Modeling Land Competition

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AIM International Workshop

Tsukuba, Japan

19-21 February 2007

Objectives

- Extend partial equilibrium land use framework to general equilibrium
  - Forestry identified as a priority model development item in review of PNNL general equilibrium framework (Second Generation Model) by U.S. EPA Science Advisory Board
  - What is the right level of abstraction for a recursive CGE model?
    - Forest dynamics
    - Number of crops, animal products, forest products
    - Geographic detail
- Improve ability to simulate impact of carbon price on land use
  - Biofuel incentive
  - Forest management (increased tree rotation age)
  - Value carbon in unmanaged land

Overview

- Modeling Approaches
  - Forestry optimization
  - Partial and general equilibrium economics
- PNNL Agriculture and Land Use Model (AgLU)
  - Brief history
  - Land allocation mechanism
- Disaggregation of US region into land subregions
- Forest dynamics
  - Determination of optimal tree rotation age
  - Carbon price and rotation age
- Steady-state simulation
- What Next?

Modeling Approaches

- Intertemporal Optimization
  - Typical for sector-specific models (e.g. forestry)
- Intertemporal Equilibrium (perfect foresight)
  - Efficiency conditions (first order necessary conditions) from intertemporal optimization model become system equations
  - Allows integration with other types of economic systems (such as agriculture)
- Recursive Equilibrium
  - Absence of look-ahead capability makes it difficult to model forestry
- Steady-State Equilibrium
  - Exploratory tool
  - Steady-state modeling of forestry may be able to inform recursive models

Relationship to Specialized Forestry Models

	partial equilibrium	general equilibrium
intertemporal optimization	TSM, FASOM	Ramsey growth model
intertemporal equilibrium	AgLU 2	intertemporal CGE
recursive equilibrium		recursive CGE
steady-state equilibrium		AgLU 2x

Brief History of AgLU

- First version completed in 1996
- Design
  - Top-down
  - Partial equilibrium
  - Can be run stand-alone or as part of MiniCAM
- Studies
  - Role of biomass in carbon policy
  - Impact of ENSO on North America
  - U.S. climate impacts

