An overview of current global human dimension methods: integrated assessment models

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Workshop on Linking Earth System Dynamics and Social System Modeling
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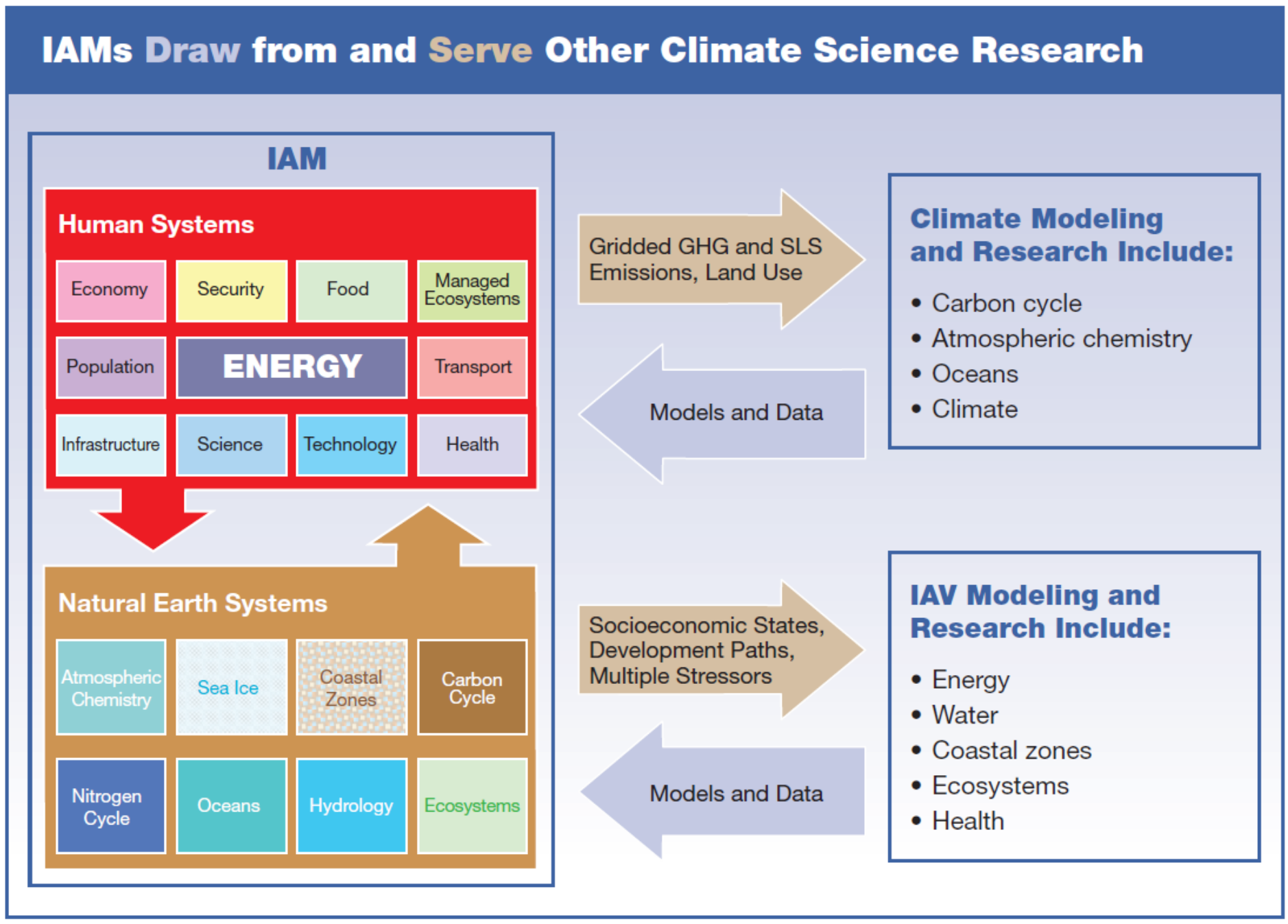
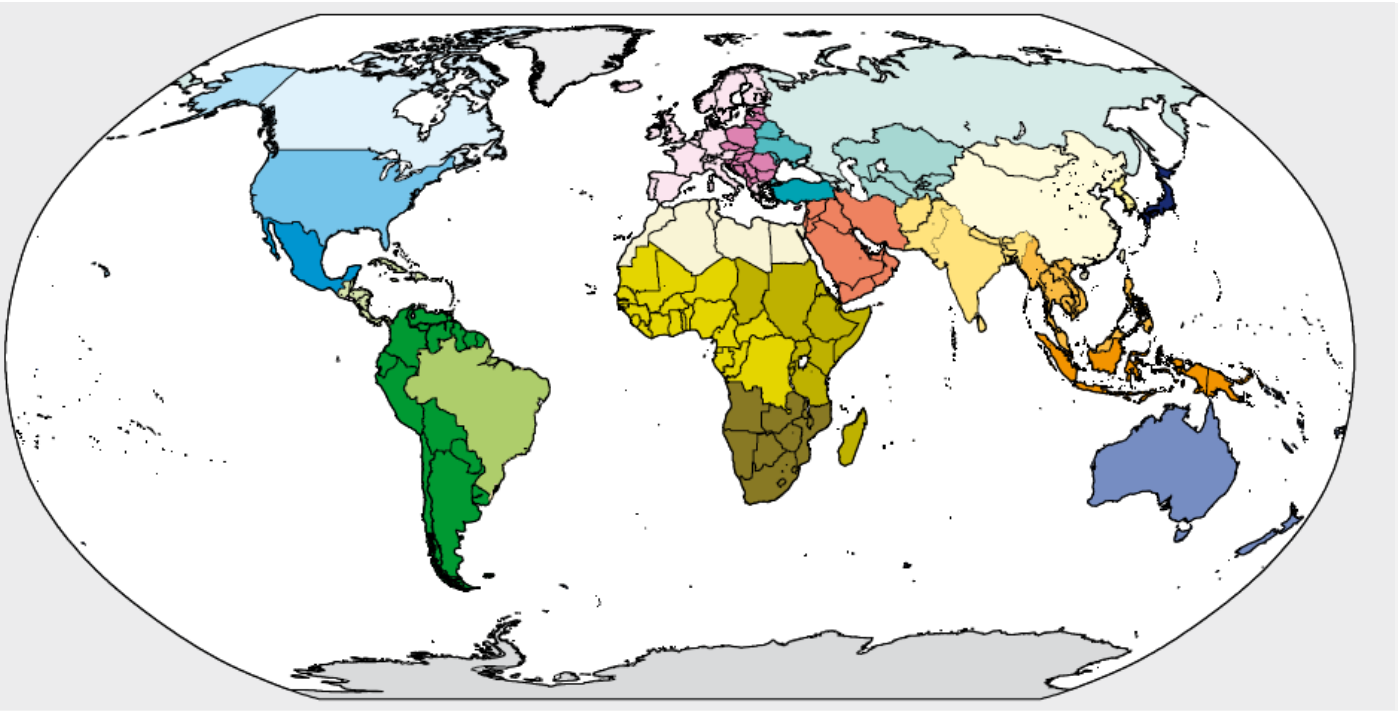
What is IAM?



