BIOPHYSICAL IMPACTS OF LAND-COVER CONVERSION: LINKING CARBON STORAGE LOSS, LAND SURFACE TEMPERATURE INCREASES, AND ENERGY BURDEN IN THE U.S. GULF COAST

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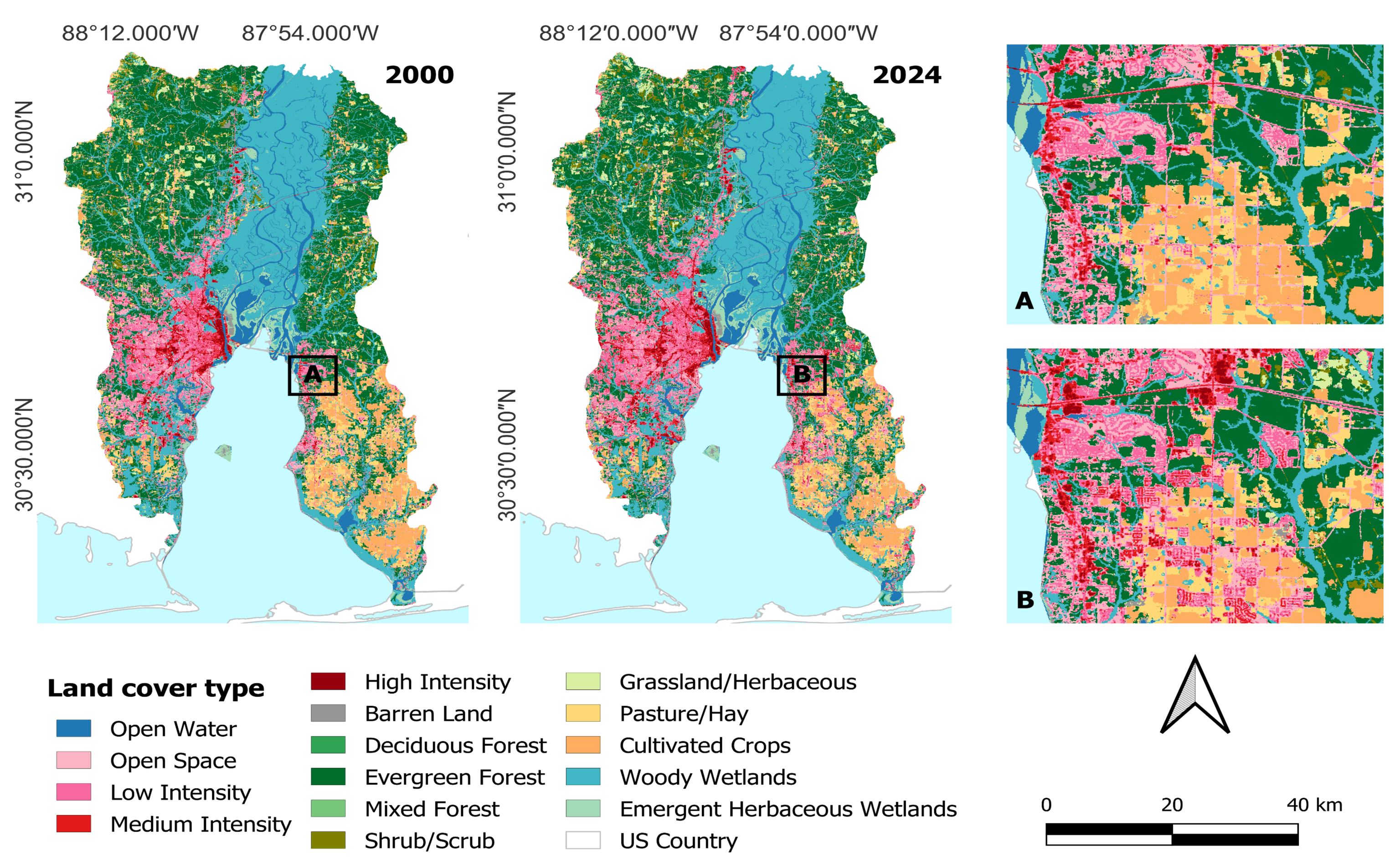
Rising energy costs in the United States are disproportionately affecting coastal and low-lying regions, where climate exposure, land-use change, and ecosystem degradation interact to amplify household energy burdens beyond what is captured by electricity rates alone. In the U.S. Gulf Coast, transitions from wetlands, floodplain forests, and other carbon-rich coastal ecosystems to degraded or urbanized land covers reduce natural climate regulation, intensify heat and flooding risks, and increase cooling demand - leading to higher total energy bills for residential, commercial, and industrial consumers. This study is informed by the ongoing development of the University of South Alabama's Delta and Coastal Alabama Wildlife, Fisheries and Carbon Flux Observatory, funded by GOMESA and currently being established in the Mobile-Tensaw Delta. The observatory provides a framework to investigate how land-use and land-cover transitions influence carbon fluxes, surface energy balance, and microclimate regulation, and how these biophysical processes translate into changes in energy demand and consumer energy burden at the community scale. Rather than focusing solely on electricity prices or rates, this work adopts a holistic energy-burden perspective that integrates total household energy expenditures, climate-driven demand (particularly cooling), and exposure to extreme heat and flooding. By linking ecosystem carbon dynamics with land-surface processes and socio-environmental vulnerability, the study highlights how degradation of natural carbon sinks can indirectly exacerbate energy affordability challenges, especially in coastal regions already facing climate stressors. The results aim to demonstrate that conserving and restoring carbon-rich coastal ecosystems can serve as complementary, nature-based strategies for decarbonization while also mitigating long-term energy burdens. This integrated approach offers actionable insights for equitable energy policy, climate resilience planning, and energy affordability in the U.S. Gulf Coast and other climate-exposed regions.