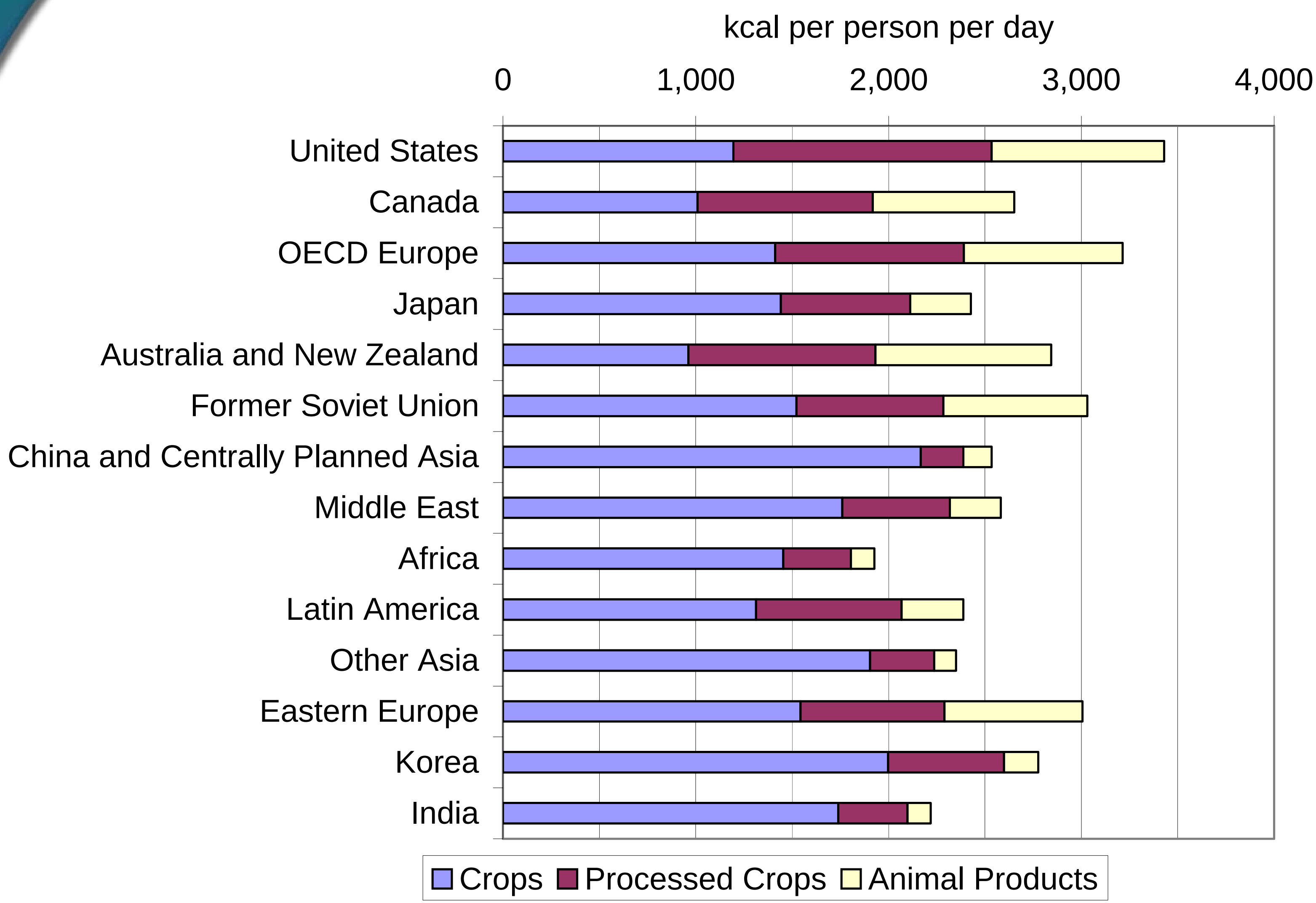
Methodology Highlights

- 15-year Time Steps from 1990 through 2095
- Land Allocation
  - Land owners compare economic returns across crops, biomass, pasture, and future trees
  - Underlying probability distribution of yields per hectare
- Forest Dynamics
  - Trees in AgLU grow for 45 years
  - Two forest markets (current and future) needed for model stability

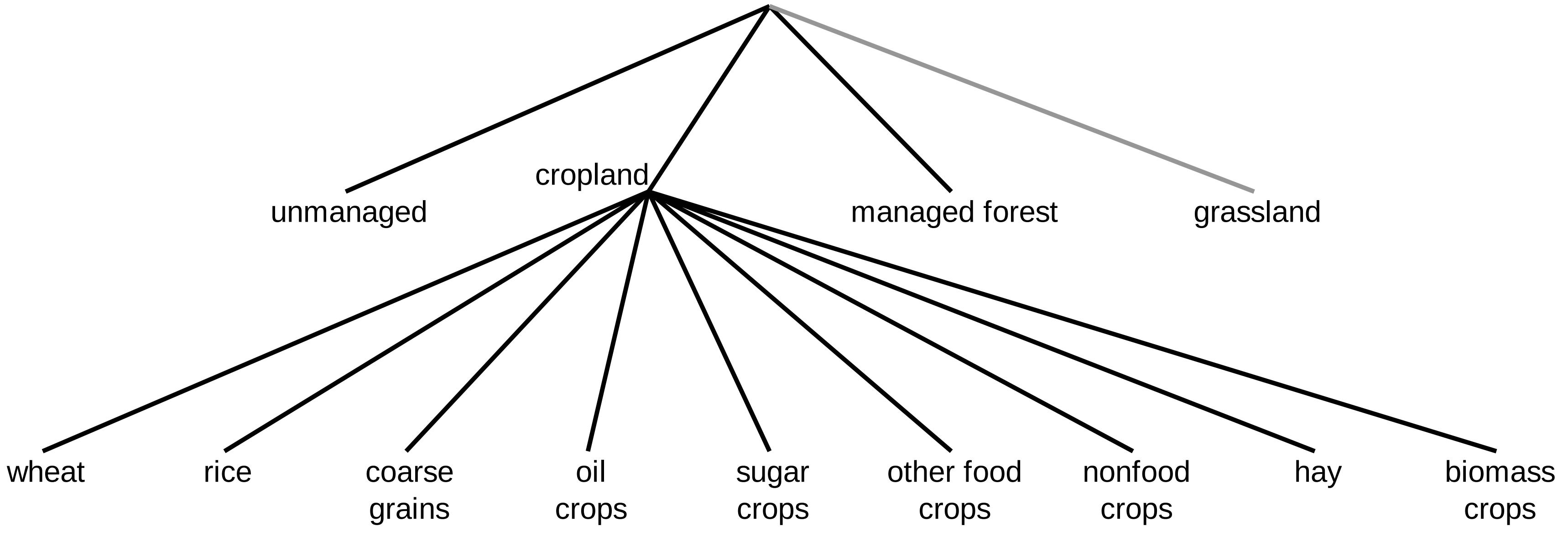
Products in AgLU

- Crops (calories)
  - Rice and Wheat
  - Coarse Grains
  - Oil Crops
  - Other Crops
- Processed Crops (calories)
  - Vegetable Oils
  - Sweeteners and Alcoholic Beverages
- Animal Products (calories)
  - Beef and other Ruminant Livestock
  - Pork and Poultry
- Commercial Biomass (calories or metric tons)
- Forest Products (cubic meters)

