Presented at

Great Rivers Reference Condition Workshop

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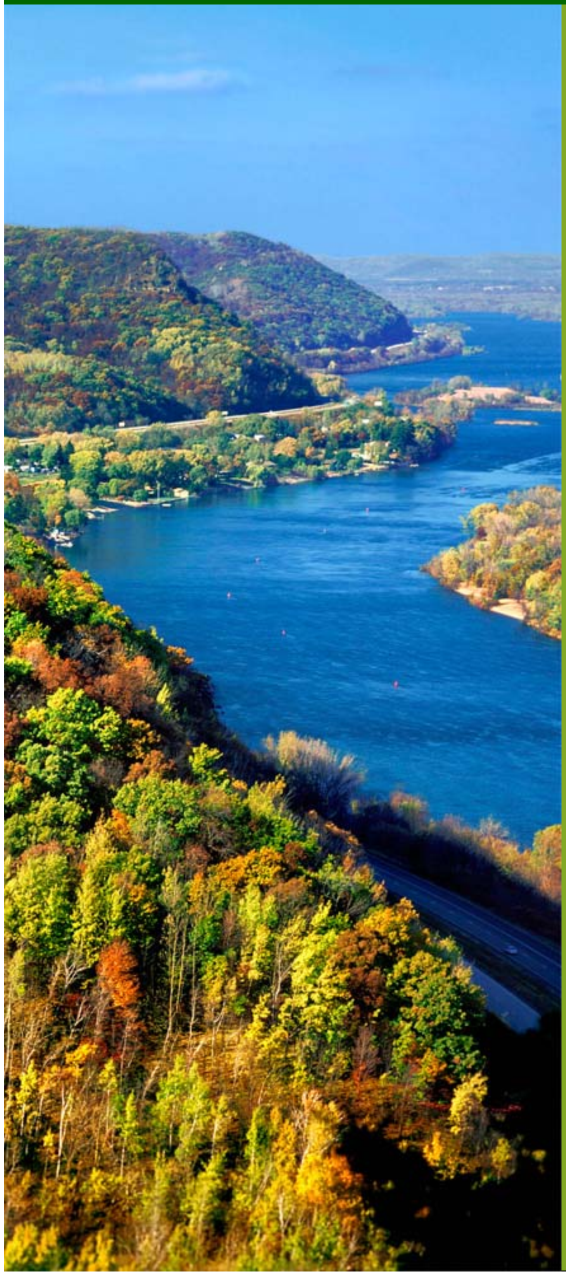
Sponsored by

The U.S. Environmental Protection Agency and The Council of State Governments

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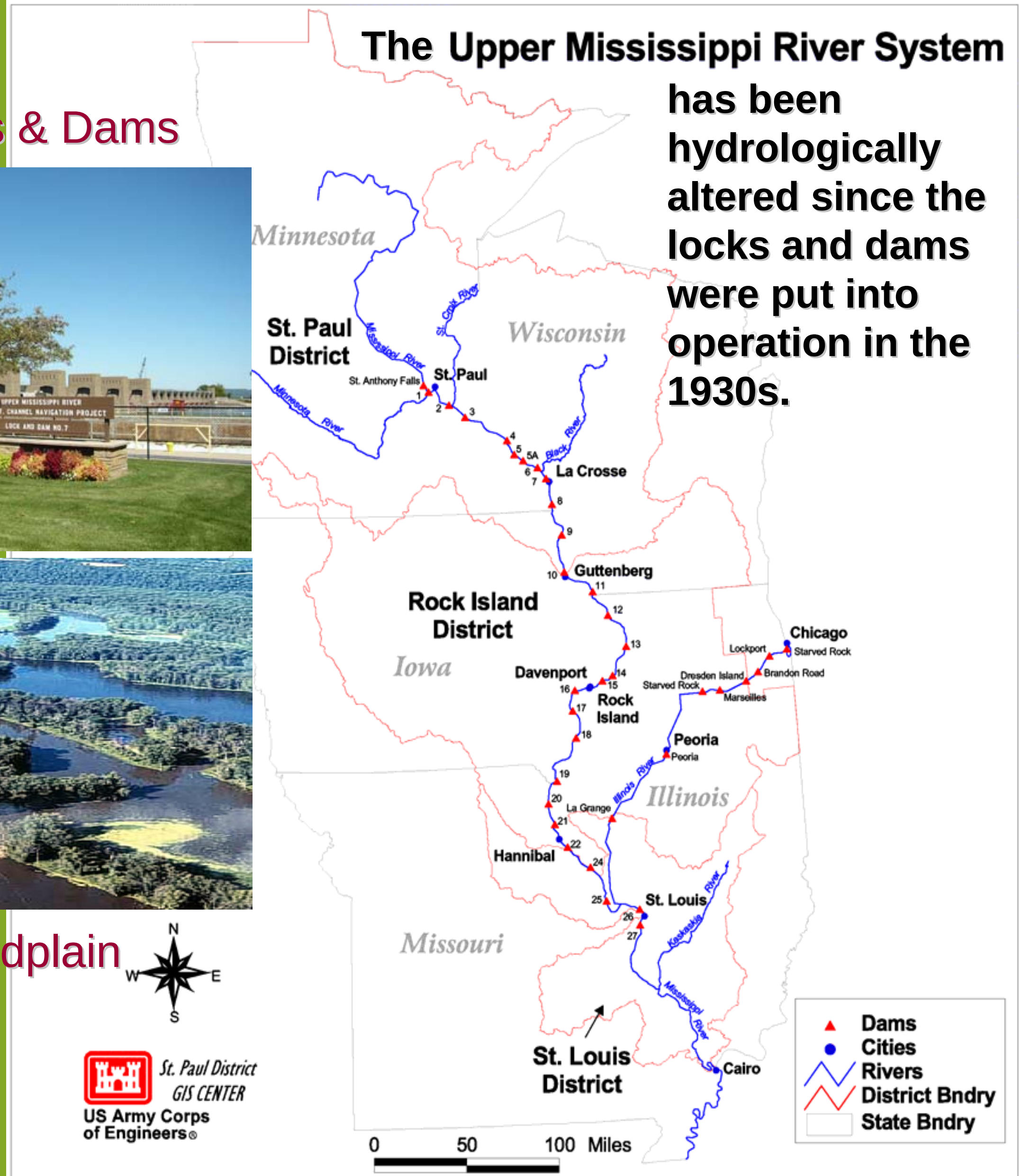
Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River

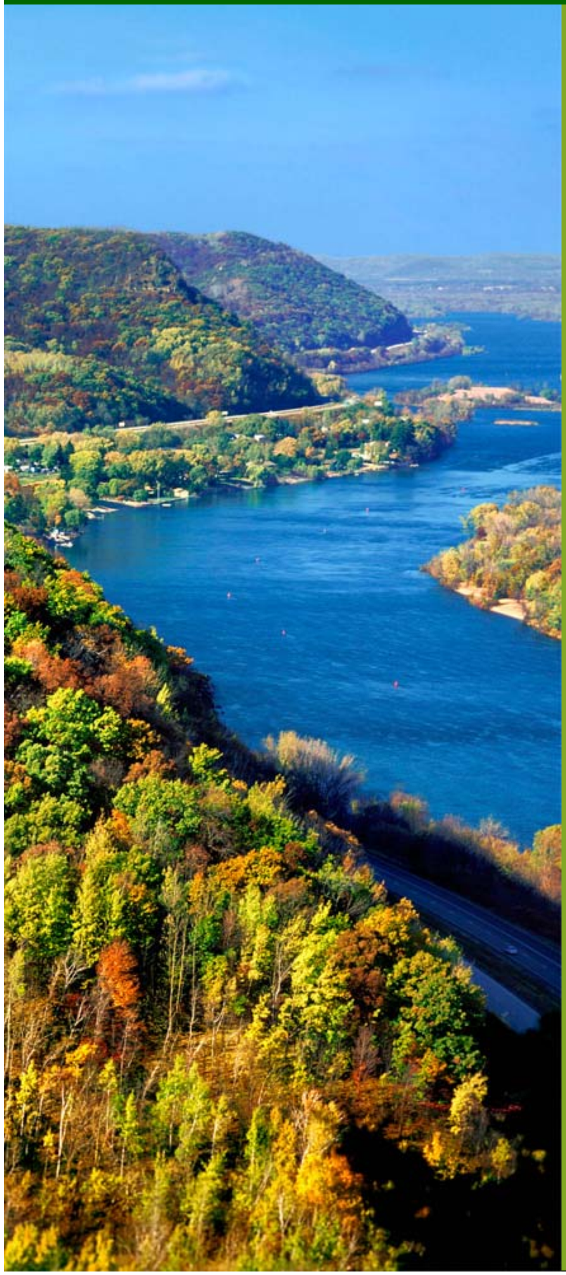
The Locks & Dams

The Floodplain

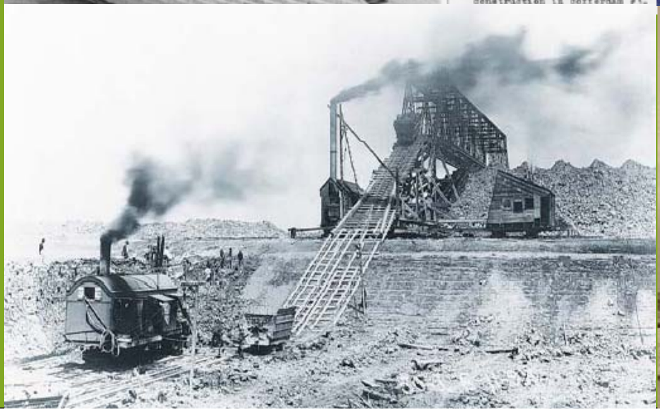
The Upper Mississippi River System has been hydrologically altered since the locks and dams were put into operation in the 1930s.

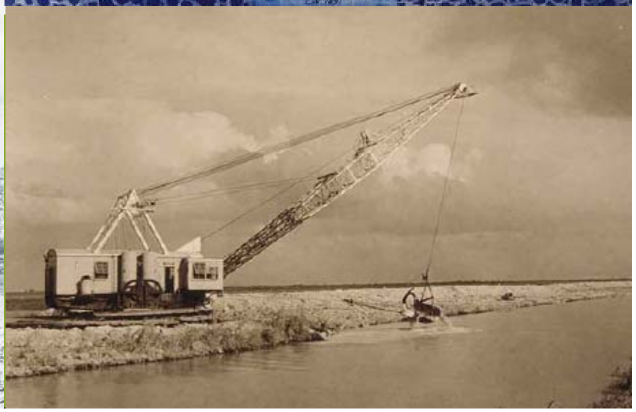


Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River



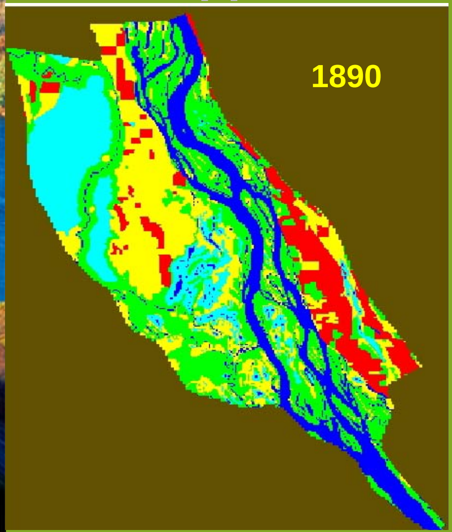
The historical conditions can be used to define objectives in the restoration and management of the Upper Mississippi River. Derivation of desired or reference conditions must also recognize that the system now consists of a series of connected impoundments that are regulated to facilitate commercial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



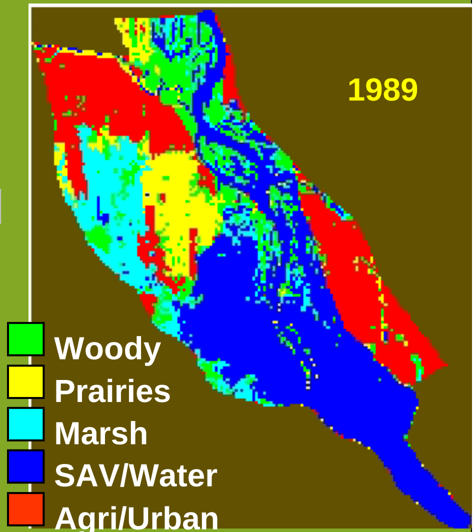


Models Supporting a Reference/Desired Future Condition for Ecosystem Restoration of the Upper Mississippi River

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.

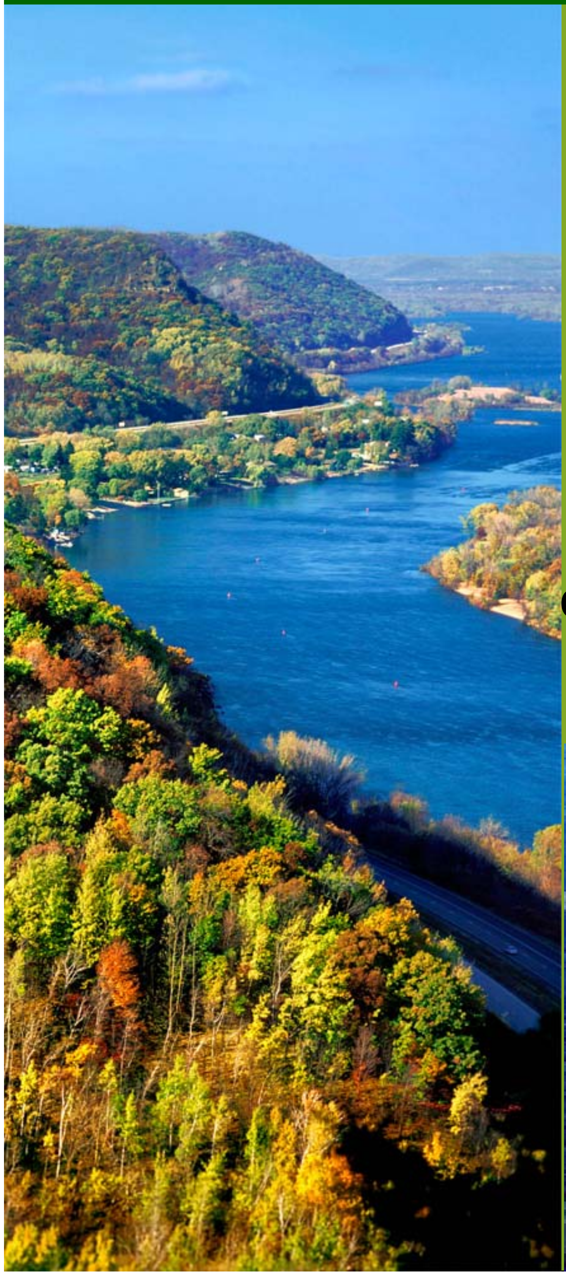


As a result, landscape patterns have been changed in historical floodplains and large open water areas were created above the dams.



