YAHARA2070

Project Update | Outreach and Modeling

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UNIVERSITY OF WISCONSIN-MADISON
Water Sustainability and Climate
In the Yahara Watershed

NSF

How could changes in land use, climate and human demand impact the benefits we derive from nature, a.k.a. ecosystem services, for future generations in the Yahara Watershed?

A Complex Problem:

Uncertainty is high.
Time frames span many generations.
People thinking rationally will reach different conclusions.
There are multiple solutions that are 'good enough'.

Approaches to complex problems:

Assume that uncertainty is large, changeable, and co-created by
people and nature working together.
Emphasize the diversity and individuality of perspectives.
Stress learning by individuals.
Expect the unexpected.

Scenarios of future change

- Facilitate long-term thinking

- Provocative, plausible, place-based stories with contrasting social and biophysical conditions

- Assist preparation for and management of uncertainty
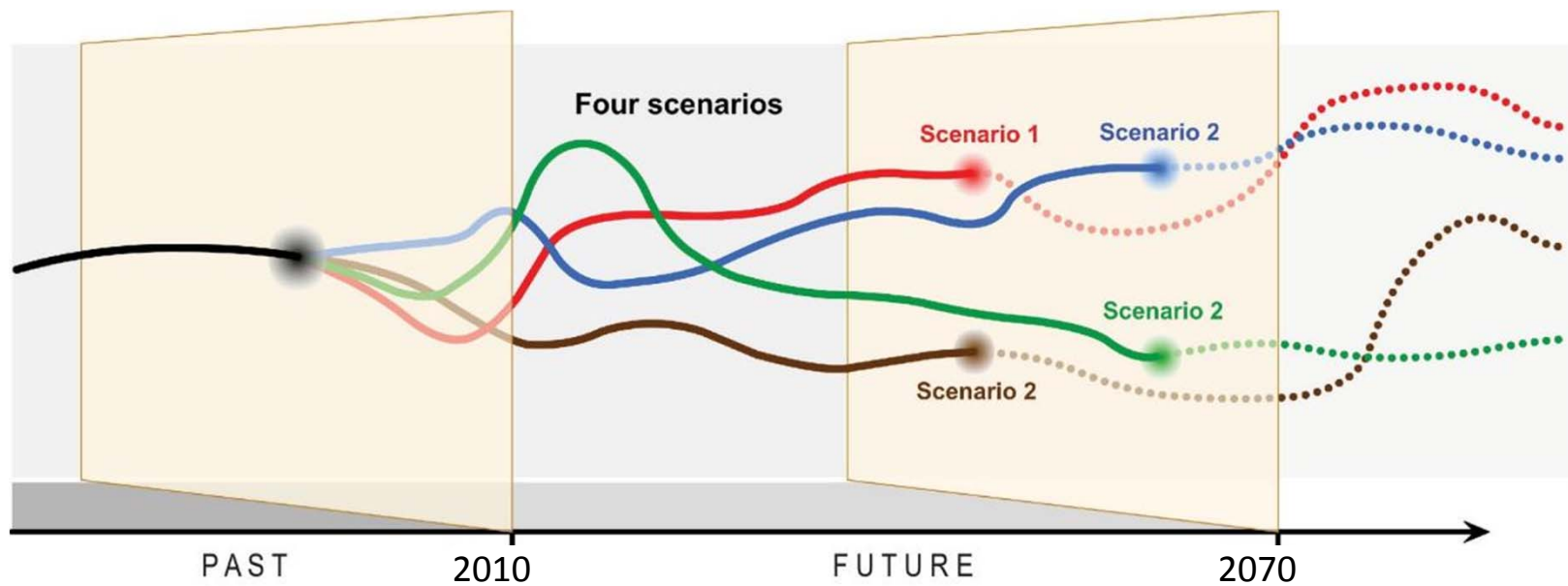
based on Carpenter et al. 2005

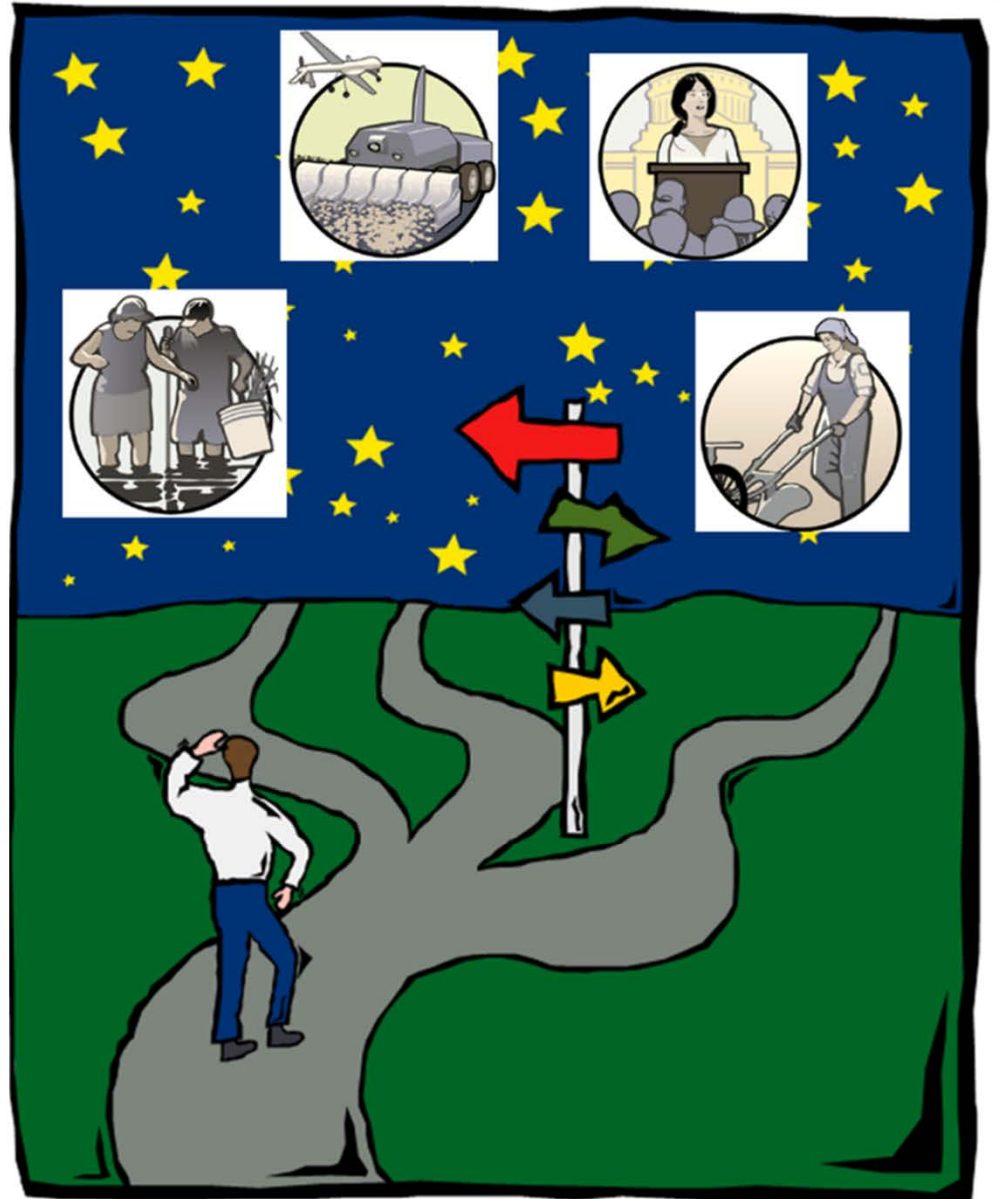# Alternative Pathways & Futures

Today

2070

The future is already here;
it's just unevenly distributed.
- William Gibson

YAHARA2070

What if?

The Scenario Narratives

Name:	Nested Watersheds	Abandonment & Renewal	Accelerated Innovation	Connected Communities
Dynamics:	Adaptation	Transformation	Adaptation	Transformation
Key Factor in Change:	Government	Inaction	Technology	Values
Nutshell:	Government intervention maintains nature's benefits	Disaster decreases population, leads to reorganization	Massive growth in technology businesses, including green tech	Global shift in values toward sustainability

Accelerated Innovation

What if we prioritize technology to solve water and climate challenges?

What if we reform how we govern to address water and climate challenges?

