Modeling Agriculture and Land Use: Climate Impacts

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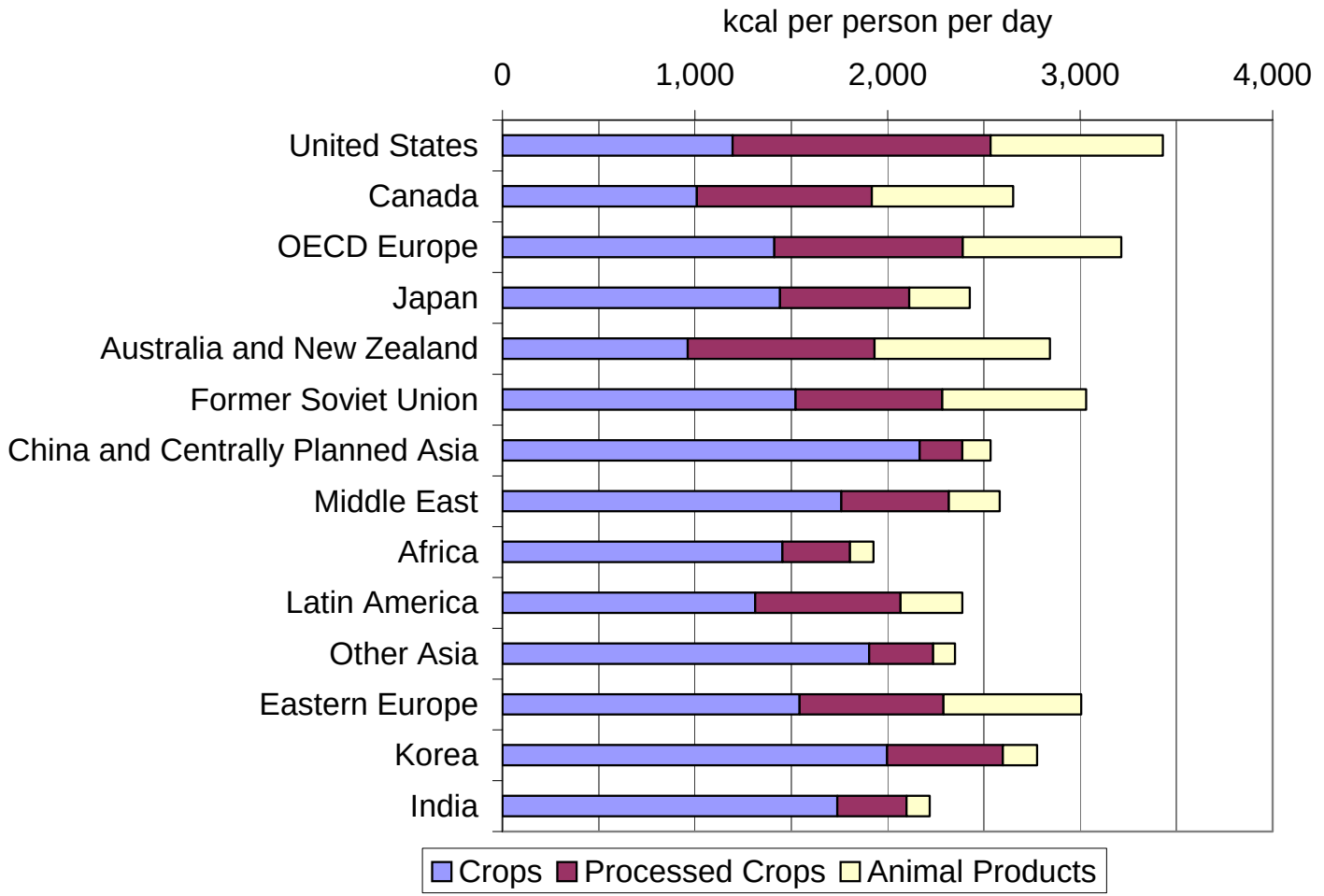
Joint Global Change Research Institute
Pacific Northwest National Laboratory and University of Maryland