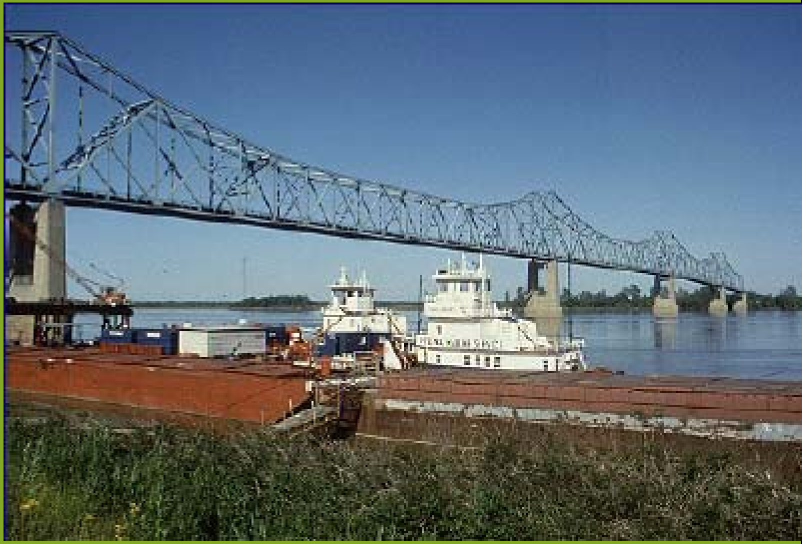
Islands characterized by woody vegetation experienced unusually prolonged unfavorable hydrologic conditions and were eliminated from many areas of the river.

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



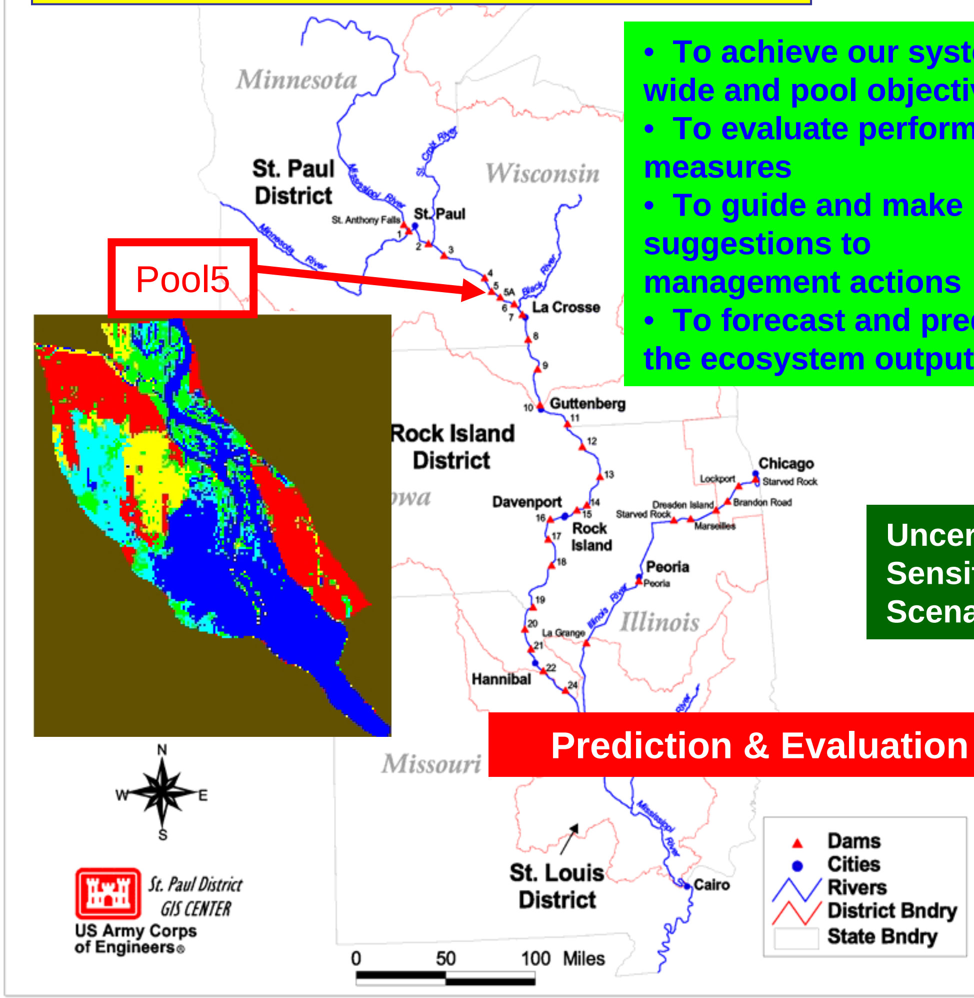
Congress now recognizes the UMRS as a nationally significant ecosystem:

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

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

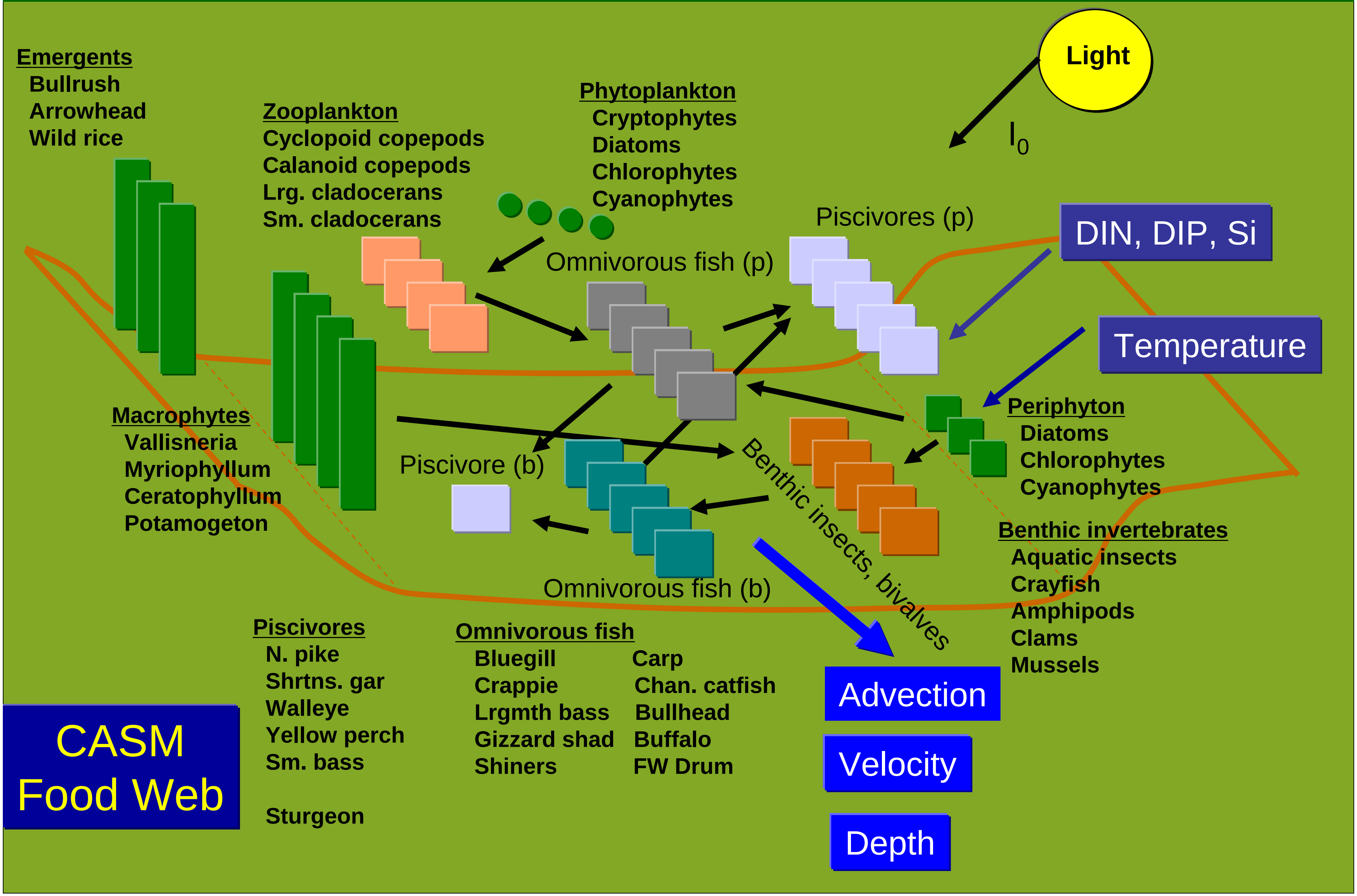
Uncertainty Analysis
Sensitivity Analysis
Scenario Analysis

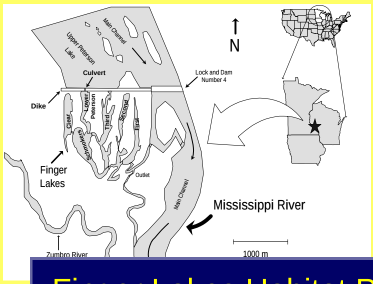
Prediction & Evaluation of Performance Measures for the Desired Goals

- 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

Model Simulation: Verification Calibration Validation

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



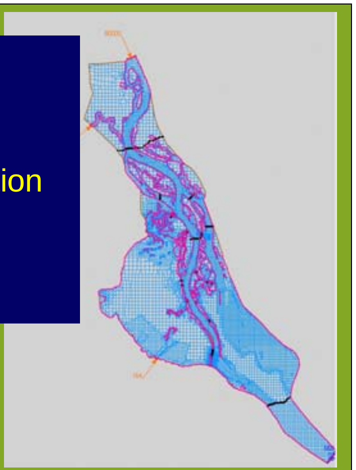


Finger Lakes Habitat Project
Johnson et al. 2000, UMESC
- Food web structure
- Water quality parameters
- Population sizes

Integration...

H&H Integration

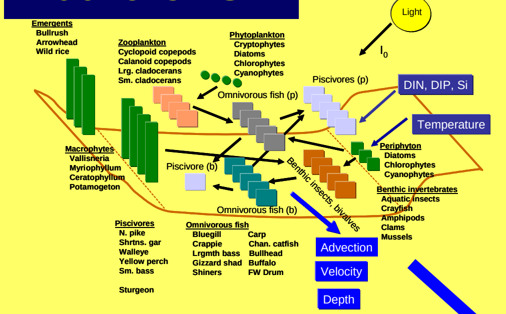
- Pool 5 RMA simulations
  by Hendrickson et al., St. Paul District
  - steady-state velocity, depth, elevation
- Development of ADH model for
  Pool 5 (Berger et al., ERDC)
  - dynamic conditions



LTRMP

- water quality data
- food web data

Pool 5 CASM



Delong et al.
Food web studies
Winona State Univ.

Rock Island
St. Paul
St. Louis
ERDC, Vicksburg

Cumulative Effects Study

- habitat distribution
- planform information
- ecological guilds

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)

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

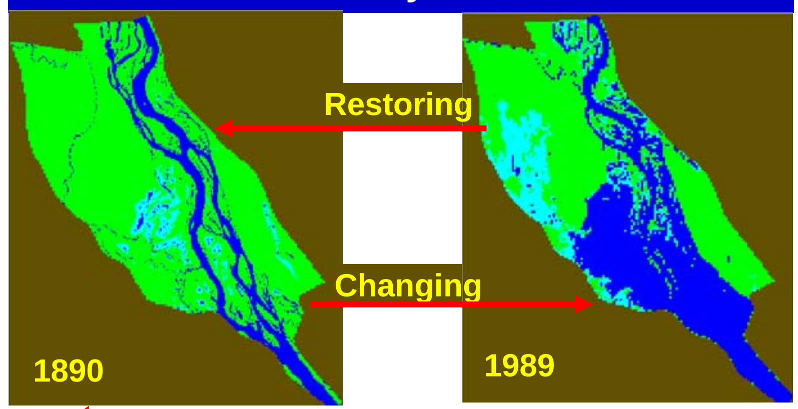
Spatially Explicit CASM for Simulation and Evaluation of the Restoration Success in Achieving Desired Future Conditions

•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 patters, such as floodplain, river channel, slough, delta, and lakes including river flows and connectivity.

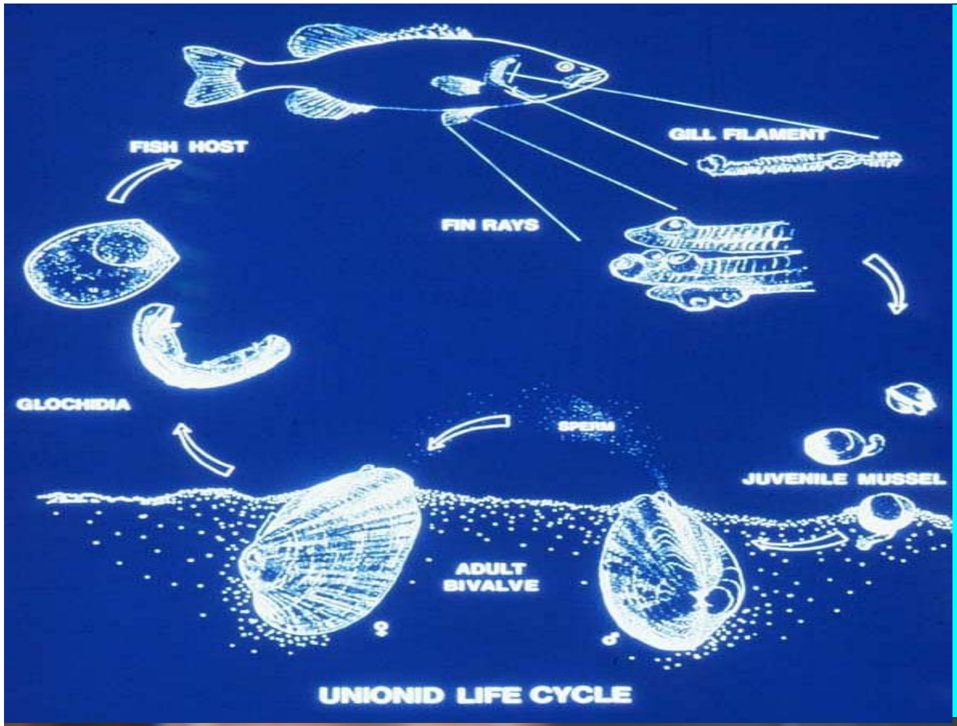


•Mussel Module
•Fish Module

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.

