Modeling Global Bioenergy Biomass Production and Environmental Effects

By Shujiang Kang

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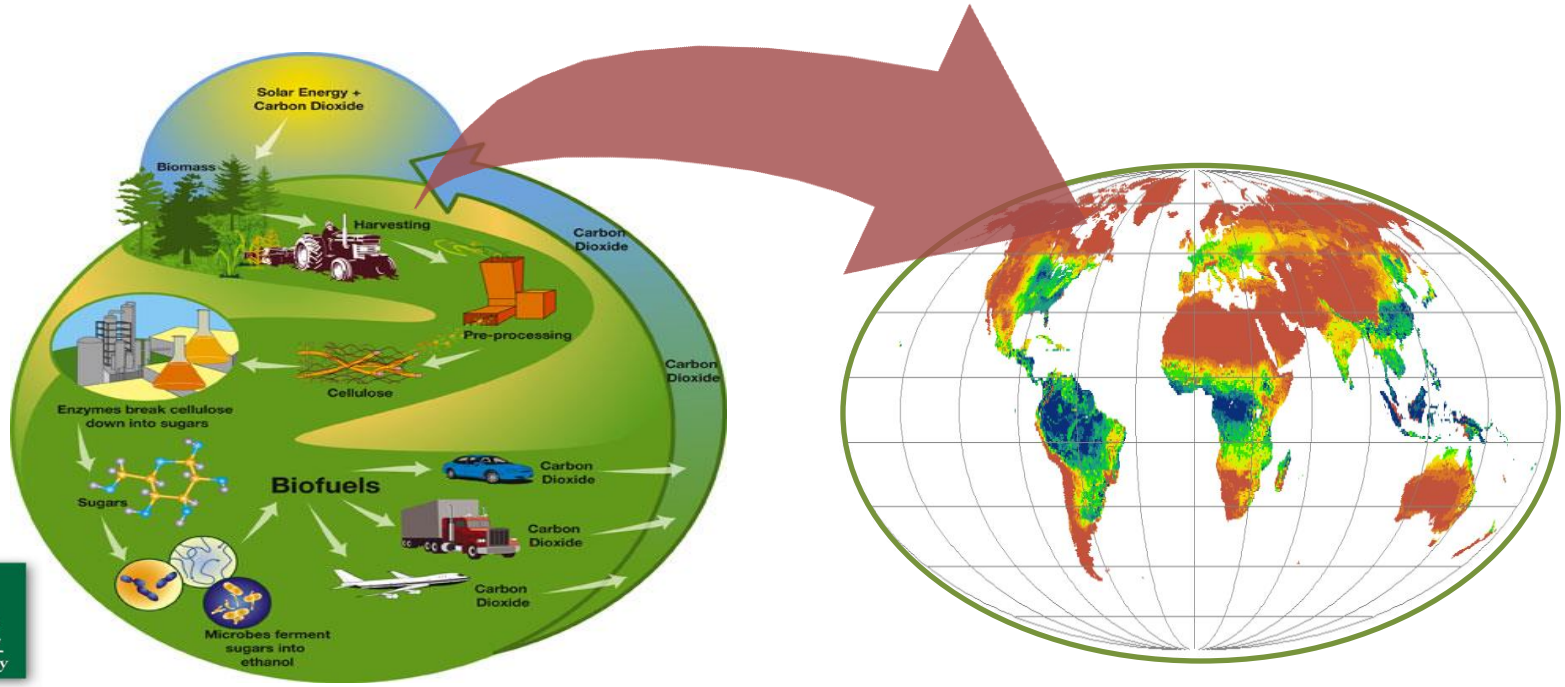

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Research Goals

- Demonstrate a data assembly and modeling platform capable of handling management variables and environmental processes/effects at continental and global scales
- Develop modeling capacity for optimization of land use among competing demands and objectives
- Explore sustainability criteria under global land use allocations and alternative scenarios, e.g., associated with climate change

High Variability & Complexity of Global Cropping Management Practices & Generalized OPS Design

Levels

- High input
- Intermediate input
- Low input

Management Practices

- Crop rotation (food & bioenergy)
- Fertilizer
- Tillage
- Irrigation
- Pesticide & herbicides

I. Regression Modeling

First-Cut Global Biomass Potential Assessment for Switchgrass, Miscanthus, Agave, & Sugarcane

- Climate data processing – CRU-NCEP (1980-2009)
- Regression model screening for switchgrass, miscanthus, agave
- Biomass production potential assessment with GIS
- Biomass production potential in pasturelands
- Biomass production potential by countries

Agave model
Nobel et al., (1989)

