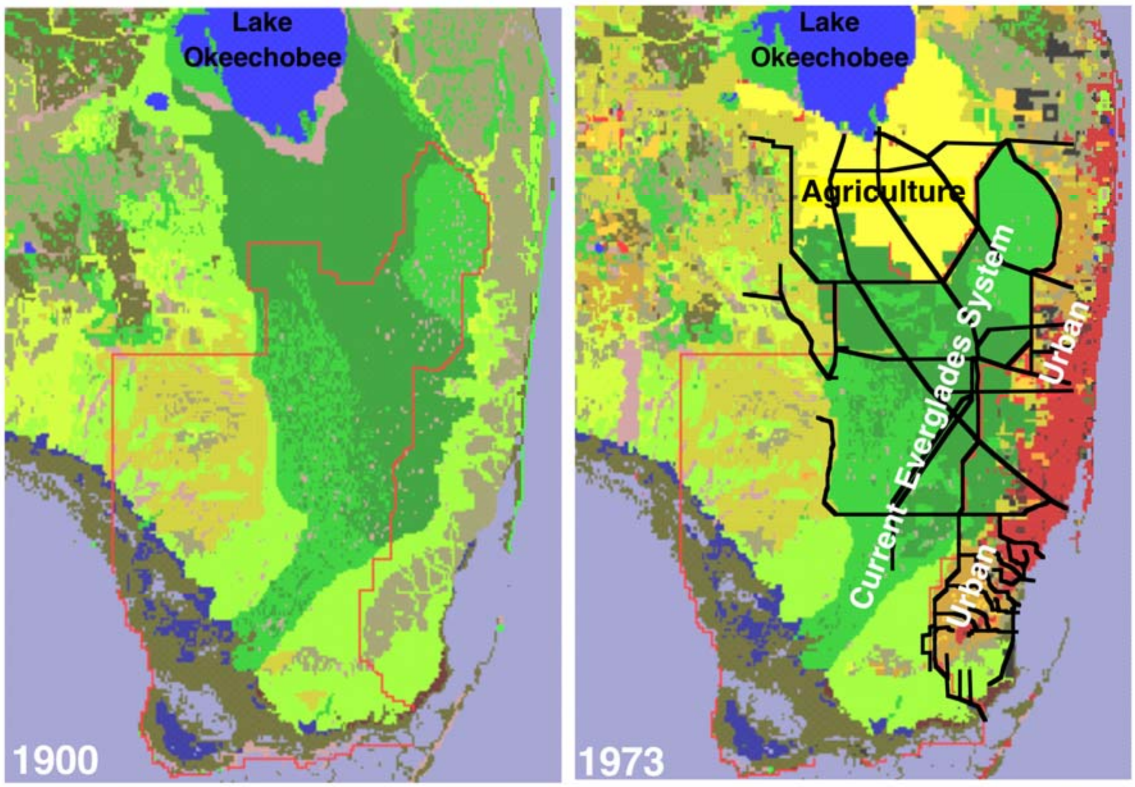
Documentation of the Everglades Landscape Model: ELM v2.5

Chapter 1: Introduction, Goals & Objectives



http://my.sfwmd.gov/elm

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Chapter 1: Introduction, Goals & Objectives

1.1 Overview

This Chapter provides the background for the Everglades Landscape Model (ELM) documentation, We review how and why the Everglades region has changed, and how the ELM is intended to be applied towards understanding and better managing the system. The Everglades landscape is “inside” a highly engineered system of inter-connected water basins, with altered water flows and nutrient additions that have caused ecological impacts during multiple decades of management. A variety of projects are underway that will attempt to restore as much of the existing Everglades as possible. While field observations and expert judgments are integral to this goal, computer modeling tools such as the ELM are part of the process of better understanding the landscape, and refining plans for its restoration. This Chapter introduces the ELM as a model that is designed to evaluate the long-term, regional benefits of alternative project plans with respect to water quality and other ecological Performance Measures.

