Linking Economic and Biophysical Models for Climate Change and Biofuel Analysis

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of Biofuel Production and Environmental Impacts
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•Sources of Support

USDA DOE
USEPA
CSiTE

Background to Presentation

Invitation stated the workshop

Explores important **challenges associated with economic and environmental modeling of biofuel production**, especially of cellulosic feedstocks.

Focuses not on modeling results, but **rather on key research gaps and methodological challenges**

- Broadening spatial and temporal scales,
- Incorporating new environmental services,
- Modeling new types of landscapes
- Modeling industrial process logistics.

Plan of Presentation

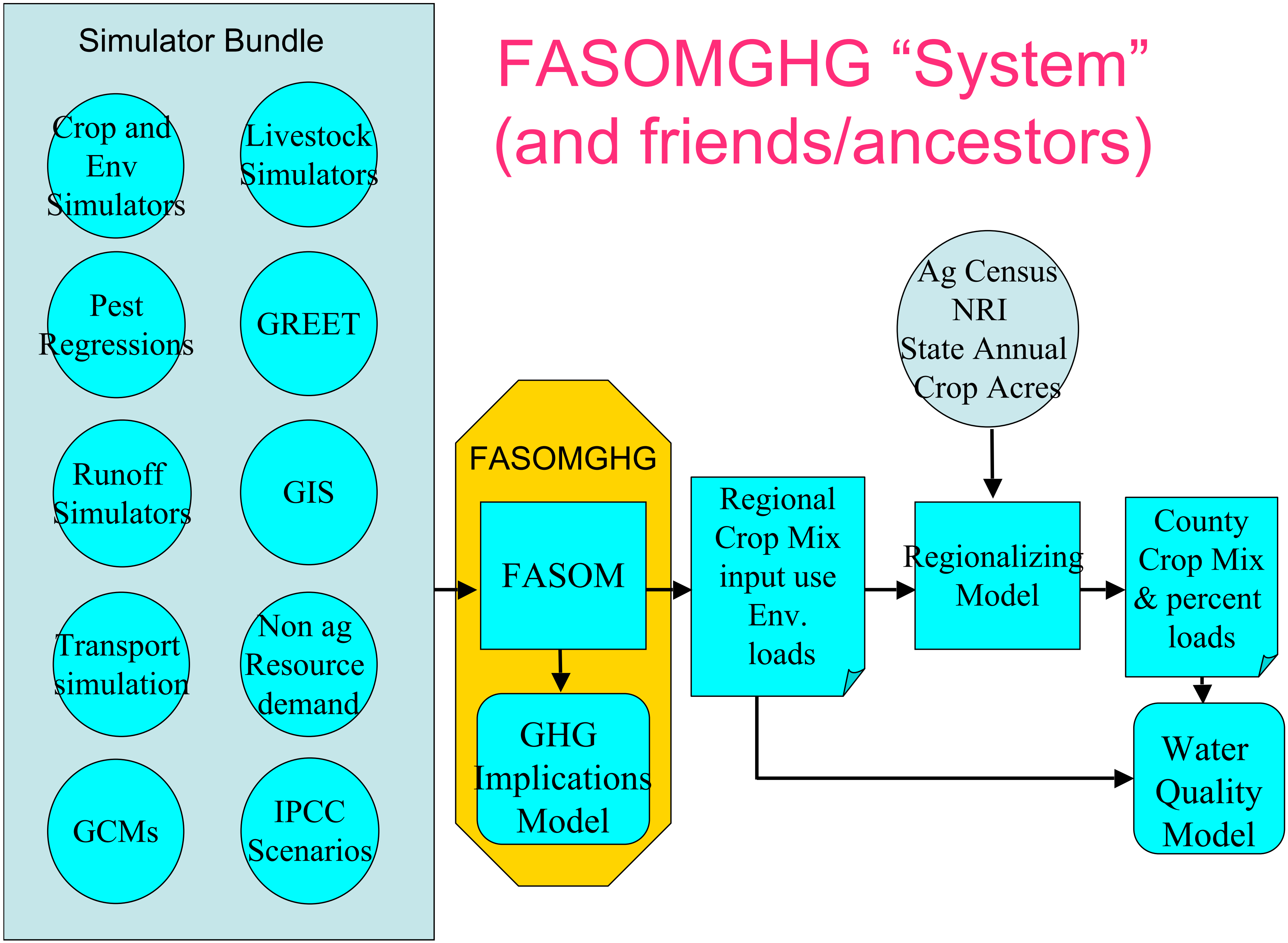
Discuss weakly coupled modeling system I use