What if we shift our values in response to water and climate challenges?

Connected Communities

What if we aren't prepared for water and climate challenges?
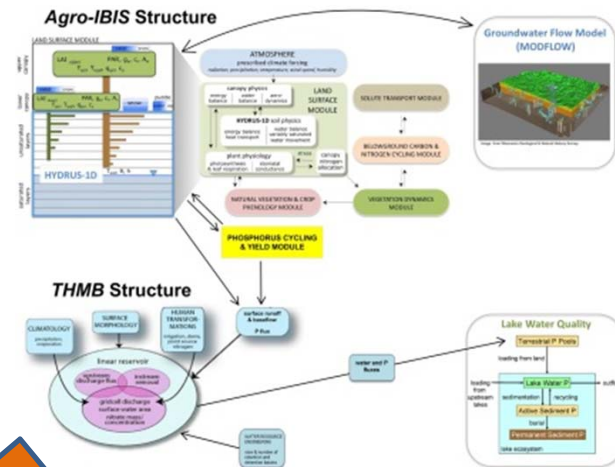
Abandonment & Renewal

The Biophysical Modeling

Translations of the stories into numbers that a biophysical computer model can understand
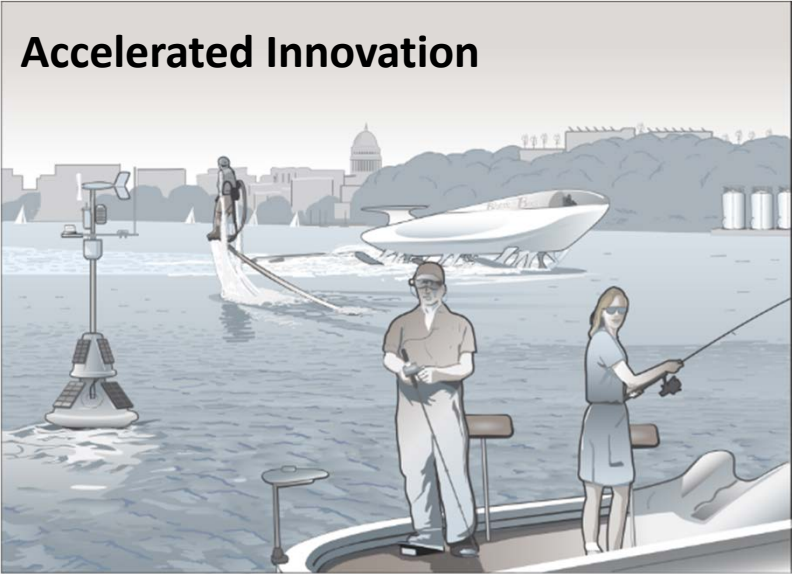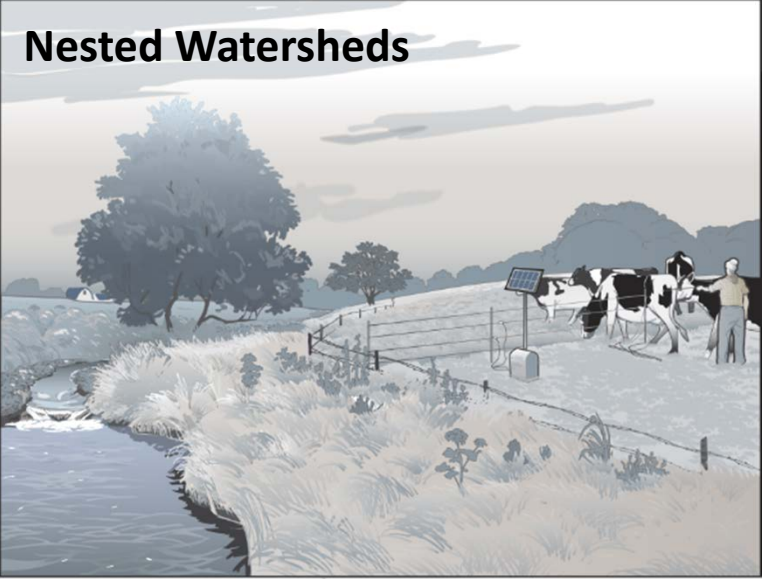
Narratives

