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EMAP
Great River Ecosystems



U.S. EPA Office of Research and Development

Environmental Monitoring and Assessment Program

Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River



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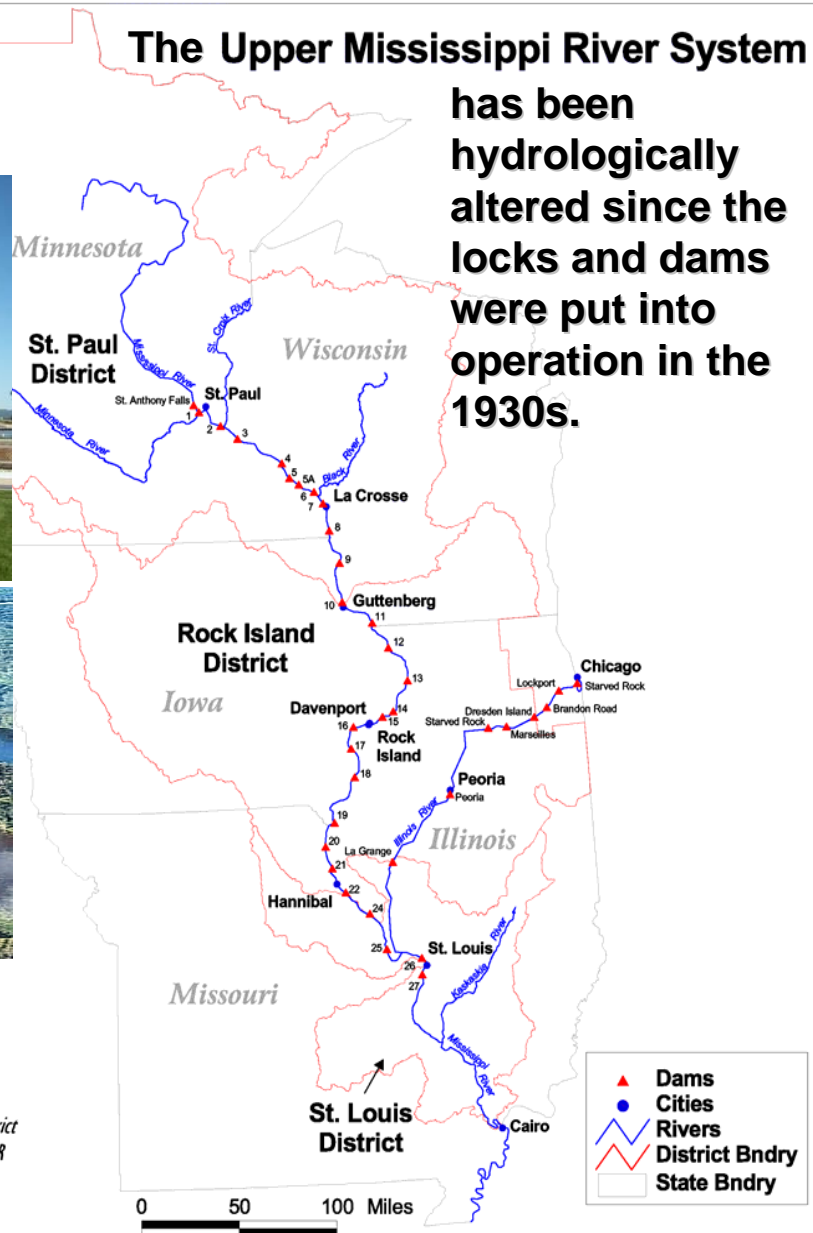


Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River

The Locks & Dams



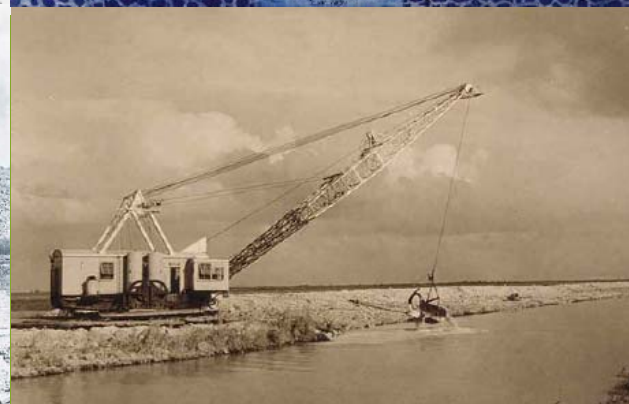
The Floodplain



Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River



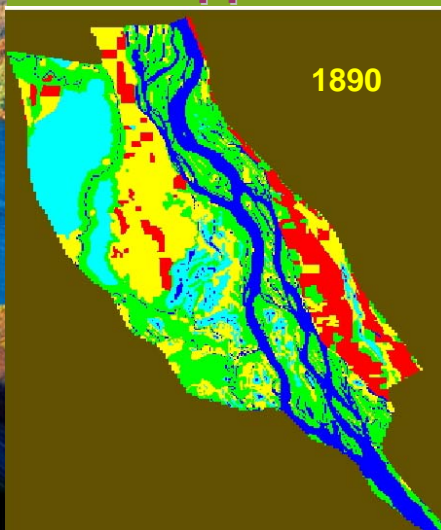
The historical conditions can be used to define objectives in the restoration and management of the Upper Mississippi River. Derivation of desired or reference conditions must also recognize that the system now consists of a series of connected impoundments that are regulated to facilitate commercial navigation.



Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River

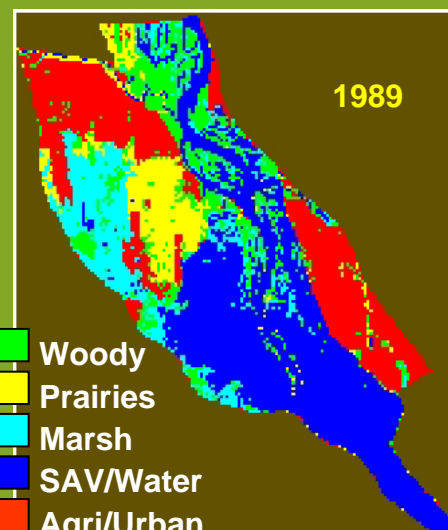


Since the early 20th century, we have effectively developed water resources, and now manage water infrastructure for commercial navigation, flood damage reduction, hydropower generation, recreation, and water supply in the Upper-Mississippi River.



1890

As a result, landscape patterns have been changed in historical floodplains and large open water areas were created above the dams.



1989

Woody
Prairies
Marsh
SAV/Water
Agri/Urban

Islands characterized by woody vegetation experienced unusually prolonged unfavorable hydrologic conditions and were eliminated from many areas of the river.

Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River

Congress now recognizes the UMRS as a nationally significant ecosystem:

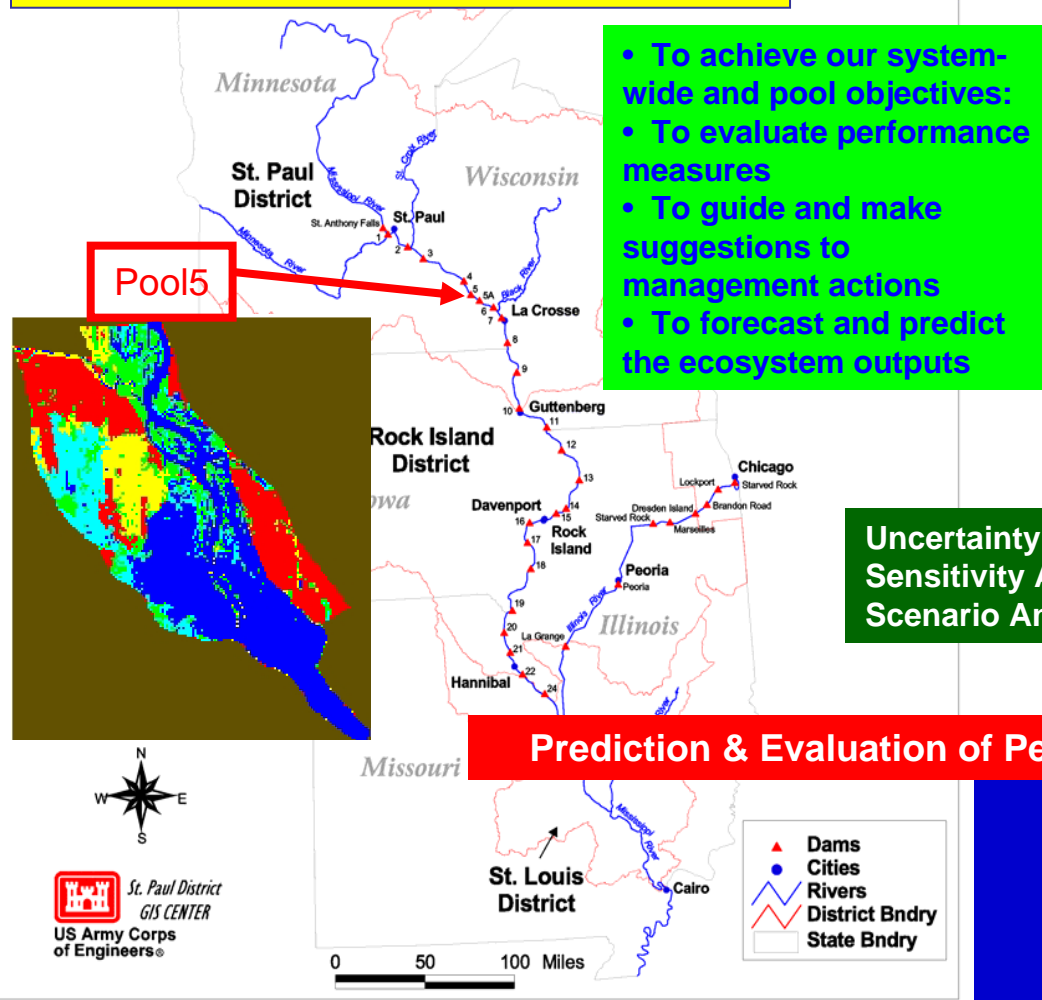
Increase the navigation efficiency of the River



Restore, protect, enhance the environmental services of the River



The model applied to each specific Pool in the Upper Mississippi River System



- To achieve our system-wide and pool objectives:
- To evaluate performance measures
- To guide and make suggestions to management actions
- To forecast and predict the ecosystem outputs

Uncertainty Analysis
Sensitivity Analysis
Scenario Analysis

Spatially Explicit CASM

- Vegetation Succession Module
- Landscape Pattern Analyst
- SAV Simulation Module
- Sedimentation Module
- Water Quality Module
- Mussel Module
- Fish Module

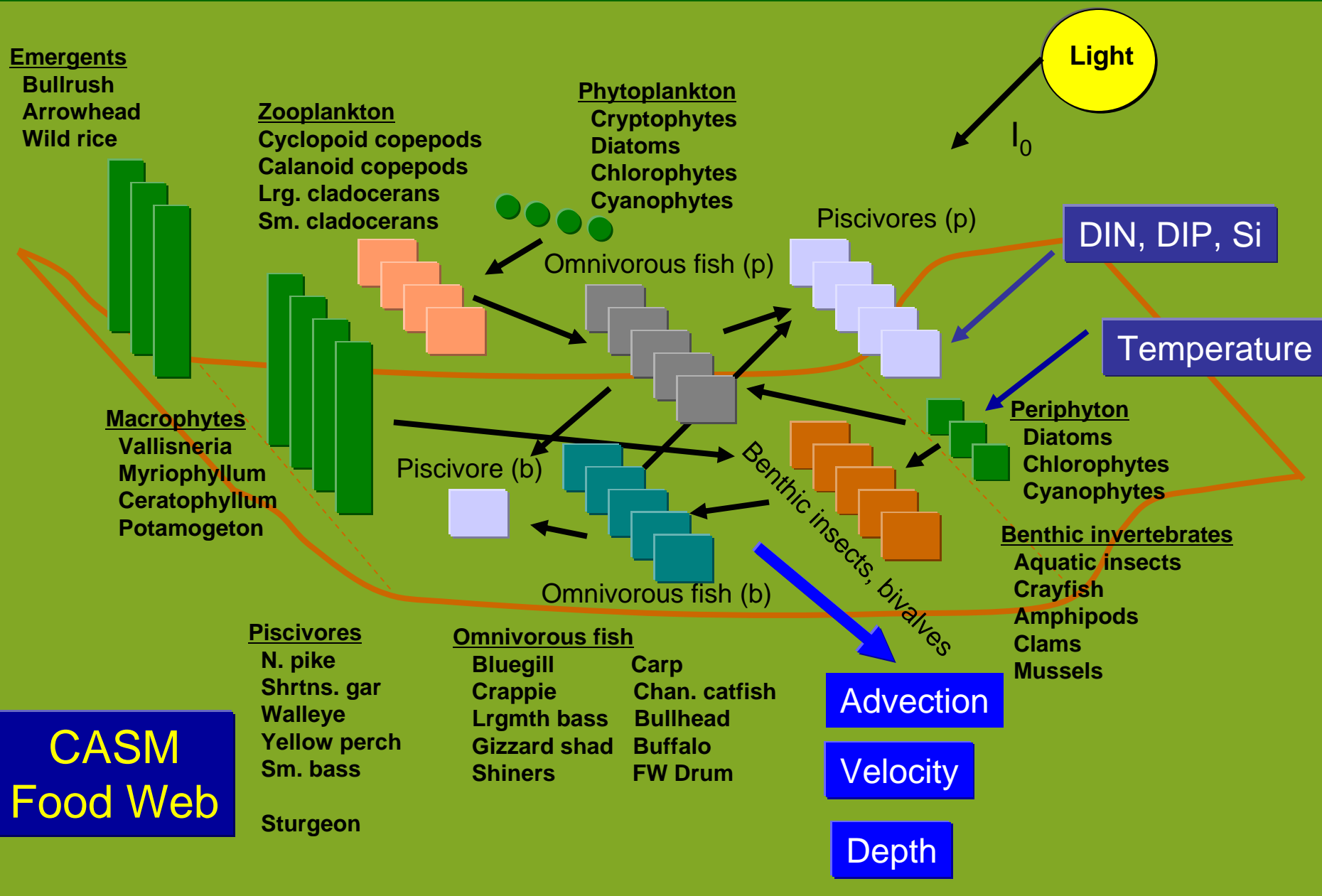
Spatial resolution: 100 x 100 m
Spatial interactions
Spatial dynamics
Spatial pattern analysis
Spatial visualization