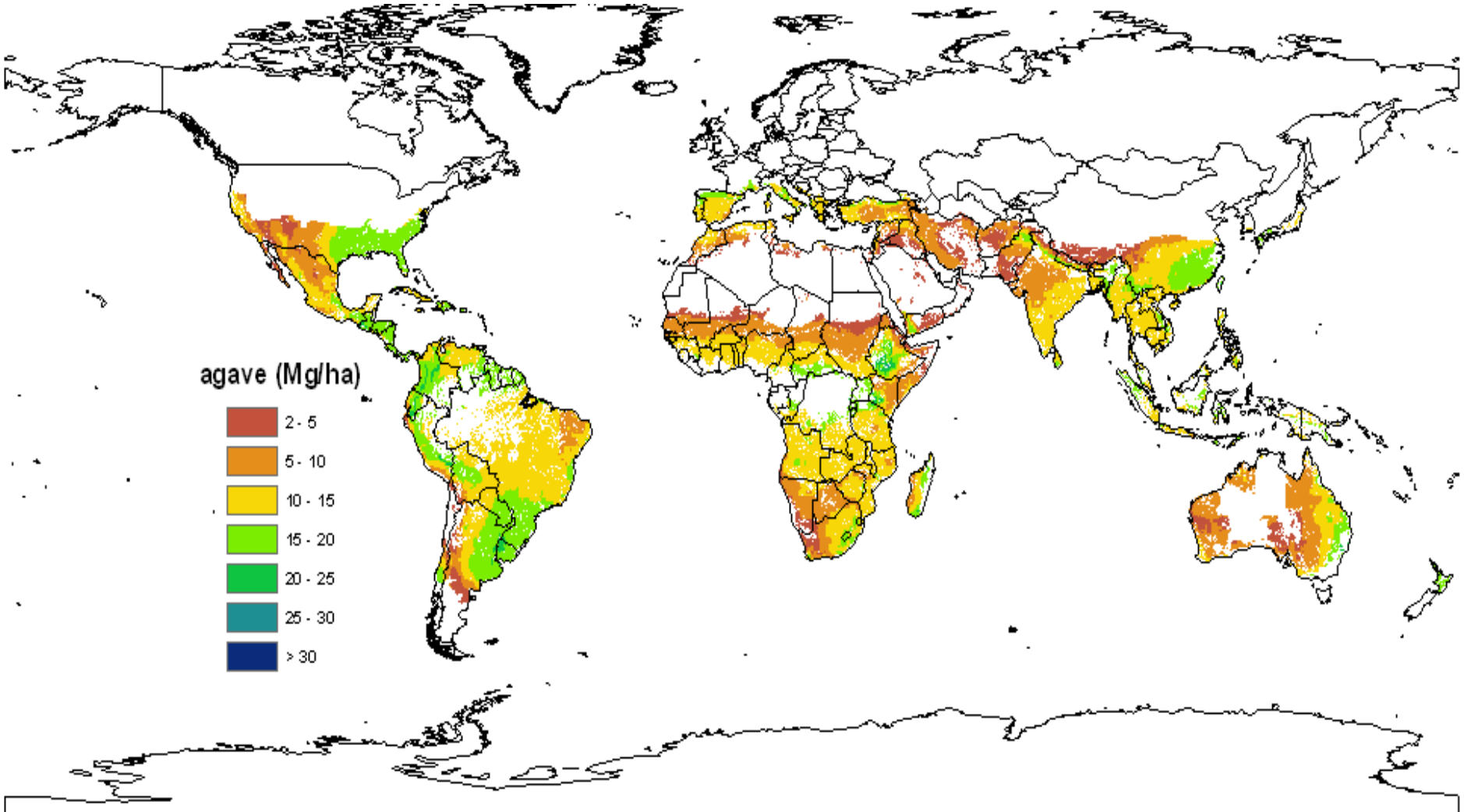
$EPI = F_R * F_T * F_P$

Where EPI is environmental productivity index,

F_R is radiation index; F_T is temperature index; F_P is precipitation index.

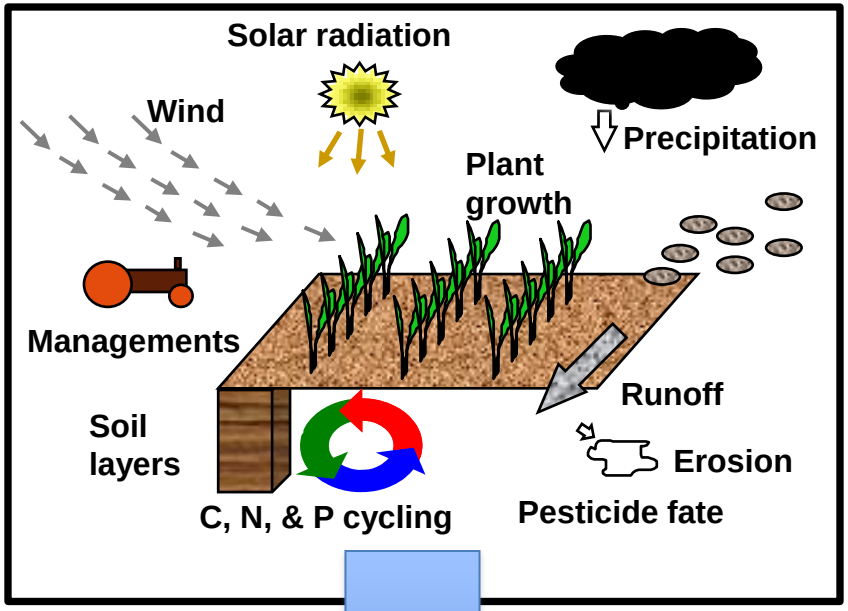
Note: significant analysis, trial and error invested to adapt EPI to a modeling formula

