# Economic Analysis of Field Crops and Land Use with Climate Change

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# Introduction

- Explore link between climate impacts analysis and economic models.
- Summarize results from biophysical models and use them to change productivity parameters in an economic model.
- Economic model provides a baseline of agricultural production and consumption over one century.
- We use a partial equilibrium model of global agriculture and land use (AgLU model), but ultimately we want this capability in a computable general equilibrium model.
- What can we say about production, consumption, land use, and economic welfare (consumer and producer surplus) with climate change?

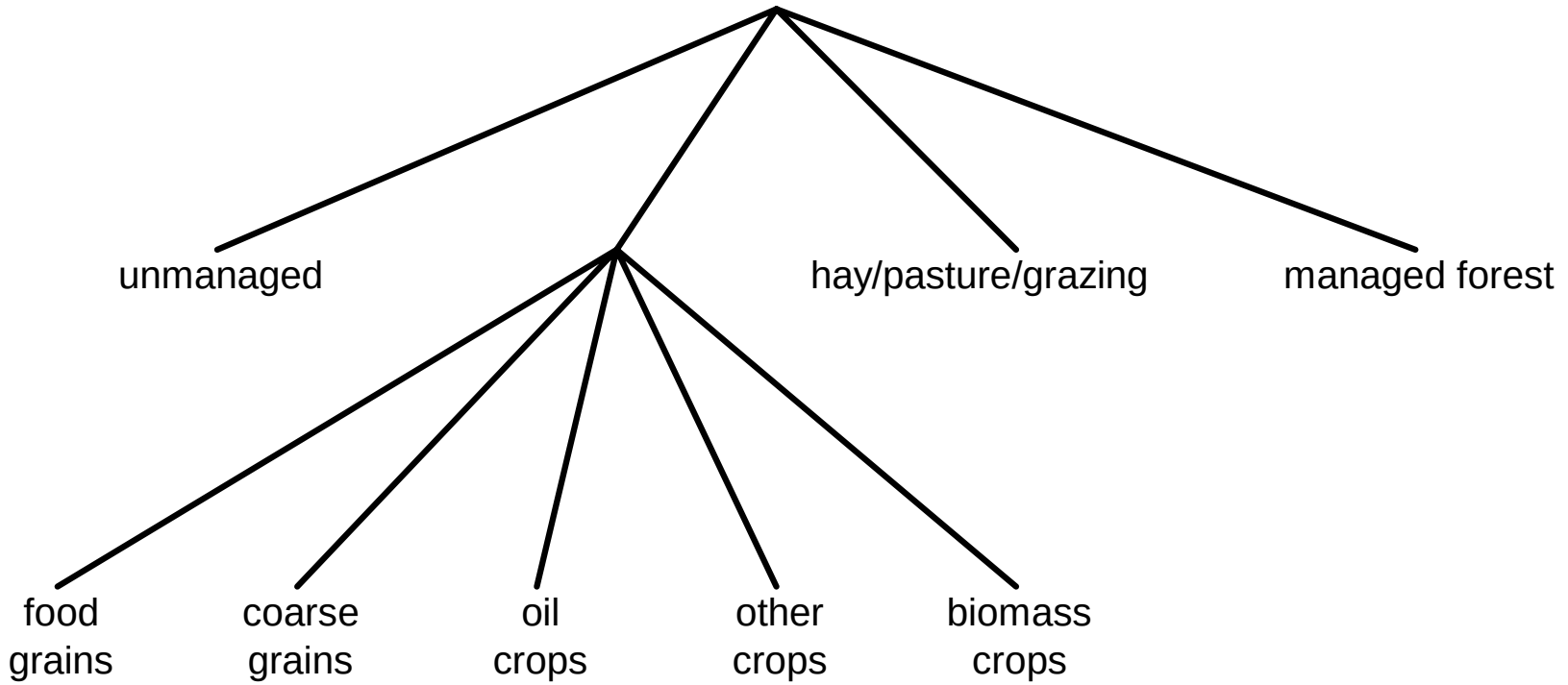
# Approach

- Select climate scenarios (3 climate models x 2 climate sensitivities x 2 levels of $CO_2$ fertilization).
- Run crop growth simulation model (EPIC) at 204 sites in U.S. for major field crops for each climate scenario.
- Run hydrology model (HUMUS) for 204 hydrologic unit areas (river basins).
- Run BIOME3 model to simulate climate impacts on forests.
- For each crop, aggregate yield change to national index using agricultural area as weights.
- Apply change in yield to economic production function in AgLU model. Compare to baseline in year 2080.
- Assumptions on change in yield in other countries
  - No change in yield outside U.S.
  - Global yield changes at same rate as in U.S.
- Summarize changes in land use, crop production, and consumer/producer welfare.

