Using Biophysical Modeling to study Food-Energy-Water Systems: The Agro-IBIS Agroecosystem Model

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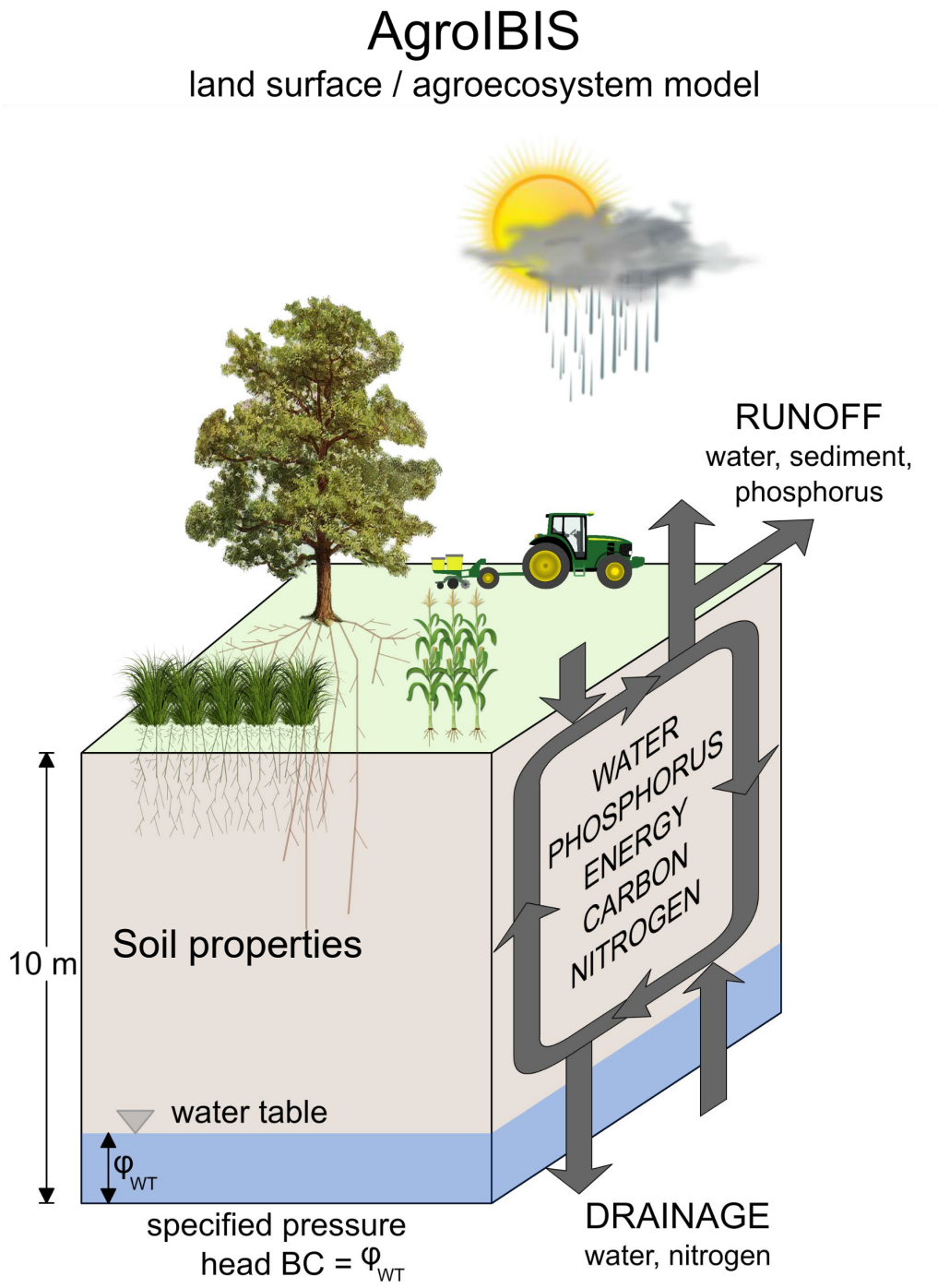
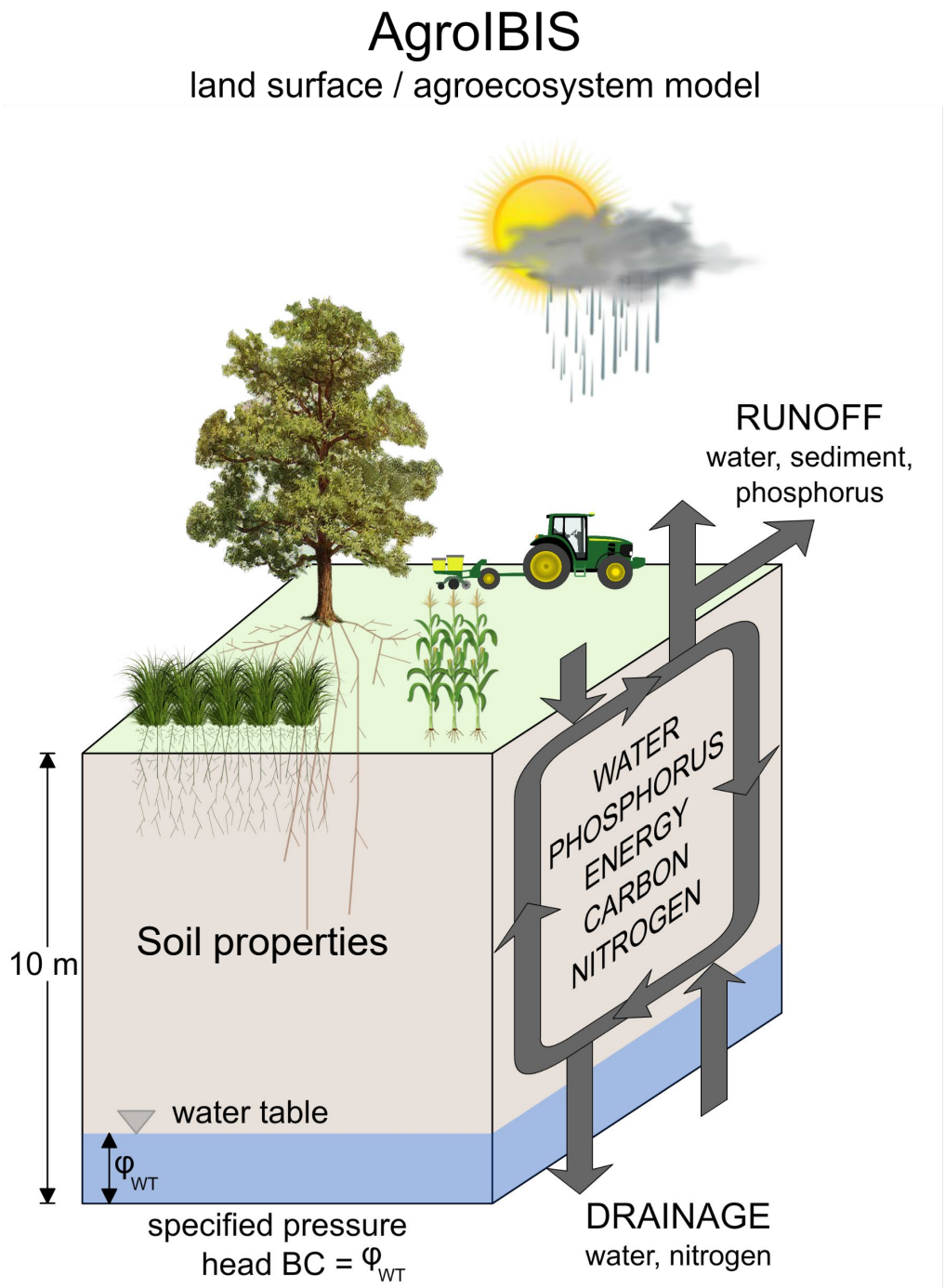
Numerical modeling of agro-ecosystems