1.2 Introduction

The Everglades region of south Florida, USA, is currently a vast system of neo-tropical estuaries, wetlands, and uplands interspersed among agricultural and urban land uses. Starting in the early part of the 20'th century, long stretches of canals were dug in attempts to drain the relatively pristine Everglades for agriculture. However, after severe flooding in 1947, the Central and South Florida (C&SF) Project was initiated. In this massive engineering feat, the U.S. Army Corps of Engineers developed an elaborate network of canals, levees, and water control structures to improve regional flood control and water supply (Light and Dineen 1994). It was ultimately very effective in managing water for those purposes, enhancing the development of urban and agricultural sectors of the region. As shown in Figure 1.1 below, dramatic increases in such land uses occurred during the 20'th century, significantly reducing the spatial extent of the "natural" Everglades system by the mid 1970's. Agricultural and urban development has generally continued through the present day, particularly along the corridors east and north of the Everglades. While the C&SF Project led to a reduction in spatial extent of the Everglades, it also fragmented the once-continuous Everglades wetlands into a series of large impoundments.

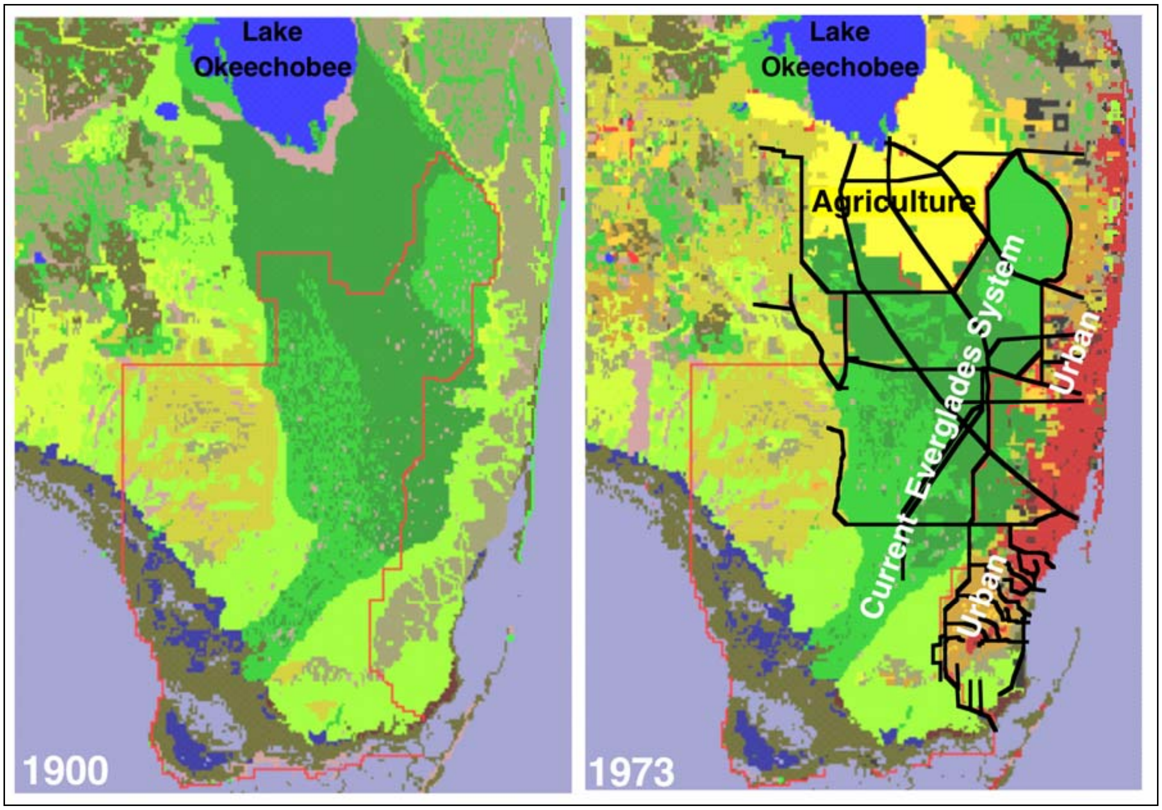

Figure 1.1. Agricultural (yellow) and urban (orange/red) land use expanded dramatically in south Florida during the 20'th century. Black lines denote some of the major canals & levees that were constructed as part of the C&SF Project. The red polygon is the domain of the Everglades Landscape Model. Land use data from Costanza (1975).