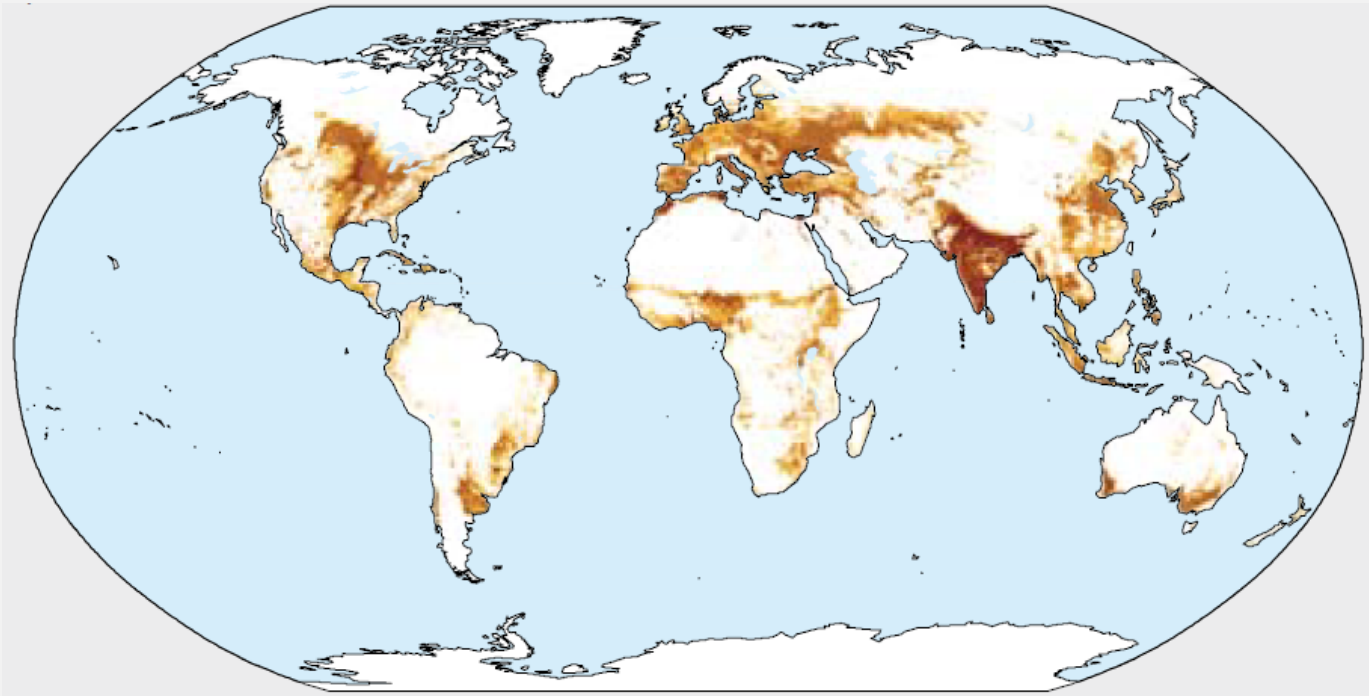
Janetos et al., 2009, DOE.



- Global scale
- Decadal to century timescale
- Insights into questions at level of nation+
- Climate change mitigation, impacts, adaptation