Food Consumption by AgLU Region



Land Allocation



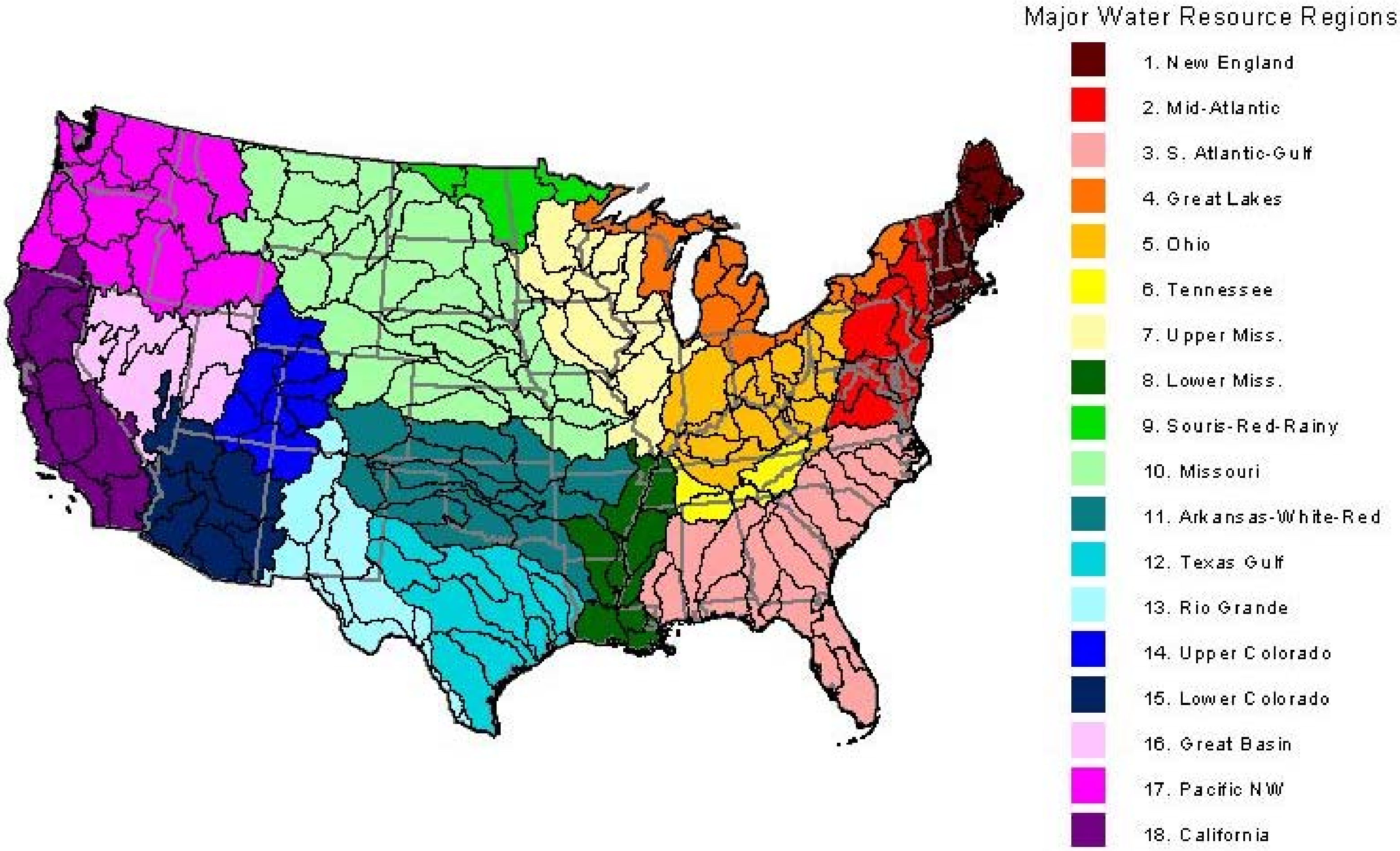
Agriculture-Forestry Data

- Agriculture-Forestry Data
  - Food balances
  - Land use data
  - Forest and agricultural production
- United Nations Food and Agriculture Organization (FAO) is the primary source of data
- Global Trade Analysis Project (GTAP) provides land use and agricultural production data for land classes within a country

US Land Classes

- Why Disaggregate?
  - Capture geographical heterogeneity
  - Terrestrial mitigation opportunities vary by land class
  - Climate impacts will vary by land class
- Hydrologic Unit Areas (HUAs)
  - 18 two-digit water basins in US
  - Fixed location
  - Useful for climate impact studies
  - Link to water supply will be important for future work on water and potential for biofuels
- Base-Year Calibration
  - No unique way to calibrate base year (calibration is something of an art)
  - Not easy to calibrate all of the following: land area by product and land class, output by product and land class, prices, costs of production
  - Exact calibration doesn't tell you where your model structure can be improved

