

**Restoration Assessment of a Forested Watershed using a Regional
Modeling Approach**

Final Report Yr. 1

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Restoration Assessment of a Forested Watershed Using a Regional Modeling Approach

ABSTRACT

Coastal swamps are among the rapidly vanishing wetlands in Louisiana. This decline has been attributed to increased flooding, nutrient and sediment deprivation, and salt-water intrusion. Understanding the contributions and interactions of these stressors is critical to the development of sound ecosystem management plans. River diversions have been proposed as tools for wetland restoration using sediment deposition and nutrient inputs to foment plant growth. Lake Maurepas, Louisiana, where a small-scale Mississippi River diversion has been proposed, provides a unique research opportunity given that long-term regional ecological data are available. The objectives of this study were: (1) to build a landscape-scale process model for the Maurepas Swamp capable of predicting regional habitat change; and (2) to initiate development of an individual-based model (IBM) for forest dynamics to evaluate community response under existing environmental and proposed restoration scenarios.

A comprehensive regional habitat simulation was developed for the Lake Maurepas Basin. This regional model included process-oriented algorithms at a watershed scale that provided a synthesis of past and current knowledge and data. The regional forest model examined large scale responses as initial steps toward assessing plant response to long-term indirect and cumulative impacts of increased river water contributions. The results indicated that the long-term effects of restoration efforts, such as river diversions, can substantially improve the Lake Maurepas wetlands. However, these results only represent generalized habitat types. In order to evaluate detailed forest dynamics, such as tree growth and stem permanence, we needed more complex landscape aggregation and vegetation productivity algorithms than those provided by the regional model. The IBM model, now under development, will meet these needs. The IBM model activities focused on compilation of tree growth rates, environmental stressor effects, and algorithm development. Predictions of immediate and long-term responses of individual trees to local, fixed stressors were examined. However, until testing of the regional forest model efforts can be completed, calibration and validation of the IBM cannot proceed.

Based on the complexity of the information required to anticipate the long-term impacts of a river diversion into a coastal swamp, the overall goal of this ongoing project is to develop a new, integrated modeling approach. This new hybrid model will combine the biological resolution and flexibility of an individual-based forest succession model with the feedback interactions, larger scale, and finer stressor dynamics of a regional model. The development of this comprehensive landscape and individual based forest succession model for the Maurepas Basin can provide improved insight into the succession dynamics of a coastal swamp.

1.0 Introduction

Coastal wetlands across southeastern Louisiana are being lost as they convert to open water. This loss is due to a combination of several regional factors that drive long-term trends in habitat change. These cumulative impacts include (1) sea-level rise and subsidence, (2) altered inflows of freshwater and sediments from the Mississippi and Atchafalaya Rivers, and (3) modifications to internal hydrology (Baumann et al. 1984; Boumans and Day 1994; Coleman 1988; Day et al. 1997; Day and Templet 1989; Gagliano et al. 1981; Reed 1995; Salinas et al. 1986; Turner 1997; Wells 1996). Understanding the contribution and interaction of these stressors is critical to the development of a sound management plan for coastal areas where freshwater diversions are implemented and used for wetland restoration.

The effects of increased penetration of saline water into freshwater wetlands become exacerbated when brackish and salt wetlands are lost. Saltwater intrusion stresses the freshwater vegetation, and as plants die, the barren sediments consolidate and sink (Boesch et al. 1994; Hatton et al. 1983). Such changes are believed to underlie the general pattern of displacement of freshwater vegetation by more salt-tolerant communities, as well as vegetation die-offs followed by conversion to open water (Roberts 1997; Wells 1996). In contrast, active sediment deposition and nutrient inputs, when associated with river discharge, lead to land preservation and restoration (Day et al. 2000; Roberts 1997).

Here in Louisiana, a unique research opportunity is available. The forested wetlands of Lake Maurepas are rapidly deteriorating, and in the past, extensive environmental and biological information has been collected (Day et al. 2001; Hoepfner 2002; Shaffer et al. 2001). A small river diversion has been proposed to enhance wetland restoration. The proposed diversion (Hope Canal) aims to enhance freshwater and nutrient input to the forested wetlands and limit salt-water intrusion (Force 2002; Force and Authority 1998). On the other hand, the diversion could increase local flooding and create an excessive nutrient load that would further stress aquatic habitats.

The study presented here focused on evaluating the effects of cumulative impacts and restoration alternatives on a forested wetland in the Maurepas Swamp. The goal of this project was to build and use a regional forest model to examine the response of forested wetland succession, production, survival, and soil building to cumulative impacts. The forest model examined such responses at a large scale in the Maurepas Basin under present environmental conditions (Figure 1.1). The regional model results can be used to assess general trends and “hot spot” areas. However, the large scale of the regional model, precludes a detailed examination of tree behavior.

We also began developing an individual-based model (IBM) to represent detailed forest dynamics and assess tree response to long-term indirect and cumulative impacts of increased river water contributions. A conceptual model of an individual-based, multi-species forest model was developed which included several major environmental gradients influencing tree growth, competition, and survival.

Habitat and forest changes must be understood in order to accurately evaluate potential cumulative impacts at a regional scale. This knowledge is critical for assessing the effects of dynamic, interacting forcing functions (e.g. river discharge, sea-level rise) on restoration approaches. The ability to evaluate the effects of cumulative impacts at a regional level makes the models valuable tools for predicting long-term landscape interactions.