1. Background

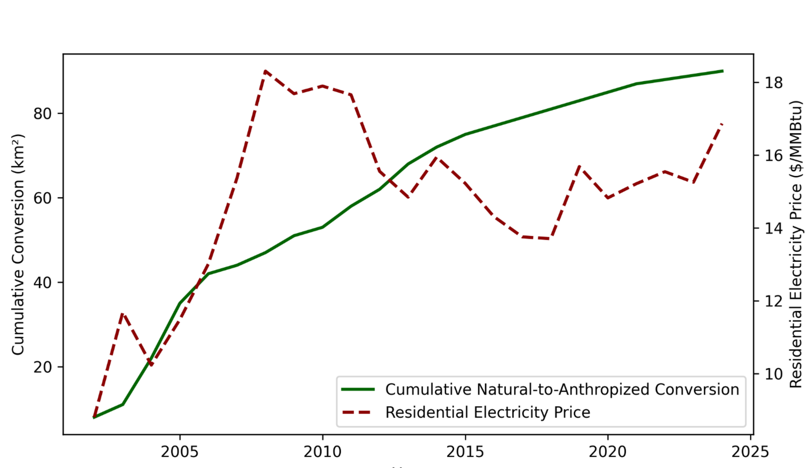
Coastal ecosystem degradation reshapes carbon and energy fluxes in climate-exposed regions. Structural land-cover change (2000-2024) and its biophysical consequences are evaluated in the Mobile-Tensaw Delta.

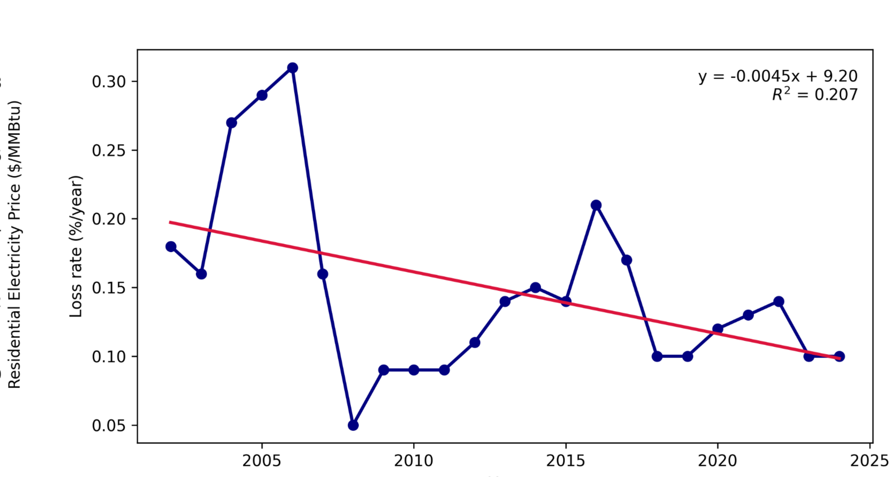
2. Structural transformation of the Delta landscape