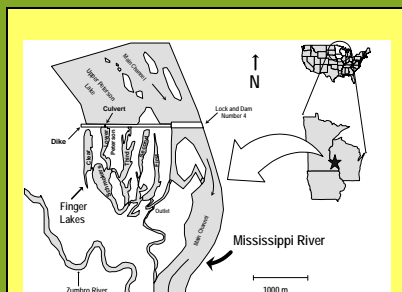
Prediction & Evaluation of Performance Measures for the Desired Goals

Model Simulation:
Verification
Calibration
Validation

- Restore natural floodplain
- Restore natural hydrology
- Reduce erosion and sediment
- Monitor and protect water quality
- Improve native fish passage at dams
- Increase backwater connectivity with main channel
- Maintain viable populations of native species in situ
- Increase side channel, island, shoal, and sand bar habitat
- Restore and maintain evolutionary and ecological processes
- Represent all native ecosystem types across their natural range of variation

Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River





Finger Lakes Habitat Project Johnson et al. 2000, UMESC

- Food web structure
- Water quality parameters
- Population sizes

LTRMP

- water quality data
- food web data

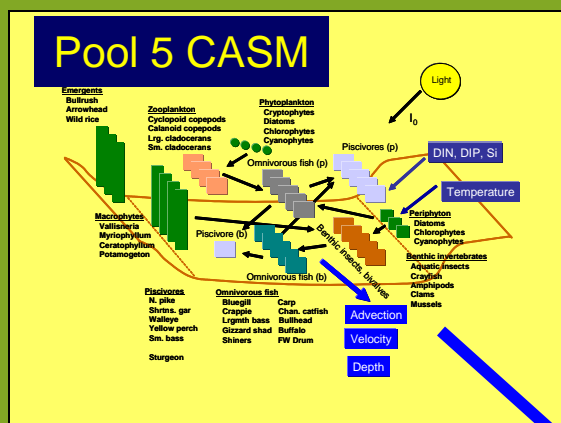
Rock Island
St. Paul
St. Louis
ERDC, Vicksburg



UMRS Navigation Feasibility Study

- fish community structure
- seasonal pattern of flows
- submodels (NavSAV, NavMSL)
- parameter values (NavLEM, NavSAV, NavMSL)
- technical input (Barko, Wilcox, Best, Whitney, Soballe)

Integration...

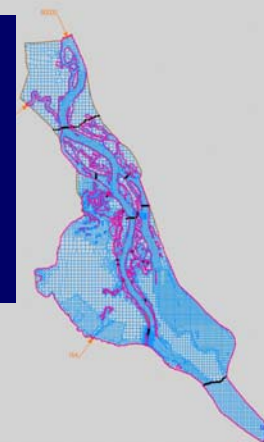


Cumulative Effects Study

- habitat distribution
- planform information
- ecological guilds

H&H Integration

- Pool 5 RMA simulations by Hendrickson et al., St. Paul District
 - steady-state velocity, depth, elevation
- Development of ADH model for Pool 5 (Berger et al., ERDC)
 - dynamic conditions



Delong et al. Food web studies Winona State Univ.

NESP

- forecast restoration outcomes
 - water level management
 - island construction
 - backwater connectivity
 - floodplain land cover/use
- risk assessment
 - probability of success
 - potential surprises
- estimate goods and services
- evaluate long-term sustainability
- integrate navigation impacts



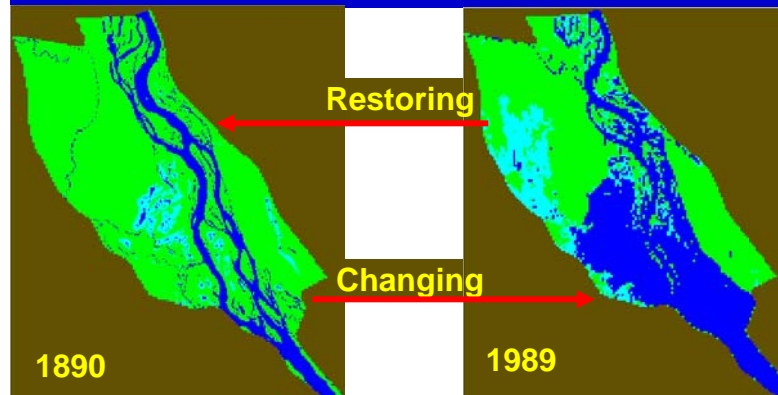
Spatially Explicit CASM for Simulation and Evaluation of the Restoration Success in Achieving Desired Future Conditions

- Vegetation Succession Module
- SAV Simulation Module

1. Maintain and sustain the critical habitat quantity (acres) and quality for different wildlife: riparian vegetation, tree islands, floodplain forests, aquatic vegetation.

- Landscape Pattern Analyst
- Sedimentation Module

2. Maintain and sustain the landscape patterns, such as floodplain, river channel, slough, delta, and lakes including river flows and connectivity.



- Water Quality Module

Nutrients (N & P)
Toxicity
Sediment

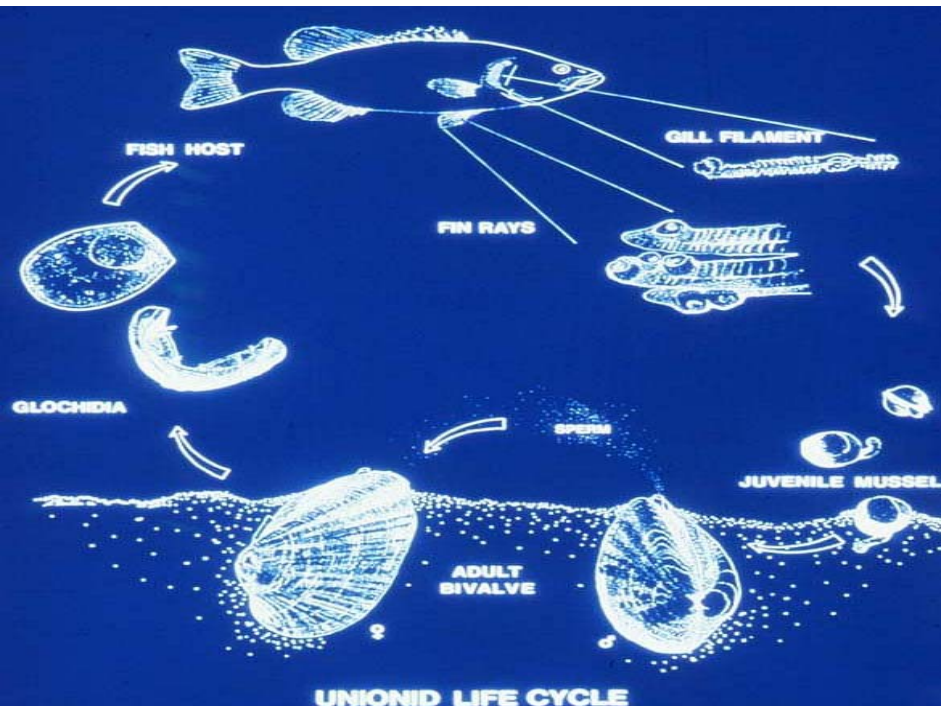
- Mussel Module
- Fish Module

3. Large rivers and their floodplains are among the most productive ecosystems in the world with an abundance of aquatic plants that provide critical habitat for the production of valuable fish, such as the sturgeons and support production of migratory waterfowl.

Spatially Explicit CASM

- Mussel Module
- Fish Module

3. Large rivers and their floodplains are among the most productive ecosystems in the world with an abundance of aquatic plants that provide critical habitat for the production of valuable fish, such as the sturgeons and support production of migratory waterfowl.

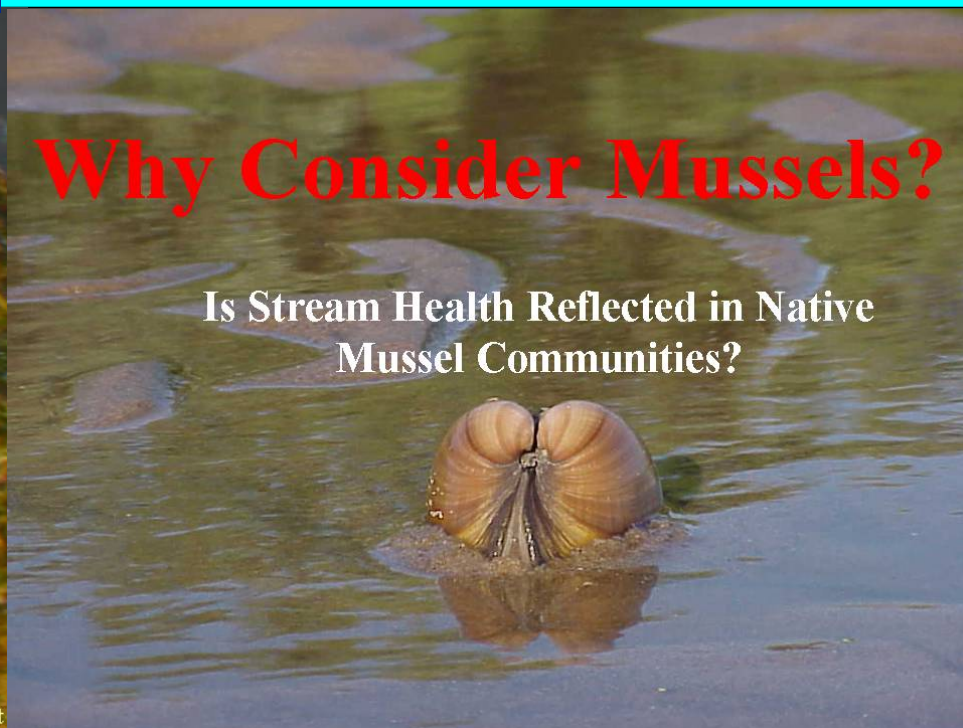


Fish are attracted to mussel beds and serve as hosts to their larvae



Why Consider Mussels?

Is Stream Health Reflected in Native Mussel Communities?