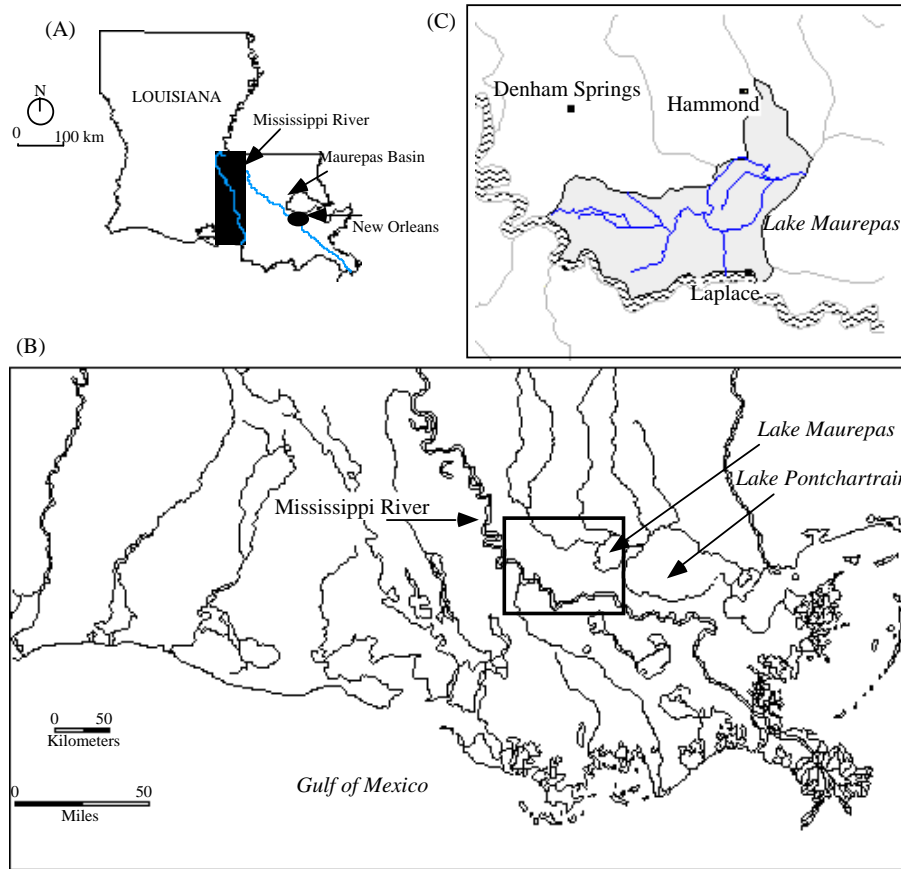


Figure 1.1 Map of the Maurepas watershed. (A) Louisiana State, (B) Louisiana Coastal Zone and (C) Lake Maurepas watershed showing the location of nearby cities and rivers.

2.0 Study Site

The wetlands of Lake Maurepas have been identified as highly degraded and in need of restoration (Force and Authority 1998). The wetlands of Lake Maurepas are within the Amite/Blind Rivers mapping unit, which includes approximately 563 km² of swamps, and 150 km² of freshwater marshes (Figure 1.1). Most of the wetlands in this area consist of *Taxodium distichum* – *Nyssa aquatica* dominated swamps, interspersed with a mixture of fresh and intermediate marshes (Shaffer et al. 2001). The swamps in this region are impacted by salt water intrusion and elevated levels of subsidence (Pezeshki et al. 1987), while the marshes are generally breaking up into open water (Barras et al. 1994) due to a lack of sediment and nutrient input (Day et al. 2001; Shaffer et al. 2003; Shaffer et al. 2001). Furthermore, Louisiana wetlands

are strongly impacted by mammalian and insect herbivory, which may cause shifts in vegetation composition (Hester et al. 1994; Hoeppner 2002; Shaffer et al. 1992).

Recognizing the diverse present and potential impacts in the ecosystem, extensive monitoring and experimental studies were undertaken to evaluate whether a freshwater diversion from the Mississippi River could help restore the region's wetlands. Baseline reports identified the need for restoration of the system and indicated that the Maurepas wetlands would benefit greatly from the infusion of freshwater, sediments, and nutrients brought by the proposed diversion (Day et al. 2001; Hoeppner 2002; Kemp et al. 2001; Lane 2002; Shaffer et al. 2003). In addition to restoring essential wetland habitats, the freshwater inputs from the diversion are expected to shorten the residence time of water in Lake Maurepas to less than a year, and measurably freshen large portions of Lake Pontchartrain. The Mississippi River diversion into this swamp has been approved as a restoration project under the Coastal Wetlands, Protection, Planning and Restoration Act (1990) and is currently in Phase 1 (engineering) of its implementation (Force 2002). The expected ecosystem responses resulting from this restoration effort provide a unique opportunity to study and model the dynamic changes in the current stressor gradients before and after a freshwater diversion.

3.0 Methods

3.1 Spatial and Temporal Databases

Several federal and state agencies were consulted in order to compile the topological and bathymetric data for the area. The spatial data comprised LIDAR topographic collection flights in 2000 (LSU Atlas web site (<http://www.atlas.lsu.edu>) and bathymetric information from NOAA 1996 (Lakes Pontchartrain and Maurepas Chart 11369). Light Detection and Ranging data consisted of geo-referenced coordinates and elevation data with high accuracy and dense coverage.

Maps collected from the USGS National Wetlands Research Center and the CADGIS Laboratory of Louisiana State University were used to create a 1 sq. km version of the habitat distribution. This version was then combined to produce a topo-bathymetry to use as base maps for the initial model runs. The spatially distributed data for the swamps and wetlands adjacent to Lake Maurepas include topological maps and vegetation classification maps. Environmental data were organized using an electronic spreadsheet format that provided both easy access and the formatting routines needed by the ecological models.

3.1.1 The Habitat Dataset

The habitat dataset was taken from the 25 m National Wetland index classification dataset. These data consist of geo-referenced classified data according to land use. The original map was classified to 14 habitat types. This original image was reclassified to the six habitat types in the model using the criteria followed in past efforts (Martin et al. 2002; Reyes et al. 2004; Reyes et al. 2000). The data were processed to 1 sq. km using an algorithm that determines majority rule standard. Each 1 km quadrangle was determined by counting the different habitat types at 25m

scale. Each quadrangle was then set to the habitat type with the largest count. The processing was done using a program written in house using java. After the dataset was aggregated, it was necessary to manually adjust the hydrological conditions. The 1 km dataset was digitally overlaid onto the 25 m dataset, and the rivers and streams in the 1 km dataset were drawn to correspond with the spatial position of the rivers and streams in the 25 m dataset. This step guaranteed that hydrological inputs into the model were correct and accurate.

3.1.2 The Elevation Dataset

The elevation dataset originated from a LIDAR dataset collected in 2002 (3001 Corporation). The data density averages five meters between points. This dataset, which is available from atlas.lsu.edu, was integrated to 1 km intervals. The corrected dataset was used on this project, as it is adjusted for false readings, tree canopy, and building interference. The bathymetric dataset was taken from a digital bathymetry model of Lakes Maurepas, Pontchartrain, and Borgne [McCorquodale 2003 #79].

The dataset was spatially processed in the same way as the habitat set. First, each data point was associated with its particular quadrangle. Then each corresponding point (x,y coordinates within the 1 sq. km cell) was added to a running total. The average elevation was computed by dividing this total by the number of points for the specific quadrangle.