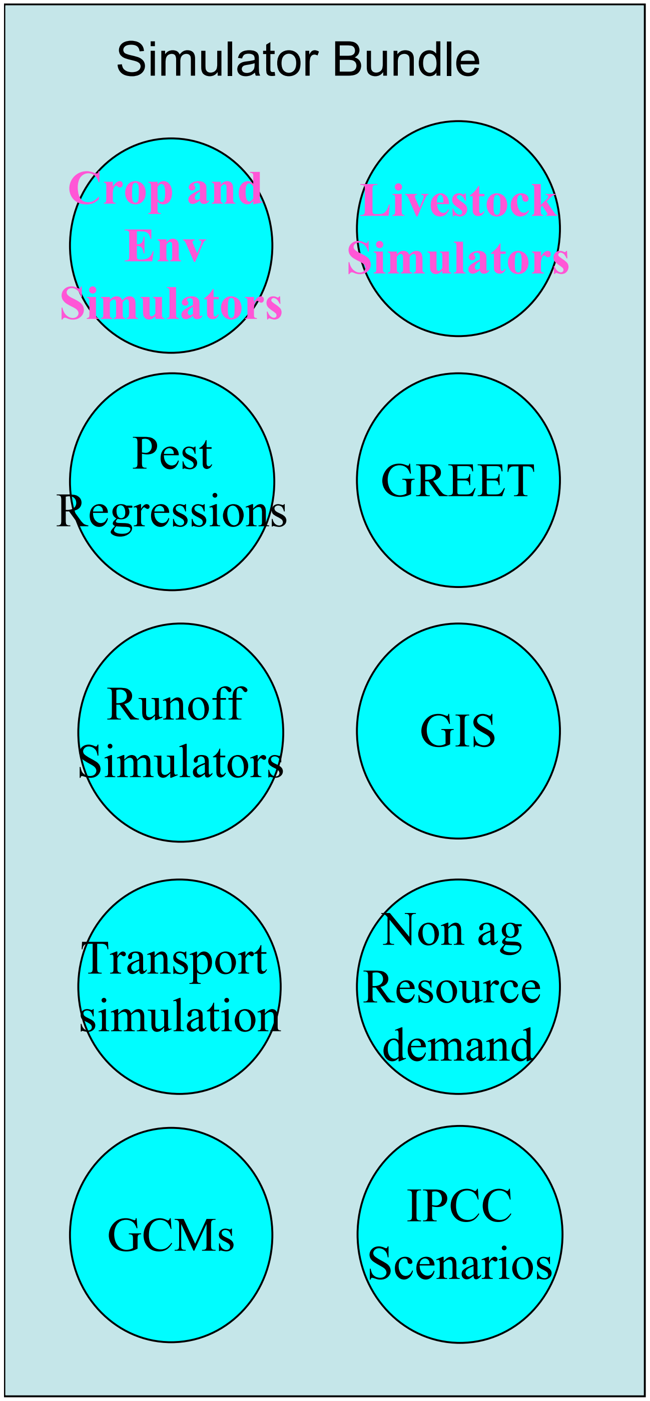
Show some results

Discuss challenges and needs that arise in use and in biophysical/economic modeling endeavor

- Broad
- Targeted areas in invitation
  - Linking spatial scales
  - Dealing with temporal issues
  - Reliably incorporating environ. services
- Challenges in modeling
  - new landscape types
  - industrial process logistics

FASOMGHG "System" (and friends/ancestors)





