# Overview of Economic Methods to Simulate Land Competition

Ron Sands

Mike Brady

Economic Research Service, USDA

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# Importance of agriculture and forestry in analysis of climate policy

- Agriculture is a large source of greenhouse gases
  - methane
  - nitrous oxide
- Carbon emissions from land-use change
- Potential to store more carbon in forests and soils
- Biofuels provide a link between agricultural and energy systems
- Impacts of climate change on agriculture

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# Policy questions

- What is the full life-cycle impact of biofuels on net greenhouse gas emissions?
- What is the potential for additional carbon storage in forests and soils?
- What is the cost, scale, and timing of various options to reduce land-based greenhouse gas emissions?

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# Overview

- Methods
- Representative approaches
  - GTAP
  - MiniCAM
  - REAP (Regional Environment and Agriculture Programming model)
  - Global Timber Model
- Research Agenda
  - Link to biophysical models
  - Determine appropriate level of geographical detail
  - Forest dynamics
  - Water

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# Methods

- Scenarios (over time)
  - Reference
  - Mitigation
  - Climate impacts
  - Mitigation + Climate Impacts
- Economics
  - Single country or global analysis
  - Partial or general equilibrium
  - Comparative static, dynamic recursive, dynamic optimization
  - Land allocation mechanism
- Land Classes
  - Grid cells
  - Agro-ecological zones (AEZs)
  - Watersheds
  - Political boundaries

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# Scenarios

| | |
|---|---|
| reference | mitigation |
| climate impacts | mitigation + climate impacts |

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# Model Classification

| | Partial equilibrium | General equilibrium |
|---|---|---|
| **Comparative static** | | FARM, GTAP-AEZ |
| **Dynamic recursive** | | |
| **Dynamic with limited foresight** | AgLU | |
| **Dynamic optimization** | FASOM, GTM | |

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# Global Trade Analysis Project (GTAP)

- Characteristics
  - General equilibrium
  - Global with international trade in all products
  - Armington trade (bilateral trade between regions)
- Land Allocation
  - Each region (country or group of countries) is partitioned into Agro-Ecological Zones (AEZs)
  - Within each AEZ, land is a primary factor of production that is allocated across agricultural and forestry activities

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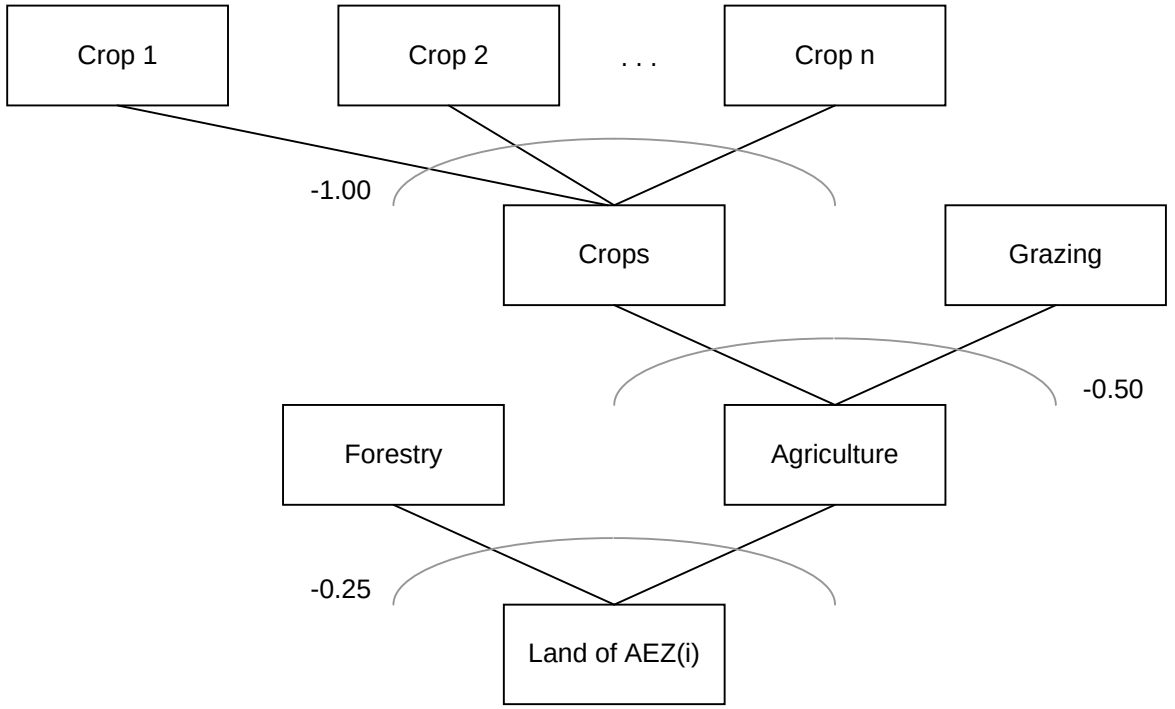
# Agro-Ecological Zones