Spatially Explicit CASM

•Water Quality Module

Nutrients (N & P)
Toxicity
Sediment

N & P Loading into the system

Vegetation
SAV

Sedimentation

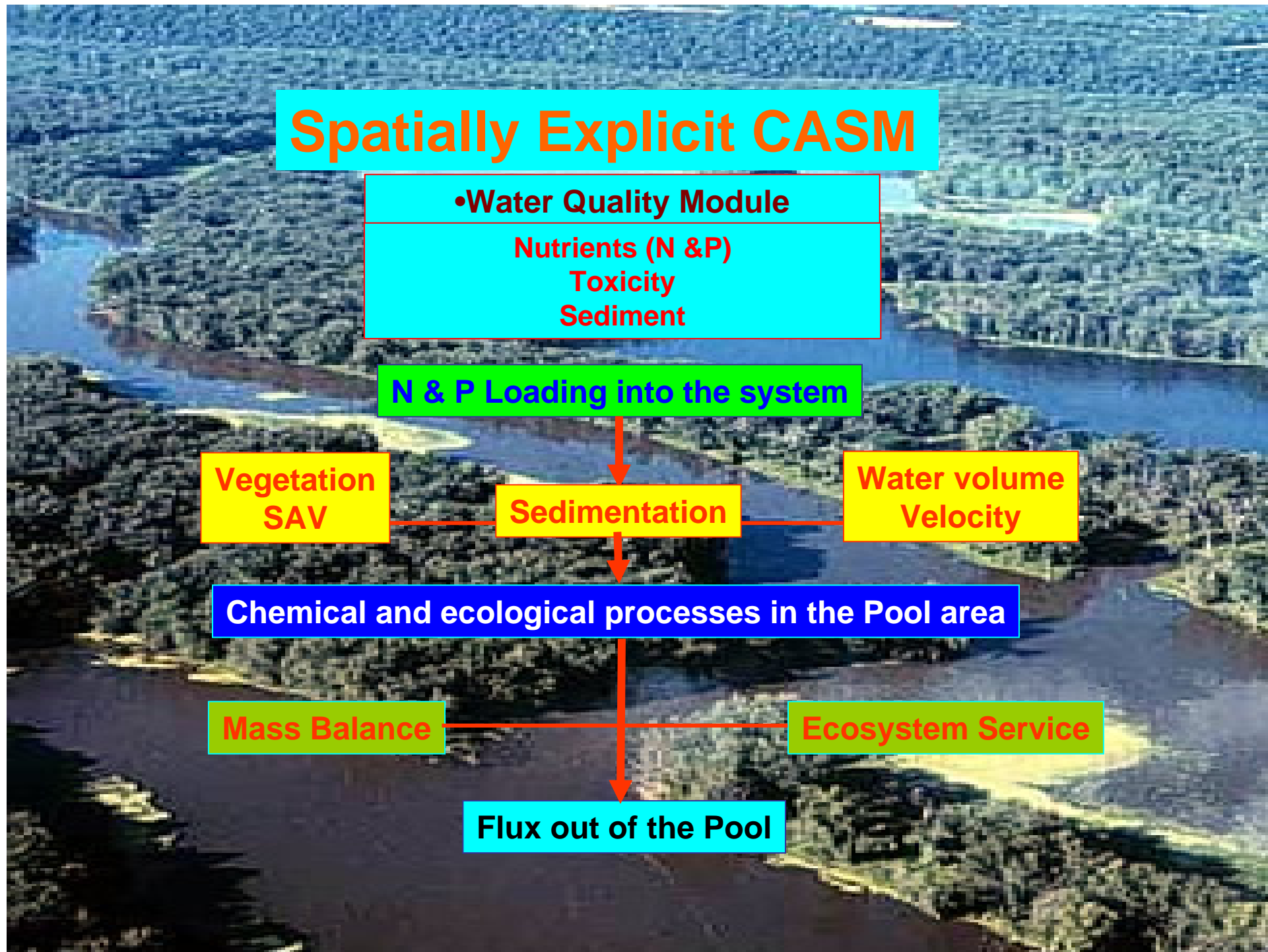
Water volume
Velocity

Chemical and ecological processes in the Pool area

Mass Balance

Ecosystem Service

Flux out of the Pool

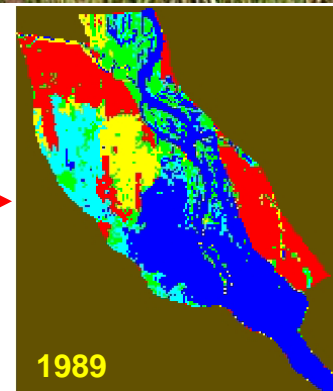
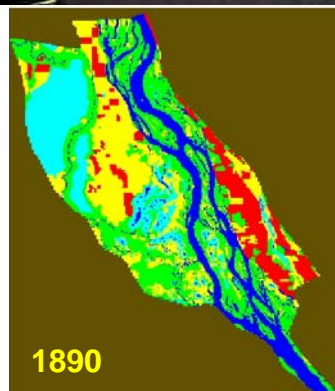


Spatially Explicit CASM

- Vegetation Succession Module
- SAV Simulation Module
- Landscape Pattern Analyst

Performance Measures:

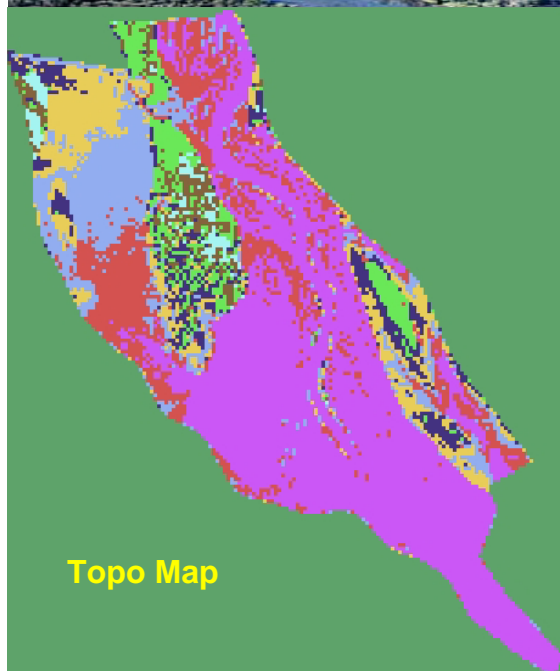
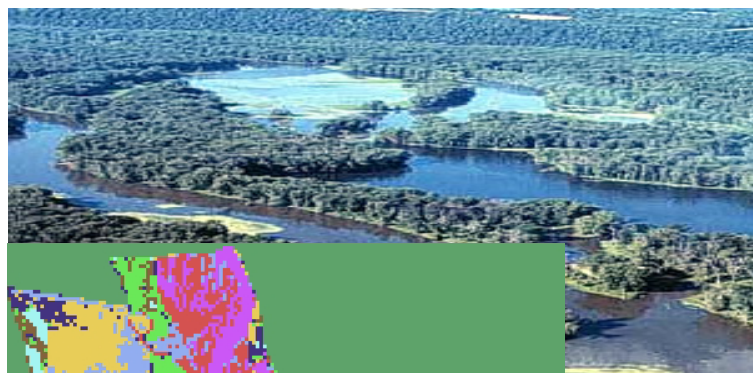
Biomass (Kg/acre)
Species composition
Biodiversity (α & β)
Habitat (Acres)
Vegetation patterns



Affecting Factors:

Water depth
Hydroperiod
Flood patterns
Drought patterns
Freeze
Nutrients (N & P)
Toxicity
Sediment
Fire

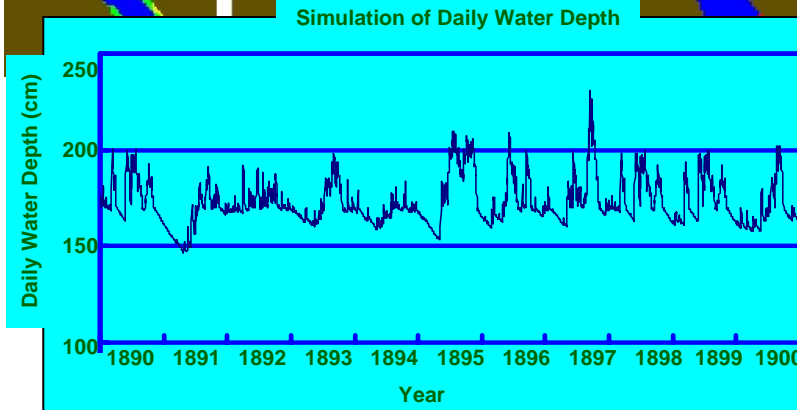
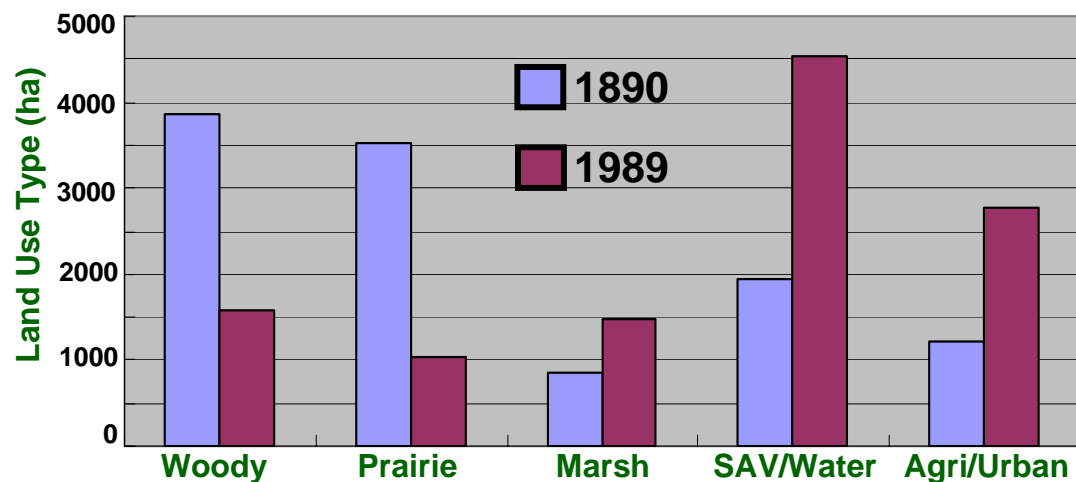
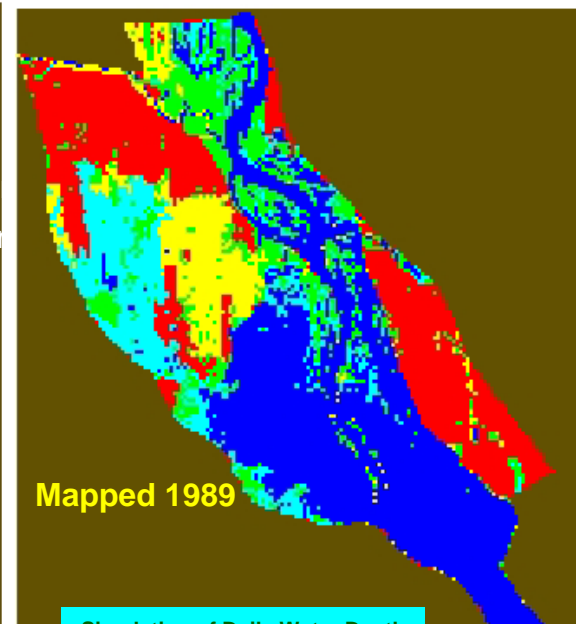
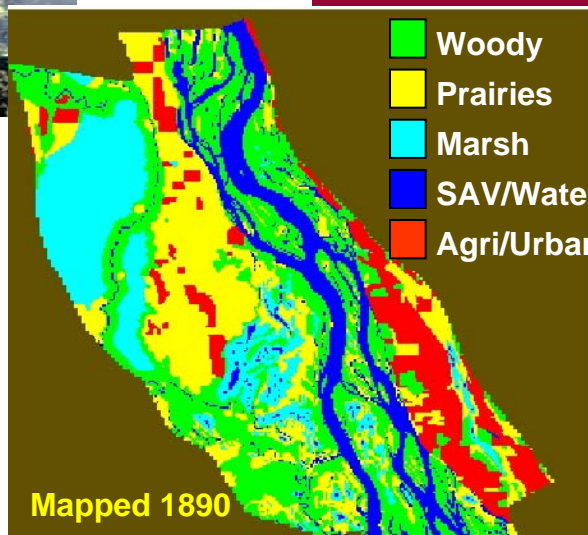




Spatially Explicit CASM

- Vegetation Succession Module
- SAV Simulation Module

How does the model work?



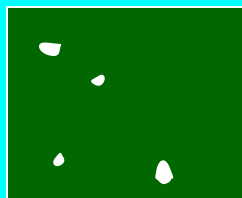


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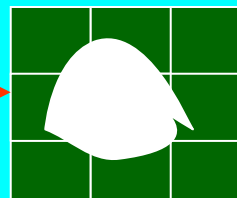
Vegetation
Succession
In Landscapes



Establishing in a cell

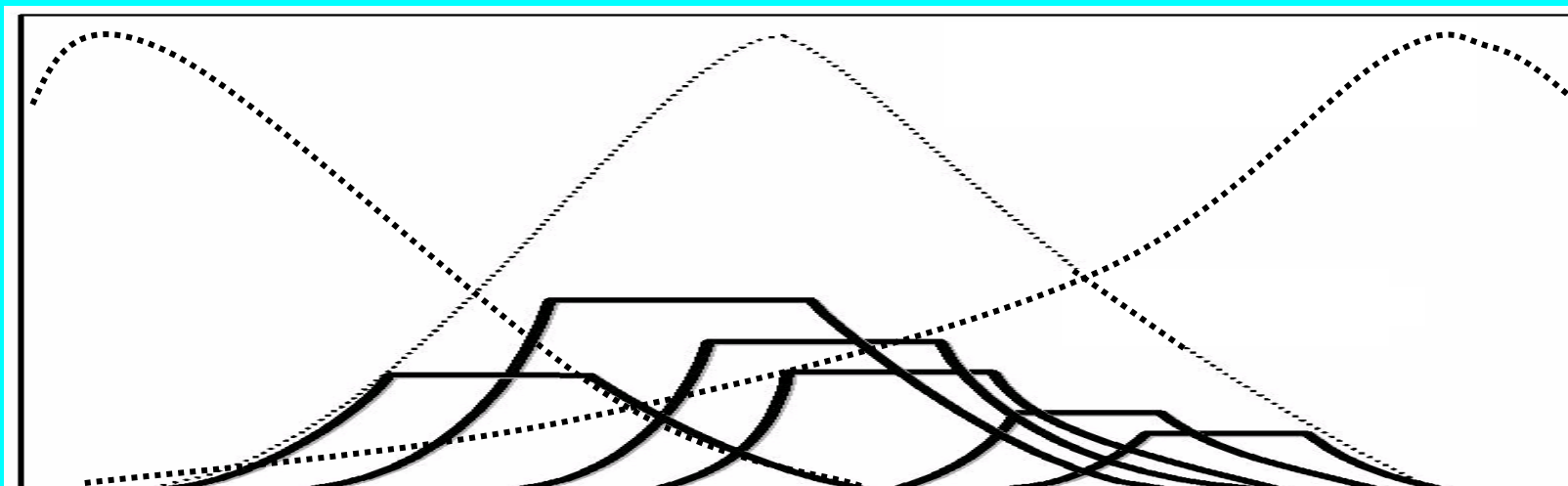


Expanding in a cell



Expanding to neighboring cells

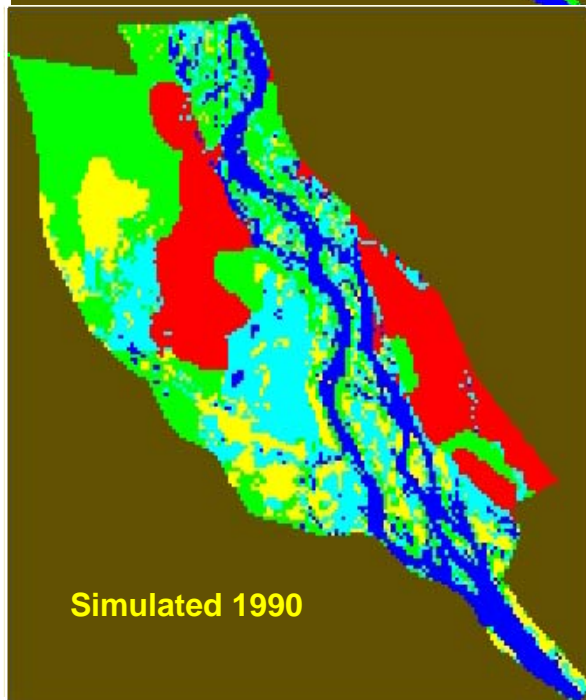
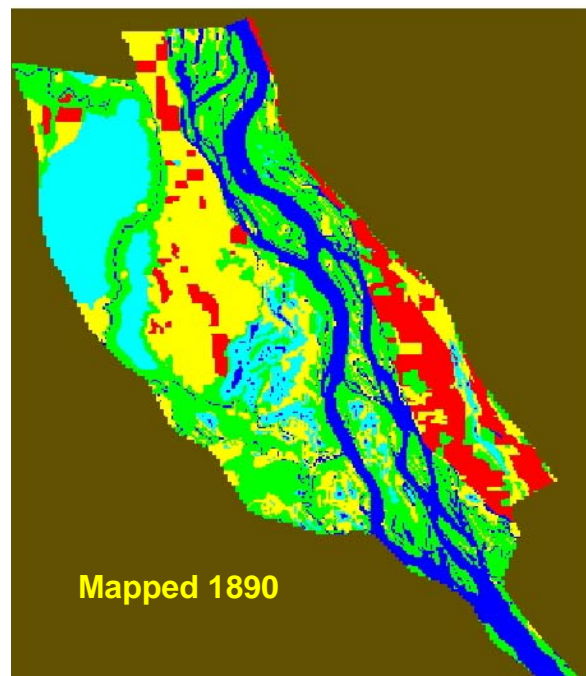
Growth Rates