•Water Quality Module

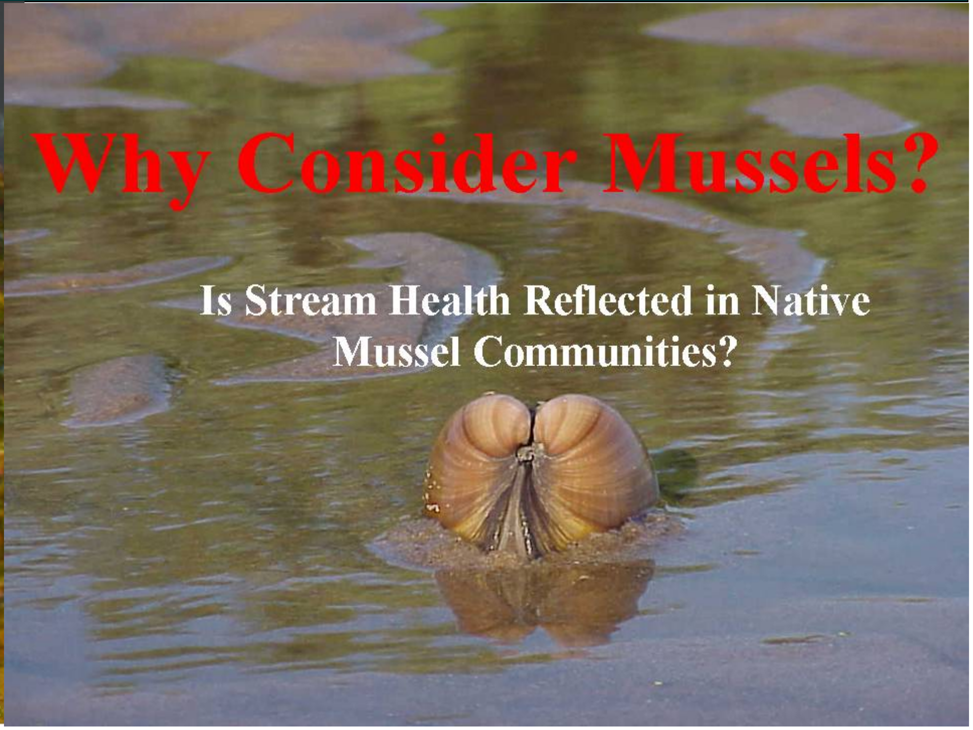
Nutrients (N &P)
Toxicity
Sediment

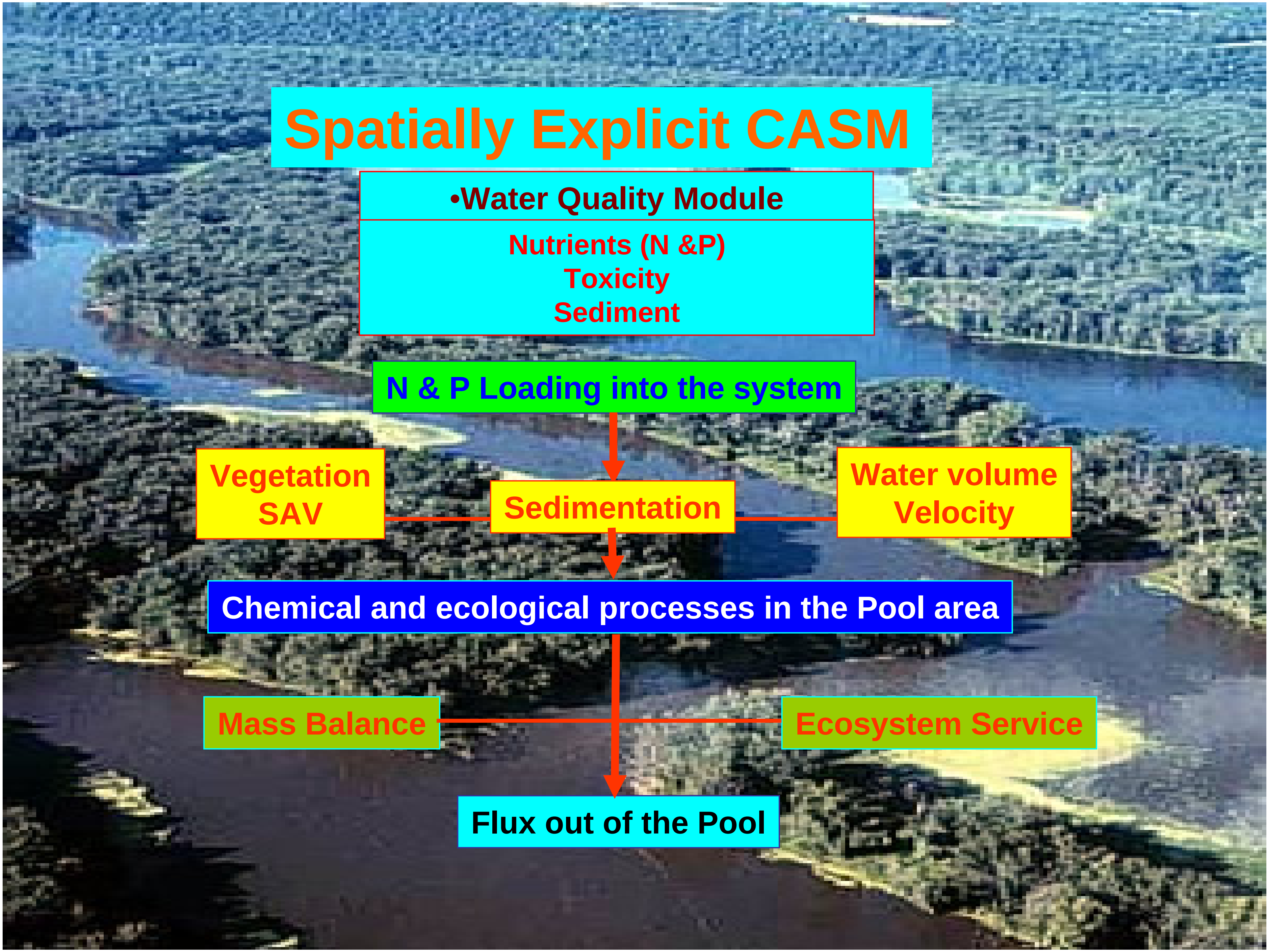


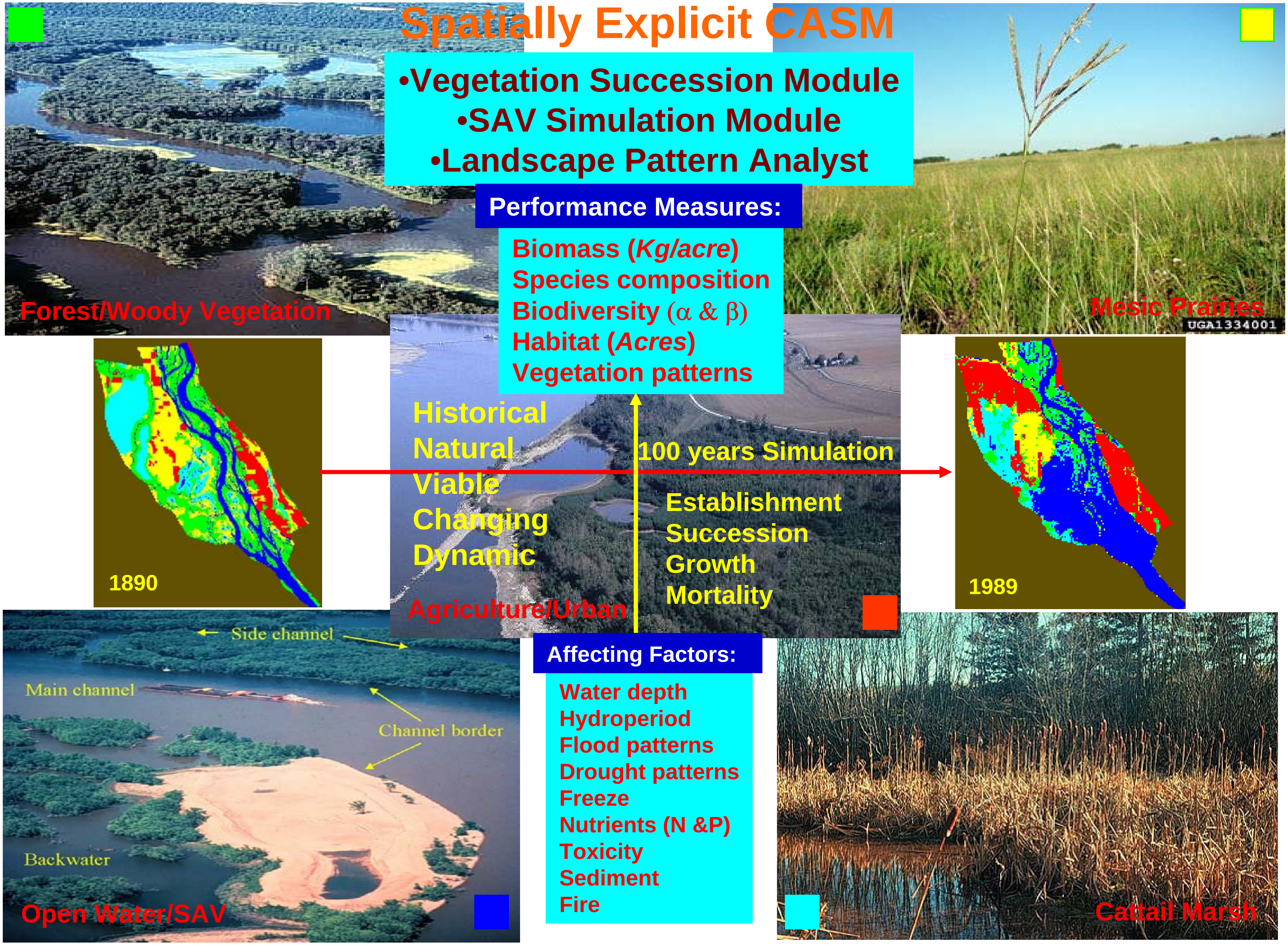
Spatially Explicit CASM

- 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.



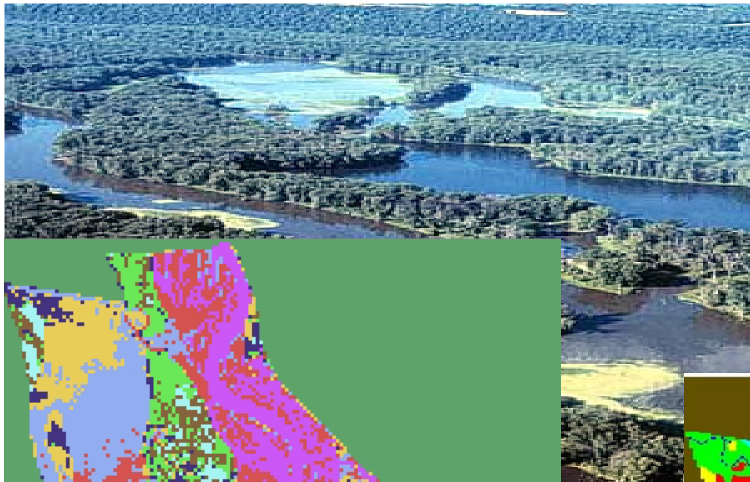

Spatially Explicit CASM
•Water Quality Module
Nutrients (N &P)
Toxicity
Sediment
N & P Loading into the system
Vegetation
SAV
Sedimentation
Water volume
Velocity
Chemical and ecological processes in the Pool area
Mass Balance
Ecosystem Service
Flux out of the Pool

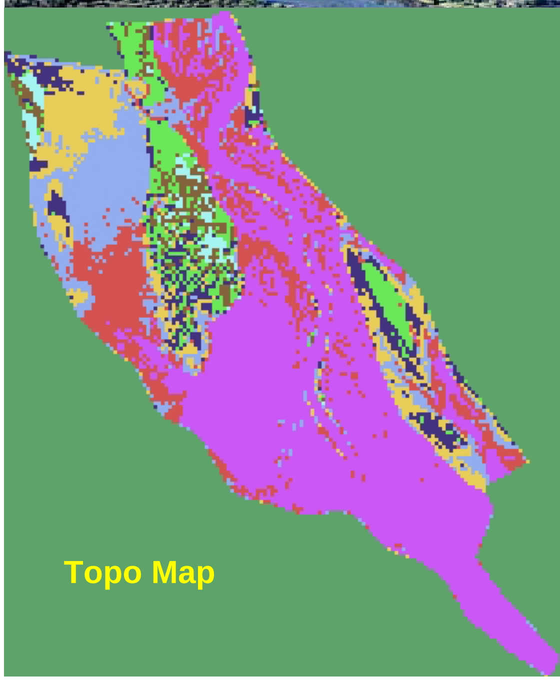

Spatially Explicit CASM
•Vegetation Succession Module
•SAV Simulation Module
•Landscape Pattern Analyst
Performance Measures:
Biomass (Kg/acre)
Species composition
Biodiversity (α & β)
Habitat (Acres)
Vegetation patterns
Forest/Woody Vegetation
Mesic Prairies
UGA1334001
1890
Historical
Natural
Viable
Changing
Dynamic
100 years Simulation
Establishment
Succession
Growth
Mortality
Agriculture/Urban
1989
Side channel
Main channel
Channel border
Backwater
Open Water/SAV
Affecting Factors:
Water depth
Hydroperiod
Flood patterns
Drought patterns
Freeze
Nutrients (N &P)
Toxicity
Sediment
Fire
Cattail Marsh

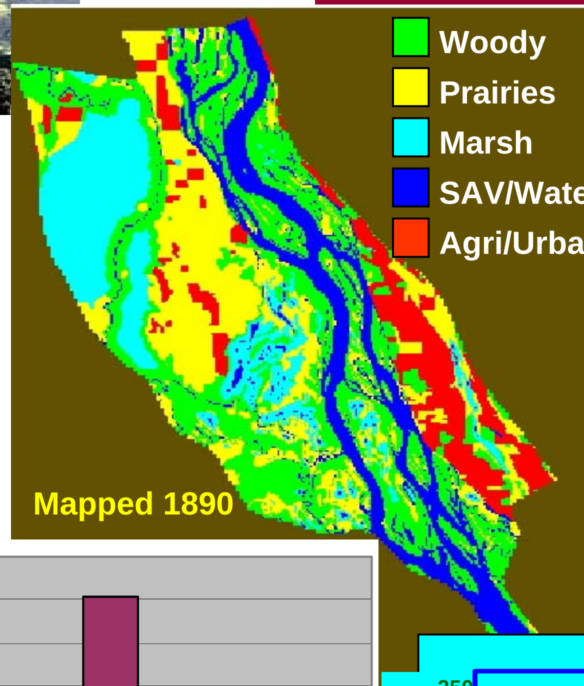
Spatially Explicit CASM

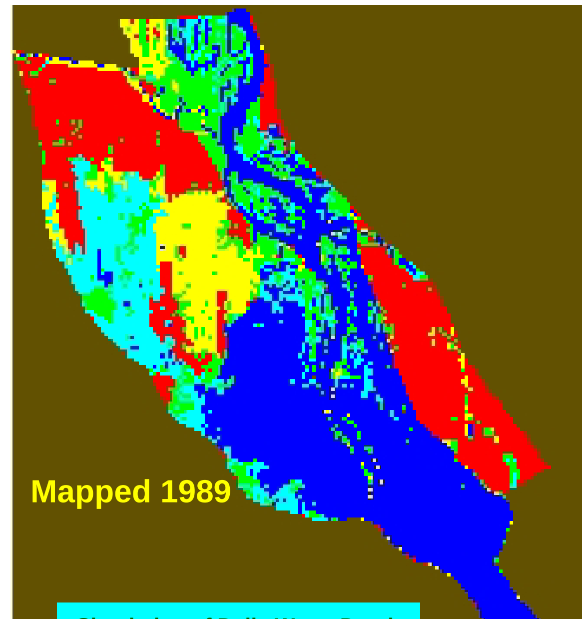
•Vegetation Succession Module
•SAV Simulation Module

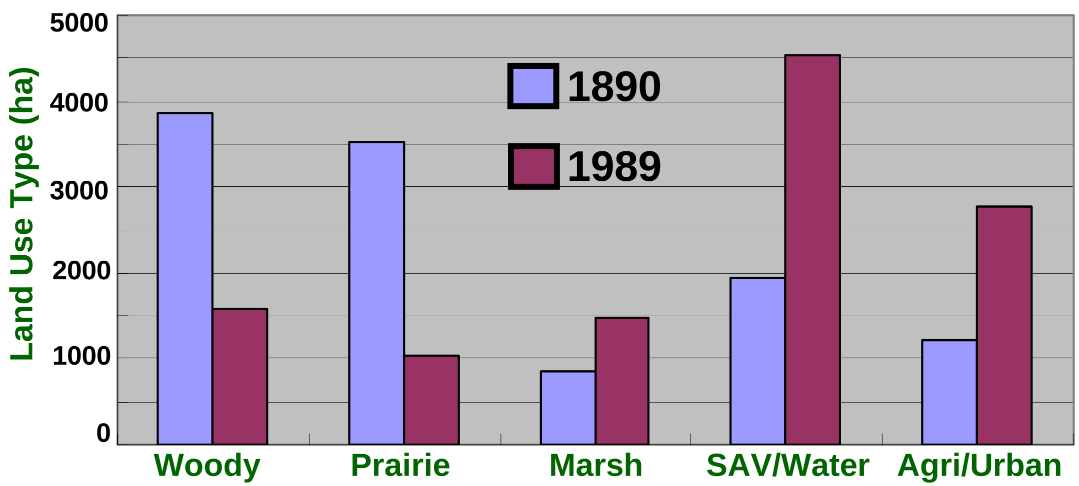
How does the model work?