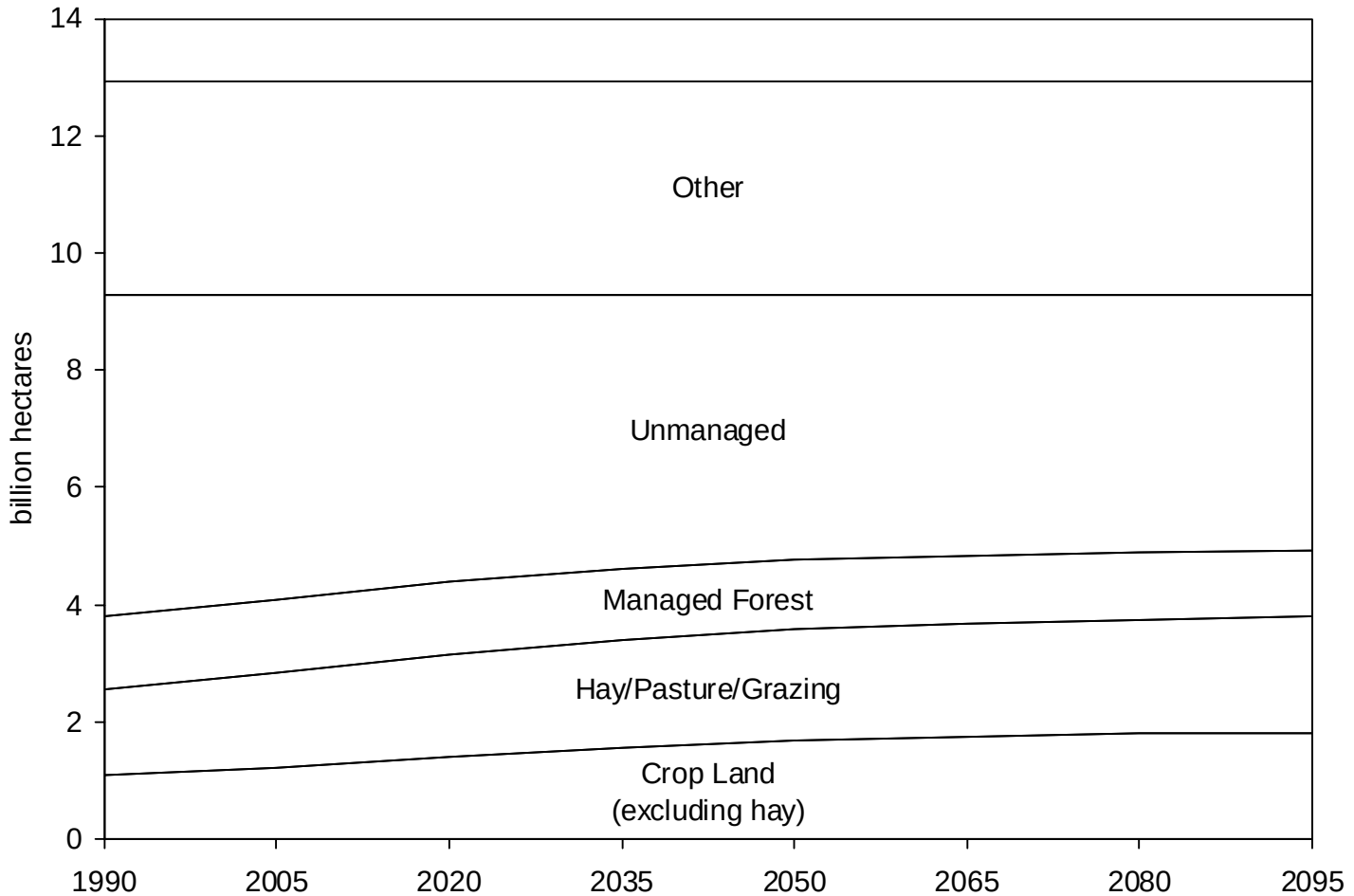
# Agriculture and Land Use Model

- First version completed in 1996
- Design
  - Top down
  - Partial equilibrium
  - 14 world regions
  - 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
- Studies
  - Role of biomass in carbon policy
  - Impact of ENSO on North America
  - U.S. climate impacts