- The AEZs represent six different lengths of growing period (6 × 60 day intervals) spread over three different climatic zones (tropical, temperate and boreal)
- The length of growing period depends on temperature, precipitation, soil characteristics and topography
- The suitability of each AEZ for production of alternative crops and livestock is based on currently observed practices, so that the competition for land within a given AEZ across uses is constrained to include activities that have been observed to take place in that AEZ

Source: Hertel, T., Lee, H.-L., Rose, S., Sohngen, B. 2008. Modeling Land-use Related Greenhouse Gas Sources and Sinks and their Mitigation Potential, GTAP Working Paper No. 44.

# Land Allocation in GTAP

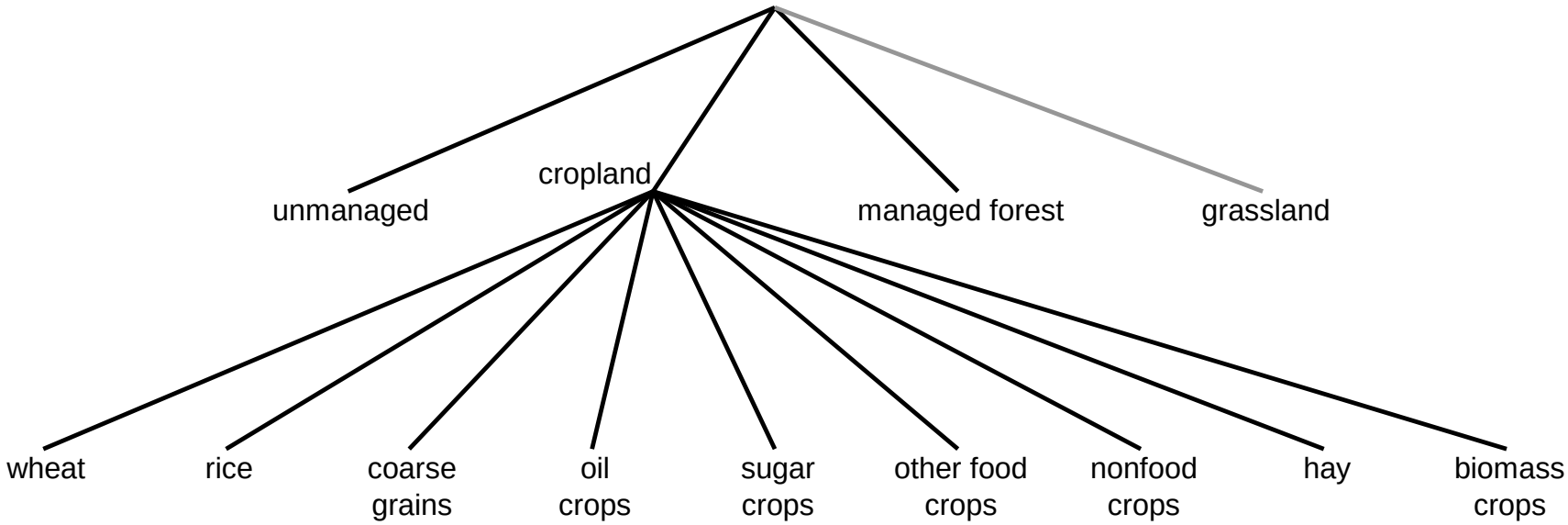