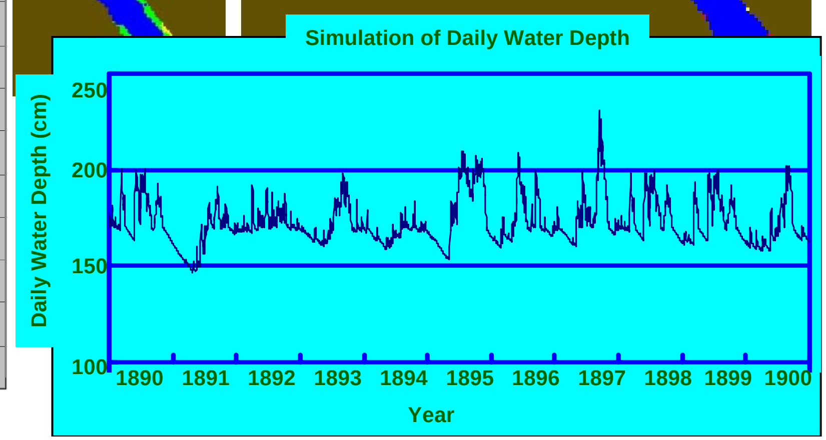










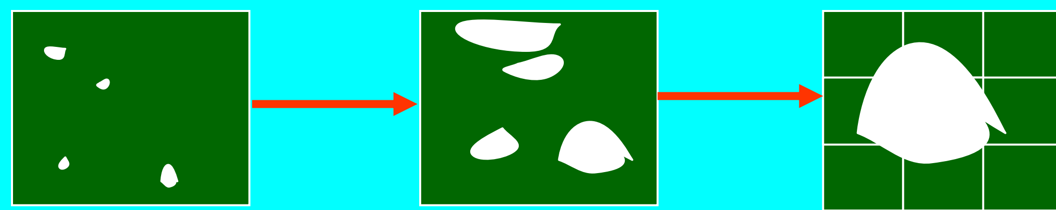


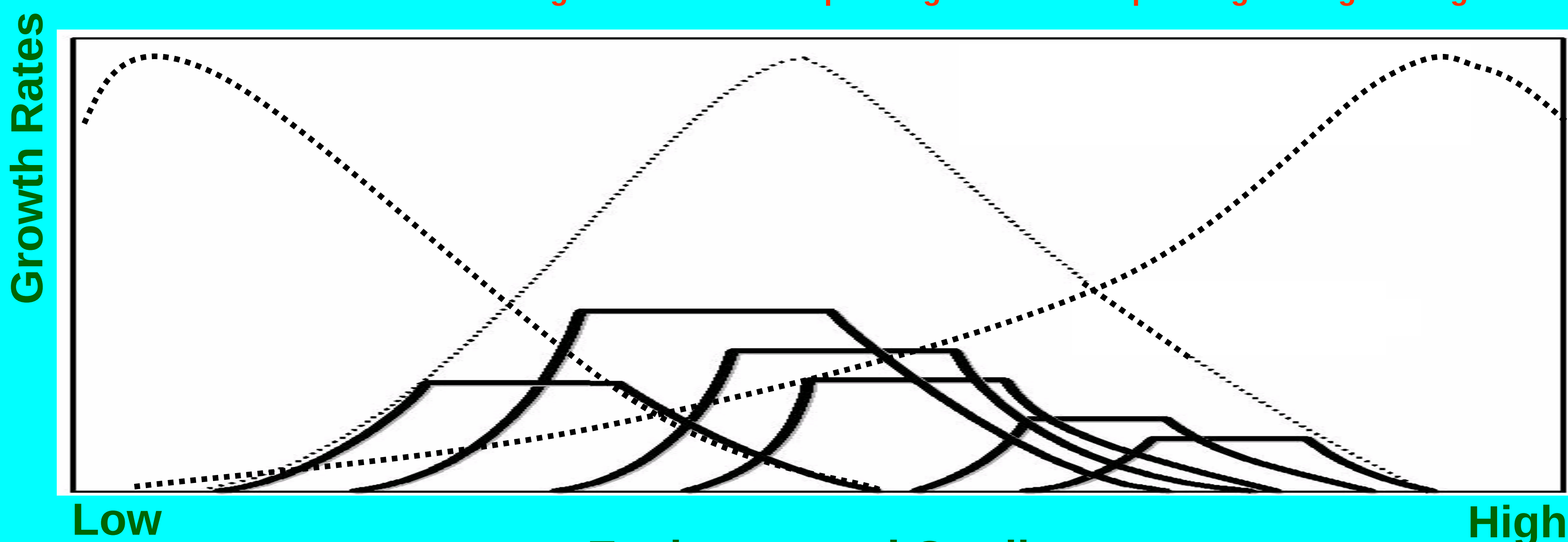
Spatially Explicit CASM

- **Vegetation Succession Module**
- **SAV Simulation Module**

How does the model work?