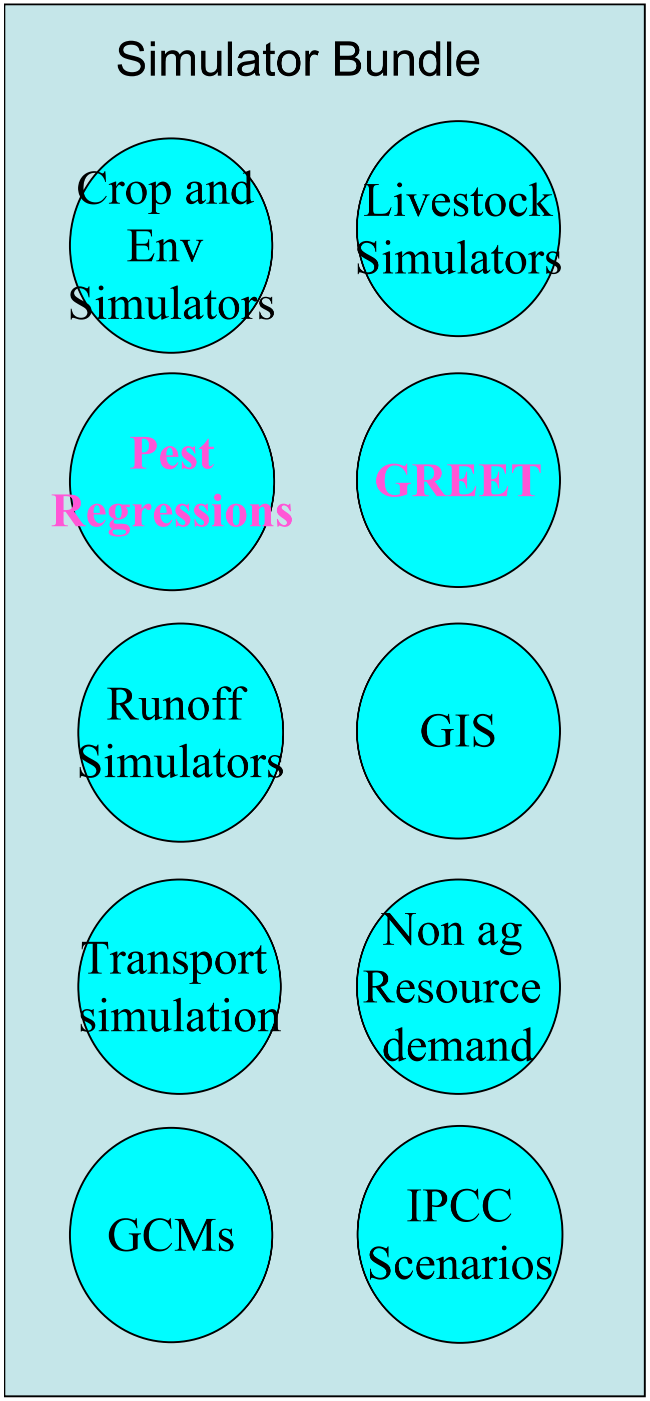
Simulator Component Functions

Crop and Environmental simulators

- Why – crop yield, input use, env emissions grass, energy crops
- What – yield, fert, water, variability, runoff, erosion
- Components – EPIC, CENTURY, CERES, Blaney-Criddle
- Example – USNA, Reilly et al

Livestock Simulators

- Why – performance, feed use, disease spread
- What – yield – meat, milk, young, land use, feed need, disease spread
- Components – PHYGROW, DADS, RIFT, AUSPREAD
- Example – USNA, High Plains