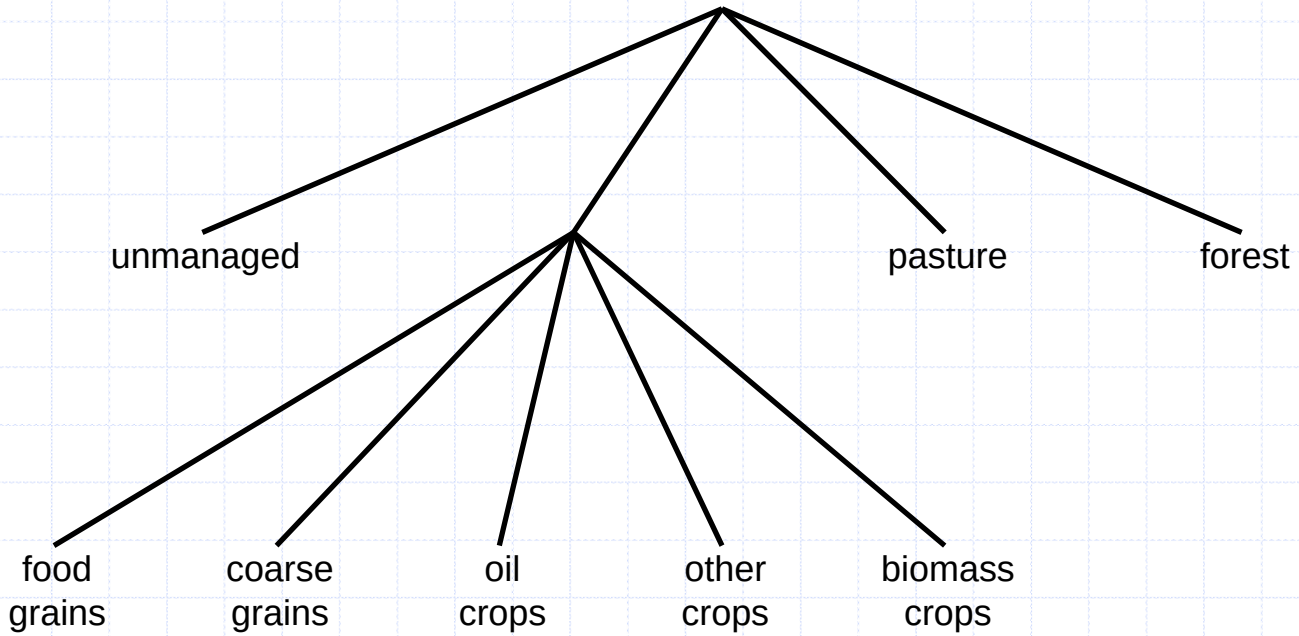
Overview

- Objective
  - Link Economic Model with Output from Crop and Forest Productivity Models
  - Response of Agricultural Production and Land Use to Climate Change
- Background on PNNL Agriculture and Land-Use Model (AgLU)
  - Demand for food
  - Land Use Decision
- Sensitivity on Global Crop Yields
- EPIC and BIOME simulations for United States