3.2 Regional Habitat Modeling

Based on previous efforts (Martin et al. 2002; Reyes et al. 2004; Reyes et al. 2000), a regional model was developed for the Maurepas wetlands. This simulation model assessed the spatial correlation between the proposed river diversion and associated down-estuary nutrient uptake and salinities. These factors are important for the survival of *Taxodium distichum* and *Nyssa aquatica*, the dominant canopy trees in the Maurepas Swamp. In consideration of the complex swamp hydrology, the model had to modify the scale of the hydrodynamic component to: (1) accommodate more channel cells, (2) allow for accurate simulation of the depositional mechanics of sediment, and (3) facilitate improved calculation of water residence times across the system.

The regional model accounts for water and suspended materials in the same way as other hydraulic models (Martin et al. 2002; Reyes et al. 2004; Reyes et al. 2000). However, limitations in computing power and the long-term nature of ecological simulations (decades vs. months) precluded the use of any of these codes. Shallow and well-mixed waterbodies can be adequately simulated using two-dimensional, horizontal plane models (Martin and Mccuccheon 1999). These assumptions remain in place for wetlands when dry and wet conditions are considered. For calibration purposes, the regional model simulated processes over a 10 year time scale. The model consisted of a grid of one square-kilometer cells, where each cell exchanged water and associated dissolved and suspended materials (e.g. salt, total suspended sediments) with its four neighbors, across model boundaries, and with the atmosphere (precipitation, etc.). A balance of material inputs and outputs has been shown to be critical for predicting marsh production and sustainability. This balance is also needed to predict how production and sustainability are affected by natural and human activities (Boesch et al. 1994; Day et al. 1997; Turner 1997).

Several regional level landscape models have been developed to help elucidate land change factors and to evaluate different management options (Costanza et al. 1990; Martin et al. 2002; Reyes et al. 2000). These spatial landscape models integrate ecosystem processes over a grid of landscape cells (Figure 3.1). Each cell contains a unit ecosystem model that represents a certain habitat type and incorporates location-specific algorithms to quantify fluxes of materials between cells (Boumans and Sklar 1990; Fitz et al. 1996). The unit ecosystem model comprises a geo-referenced cell that is connected to its four nearest neighbors by the exchange of water and suspended and dissolved materials (salts, nitrogen, phosphorus, and suspended organic and inorganic sediments). The change in water level in each cell is determined in the model by water exchanges in and out of the cell across all four boundaries plus surplus rainfall (precipitation minus evapotranspiration). Water crossing from one cell to another carries both organic and inorganic materials. These suspended particles are partitioned between being deposited, resuspended, lost due to subsidence, and carried to the next cell. The relative rates of each of these exchanges in each location are a function of habitat type. Plants and nutrients within each cell also influence these exchanges and flows. Changes in other abiotic material concentrations (i.e. salts) are also a function of water flow between cells and concentration of materials in the cells, along with internal deposition and resuspension.

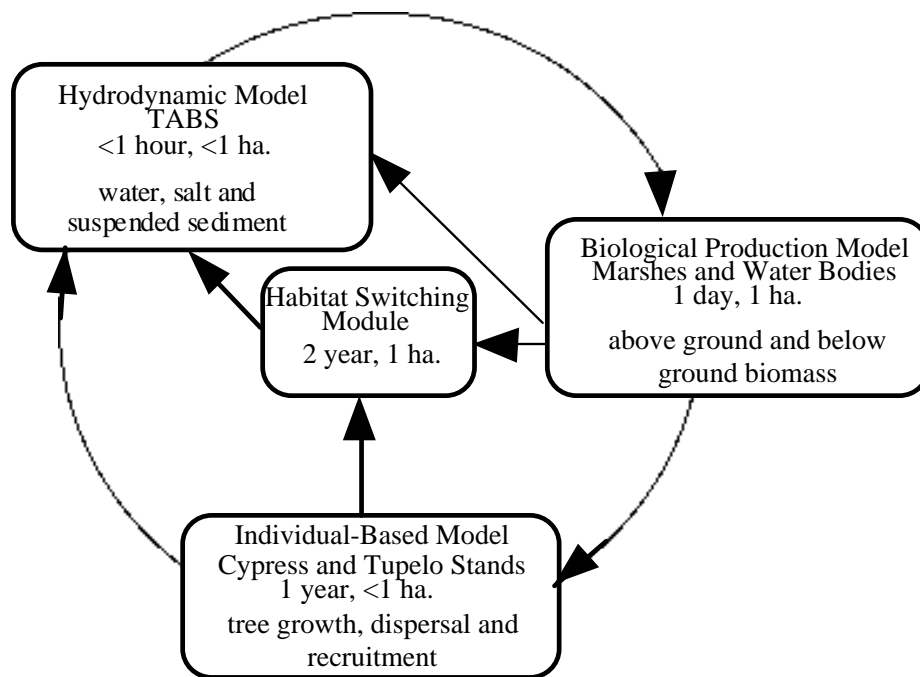


Figure 3.1 Diagrammatic representation of the interactions among the regional modeling components. Temporal and spatial scales are indicated.

3.3 Individual Based Forest Modeling

Individual-based forest succession models describe the habitat as a mosaic of closed tree canopies, where light availability is the critical component for tree growth (Botkin et al. 1972; Shugart et al. 1973). In the individual-based forest models, individual trees of different species are affected differently by stressors (i.e. flooding stress, soil conditions), and are subjected to

different mortality and regeneration rates. The individual-based models can simulate the dynamics of forest succession across environmental gradients (Botkin et al. 1972; Pearlstine et al. 1985; Phipps 1979; Xiao et al. 2002) over time scales ranging from single years (Xiao et al. 2002) to several decades (Botkin et al. 1972) and even centuries (Pearlstine et al. 1985; Phipps 1979).

Initial activities included developing a conceptual model of an individual-based, multi-species forest model. Several major environmental gradients influencing tree growth, competition, and survival were identified, and their interactions were examined (Figure 3.2). Tree responses to environmental conditions were modeled on an individual-basis. Individual trees were contained within 10 x 10 m gap plots; thus individual tree locations within a given plot were not specified (Figure 3.3). Inter-tree competition was accounted for by shading within each plot. Plots were arranged in a spatial grid on the landscape, so that each plot has a unique, identifiable location. Mortality was represented as suppressed growth depending on salinity exposure, wind throw, and an aging component (Figure 3.2). Mortality is also the mechanism by which standing biomass is reduced, thus forming canopy gaps in the swamp. Seed production and germination depend on the standing biomass of each tree per species. Once seeds have been dispersed, germination can occur if there is no flooding (Figure 3.2). Seedlings will grow unless they encounter high levels of salinity, long flooding duration, submergence, or excessive shading.

