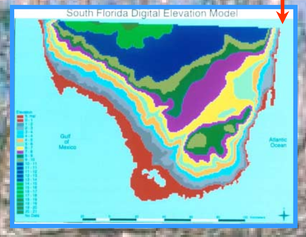
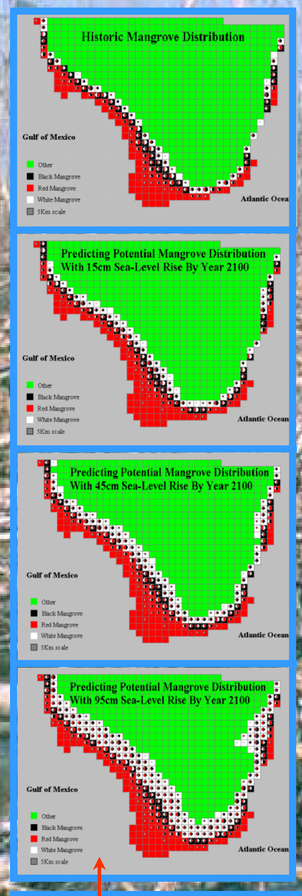
Mangrove Modeling of Landscape, Stand-level, and Soil-Nutrient Processes for the Everglades Restoration Project

Thomas W. Doyle[1], Robert R. Twilley[2], Victor H. Rivera-Monroy[2], and Ken W. Krauss[1]

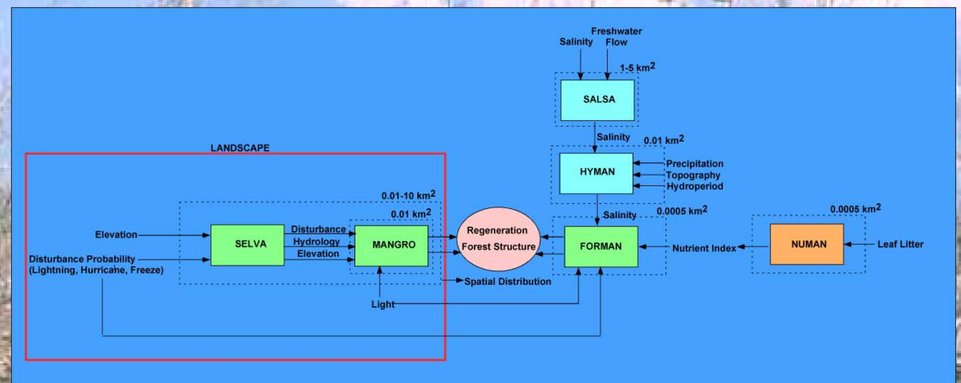
[1] US Geological Survey, National Wetlands Research Center, Lafayette, LA, 70506 (USA)
[2] University of Louisiana at Lafayette, Center for Ecology and Environmental Technology, Lafayette, LA, 70504 (USA)

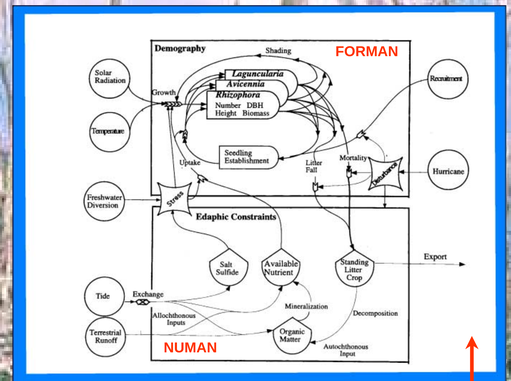
SELVA-MANGRO is superimposed on top of this digital elevation model for the south Florida region. As MANGRO passes hectare-specific data to SELVA, the output assumes the user-specified spatial structure of SELVA.





SELVA-MANGRO simulations assuming three scenarios of global sea-level rise by 2100.





FORMAN, NUMAN, HYMAN

One of our primary objectives is to simulate the mechanistic effects of spatial gradients in soil characteristics on the growth and development of mangrove wetlands. Thus, we are linking a model of forest dynamics (FORMAN) with submodels of hydrology (HYMAN) and nutrient diagenesis (NUMAN). The JABOWA-FORET individual gap models were used as a basic design to develop a gap model that simulates mangrove forest development (FORMAN). FORMAN is an individual-based mangrove succession model that simulates the influence of physical factors on species distribution and productivity on an annual basis. This mangrove model has been validated using data obtained in four stations along the Shark River estuary where basal areas simulated with the model closely matched basal areas observed in the field. The HYMAN model (*output not shown*) is a hydrology model that simulates the mass balance of freshwater and tidal inputs, and calculates porewater and surface salinity. The model explicitly includes transpiration and evaporation for a better account of daily water loss.