Low

Environmental Gradient

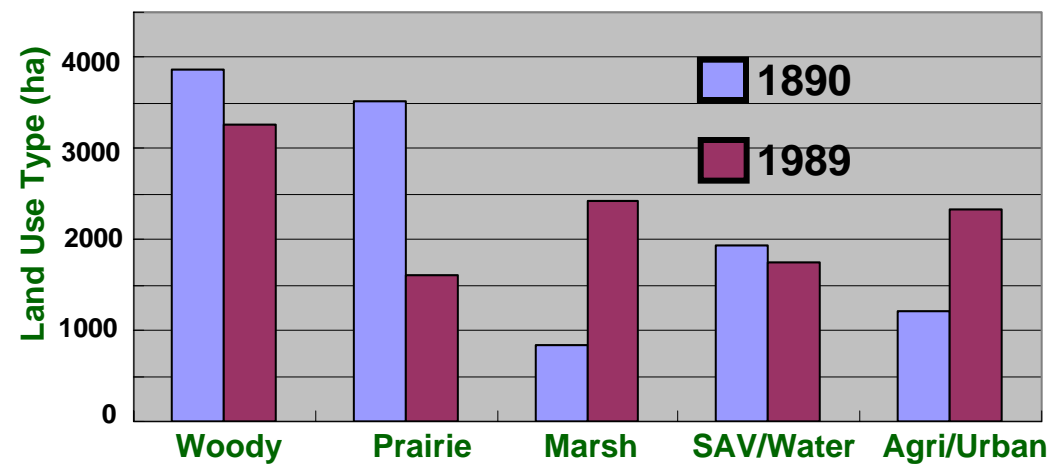
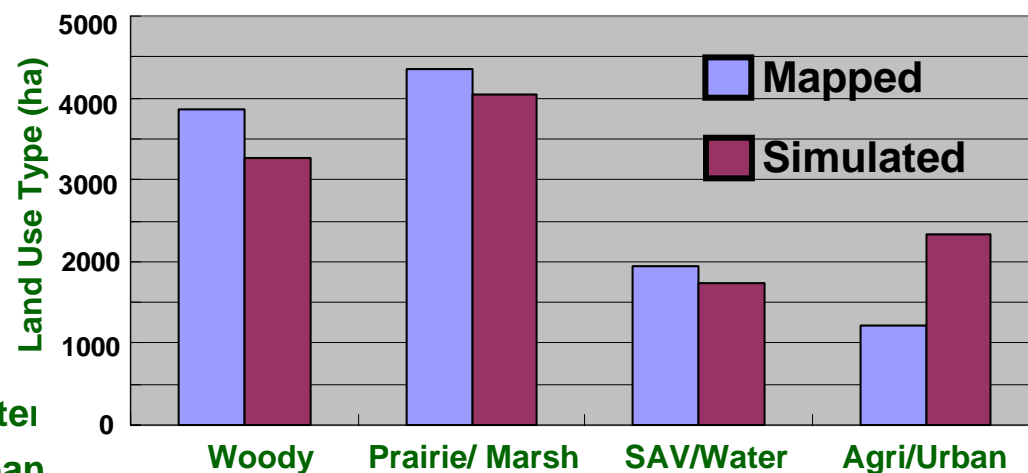
High

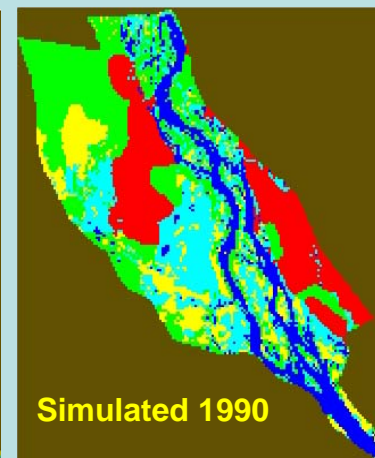
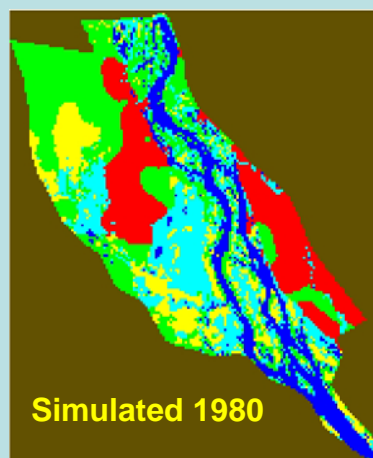
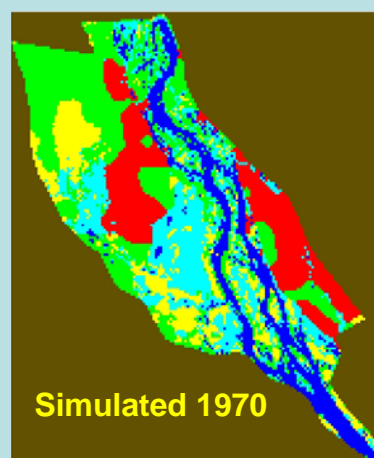
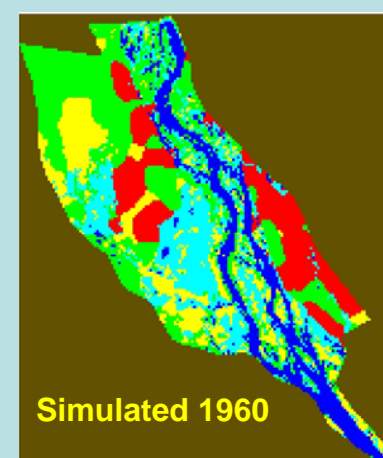
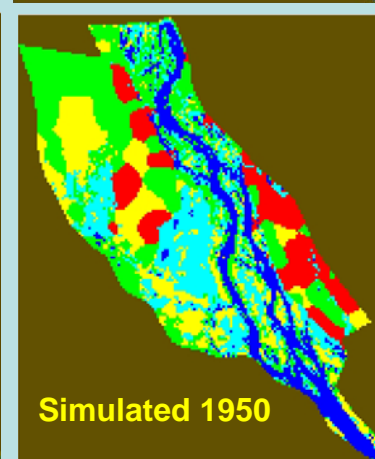
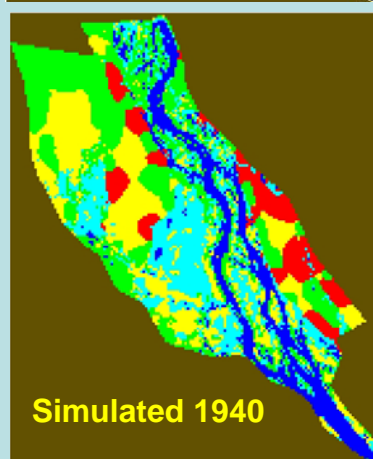
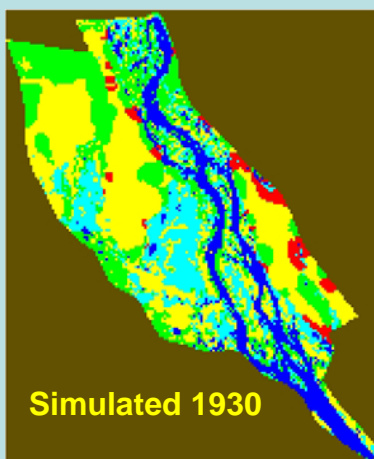
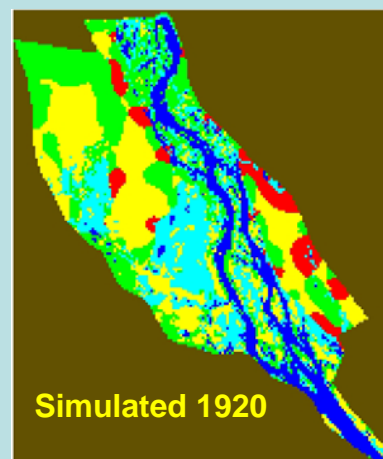
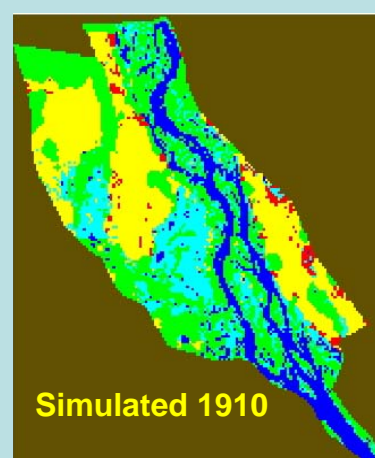
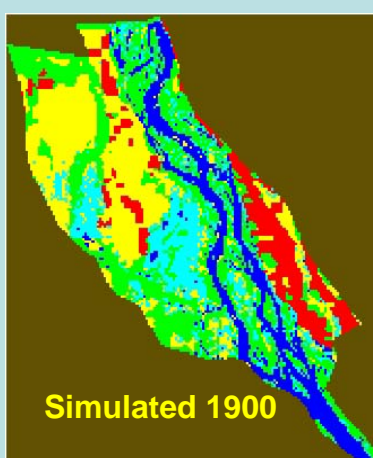
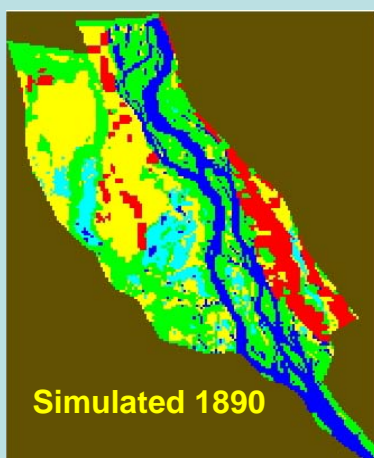
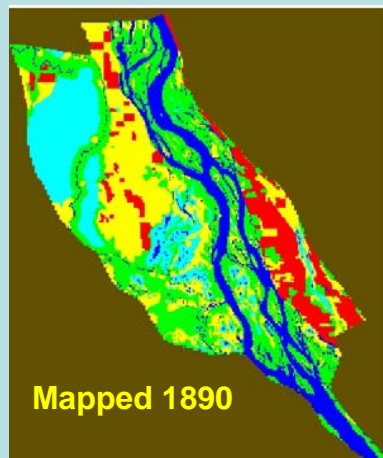


Spatially Explicit CASM

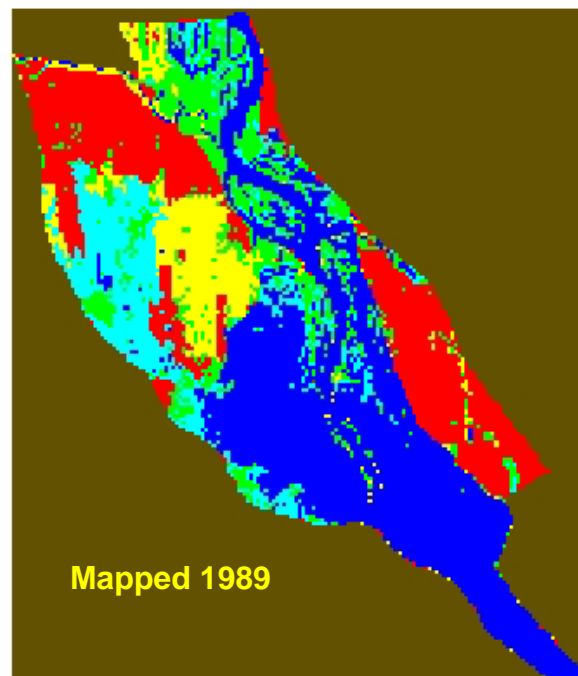
- Vegetation Succession Module
- SAV Simulation Module