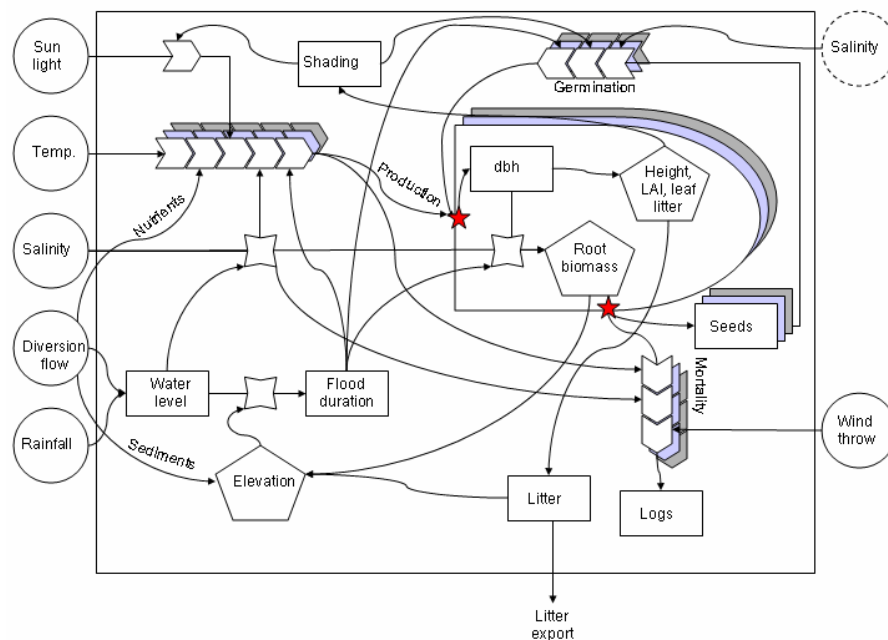


Figure 3.2 Diagrammatic representation of a tree's interactions with its environment. Forcing functions are identified by circles. Red stars indicate derived functions as expressions based on total tree production and not as a sub-category of production (i.e. root biomass, dbh, litter fall). Triple shading indicates species-specific functions or units.

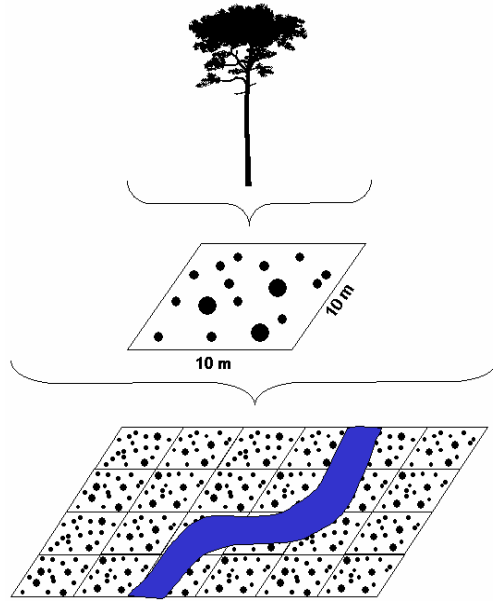


Figure 3.3 *Conceptual model of the hierarchical structure for the watershed and individual-based models. The panels show the relationship between individual trees, plots, and the landscape.*

Tree growth (primary production) was determined by species-specific responses to available sunlight, temperature, nutrient availability, salinity, and flooding duration and depth (Figure 3.2). Overall primary production was then allocated into wood, leaf, and root production based on species specific translocation ratios. Interspecies effects, such as an increase in leaf production and tree height, resulted in shading of adjacent smaller trees. A feedback loop considered the production of leaf litter and root biomass as factors that increase elevation after decomposition, thus decreasing flooding duration and depth.

At the landscape level, materials were transported from cell to cell in four directions, with shading from each cell affecting neighboring cells (Figure 3.3). Several forcing functions included: available sunlight, temperature, salinity, rainfall, and diversion inflows of nutrients, water, and sediments. Wind throw was identified as another potential forcing function that could act as a disturbance depending on hurricane strength as described in historical records.

The cumulative effects of environmental impacts translated as local ecosystem processes (duration of flooding, material transport over the wetland, and vegetative biomass). These processes were then evaluated to examine their role in swamp and marsh sustainability. Figure 3.4 depicts the varying time scales used in the model. These time scales ranged from days (for nutrient transformations) to weeks (flooding, salt pulses), to seasons (plant productivity, herbivory), to years (marsh succession), to decades (swamp succession), and even to centuries (subsidence and habitat change).

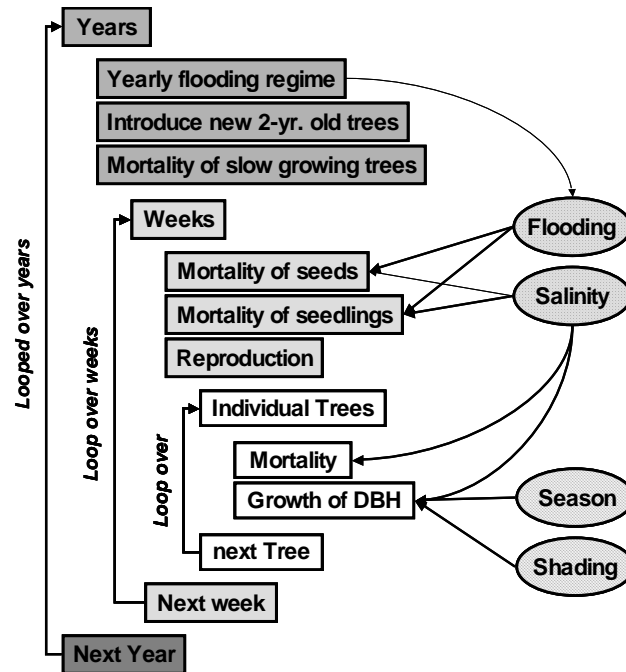


Figure 3.4 Temporal model structure of the individual-based tree model. Boxes indicate time levels and tree behaviors modeled; ovals represent environmental impacts. Shading denotes the level of each nested component of the model. Mechanistic feedback loops and interactions are not included.

Physiological parameter values required by the model, such as maximum tree age, maximum tree size, maximum annual growth, and biomass allocation ratios were drawn from a variety of sources, including previously published forest succession models (i.e. SWAMP, FORFLO, and SIMS), peer-reviewed journal articles, and field data. Species-specific response curves or tolerance levels (i.e. very tolerant, tolerant, intolerant) for each of the environmental stressors identified remain to be constructed from available field data and literature values.