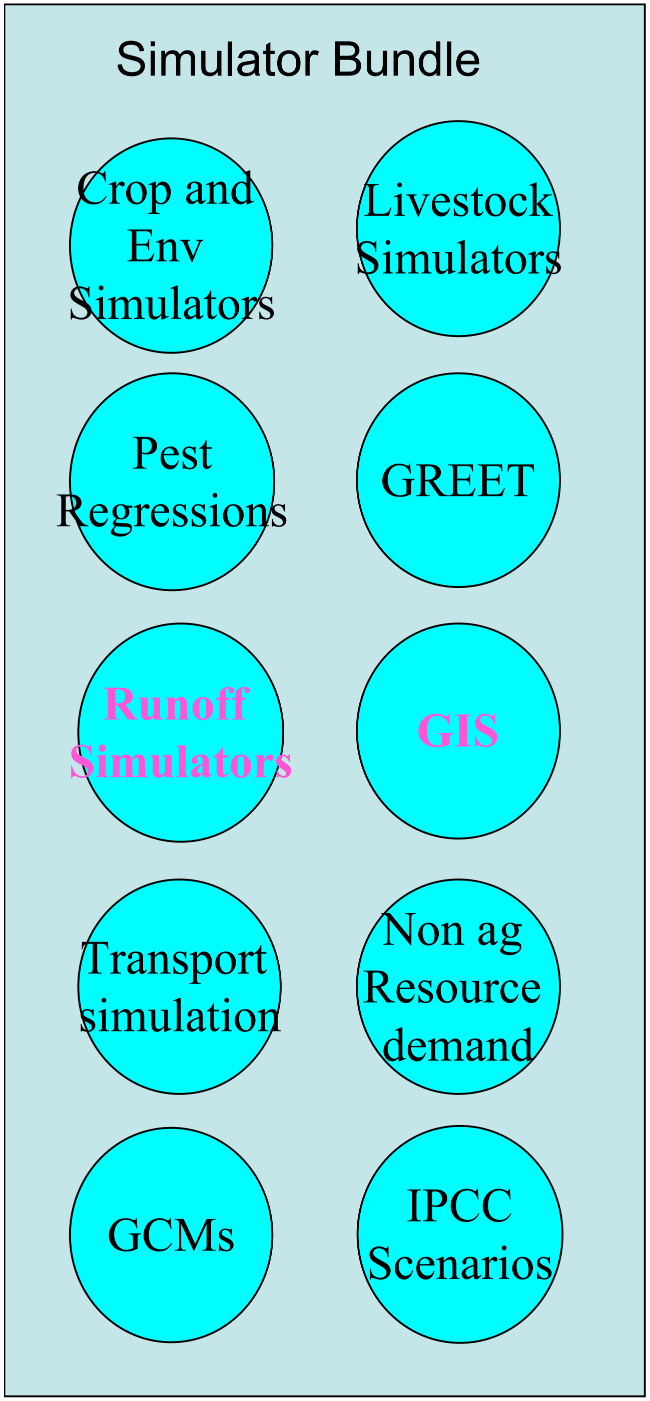
Simulator Component Functions

Pest regressions

- Why – pest damages and climate
- What – pest cost increases w climate changes
- Components – regression from USDA data
- Example – USNA, Reilly et al, Chen and McCarl

GREET

- Why – GHG LCA data
- What – GHGs from input manufacture, fuel use, processing
- Components – GREET, FASOM GHG acct
- Example – Adams et al, Murray et al, McCarl, Argonne