What is the Agro-IBIS model: represents development and growth of grasses, forests, and crops, and the cycling of carbon, water, energy, phosphorus, and nitrogen in soil-plant-atmosphere system

Informs us how crop yields might respond to weather variability and irrigation and nitrogen fertilizer management

Informs us how much nitrate/phosphorus may be lost to groundwater and surface water ways as a function of management, weather variability, and soil heterogeneity



Why do we need to use models?

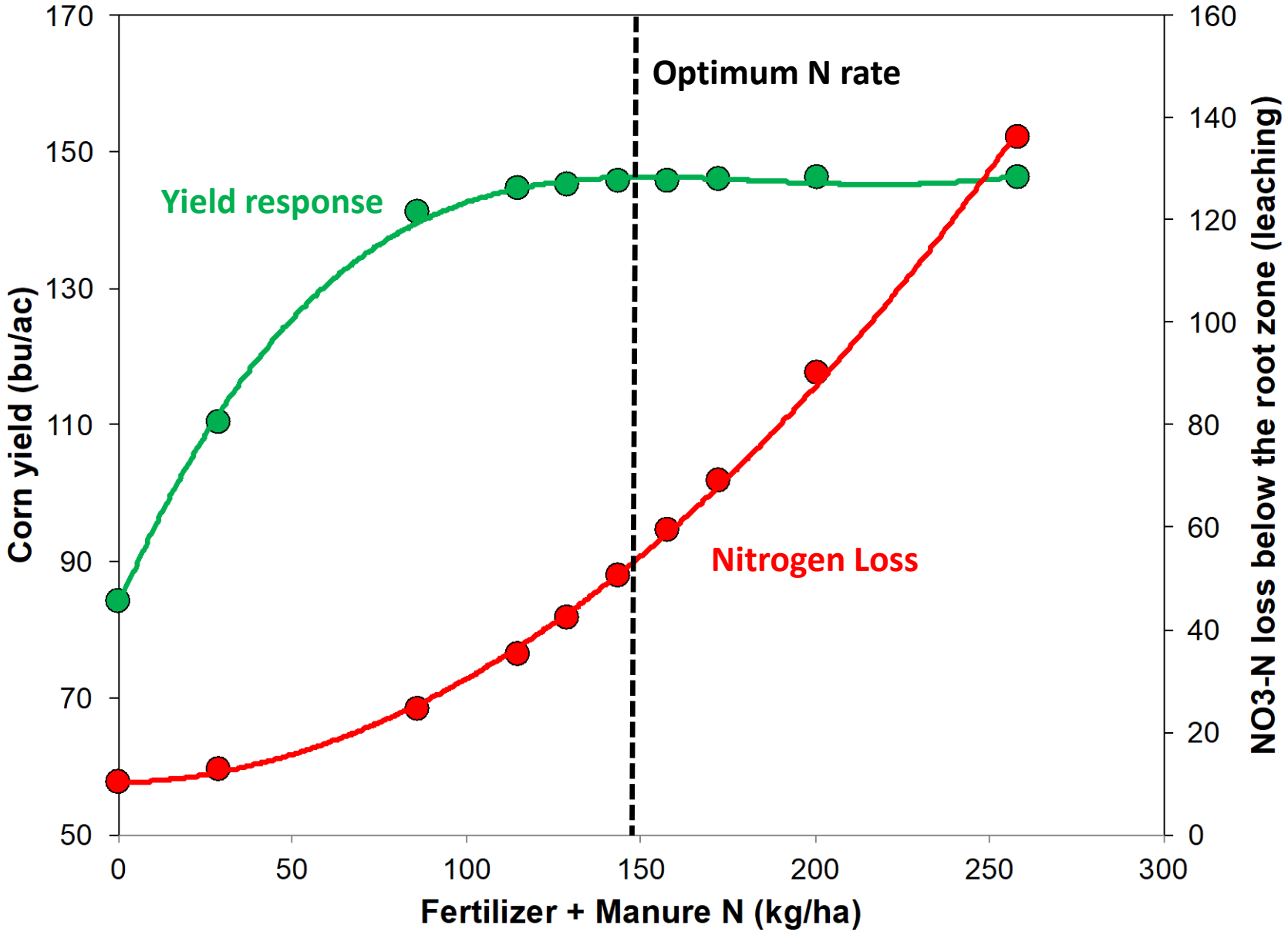
We can't perform field experiments across all farms/fields