Source: Hertel, T., Lee, H.-L., Rose, S., Sohngen, B. 2008. Modeling Land-use Related Greenhouse Gas Sources and Sinks and their Mitigation Potential, GTAP Working Paper No. 44.

# MiniCAM

- Characteristics
  - Partial equilibrium
  - Global with international trade in energy and agricultural goods in 14 regions
  - Net trade between regions in primary energy, primary agriculture and biofuels
- Land Allocation
  - Each region (country or group of countries) is assumed to have yield distribution for each crop
  - Statistical approach to land allocation based on yield distribution, and correlation of yield between crops

# Allocation of land in MiniCAM



# Calculation of Land Shares

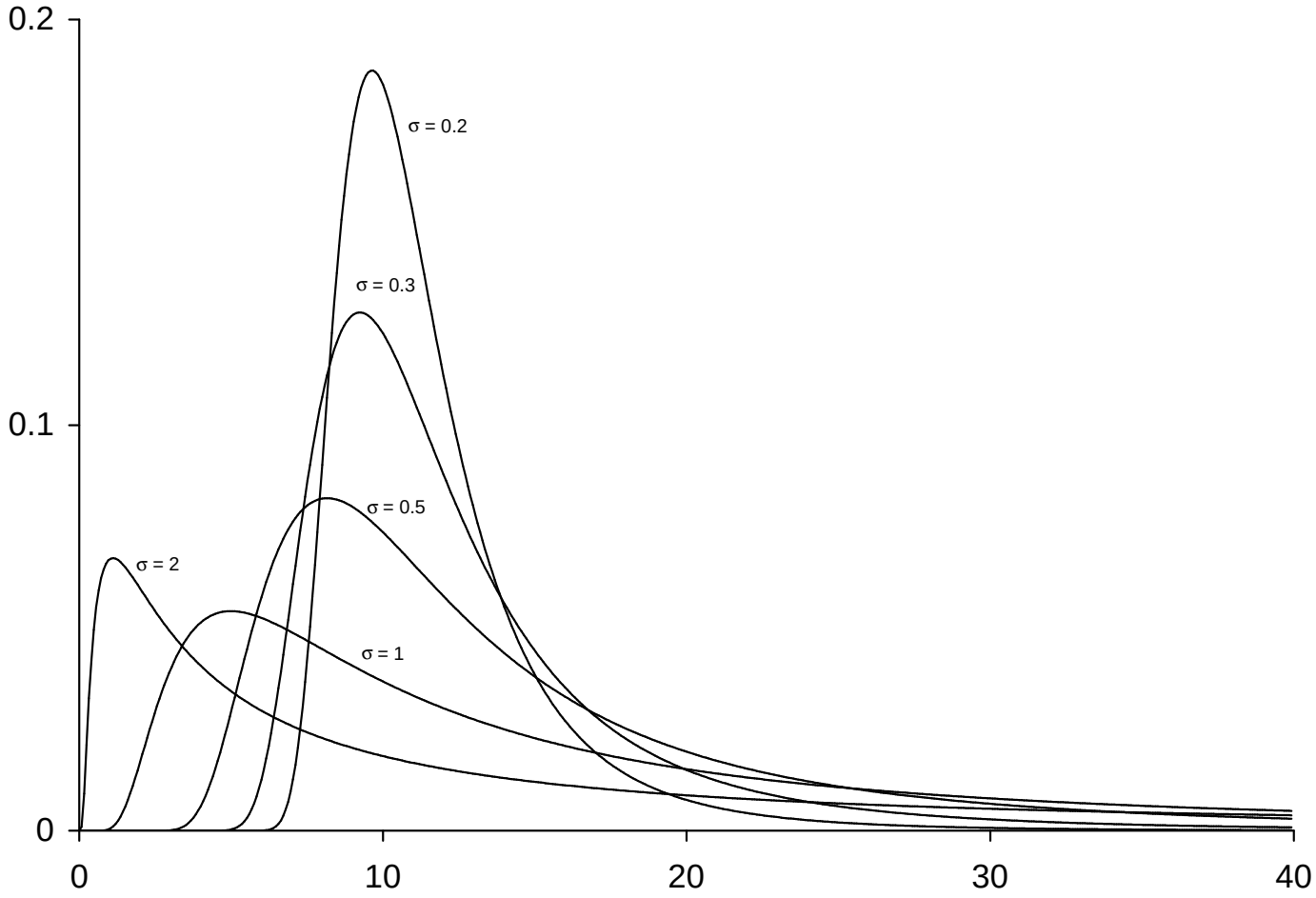
$$s_i = \frac{\bar{\pi}_i^{1/\alpha_2}}{\sum_k \bar{\pi}_k^{1/\alpha_2}}$$