- Spatial expansion of anthropized surfaces and loss of natural cover (2000-2024)

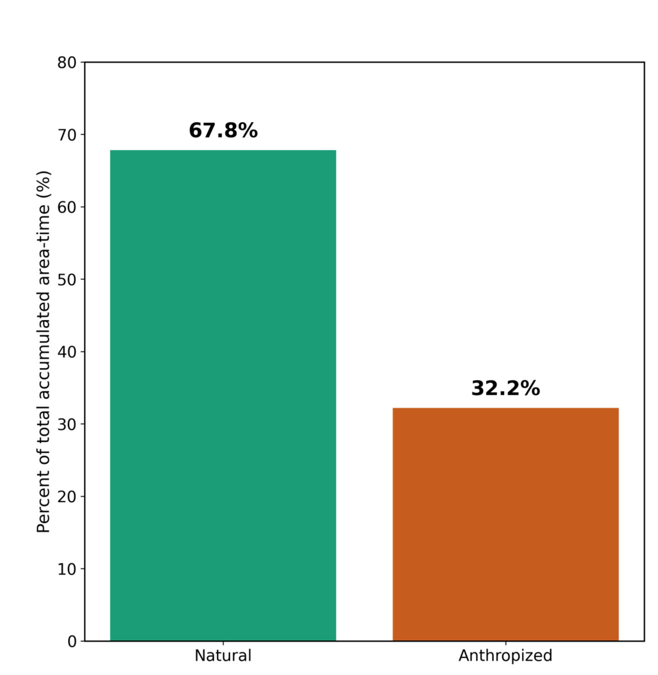


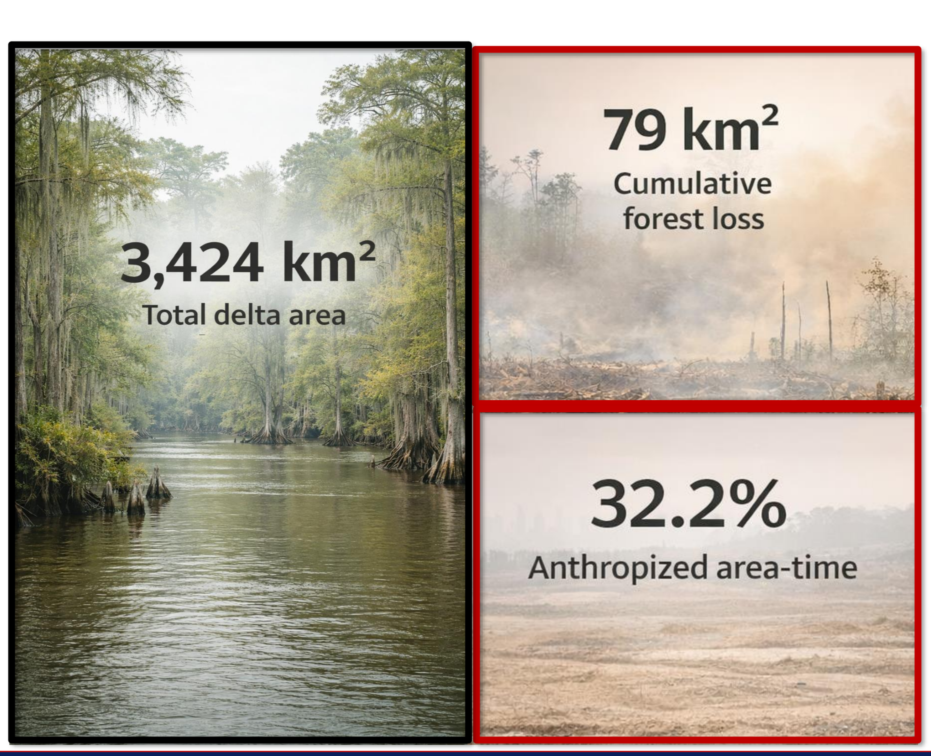
- Cumulative and annual forest loss in the Mobile-Tensaw Delta (2000-2024)