Food Consumption by AgLU Region



AgLU Land Allocation



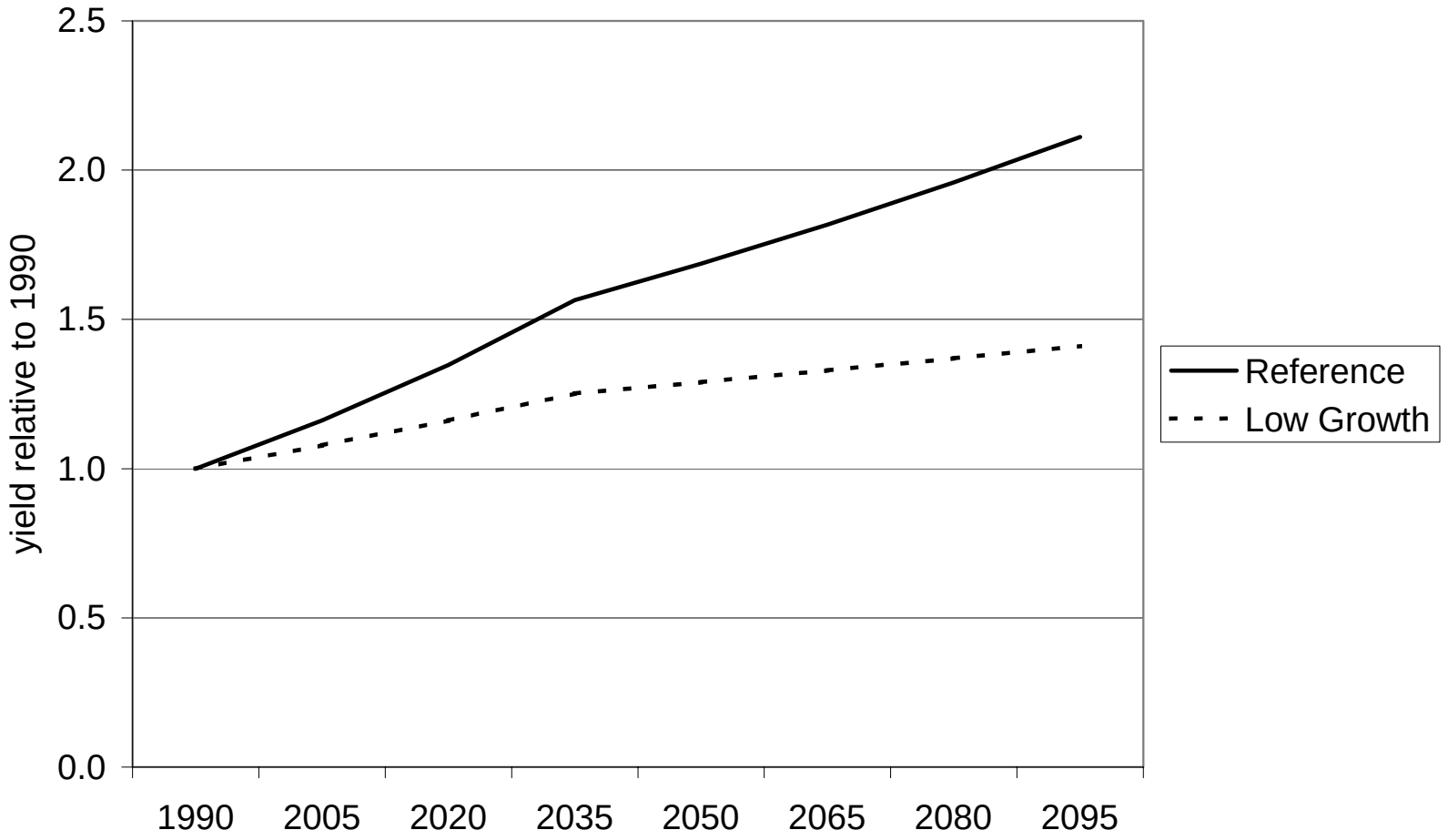
Calculation of Land Shares