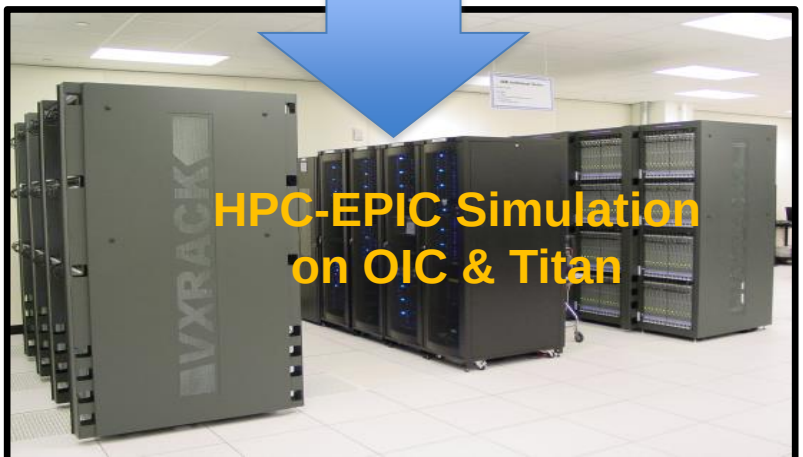
Global Agave Biomass production Assessment in Pasturelands (>2Mg/ha)



II. Biophysical Modeling

Environment Policy Integrated Climate (EPIC) Model to HPC-EPIC

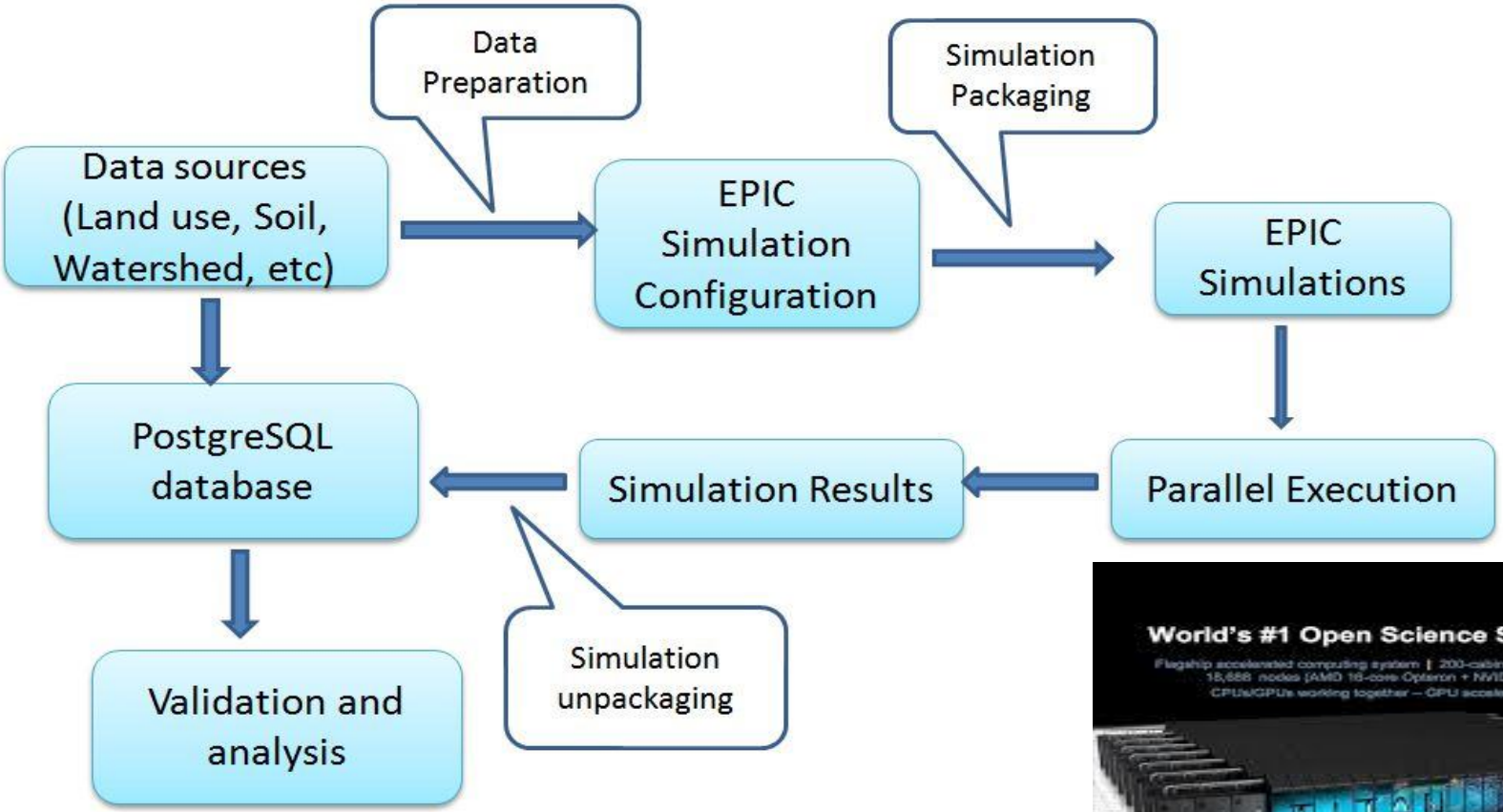


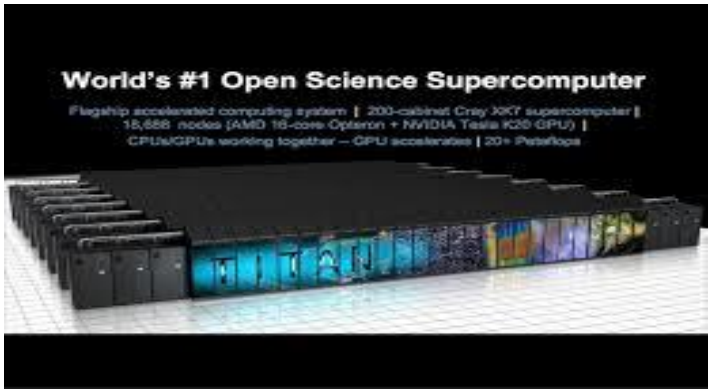


- Developed by USDA in 1980s
- EPIC continually improved over 30 years
- Model for BMPs used by USDA-NRCS
- Calibrated for 94 food & bioenergy crops, tested in over 60 countries / regions
- Key processes simulated
  - ✓ Plant growth and yield
  - ✓ Management: tillage, fertilizers, irrigation, pesticides
  - ✓ Water balance; irrigation, drainage
  - ✓ Carbon cycling, including eroded carbon
  - ✓ Nitrogen cycling
  - ✓ Erosion by wind and water
  - ✓ NPS pollutant fate