Simulator Component Functions

Runoff simulators

Why – water availability under climate/ El Nino

What – water changes as climate changes

Components – SWAT, USGS, regressions from water data

Example – USNA, Reilly et al, Chen, Gillig and McCarl

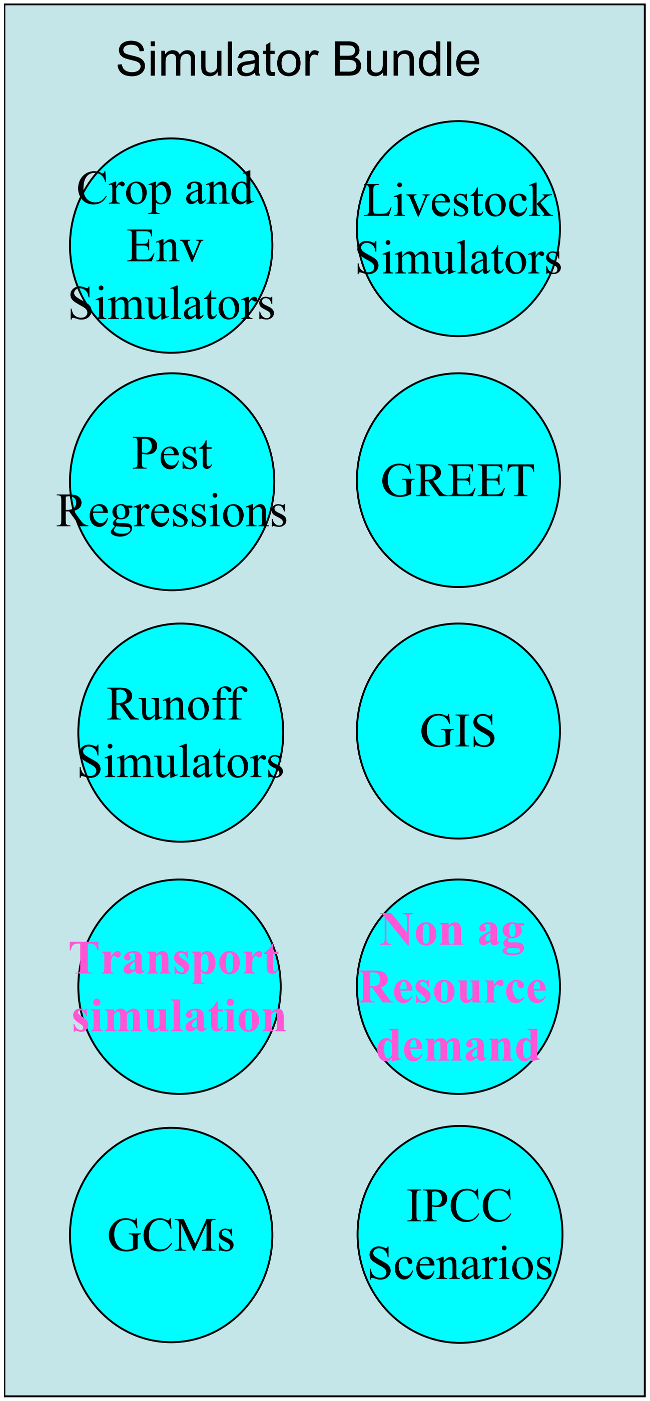
GIS

Why – Producer location, crop suitability

What – Suitable land, herd location

Components – Misc data

Example – Ward et al High plains



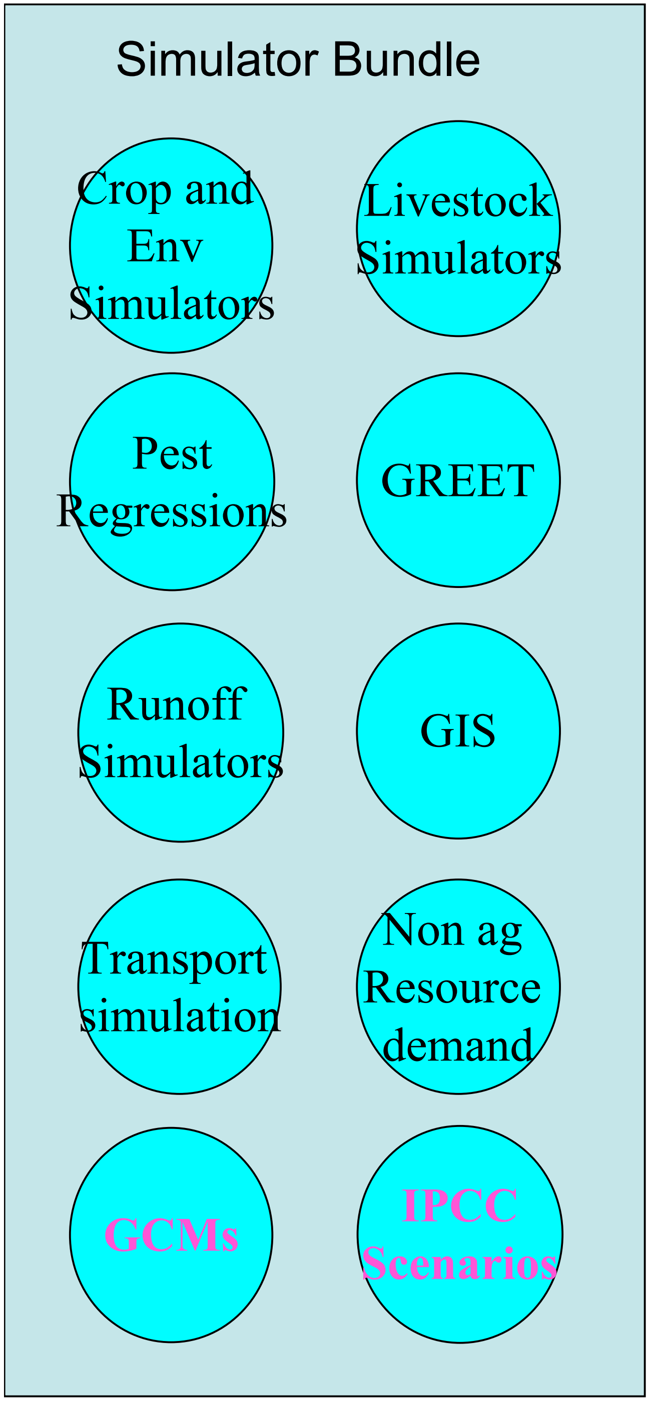
Simulator Component Functions

Transport simulators

- Why – Hauling distance and GHGs
- What – Cost and hauling distance
- Components – Algebraic model
- Example – McCarl, Annals of OR

Non Ag Resource demand

- Why – Water competition, land conversion
- What – Water demand, Land demand, Water quality demand