Presently, the IBM for the Maurepas Swamp consists of four plots with two species under four combinations of scenarios: periodic and extended flooding, and low and no salinity. Tree primary productivity was calculated annually through the addition of litter fall and wood production (Brown 1981; Conner and Day Jr. 1992; Mitsch and Ewel 1979) Annual litter production was modeled explicitly, based on current species productivity and biomass allocation relationships. Wood production can be defined as the difference in wood biomass from the beginning to the end of the year, which, in turn, can be computed from the modeled tree diameters using wood biomass regression formulas found in the literature (Clark et al. 1985; Muzika et al. 1987; Scott et al. 1985). Wood production per tree was then summed by species per plot. The primary production of each tree species per model-plot was calculated separately to identify the dominant tree species per plot. In addition, the primary production data of all species per plot were added to yield a total measure of primary production that is comparable to literature values of forested wetland productivity.

The IBM code included a time-step of one week for a simulated time-period of 300 years in 100 sq. meter (1 ha) plots. The individual trees had three life-stages modeled with different tolerances according to seeds, one and two year-old seedlings, and an aggregate for growing and mature trees. The forcing functions included: flooding duration, salinity, and light (as a proxy for season). The only density dependent resource variable was shading.

4 Results

4.1 Spatial and Temporal Databases

The environmental information for the area comprised by the swamps and wetlands adjacent to Lake Maurepas was classified in spatially distributed and time-series records. Study area maps were collected from three different sources.

- The LA Dept. of Transportation (LA DOT) provided us with regular quad maps for the area. The use of these maps allowed localization of the time-series monitoring stations and precise delimitation of boundary conditions.

- The USGS National Wetlands Research Center prepared vegetation/habitat maps of the coastal zone for three different years (1956, 1978, and 1988). Unfortunately, only the set for 1988 was available for the study area. This raster habitat/classified Landsat Thematic Mapper Data information allowed analysis of trends, land loss, and vegetation succession. The maps were digitized and georeferenced with GIS software (ArcView) that facilitated manipulation of the data.

- The CADGIS Laboratory of Louisiana State University has classified and archived satellite images (SPOT and ERDAS) of the coastal zone on a regular basis. The laboratory has granted us access to this digital information. This digital dataset was transferred into the MFWorks GIS system on a Macintosh computer using rasterized information. Figure 4.1 depicts the NWRC habitat map reclassified for the regional habitat model at 25 m resolution.

The hydraulic data were compiled from the Water Resources Data Books—Water Year produced by USGS and LA DOT. The Water Resources Division of USGS provided us with electronic files for several monitoring stations. The parameters recorded were: discharge, gage height, water temperature, and specific conductance. The length of record varied from 1978 to the present and from 1992 until the present.

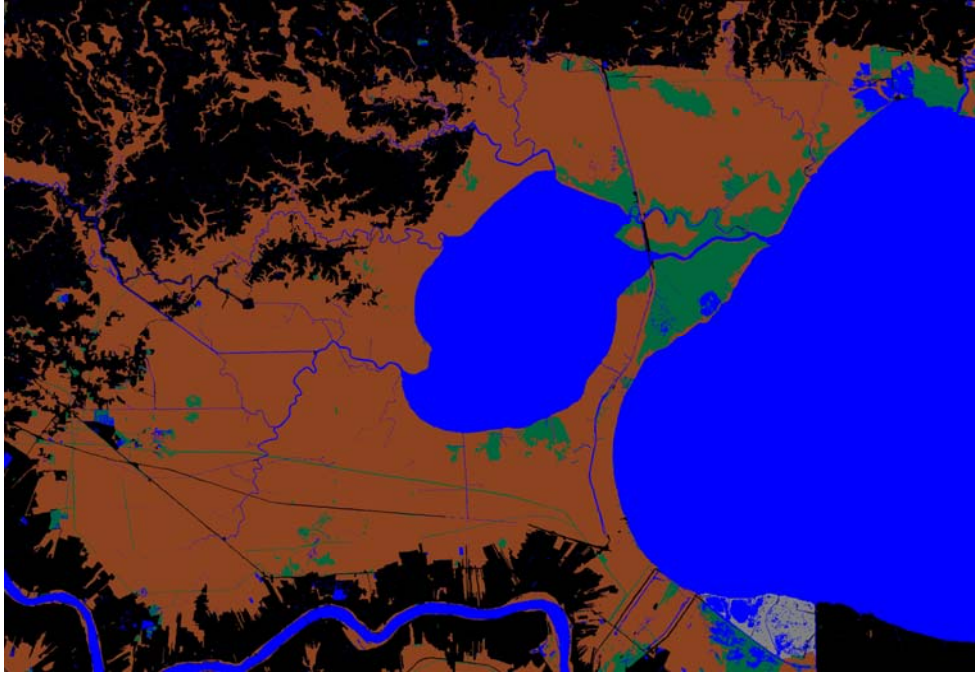


Figure 4.1 NWRC habitat map reclassified to six habitats for the regional habitat model at 25 sq. m resolution.

Daily climate data included precipitation, air temperatures, and wind direction and speed. The range of parameters monitored included: peak gust speed, wind speed average, precipitation, relative humidity, total sunshine, total potential sunshine, temperature maxima and minima, daily mean air temperature, departure from normal temperature, dew point, and barometric pressure. Several additional sources of temporal information were consulted. Robert Lane from the Coastal Ecology Institute of LSU provided water temperature and chlorophyll concentrations, Dr. Paul Kemp from CEI provided monthly water levels from six stages within the Hope Canal proximity. Ecological parameters and rates have been collected specifically from the scientific literature and some from ongoing field studies (Shaffer et al. 2003; Shaffer et al. 2001).

4.1.1 Habitat Dataset

The habitat dataset was processed to 1 sq. km using a majority rule algorithm that determined the predominant habitat by counting the different habitat types at 25m scale in a 1 sq. km grid (Figure 4.2) and reclassifying the cell by the habitat type with the largest count. After the map was aggregated, a manual verification was done to adjust the accurate hydrological channelization.

This manual verification was done by digitally overlaying the reclassified 1 sq. km map onto the 25 m map. Water habitat type values were then assigned to rivers and streams in the 1 km dataset. These values corresponded with the spatial position of the rivers and streams in the 25 m dataset (Figure 4.2). This step guaranteed that hydrological inputs into the model were correct and accurate. The reclassified 1 sq. km map served as the initial habitat map for the watershed model. River and stream cells were tagged under a different set of rules during the bathymetric

analysis (see next section). It was important to identify and georeference these cells, because they serve as major conduits of water during low flow conditions.