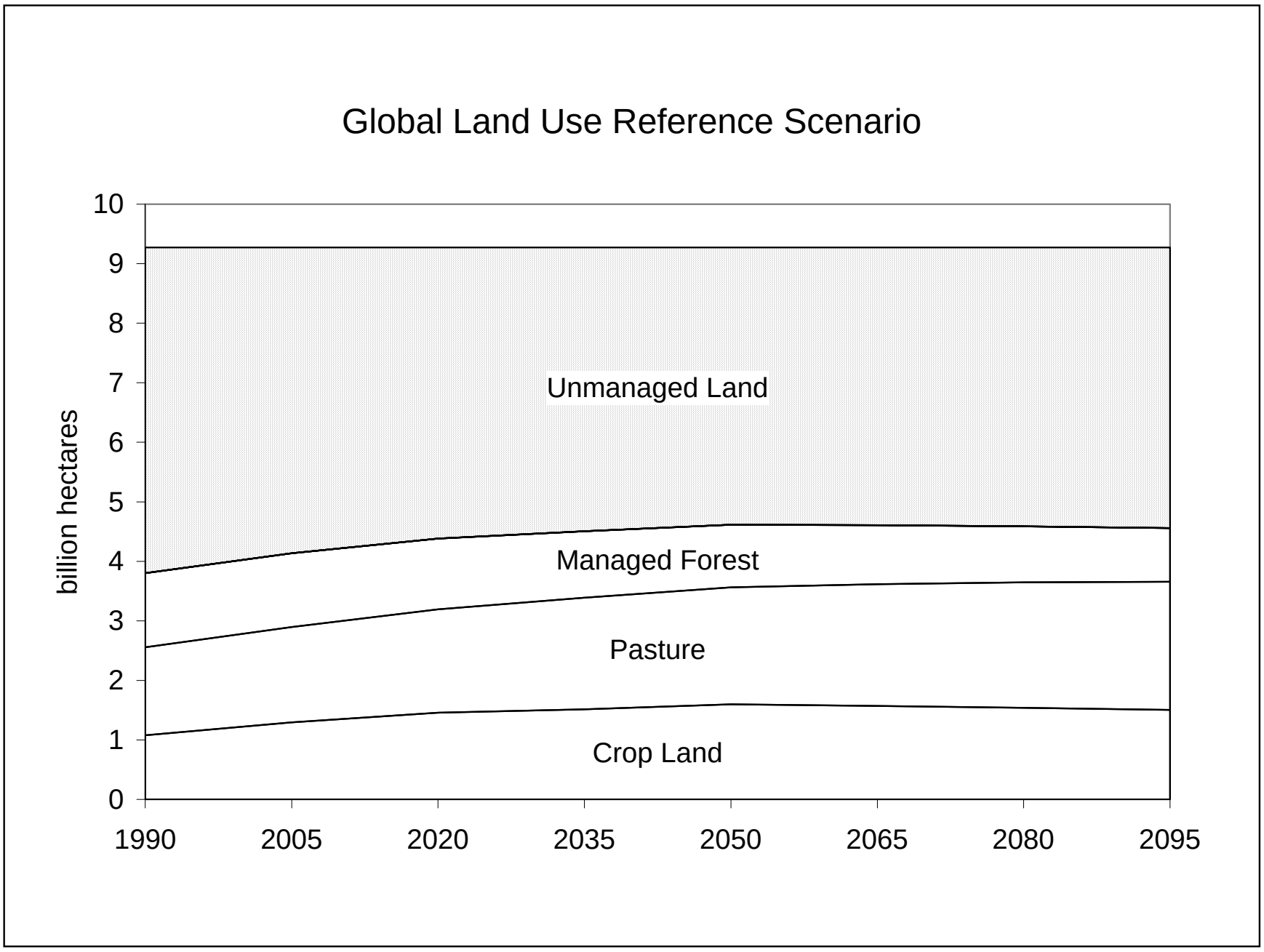
$$s_i = \frac{\bar{\pi}_i^{1/\lambda}}{\sum_k \bar{\pi}_k^{1/\lambda}}$$