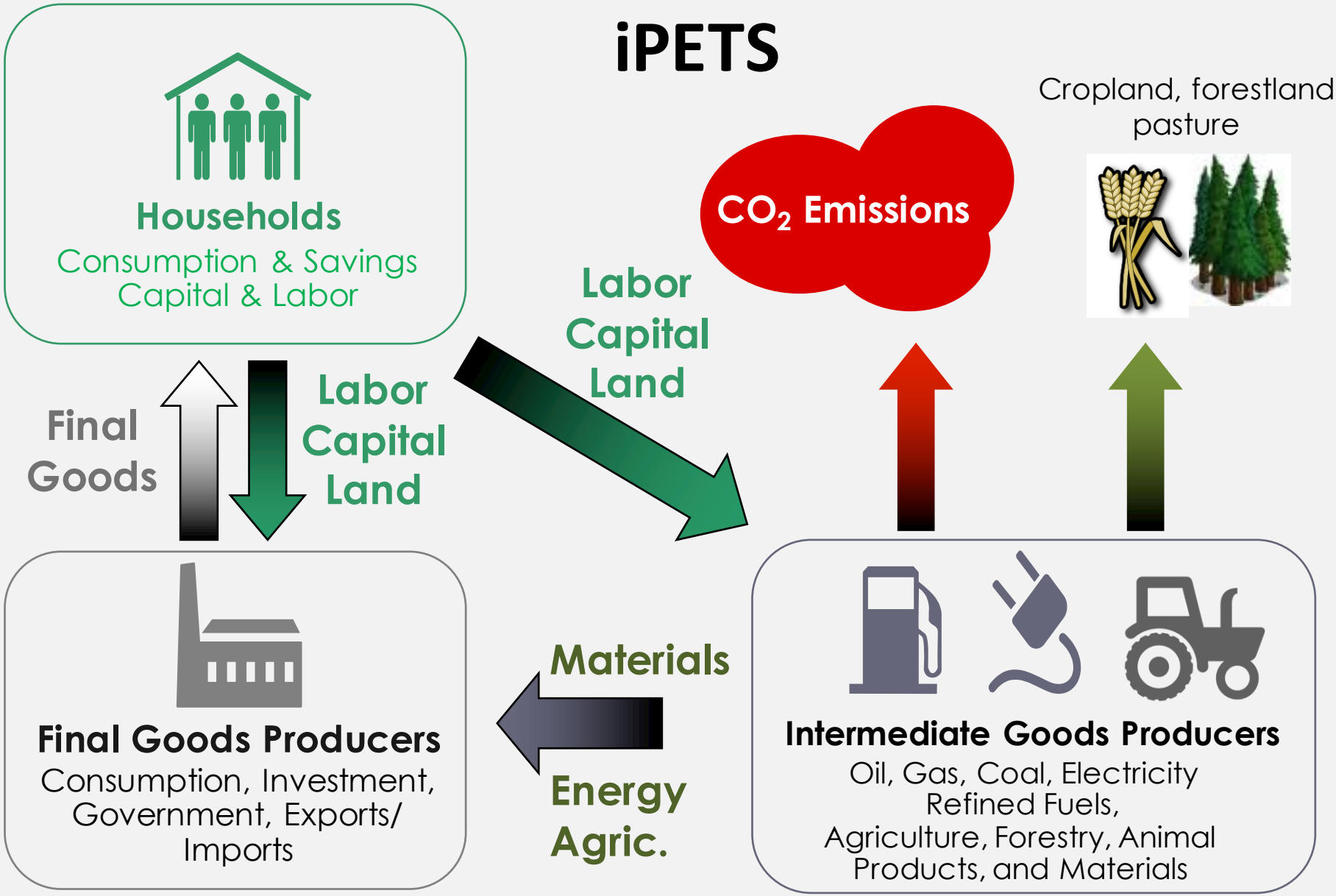
Some factors/processes represented at finer resolution:

- soils
- **climate**
- population
- urban extent
- GDP
- land use
- emissions



Figures from IMAGE model, from Bouwman, Kram and Klein Goldewijk, 2006.

Model structure and components



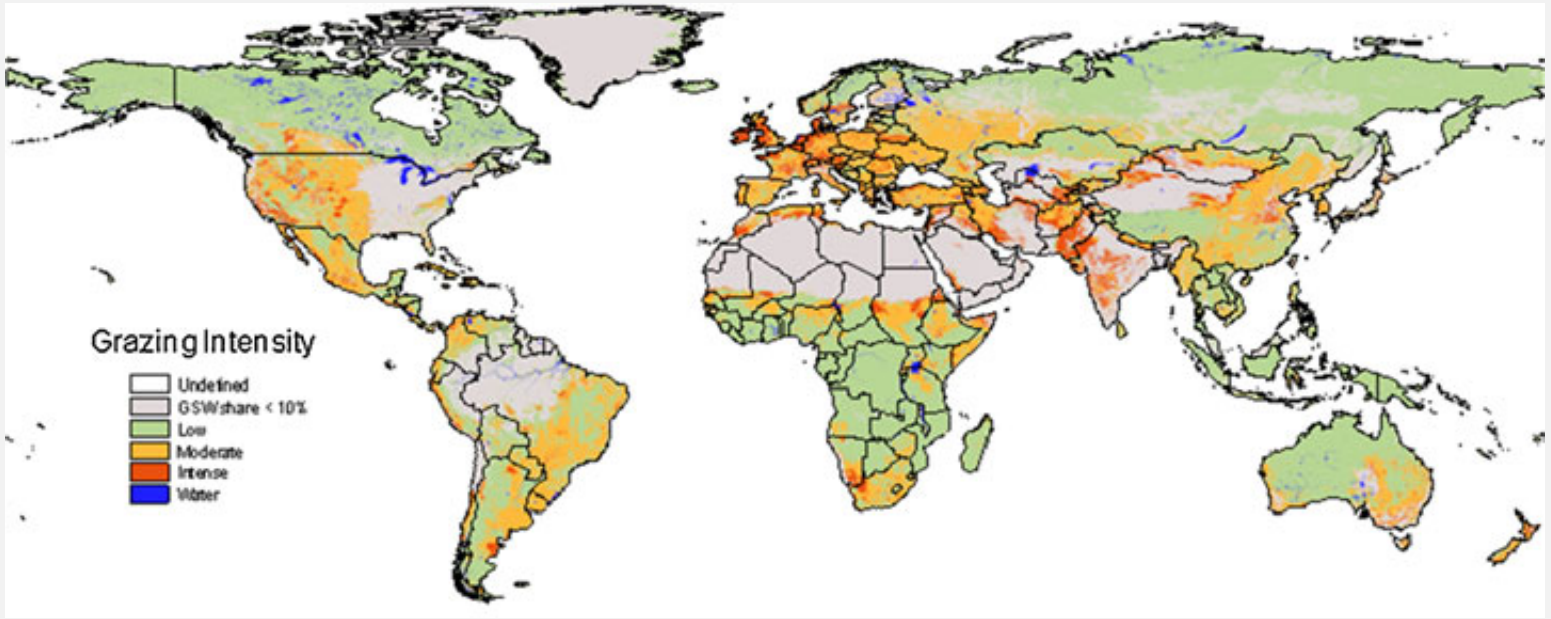
IIASA downscaling of RCP-8.5

NPV of Forestry vs. NPV of Agriculture

NPV forestry = f(planting costs, timber price, timber volume, rotation length, carbon benefits)

NPV agriculture = f(land suitability, population density, land price)

Grazing intensity, RCP-8.5, MESSAGE model, 2000



Decision making in IAMs

Behavioral and Decision-making Processes

Households (regional)