Models allow us to examine how management decisions, soil differences, and weather variability impact responses at **large spatial scales** over **long time periods**

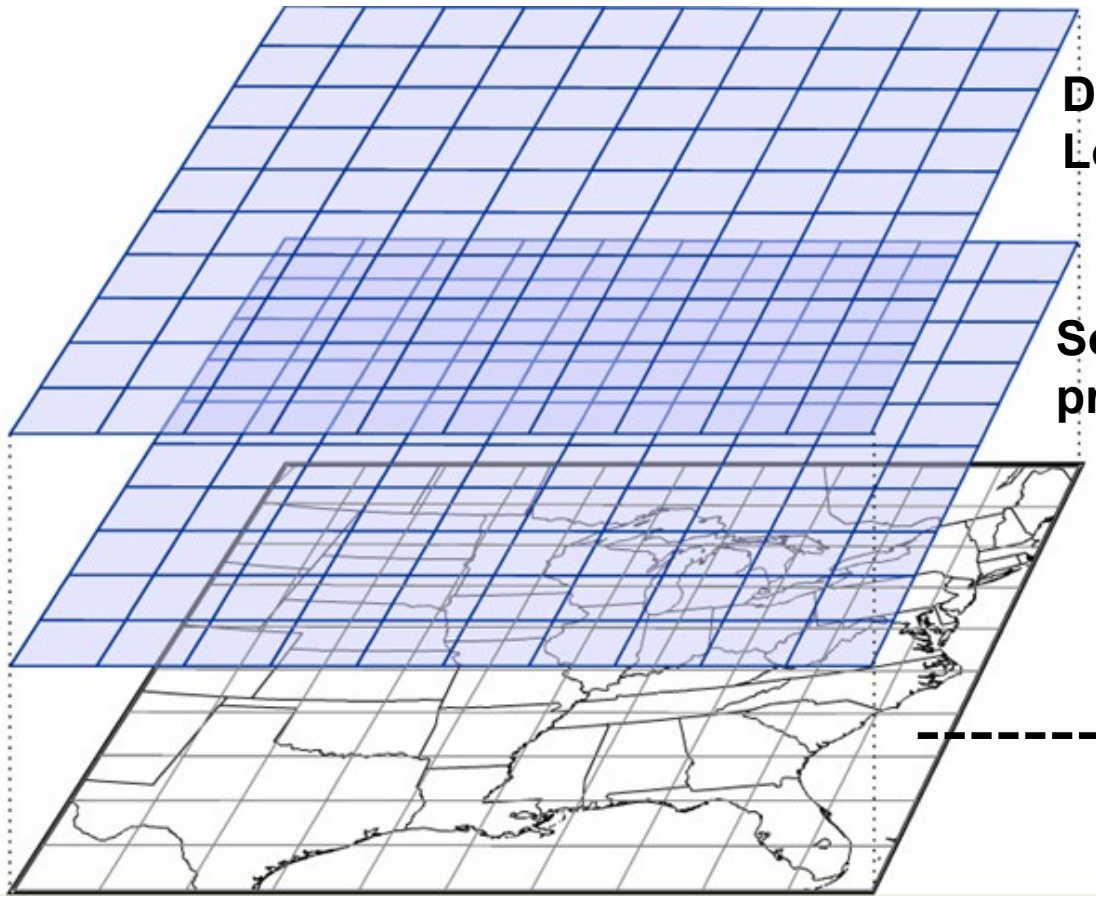
Models allow us to examine **scenarios** that have relevance to **policy decision-making** and **improved land management**

Modeling builds our understanding of nitrogen leaching and yield responses

Agro-IBIS used for a single farm growing continuous corn, no irrigation, sandy soils



Agro-IBIS requires biogeophysical information to run an experimental scenario: **model drivers**