Models

Potential future states for well-being

Using Yahara 2070: Ask cross-cutting questions

Connected Communities

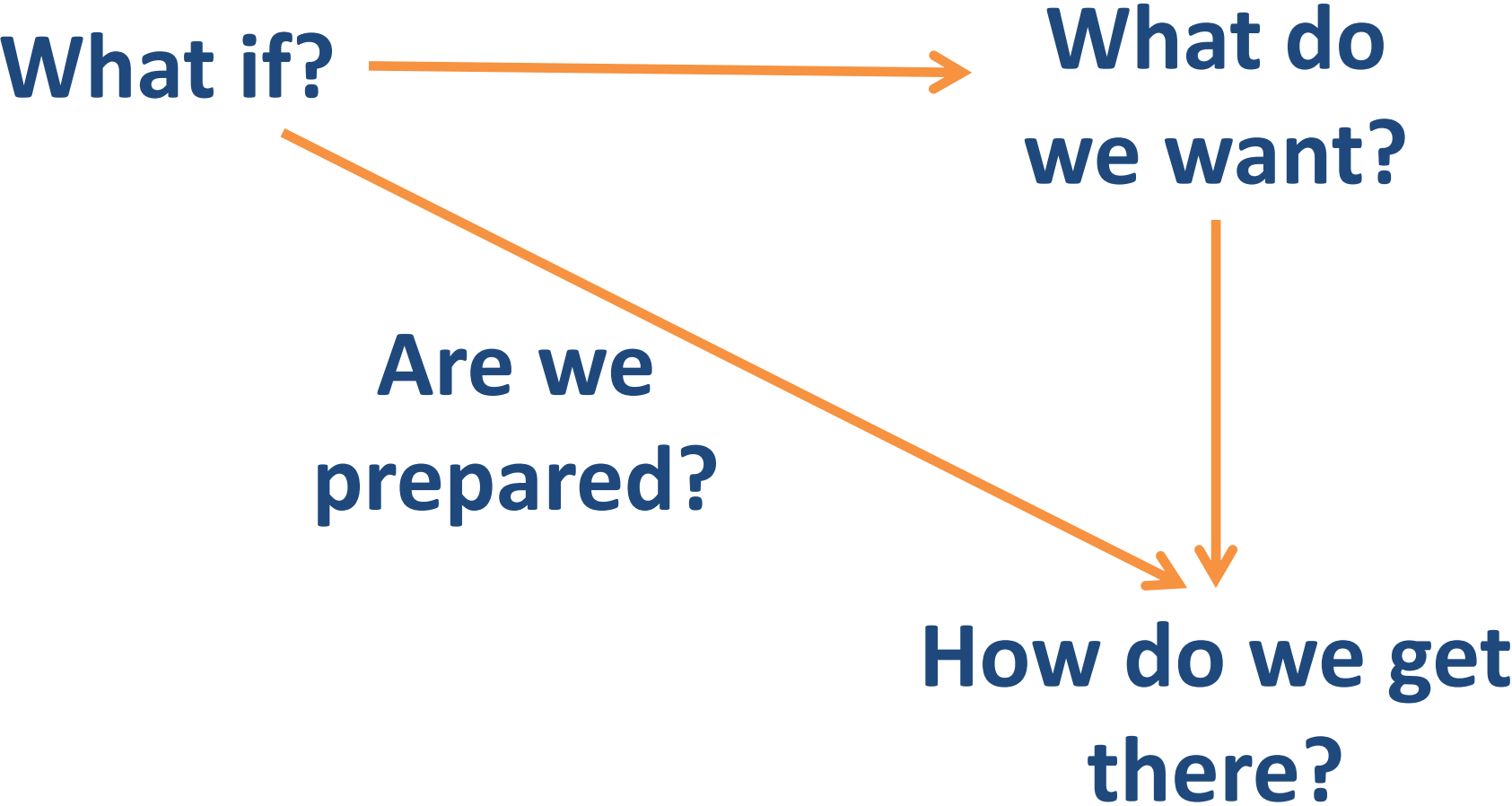Accelerated Innovation

Nested Watersheds

Abandonment & Renewal
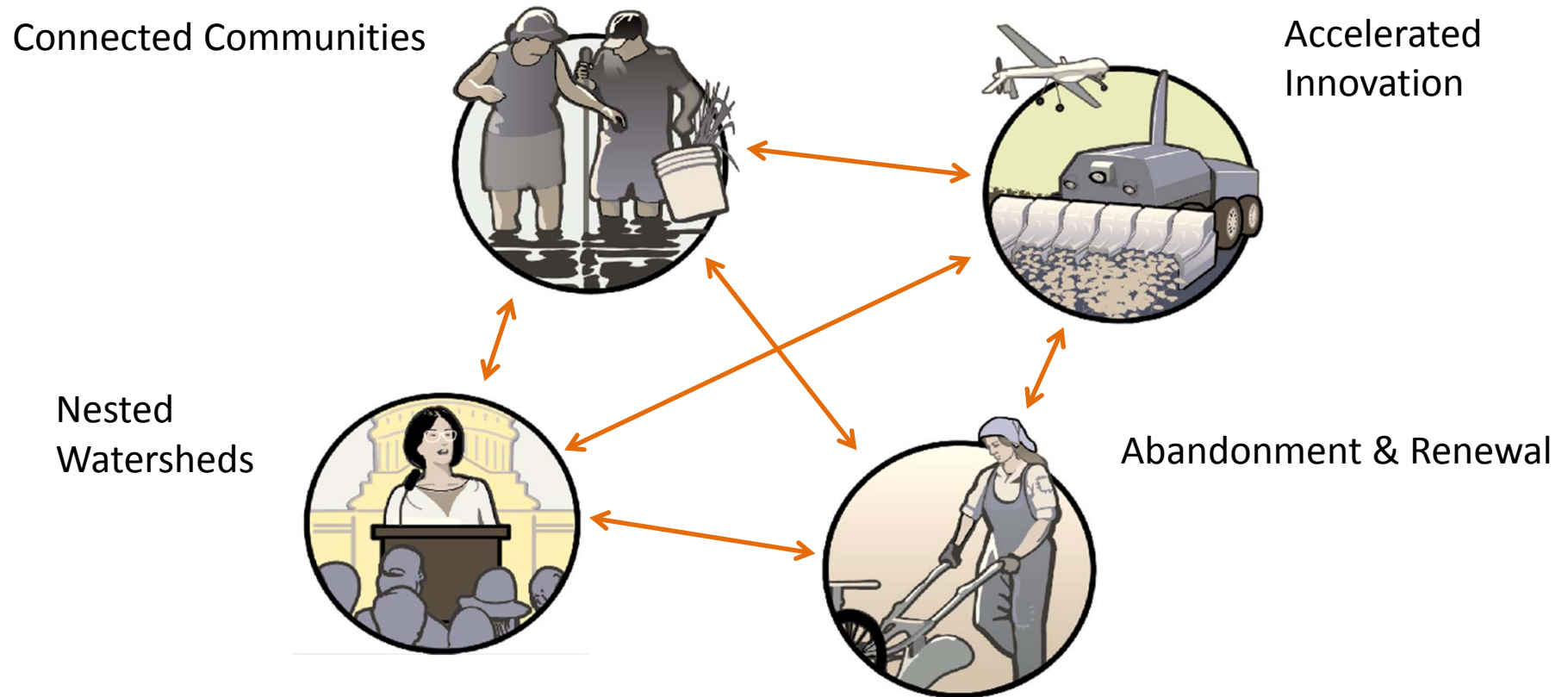
What are the worst threats about the future and how can we avoid them?
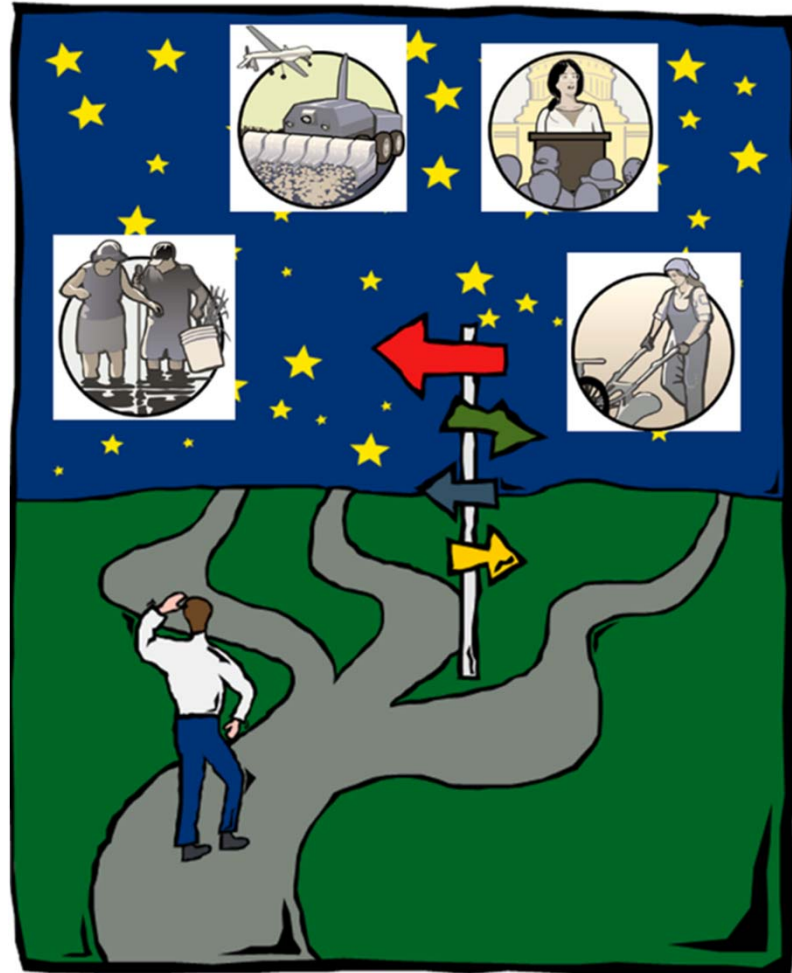
What are the best ideas about the future and how can they be combined?

What could we do differently?

Using Yahara 2070: Create desirable pathways

What if? → **What do we want?**

What do we want? → **How do we get there?**

What if? → **How do we get there?**

Are we prepared?

The "5th" scenario:
What kind of future do we want?

Leitbild = A guiding vision for the future

"If you want to build a ship, don't start with collecting wood, cutting the plank and assigning work, but awake in people the longing for the wide and open sea."

– Antoine de Saint-Exupery (*Citadelle*)

Backcasting:
How can we get to our desired future?

Consensus | Decision Making | Coordinated Action

Scenarios Outreach Approach

- Suited for long-term, persistent problems that need sustainable solutions

- Partnerships are key to ownership and follow-up

- Tie outreach to ongoing work and processes

- Good facilitation is necessary

Potential Outreach Implications

- Create needed space for long-term thinking

- Broaden scope of potential solutions
  - Shift frame of and approaches to a problem
  - Inspire new ideas or ways of thinking