- Maximize utility, given prices and budget constraint

Producers (regional)

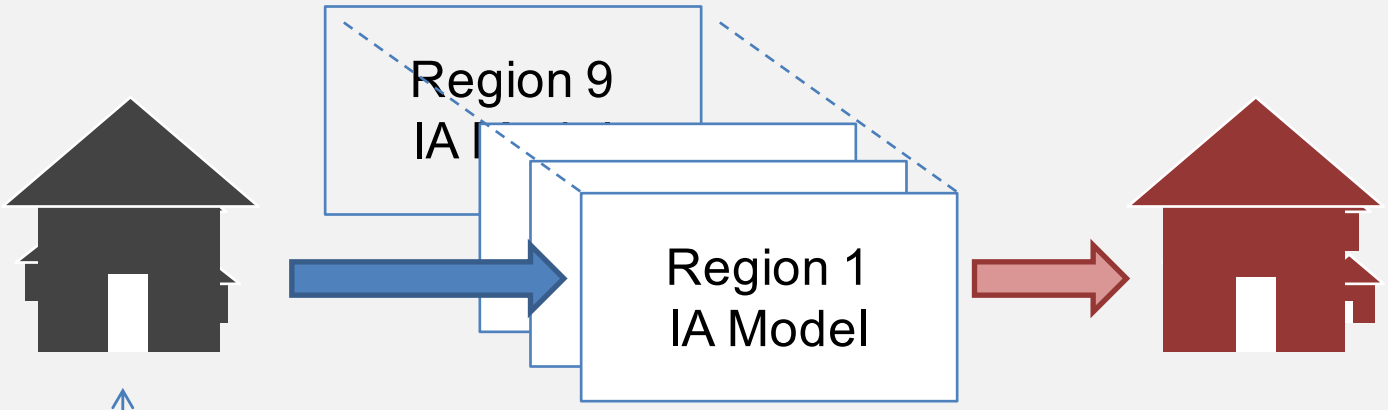
- Maximize profits (minimize costs), given market clearing condition

Producers (spatial)

- Rule-based allocation of land use to grid cells (e.g., IMAGE, GLM)
- Regression-based allocation based on historical patterns (e.g., iPETS, IGSM)
- Explicit simulation of profit maximizing decisions at each grid cell, constrained by total regional land use (e.g., GLOBIOM)

HH Characteristics
Labor supply
Preferences
Substitution
Initial capital

HH Outcomes
Consumption
Income
Savings



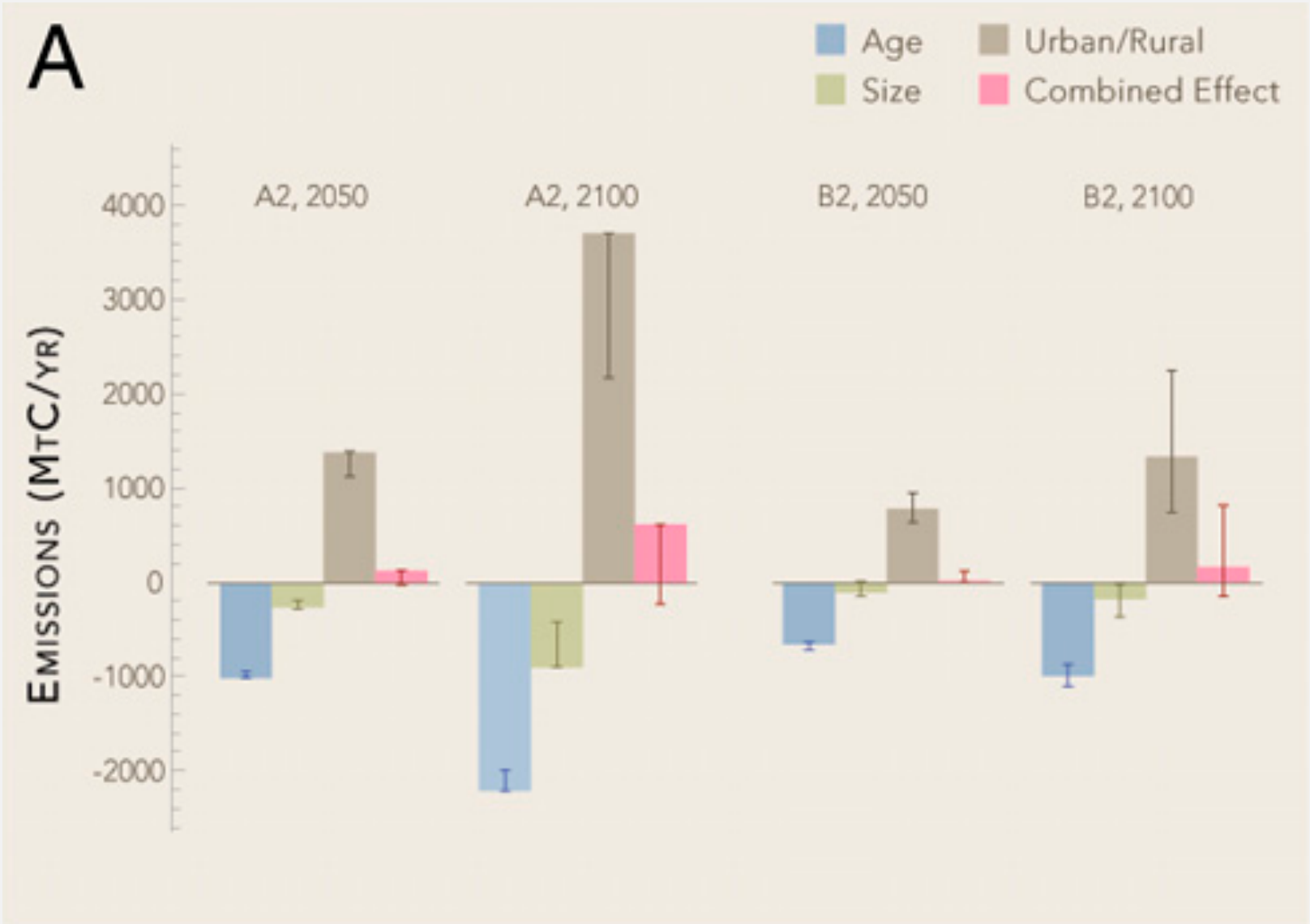
Characteristics by Type

Urban/Rural, Age,
Size, Income

Household
Survey Data

See van Ruijven et al., 2015, for a review.