HPC-EPIC Modeling Workflow

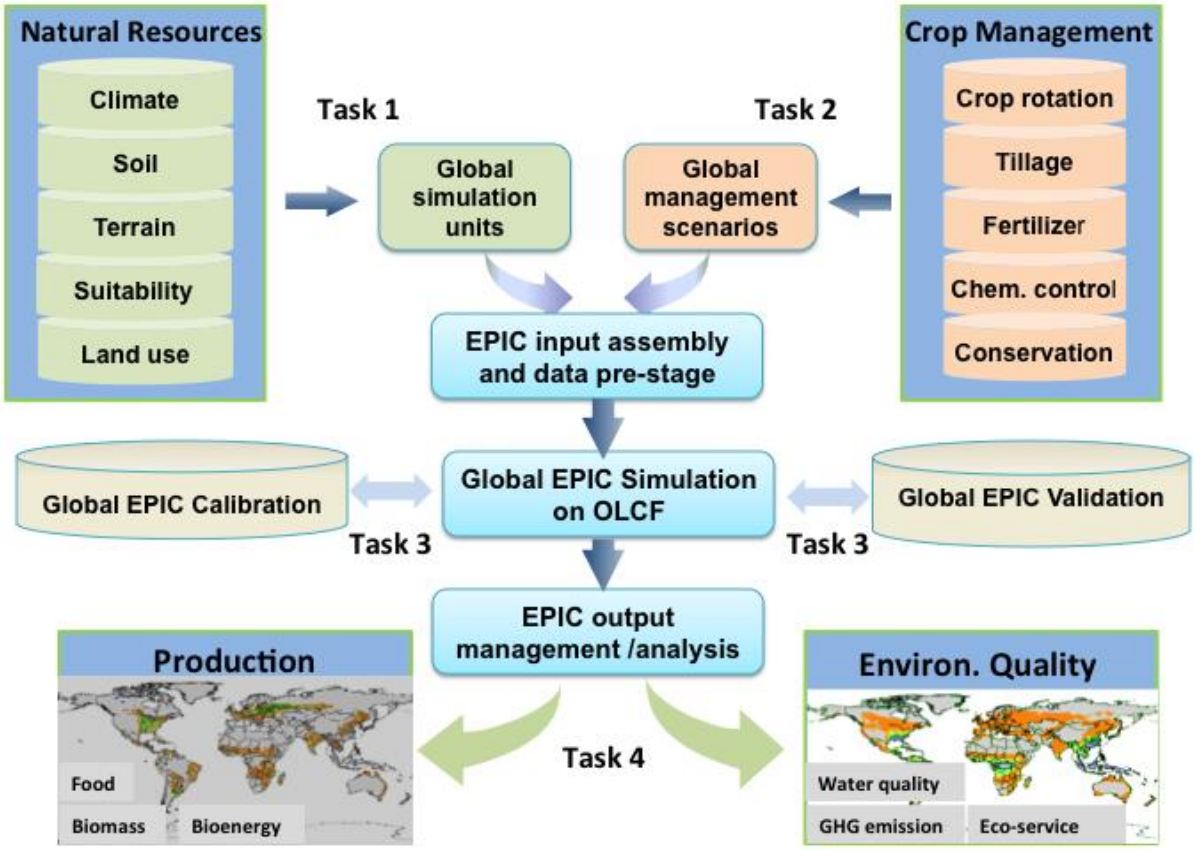
Adapting EPIC to HPC environment (cluster and supercomputer) with parallel design





Global Modeling Platform Design

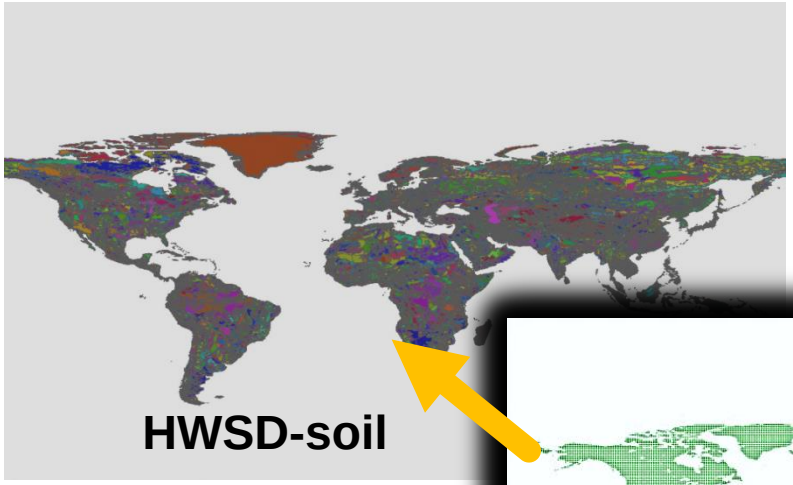
- T 1. Assembly of input and forcing datasets, and formulation of Global Simulation Units (GSUs)
- T2. Development of crop/bioenergy management system files