- Enhance social learning
  - Values, beliefs, behavioral intent
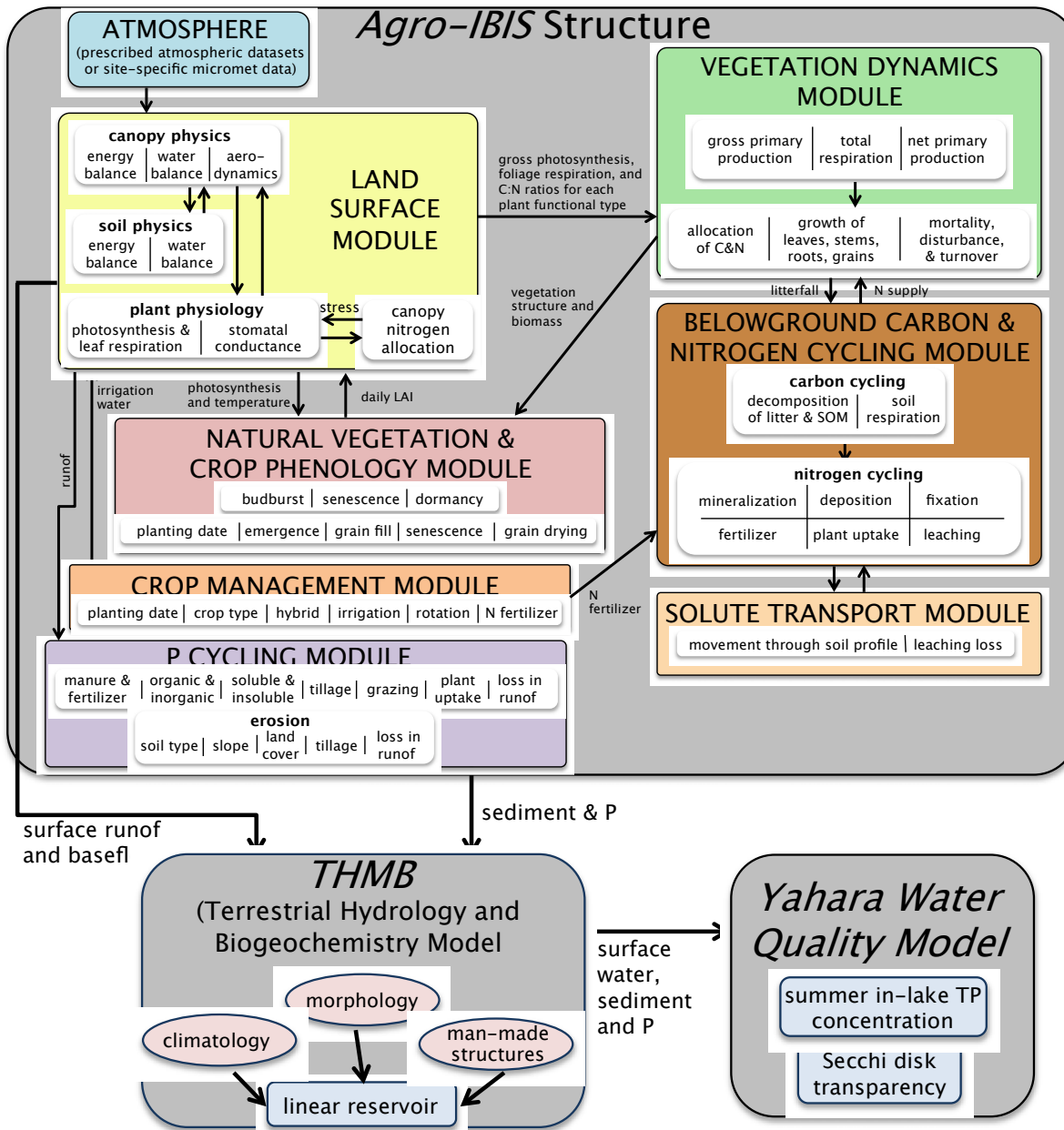 - Network building and collaboration

Yahara2070.org

Discussion guide
coming soon!

Contact Jenny:
jseifert2@wisc.edu

Follow us:
@YaharaWSC

Modeling Approach

*Agro–IBIS* Structure

ATMOSPHERE
(prescribed atmospheric datasets or site–specific micromet data)

LAND SURFACE MODULE

canopy physics
| energy balance | water balance | aero–dynamics |

soil physics
| energy balance | water balance |

plant physiology
| photosynthesis & leaf respiration | stomatal conductance |

stress

canopy nitrogen allocation

gross photosynthesis, foliage respiration, and C:N ratios for each plant functional type

vegetation structure and biomass

irrigation water

photosynthesis and temperature

daily LAI

runof

NATURAL VEGETATION & CROP PHENOLOGY MODULE
| budburst | senescence | dormancy |
| planting date | emergence | grain fill | senescence | grain drying |

CROP MANAGEMENT MODULE
| planting date | crop type | hybrid | irrigation | rotation | N fertilizer |

P CYCLING MODULE
| manure & fertilizer | organic & inorganic | soluble & insoluble | tillage | grazing | plant uptake | loss in runof |

erosion
| soil type | slope | land cover | tillage | loss in runof |

VEGETATION DYNAMICS MODULE
| gross primary production | total respiration | net primary production |
| allocation of C&N | growth of leaves, stems, roots, grains | mortality, disturbance, & turnover |

litterfall   N supply

BELOWGROUND CARBON & NITROGEN CYCLING MODULE

carbon cycling
| decomposition of litter & SOM | soil respiration |

nitrogen cycling
| mineralization | deposition | fixation |
| fertilizer | plant uptake | leaching |

N fertilizer

SOLUTE TRANSPORT MODULE
| movement through soil profile | leaching loss |

surface runof and basefl

sediment & P

THMB
(Terrestrial Hydrology and Biogeochemistry Model

morphology

climatology

man-made structures

linear reservoir

surface water, sediment and P

Yahara Water Quality Model

summer in–lake TP concentration

Secchi disk transparency

1. Land Surface, Agroecosystem Model (AgroIBIS-VSF)
2. Hydrologic Routing Model (THMB)
3. Empirical Lake Water Quality Model

- Capabilities
  - Grid-based
  - Accounts for fluxes of
    - Water
    - Energy
    - Carbon
    - Nitrogen
    - Phosphorus
  - Diverse land covers
    - 7 crop types
    - Urban cover
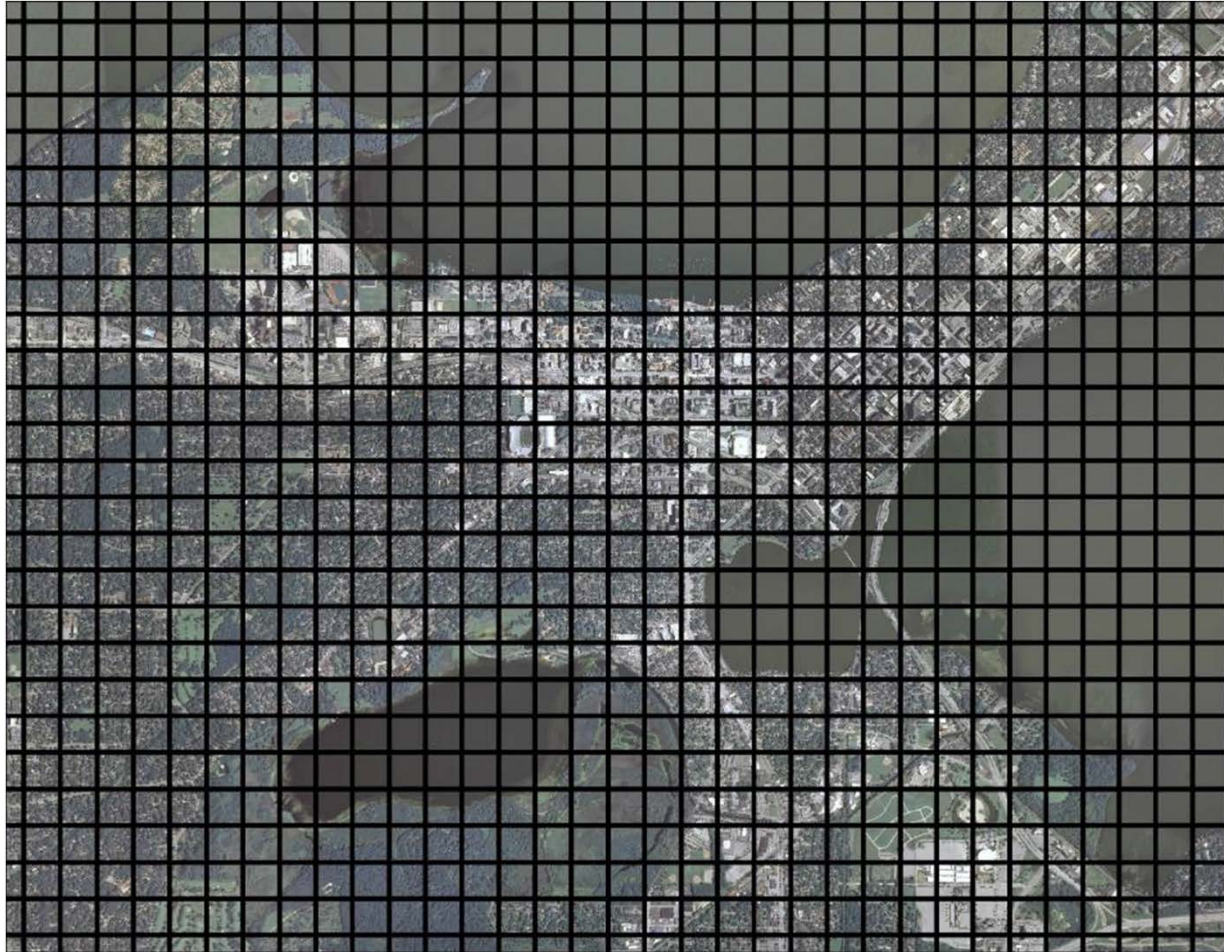 - Plant growth limited by water and nitrogen