# AgLU Land Allocation

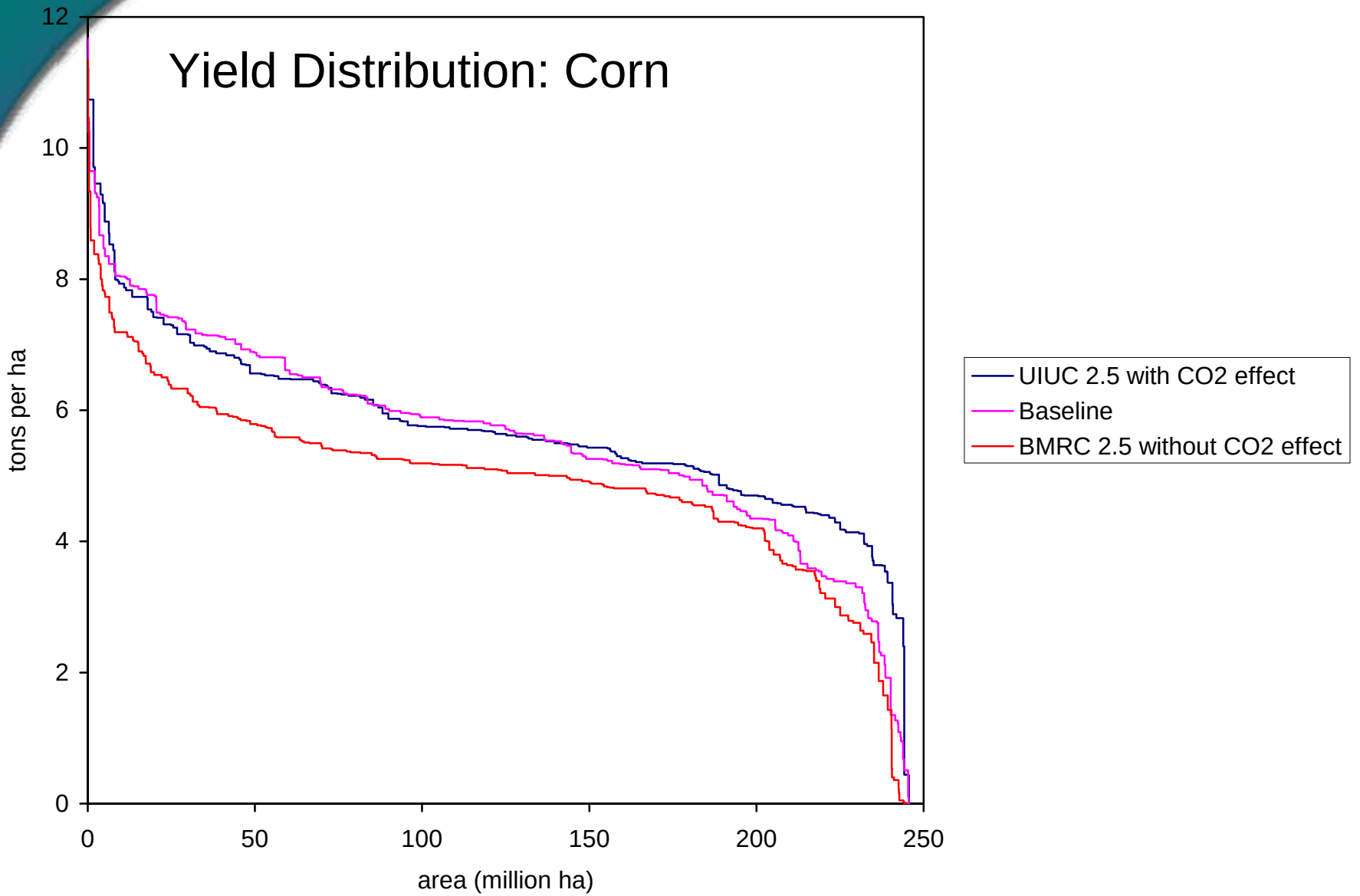


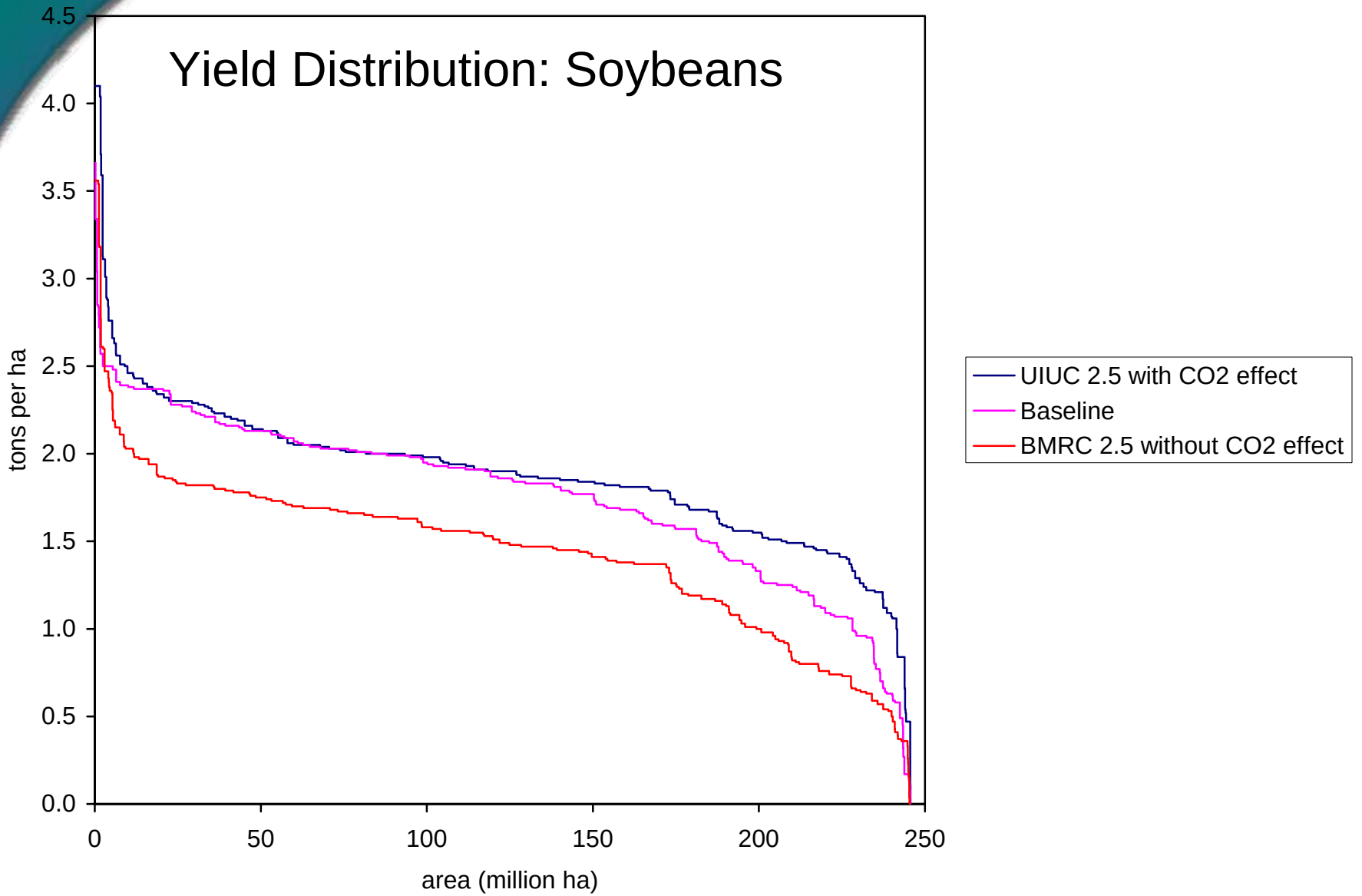
# Baseline Global Land Use

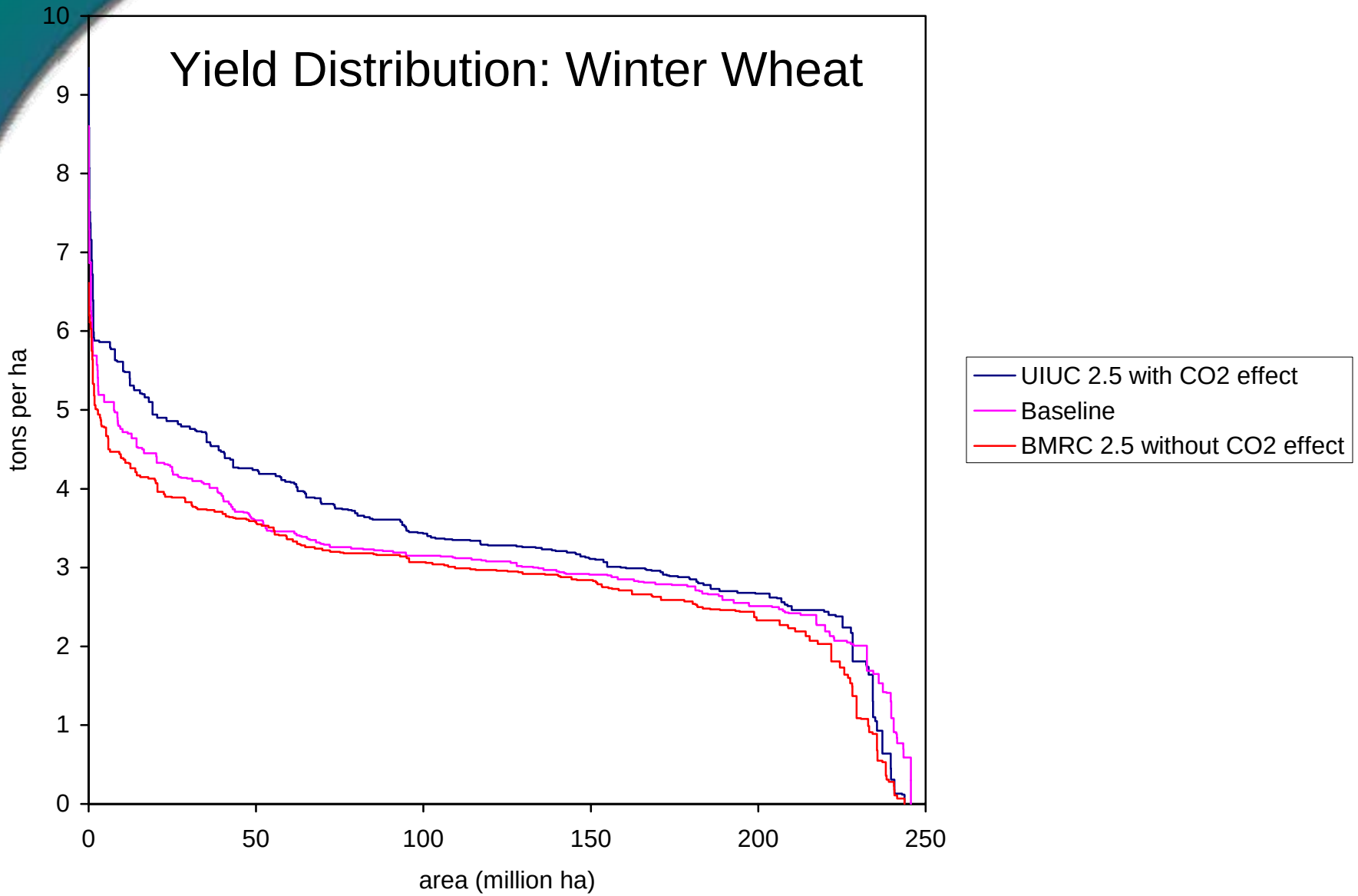


# Simulated EPIC Yield with Restricted Irrigation (tons per hectare)

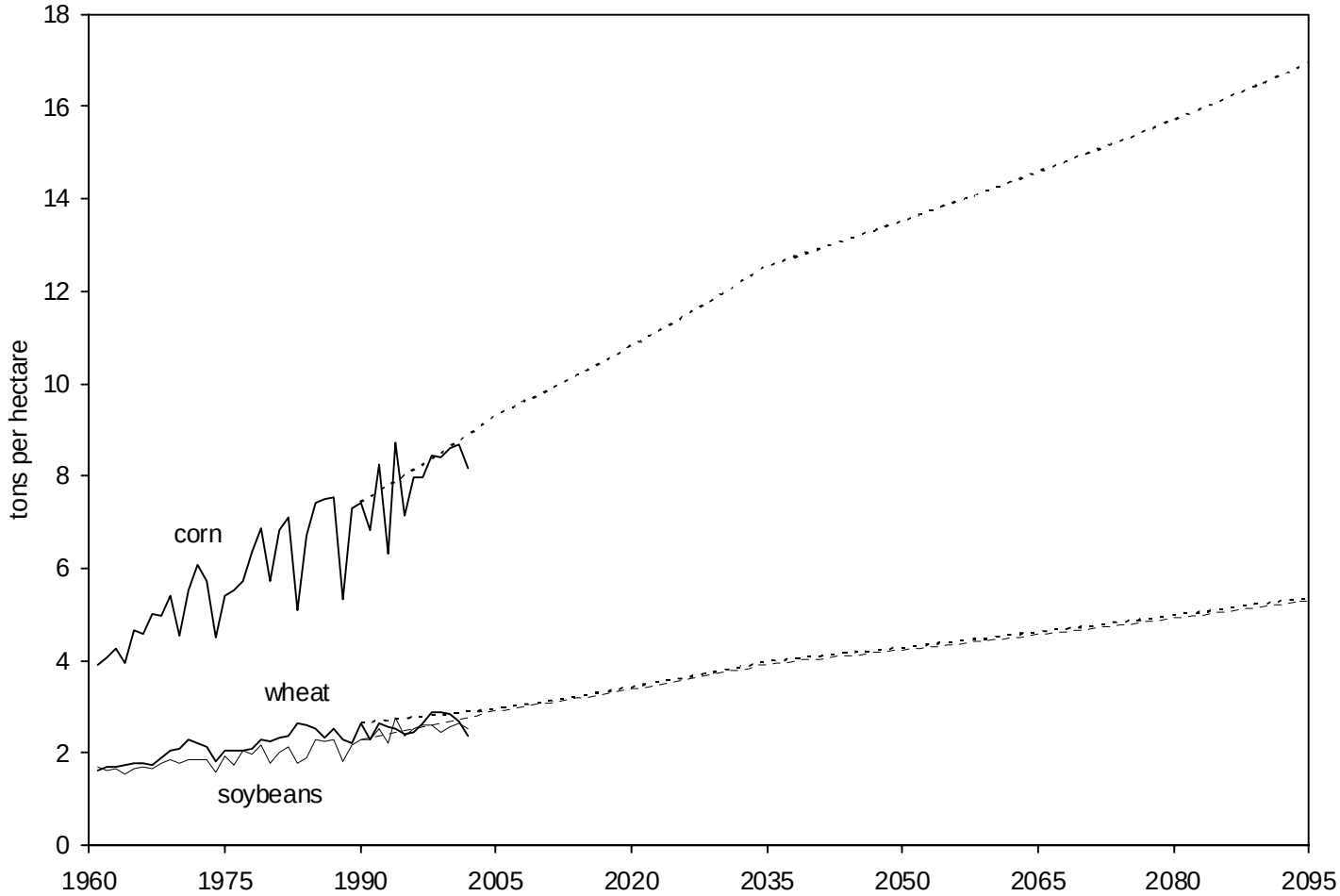
| Scenario | Corn | Soybeans | Winter Wheat |
|---|---|---|---|
| Baseline | 5.61 | 1.77 | 3.11 |
| without $CO_2$ effect | | | |
| BMRC 1.0 | 5.49 | 1.67 | 3.02 |
| BMRC 2.5 | 4.95 | 1.44 | 2.90 |
| UIUC 1.0 | 5.57 | 1.74 | 3.02 |
| UIUC 2.5 | 5.35 | 1.61 | 2.88 |
| UIUC 1.0 + sulfates | 5.54 | 1.73 | 3.00 |
| UIUC 2.5 + sulfates | 5.30 | 1.60 | 2.84 |
| with $CO_2$ effect | | | |
| BMRC 1.0 | 5.92 | 1.99 | 3.58 |
| BMRC 2.5 | 5.43 | 1.71 | 3.45 |
| UIUC 1.0 | 6.02 | 2.05 | 3.58 |
| UIUC 2.5 | 5.75 | 1.89 | 3.40 |
| UIUC 1.0 + sulfates | 5.99 | 2.04 | 3.56 |
| UIUC 2.5 + sulfates | 5.71 | 1.88 | 3.35 |