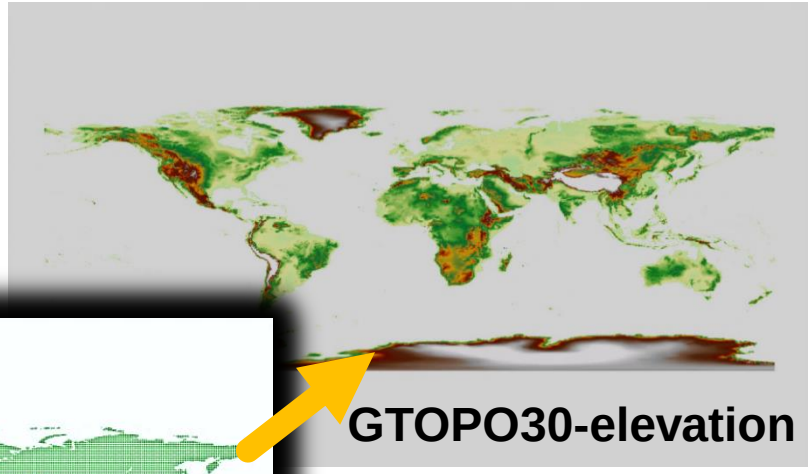
- T3. Establish platform for systematic calibration and validation of model simulations with available agricultural data.
- T 4. Global simulations and data management and post-processing using parallel computing.

Global Modeling Units & Major Data Inputs

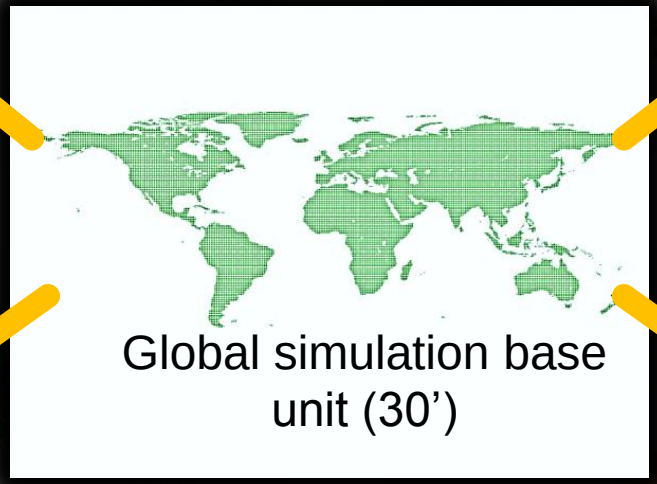
62,482 GMU with 0.5 degree as the base simulation units derived from global land mask



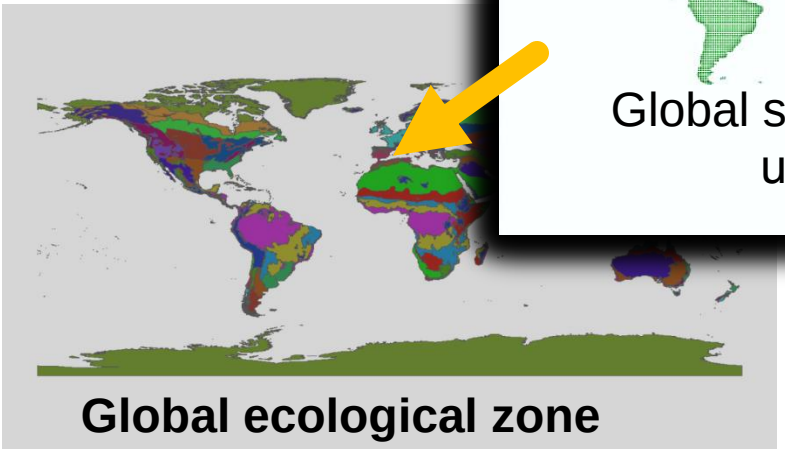
HWSD-soil



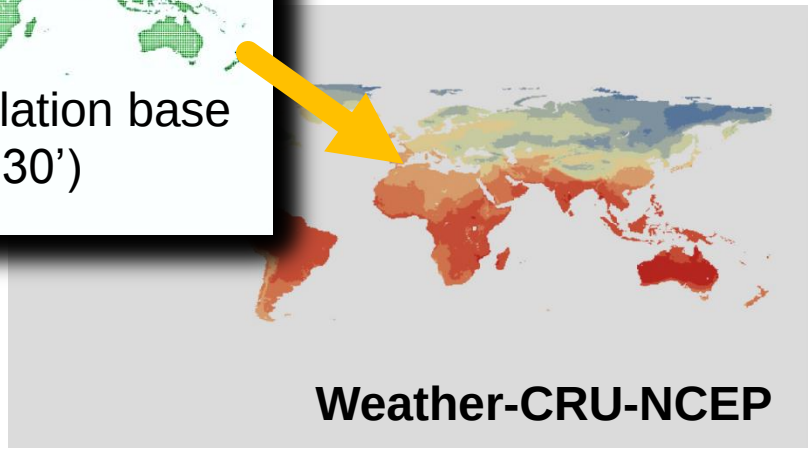
GTOPO30-elevation



Global simulation base unit (30')