220 m x 220 m Grid
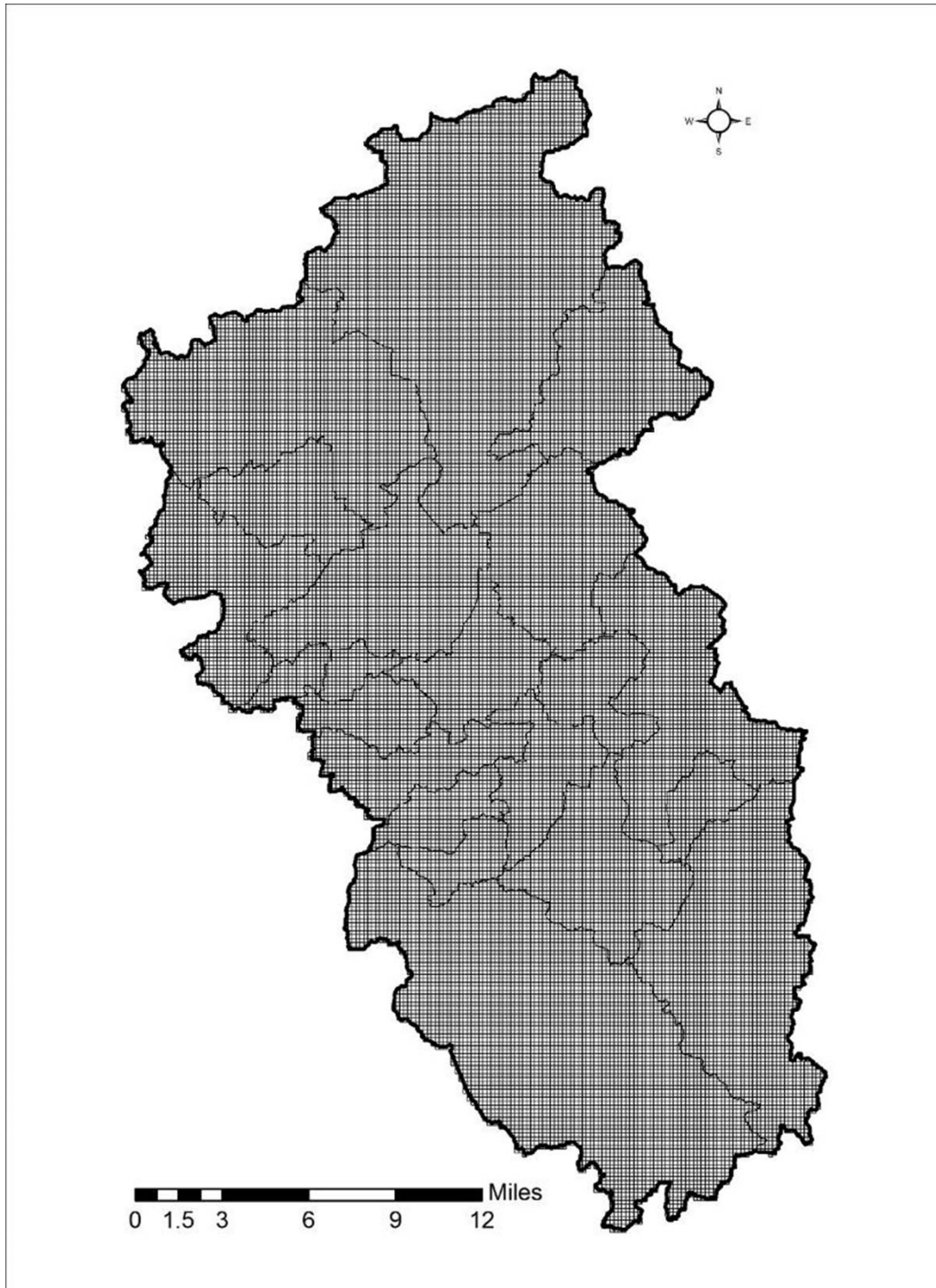
220 m x 220 m Grid
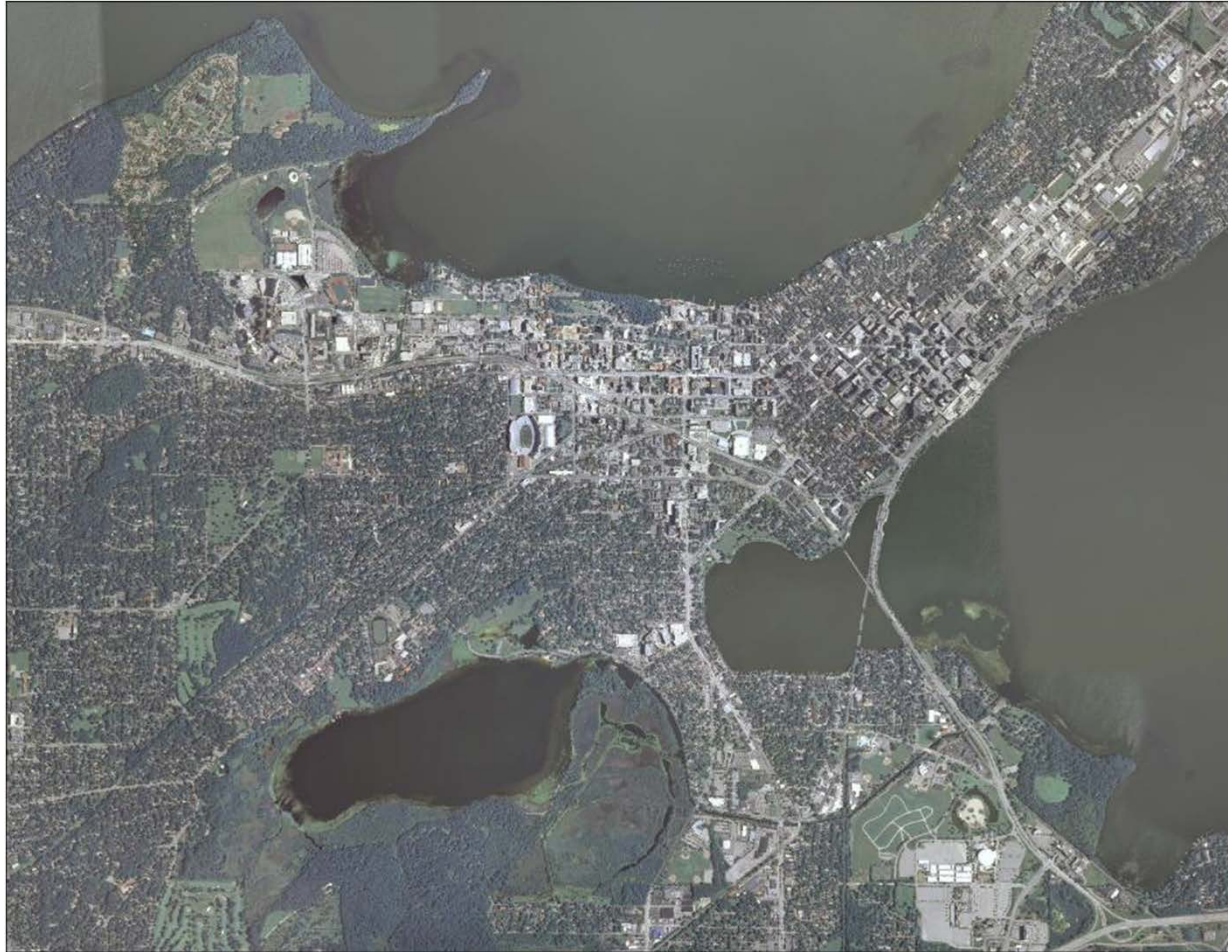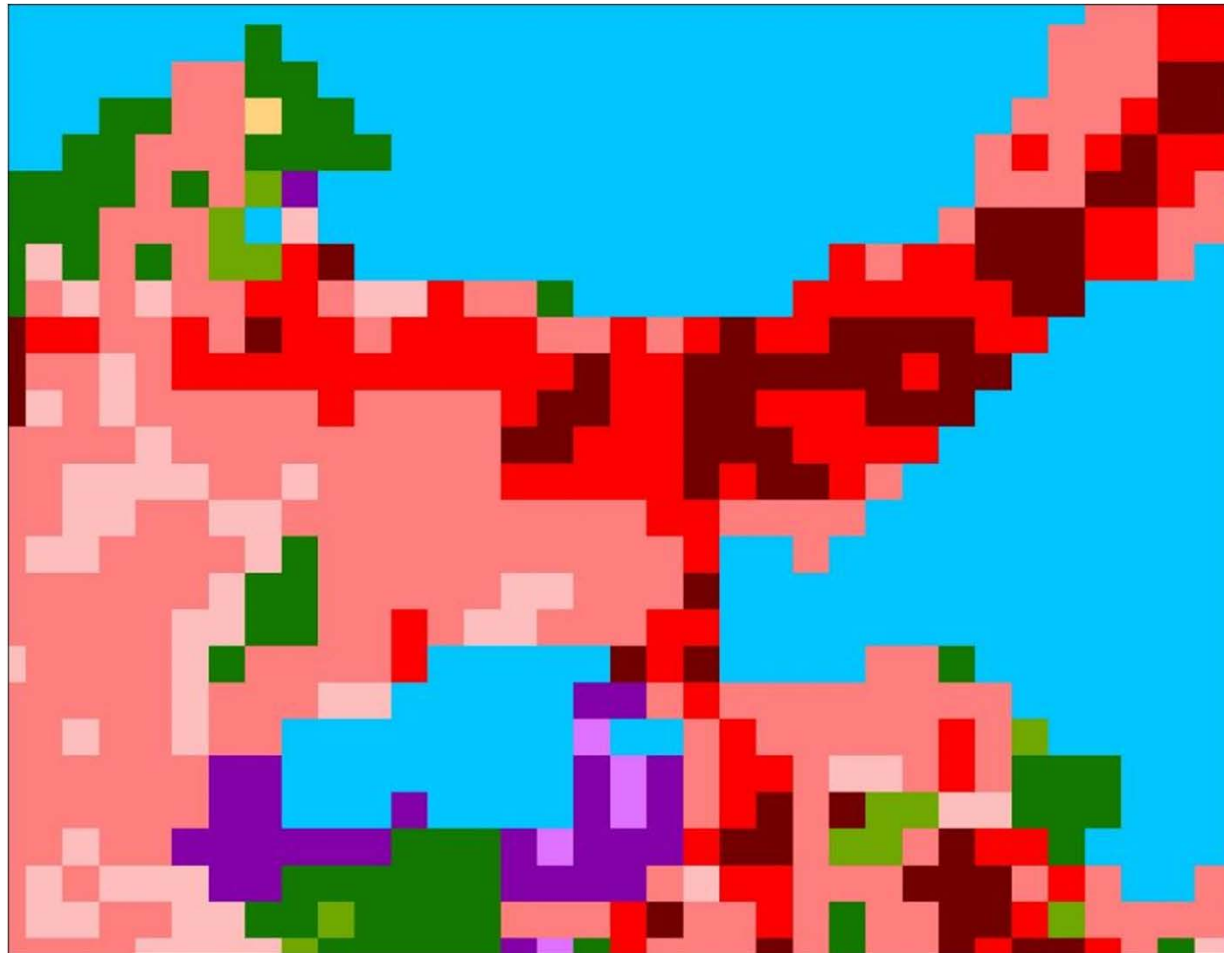
220 m x 220 m Grid

