Multi-vegetation feedbacks affecting flow and sediment routing in Everglades ridges and sloughs

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How do sediment transport and ecogeomorphic interactions involving water flow, sediment, and multiple species of vegetation influence the hydrodynamic and morphodynamic processes important for shaping the Everglades ridge and slough landscape?
Previous works with a single vegetation species landscape evolution

Lab experiment a single rigid vegetation by Nepf Laboratory at MIT (1 roughness)

Modeling with a single vegetation species by Kirwan & Guntenspergen (1 roughness)
Previous works suggest that patch-scale steering and regional water level feedbacks cause ridge widths to stabilize.

But how does patch-scale steering vary as a function of water level and vegetation characteristics?

Larsen and Harvey, *Am. Naturalist*, 2010
Computational domain

Delft3D model + vegetation module

Schematization of velocity profile by Baptist et al., 2005
SLOUGH & RIDGE MODEL
GEOMETRY

W: slough width (m) = 120, 260, 400 m

R: Slough relief (m) =
0.1 (degraded – present)
0.2 (preserved – present)
0.4 (intermediate)
0.7 (historical estimates)

S: Slope (-) = 0.00003 (1.5cm in 500m)

h: water level (m) = 0.4 – 0.9 m

n: vegetation density (m\(^{-1}\)) =
Sawgrass (Cladium) 1-5
Spikerush (Eleocharis) 5-10

VEGETATION
CHARACTERISTICS

n = m \times D \quad m = N_s/m^2

SEDIMENT CHARACTERISTICS
Cohesive sediment \( w_s \) = 0.11 cm/s
Susp. Sed. Conc. = 1 kg/m\(^3\)

n = m \times D \quad m = N_s/m^2

D: stem diameter (m)
Model runs set-up

No vegetation (Control run)

Vegetation only on ridges

Vegetation on ridges & sloughs

Vegetation on ridges & sloughs (50% spikerush 50% sawgrass)
Initial conditions: Velocity in slough 0.0142 m/s with no vegetation
Vegetation in the slough

Velocity gradient between ridge & slough

Graph showing velocity (m/s) against x (m) with high and low vegetation density regions.
REMINDER: Velocity differential between ridge and slough governs whether ridges are stable or expanding!

Larsen and Harvey, *Am. Naturalist*, 2010
When water levels are high, slough velocities are much less sensitive to vegetation in sloughs but remain sensitive to vegetation density on ridges. Around wide ridges, sediment deposition threshold would shift downward into slough!
High differential velocities $\rightarrow$ High differential sediment transport

$R^2 = 0.9395$

Entrainment in slough, deposition on ridge
**Sediment transported on ridges originates from sloughs**

Single pulse of sediment in a complex slough & ridge landscape

\[
\text{%WF} = \frac{W_r \text{ridge}}{W_{F \text{tot}}} \\
\text{%SF} = \frac{\text{Sed.ridge}}{\text{SedF_{tot}}}
\]

\[R^2 = 0.7101\]
Future works: Modeling Complex Topography
Summary

• Differential ridge-slough vegetation density creates the differential velocities needed to achieve stable ridges.

• Slough vegetation has greatest impacts on patch-scale steering at low water levels.

• Ridge width matters for patch-scale steering! Around wide ridges, sediment entrainment threshold shifts further into slough.
THANKS!
Model runs set-up

- No vegetation (Control run)
- Vegetation only on ridges
- Vegetation on ridges & sloughs
- Vegetation on ridges & sloughs (50% spikerush 50% sawgrass)

Base case
Increased velocity
Decreased velocity
Nondimensional veg. volume ridge = vegetation height on ridge [m] * vegetation density on ridge [m\(^{-1}\)] * Number cells vegetated [-]

\[\Delta \text{veg. volume} = \text{nondim. veg. volume ridge} - \text{nondim. veg. volume slough}\]

R\(^2\) = 0.7719