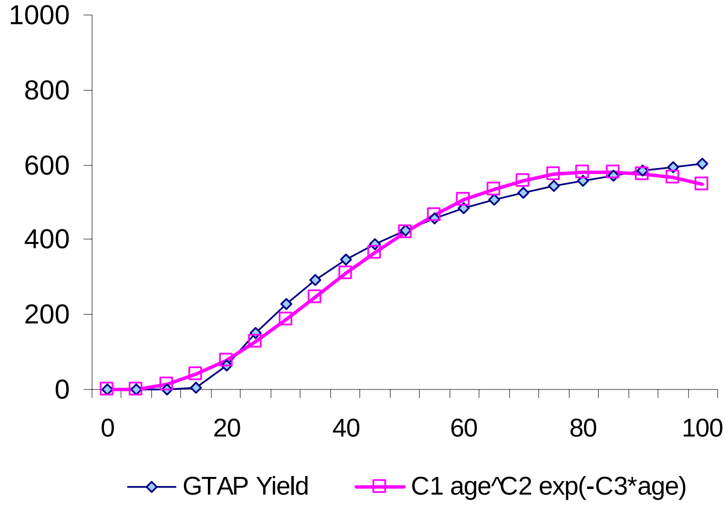
Major Water Resource Regions



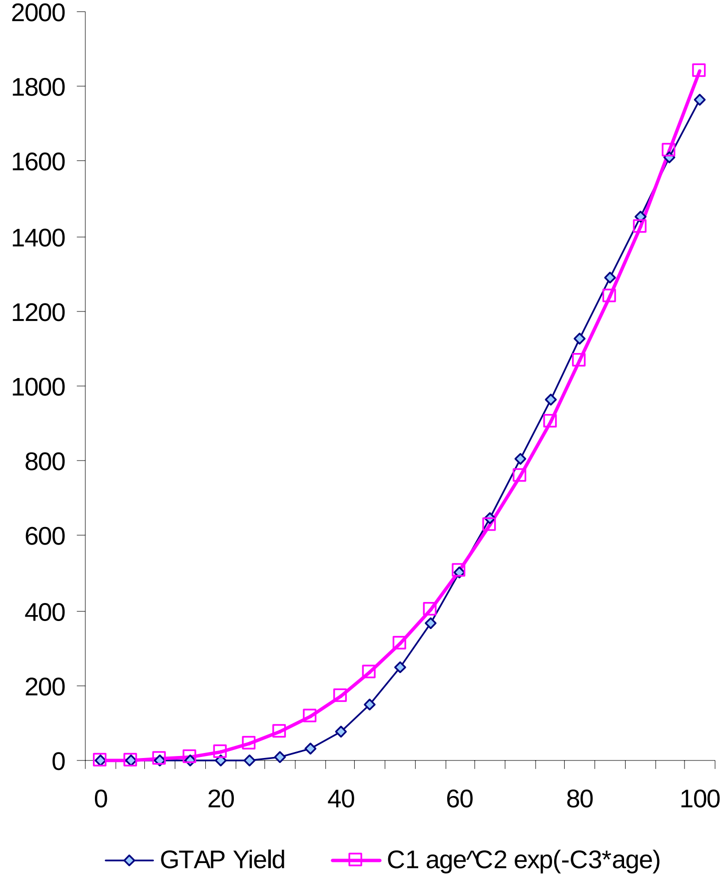
Forest Dynamics

- Tree growth curves vary across United States
- Calibration of growth curve to data provided through GTAP
- Response of forest production to carbon incentive
  - Optimal tree rotation age increases with carbon price
  - Faustmann equation (modified by carbon incentive) is an extra system equation paired with unknown rotation age
  - Modified Faustmann equation includes term that integrates carbon stock or increment of carbon sequestered over tree growth curve
  - Can calculate carbon incentive either as a rental paid for carbon storage or as full payment for increment sequestered
  - Computational burden can be reduced by selecting functional form for tree growth curve that has closed-form integral

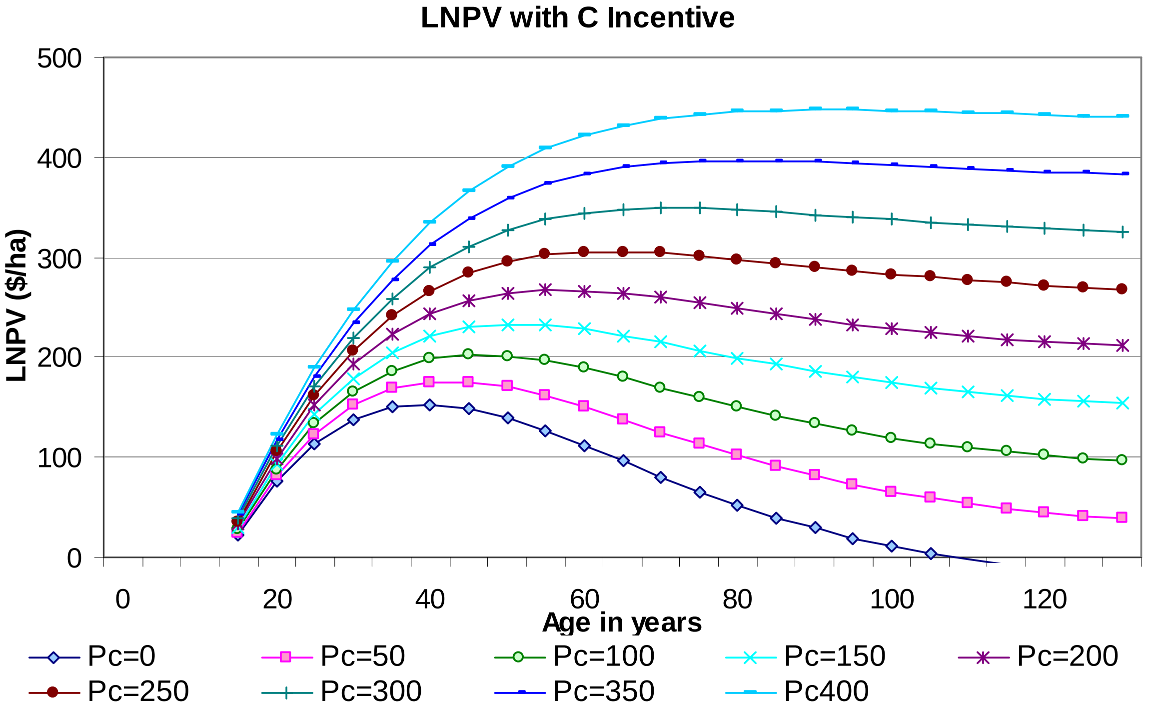
Tree growth curve for southeastern pine plantations
(yield in cubic meters as a function of tree age)