Water historically flowed from the northern parts of the region into and through the Everglades largely as overland sheet flow. This flow regime changed to point releases at the pumps and weirs of water control structures. Operational criteria for these managed flows dictated the timing and magnitude of water distribution into and within the Everglades, further modifying its hydrology. Many of these inflows also carried higher loads of nutrients into the historically oligotrophic Everglades, as a result of agricultural and urban development. The altered distribution and timing of flows in a fragmented watershed, combined with increased nutrient loads into the Everglades, changed this mosaic of habitats. Increasingly, the public and scientific communities were concerned that ecological structure and function would continue to decline within this nationally and internationally protected landscape. In the late 20th century, it became apparent that revisions in the infrastructure and operations of the C&SF Project were necessary in order to halt further ecological degradation, and a plan to restore the Everglades was developed by federal and state agencies (USACE and SFWMD 1999). After years of effort, the Comprehensive Everglades Restoration Plan (CERP) was developed, and has been implemented as a thirty year project to address the future of south Florida's ecology – while also enhancing urban and agricultural water supply for what is anticipated to be a doubling of the regional population by 2050.

In the Everglades, the existing management infrastructure bisects the area into a series of impoundments, or Water Conservation Areas (WCAs). Everglades National Park is south of these WCAs, while Big Cypress National Preserve is to the west (Figure 1.2). Agricultural land uses dominate the area just north of the Everglades, while extensive urban land uses predominate along the eastern boundary of the Everglades. Lake Okeechobee, historically bounding the northern Everglades marshes, is now connected to those marshes via canal routing.

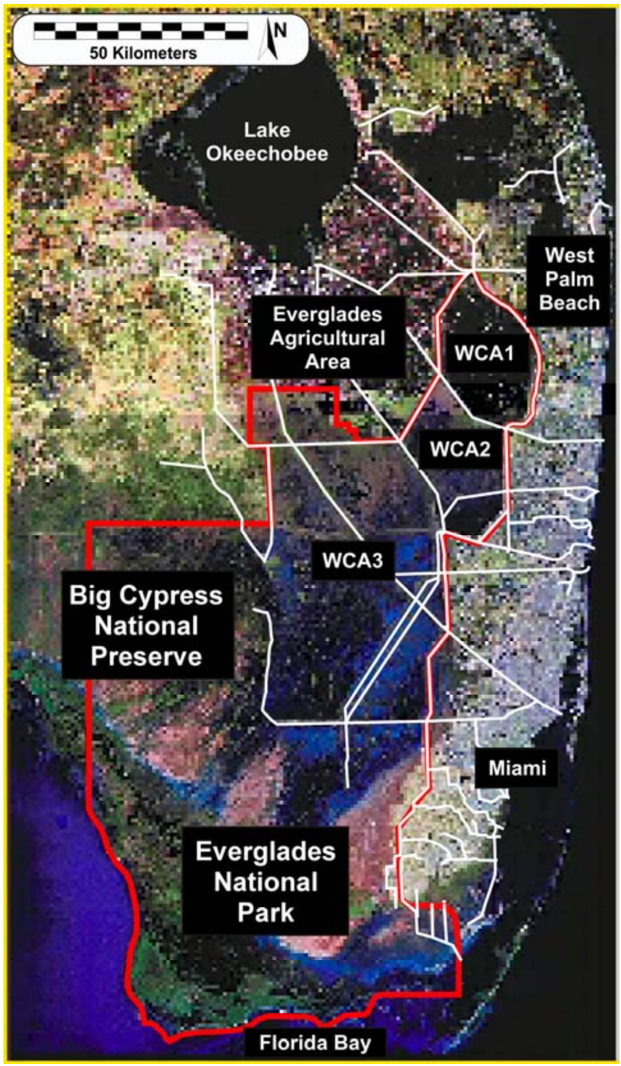

Figure 1.2. A mid-1990's satellite image of south Florida, showing the locations of major subregions in and around the greater Everglades. The red polygon is the domain of the Everglades Landscape Model.