Land share for land use i is an increasing function of profit rate (lambda is positive).

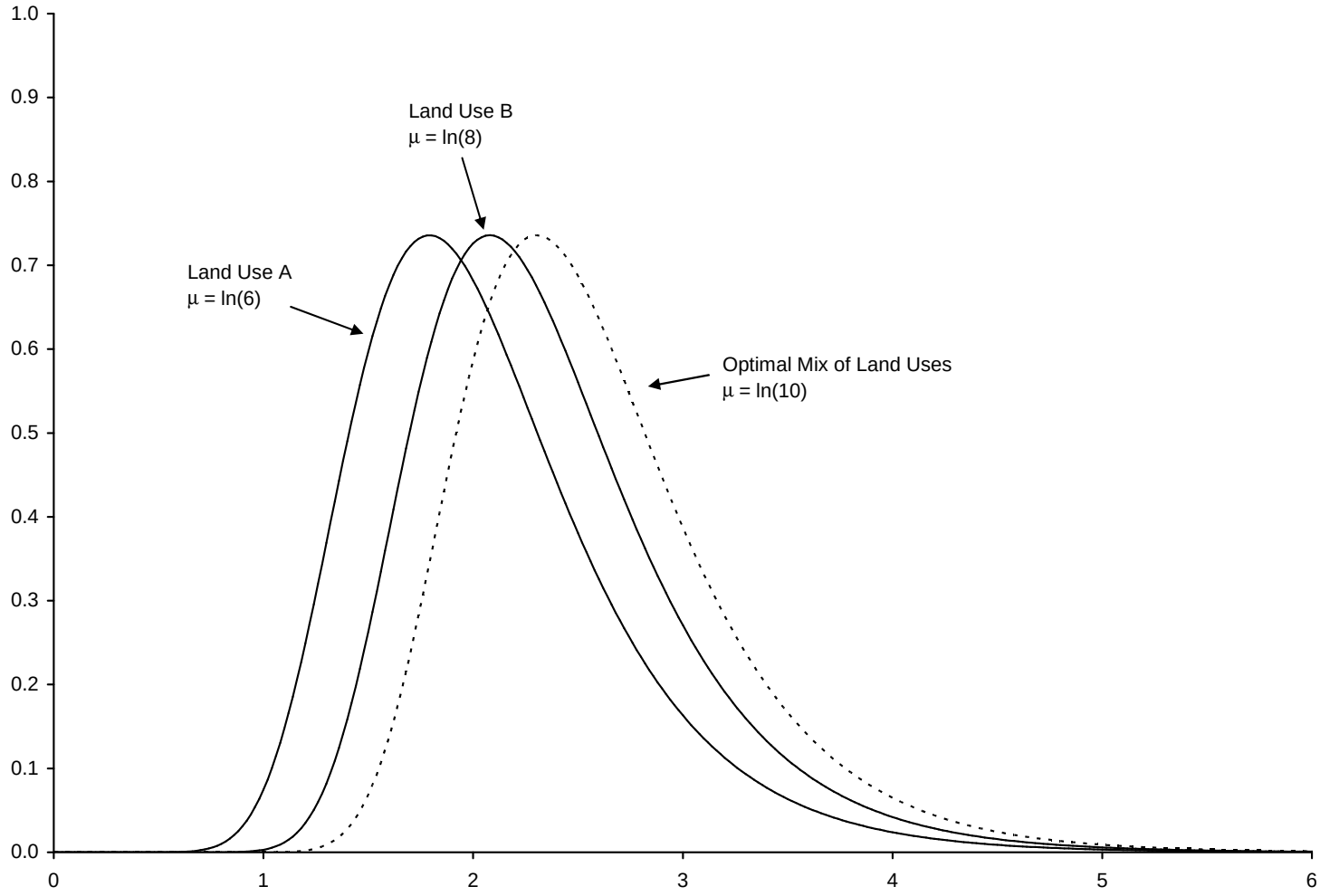
$$\bar{\pi}_i = \bar{y}_i\left(p_i - g_i\right)$$