Tree growth curve for Pacific Northwest
(yield in cubic meters as a function of tree age)

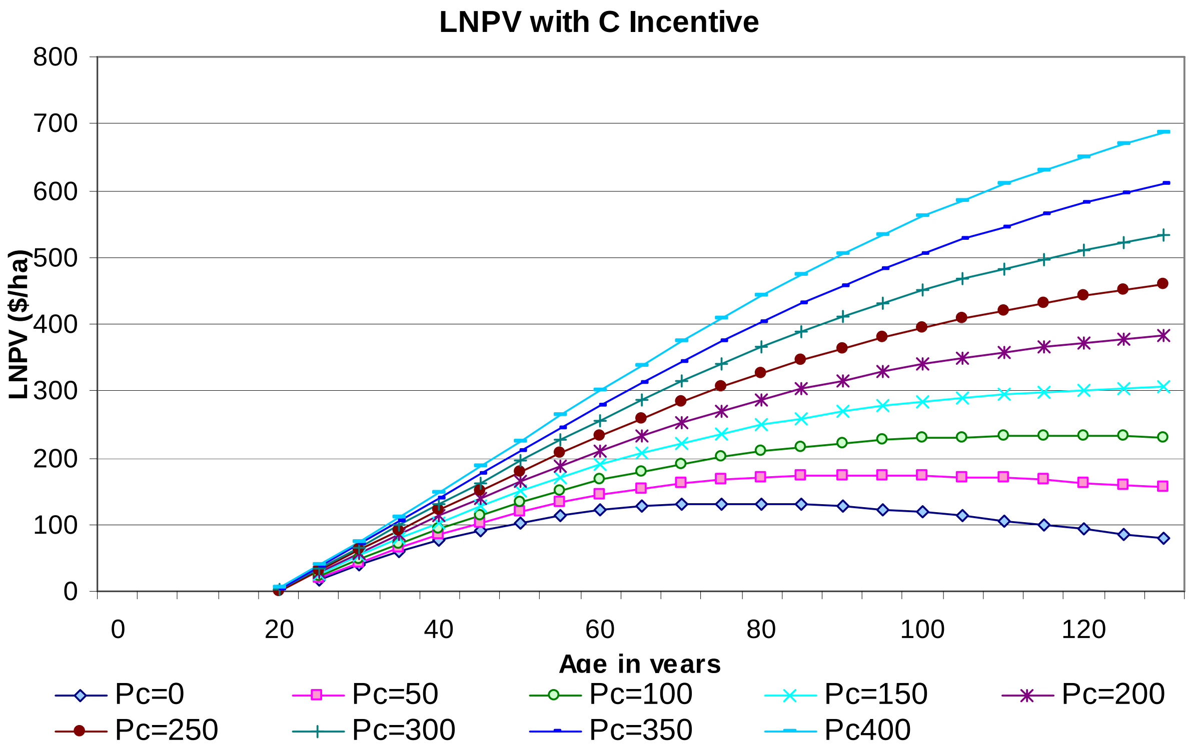


Levelized net present value per hectare at various carbon prices: southern pine plantation trees



Assumptions: p_t = \$49 per cubic meter, c_g = \$1,000 per hectare,
k = 0.2 metric tons carbon per cubic meter of wood,
r = 3%, all stored carbon is released to the atmosphere at harvest

Levelized net present value per hectare at various carbon prices: Pacific Northwest trees