Anthropogenic nutrient enrichment was introduced into the Everglades from management of agricultural, and to a lesser extent, urban runoff. Because of the significant, negative, impacts of this nutrient loading on the naturally oligotrophic system, a series of wetlands is being created along the northern periphery of the Everglades. These Stormwater Treatment Areas (STAs) are intended to serve as natural nutrient filters to remove nutrients (primarily phosphorus) from waters flowing into the Everglades. The first constructed wetlands to be in operation were effective in reducing phosphorus concentrations well below the interim target of 50 $ug \cdot L^{-1}$ (Chimney et al. 2000, Nungesser et al. 2001), and will be supplemented with other phosphorus removal mechanisms and on-farm best management practices to reduce Everglades inflow concentrations to the threshold target of 10 $ug \cdot L^{-1}$ (FDEP 2000).

The managed system enables a variety of flow distributions. Operation of the entire system for flood control, water supply, and the environment is governed by a complex set of rules adopted and modified over time by the South Florida Water Management District and the U.S. Army Corps of Engineers. Control over this system is managed by operating a large number of pumps, weirs, and culverts to pass water into the canals and wetlands, distributing it as needed in various parts of the regional system. Thus, different regions of the Everglades experienced different hydrologic regimes, often to the detriment of the wetland ecosystems. Under the CERP, there will be significant decompartmentalization of the levees impounding parts of the Everglades, increased storage above and below ground, and modified flows throughout the south Florida landscape (USACE and SFWMD 1999).

Changes to the hydrologic and nutrient management under the CERP is anticipated to provide some level of restoration of the Everglades system. However, there is significant uncertainty in the potential ecological response. In order to better understand and plan the restoration process, 1) predictive simulation models are being used to refine the plan, and 2) an extensive monitoring and adaptive assessment procedure (CERP_Team 2001b) is being implemented. The primary simulation tool used to date is the South Florida Water Management Model (SFWMM), a model with rule-based management of water flows and resultant water levels in the entire south Florida region, from Lake Okeechobee to the southern Everglades (HSM 1999). Most of the Everglades restoration targets were derived from the Natural System Model. This hydrologic companion to the SFWMM is basically the SFWMM with the water management infrastructure removed, adjusting various data to attempt to simulate the regional hydrology prior to any drainage efforts (SFWMD 1998). The Everglades Landscape Model (ELM) is a regional scale, process-oriented simulation tool designed to develop an understanding of the ecological interactions in the greater Everglades landscape. The ELM integrates modules describing the hydrology, biogeochemistry, and biology of ecosystems in a heterogeneous mosaic of habitats that comprise the Everglades.

1.3 Purpose of models

Simulation models are explicit abstractions of reality, and at best are tools that should provide insights into a better understanding of a problem. The Everglades hydrologic simulation models referenced above have provided very useful insight. However, they do not, and were not intended to, provide by themselves a full understanding of the long term ecosystem dynamics in the Everglades. “Restoring” the Everglades ecology involves “getting the water right” (CERP_Team 2001a). However, even if a “perfectly” accurate model of water depths and flows were available, there still would exist significant uncertainties in how much water is needed at which times, over what spatial and temporal scales. Importantly, the nutrients associated with that water are fundamental components of the ecosystem function in the landscape.

To better understand the long term ecological effects of changing hydrologic regimes, it is important to assess the *cumulative* influence of the magnitude and timing of the changes. Interacting with these hydrologic dynamics are the nutrient transformations and transport. As the physical and chemical dynamics interact with the biological communities, the system dynamics cumulatively define the transient ecosystem states under different conditions. While the basics are well-understood, and many of the details known, there remain uncertainties in predicting all potential changes in the Everglades.

We do, however, have a very good understanding of the interactions among general ecosystem processes, and of the nature of changes at the landscape scale.

Interactions are the essence of ecosystem science. Ecology has been classically defined as the interactions of organisms (including plants) and their environment (Odum 1971). For the Everglades region as an entity, a relatively simple model is desired that can capture the cumulative, interactive nature of the ecosystem dynamics, synthesizing the state of our understanding of the general ecosystem processes. The level (or scale) of computational complexity can be relatively coarse, which is dependent upon our current scientific knowledge-base. Fundamentally, there is a need for a model - or models - that can quantify the relative potential (or probability) of long-term cumulative ecosystem responses to altered hydrologic and nutrient inputs across the greater Everglades landscape. The challenge is to synthesize Everglades habitat change, with habitats being an integrated combination of hydrologic, water quality, soils, and periphyton/plant variables that are simulated with a reasonable degree of relative certainty. With such a model, the trends in relative habitat change could be evaluated under different scenarios of hydrologic/nutrient management.

