NSF EaSM2 Project:
Linking Human and Earth System Models to Assess Regional Impacts and Adaptation in Urban Systems and Their Hinterlands

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Collaborators: Nate Brunsell (KU); Prasanth Meiyappan (UIUC) ; Bryan Jones (CUNY); Brian Kauffman, Bas van Ruijven, Xiaolin Ren, Leiwen Jiang, Dan Runfola (NCAR)
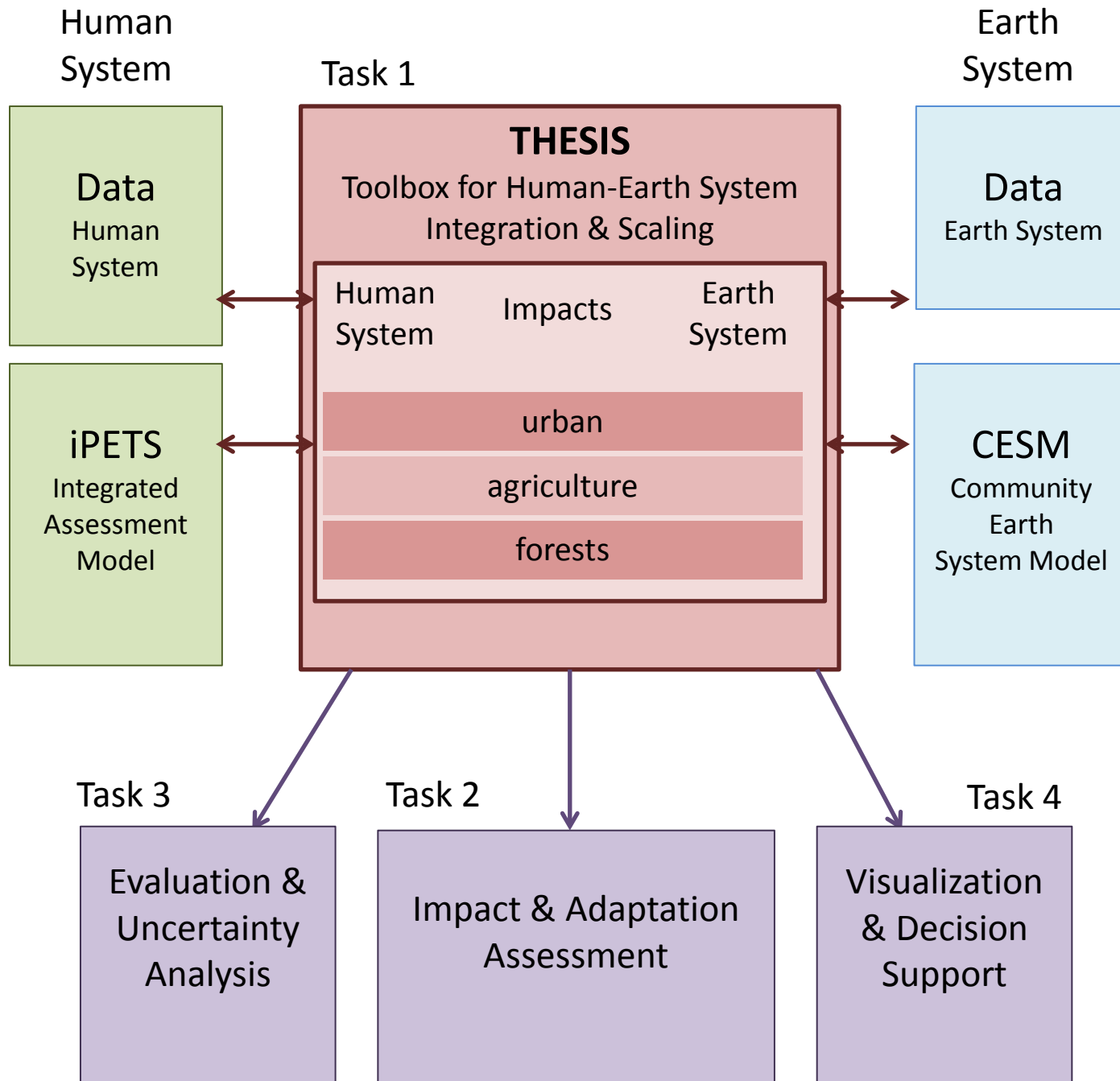
Project Aims

Improve understanding of the joint consequences of socioeconomic development and regional climate change

> Case studies: Brazil, India, China

> Impacts: Agriculture, forestry, urban areas (heat stress, building energy use)

Develop and apply tools to improve ability to integrate human and earth system models

Human
System

Task 1

Earth
System

THESIS
Toolbox for Human-Earth System
Integration & Scaling

Data
Human
System

Data
Earth System

Human
System

Impacts

Earth
System

iPETS
Integrated
Assessment
Model

urban

agriculture

forests

CESM
Community
Earth
System Model

Task 3

Task 2

Task 4

Evaluation &
Uncertainty
Analysis

Impact & Adaptation
Assessment

Visualization
& Decision
Support

Impact/adaptation assessment

One climate scenario (RCP4.5), two socioeconomic scenarios (SSP 5, 3)

Adaptation variants (none vs. modest vs. aggressive)

Evaluation and uncertainty assessment

13 Types of THESIS Tools

	Spatial Distribution	Properties	IAM Consistency	Impact Assessment
Urban	◑	◑	○	
Agric	◑	◑	○	
Forest				