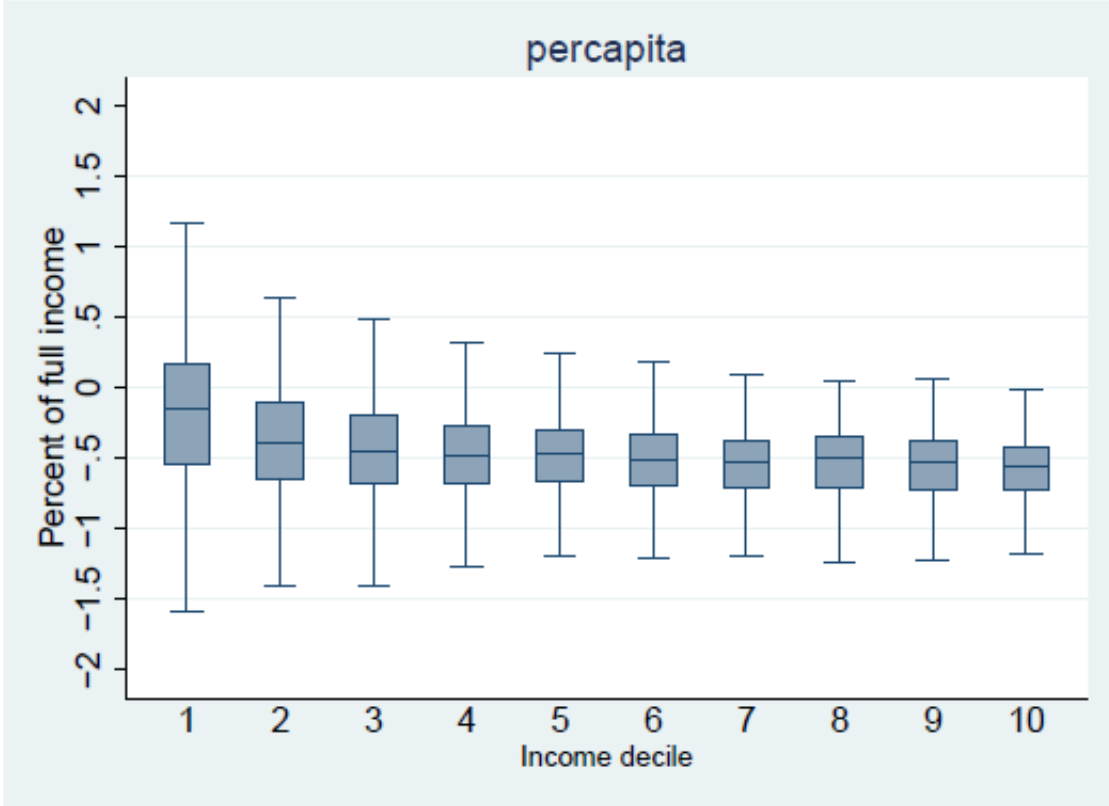
Multiple Household Types



O'Neill et al., 2010. iPETS model.

Multiple Household Types

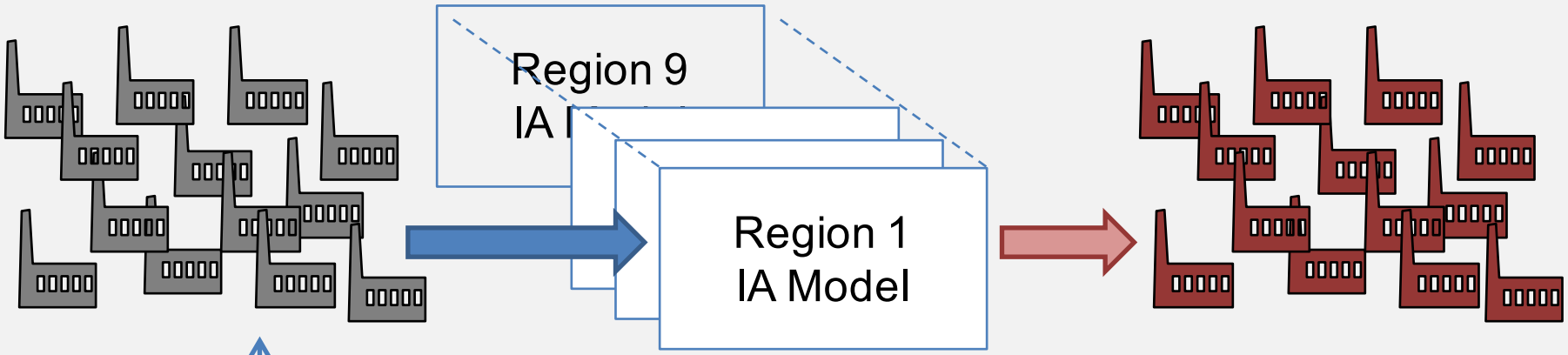
- MIT US model
- 15,000+ households as individual agents
- Implications of cap and trade scheme
- Variations in effects within groups can swamp across-group effects



Rausch et al., 2011.