- Components – Regressions, projections
- Example – Chen, Gillig and McCarl, Adams et al



Simulator Component Functions

GCMs

Why – Climate conditions under GHGs
What – Temperature, Rainfall, variability
Components – IPCC Suite
Example – IPCC 2007

IPCC Scenarios

Why – Future of society and emissions
What – Population, GHG emissions, Income
Components – IPCC SRES
Example – IPCC 2007

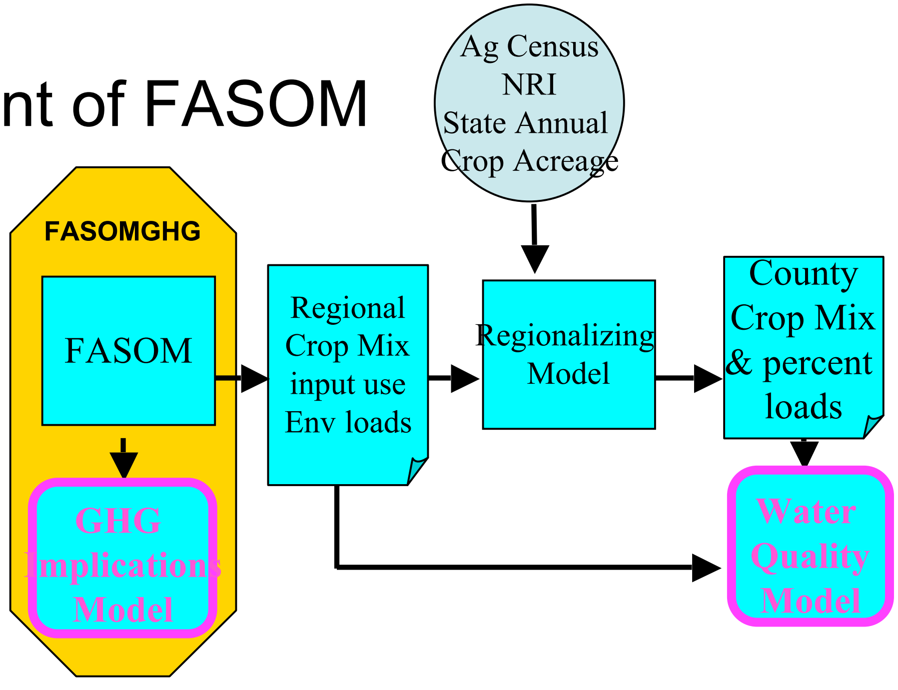
Output Simulator Component Functions

Water quality simulator

- Why – Water implications of land use
- What – Chemistry, erosion load
- Components – SWAT, NWPCAM, Regressions
- Example – Pattanayak st al, Atwood et al

GHG implications simulator

- Why – GHG implications, Mitigation response
- What – Net GHG effects
- Components – GHG component of FASOM
- Example – Murray et al