Figure 4.2 Reclassified study area at 1sq. km scale. Initial base map for the regional model.

4.1.2 Elevation Dataset

The LIDAR elevation dataset, collected in 2002, was integrated to 1 km intervals. The bathymetric dataset was taken from a digital bathymetry model of Lakes Maurepas, Pontchartrain, and Borgne.

The dataset was spatially processed in the same way as the habitat set. First, each data point was associated with its particular quadrangle. Each corresponding point (x,y coordinates within the 1 sq. km cell) was added to a running total, which was then divided by the total number of points for the specific quadrangle to compute the average elevation (Figure 4.3).

Hydraulic conduits (i.e. rivers and bayous) in the vicinity of Lake Maurepas were coded under a “hydraulic equivalent” assumption. Since all of the waterways were less than 1 km in width, a computation of depth and width was done to maintain equivalent volumes for the channels. Thus, a 30 m wide and 8 m deep channel had coding equivalency of 1 km width and 0.24 m depth.

4.2 Regional Habitat Modeling

The goal of this project was to build and use a regional forest model to examine the response of forested wetland succession, production, survival, and soil building to cumulative impacts. To accomplish this goal, the regional model was implemented with a spatial calibration done in three steps. First, the model was run repeatedly until the land/water ratio matched the initial

habitat map. The model was then calibrated to habitat type proportions and habitat distribution. For land/water ratios, the Maurepas model was run using the 1988 forcing functions exclusively until stable conditions were reached and all modules were running concurrently.

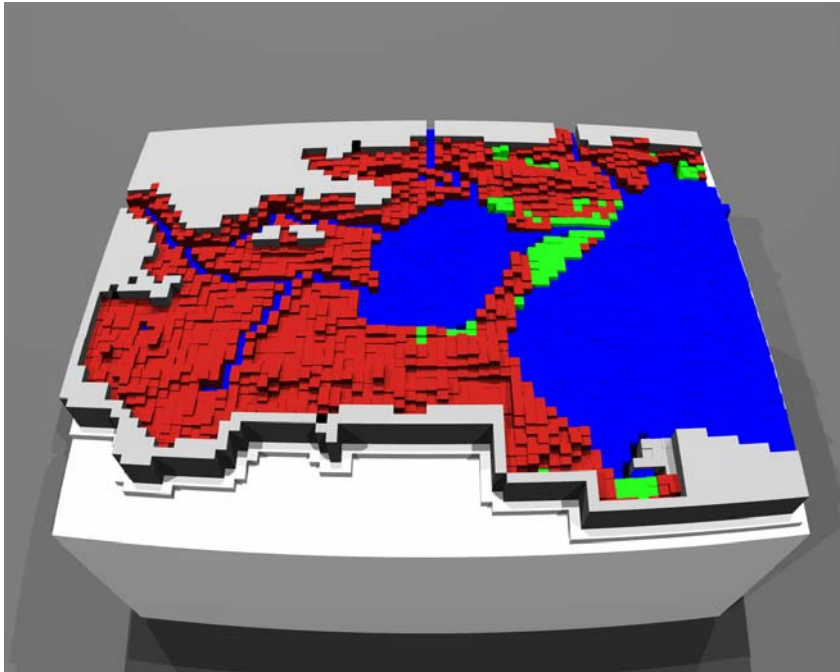


Figure 4.3 *Three dimensional representation of topography and bathymetry of the Lake Maurepas watershed.*

During the second step, matching habitat proportions, the regional model was tested by varying several of the spatially distributed parameters (salinity limits, elevation and Manning's coefficient) by using historical climate records. After a 10-year simulation, the average salinity change was 1.2, with a maximum salinity change of 3.87. This changing salinity yielded fluctuations in the total number of cells per habitat. A spatial subtraction was done from the initial salinity map and the 10 yr. map to identify the location of the impacted areas (Figure 4.4). This analysis highlighted the importance of the hydraulic conduits and a slow increase in salinity in the eastern most areas.

The third step in the spatial calibration was a goodness-of-fit analysis (Costanza 1989) between the 1988 model and USFWS reclassified maps (Figure 4.2). The model was repeatedly run, varying the initial spatial parameters (e.g. initial elevation) until the overall fit improved to 85 or better using the criteria established by Reyes (2000 and 2004). The calibrated base case simulations yielded a fit of 92.4 for the Maurepas Basin (Figure 4.5).

The original landscape model was designed to simulate ecological processes that produce broad habitat patterns (Reyes 2000, Martin 2002). The original model was calibrated to match these landscape patterns such that all land loss processes would be implicitly included. The present model incorporated all land loss factors, since these maps reflect all of the effects impacting the

landscape. The Maurepas model did not explicitly incorporate local processes (less than 1 km² cell) and thus, does not accurately recreate historical land changes of a particular cell.

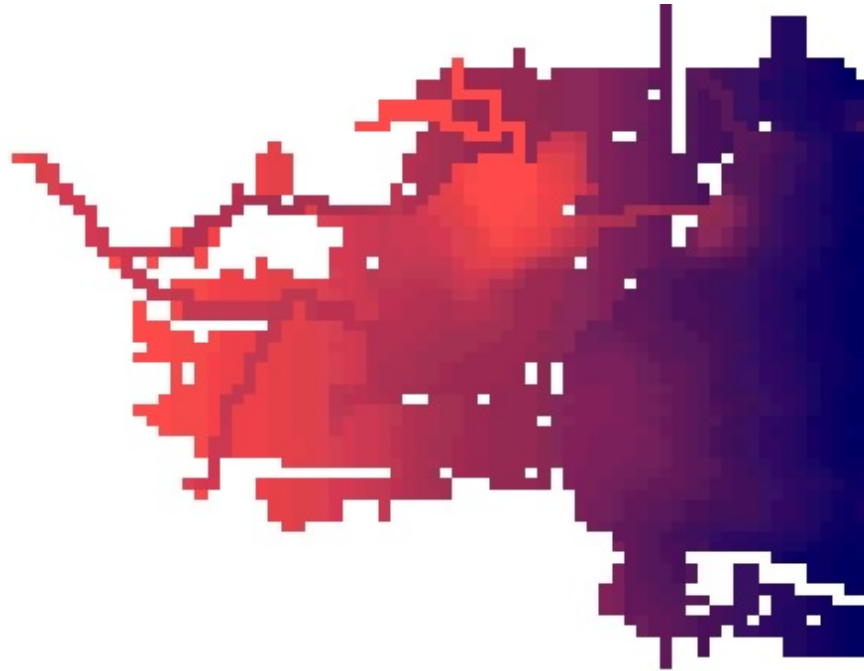


Figure 4.4 Gradient of salinity changes for a 10-year simulation. Red areas indicate fresh conditions, blue areas indicate higher salinities.