Verification





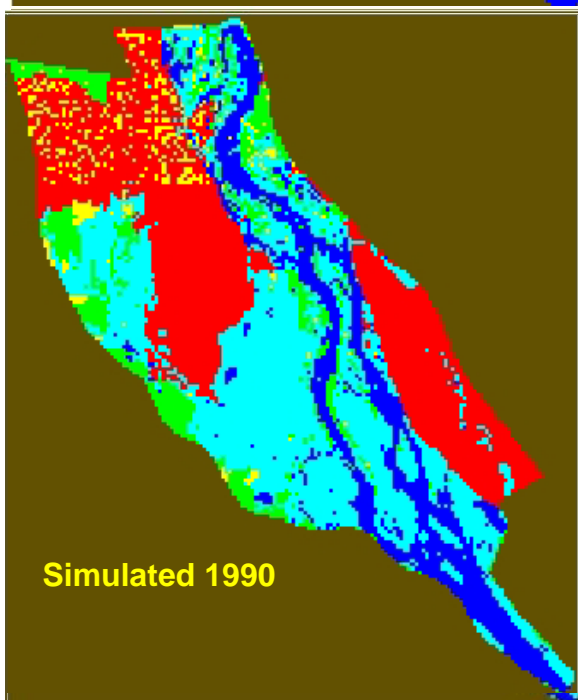
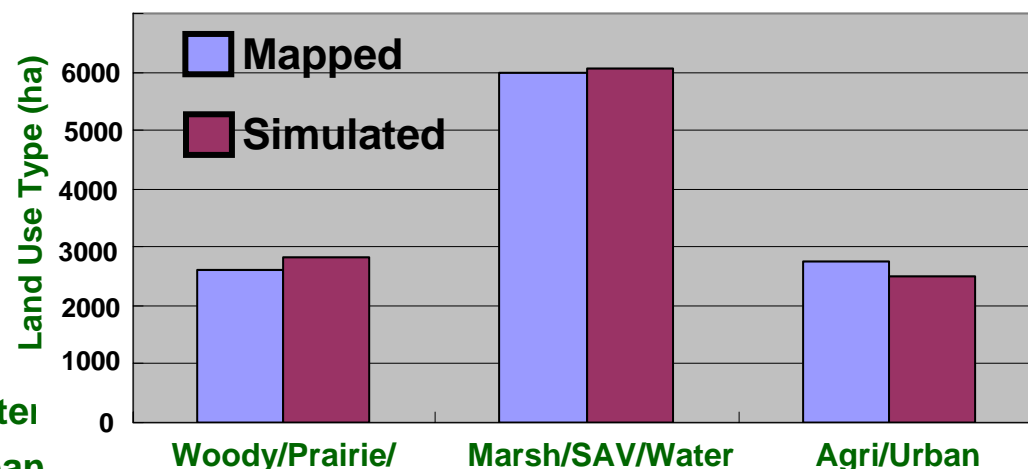
- Woody
- Prairies
- Marsh
- SAV/Water
- Agri/Urban



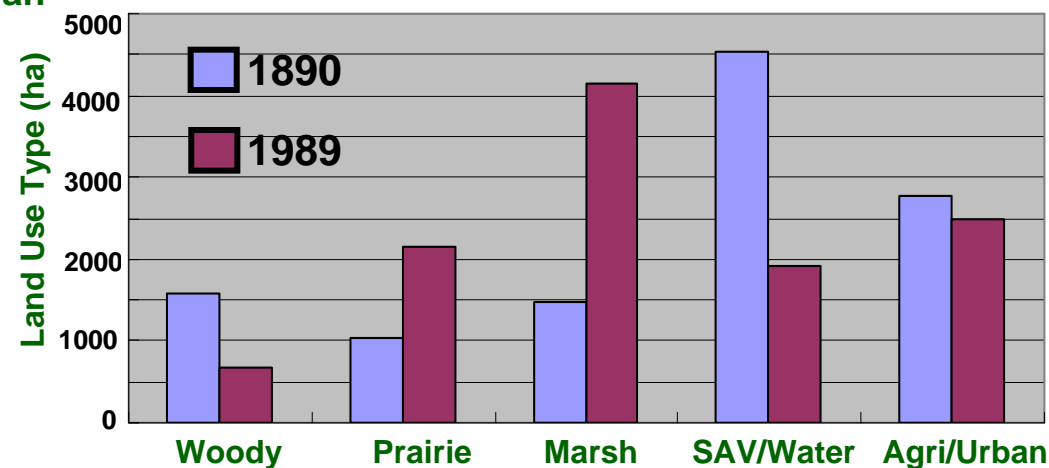
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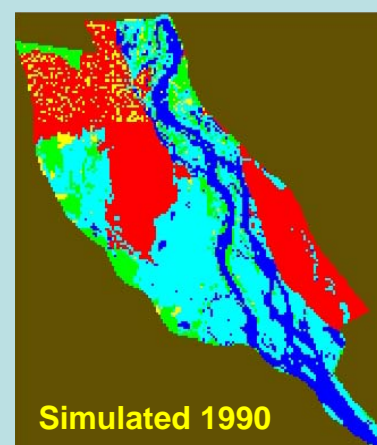
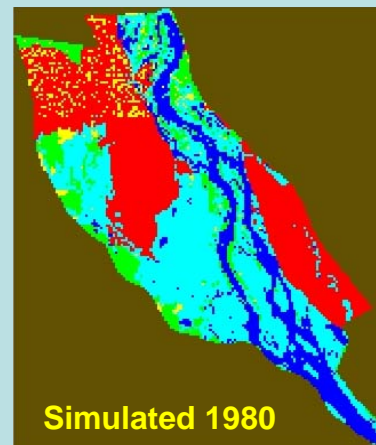
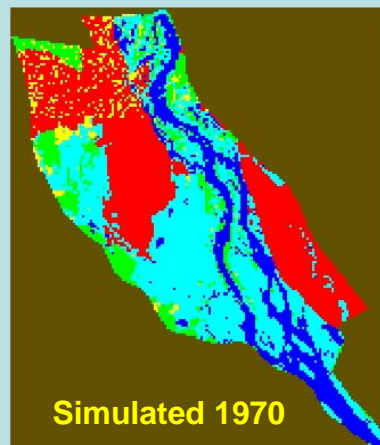
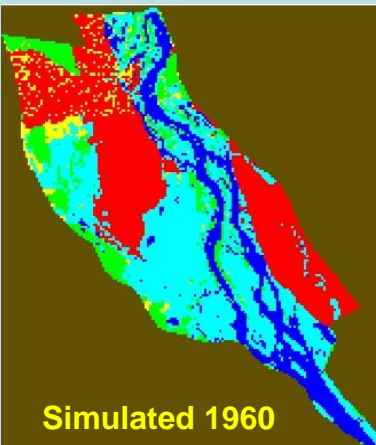
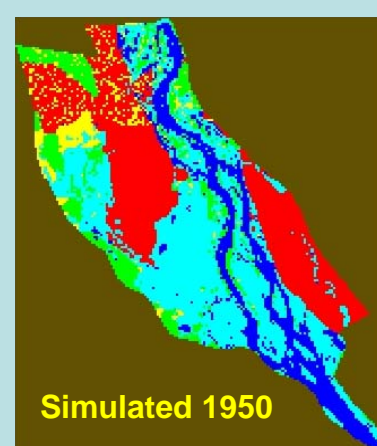
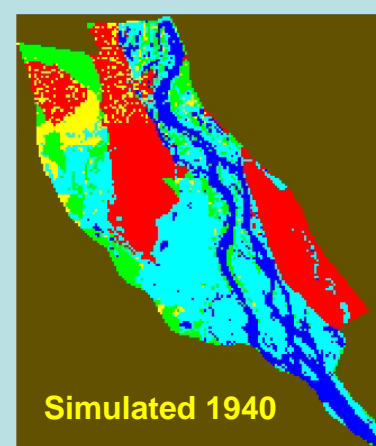
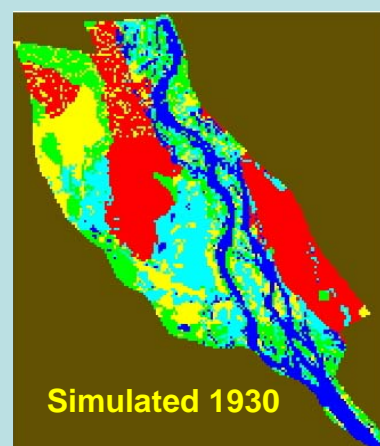
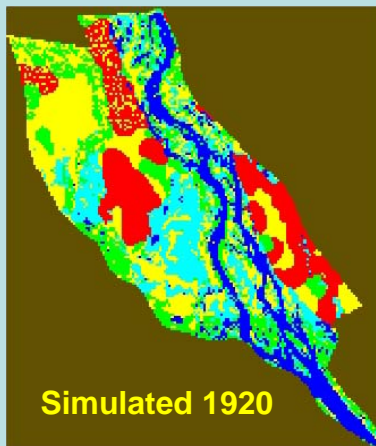
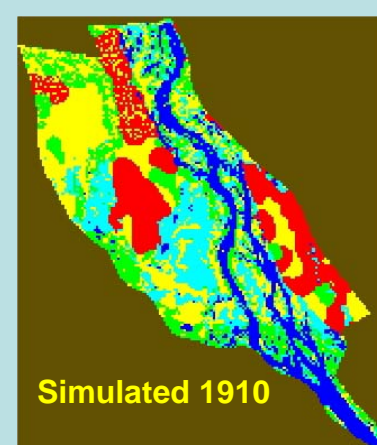
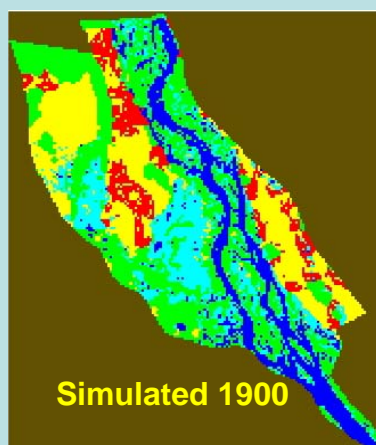
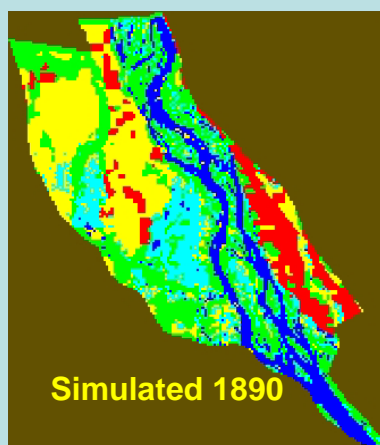
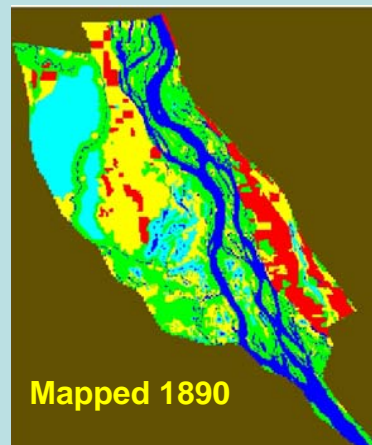
- Vegetation Succession Module
- SAV Simulation Module

Verification

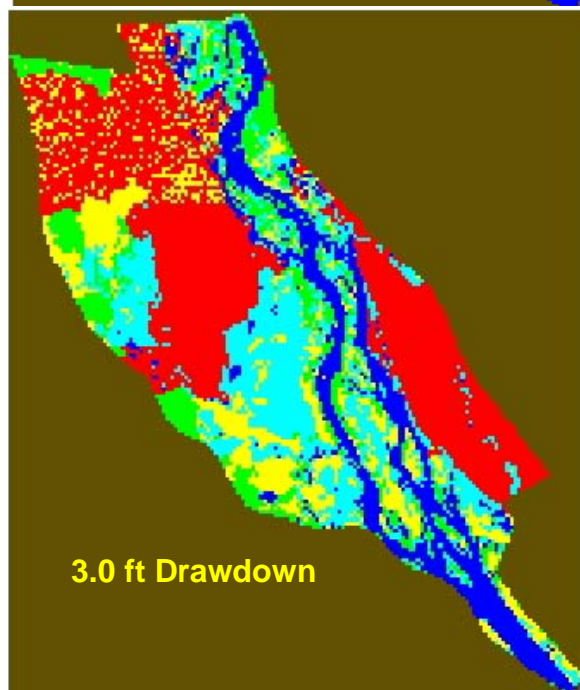
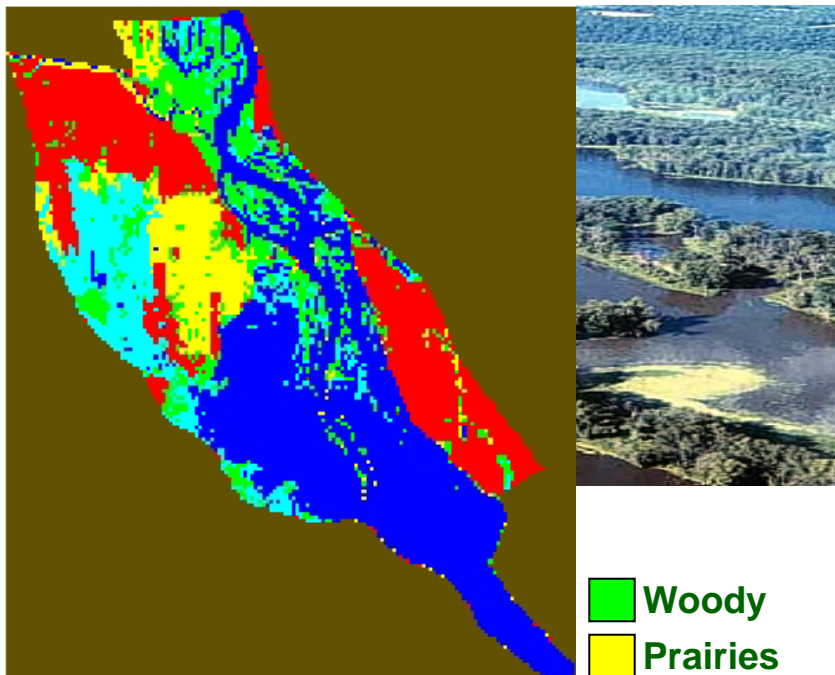