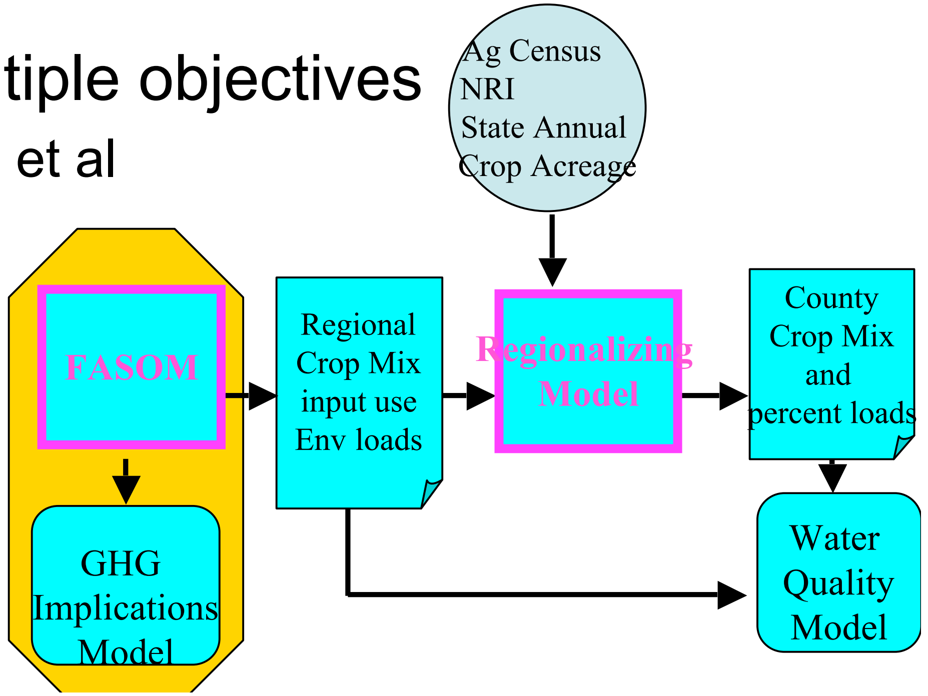
Economic Component Functions

FASOM

- Why – Land use change, market effects, Welfare
- What – Acres, exports, prices, mitigation choice,
- Components – Forest and Ag simulator
- Example – Adams et al, Murray et al

Regionalizing Model

- Why – Link to localized env models
- What – Land use by county
- Components Humus model, multiple objectives
- Example – Pattanayak et al, Atwood et al



Simulator Component Functions

Others

- Forest simulators
- Fire simulators
- Processing plant models
- Regional Logistics
- International economics
- Economy wide models

Example uses
(Note I was told not to dwell on results)

- Crop Simulation in a Climate change context
- Life Cycle GHGs in a Biofuel Context
- Broader GHGs in a sectoral LCA context
- Global GHGs in a market LCA context
- Water quality in GHG mitigation

Broad Challenges

Avoiding the Land Mines

Biofuel crop issues

Things we have not done

Bringing common sense to the table

Broad Challenges

Avoiding the land mines - Stories from 25 years of models

Curse of spatial GIS data

- Understanding of its basis – where are feedlots
- Confidentiality – King ranch
  - Intensive livestock
  - Will we see data for energy crops - ownership
- Difficulty with things that change
  - Notill, Crop inputs

Registration/reliability temptation of simulation results

- Validation points
- Observation basis for inferences – nitrogen infiltration
- Models might compare w known items, do QA maps
- They give results not data and need a critical eye
  - – high plains corn

Broad Challenges

Avoiding the land mines - Stories from 25 years of models

Inference from other crops and places

- Corn soy wheat for cotton and sorghum
- Florida to California tomatoes

"Intelligent extrapolation"

- Crop reporting district to premise
- Livestock herd and DADs

Remembering economics

- Law of one price and transport costs – ozone and rff
- Economics and technical potential
- Limited opportunities and potential sequestration only
- Economics and competitive potential
  - Ignoring market – leakage and indirect land use
  - Induced innovation – GREET emissions revision
  - Yield advance and inputs