220 m x 220 m Grid

2010
Land
Cover

Legend

- Alfalfa
- Corn
- Vegetables and Fruit
- Small Grains
- Soybeans
- Hay
- Pasture
- Developed - High Intensity
- Developed - Med Intensity
- Developed - Low Intensity
- Developed - Open Space
- Deciduous Forest
- Grassland
- Herbaceous Wetlands
- Woody Wetlands
- Open Water

Yahara 2070 Scenarios

- Quantitative modelling can lead to substantial enrichment of scenario narratives
  - For example, exploring soil phosphorus drawdown OR unincorporated manure application

- Our modeling suite allows for high specificity of spatial input data and parameters
  - Major challenge to create the input datasets!

- Scenario criteria
  - Vivid and detailed
  - Include extreme events
  - Provocative
  - Plausible
  - Contrasting
  - Coherent and consistent


based on Carpenter et al. 2005
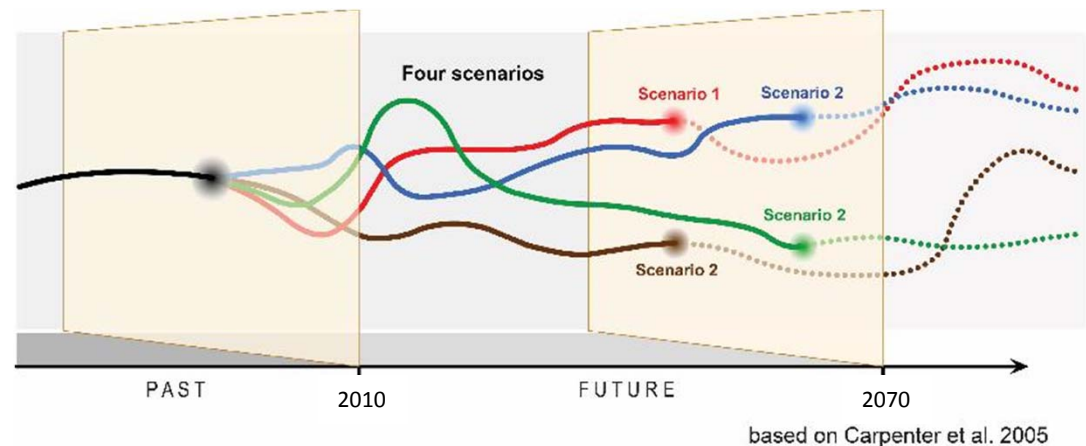
Categories for Narrative to Model Translation

1. Land Cover
   - 15 functional types
   - First, determine watershed-scale changes
   - Then, spatially distribute using set of transition rules
2. Land / Nutrient Management
   - Manure and fertilizer application
   - Tillage and conservation practices
3. Climate
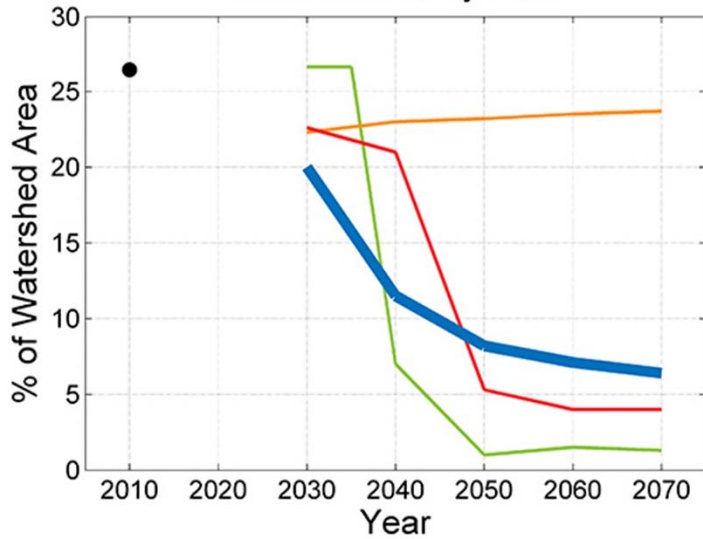   - Precipitation, air temperature
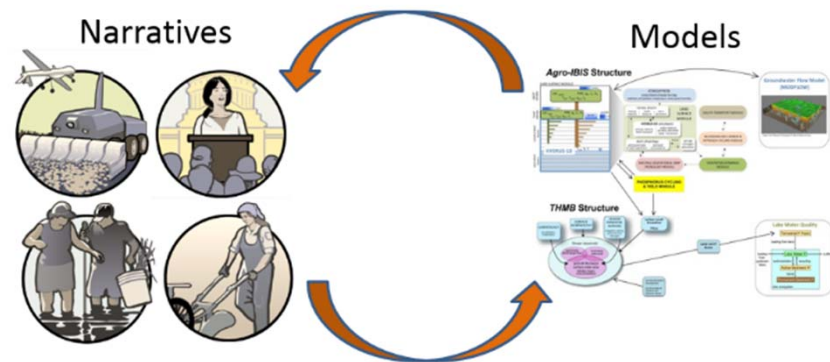
Develop Watershed-Scale Driver Curves