A comparison of these spatial changes (Table 4.1) showed an increase in fresh and intermediate marshes as swamp habitat deteriorates. Interestingly enough, the brackish marsh also lost 3 sq. km, while open water showed a minimal increase.



Figure 4.5 Ten year simulation results for the Maurepas regional model.

Table 4.1 Habitat type distribution (in sq. km) for initial and 10-year simulation.

Habitat Type	Initial Map	10 year map
Fresh marsh	2	76
Intermediate marsh	101	103
Swamp	1190	1115
Brackish	19	16
Open water	1174	1176
Uplands	765	765

The changes shown in Figure 4.5 demonstrated the ability of the regional model to consider spatial changes and forecast habitat trends. However, these calibration runs indicated a need to obtain more accurate information about the mechanics of swamp processes, given that a temporal transition from swamp to fresh or intermediate marsh should take longer than 10 years. In a process similar to the one used for the initial and final salinities, a habitat difference map was produced to examine the spatial changes (Figure 4.6), and a difference table was constructed (Table 4.2) to evaluate which habitats changed. The cells with lower biomass were found mostly on the southern shore of Lake Maurepas. Some of these changes also occurred in the area where the proposed diversion is planned.

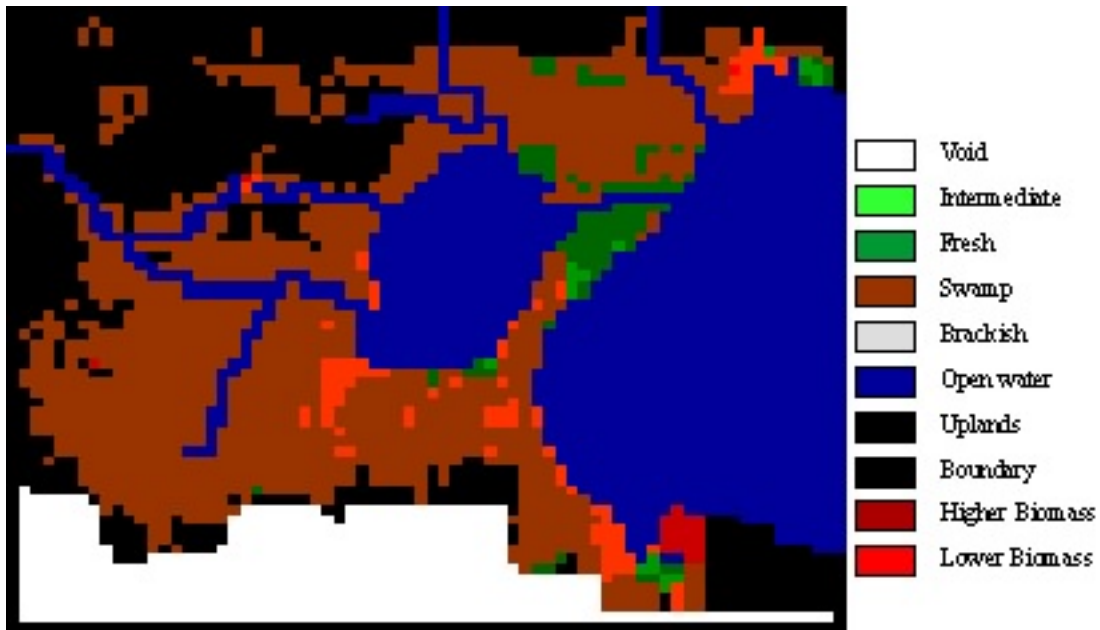


Figure 4.6 Habitat difference map. Notice that red shades indicate changes in biomass (habitat type yet to be determined).

Table 4.2 Habitat transition and number of cells (1 sq. km) where those occurred.

Difference	Num of Cells
Intd-Frsh	1
Swmp - Frsh	19
Swmp - Intd	55
Brck - Intd	3
Frsh - Intd	17
Swmp - Brck	1
Frsh - Wtr	1
Intd - Wtr	1

4.3 Individual Based Forest Modeling

Calibration, verification, and sensitivity analyses for the initial IBM were performed. The field data used for calibration and verification were measured at 40 25 m x 25 m sites throughout the roughly 180 km² area of interest in the Maurepas Swamp (Hoeppepner 2002; Shaffer et al. 2001). The IBM used field data from 2000-2004, which included a severe drought (2000-2001) as well as two hurricanes (Shaffer et al. 2003). These data should thus be reflective of most environmental conditions likely to occur in the forested wetlands of interest.

The initial conditions calculated three trees of each species on each of four replicate plots in which each initial tree diameter at breast height (DBH) was 3 cm, and initial tree age was a mature (i.e. reproduction capable) tree aged five years. The results showed that salinity had a greater effect than degree of flooding in either of the two species (cypress and tupelo) (Figure 4.7).

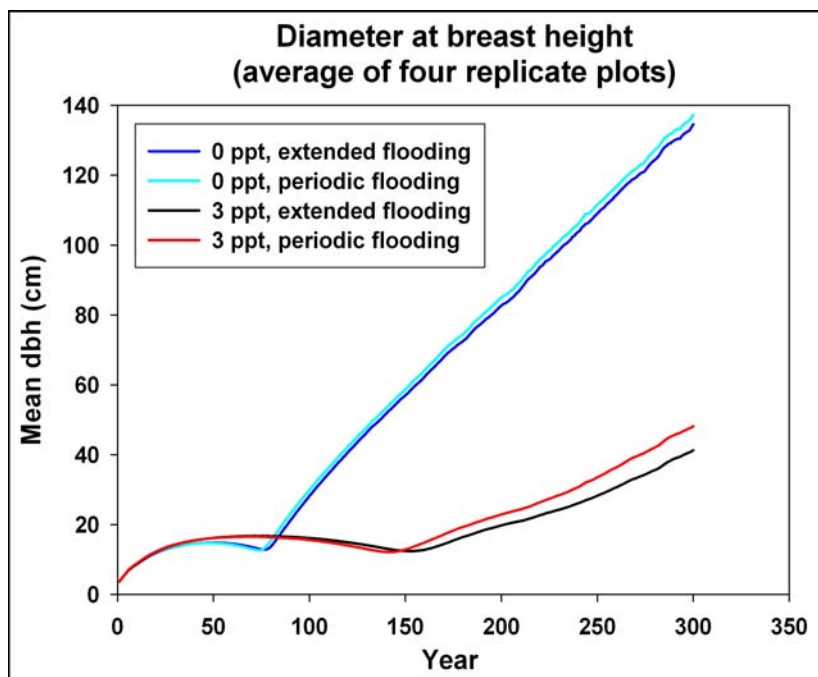


Figure 4.7 Diameter at breast height (DBH) for all tree species under diverse flooding and salinity regimes.