Vegetation Succession In Landscapes

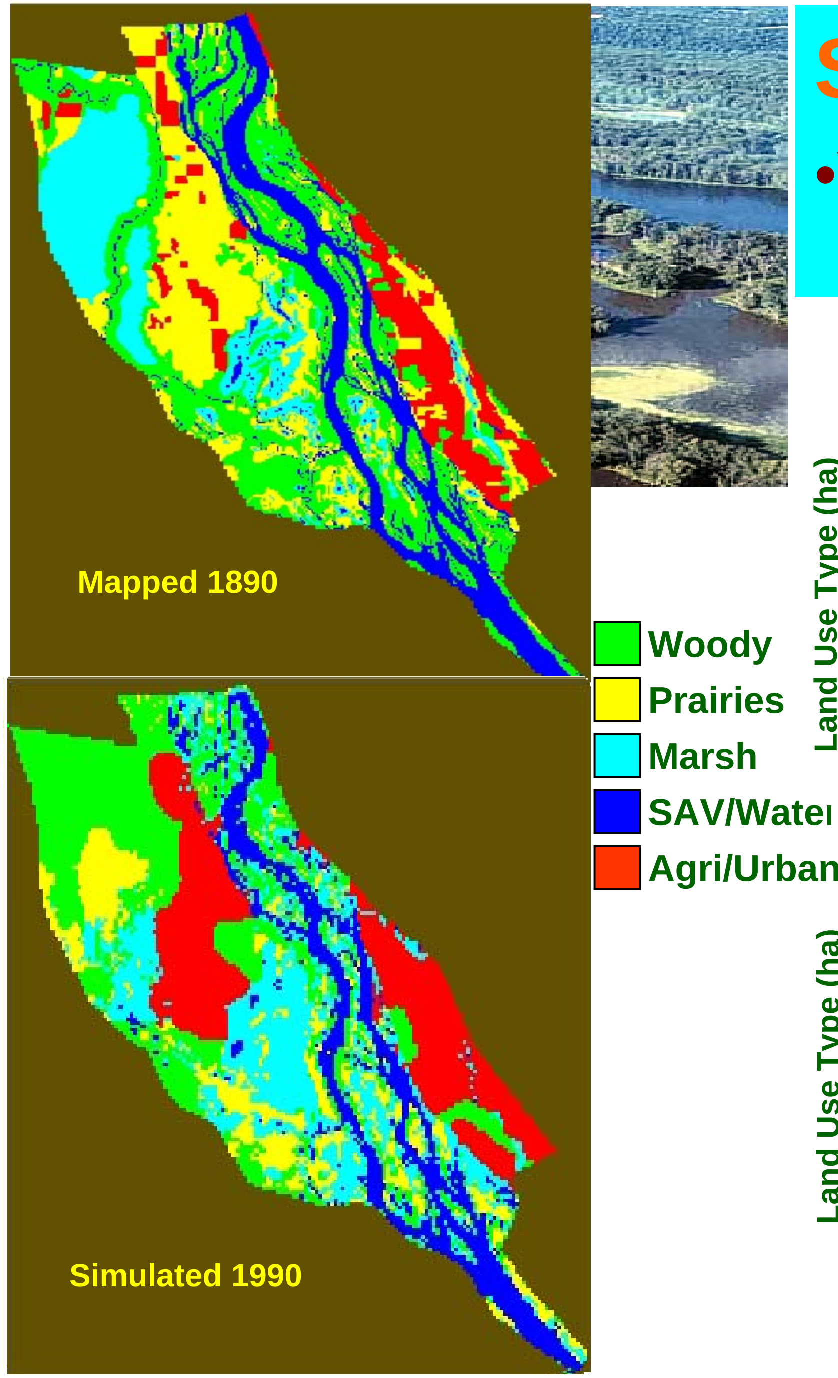


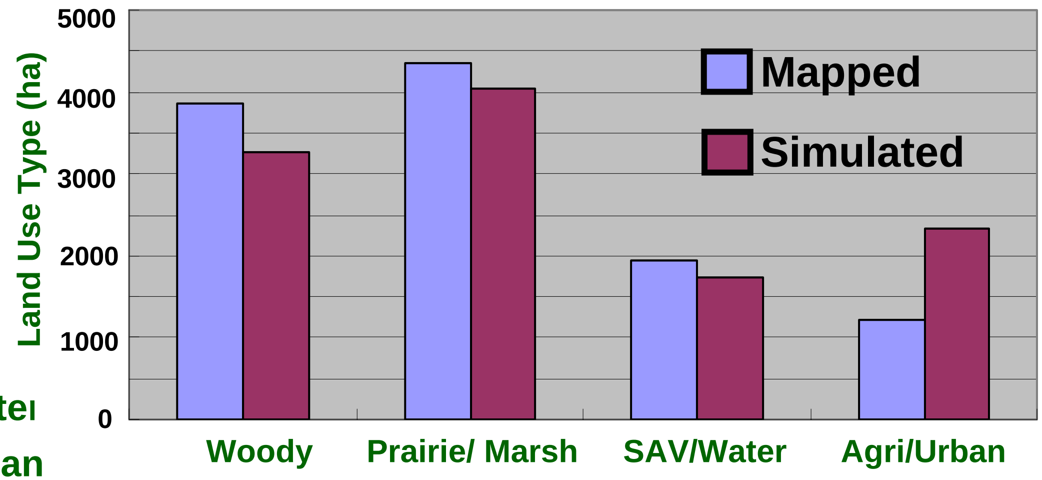


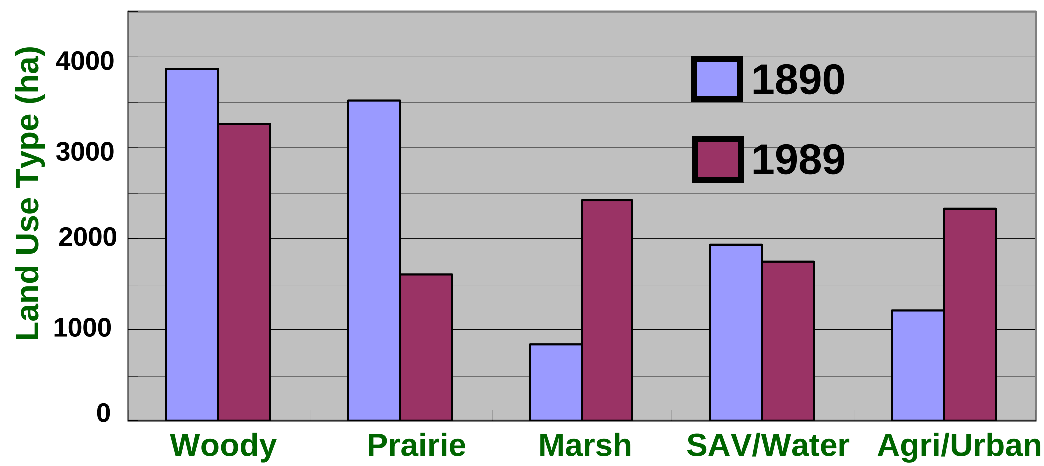
Spatially Explicit CASM

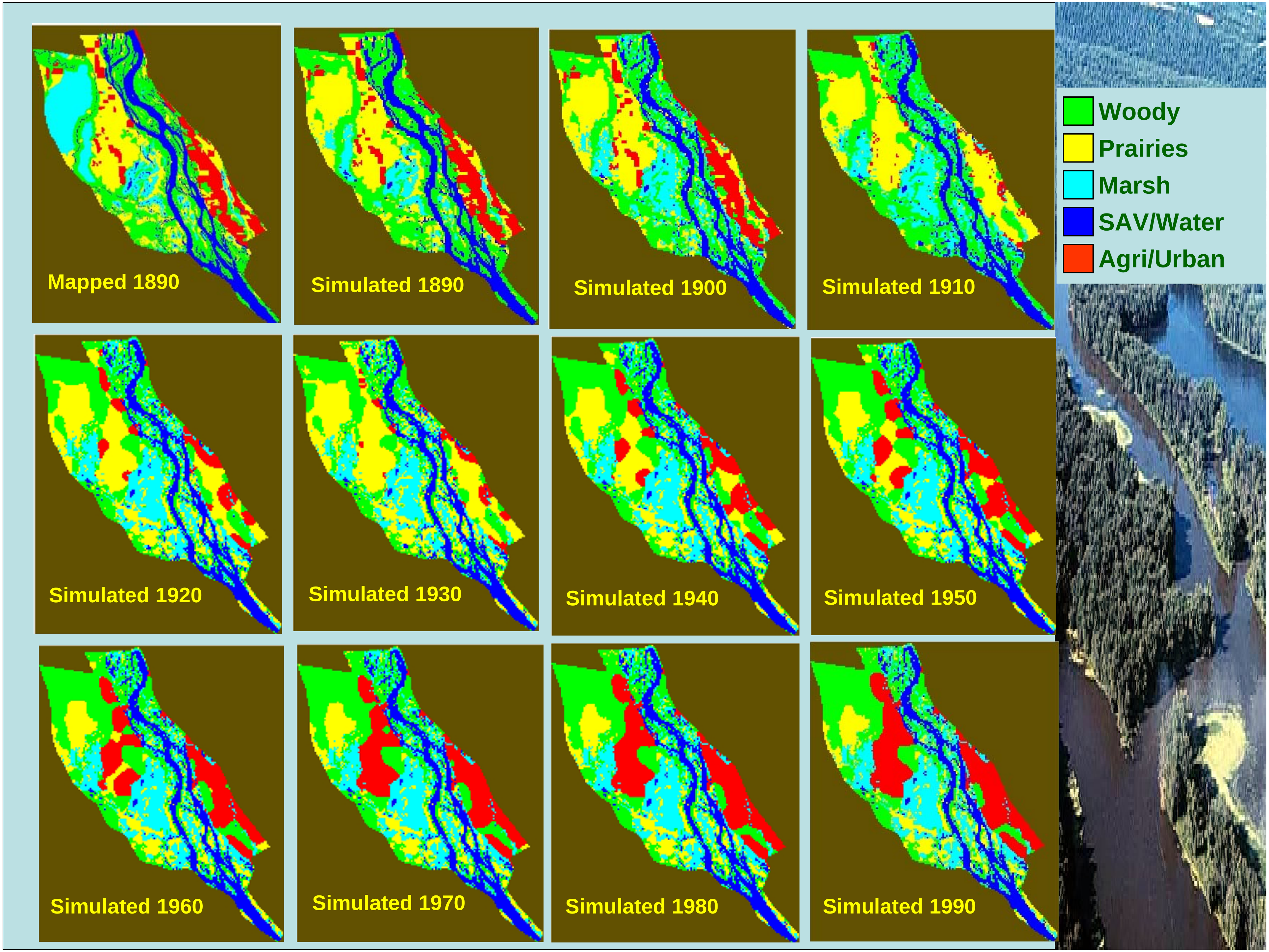
- Vegetation Succession Module
- SAV Simulation Module

Verification



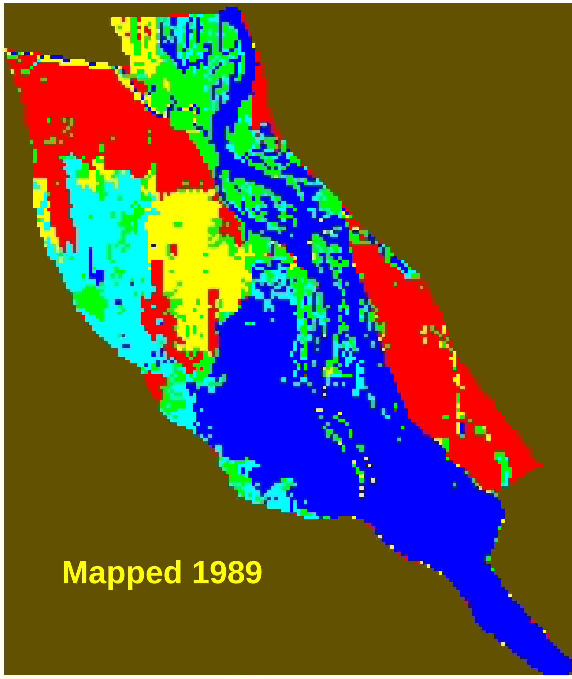


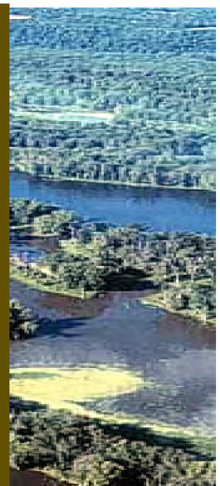


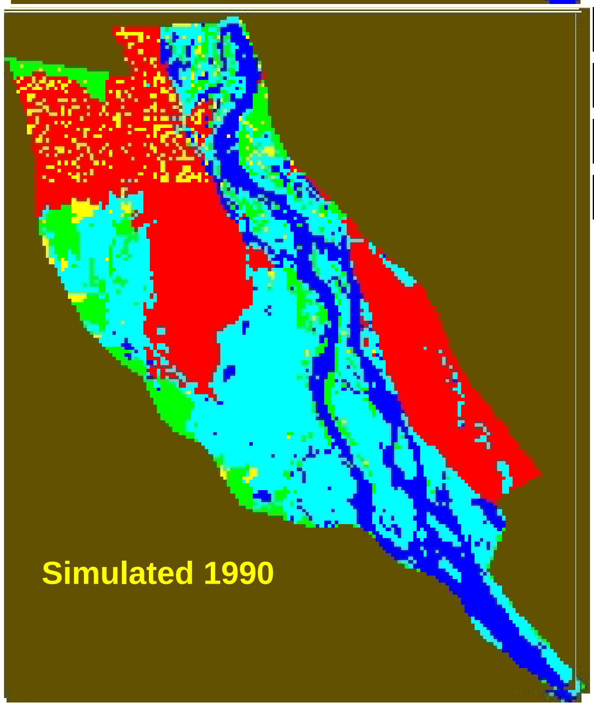

Woody
Prairies
Marsh
SAV/Water
Agri/Urban
Mapped 1890
Simulated 1890
Simulated 1900
Simulated 1910
Simulated 1920
Simulated 1930
Simulated 1940
Simulated 1950
Simulated 1960
Simulated 1970
Simulated 1980
Simulated 1990

Spatially Explicit CASM

•Vegetation Succession Module
•SAV Simulation Module







Woody
Prairies
Marsh
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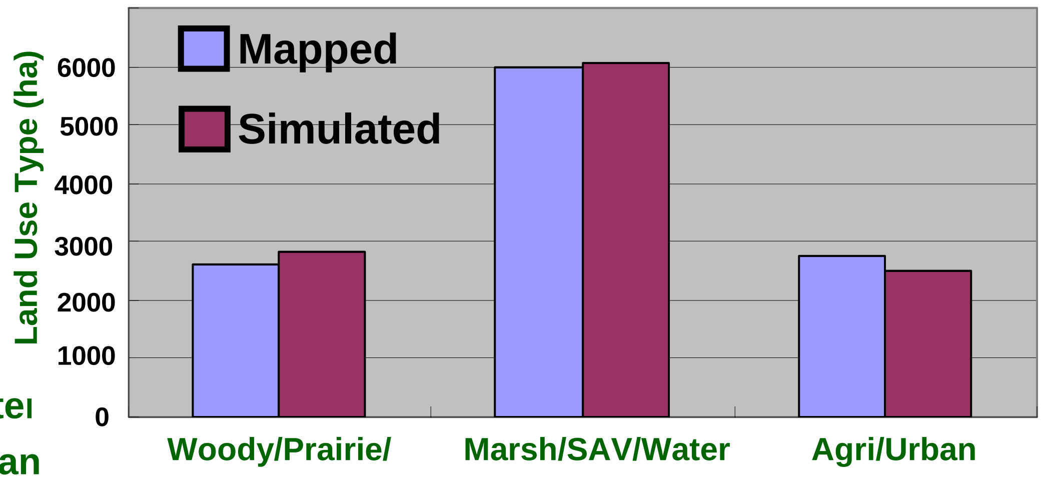
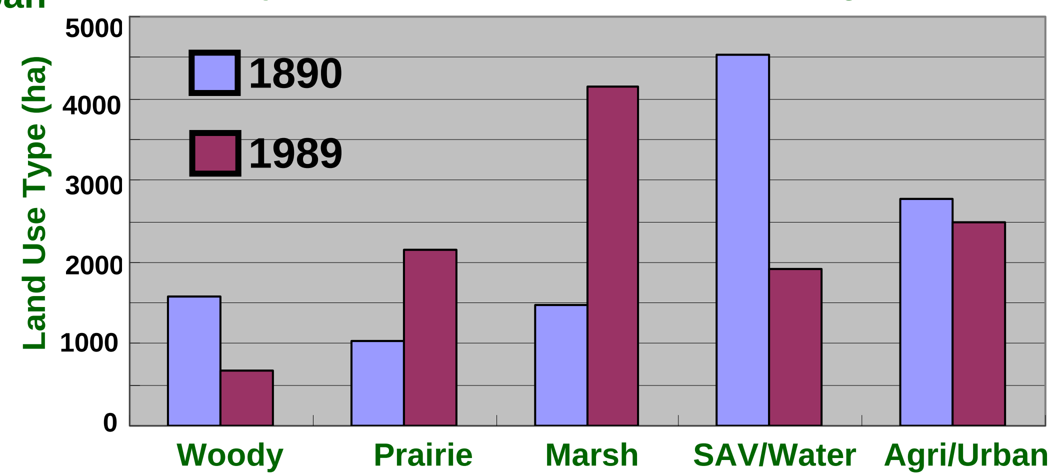
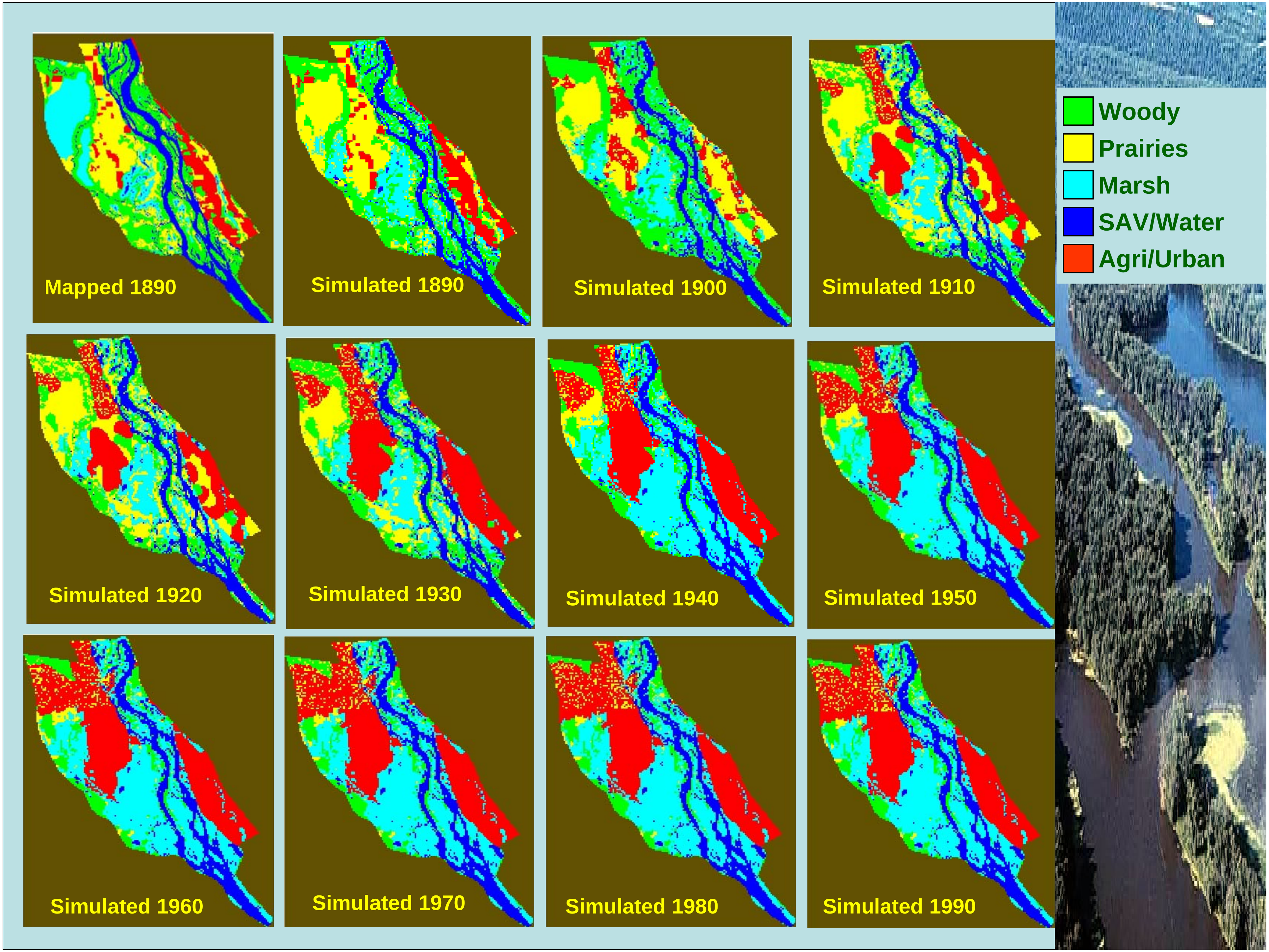
Verification