Yield Distribution: Corn
tons per ha
area (million ha)
0
2
4
6
8
10
12
0
50
100
150
200
250
UIUC 2.5 with CO2 effect
Baseline
BMRC 2.5 without CO2 effect


Yield Distribution: Soybeans
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
tons per ha
0
50
100
150
200
250
area (million ha)
UIUC 2.5 with CO2 effect
Baseline
BMRC 2.5 without CO2 effect


Yield Distribution: Winter Wheat
tons per ha
area (million ha)
0
1
2
3
4
5
6
7
8
9
10
0
50
100
150
200
250
UIUC 2.5 with CO2 effect
Baseline
BMRC 2.5 without CO2 effect

# Historical Crop Yields in the United States (solid lines) and Future Projections



# Yield Patterns Relative to Baseline

| AgLU sector | Biophysical model | BMRC 2.5 °C no $CO_2$ effect | UIUC 2.5 °C no $CO_2$ effect | UIUC 2.5 °C with $CO_2$ effect |
|---|---|---|---|---|
| Food grains | EPIC winter wheat | -6.8% | -7.6% | 10.8% |
| Coarse grains | EPIC corn | -11.7% | -4.6% | 2.5% |
| Oil crops | EPIC soybeans | -18.7% | -8.9% | 6.9% |
| Miscellaneous crops | none | | | |
| Pasture | EPIC hay | -16.1% | -7.0% | 7.7% |
| Forests | BIOME3 | -85.3% | -1.4% | 42.9% |
| Commercial biomass | EPIC hay | -16.1% | -7.0% | 7.7% |