+ Scenario Builder

○ Tool development underway

◑ Tool development WELL underway

Example: Urban Properties Tool

Urban Properties Tool

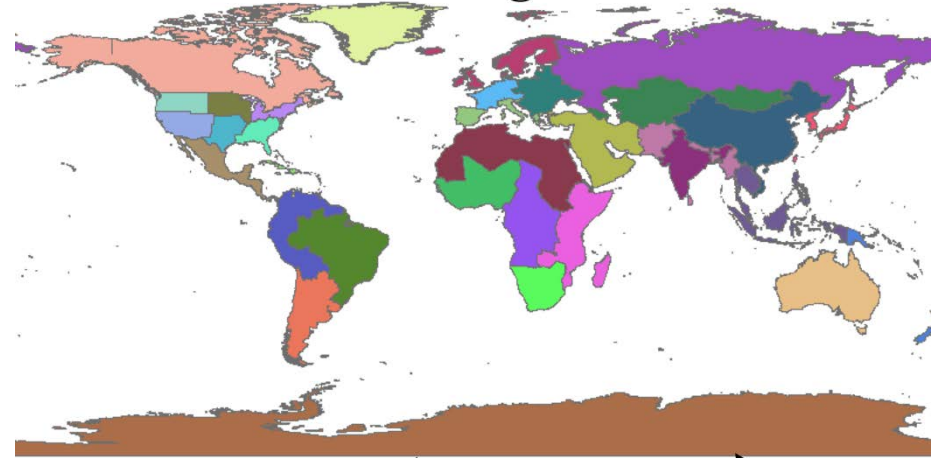Material Properties

↓

Wall/Roof/Road Properties

↓

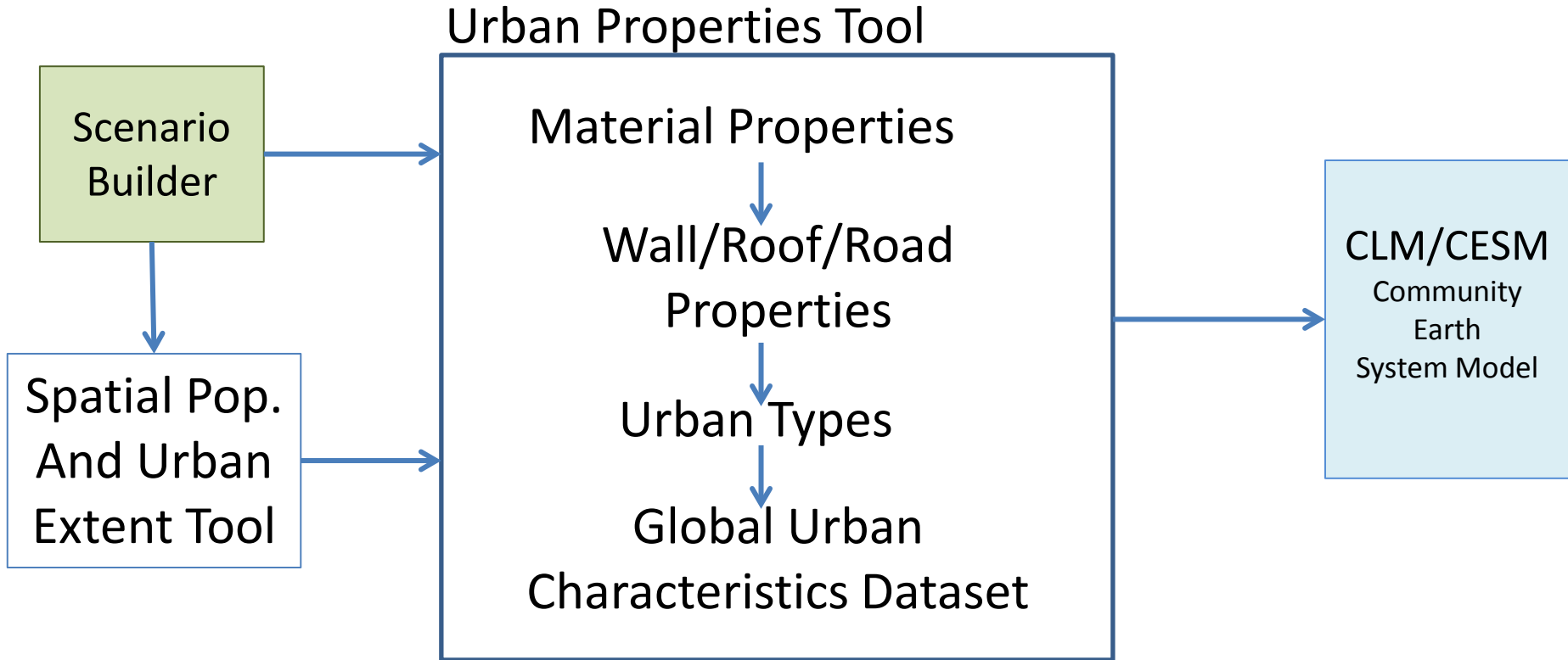Urban Types
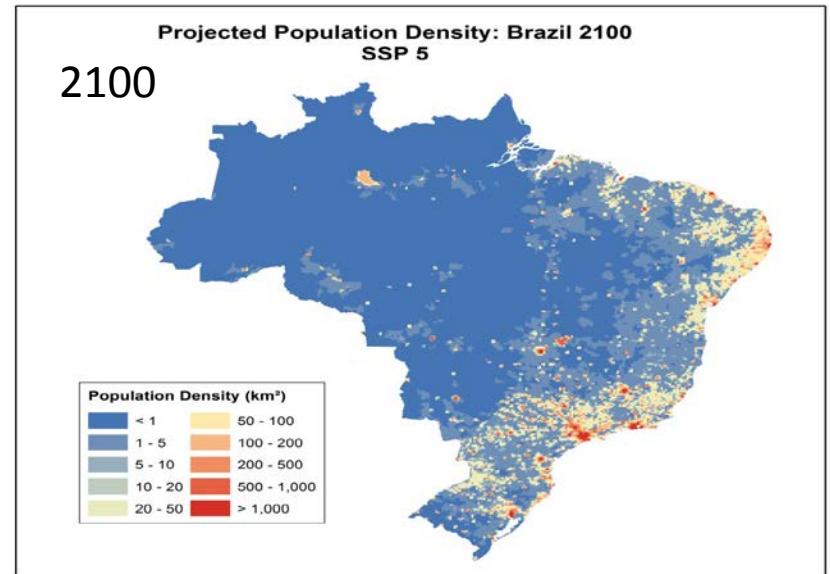
↓

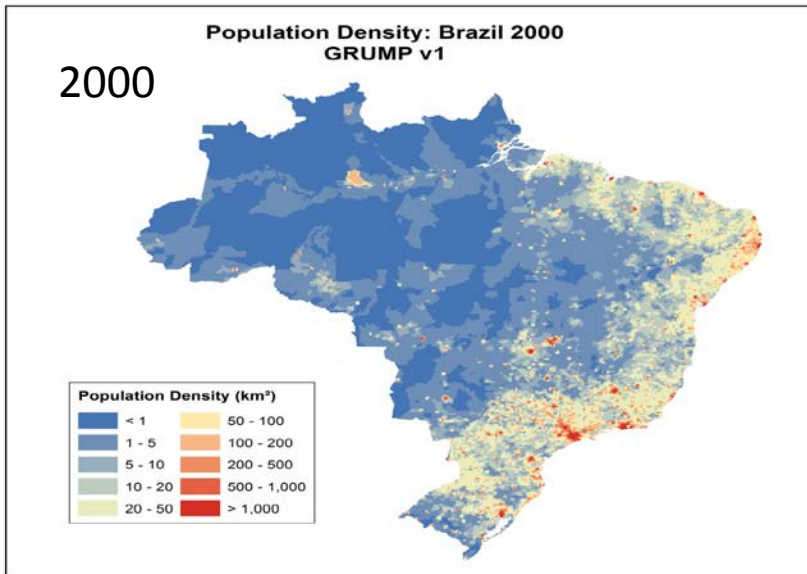Global Urban Properties Dataset

Global Regions

[...]