Profit rate equals average yield times price received less non-land cost of production.

# Log-Gumbel probability density functions (fixed scale parameter and varying shape parameters)



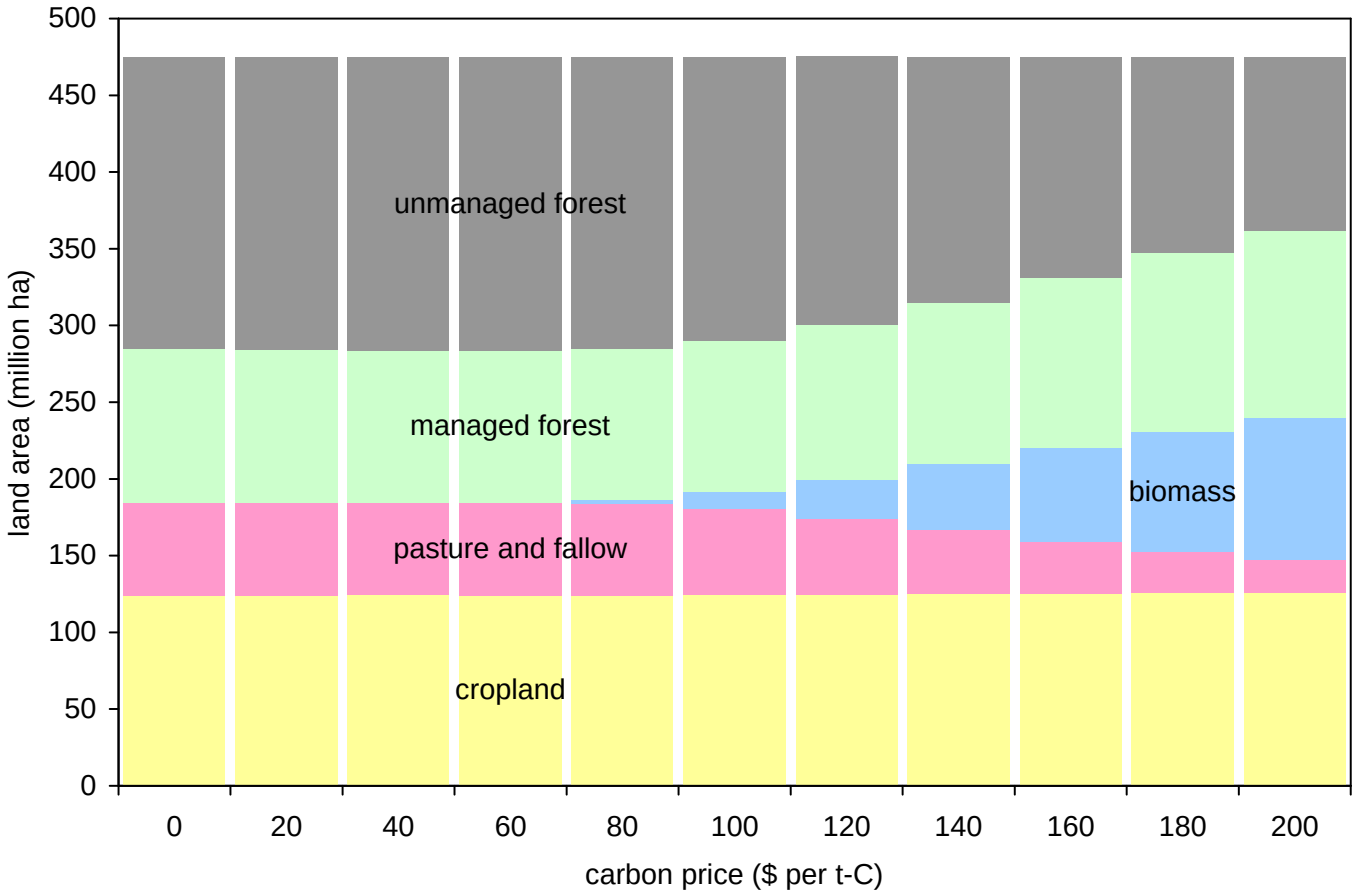
# Gumbel probability density functions representing log of profit rates (sigma = 0.5)