1.4 ELM goals and objectives

The ELM is a regional-scale, integrated ecological assessment tool designed to understand and predict the relative response of the landscape to different water management scenarios in south Florida, USA. In simulating changes to habitat distributions, the ELM dynamically integrates hydrology, water quality, soils, periphyton, and vegetation in the Everglades region. The model has been used as a research tool to better understand the dynamics of the Everglades, enabling hypothesis formulation and testing. This is a critical, ongoing application of the model. However, one of the primary objectives of this simulation project is to evaluate the relative ecological performance of alternative management scenarios.

Goals*: Develop a simulation modeling tool for integrated ecological assessment of water management scenarios for Everglades restoration*

- Integrate hydrology, biology, and nutrient cycling in spatially explicit, dynamic simulations
- Synthesize these interacting hydro-ecological processes at scales appropriate for regional assessments
- **Understand and predict the relative responses of the landscape to different water and nutrient management scenarios**
- Provide a conceptual and quantitative framework for collaborative field research and other modeling efforts

1.4.1 Objectives, current model version

The ELM simulates an integrated set of dynamic ecosystem interactions, but has initially focused on the “water quality” component of those dynamics for regional applications. The first regional application of ELM was released in the spring of 2000. That version (ELM v2.1) was intended to address several Performance Measures that relate to the water quality of the greater Everglades region. The current ELM v2.5 continues to focus on those water quality objectives, with enhancements to the model capabilities and documentation. The following are Performance Measures were initially approved by the CERP RECOVER (REstoration COordination and VERification) Water Quality Team and Regional Evaluation Team (RECOVER-RET 2004) for use in Everglades restoration planning. The Performance Measures are undergoing (June 2006) further review by other RECOVER teams. The ELM v2.5 is available to address the following Performance Measures:

Specific objectives: *compare alternative management scenarios, predicting relative differences in ecological (water quality) variables from a long-term, regional perspective*

- Concentration of Total Phosphorus (TP) in surface water (GE-4[1])
- Net loading (accumulation) of TP in the ecosystem (GE-5)

These Performance Measures are specified in detail in the Model Application Chapter of this documentation. The spatial and temporal scales associated with these Performance Measures are relative to RECOVER's goal to understand and predict system response over long time scales across the regional system (>10,000 km^2). Although the spatio-temporal grain associated with these Performance Measures has not been explicitly defined by RECOVER for all Performance Measures, a seasonal to annual temporal grain, and gradients with a 1-km spatial grain, are consistent with our ability to discriminate ecologically significant spatial patterns and temporal trends across the greater Everglades.

1.4.2 Objectives, future model version

Consistent with its research goals, the ELM will continue to be a work in progress, in parallel with advances in research and knowledge of the Everglades system. We collaborate with researchers across a variety of disciplines, both within the South Florida Water Management District and from other agencies and academic institutions. As a result of this ongoing work, we anticipate that the next major update, to ELM v3.0, will provide a useful degree of confidence in applying the ELM to the following Performance Measures (as proposed to CERP RECOVER):

Specific objectives*: (for future version), compare alternative management scenarios, predicting relative differences in ecological variables from a long-term, regional perspective*

- "Water quality" Performance Measures listed above
- Periphyton biomass & community type
- Macrophyte biomass & community type
- Soil accretion & soil phosphorus concentration

[1] GE-4 and GE-5 are the current Performance Measure labels used by RECOVER. These Performance Measures are described in the Model Application Chapter of the ELM documentation; further background information and descriptions of other Performance Measures are provided in the Programs – RECOVER links at www.evergladesplan.org

In an early subregional application of ELM (version 1.0), sufficient data were available for us to demonstrate (Fitz and Sklar 1999) that the model could effectively match historical observations of surface and pore water phosphorus, soil accretion, macrophyte biomass, and sawgrass-cattail succession. As an example of the reliability of results in this landscape modeling project, Figure 1.3 shows the good matches between observed vs. simulated porewater nutrients and cattail succession (from a 17-year simulation). The Model Performance Chapter of this ELM v2.5 documentation summarizes other ecological performance characteristics of the updated model.