Example: Urban Properties Tool

Urban Properties Tool

Scenario Builder

Spatial Pop. And Urban Extent Tool

Material Properties

↓

Wall/Roof/Road Properties

↓

Urban Types

↓

Global Urban Characteristics Dataset

CLM/CESM
Community Earth System Model

Spatial Population Distribution

2000

Population Density: Brazil 2000
GRUMP v1

2100

Projected Population Density: Brazil 2100
SSP 5

Courtesy: Bryan Jones

Spatial Urban Land

2000

2030
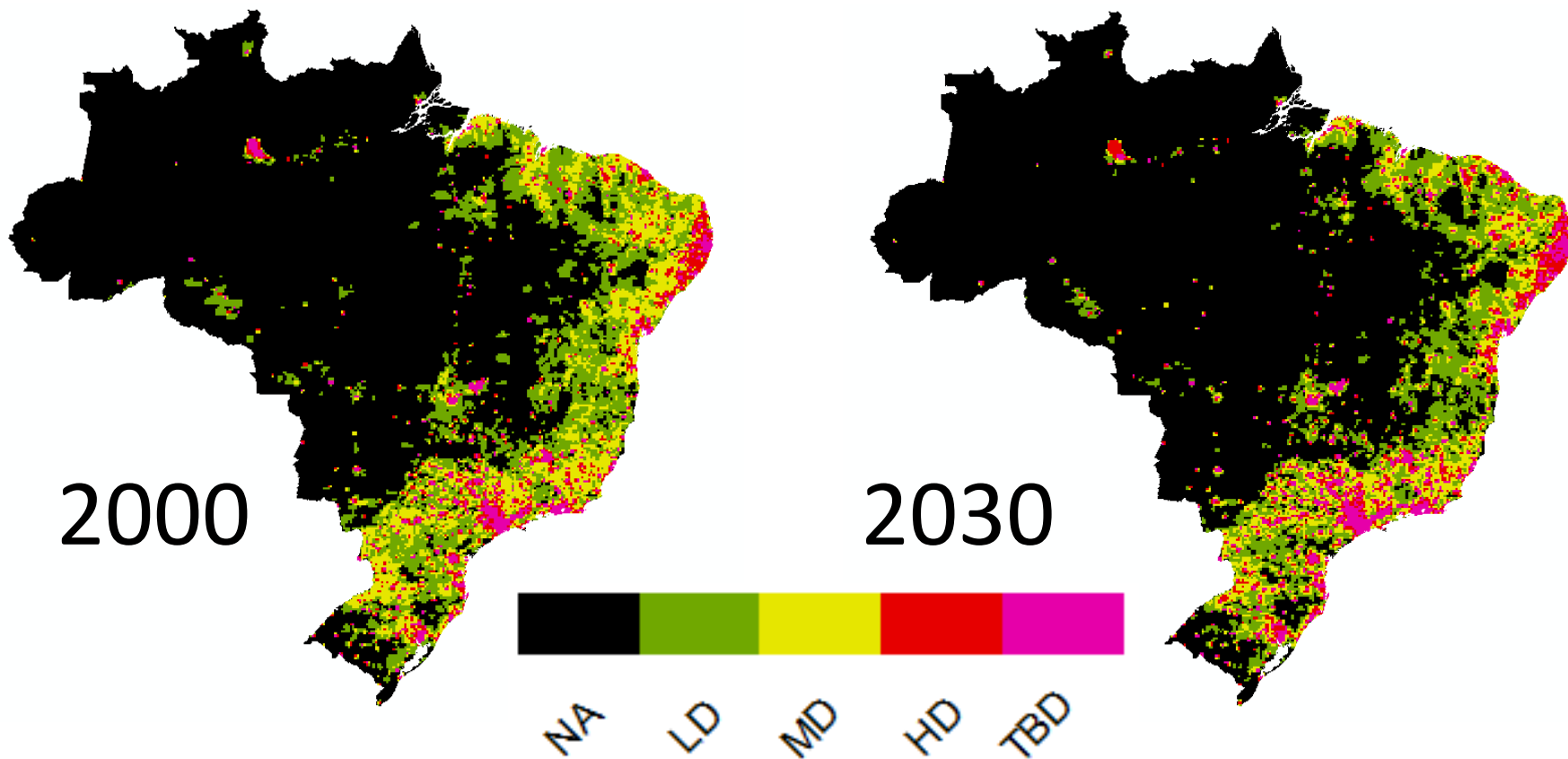
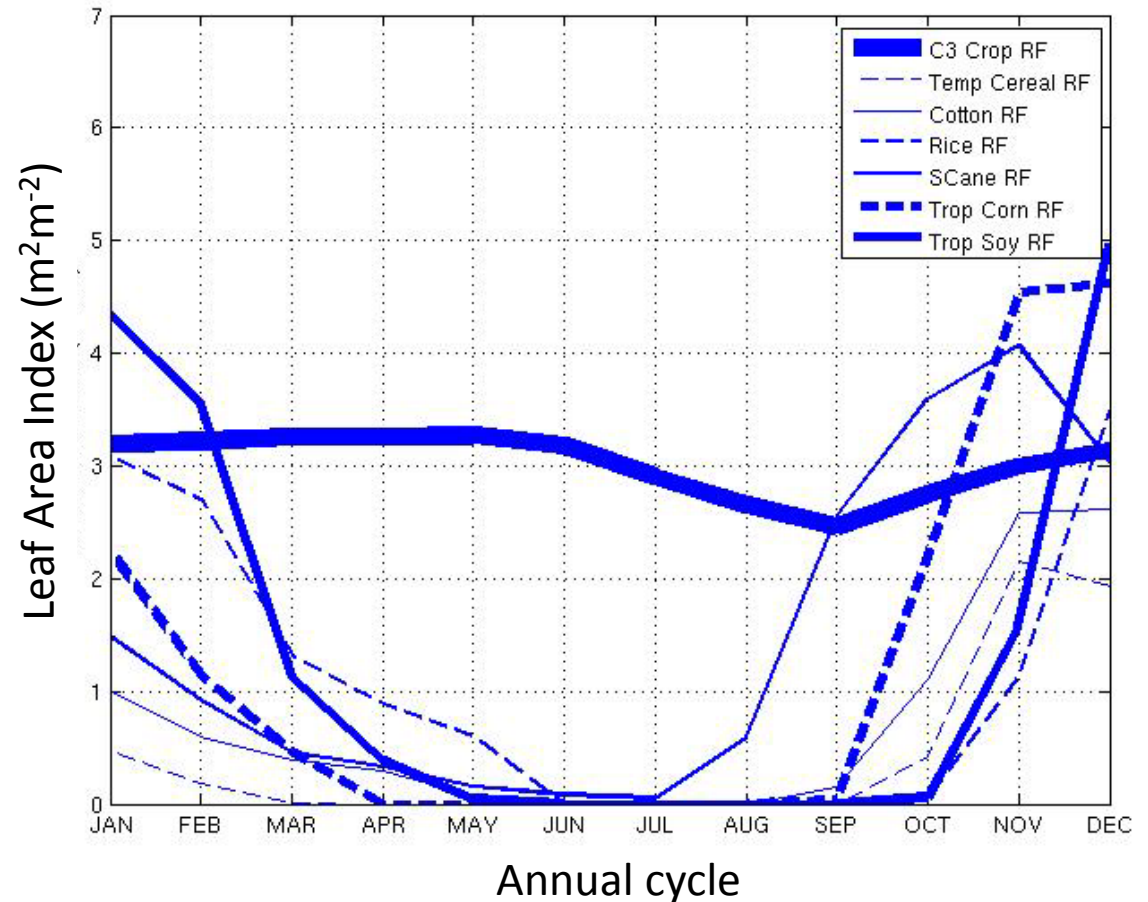Courtesy: Dan Runfola