- Woody
- Prairies
- Marsh
- SAV/Water
- Agri/Urban





- Woody
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Spatially Explicit CASM

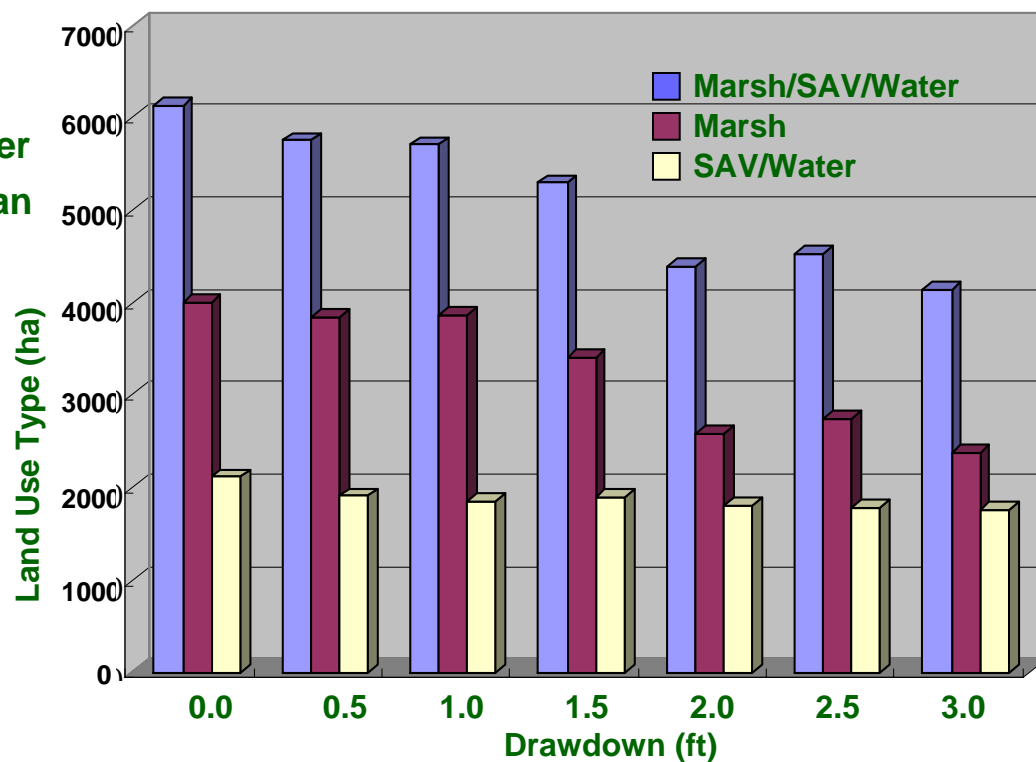
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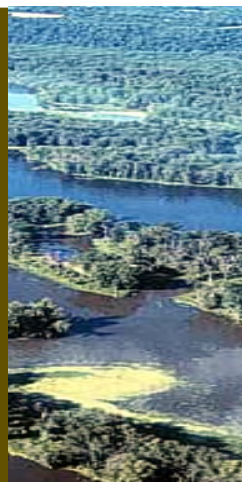
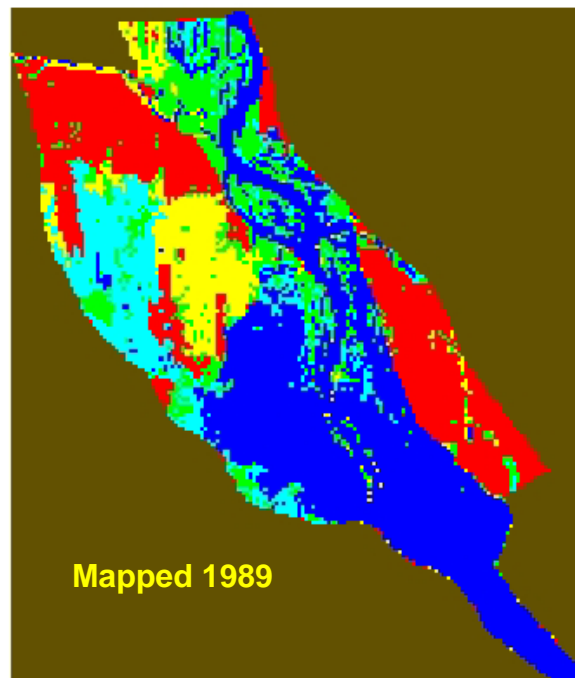
SECASM as a management tool for:

Scenario Simulations

Testing Hypotheses

Performance Measures

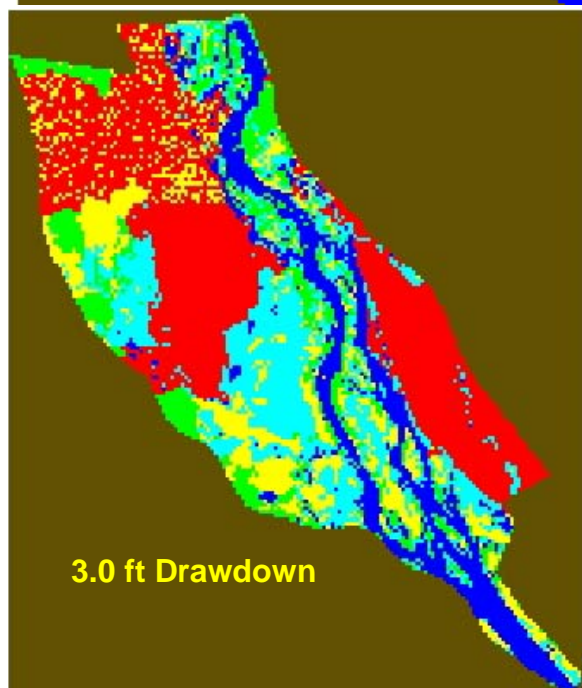
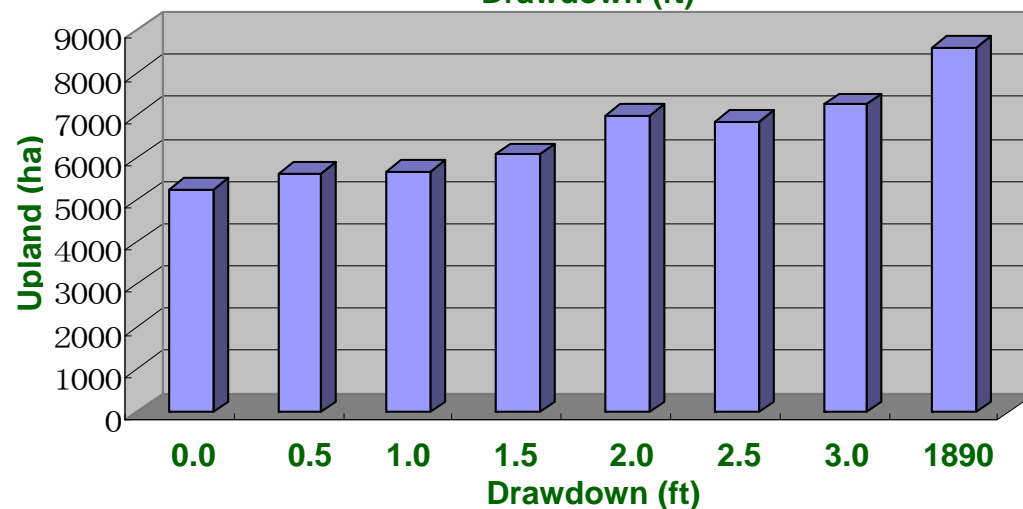
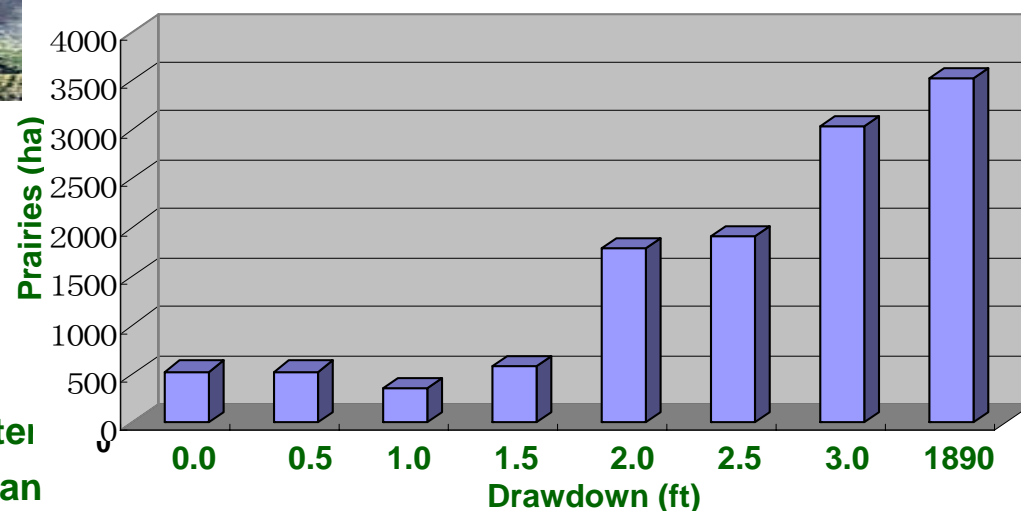




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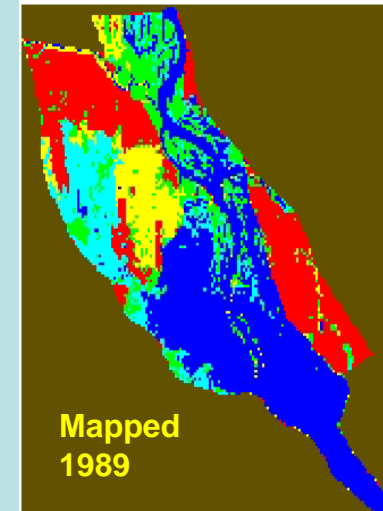
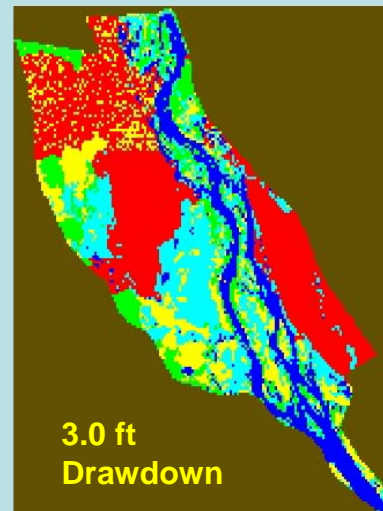
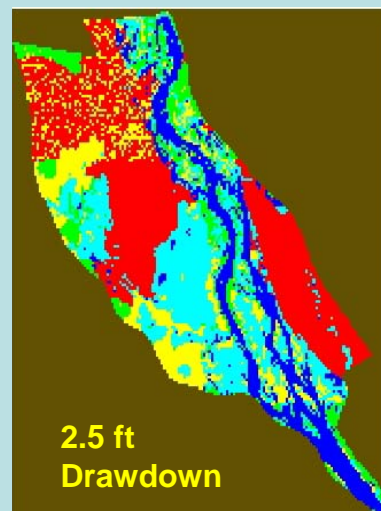
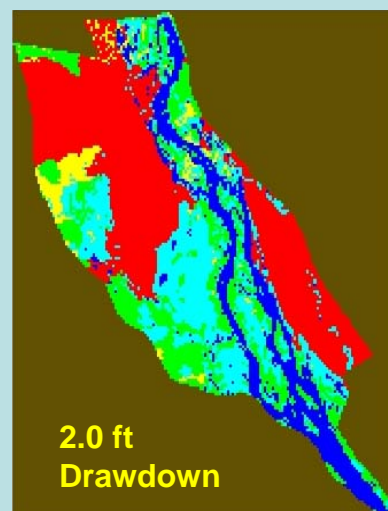
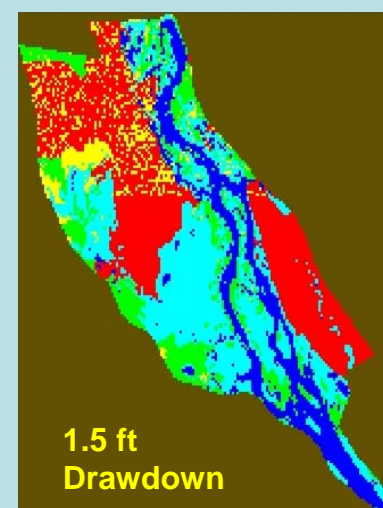
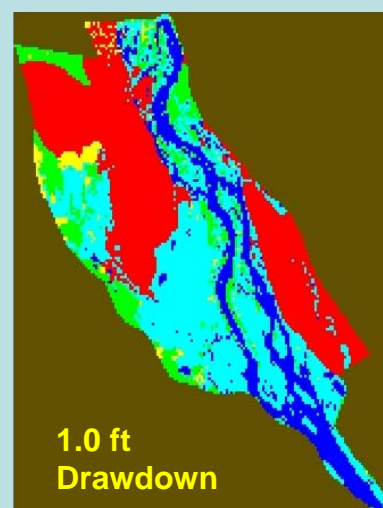
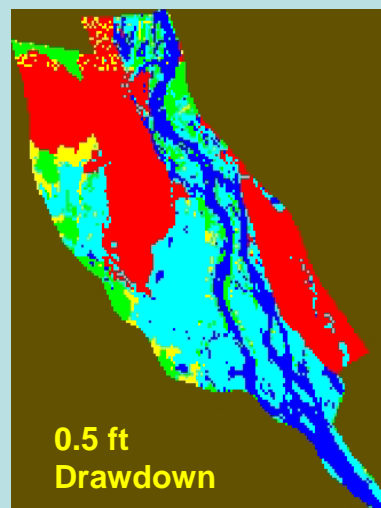
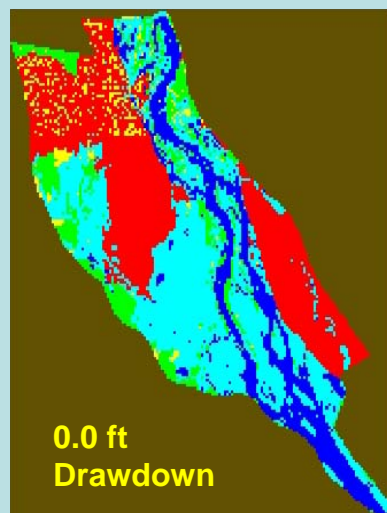
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Scenario Simulations