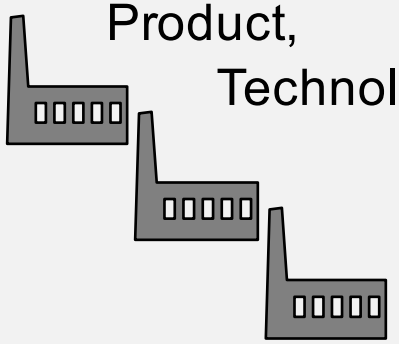
Industry Characteristics
Input mix (initial)
Productivities
Production structure
Substitution

Industry Outcomes
Production
Demand for inputs
(including land)



Characteristics by Type

Product,
Technology, …



Production Data

New Types?
Large vs small scale
(e.g., HH production)
Access to trade
Sub-region
(e.g., Frontier)

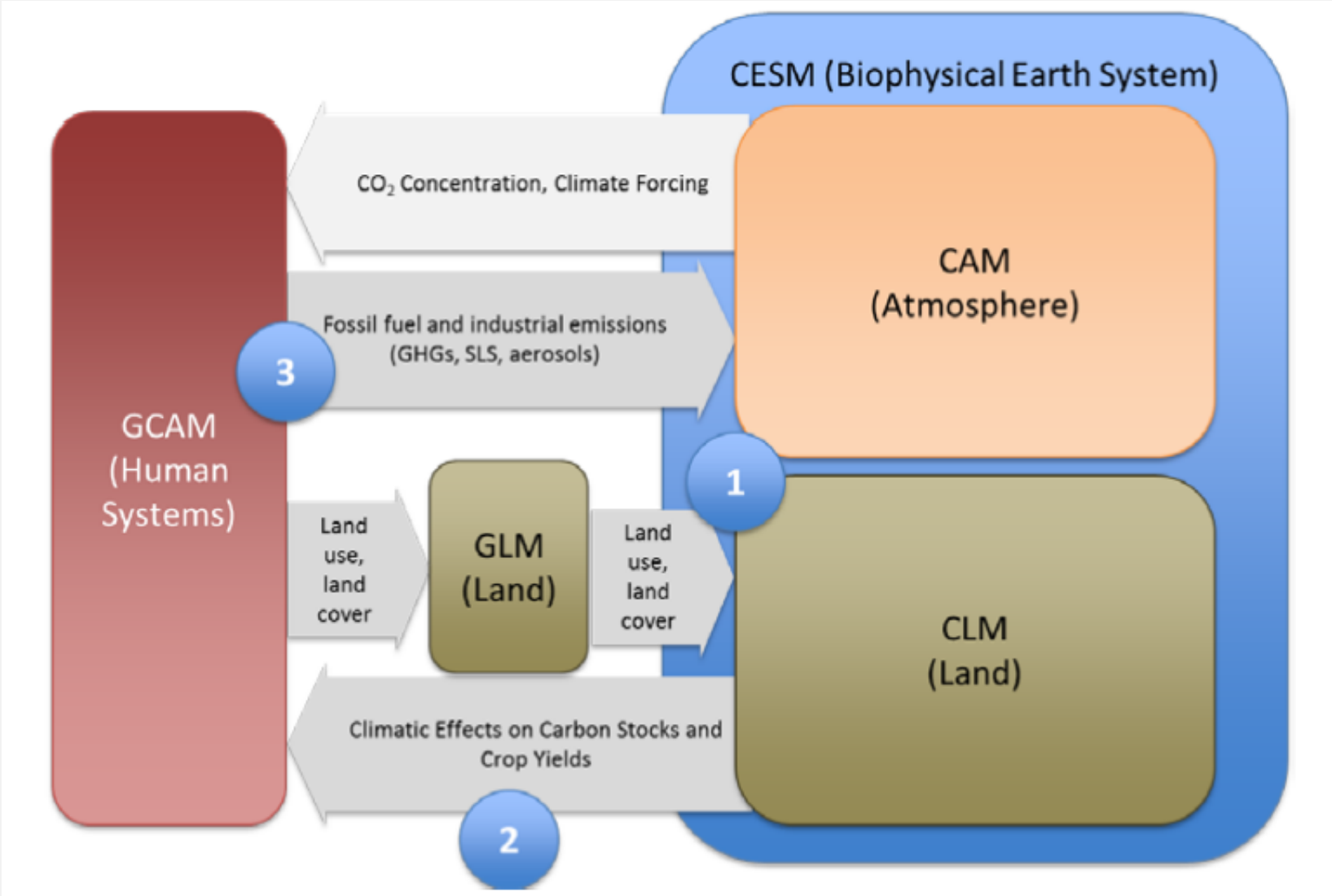
Coupling human and natural systems in IAMs

Approaches to coupling

Method	Advantages	Examples
A (off-line information exchange, one-way)	• Work with existing terminology and tools • Transparent information exchange • Flexibility • Separate research strategies	THESIS
B (improved IAMs)	• Allows for good representation of uncertainty • Model complexity tailored to question • Detail in treatment of socio-economic processes	Climate model emulation
C (improved ESMs)	• Higher resolution analyses than in IAMs • Detail in treatment of biophysical processes	Urban, ag mgmt in ESMs
D (full coupling)	• Assessment of feedbacks • Highest degree of consistency	IMAGE-CNRM GCAM-CESM