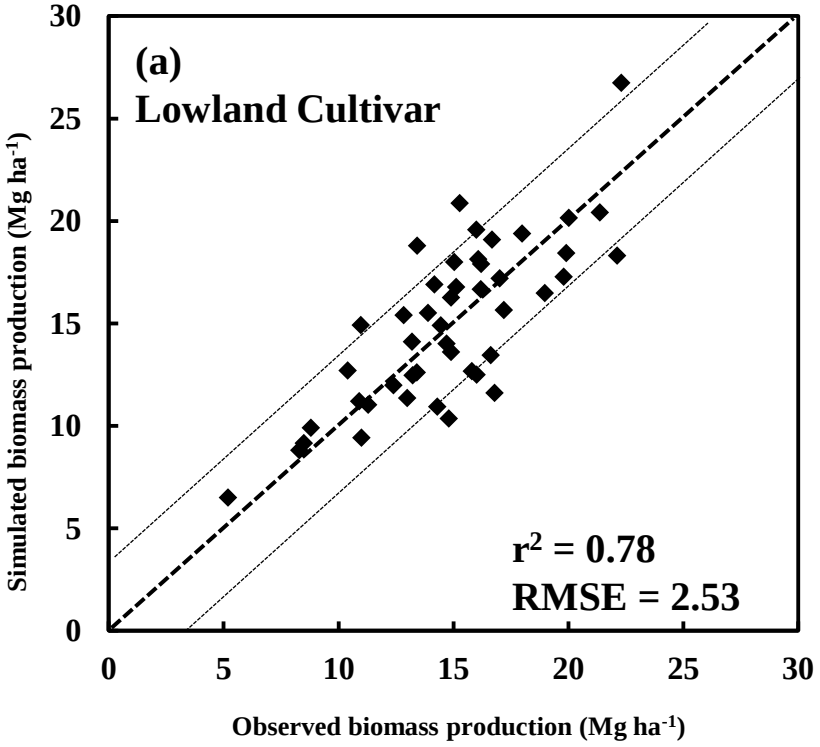
Global ecological zone

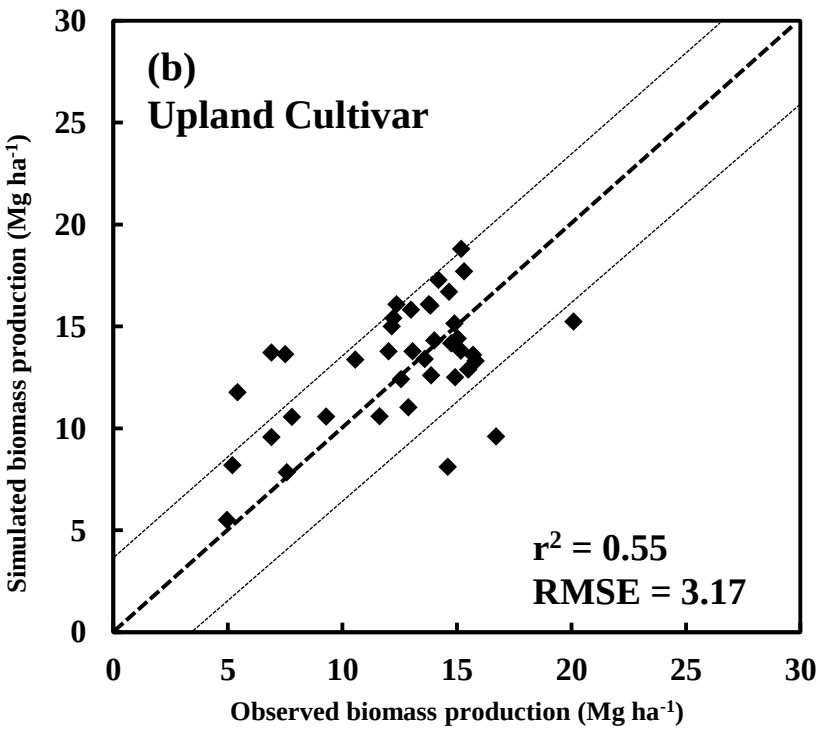


Weather-CRU-NCEP

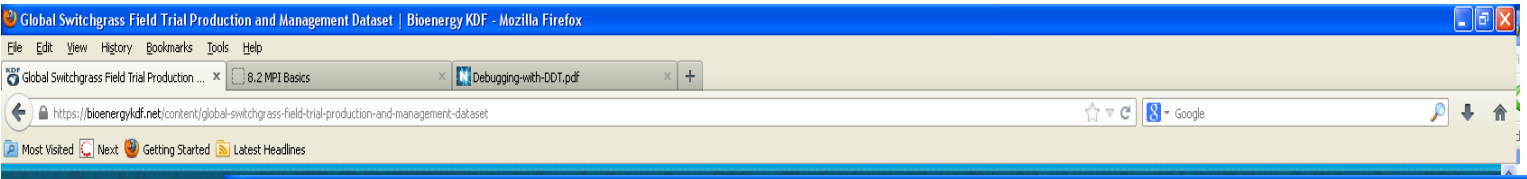
Global Bioenergy Crop Database, Calibration & Validation - Switchgrass