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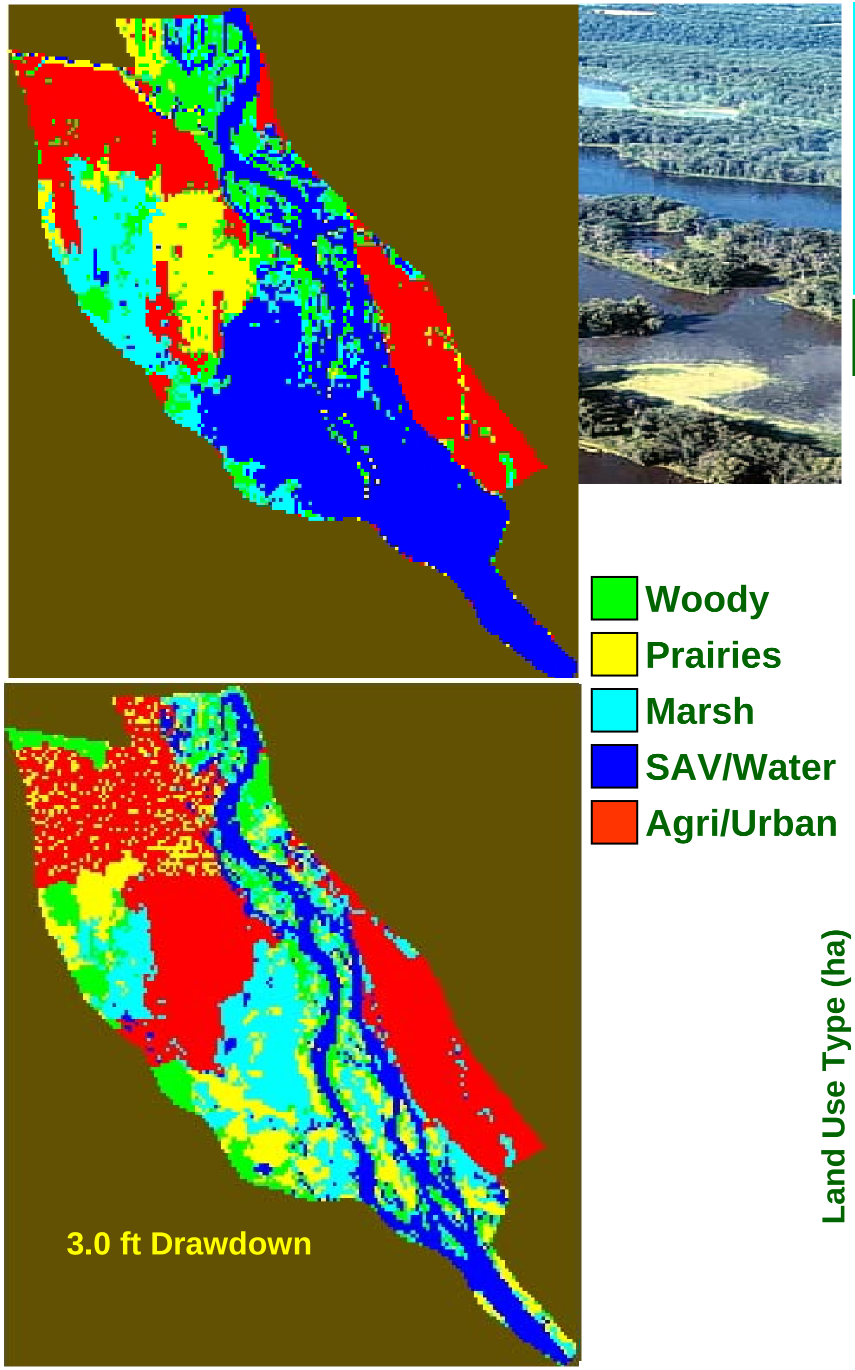
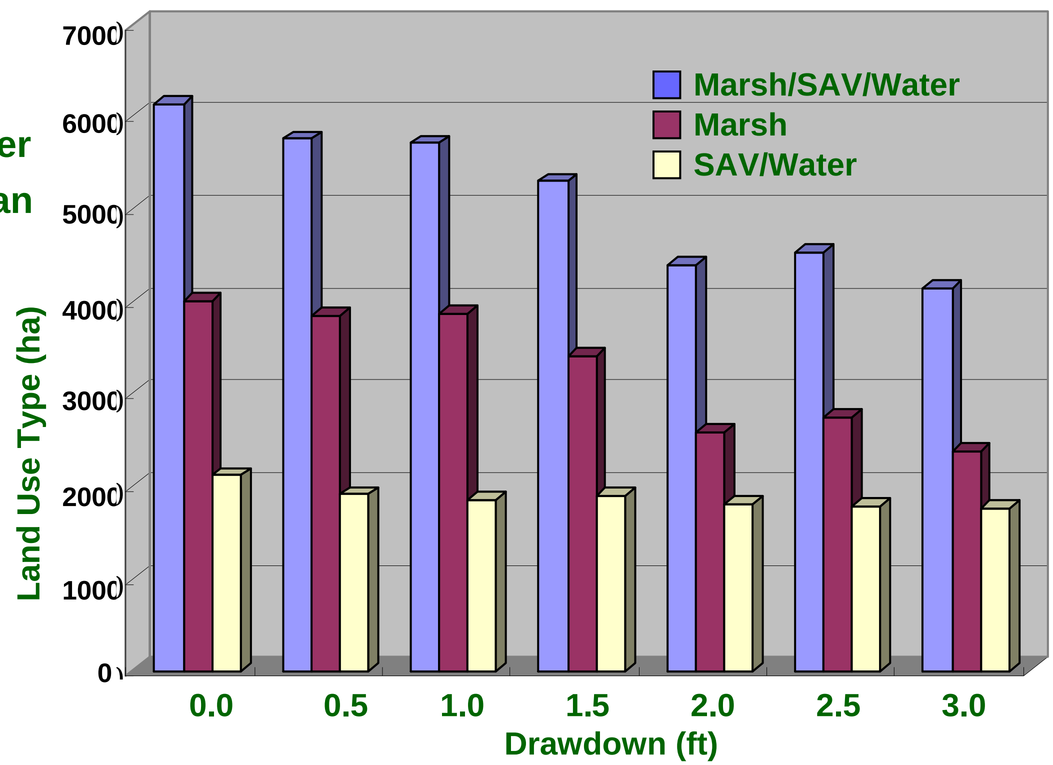
Spatially Explicit CASM

•Vegetation Succession Module
•SAV Simulation Module



SECASM as a management tool for:

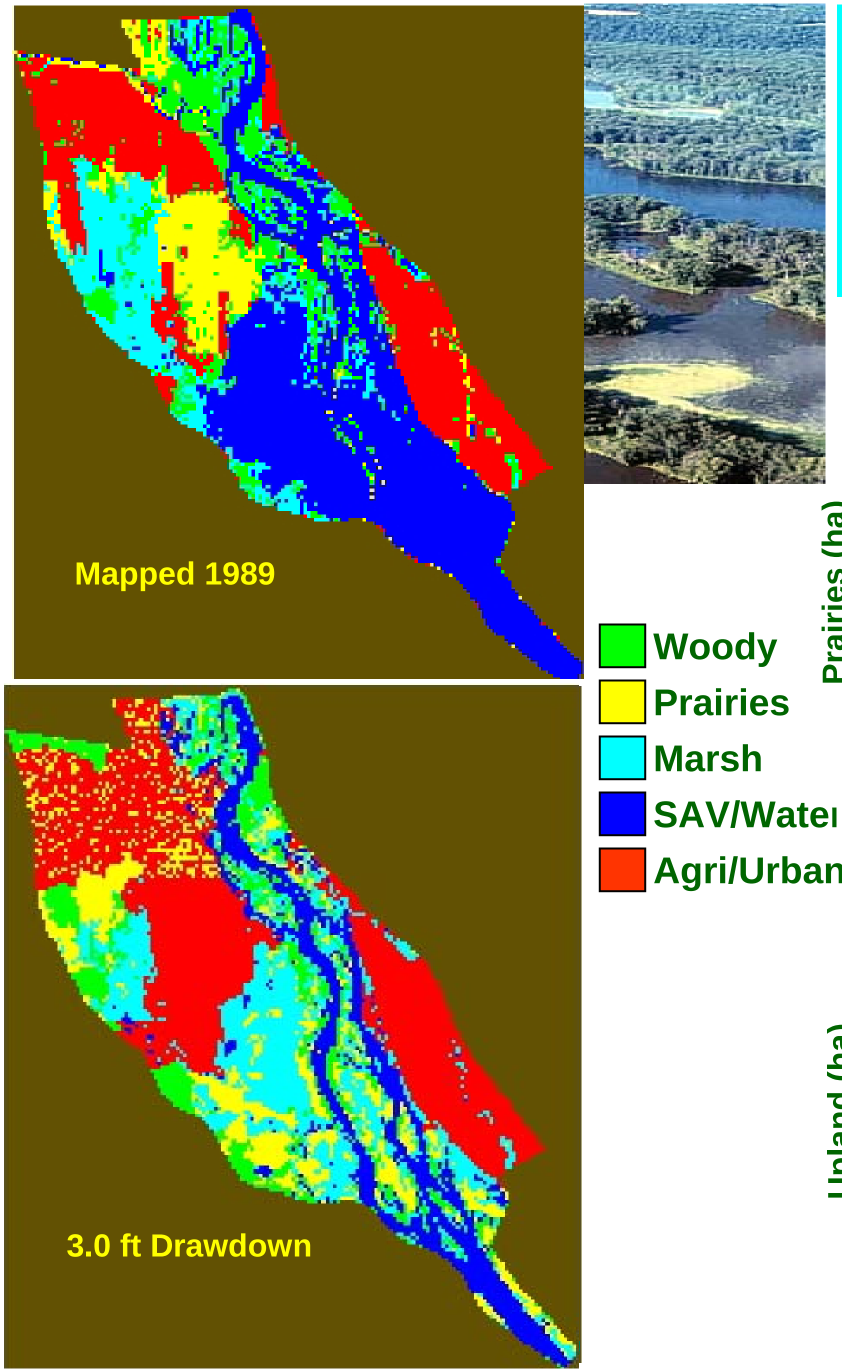
- Scenario Simulations
- Testing Hypotheses
- Performance Measures