- Woody
- Prairies
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Scenario Simulations of Drawdown

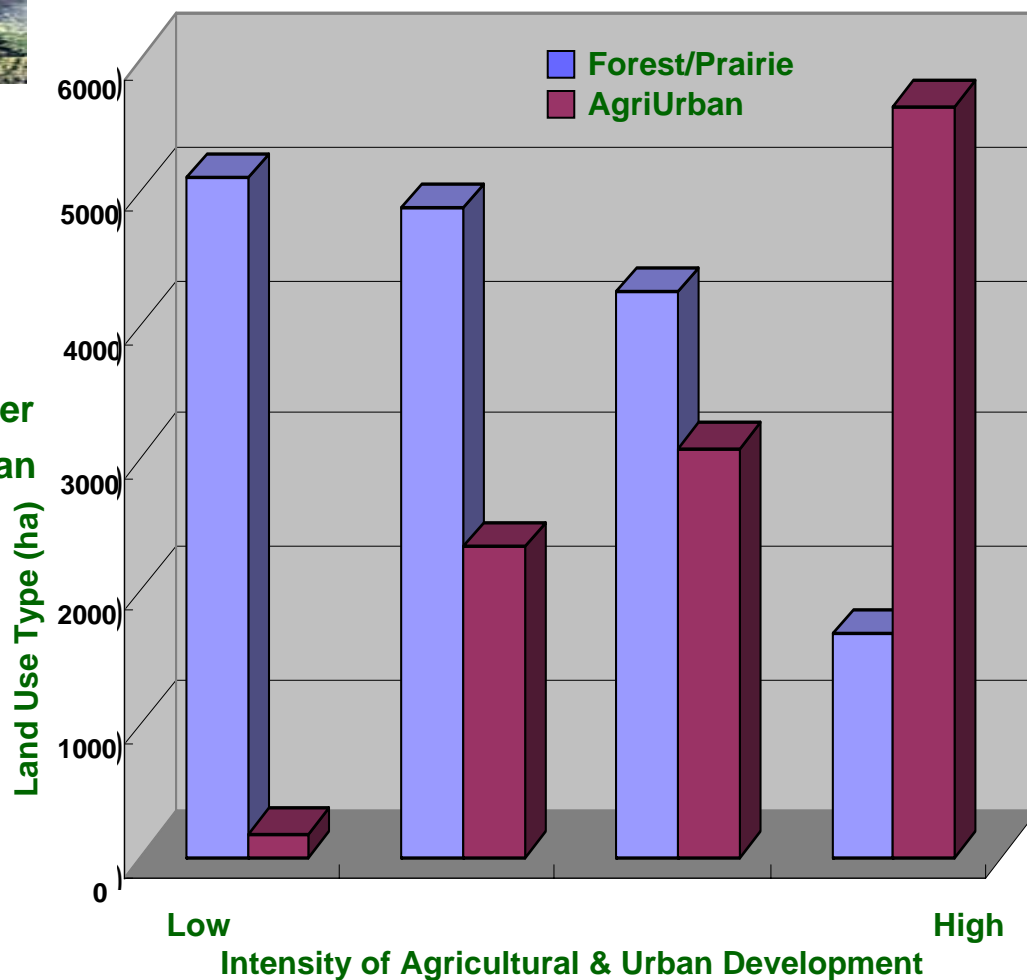
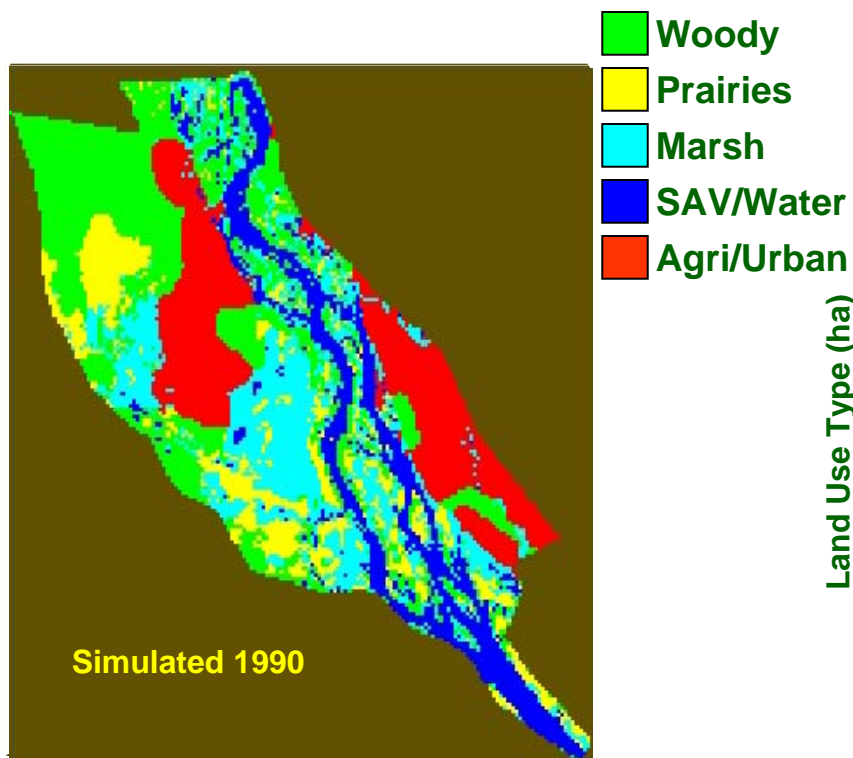




Spatially Explicit CASM

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- SAV Simulation Module

Testing Hypotheses

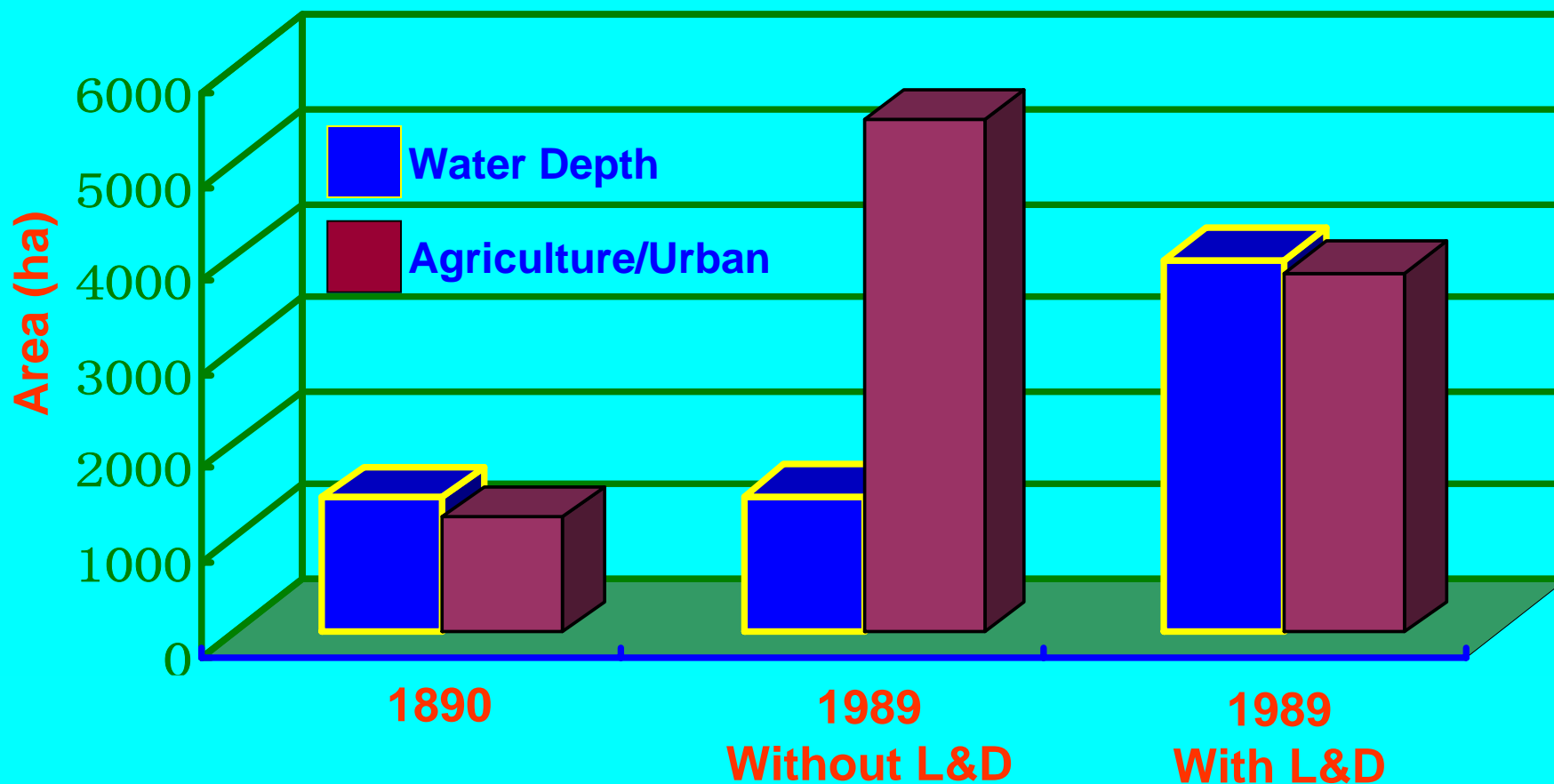




Spatially Explicit CASM

- Vegetation Succession Module
- SAV Simulation Module

Testing Hypotheses





Spatially Explicit CASM

•Landscape Pattern Analyst

Performance Measures

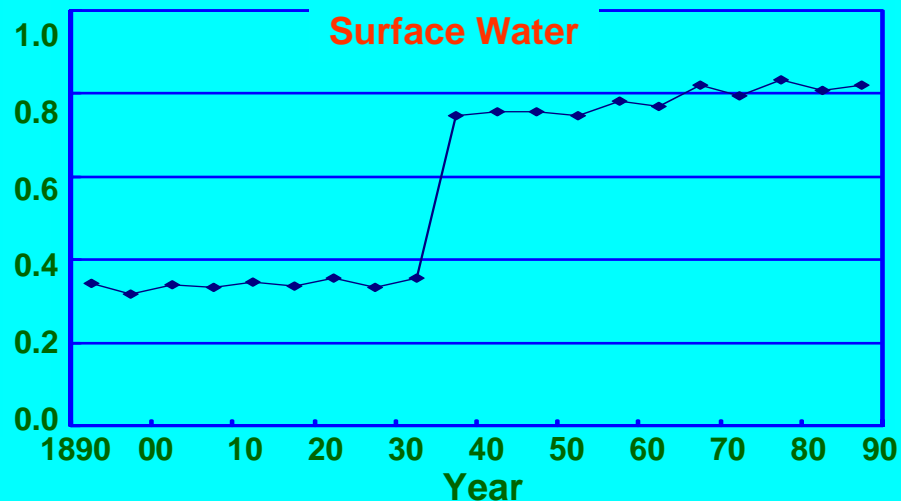
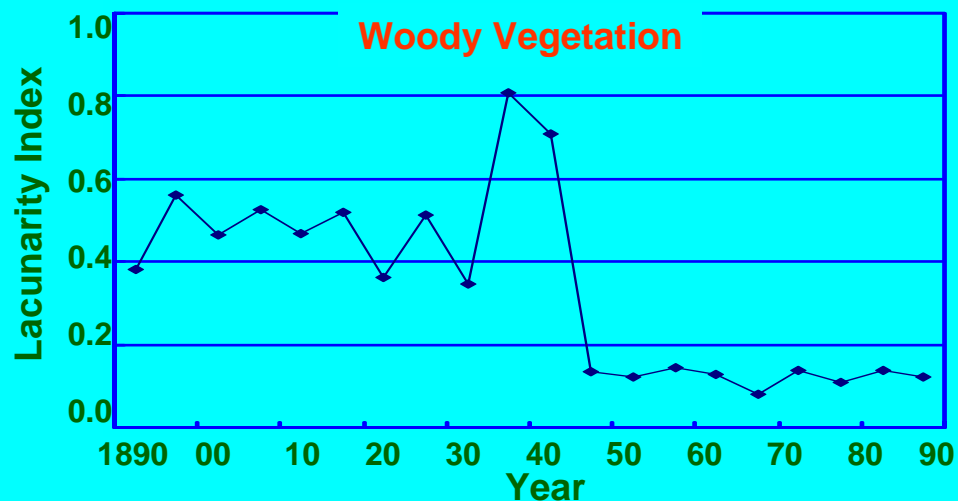
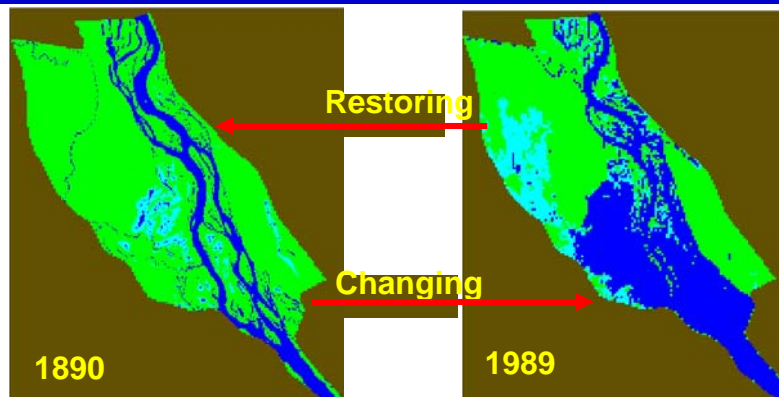
Maintain and sustain the landscape patterns, such as floodplain, river channel, slough, delta, and lakes including river flows and connectivity.