Spatial land use tool

Cropland 2005

Cropland 2050
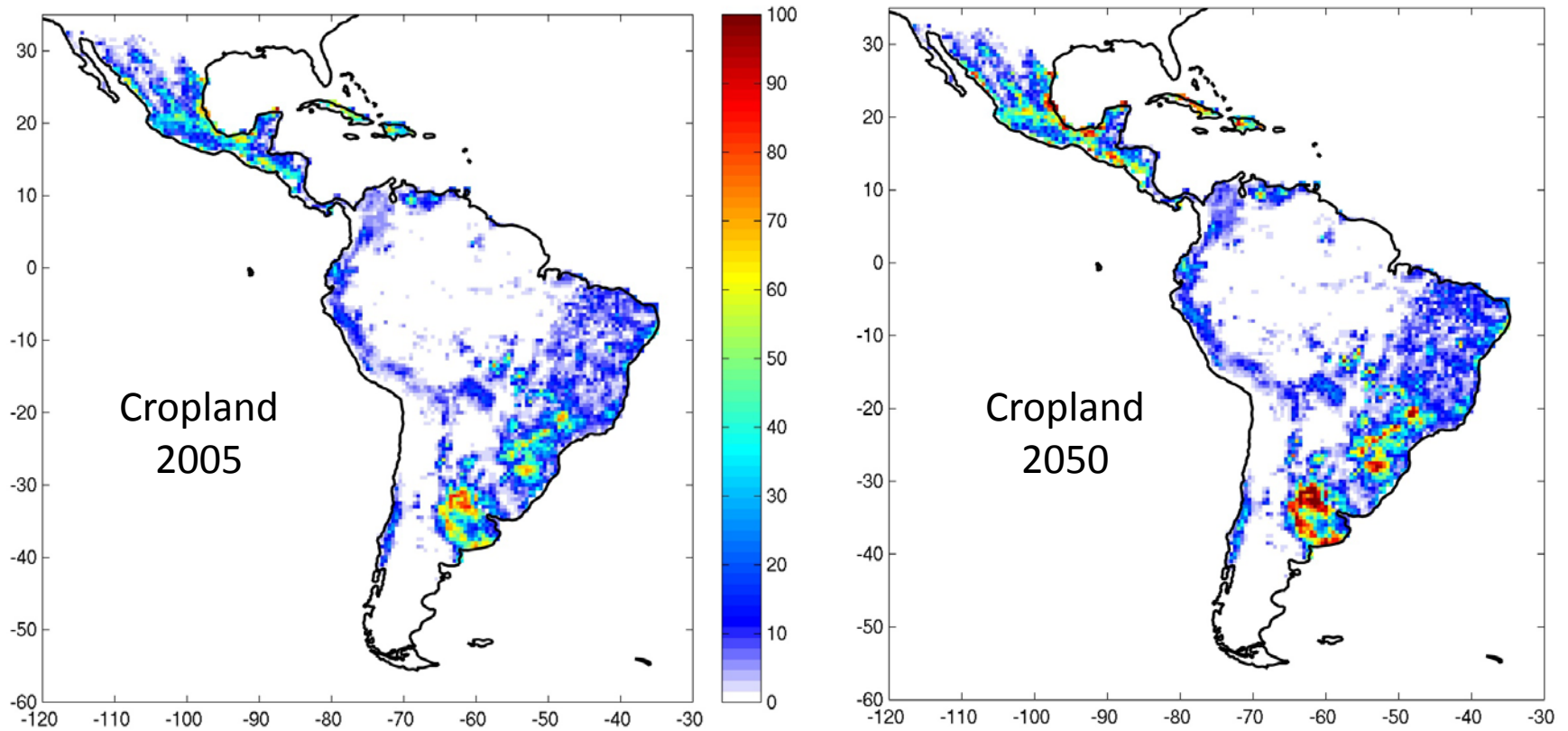
Courtesy: Prasanth Meiyappan

Agricultural properties tool:
New crop types

Cotton
Rice
Sugar cane
Tropical corn
Tropical soy

Courtesy: Sam Levis, Andrew Badger

Relevance to SDWG

Fostering dialogue
- Hopefully

Needs for CESM development
- CLM-Crop comparison to other crop models, response to management
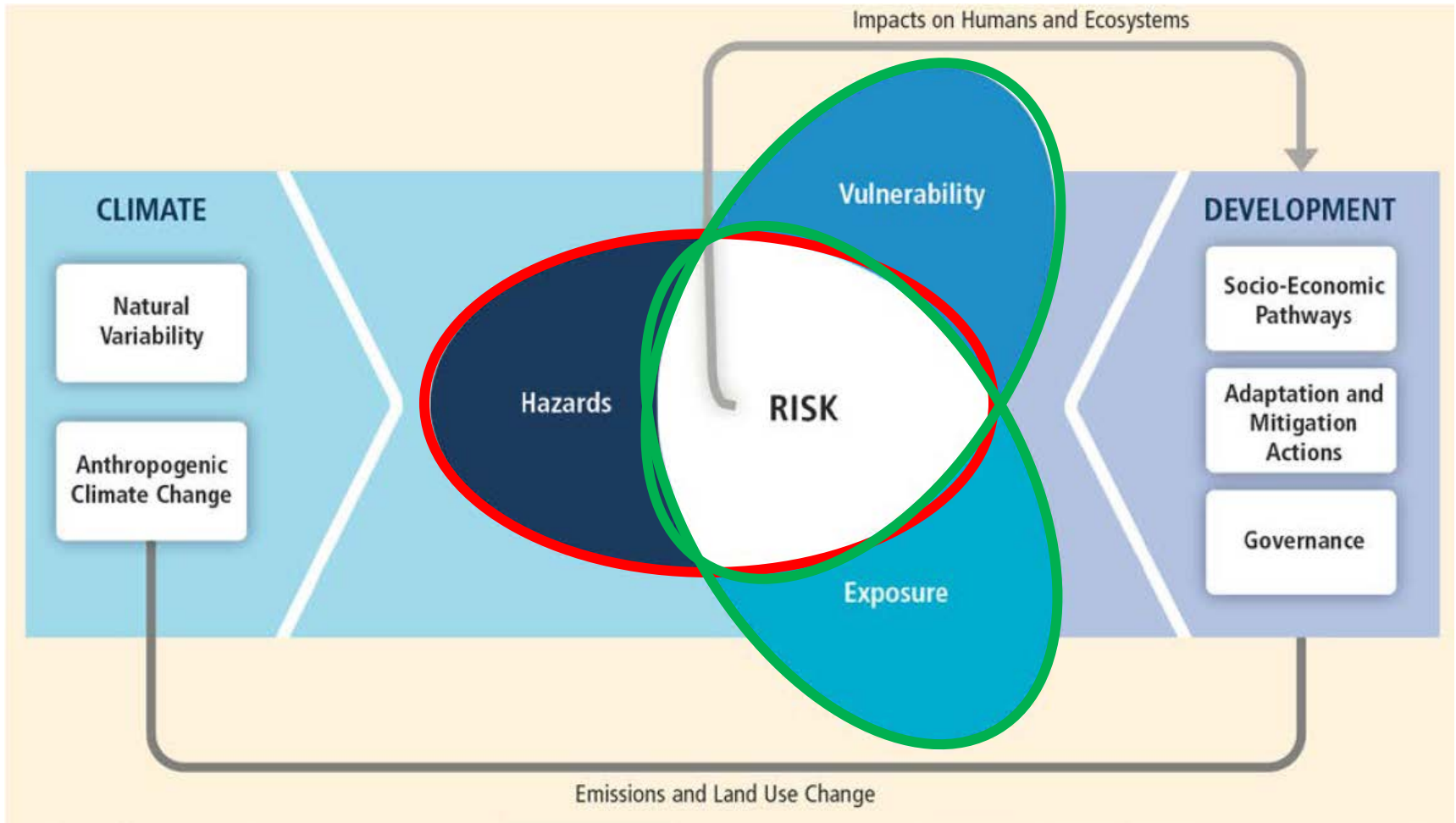- Dynamic land units for crops and urban areas