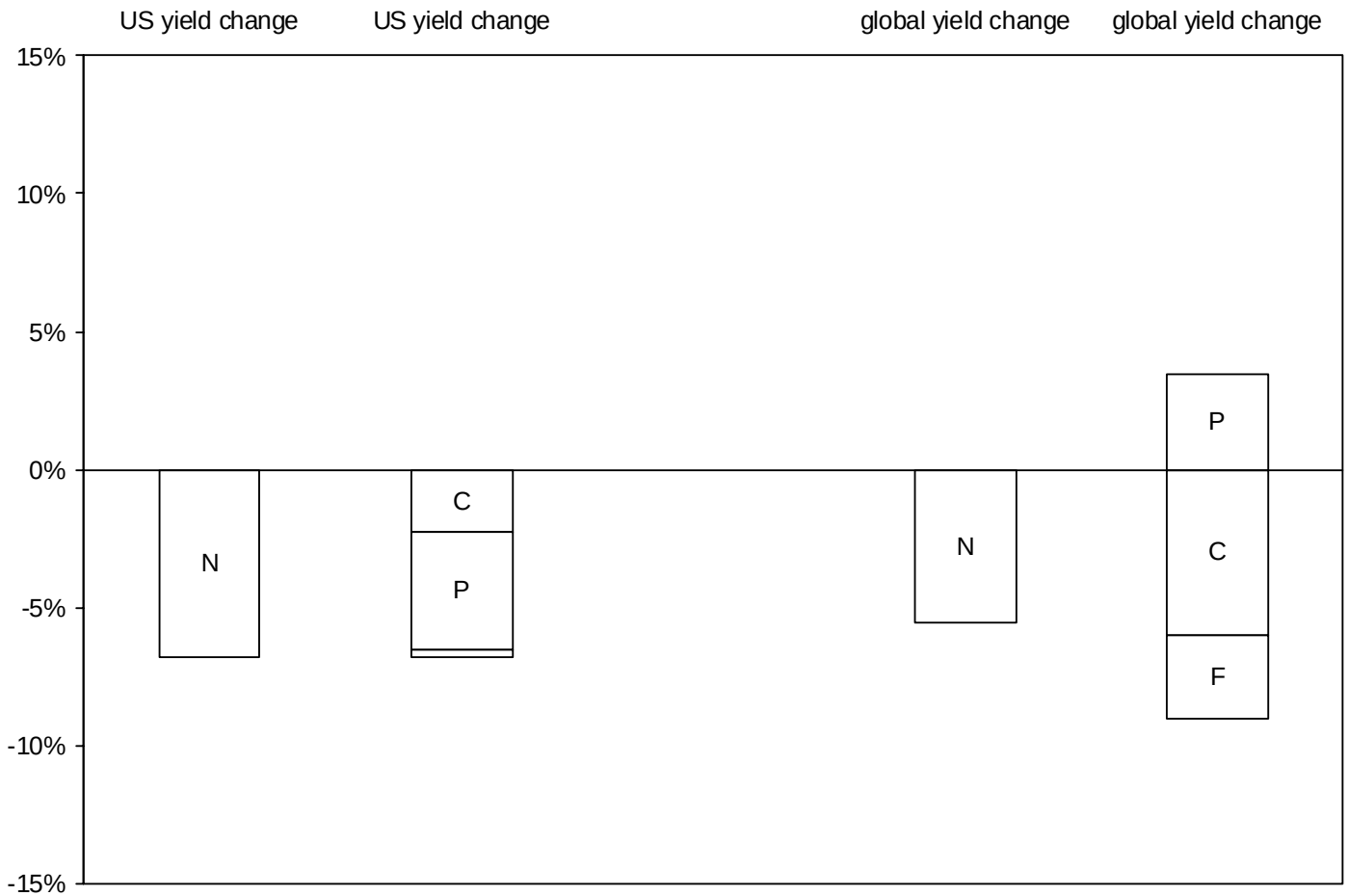
# Economic Welfare

- Net output
  - Essentially GDP from the agricultural and forestry sector.
  - Quantity index of output less the fraction used as inputs to other agricultural activities (e.g., crops used as animal feed).
  - Can be calculated in a partial equilibrium framework by placing agricultural and forestry sector in an input-output framework.
- Change in net output
  - Measure of change in total welfare
  - Difference between net output in baseline and climate scenario
  - Can be partitioned into components for producers and consumers.