Overview:

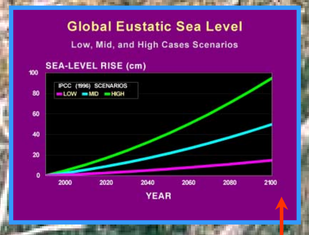
Coastal wetlands of south Florida have been and will continue to experience significant changes in their hydrologic regimes as a function of rising sea-level and alterations in freshwater loading. Because mangroves thrive in the intertidal zone between land and sea, these systems are expected to undergo the most severe changes in both marine influence and freshwater drainage. A suite of spatial simulation models have been developed for south Florida mangrove communities that, with additional empirical inputs and modifications, can be linked to output of existing CERP hydrological models to predict changes in mangrove habitat quality and distribution under different water management scenarios.

SELVA-MANGRO

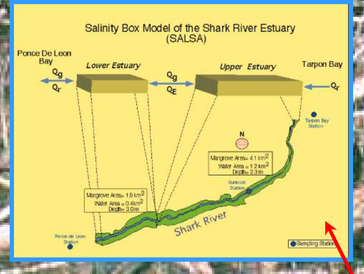
SELVA-MANGRO was originally developed to review the impact of climate change phenomena, hurricanes and sea-level rise, on the structure and function of mangrove communities across south Florida. The model was initialized for landscape assessments in federal landholdings within the south Florida coastal zone, including Everglades National Park. Field studies have been conducted to supplement model development, including post-hurricane descriptions of forest structure, tree growth, and succession. Experimental greenhouse and growth chamber studies have been implemented to determine species tolerance and response to growth limiting conditions of light, salinity, and hydrology. Model refinements and validation continue.

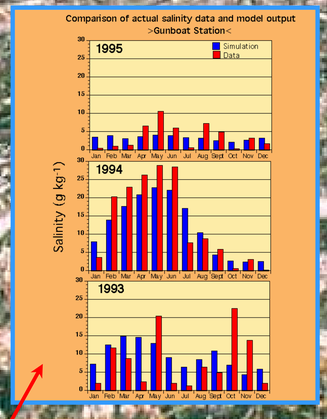
Specifically, efforts have focused on re-calibration of model predictions based upon 10-year post-Hurricane Andrew mangrove forest recovery patterns, incorporation of litterfall and woody debris functions into SELVA-MANGRO, determination of micro-scale patterns and environmental sensitivity of mature tree growth, development of tidal coefficient multipliers for linkage of hydrological predictors to the digital elevation model on which SELVA-MANGRO is nested, determination of flooding effects on mature mangrove forest transpirational patterns, and reformatting of SELVA-MANGRO into a user-friendly interface program.

SELVA-MANGRO currently runs on a 1 ha land unit but averages output on a larger, user-specified grid, which is also linked to an average elevation. Hence, linkage of the model to hydrological functions, such as the South Florida Water Management District's 2 × 2 hydrology grid, will be fairly straight-forward. An important step in this scaling from a landscape simulation to a stand-level simulation is cross-validating SELVA-MANGRO predictions and merging SELVA-MANGRO predictions with FORMAN, NUMAN, HYMAN, and SALSA stand-level forest structural, nutrient, hydrological, and hydrology box models, respectively. Collectively, linking to other models will assist in identifying processes implicit to mangrove mortality, structure, and productivity with different hydrological change scenarios.



Three scenarios of global sea-level rise modeled by SELVA-MANGRO. Model refinement for the Critical Ecosystem Studies Initiative (CESI) will involve various freshwater loading scenarios in addition to sea-level rise simulations.

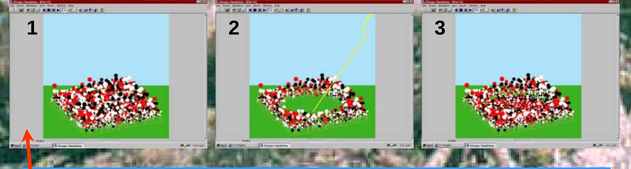




SALSA

The Salinity Box Model of the Shark River Estuary (SALSA) includes the effects of freshwater inflows (advection) and tidal flushing (dispersion) on the transport of water and salt through a series of sequential, one-dimensional volume elements (boxes). A tidally averaged flow (Q_g) from Ponce de Leon Bay (Gulf of Mexico) was assumed to be constant throughout the estuary and was calculated using long-term salinity and freshwater inflow data. Q_g was then used in a simple mixing equation to estimate salinity in the upper and lower Shark River estuary at different river discharges and to calculate tidally averaged exchange flows (Q_E) between boxes.

FORMAN-generated 100-yr projections of mangrove forest development in response to changing salinity for three stations along the Shark River. Each simulation represents a salinity decrease of 50% from levels measured in 1999.



SELVA-MANGRO model simulation of forest structure and complexity for a single 1 ha grid (1) before, (2) during, and (3) after a lightning strike.

Performance measures resulting from the current integration of landscape and individual-based models include:

- Mangrove forest structure and complexity
  (e.g., basal area, forest height, species composition)
- Salinity
- Accretion rate
- Frequency and duration of inundation