Relevant CESM simulations
- Idealized simulations to support consistency tools

New CESM linkage code
- THESIS toolset, integration with iESM

Based on IPCC *SREX* (2012) SUMMARY FOR POLICY MAKERS

Types of THESIS tools

Task 1a: Agriculture and Forest System tools
- Spatial allocation of rural land-use
- Characterizing agricultural and forest properties
- IAM-CESM consistency in agriculture and forestry
- Agriculture and Forest Impact assessment tool
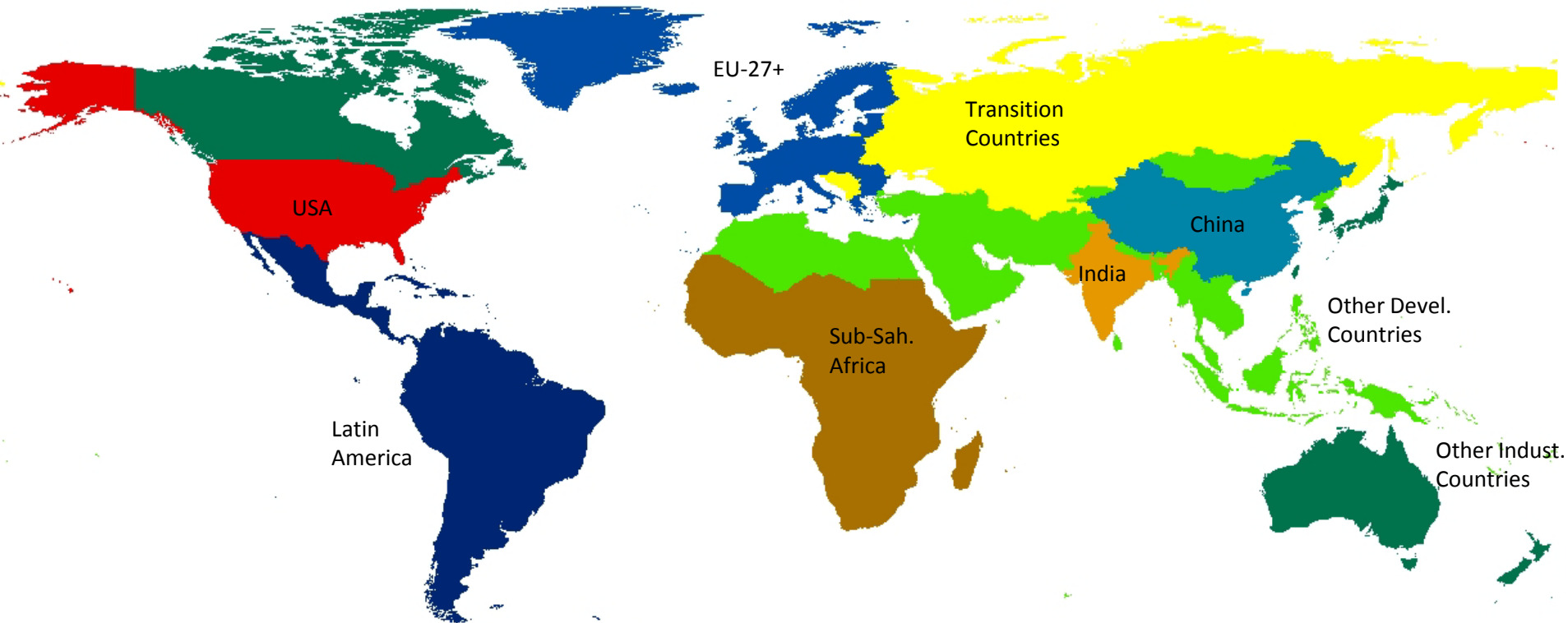
Task 1b: Urban System Tools
- Spatial projections of population density, urban extent, and urban household characteristics
- Characterizing urban properties
- IAM-CESM consistency in urban energy use
- Urban impact assessment

Integrated Population-Economy-Technology Science (iPETS) Model:
CGE, forward-looking, 9 regions

External Collaborators: M. Dalton (NOAA); A. Jain (U. Illinois); R. Fuchs, S. Pachauri (IIASA); E. Balistreri (Col. School of Mines)
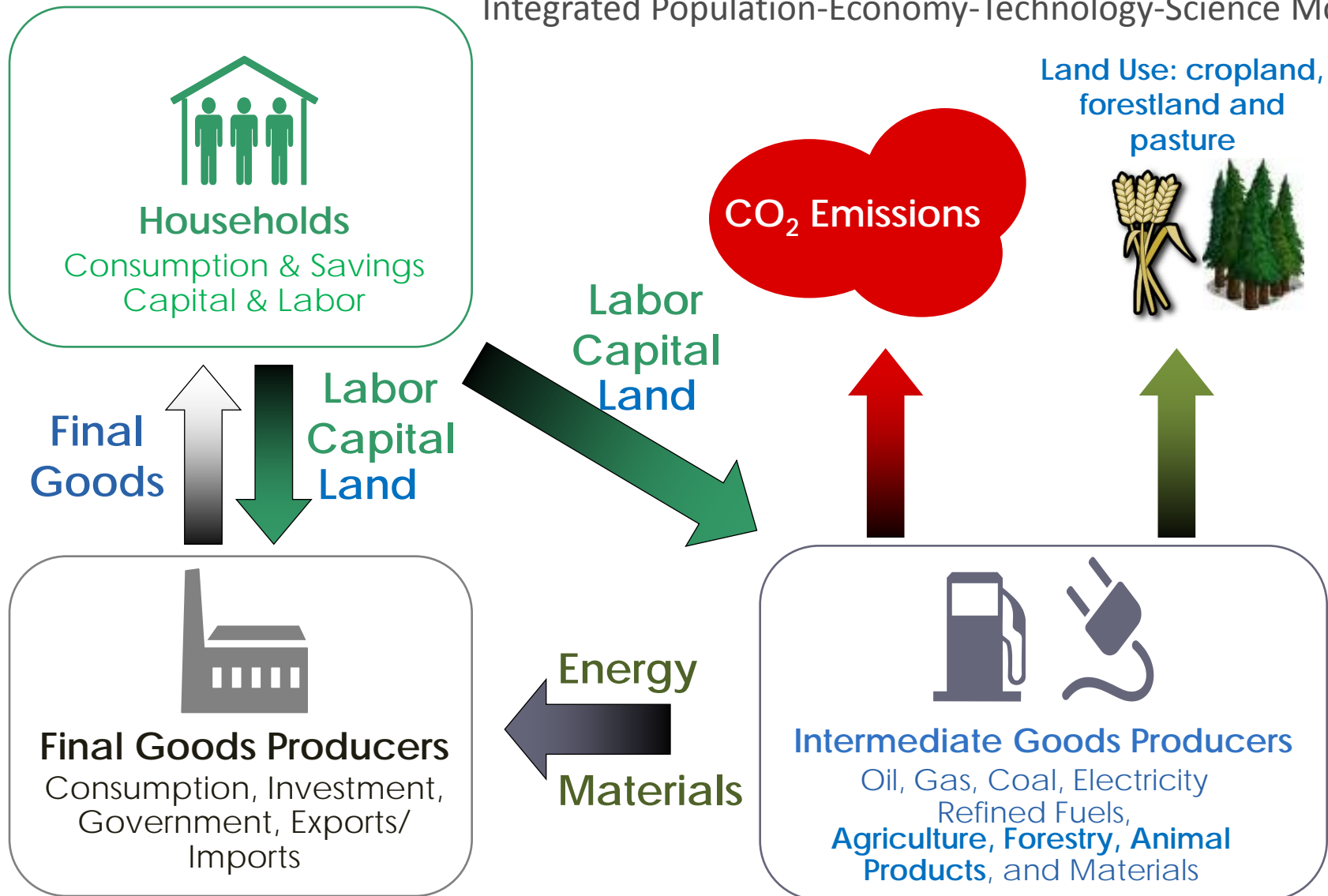
Community orientation: Code freely available