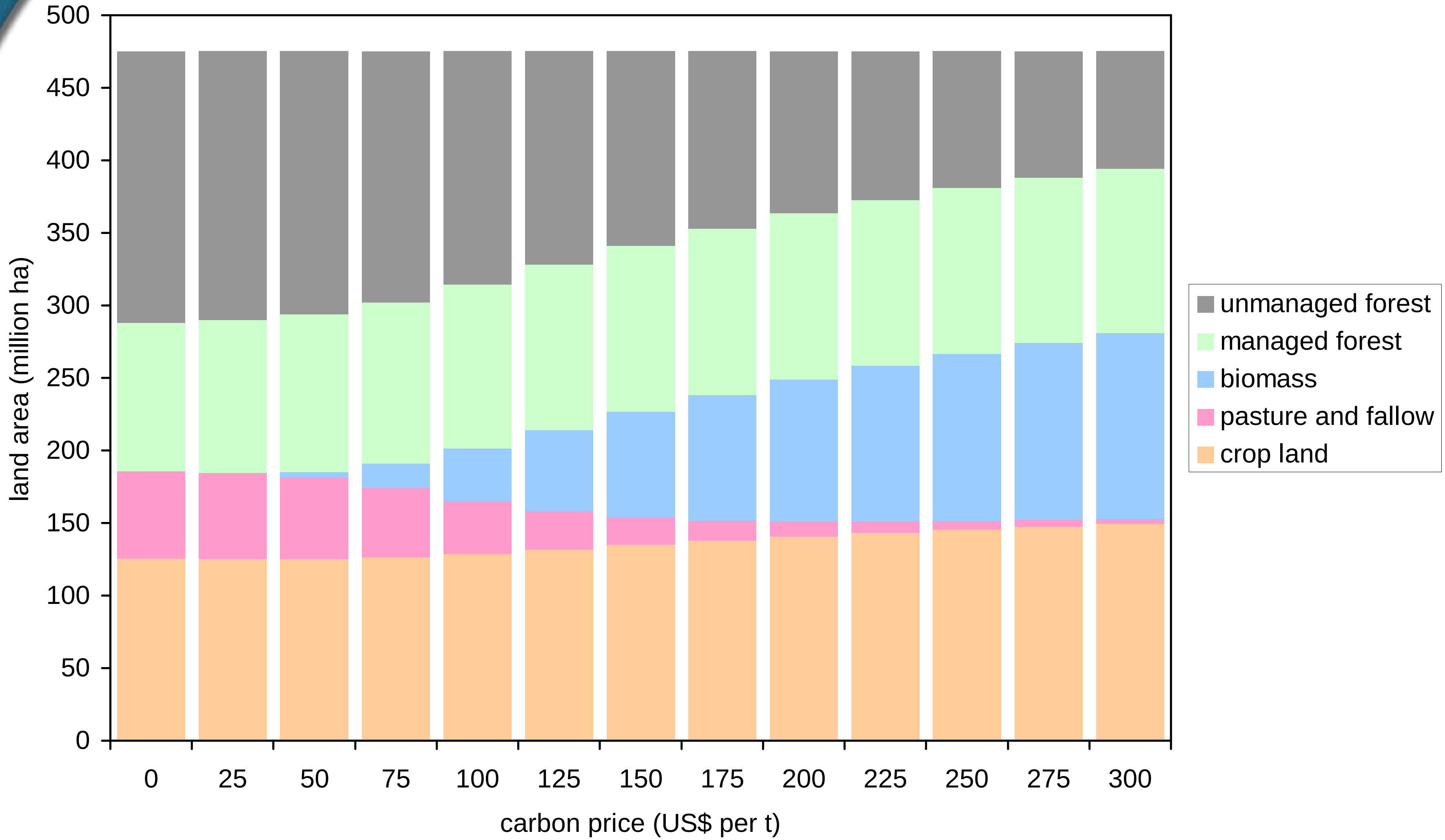


Assumptions: p_t = $49 per cubic meter, c_g = $750 per hectare,
k = 0.2 metric tons carbon per cubic meter of wood,
r = 3%, all stored carbon is released to the atmosphere at harvest