Broad Challenges

Avoiding the land mines - Stories from 25 years of models

Well meaning programmer and extrapolation

- If it can be used run it – Nevada Corn
- Transferring management files

Enthusiastic technology advocate

- Bias in data – Southern switchgrass - marginal land
- Strive for objectivity – “it was for DOE” – cost and input

Myopic analysis small region

- Special case
- Ignores market and technological treadmill
  - Price elasticity and indirect land use
- Out of region movement
- Out of region induced activity - leakage

Broad Challenges

Avoiding the land mines - Stories from 25 years of models

Ignoring interactions and supply chain inputs – seed to use

- Carbon only
- Seed production
- No inputs
- No offsets
- Single opportunity analyses

Time to do it well

- Money
- Committed staff

Multidisciplinary team

Broad Challenges - Biofuel based Challenges

New crops
- Acceptable areas – GIS tie
  - Marginal land yields
    - Most experiments elsewhere
    - Most speculation there
  - Large scale effects
    - Input use and Yields
    - Pest damages
    - Crop density
    - Locational specificity/national need
  - Benchmarking data

Seasonality

Stochastics

Byproducts
- Livestock and logistics/movement/drying
  - Downward sloping demand

Things we Need to Look at

Stationarity - Climate change, Water, Markets

Technical progress - Rate and links to inputs

Induced innovation and changing LCA

Indirect GHGs – Sectoral level equilibrium
Land competition domestic and overseas

GHG fungibility – amounts
Uncertainty, Leakage, Additionality,
Permanence and sequestration

GHG rules and biofuels - exemption

Targeted Challenges Linking Spatial Scales

- Meshing Postage stamp sized GIS and biophysical areas with economic models
- Input issues
  - Representative areas
  - Using right spatial data given its frailties
  - Aggregation
    - Non adjacent homogeneity
    - Averaging
  - Information and economic region size
    - Crop budgets
  - Dealing with non stationarity
    - Adding crops
    - Varying rotations

Targeted Challenges

Linking Spatial Scales

Meshing broad area economic models with postage stamp sized GIS and biophysical/environmental

Output issues

Disaggregation of land use and input use

My form of intelligent distribution (Atwood et al, Pattanayak et al)

Multi-objective (C2-C7) deviation minimizing model

Variables are county level allocation of crop areas

- C1 **Aggregate region crop/ irrigation acres equals multicounty total**
- C2 County cropped area is below **maximum historic cropped area**
- C3 County cropped area is above **minimum historic cropped area**
- C4 County area irrigated is below **historic maximum irrigated area**.
- C5 County crop area below **maximum observed area for that crop**.
- C6 County crop area above **minimum observed area for that crop**.
- C7 Consistency with **FASOM historical crop mix** choice
- C8 County crop conforms to **historic relation with adjacent counties**

Uses NRI and Census – reliable?

Targeted Challenges

Dealing with Temporal Issues

Within year

- Seasonality – snow and residues
- Storage

Between years

- Uncertainty and bufferstock
- Dynamics of Market penetration, capital stock needs and depreciation
- Constraints to area expansion

Technical change – induced innovation

- Food crop progress
- Biofeedstocks
- Cellulosic ethanol
- Energy recovery efficiency

Targeted Challenges

Reliably Incorporating Environmental Services

GHGs

- Sequestration dynamics
- LCA and induced innovation
- Full equilibrium sector
- Market induced leakage
- Additionality
- Carbon pricing policy and energy price
- Uncertainty

Pollution

- Nutrients to surface - can we believe models?
- Nutrients to ground - can we believe models?
- Refinery wastes
- NOx, SOx, Mercury

Targeted Challenges

Challenges in Modeling New Landscape Types

Moving away from traditional crops and rotations

- Analyzing new opportunities
- Data to build on
- Running new possibilities & rotations
- Induced innovation
- Non stationarity

New crop issues from above

Targeted Challenges

Challenges in Modeling Industrial Process Logistics

Seasonality, diversification of feedstocks

Pollution, GHGs

Storage, spoilage and GHGs

Byproducts

Waste disposal

Other Needs

Regional plant/logistics model

National model link

International models

Pests

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