IA Model: iPETS

Integrated Population-Economy-Technology-Science Model

Households
Consumption & Savings
Capital & Labor

CO$_2$ Emissions

Land Use: cropland, forestland and pasture

Final Goods

Labor Capital Land

Labor Capital Land

Energy

Materials

Final Goods Producers
Consumption, Investment, Government, Exports/ Imports

Intermediate Goods Producers
Oil, Gas, Coal, Electricity Refined Fuels, **Agriculture, Forestry, Animal Products**, and Materials

Results for Latin America

Land Use Distribution

Million Ha

- Cropland
- Pasture
- ManagedForest
- Other Arable

2500
2000
1500
1000
500
0

Base (2004) 2020 2050 2080 2100
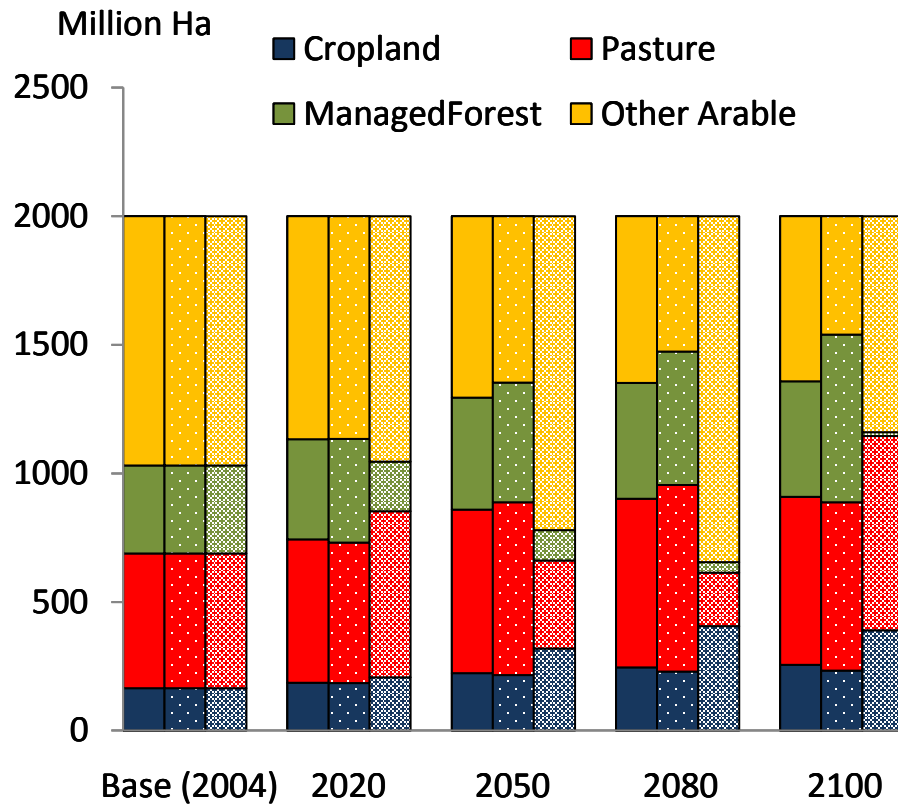
Per Capita Food Consumption

$1000

- Meat&Diary
- Crop

2.5
2
1.5
1
0.5
0

Base (2004) 2020 2050 2080 2100
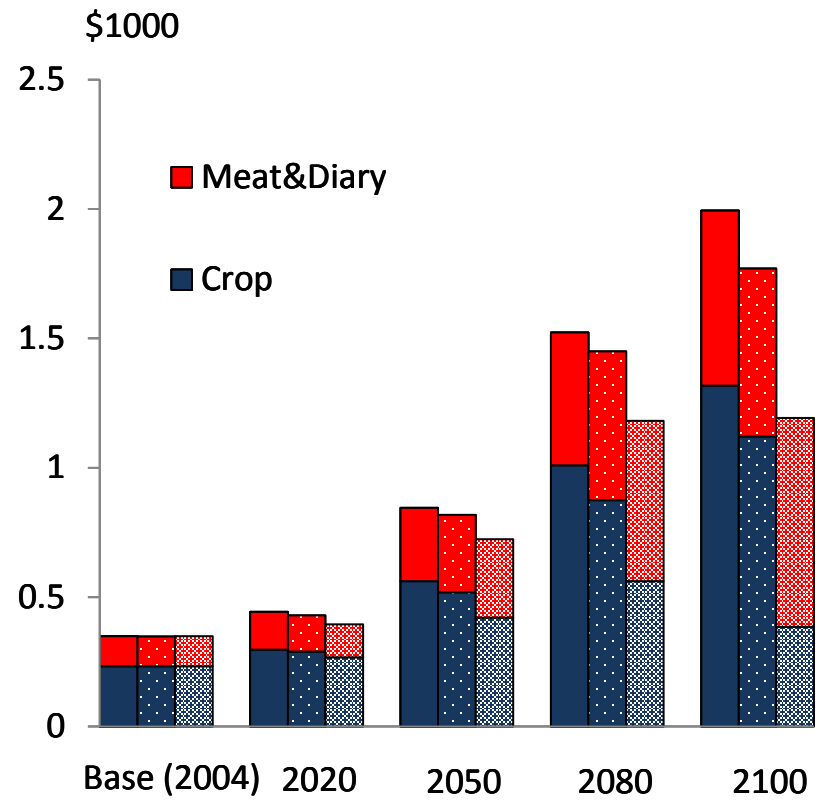
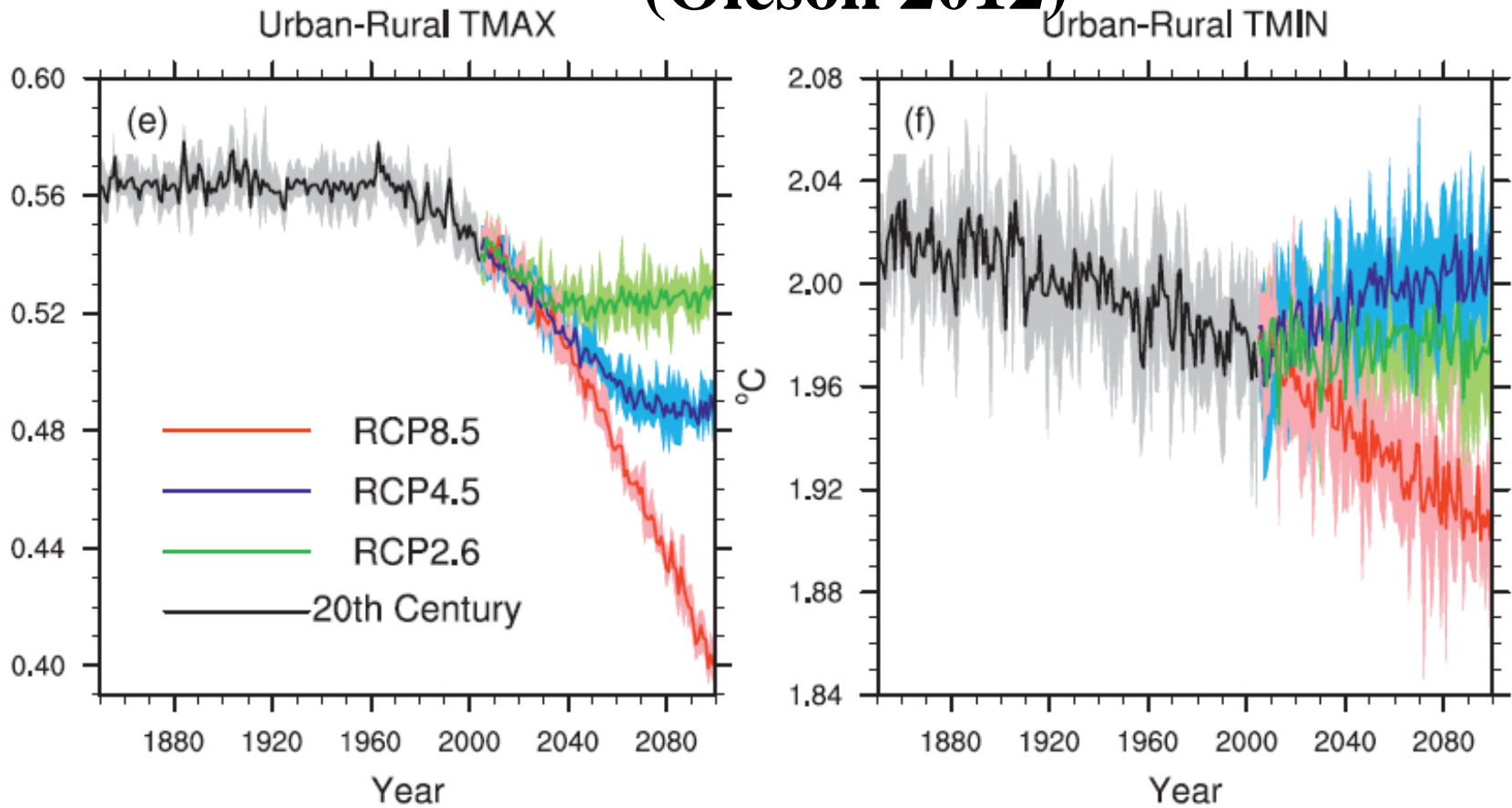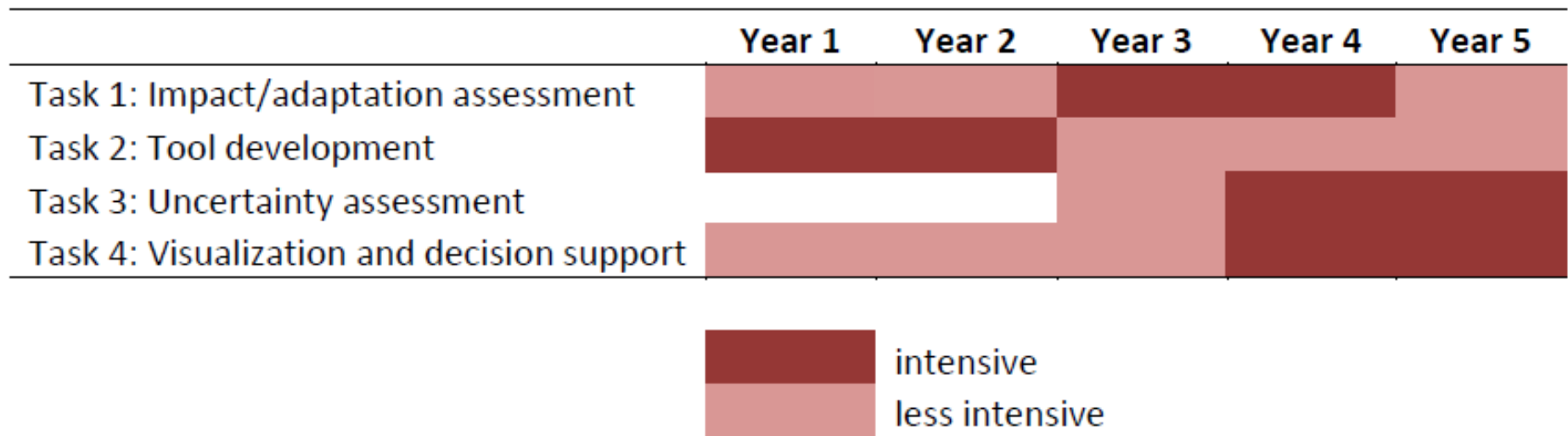Baseline   Total Factor   Partial Factor