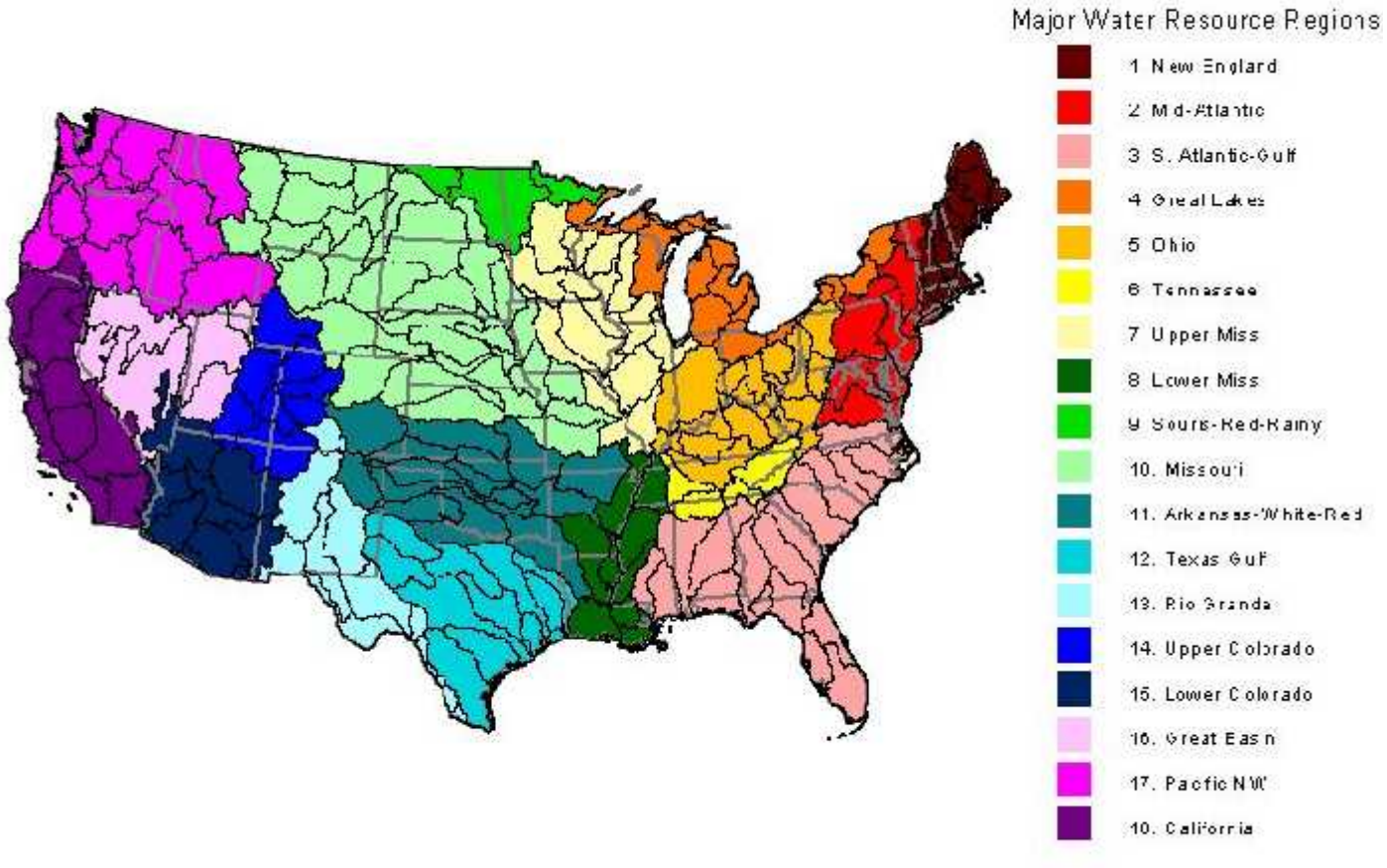
# Random variables and distribution functions