Under fresh water conditions, tupelo tended to dominate over cypress (Figures 4.8 and 4.9). This result could be attributed to a competitive advantage for tupelo trees. Under higher salinity conditions, the opposite competitive advantage allowed the cypress population to dominate in number of individuals and basal area. As a consequence of this increased basal area, both species inhibited the recruitment of sub-canopy trees due to shading.

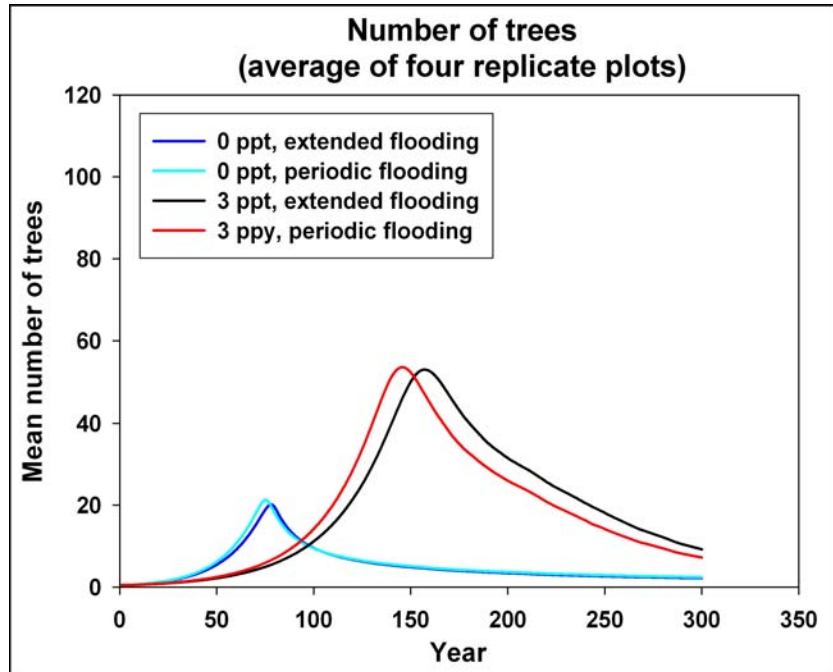


Figure 4.8 Total number of cypress trees under the different scenarios.

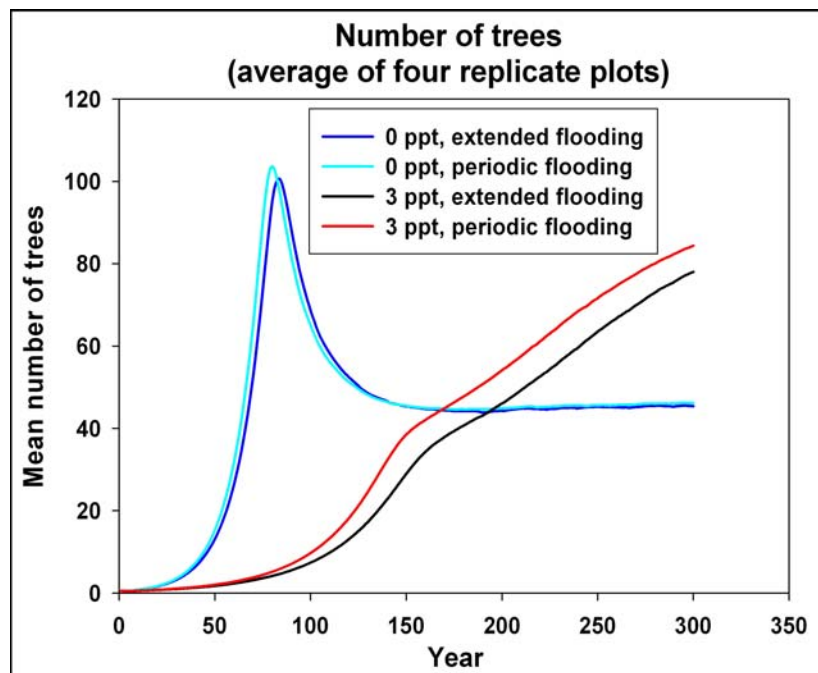


Figure 4.9 Total number of tupelo trees under the different scenarios.

5.0 Discussion

Overall, the regional model examined the consequences of physical forcing in the Maurepas system, and how cumulative impacts interacted to produce changes in habitat distribution. The spatial modeling effort included the collection, organization, and synthesis of environmental data, combined with the development, update, and implementation of the landscape simulation model that incorporates a detailed soil-building component.

The results showed a substantial lowering of photosynthetic biomass and the location of those habitat changes. However, the habitat switch algorithm (Figure 3.1) interprets a lowering of biomass as trees going to grass. This resulted in an over-simplification of the forest processes. In recognition of the inability of the regional model to accurately forecast swamp deterioration, the habitat type was not determined in Figure 4.6 for those changing cells. Instead cells were labeled as “higher biomass” or “lower biomass” rather than as initial conditions. These preliminary results indicated the need to revise the algorithms and use a more detailed approach.

Several individual-based forest succession models have been developed since the early 1970s (Porte and Beartelink 2002), however, only a few have dealt with wetland forests. Most of the individual-based forest succession models were developed for upland forests and use light as the major limiting factor. Recent advances allow consideration of soil moisture and quality and nutrient gradients in the modeling process (Caspersen et al. 1999). The few individual-based forest succession models that consider flooding as a major environmental stressor (Pearlstine et al. 1985; Phipps 1979; Xiao et al. 2002) are all descendants of the JABOWA model (Botkin et al. 1972).

The cypress forest modeling efforts were set to explore the effects of short and long time-scale environmental processes on individual trees as they conform a forest swamp through the Maurepas wetlands. The IBM simulated tree characteristics: stand density, basal area, species composition, recruitment, and productivity. To capture the benefits of both types of models, the IBM model will be dynamically coupled with the regional watershed model. This new hybrid model will better capture the spatial and temporal variation in environmental stressors as well as the feedback interactions between forest and the watershed.

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