Urban Heat Island Implications
(Oleson 2012)

Timeline

2. Timeline for the project and its tasks including milestones

	Year 1	Year 2	Year 3	Year 4	Year 5
Task 1: Impact/adaptation assessment					
Task 2: Tool development					
Task 3: Uncertainty assessment					
Task 4: Visualization and decision support					

intensive
less intensive

IAMs Draw from and Serve Other Climate Science Research

IAM

Human Systems

Economy	Security	Food	Managed Ecosystems
Population	ENERGY		Transport
Infrastructure	Science	Technology	Health

Natural Earth Systems

Atmospheric Chemistry	Sea Ice	Coastal Zones	Carbon Cycle
Nitrogen Cycle	Oceans	Hydrology	Ecosystems
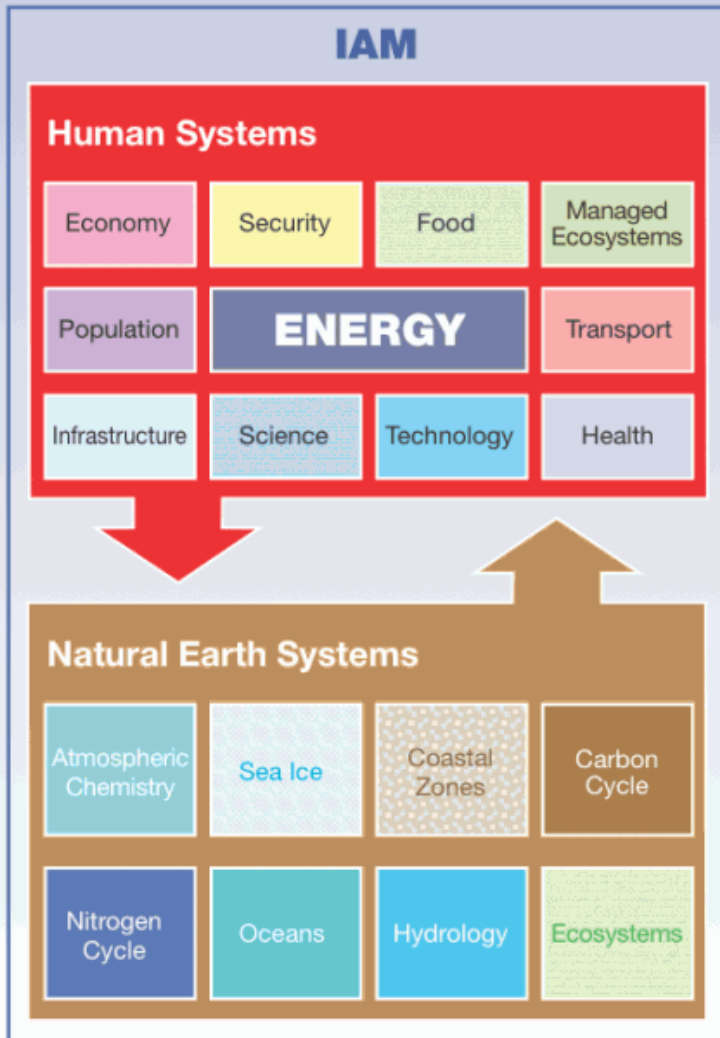
Gridded GHG and SLS Emissions, Land Use →

← Models and Data

Climate Modeling and Research Include:

- Carbon cycle
- Atmospheric chemistry
- Oceans
- Climate

Socioeconomic States, Development Paths, Multiple Stressors →

← Models and Data

IAV Modeling and Research Include:
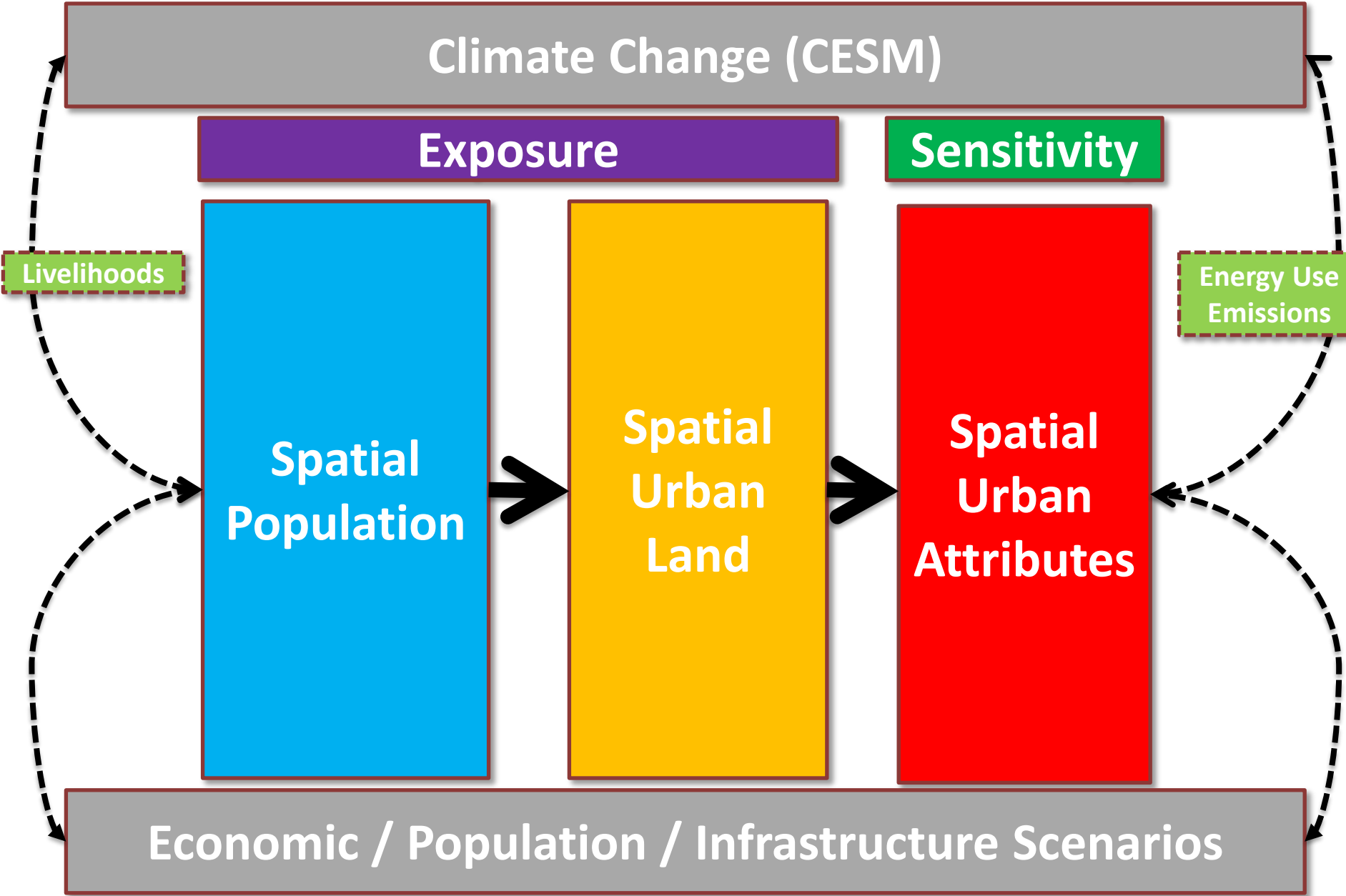
- Energy
- Water
- Coastal zones
- Ecosystems
- Health

Comparing results: 2005

Model	Scope	AC	HEAT	WASTE	TOTAL
ESMs					
CESM-CLMU	HAC in all buildings	0.6 EJ	129 EJ	26.2 EJ	155.2 EJ
IAMs					
GCAM	HAC in all buildings	16.6 EJ	37.2 EJ	12.7 EJ	49.9 EJ
TIAM-world	HAC in all buildings	10 EJ	35.8 EJ	10.1 EJ	45.9 EJ

For reference:

IEA 2008: 331 EJ Primary Energy in urban areas

IEA 2011: 191 EJ Primary Energy use in buildings

preliminary results, subject to change. Traditional biomass excluded

Urban attributes: Improved urban model

CLM Urban model
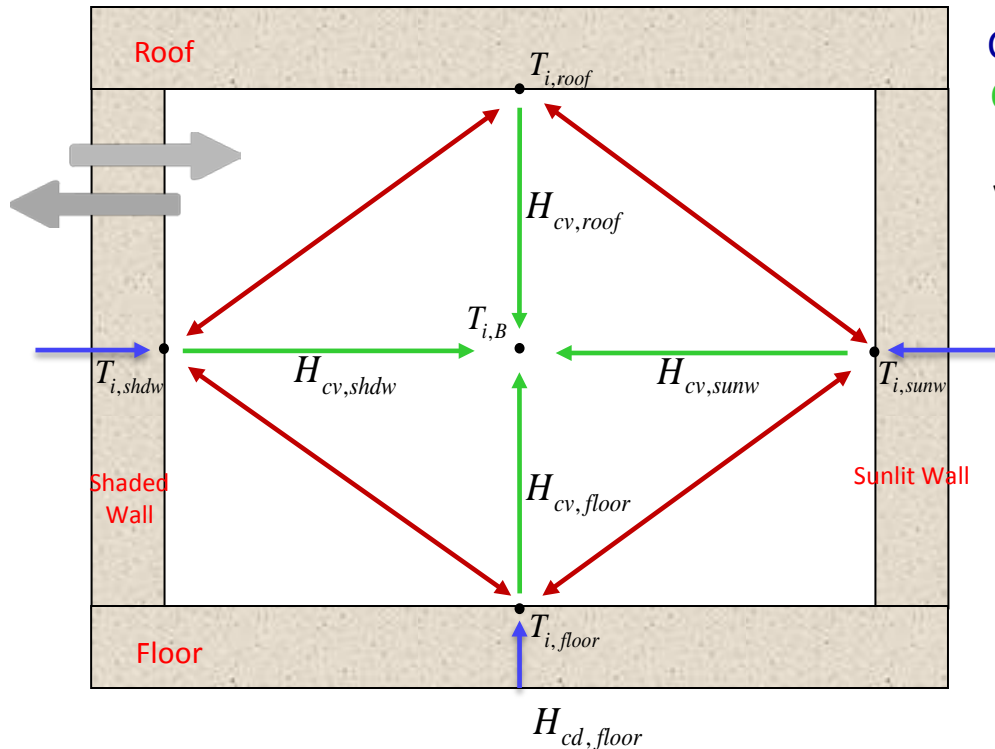
Conduction
Convection
Radiation
Ventilation

Courtesy: Keith Oleson, Johan Feddema

Year 2005 global building heating/cooling energy demand (TW)

Estimated (IEA and UNEP)	3.1
CLMU Version 1	9.0
CLMU Version 2	3.0