- Cumulative structural composition areas

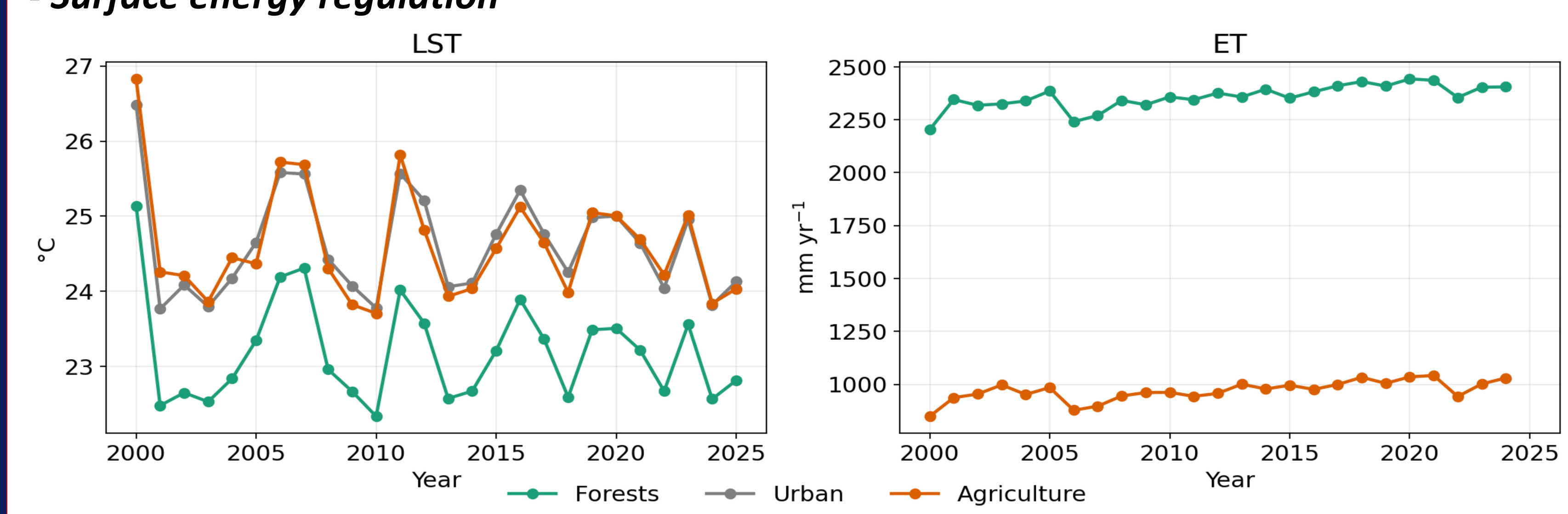




3. Biophysical consequences of land-cover change

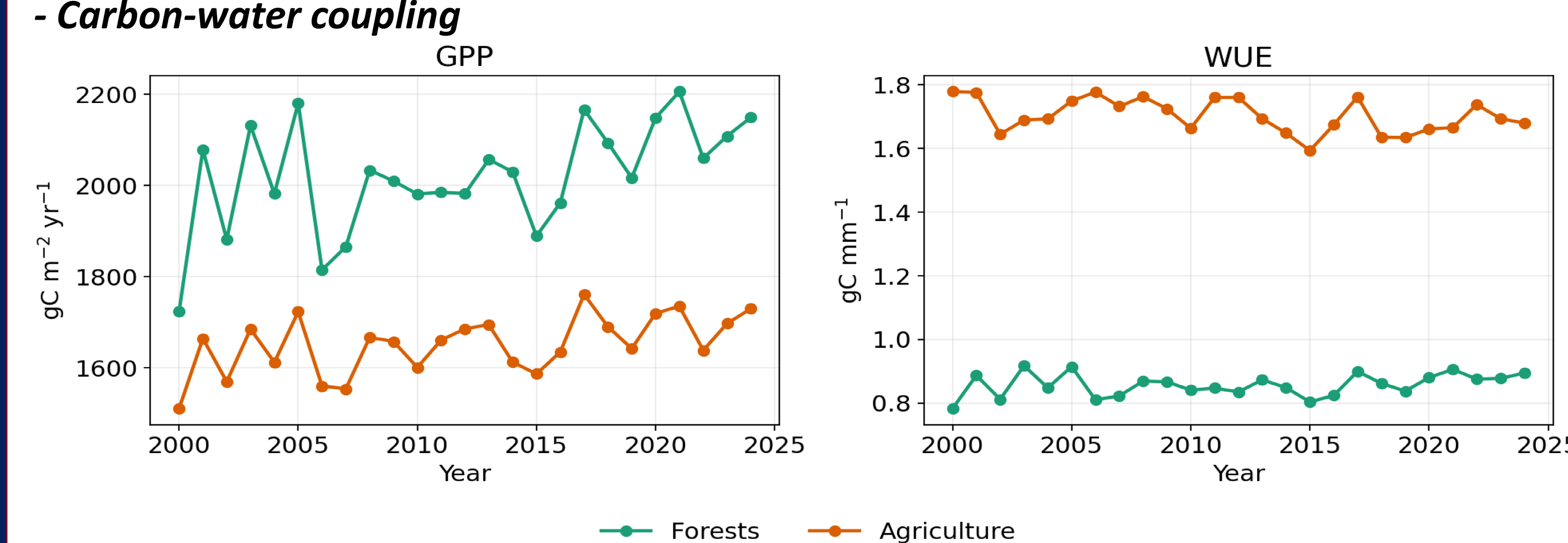
Distinct land-cover types exhibit consistent differences in surface energy regulation and carbon-water coupling.