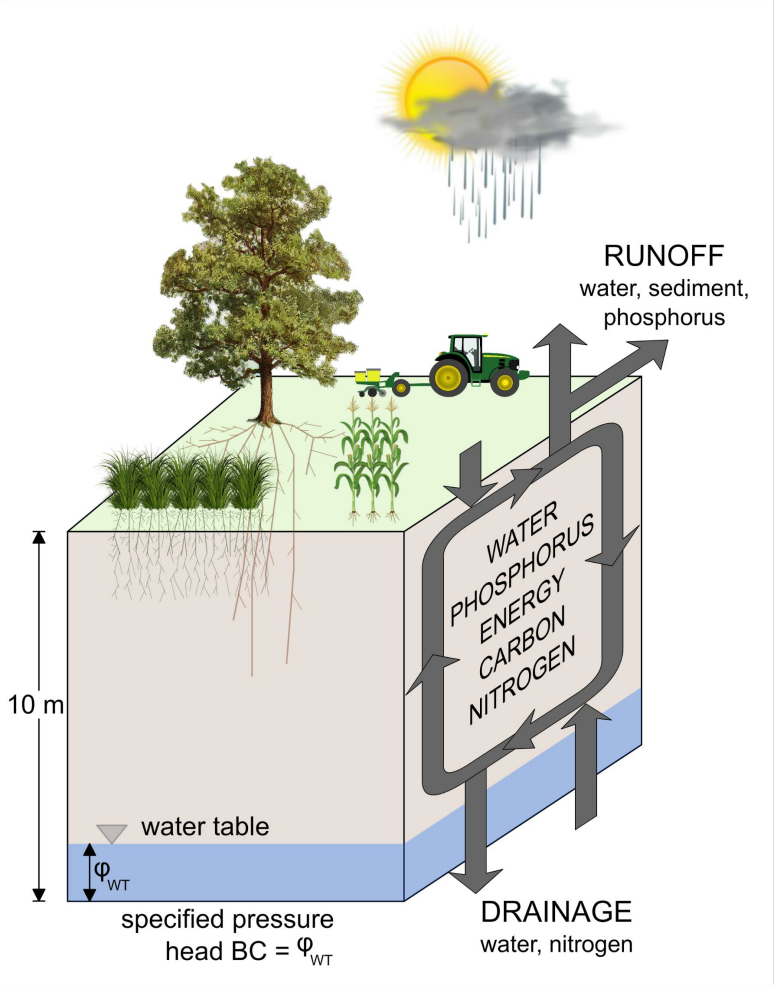


Daily weather/
Long term climate

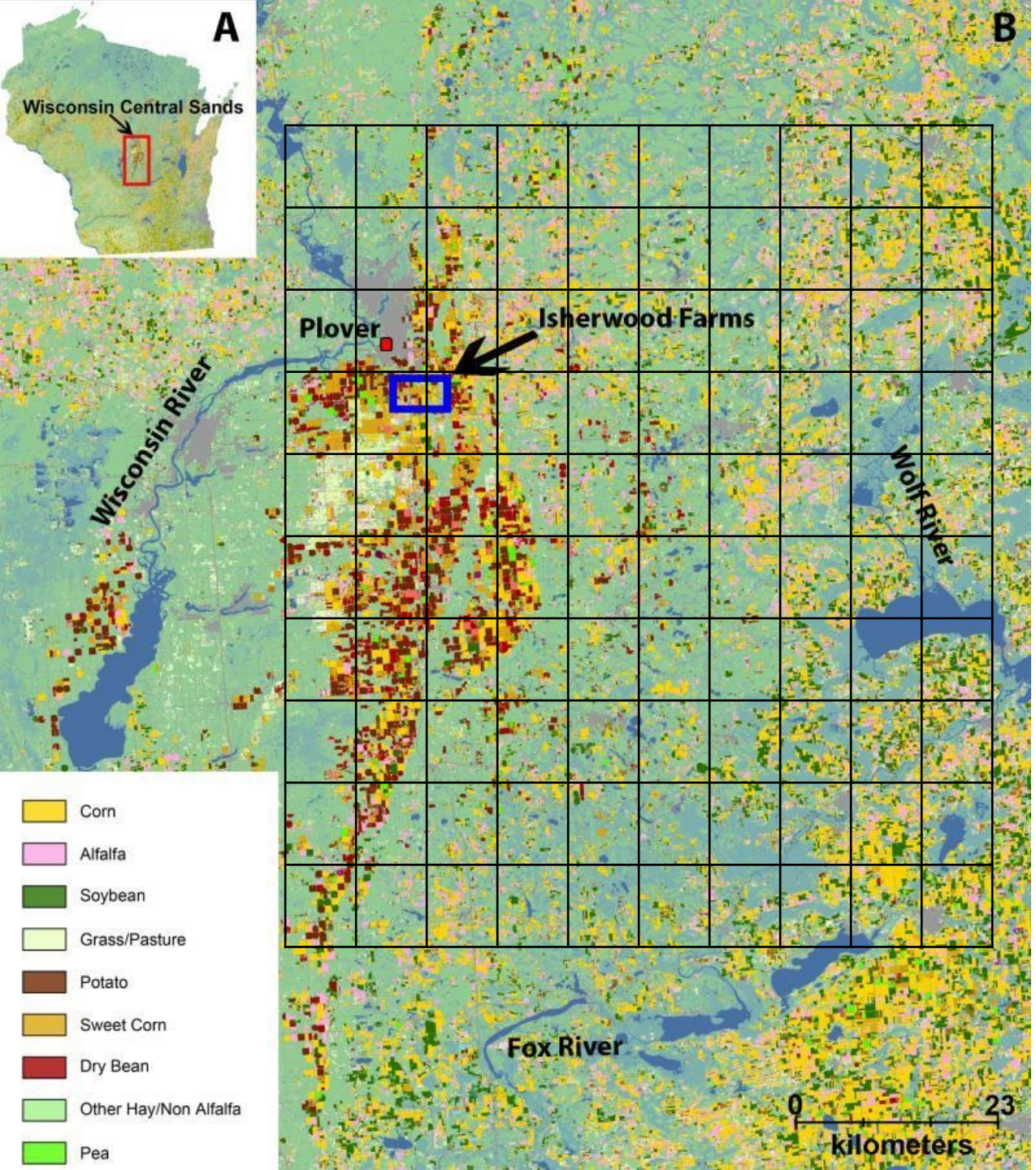
Soil texture & physical properties

Vegetation type and ag land management

AgroIBIS
land surface / agroecosystem model



Model is executed in every ”grid cell”