- More readily modified and decided upon as a group

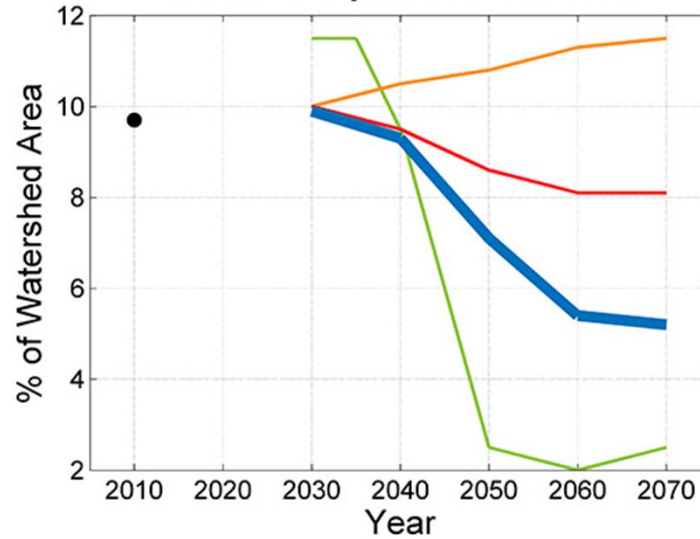- Contrasts between scenarios easier to implement
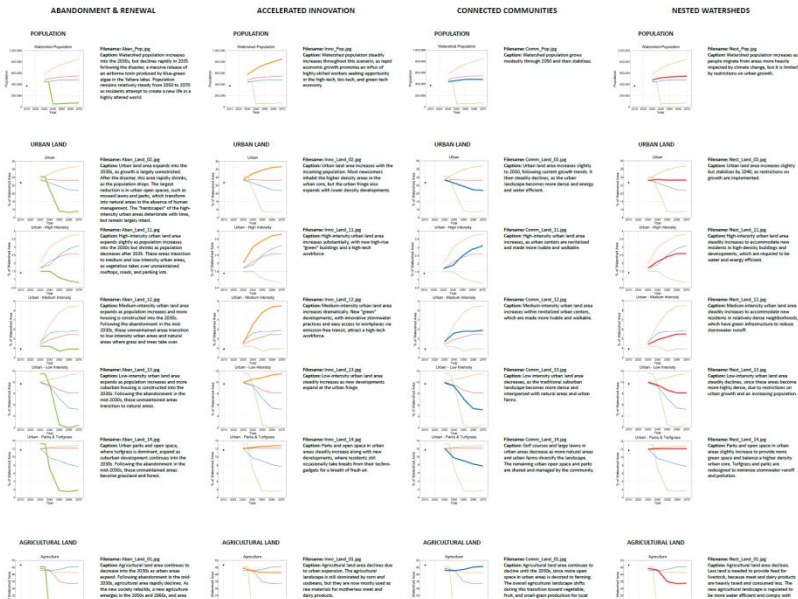
Land covered by Corn

- Land Area Percentage in 2010
- Abandonment & Renewal
- Accelerated Innovation
- Connected Communities
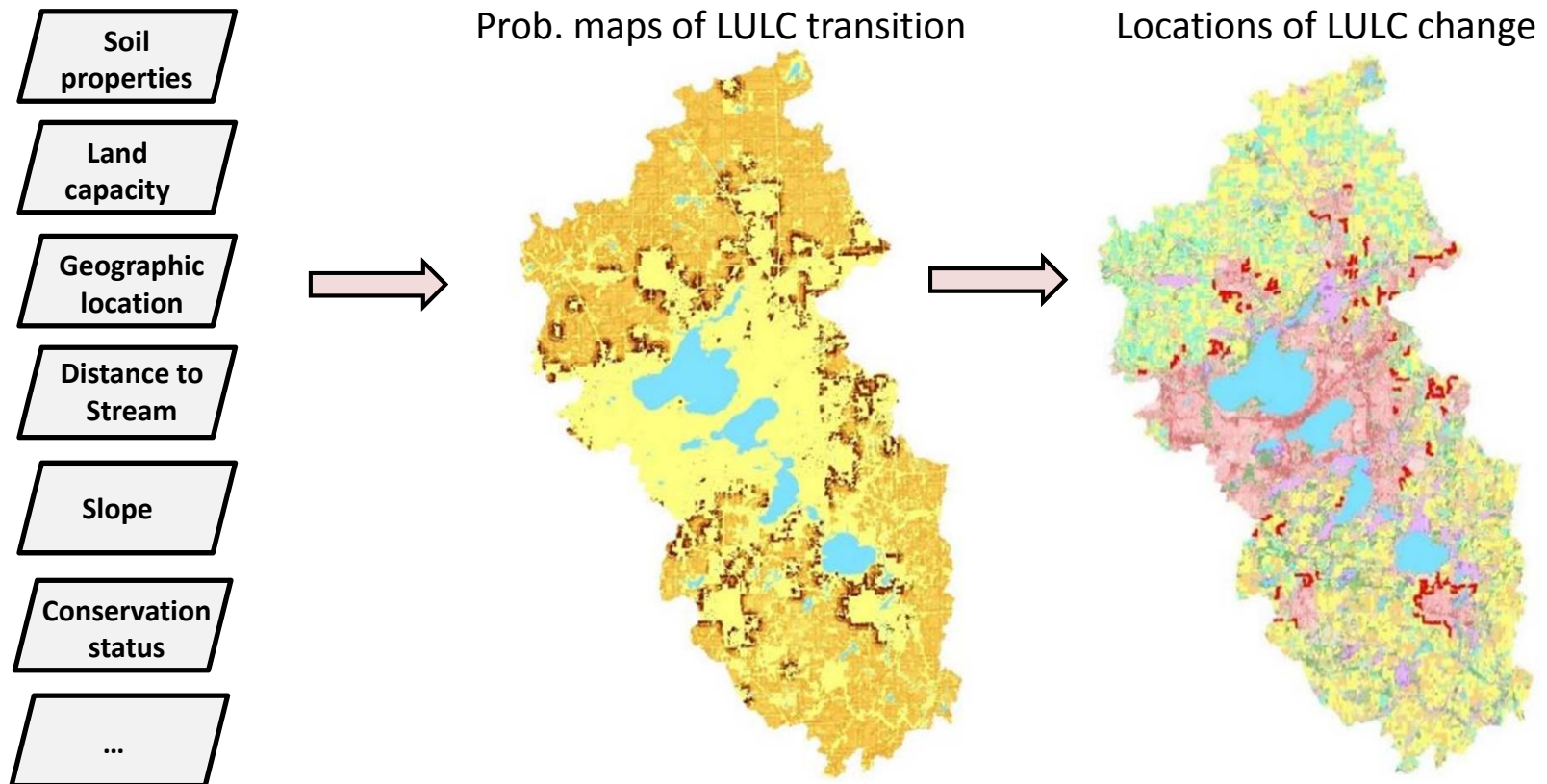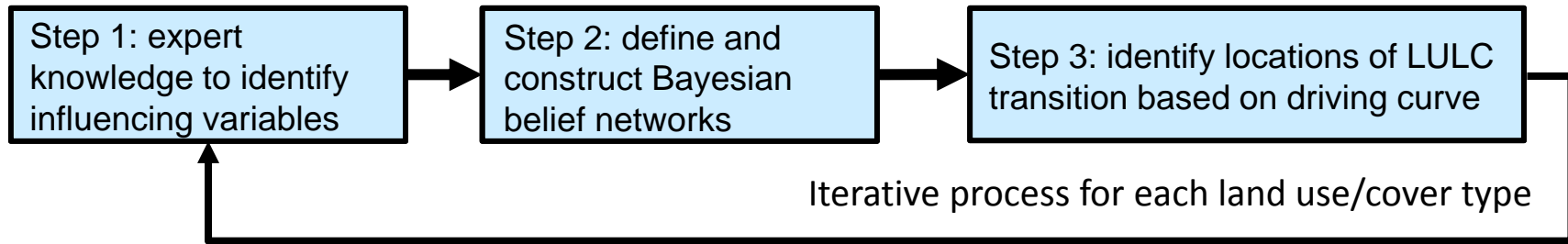- Nested Watersheds