- Surface energy regulation



*Urban areas exhibit substantially reduced vegetative evapotranspiration compared to forest and agricultural systems.

- Carbon-water coupling

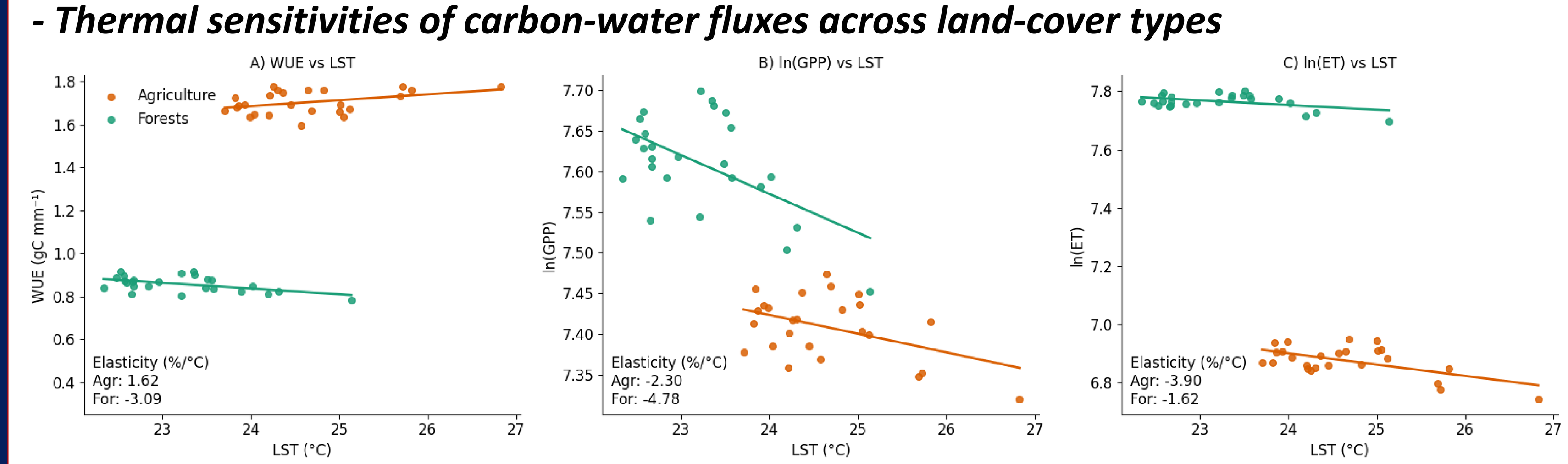


Forests: ↓LST · ↑ ET · ↑ GPP · ↓ WUE **Agriculture** | **Urban:** ↑ LST · ↓ ET · ↓ GPP · ↑ WUE