| | | parameters | | |
|---|---|---|---|---|
| variable | distribution | location | scale | shape |
| yield | Log-Gumbel | (none) | $\bar{y}_i$ | ± |
| profit rate | Log-Gumbel | (none) | $®_i$ | ± |
| ln(profit rate) | Gumbel | $\ln(®_i)$ | ± | (none) |

# Simulated land use in the United States as a function of carbon price. (population and agricultural productivity are held constant)



# Major watersheds in the U.S. Each color represents a 2-digit watershed. (within each color are watersheds at the 4-digit level)



# REAP (Regional Environment and Agriculture Programming model)

- Characteristics
  - Static partial equilibrium model of the U.S.
  - Linked to EPIC crop process model
- Land allocation
  - Land divided into 50 production regions; forty-five have some agriculture
  - Land in cropland, pasture, and Conservation Reserve Program
  - Within each region land is further divided into erodible and highly erodible

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# Global Timber Model

- Characteristics
  - Global, dynamic, partial equilibrium model of the forest sector
  - Currently being expanded to include links to the agriculture sector (GFAM)
- Land allocation
  - 18 regions and approximately 200 timber types
  - Uses agro-ecological zones to represent differences in climate
  - Timber areas are categorized accordingly to degree of industrialization, management intensity, and plantation establishment

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# Research Agenda

- Link to biophysical models
  - If land classes are fixed in location, then biophysical models can be used to simulate yield and input requirements as a function of climate, soils, and management practices (including irrigation)
  - EPIC and CENTURY are commonly used
- Land classes
  - How many and what type?
  - At what level should we collect data? To what level should data be aggregated?
  - How do policy questions influence construction of land classes?
- Forest dynamics
  - Forestry is inherently intertemporal
  - What are the options for linking forestry with agriculture?
- Water
  - Global and national models do not have explicit water constraints
  - Water availability limits expansion of crops and biofuels
  - A monthly time step may be needed to simulate water supply and demand
  - Using watersheds as land classes my help with simulating climate impacts
  - Are we limited more by data or by methods?
- Biofuels and indirect land use change
  - What level of spatial detail is needed?
  - What trade patterns are expected?

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