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

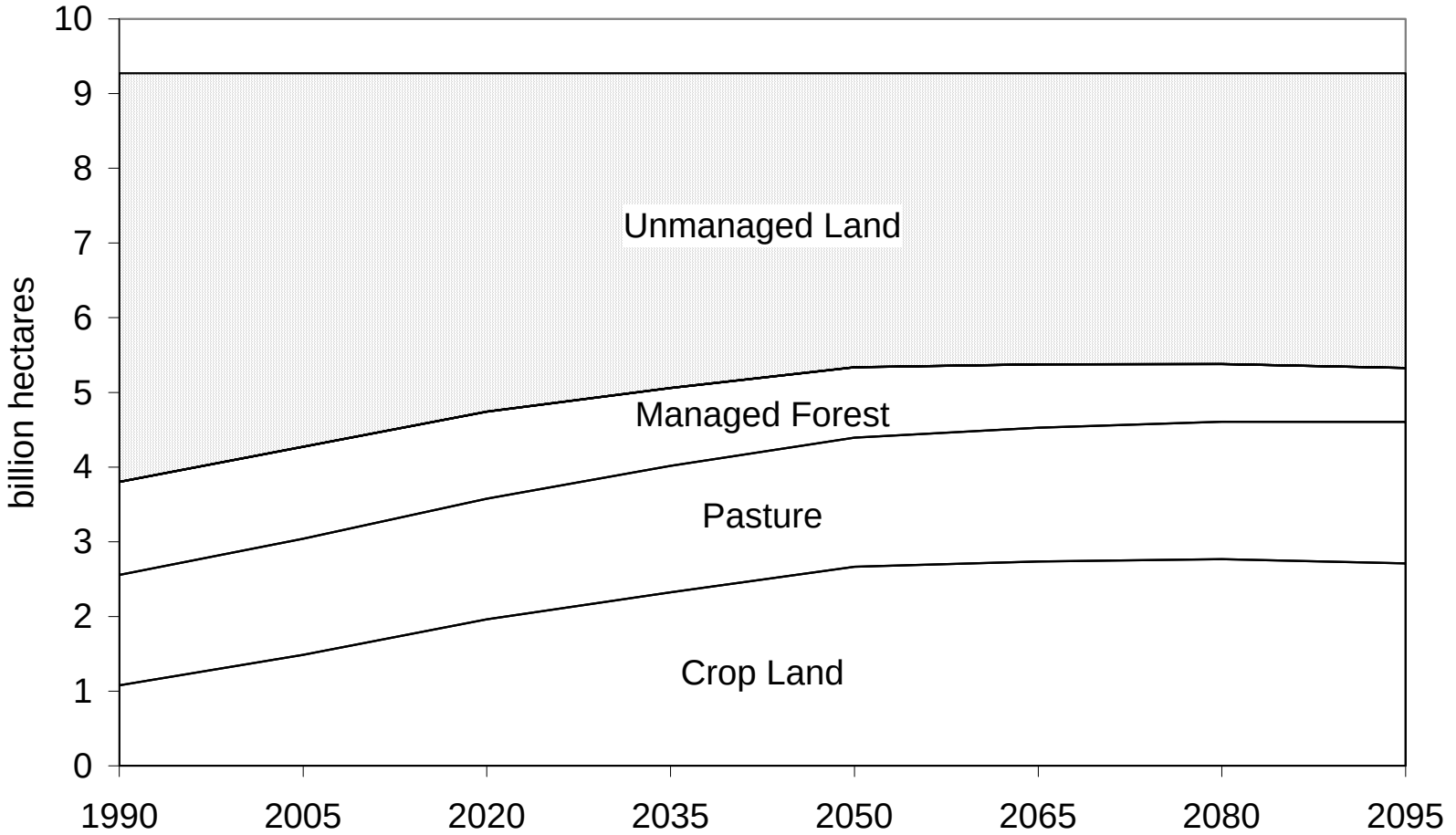
$$\bar{\pi}_i = \bar{y}_i \left(P_i - G_i \right)$$