We anticipate that completion of upcoming ELM v3.0 data and model analyses will further demonstrate the model utility in evaluating changes to habitats associated with these integrated ecological variables across most of the greater Everglades region.

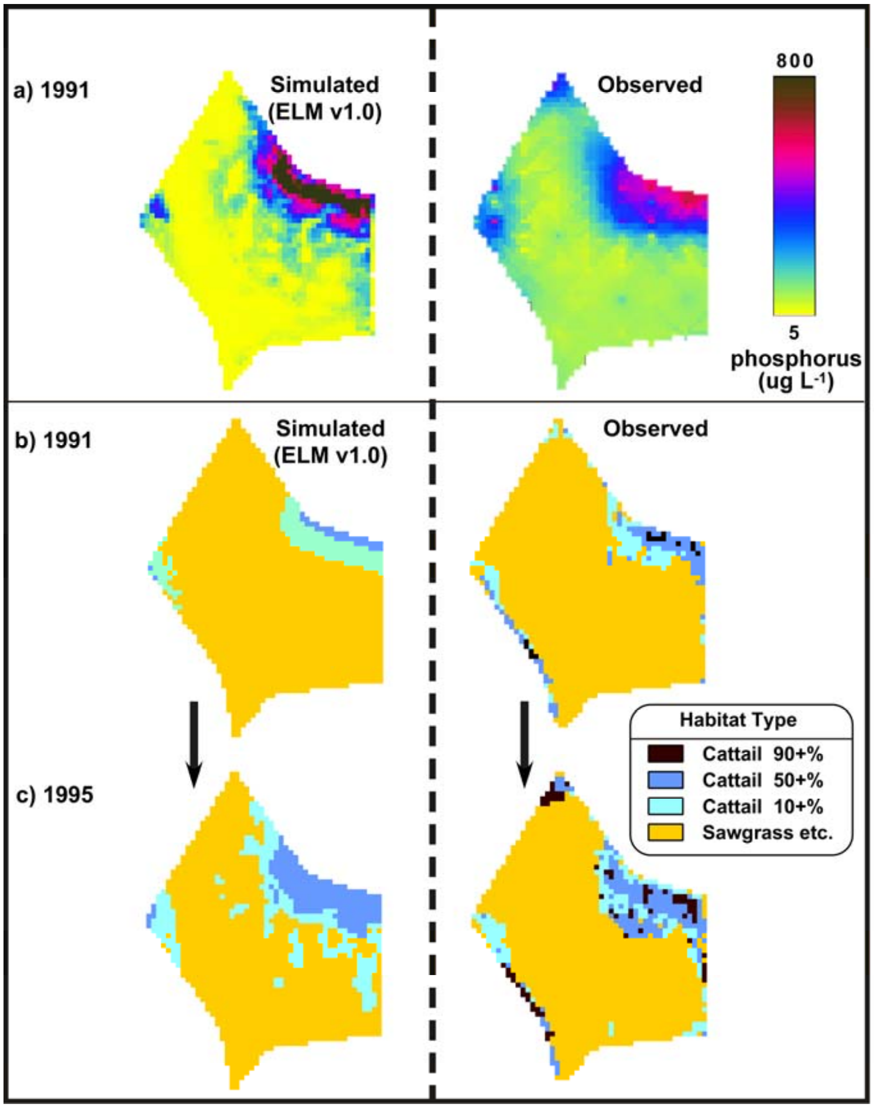

Figure 1.3. Early ELM v1.0 results in Water Conservation Area 2A (WCA-2A), showing observed and simulated a) porewater phosphorus increases in 1991, and cattail encroachment in b) 1991 and c) 1995. The model was driven by historical inflows and nutrient loads in a simulation from 1980 – 1996. See Fitz and Sklar (1999) for details.

1.5 Literature cited

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