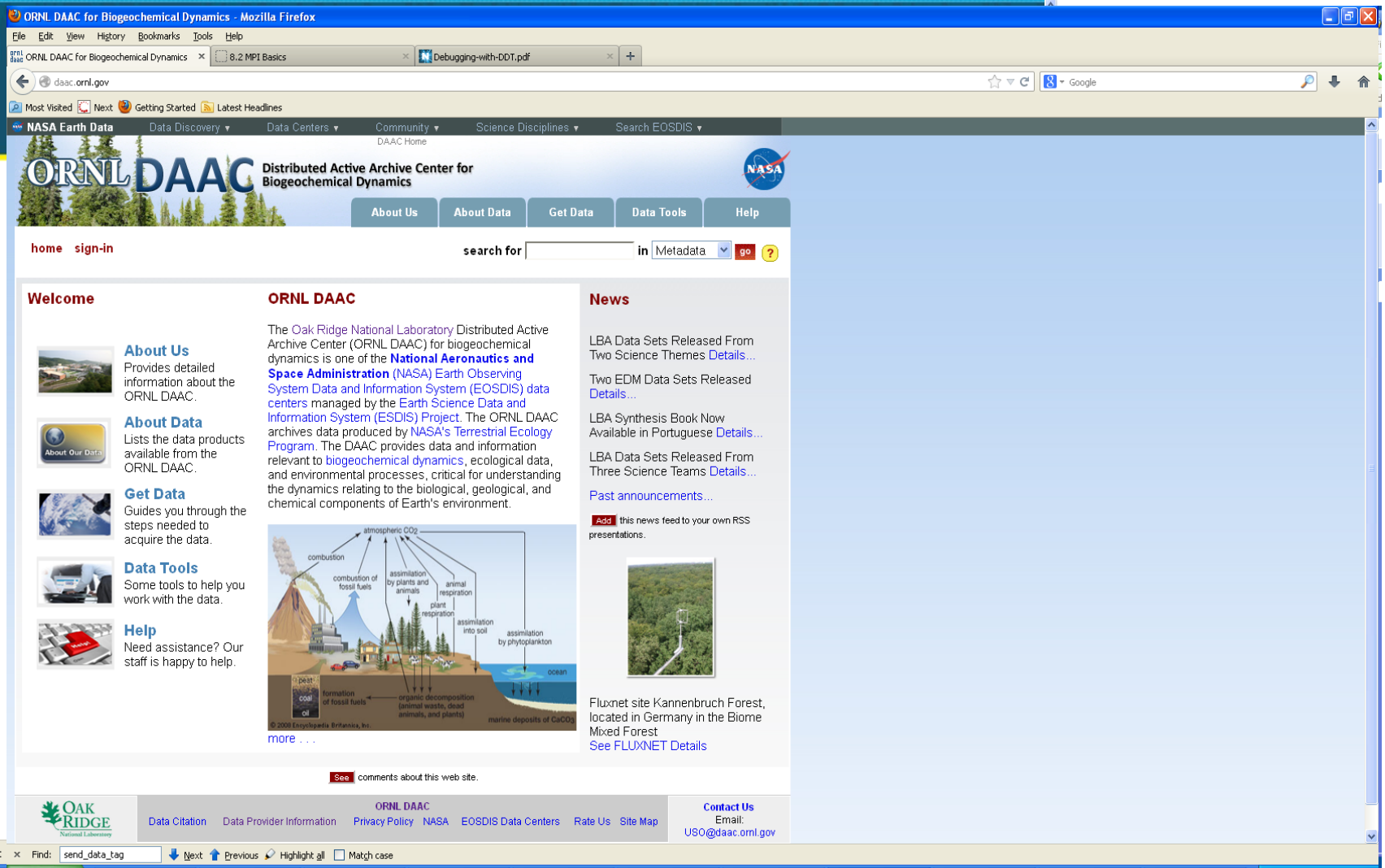
- Over 1400 site-year datasets of five continents – online global database and update
- Ecological zone based calibration and validation





Database Management & Analysis at ORNL





Global Switchgrass Biomass Production Potential

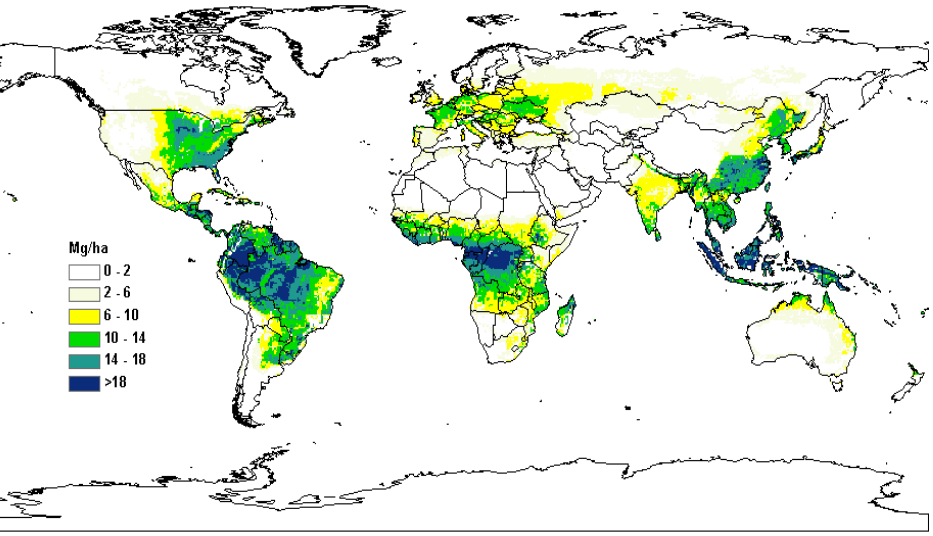


Fig. 1. Projected switchgrass productivity (Mg/ha)