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

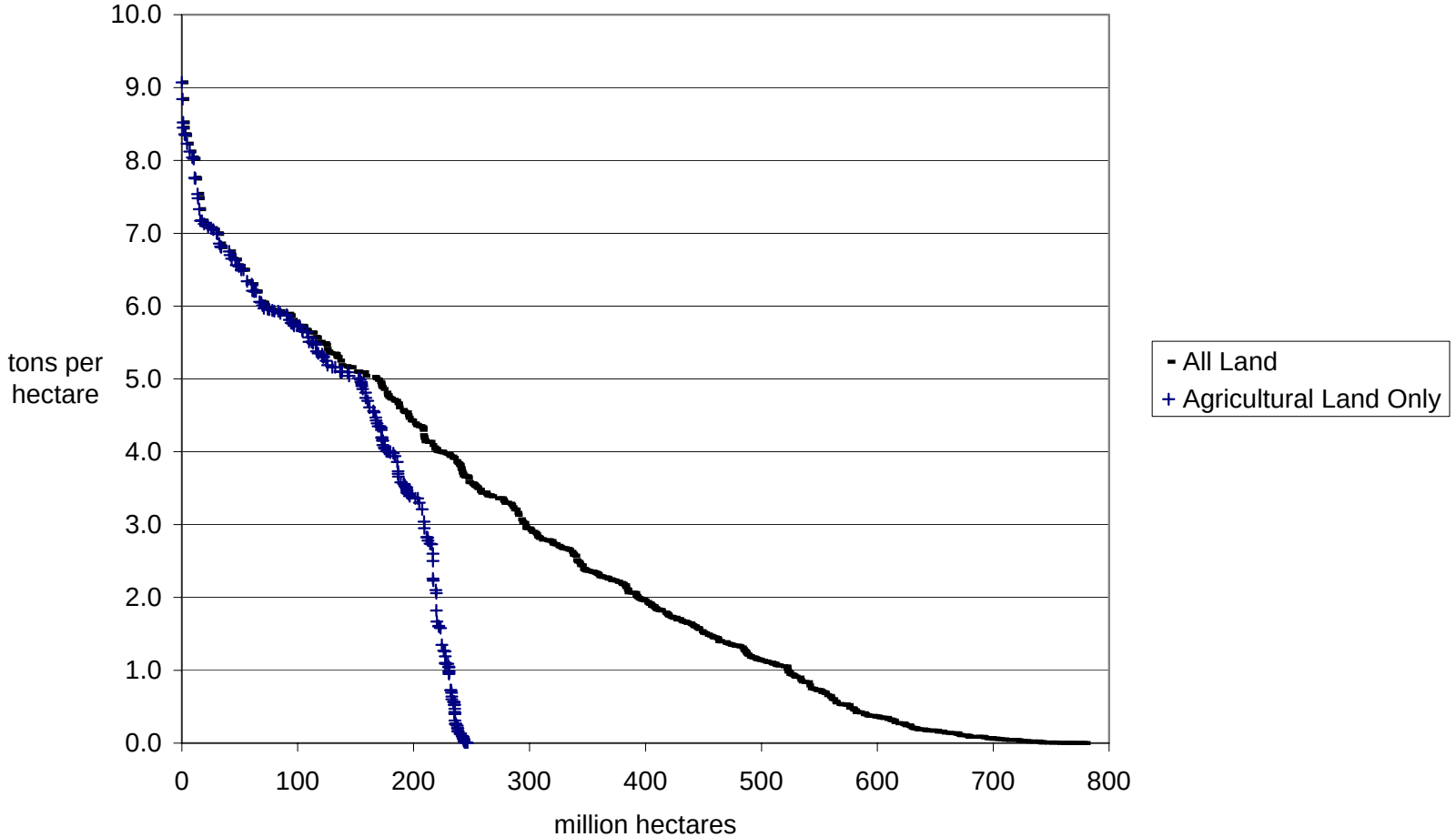

Growth in Global Average Crop Yields
yield relative to 1990
2.5
2.0
1.5
1.0
0.5
0.0
1990
2005
2020
2035
2050
2065
2080
2095
Reference
Low Growth


Global Land Use Reference Scenario
billion hectares
10
9
8
7
6
5
4
3
2
1
0
Unmanaged Land
Managed Forest
Pasture
Crop Land
1990
2005
2020
2035
2050
2065
2080
2095