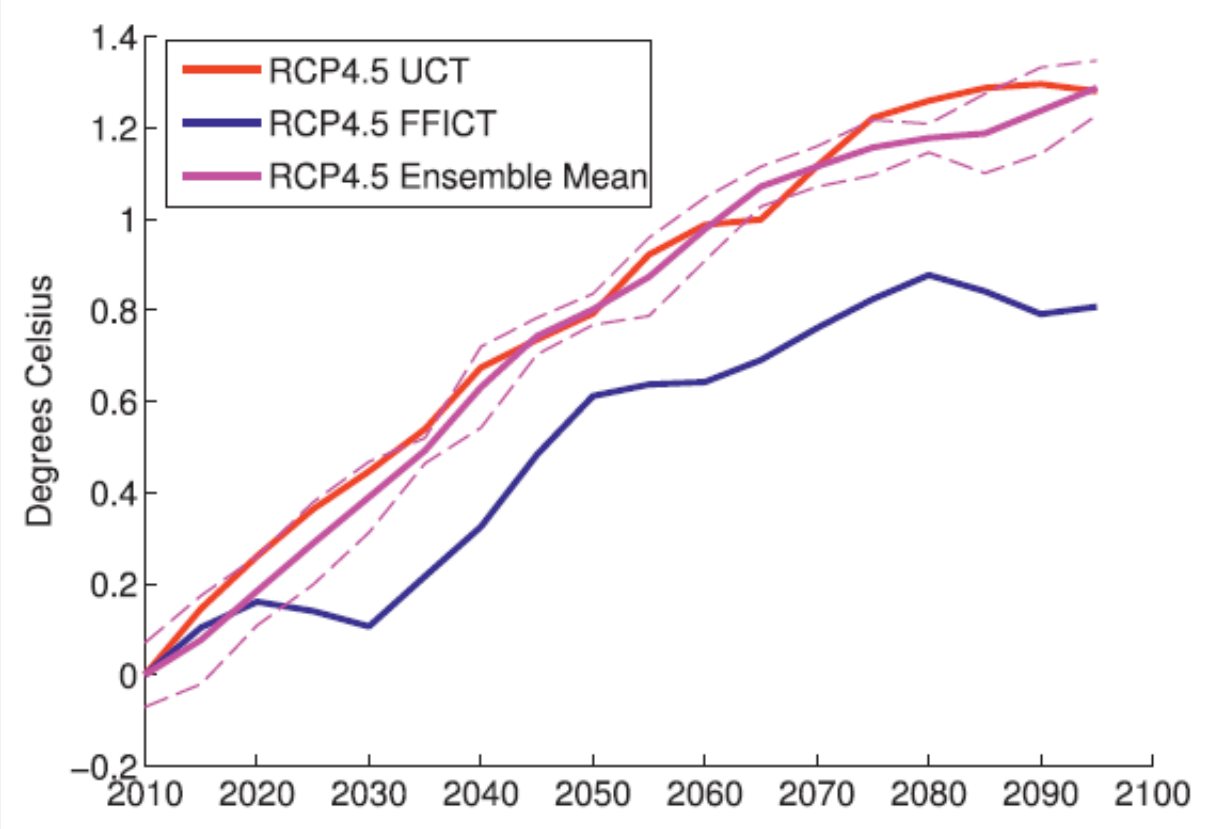
van Vuuren et al., 2012.

GCAM-CESM (iESM)

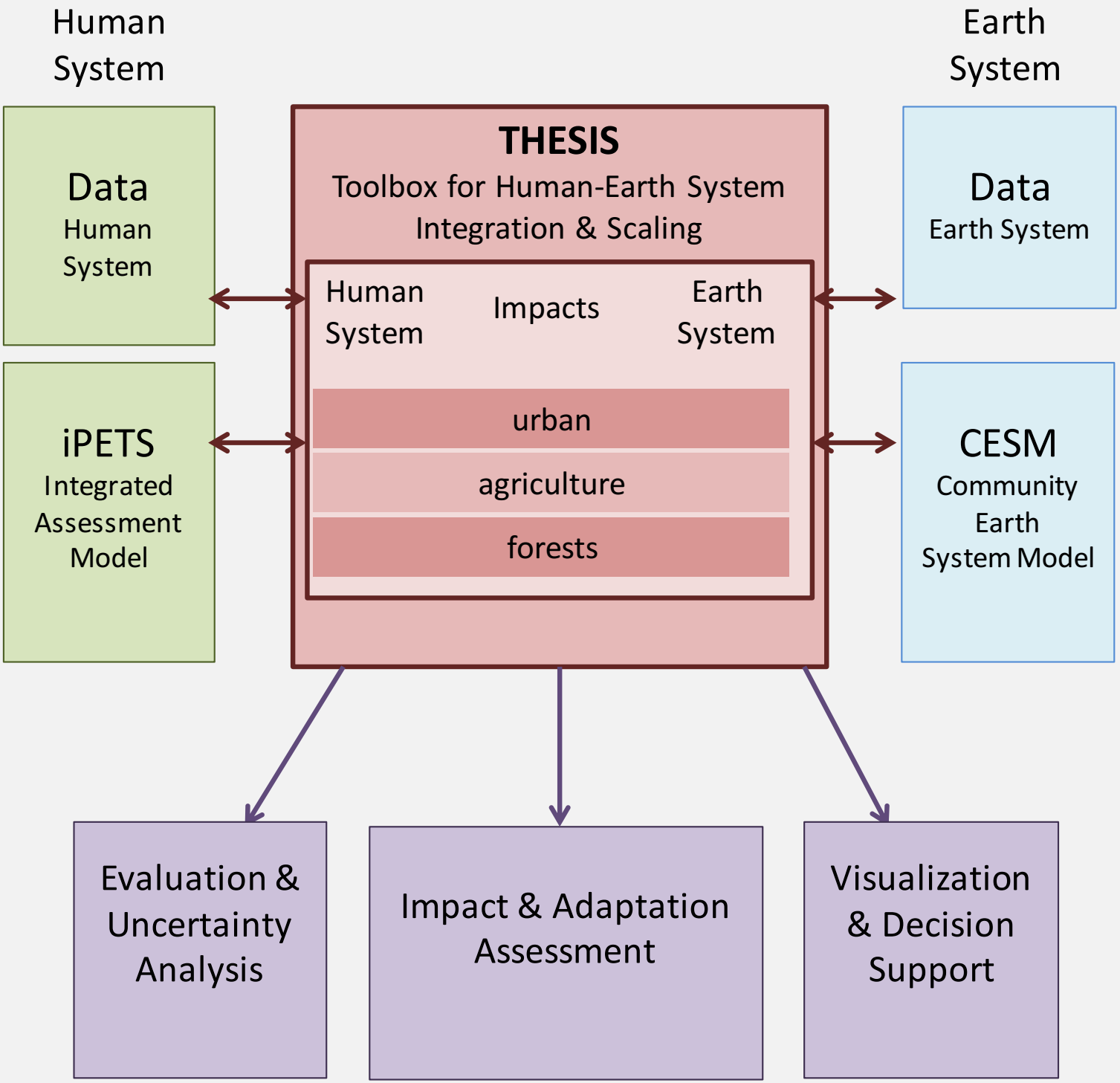


Collins et al., 2015.

iESM result



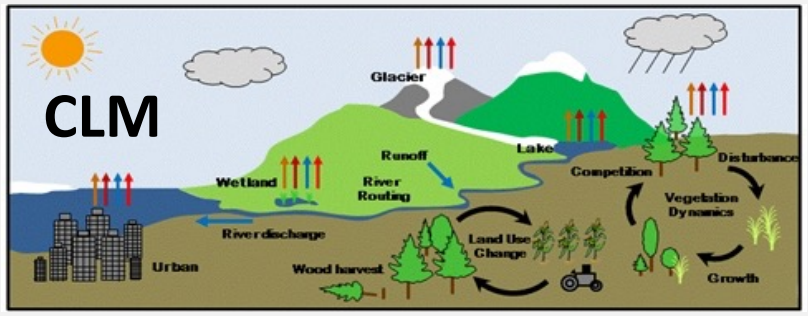
Jones et al., 2015.