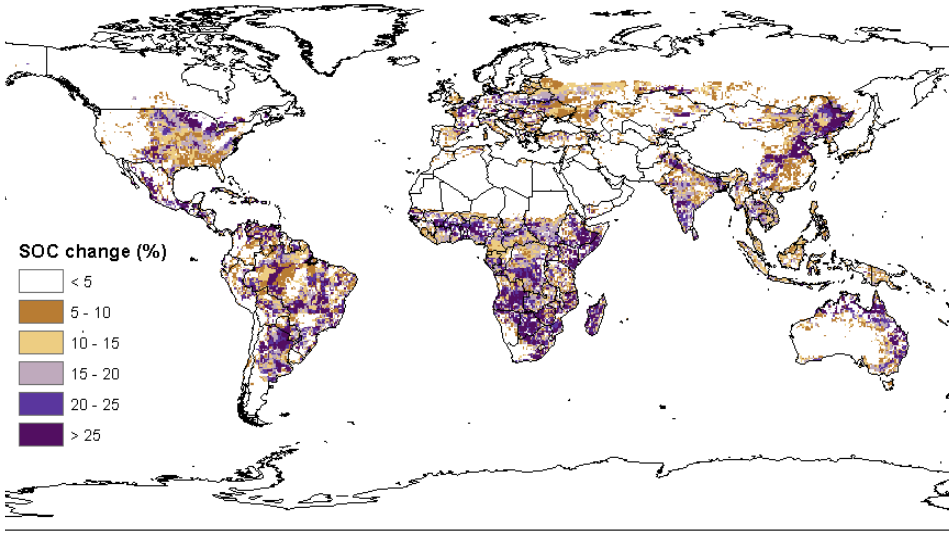
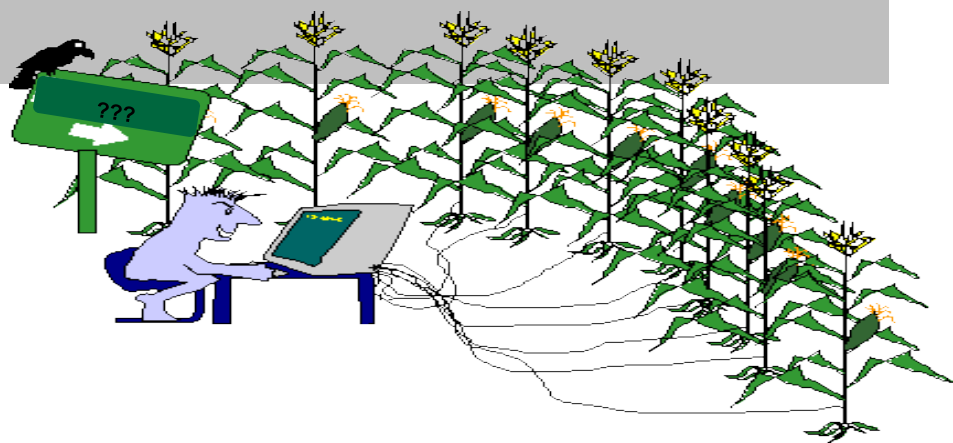


Fig. 2. Estimated soil organic carbon change (%) assuming 30 years of switchgrass cultivation

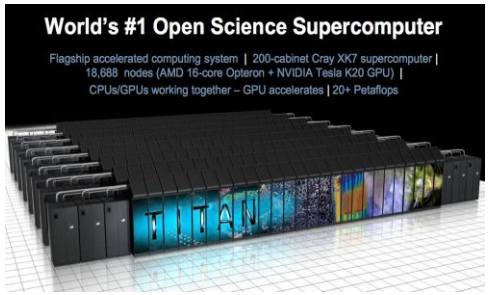
Uncertainty and Challenges

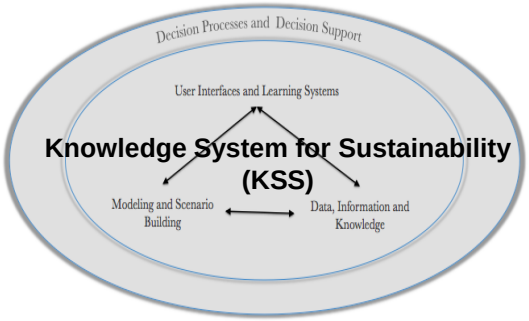
- Model inputs (quality and quantity)- soil, weather, …
- Scaling issues – balancing resolutions for diverse needs
- Global bioenergy crop trials - model calibration & validation
- Environmental effects and climate change impacts
- Huge database management and data processing



Future Directions of Global Modeling Effort

- High-resolution modeling and data management (meter-scale simulations)
- Various bioenergy crops (sugarcane, miscanthus, agave, trees, etc.)
- Model land allocation optimization to meet growing demands for food and bioenergy
- Improve data sets and modeling platform to support land-use planning and respond to needs of decision-makers
- Support international collaboration network to improve global land modeling that integrates food, energy, fiber, and other services





Acknowledgement

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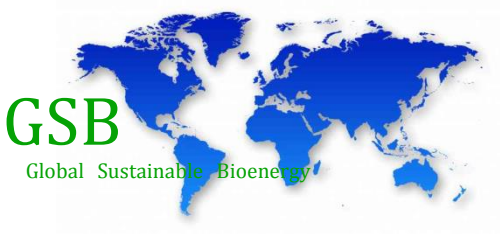
- Oak Ridge Leading Computing Facility, ecosystem modeling of ESD and CCSI at ORNL

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