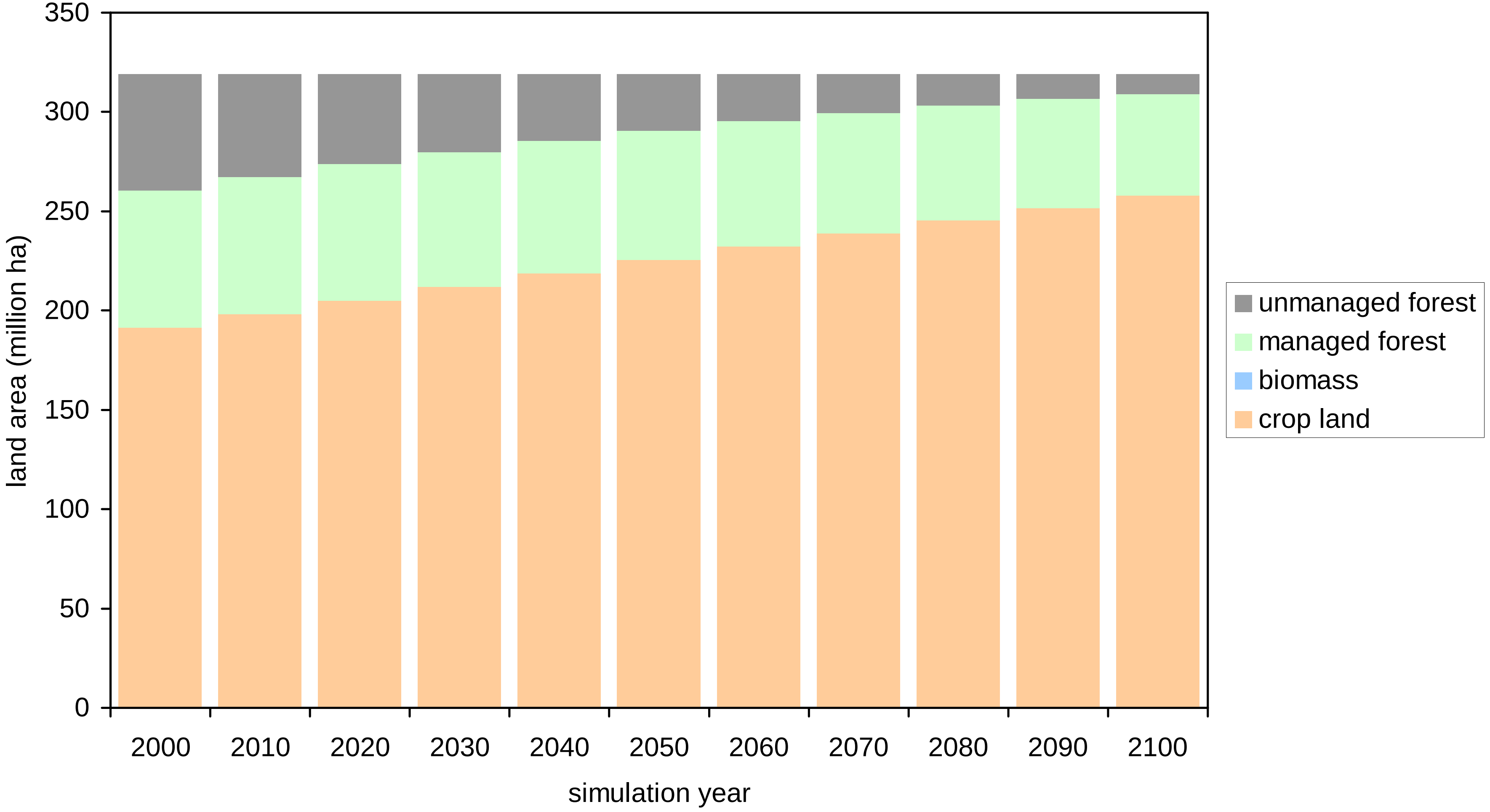
Steady-State Land Use Simulation

- United States
  - Land use as function of carbon price (up to US$ 300 per ton of carbon)
  - All other drivers held constant: population growth, agricultural productivity, income
- India
  - Land use over time is sensitive to difference in growth rates between agricultural productivity and population growth
  - Three baselines
    - Agricultural productivity < population growth
    - Agricultural productivity = population growth
    - Agricultural productivity > population growth

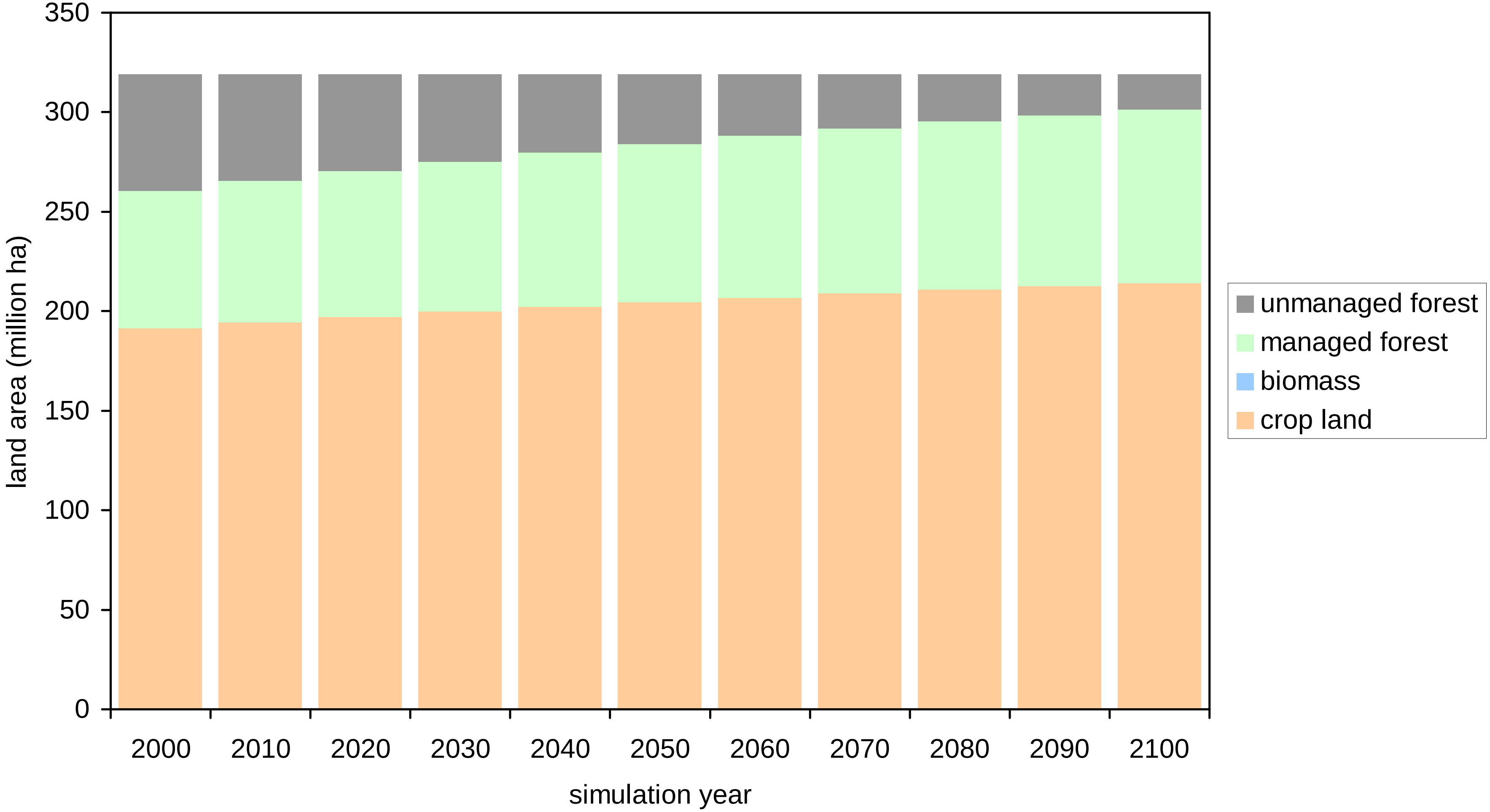
US Land Simulation with Varying Carbon Prices