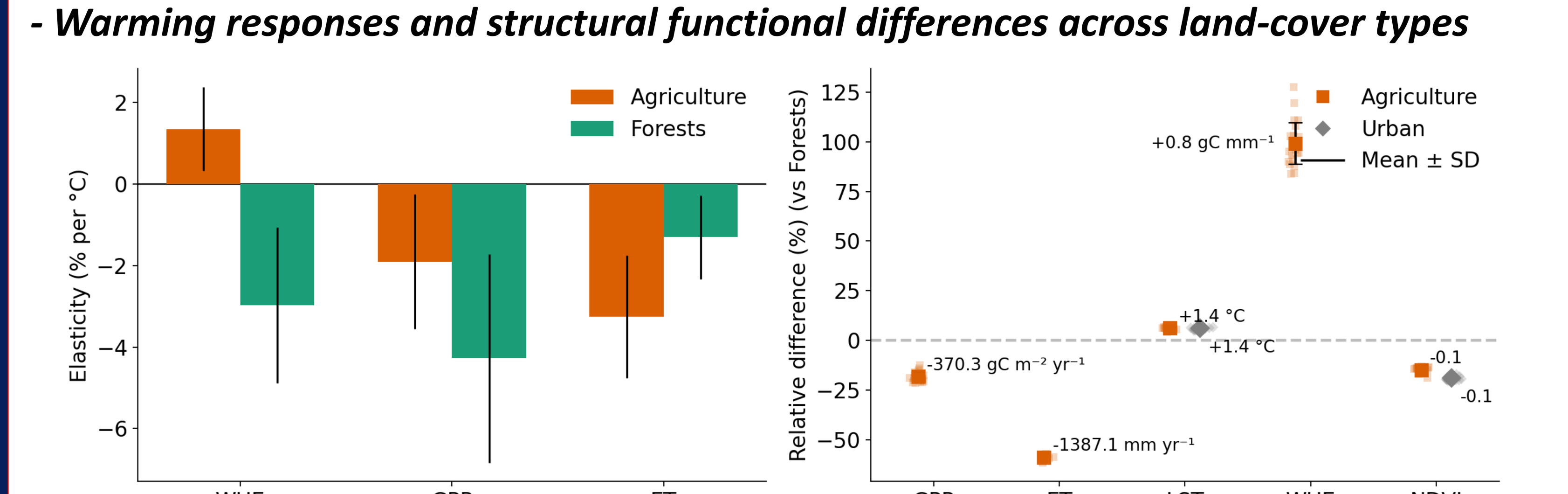
4. Differential thermal sensitivity across land-cover types

Year-controlled elasticities show that warming affects carbon uptake and evaporative cooling unevenly across land-cover types.

- Thermal sensitivities of carbon-water fluxes across land-cover types



- Warming responses and structural functional differences across land-cover types



5. From Ecosystem Degradation to Energy Burden

Natural cover loss
Reduced evapotranspiration (↓ ET)
Higher land surface temperature (↑ LST)
Higher cooling demand
Higher household energy expenditure

6. System-level implications

- **Forest loss weakens evaporative cooling and carbon uptake;**
- **Warming amplifies functional disparities across land-cover types;**
- **Reduced ecosystem regulation increases cooling demand exposure;**
- **Biophysical degradation contributes to long-term energy burden risk in climate-exposed coastal regions.**

References
de Oliveira, Gabriel, John Lehrter, Sean Powers, Guilherme Mataveli, and Celso Santos. "Safely Manage Alabama's Mobile-Tensaw Delta." Science 384, no. 6699 (2024): 966–966. https://doi.org/10.1126/science.adn4393.
Mullins, L., J. Cartwright, S. L. Dykstra, et al. "Warming Waters Lead to Increased Habitat Suitability for Juvenile Bull Sharks (Carcharhinus leucas)." Scientific Reports 14 (2024): 4100. https://doi.org/10.1038/s41598-024-54573-0.

University of South Alabama's Delta and Coastal Alabama Wildlife, Fisheries and Carbon Flux Observatory

National Academies Sciences Engineering Medicine
Poster Session | February 25 at 5:15 PM
Understanding and Addressing Energy Affordability in the U.S.