Low-Intensity Urban Land Area

- Land Area Percentage in 2010
- Abandonment & Renewal
- Accelerated Innovation
- Connected Communities
- Nested Watersheds

Spatial allocation of driving curve: Bayesian Belief Network

(Haines-Young 2011; McClosky et al. 2011)

Step 1: expert knowledge to identify influencing variables	→	Step 2: define and construct Bayesian belief networks	→	Step 3: identify locations of LULC transition based on driving curve

Iterative process for each land use/cover type

Soil properties

Land capacity

Geographic location

Distance to Stream

Slope

Conservation status

…

Prob. maps of LULC transition

Locations of LULC change

Legend:
- Alfalfa
- Corn
- Fruits/Veg
- Small grains
- Soybean
- Hay
- Pasture
- Developed/high density
- Developed/medium density
- Developed/low density
- Developed/open space
- Deciduous forest
- Grassland
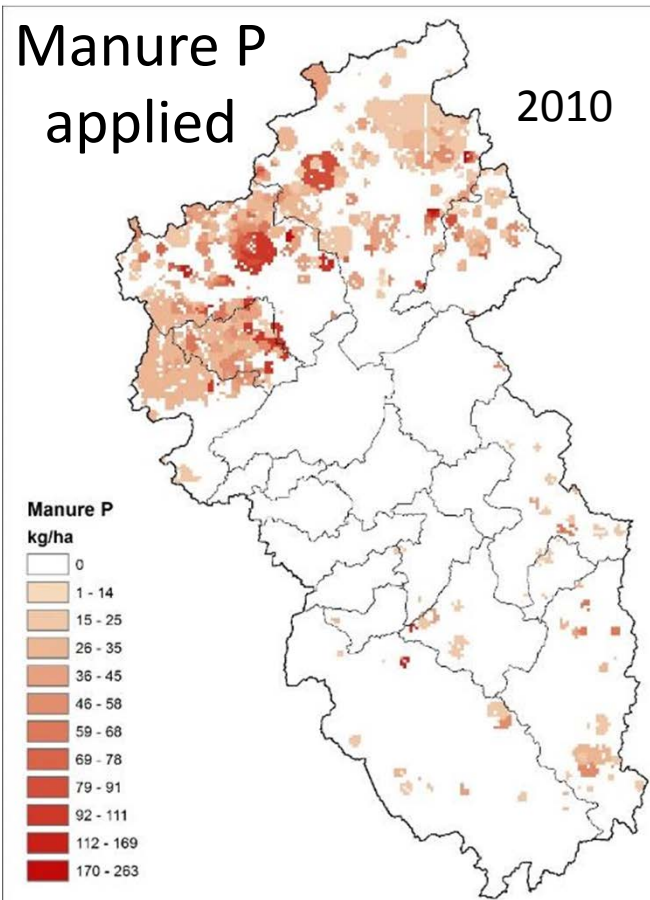- Herbaceous wetland
- Woody wetland
- Open water
- Barren

Land / Nutrient Management Drivers

- Necessary data inputs
  - Number of animal units by type → manure production
  - Milk production → manure production
  - Number of livestock operations → manure distribution
  - Relative fertilizer application rates

Manure P applied — 2010

Manure P kg/ha
- 0
- 1 - 14
- 15 - 25
- 26 - 35
- 36 - 45
- 46 - 58
- 59 - 68
- 69 - 78
- 79 - 91
- 92 - 111
- 112 - 169
- 170 - 263

- Modification of existing conditions
  - County datasets on livestock numbers and locations
  - County-level USDA Ag Census data
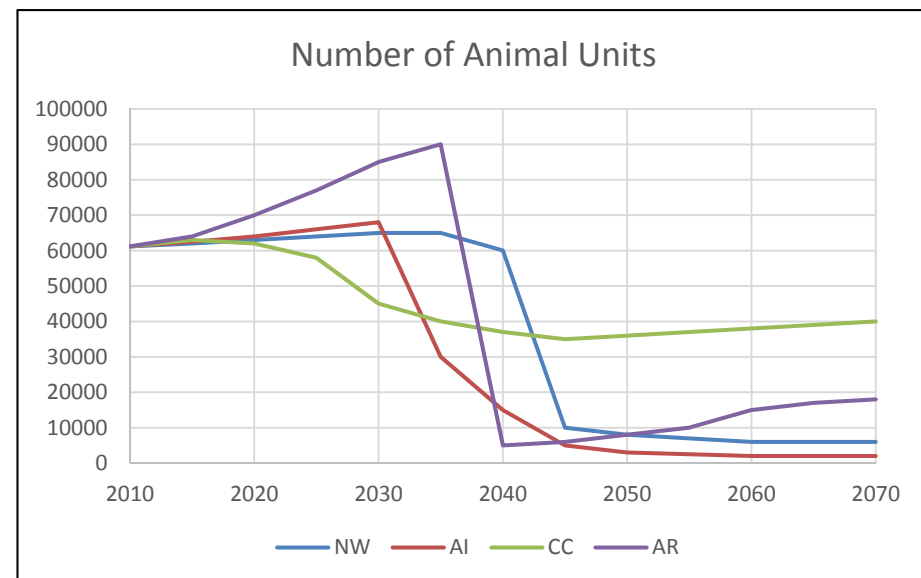
Number of Animal Units

Changes in Climate

- Balance between…
  - the best predictions from climate models
  - flexibility to create specific events within narrative

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- Probabilistic downscaling approach
- 13 climate models
- 3 emission scenarios
- 3 realizations
- = 234 climate scenarios

- Calculate summary statistics
  - Average temperature, precipitation, frequency of extreme events
- Match to scenario narrative

Changes in Climate

- Balance between...
  - the best predictions from climate models
  - flexibility to create specific events within narrative

STOCHASTIC WEATHER GENERATOR

- Input the matched climate model data
- Calculates statistics
- Creates "synthetic" climate for X years
- Pick out 20-year period that matches narrative timing
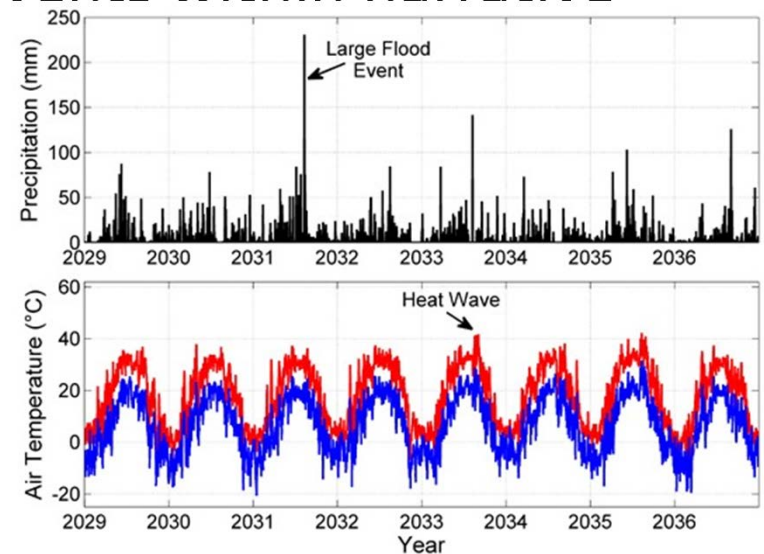
CLIMATE DRIVERS (daily precipitation, daily max/min air temperature)

Want to engage?

- We're looking for groups with which to pilot the discussion guide. If there is a group from your constituency, within your municipality staff, or among municipalities who would like to take part, please contact Jenny Seifert at jseifert2@wisc.edu

- Be on the lookout for information about the potential Yahara Watershed Stewardship Summit later in the year

- If you would like us to present on Yahara 2070 to your municipality council, please also contact Jenny.

"Legacy" of Yahara 2070

- The novel suite of models will expand capacity to estimate future impacts on ecosystem services

- The scenarios and all outreach materials will remain publicly available online after the project ends for groups to use on their own

- We hope the scenarios will help individuals and groups tackling complex problems, such as water sustainability and climate change, to incorporate long-term thinking into planning and decision-making processes and to generate new ideas and collaborations to help solve complex problems.