Human System
Earth System
Data
Human System
THESIS
Toolbox for Human-Earth System Integration & Scaling
Human System
Impacts
Earth System
urban
agriculture
forests
Data
Earth System
iPETS
Integrated Assessment Model
CESM
Community Earth System Model
Evaluation & Uncertainty Analysis
Impact & Adaptation Assessment
Visualization & Decision Support

Types of THESIS Tools

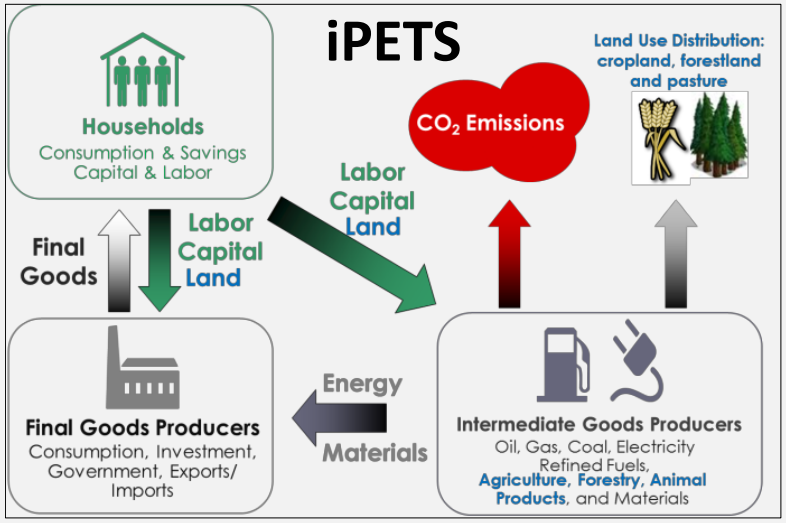
	Spatial Distribution	Properties	IAM Consistency	Impact Assessment
Population	Spatial population	Population characteristics		
Urban	Spatial urban land cover	Building properties	Building energy use	Heat wave exposure
Agriculture	Spatial ag land use	Crop type and management	Crop yield	
Forest	Spatial forestry land use	Forest type and management	Forest yield	

CLM Crop Modeling



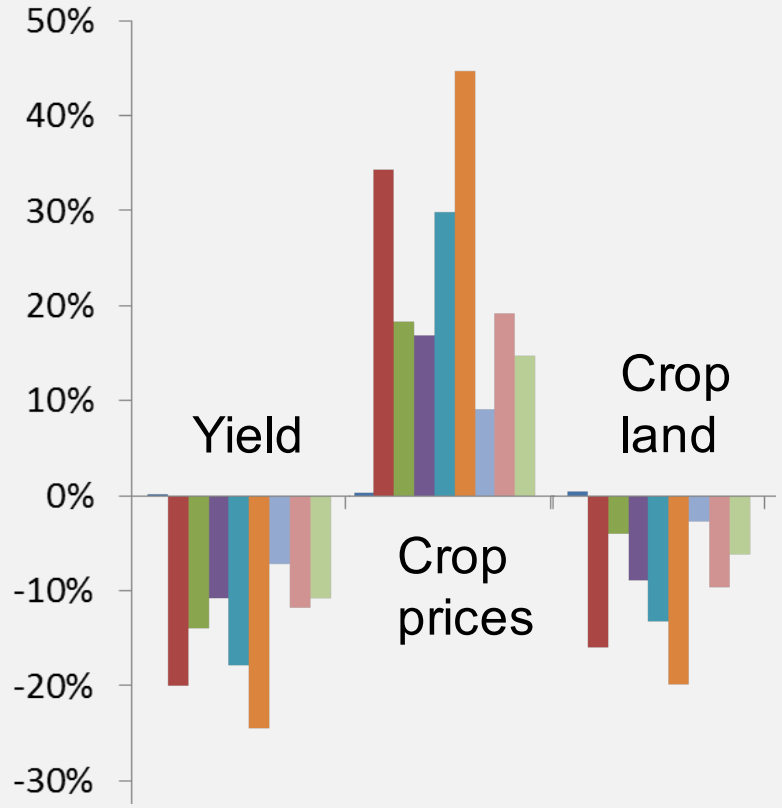
Levis et al., 2016

iPETS Integrated Assessment Model



Ren et al., subm.

Impacts, 2061-2080, RCP8.5, SSP5
Nine world regions



Ren et al., 2015.

Justification for coupling: Land use <-> climate example

Insufficient:

- Does land use change affect climate?
- Does climate affect land use decisions?
- Even if both are true, coupling not necessarily required.

Sufficient:

- Is the climate effect of a plausible amount of land use change large enough to cause a change the original land use decision that is substantial compared to other uncertainties in the problem?

To answer this question, the highest priority step is not to couple the models, especially if coupling is difficult

Proposed directions

Decision making
- New types of producers, consumers, or other institutions
- Additional scales
- Change in rules by which they interact

Coupling human-earth systems
- Systematic investigation of one-way influences
- Two-way coupling at regional scales
- Two-way coupling at global scales for the intrepid

In general
- Identify specific research question, and hypothesis for why a new type of model or approach is needed to address it
- Consider multiple possible approaches to coupling