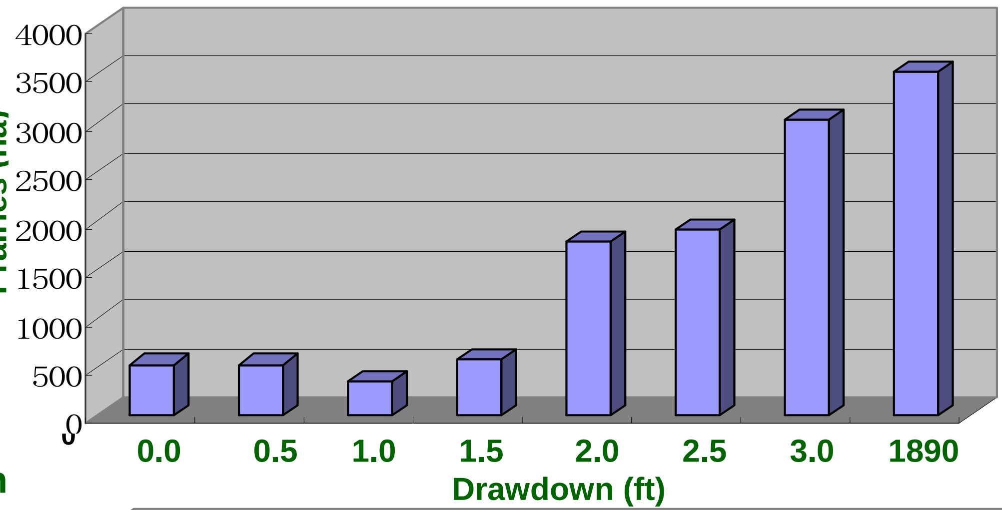


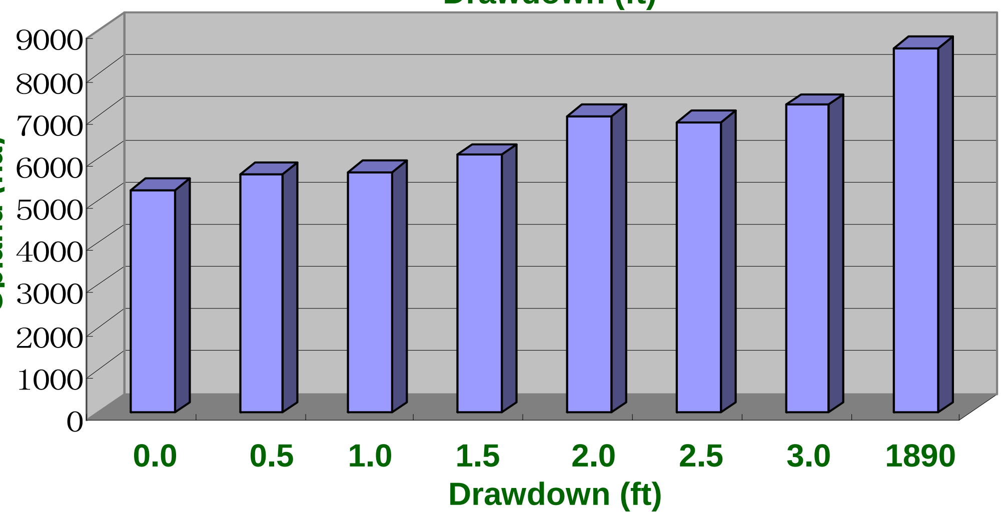
Spatially Explicit CASM

- Vegetation Succession Module
- SAV Simulation Module

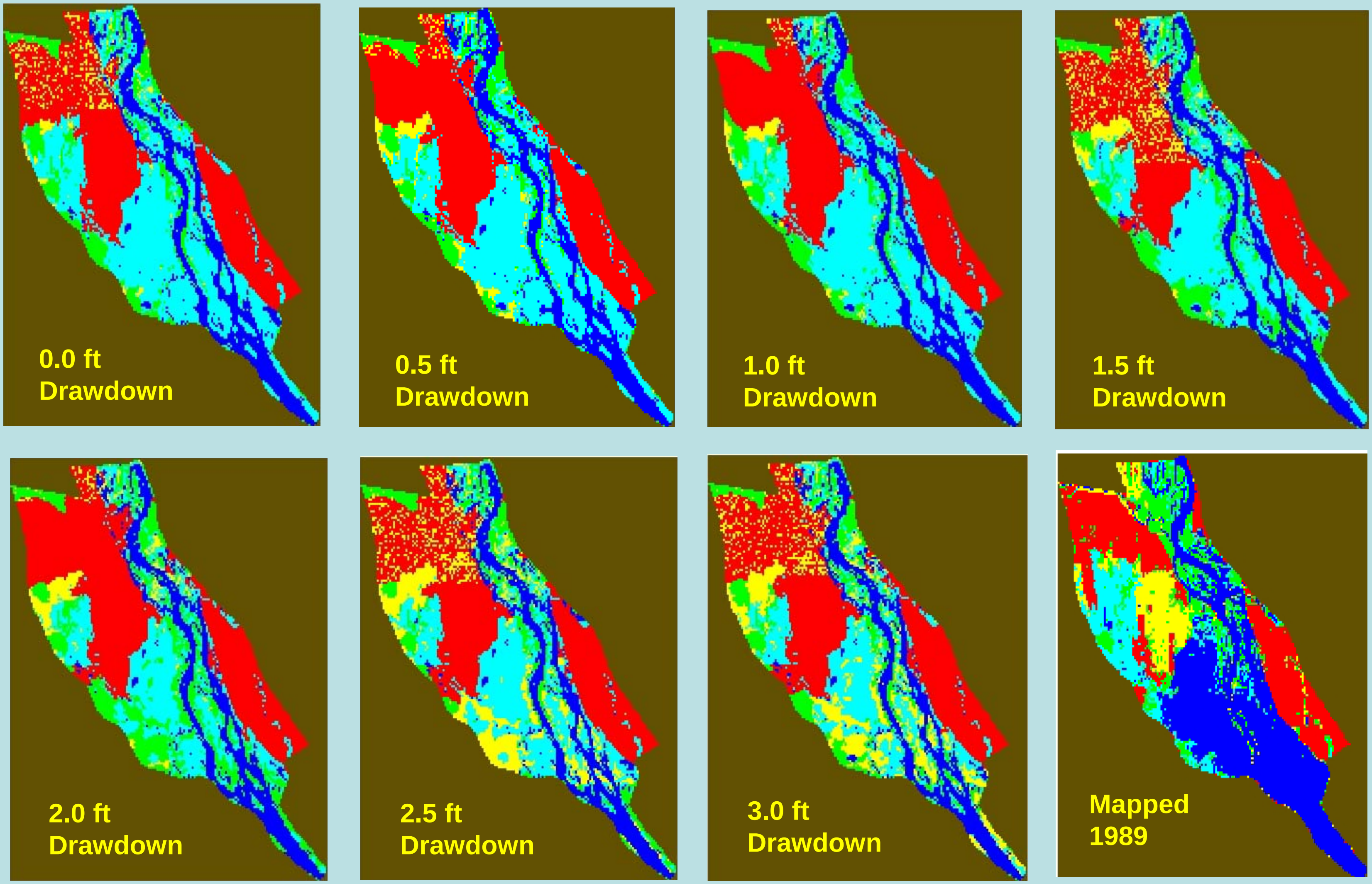
Scenario Simulations







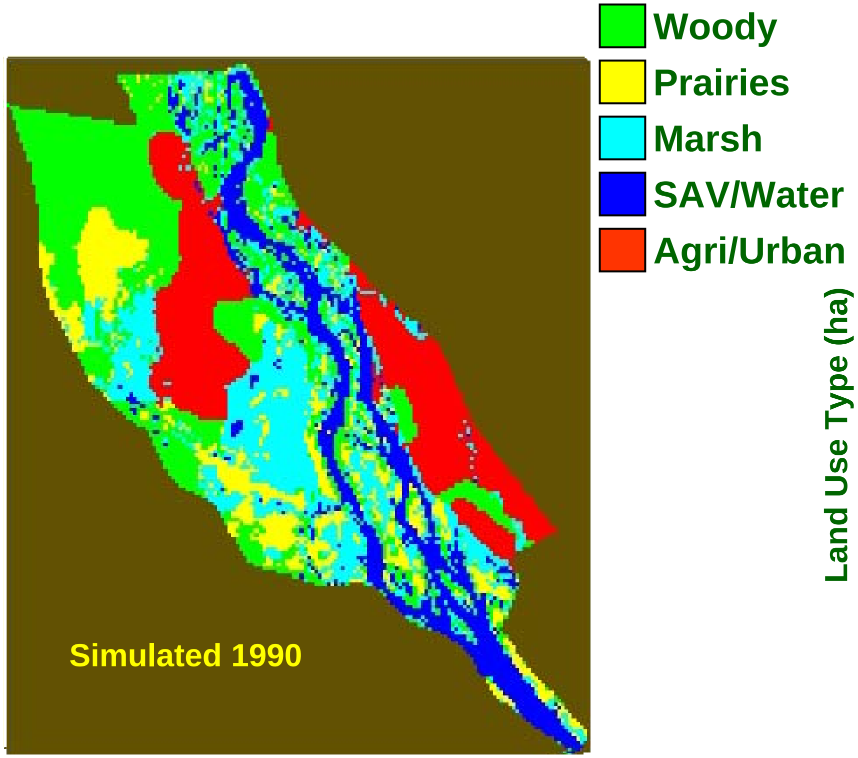
Scenario Simulations of Drawdown

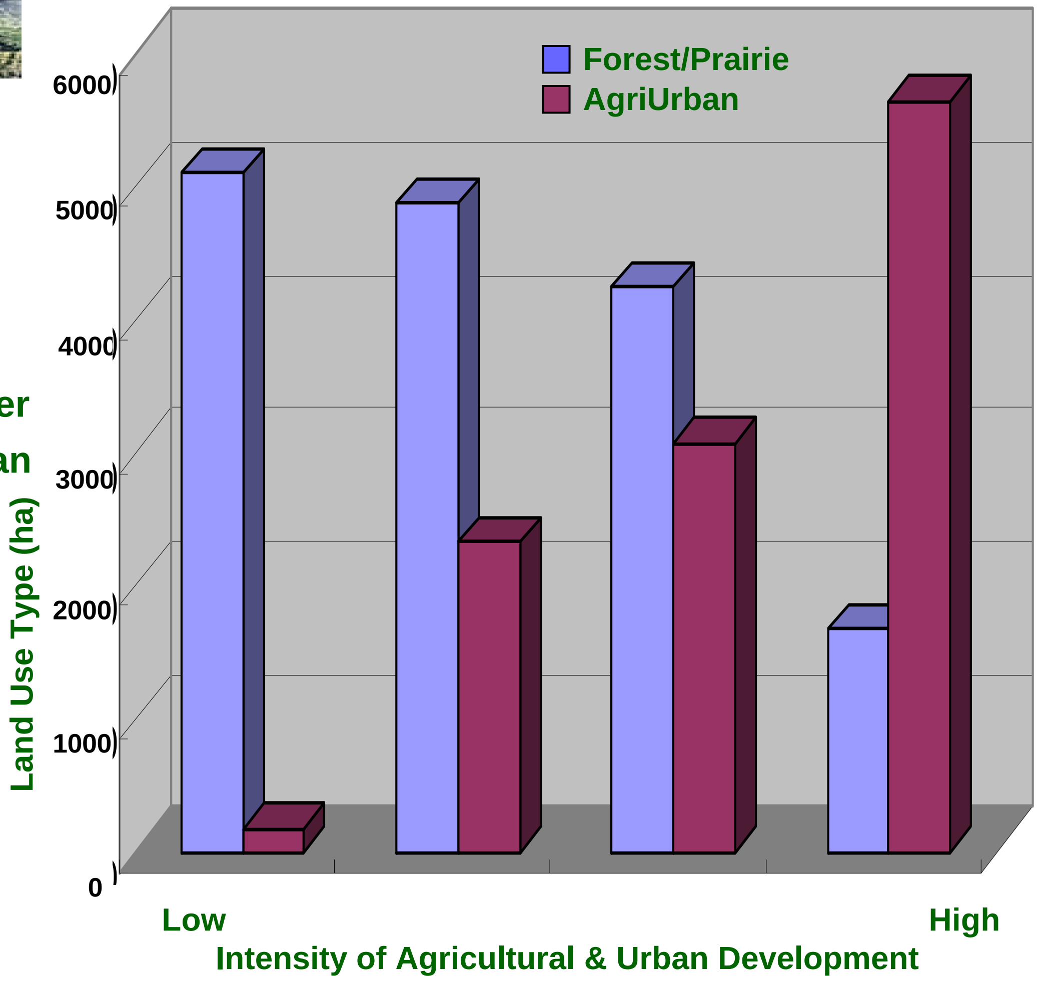


Spatially Explicit CASM

•Vegetation Succession Module
•SAV Simulation Module

Testing Hypotheses





Spatially Explicit CASM

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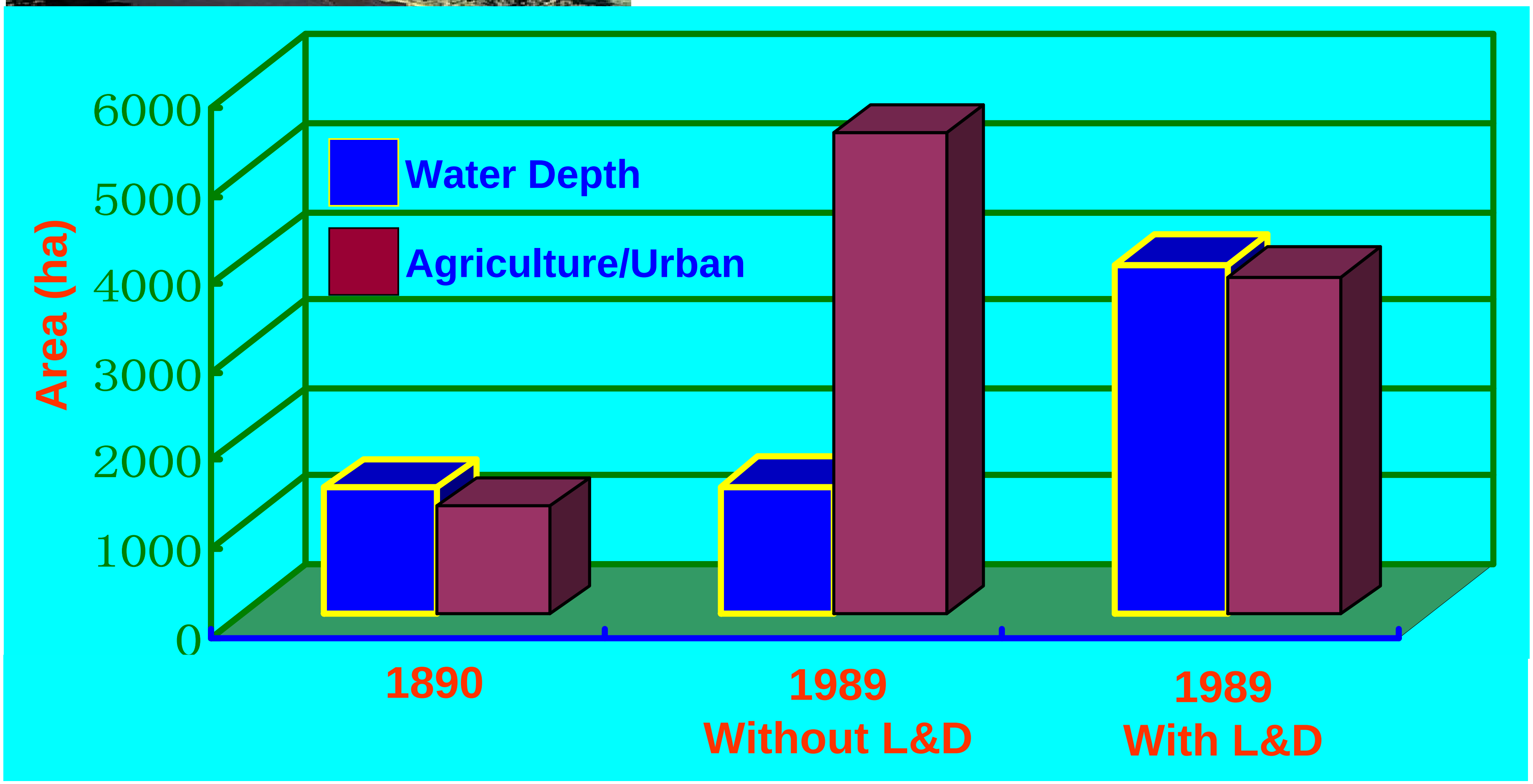


Spatially Explicit CASM

•Landscape Pattern Analyst

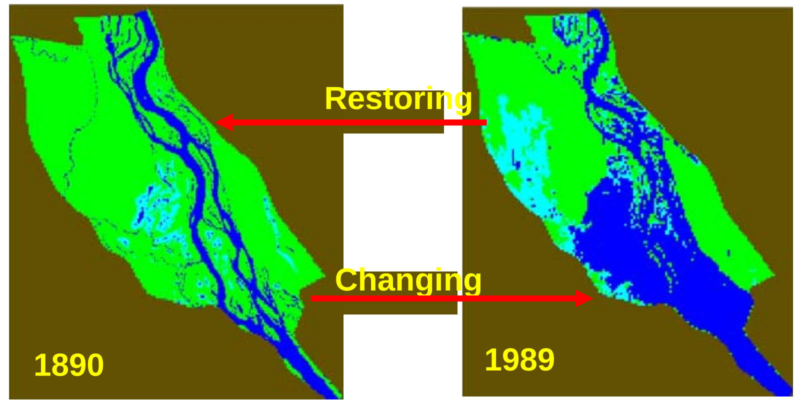
Performance Measures

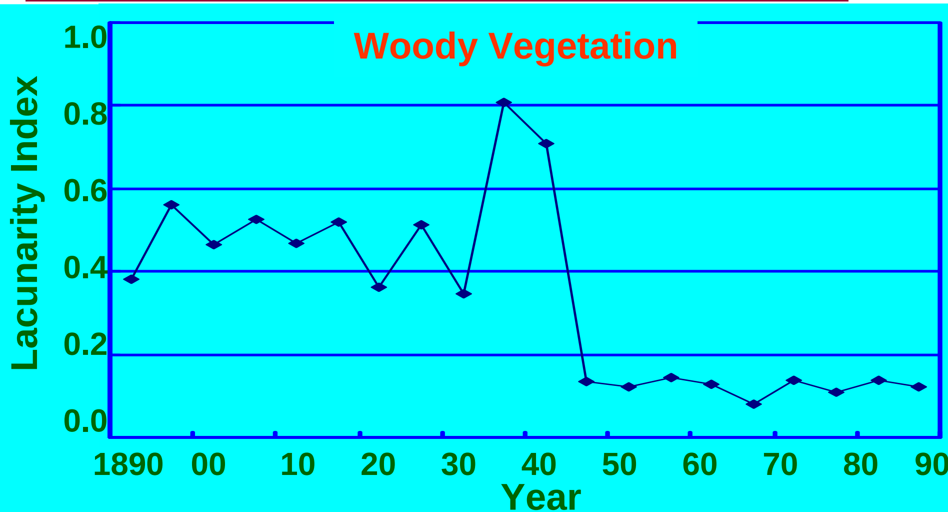
Maintain and sustain the landscape patters, such as floodplain, river channel, slough, delta, and lakes including river flows and connectivity.

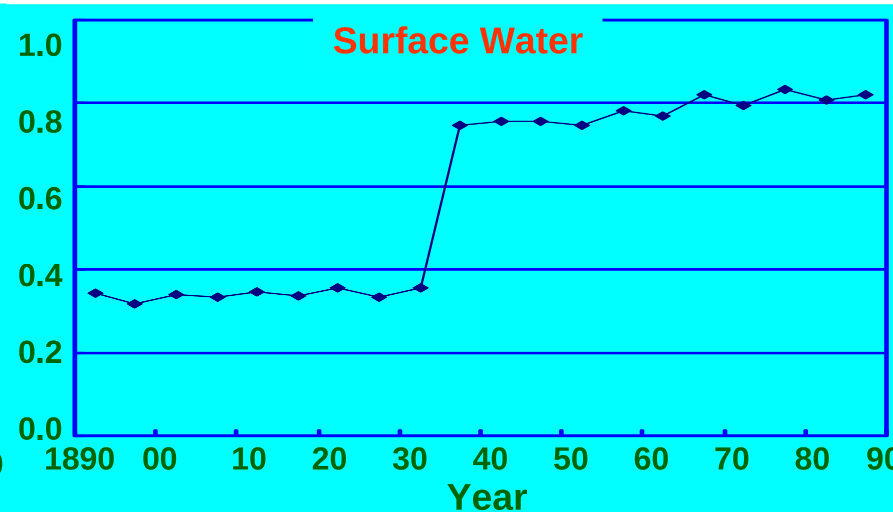
"Lacuna" means holes and hence lacunarity is a measure of "holeness" or "connectiveness". Lacunarity Index (λ) is expressed as:

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

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.