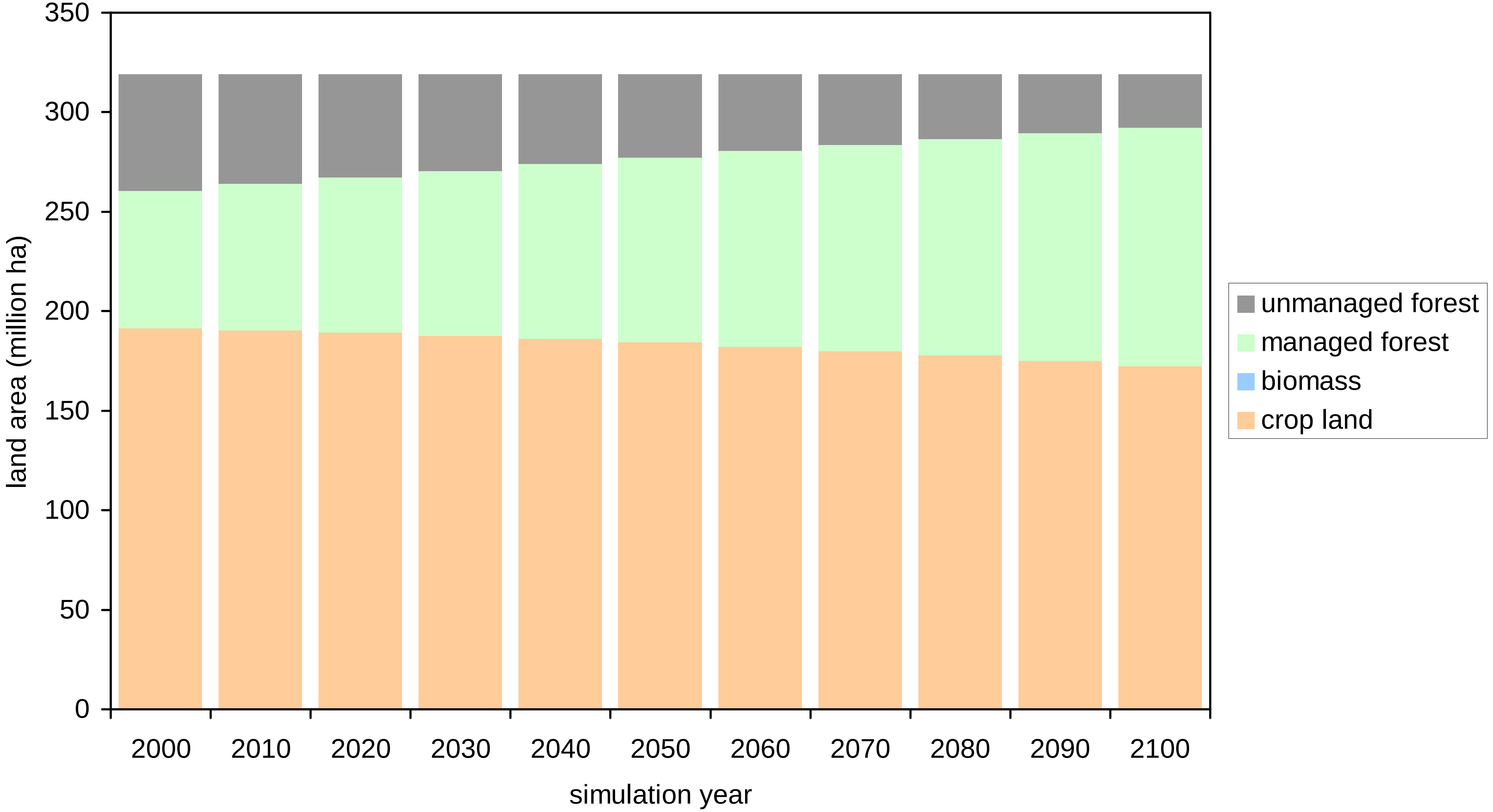
India Land Simulation with Agricultural Productivity Growing Slower than Population



India Land Simulation with Agricultural Productivity Same as Population Growth Rate



India Land Simulation with Agricultural Productivity Growing Faster than Population



What Next?

- Near Term
  - Alternative biofuel pathways
  - Enhancements to India model
    - Demand and supply of fuelwood
    - Land subregions
- Longer Term
  - International trade and food security
  - Valuing carbon in unmanaged land
  - Crop rotation and multiple crops per year
  - Water as a limiting resource