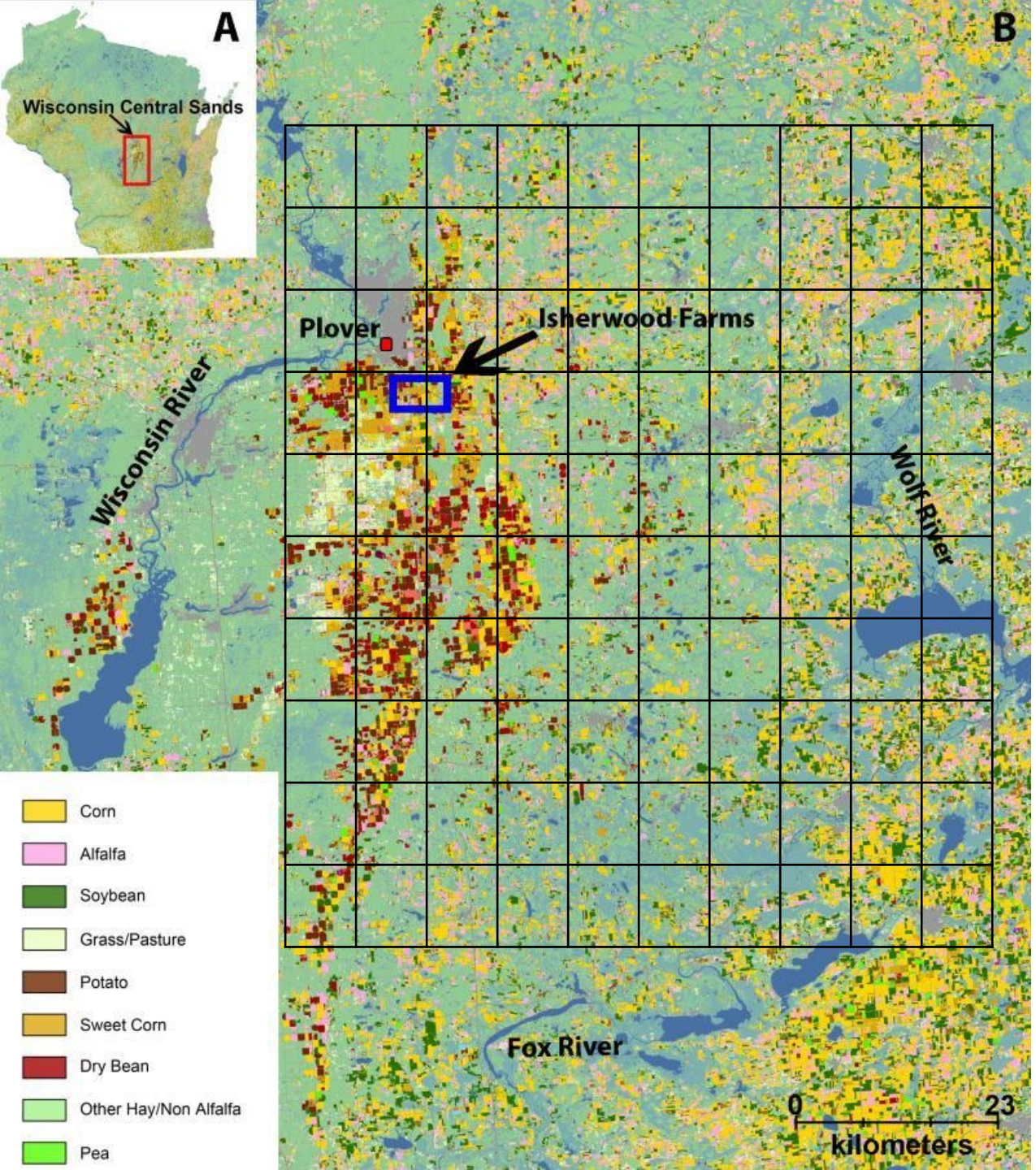


Agro-IBIS is executed across "grid cells" to assess impacts of large-scale change (*climate, land management*)

Grid cell value represents an "average" over that space

When we look at the response over large regions, we improve our understanding of large scale impacts and risks associated with land management practices

Helps guide us to more informed ag management and policy decision-making



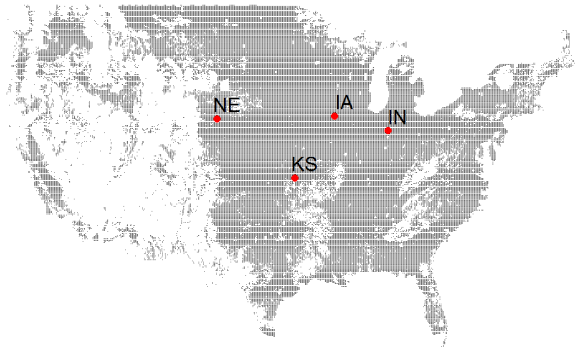
Agro-IBIS can then be used to ask broad questions about impacts to water quality:

If we spread manure in fall and spring, how much will this reduce nitrate leaching and improve regional water quality?

If we apply N fertilizer 4x during the growing season (instead of 2x), what are the impacts?

If I plant a cover crop in fall, will this reduce nitrate leaching to groundwater?

