

Summary

The Everglades Landscape Model (ELM) incorporates several fundamental submodels that affect water, nutrients and plant biomass in the model landscape, with each model operating at different spatial scales. The unit model is at the ecosystem level and simulates primarily the "vertical" dynamics of nutrient cycling, evapotranspiration, plant growth, etc. within an homogeneous ecosystem represented by one raster cell in the gridded model area. This model is replicated in the ~10,000 cells that comprise the heterogeneous landscape of the spatial model at the landscape scale, which simulates the cell-to-cell horizontal fluxes of nutrients, water and fire in response to simulated conditions in neighboring cells of the model landscape. A third fundamental model within the ELM is that of canals, levees and control structures. Canals and associated levees are represented by a set of vector objects that interact with a defined set of raster landscape cells at a fast rate over long distances. Finally, the habitat switching model of ELM defines the changing of habitats according to successional rules. Because this switching among sets of habitats effectively switches among sets of model parameters that are varied in the sensitivity analysis, the analyses here implicitly include the changing of habitat types with their different parameter sets.

The influence of landscape habitat heterogeneity on model behavior is accommodated by varying the parameter sets associated with the unit model, a process determined by a landscape cell's habitat type. Differences in habitat type (which also changes over long time scales) may alter ecosystem dynamics, which in turn may change the horizontal flux of water and nutrients across the landscape. There are a very large number of combinations of parameters in this complex model (approximately 80 parameters) over a heterogeneous landscape (6 fundamental habitats, with more when using mixtures of fundamental habitats). The explicit testing of the full spatial model sensitivity to varying multiple parameters at a time is prohibitive both from a computational perspective and from a conceptual viewpoint. Indirect interactions at the ecosystem level coupled with significant spatial heterogeneity and pattern- effects on the processes makes the interpretation of massive series of output with multiple combinations of parameter changes and habitat heterogeneity difficult at best. The results would likely be open to a variety of interpretations. Thus, we sought to discern the basic model behavior at different levels of model scale, using results from the ecosystem level to aid in directing analyses at two landscape scales of different complexity and areal extent.

We partitioned the sensitivity analyses into a set that parallels the model structure. We varied habitat specific parameters at the unit ecosystem model level in order to determine which parameters had the most significant influence on model dynamics at the scale of an homogeneous ecosystem within one model cell. The important state variables for the model objectives were: water stage, nutrient concentrations in interstitial sediment water and in ponded surface water, organic matter deposited in the sediments, and the biomass of macrophytes and periphyton. Parameter changes that resulted in non-trivial changes to these variables' model behavior at the unit model level were identified for further analysis at the scale of the landscape. Moreover, variables that flux spatially (horizontally), and variables that have significant influence on such fluxes, are "landscape driver" variables and have the potential to alter the landscape pattern: the most important of these are water levels, nutrient concentrations and macrophyte biomass. Particular attention was paid to parameters that changed these driving variables.

For the bulk of the analyses of ecological sensitivity at the spatially explicit scale, we rescaled a subregion of the ELM. The Conservation Area Landscape Model (CALM) is a spatial ecological model of WCA2A at a higher spatial resolution than the ELM (1,734 0.25km² cells vs 10,264 1.0 km² ELM cells). The CALM contains a unit model identical to the ELM and has the same forcing functions where appropriate, e.g., structure inflows and precipitation registered at one station. This model contains borrow canals along its interior periphery, with historical data input through S10 structures and outflows through the S11 (and several other) structures according to the drydown management schedule. Due to the significantly higher quality/quantity of data for WCA2A (and faster runtime), the CALM is being used as the test platform for debugging and calibrating much of the ecological (including hydrologic)

components of the larger ELM.

After determining the influence of various parameter changes at the scale of the spatially explicit CALM, we analyzed the full ELM that contains the full canal/levee vector network and more vegetation types. Whereas the CALM has a relatively simple canal configuration, the ELM contains the complex canal/levee network, with structure flows that are determined by either historical data or management rules (all database driven instead of hard coded). For these analyses, we focused on the hydrologic component of the ELM, determining the model behavior under varying water/nutrient inflows (through the S-5 through S-8 structures), alteration in flow rates through structures, and Manning's roughness coefficient.

Some of the parameters that we found to be most influential on model dynamics in terms of water and nutrient levels and plant biomass have relatively high uncertainty and low measurement quality. The plant nutrient requirements (expressed as coefficients in Michaelis-Menton kinetics) and the maximum rate of net primary production of macrophytes were two biological processes which are uncertain, but which have significant influence on landscape-level changes in both nutrient levels and plant biomass. The initial concentration of PO₄ sorbed to organic sediments was a potentially important factor in determining the nutrient levels in the landscape and subsequent plant production. The macrophyte maximum Leaf Area Index (linked to changing plant biomass) had broad effects, altering transpiration and thus water levels, ultimately altering plant production levels in the landscape. The influence of changing the Manning's roughness coefficient had the potential to alter water levels in certain regions, but small changes in parameters that determine evaporative water losses (evaporation and transpiration) resulted in more significant landscape level changes in water supply.

These landscape scale models, (CALM and ELM, each using the same unit model), proved to be operationally robust to varying parameters within ranges that are feasible within the Everglades landscape. The model has constraints such that even unrealistic combinations of ecological parameters or forcing functions result in model dynamics that are within reason in that they stay within ranges that are potentially observable. Water supply via the canal network can significantly alter both the water and nutrient regime of the more northern Everglades, and further evaluation is one of the scenarios that we are currently performing.