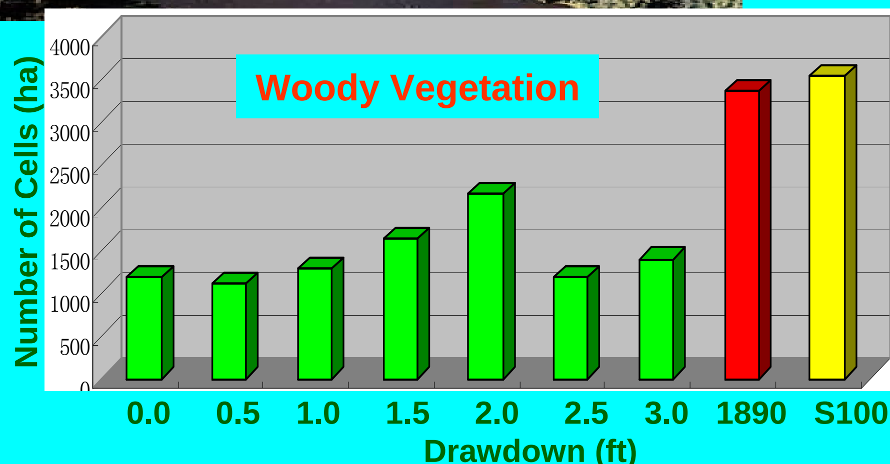


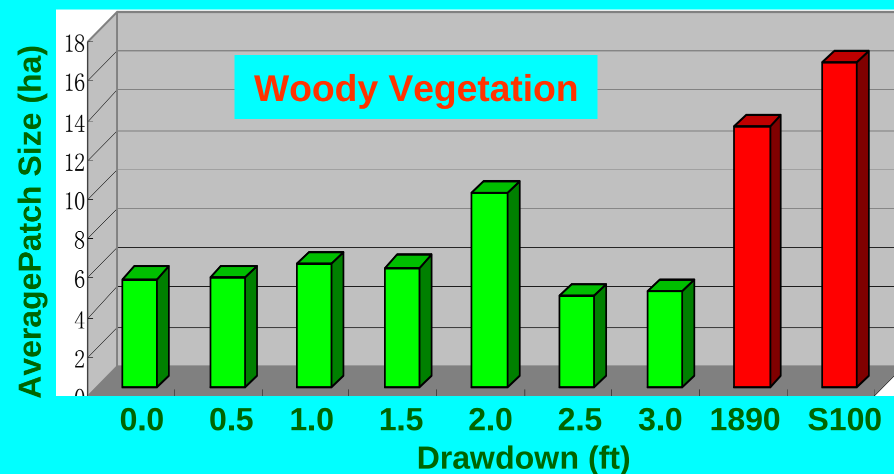
Spatially Explicit CASM

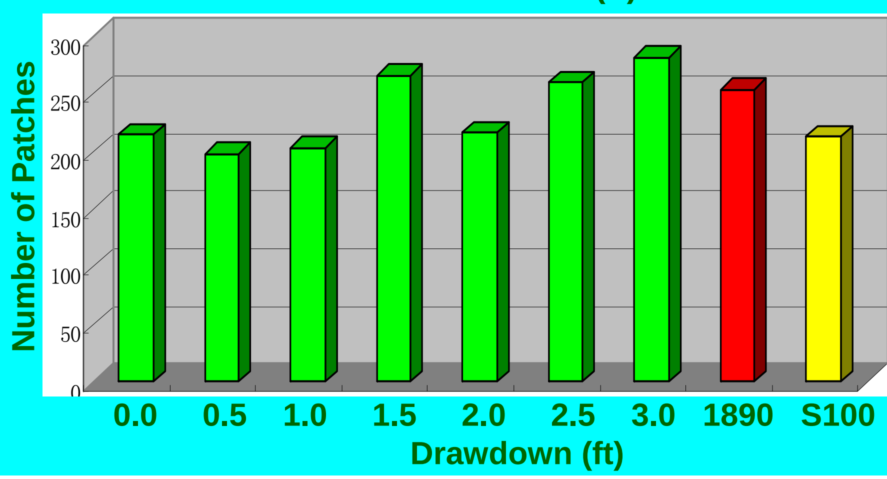
•Landscape Pattern Analyst

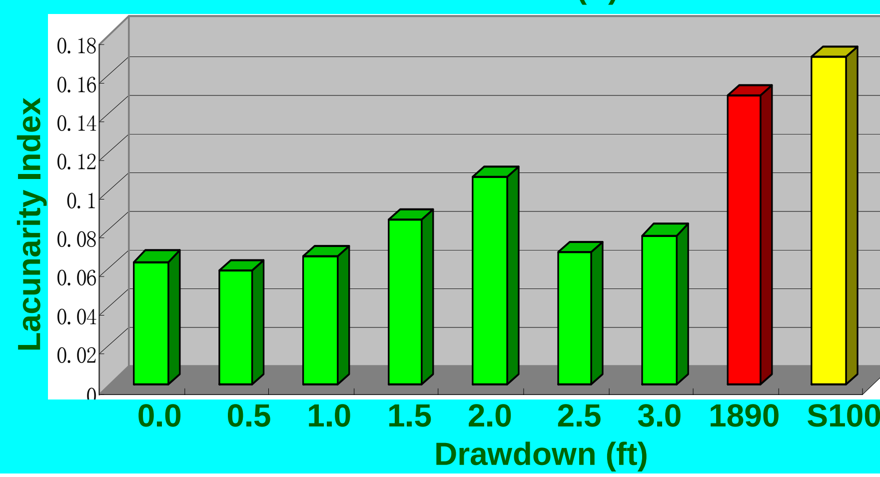
Performance Measures

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







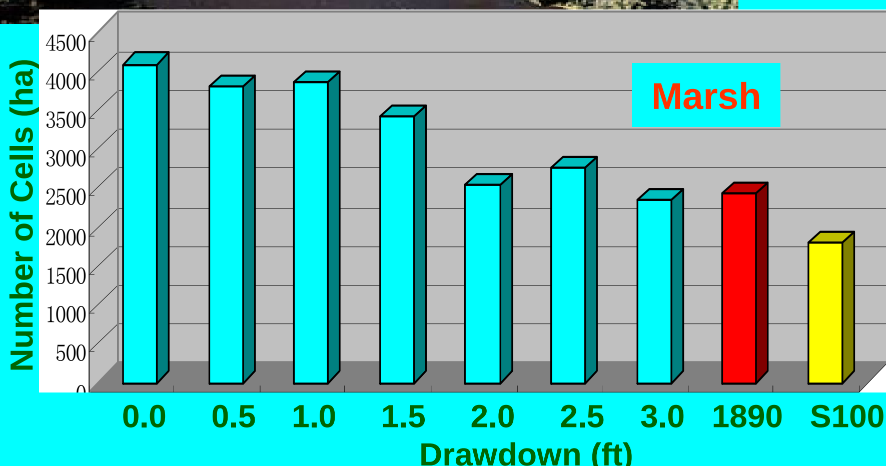


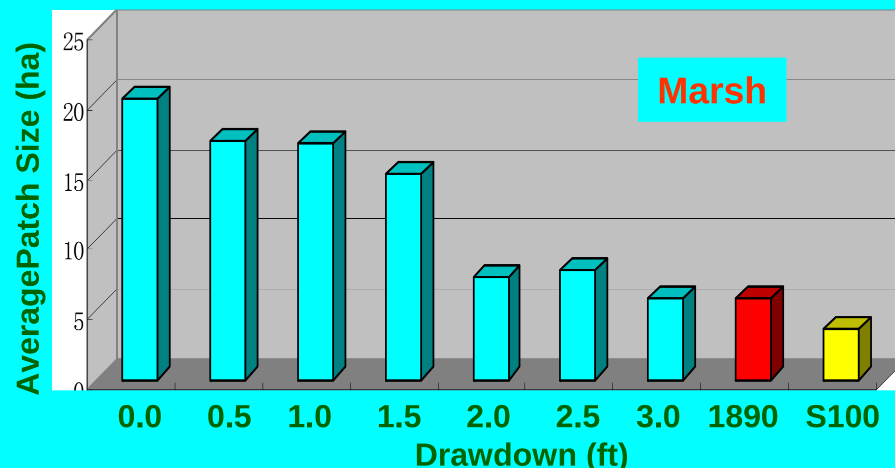
Spatially Explicit CASM

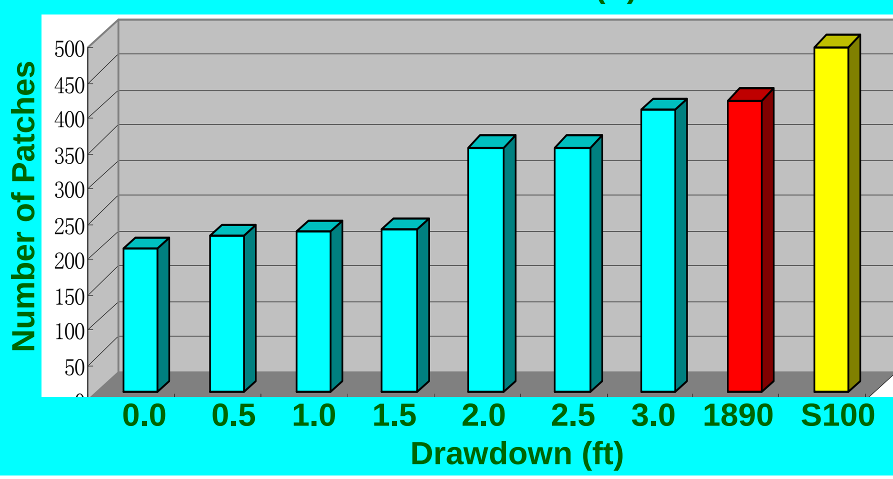
•Landscape Pattern Analyst

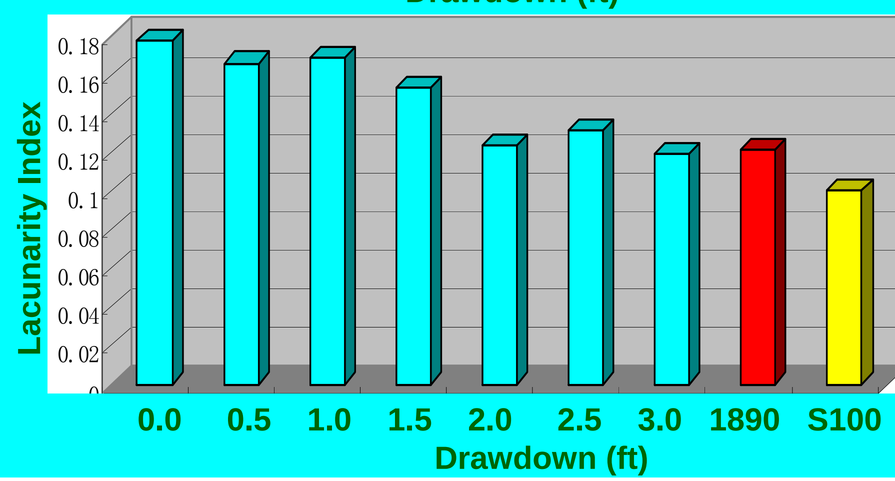
Performance Measures

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

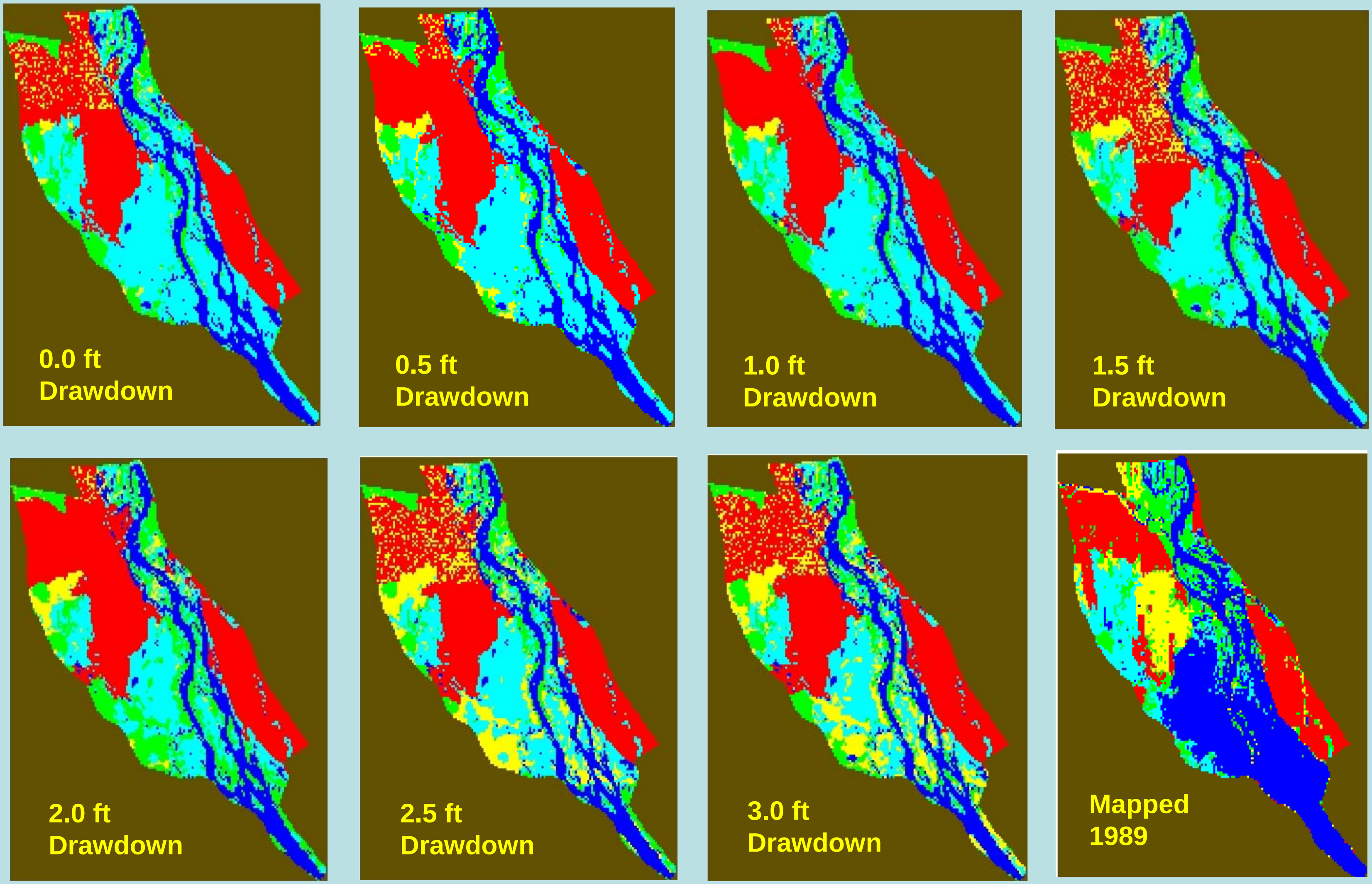








Thank you!


0.0 ft
Drawdown
0.5 ft
Drawdown
1.0 ft
Drawdown
1.5 ft
Drawdown
2.0 ft
Drawdown
2.5 ft
Drawdown
3.0 ft
Drawdown
Mapped
1989