intricate link between the different factors contributing to CH_4 emissions.

Note: *Taxodium distichum* is commonly known as bald cypress, cypress, or swamp cypress. They are valued for their durable lumber, decay-resistant properties, ecological importance, and their ability to facilitate wetland restoration. The presence of knees (Figure 8) is an inherited characteristic of bald cypress, yet, little is known about the knees, their development and functions.

Figure 8: Knees of the *Taxodium distichum*

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