“Lacuna” means holes and hence lacunarity is a measure of “holeness” or “connectiveness”.

Lacunarity Index (λ) is expressed as:

$$\lambda(r) = \Sigma S^2 Q(S, r) / [Q(S, r)]^2$$

where ($r=2$) is the size of a gliding box across a landscape, S is the number of cells of a given vegetation type within the gliding box, and $Q(S, r)$ is the corresponding frequency of a given vegetation type occurring in the gliding box. Two attributes were recognized, woody vegetation and pounding water. High value means high connectivity. Low value means more fragmented.



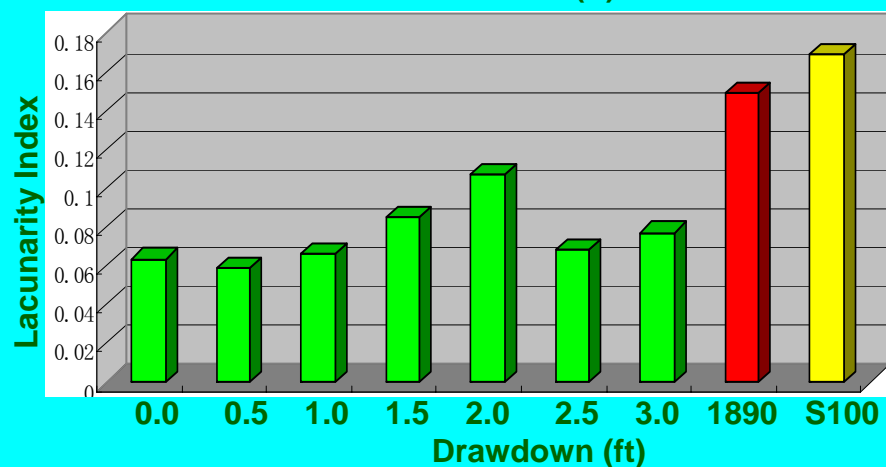
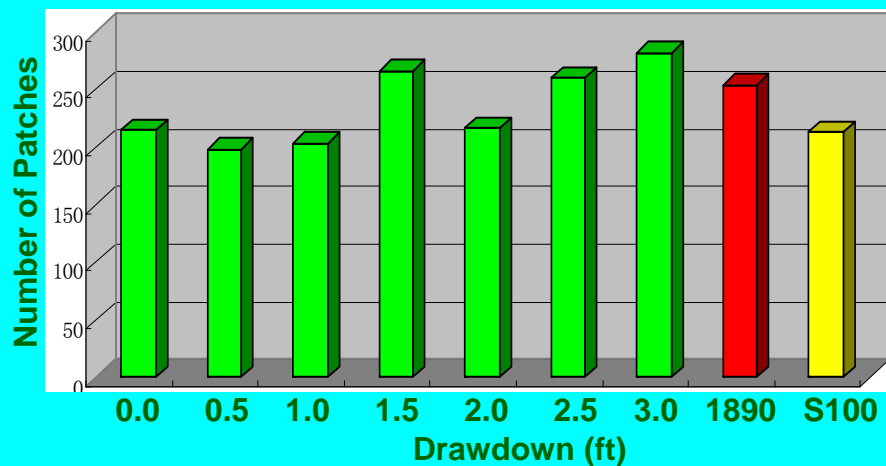
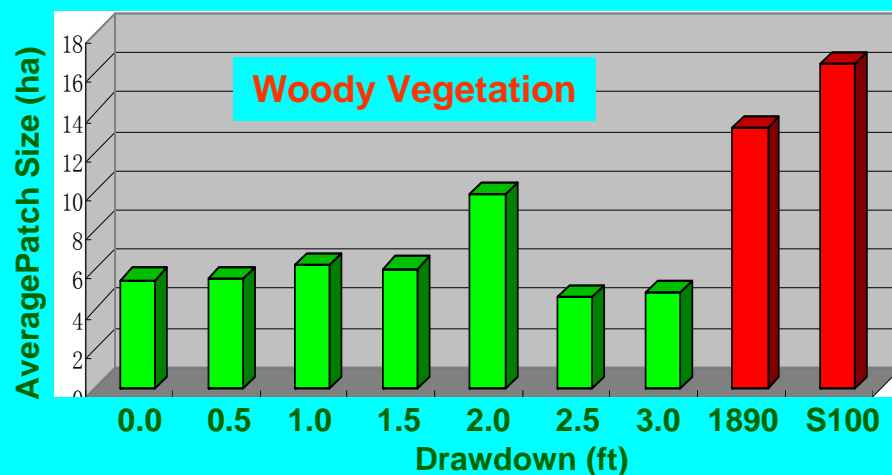
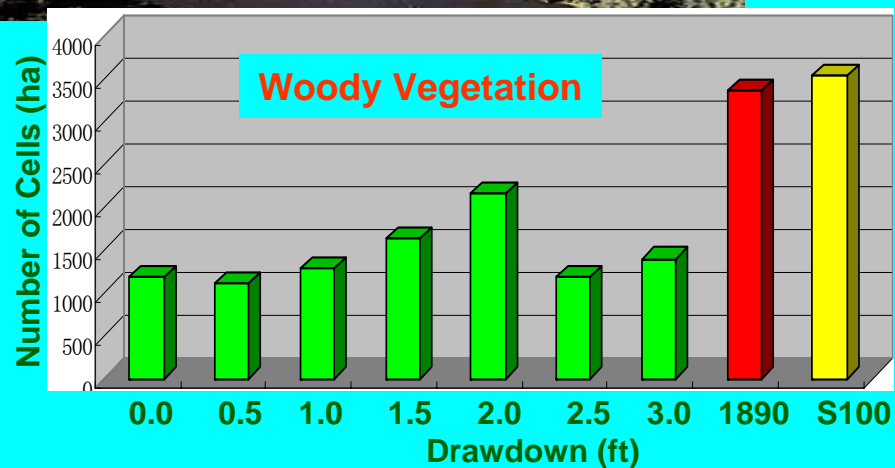


Spatially Explicit CASM

•Landscape Pattern Analyst

Performance Measures

- Measuring the success?
- Quantifying?
- Evaluating restoration alternatives?



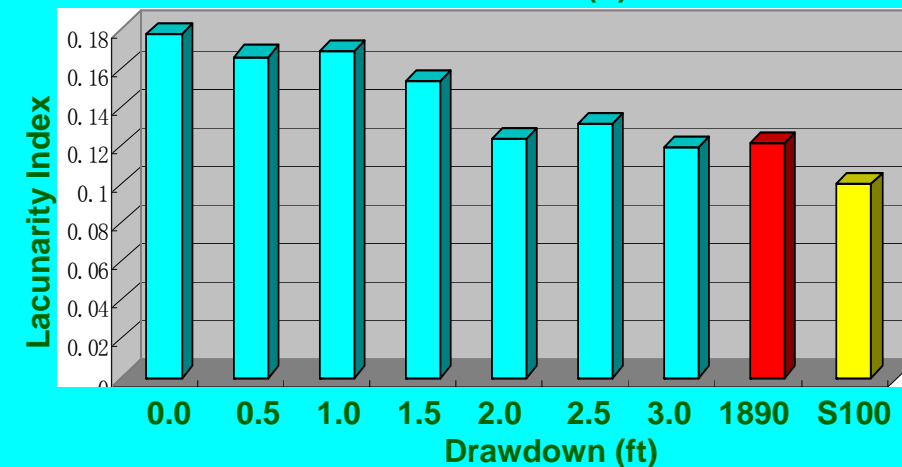
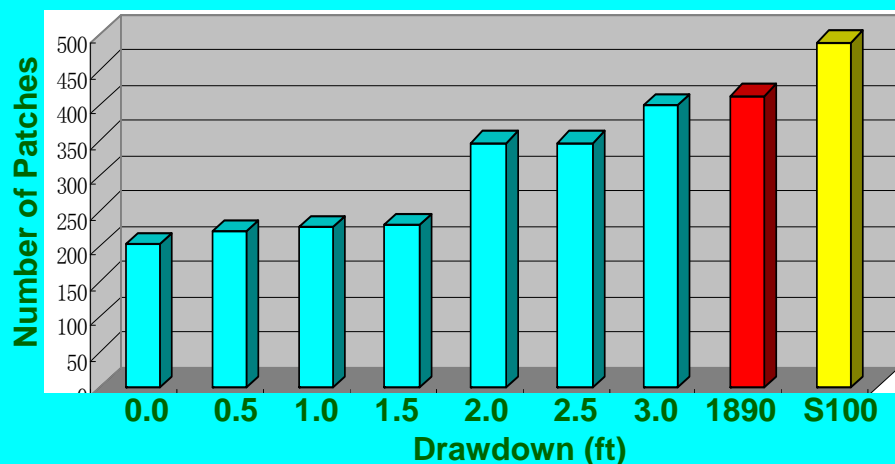
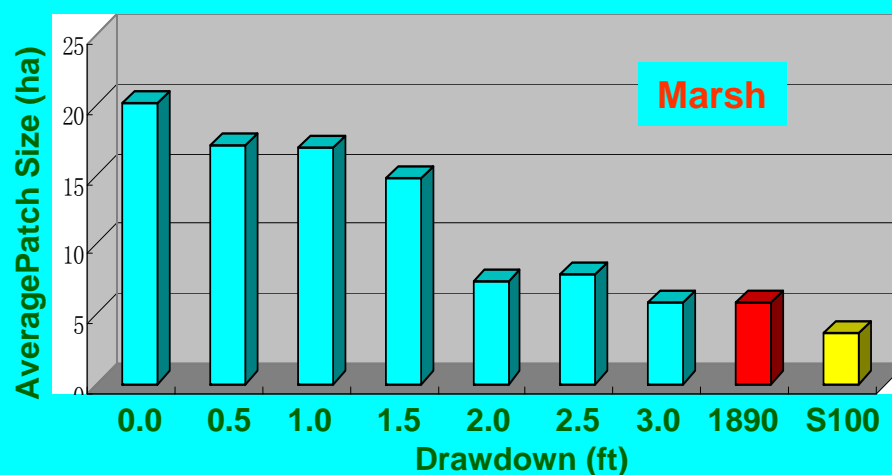
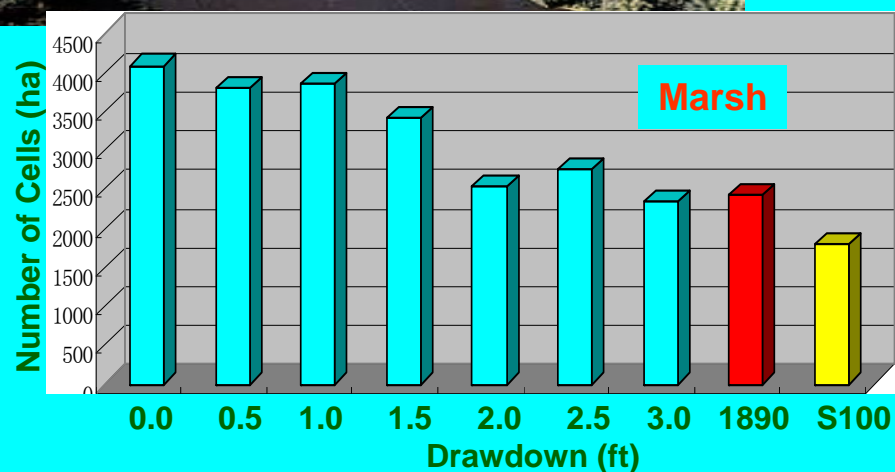


Spatially Explicit CASM

•Landscape Pattern Analyst

Performance Measures

- Measuring the success?
- Quantifying?
- Evaluating restoration alternatives?



Thank you!