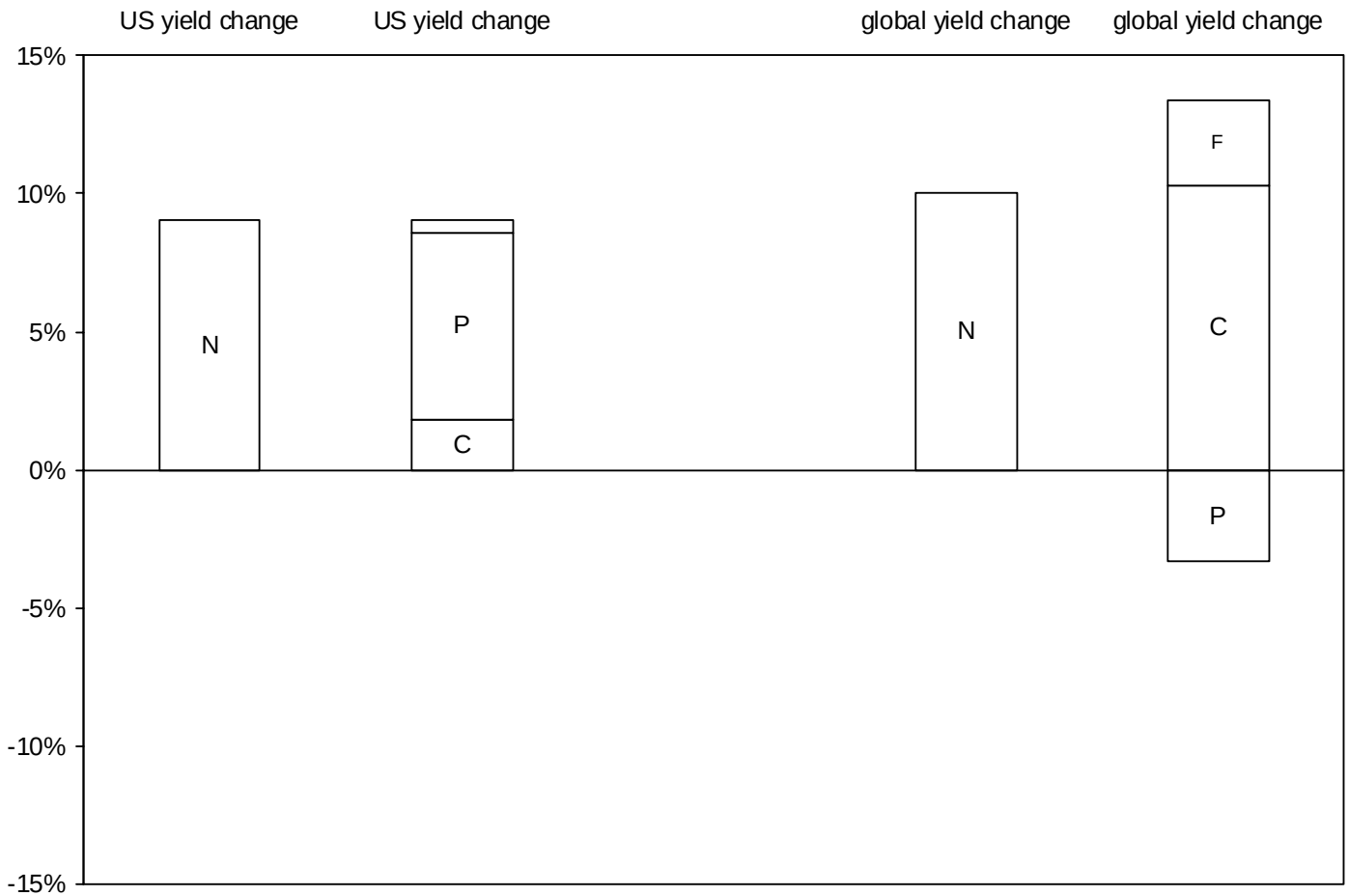
# Changes in U.S. Consumption and Net Output Relative to Baseline in 2080

| Scenario | change in consumption | change in net output | components of change in net output | | |
|---|---|---|---|---|---|
| | | | consumer | producer | trade |
| without $CO_2$ effect | | | | | |
| BMRC 2.5 | -1.0% | -16.6% | -4.3% | -12.1% | -0.2% |
| UIUC 2.5 | -0.4% | -6.8% | -2.3% | -4.2% | -0.3% |
| UIUC 2.5 + sulfates | -0.5% | -7.3% | -2.5% | -4.5% | -0.3% |
| with $CO_2$ effect | | | | | |
| BMRC 2.5 | 0.0% | -2.5% | 0.4% | -3.2% | 0.3% |
| UIUC 2.5 | 0.4% | 9.0% | 1.8% | 6.8% | 0.4% |
| UIUC 2.5 + sulfates | 0.4% | 8.0% | 1.9% | 5.8% | 0.2% |

# Change in U.S. Net Output (N)
# UIUC (2.5 ºC) *without* $CO_2$ Effect



# Change in U.S. Net Output (N)
# UIUC (2.5 ºC) *with* $CO_2$ Effect



# United States Summary by Sensitivity Scenario

| Scenario | Simulation Year | Total U.S. Crops Production (Pcal) | Total U.S. Crops Land Use (million ha) | U.S. Land Rent (1990 = 100) |
|---|---|---|---|---|
| Baseline | 1990 | 1,143 | 99.0 | 100 |
| Baseline | 2080 | 2,770 | 157.8 | 123 |
| Change in U.S. yields | | | | |
| UIUC 2.5 without CO2 effect | 2080 | 2,645 | 151.8 | 120 |
| UIUC 2.5 with CO2 effect | 2080 | 2,717 | 143.0 | 137 |
| U.S. yield change applied globally | | | | |
| UIUC 2.5 without CO2 effect | 2080 | 2,942 | 178.4 | 125 |
| UIUC 2.5 with CO2 effect | 2080 | 2,605 | 144.8 | 119 |

# Conclusions

- Uncertainties
  - Climate scenarios
  - $CO_2$ fertilization effect
  - Crop productivity growth in baseline
  - Climate impacts in other countries
- Welfare
  - Net output is a quantity index that combines effects of yield change across crops.
  - Change in net output represents overall change in welfare; it can be decomposed into changes in consumer and producer welfare.
  - Consumer welfare generally moves in same direction as net output.
  - Producer welfare is tied to the price of land; it can move in either direction depending on what happens to crop yield in other countries.