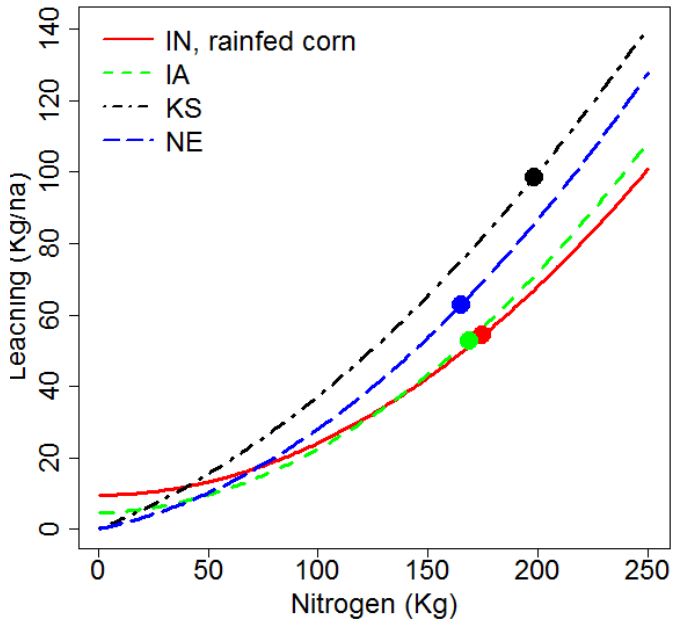
Agro-IBIS simulations are used to develop functions used in an economic model (SIMPLE-G)



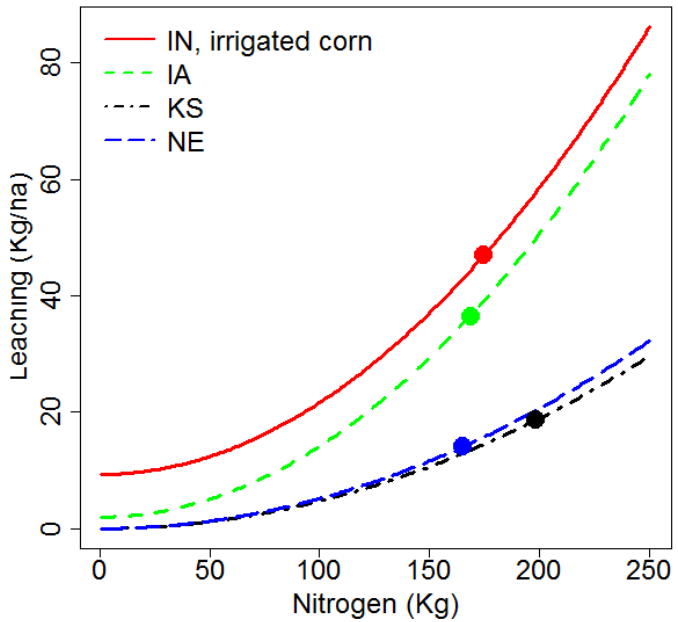
Quadratic leaching function

$$Leaching(N) = a + b \times N + c \times N^2$$

Rainfed



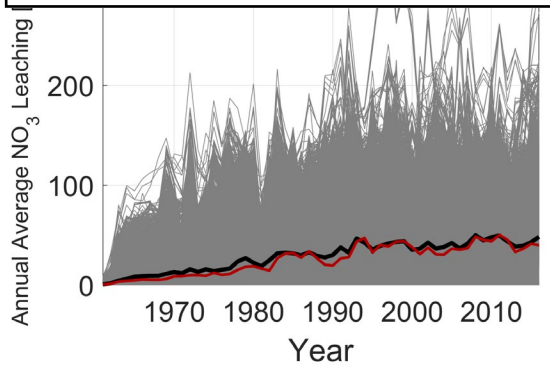
Irrigated



This approach allows us to ask questions about **policy implications of state and federal programs** and how these impact the planted area of particular crops, the amount of fertilizer added to the landscape, and resulting water quality

- *Renewable Fuel Standard (ethanol)*
- *Conservation Reserve Program*
- *New programs to incentivize BMPs, cover crops, organic farming, regenerative ag, etc.*

Figure credits: Jing Liu & Tom Hertel, Purdue University



Agro-IBIS Simulated Nitrate-N leaching for Continuous Corn using gridded N-fertilizer, soils, and weather data

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We need to consider ecosystem service tradeoffs simultaneously

- Models allow us to explore these complex interactions
- No ideal scenario
- Many tradeoffs exist
- What choices increase resiliency of food-energy-water systems?