Global Land Use: Reduced Growth in Crop Yields

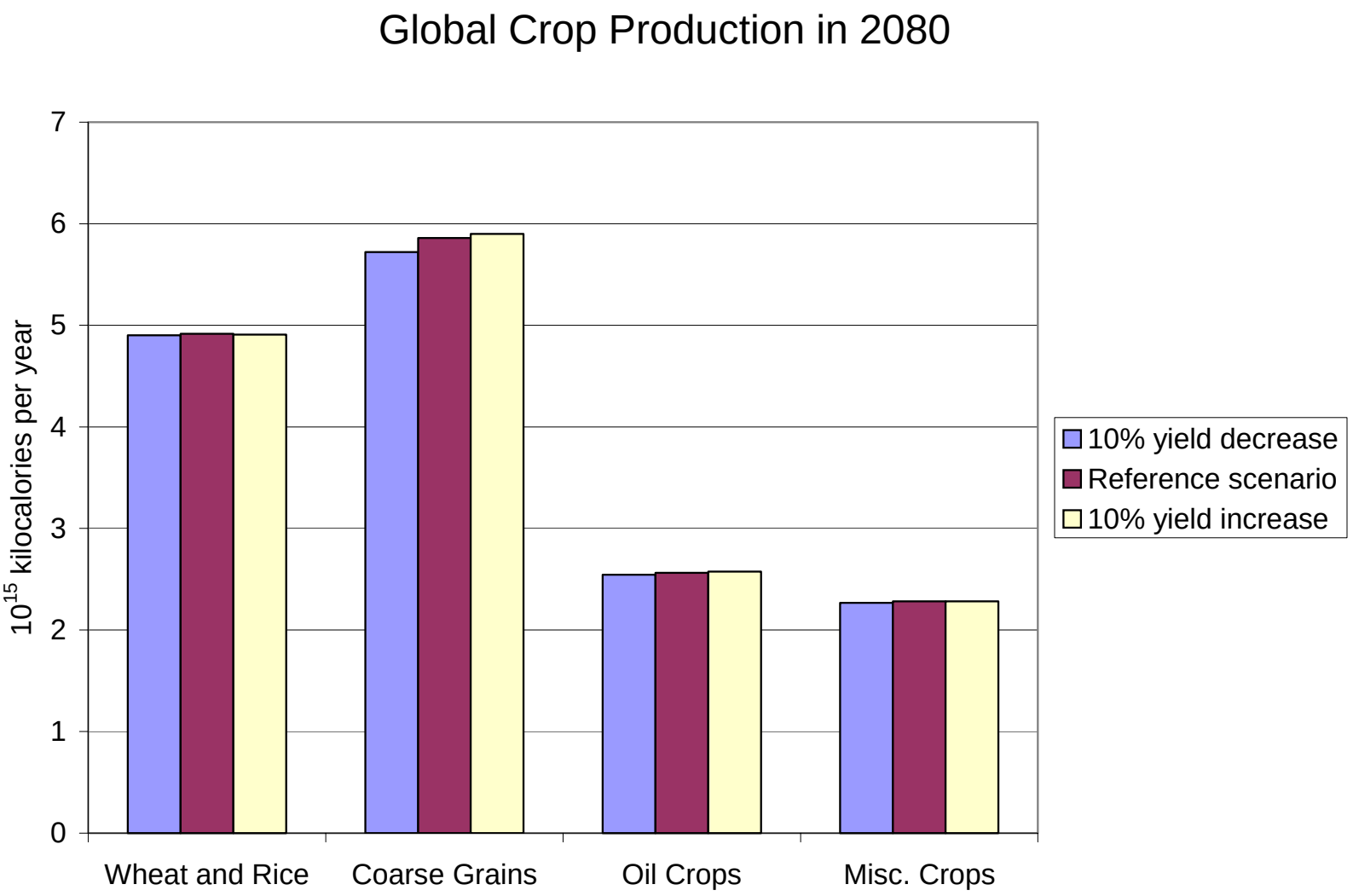


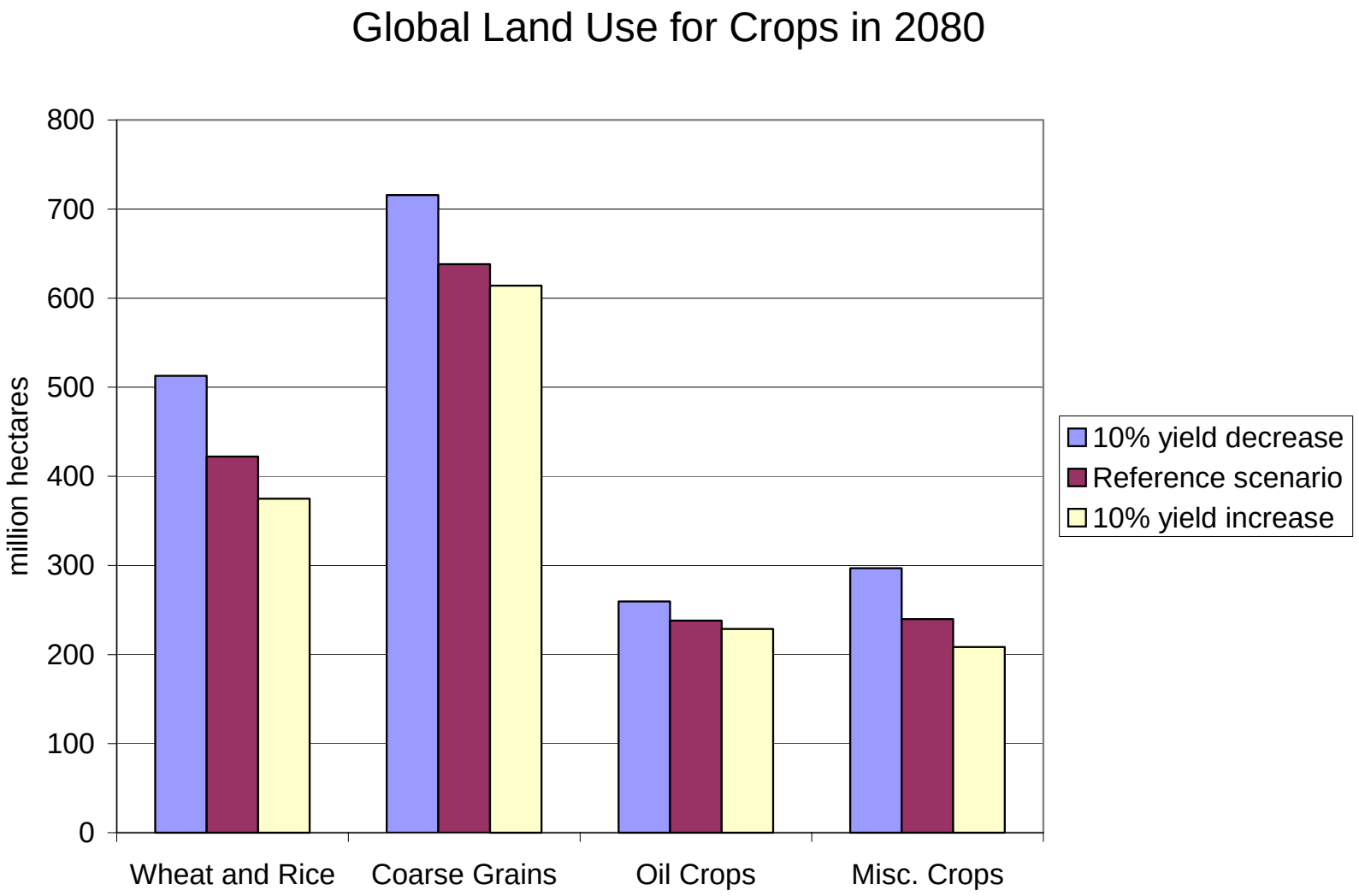
Full-Out Corn Production (United States)



Global Sensitivity Analysis

- Global Change in Crop Yields
  - +10% by 2080
  - Reference Growth Rate
  - -10% by 2080
- Global Crop Production
- Global Land Use for Crops


Global Crop Production in 2080
7
6
5
4
3
2
1
0
10^{15} kilocalories per year
Wheat and Rice
Coarse Grains
Oil Crops
Misc. Crops
10% yield decrease
Reference scenario
10% yield increase


Global Land Use for Crops in 2080
800
700
600
500
400
300
200
100
0
million hectares
Wheat and Rice
Coarse Grains
Oil Crops
Misc. Crops
10% yield decrease
Reference scenario
10% yield increase

Impacts on Crop Yield

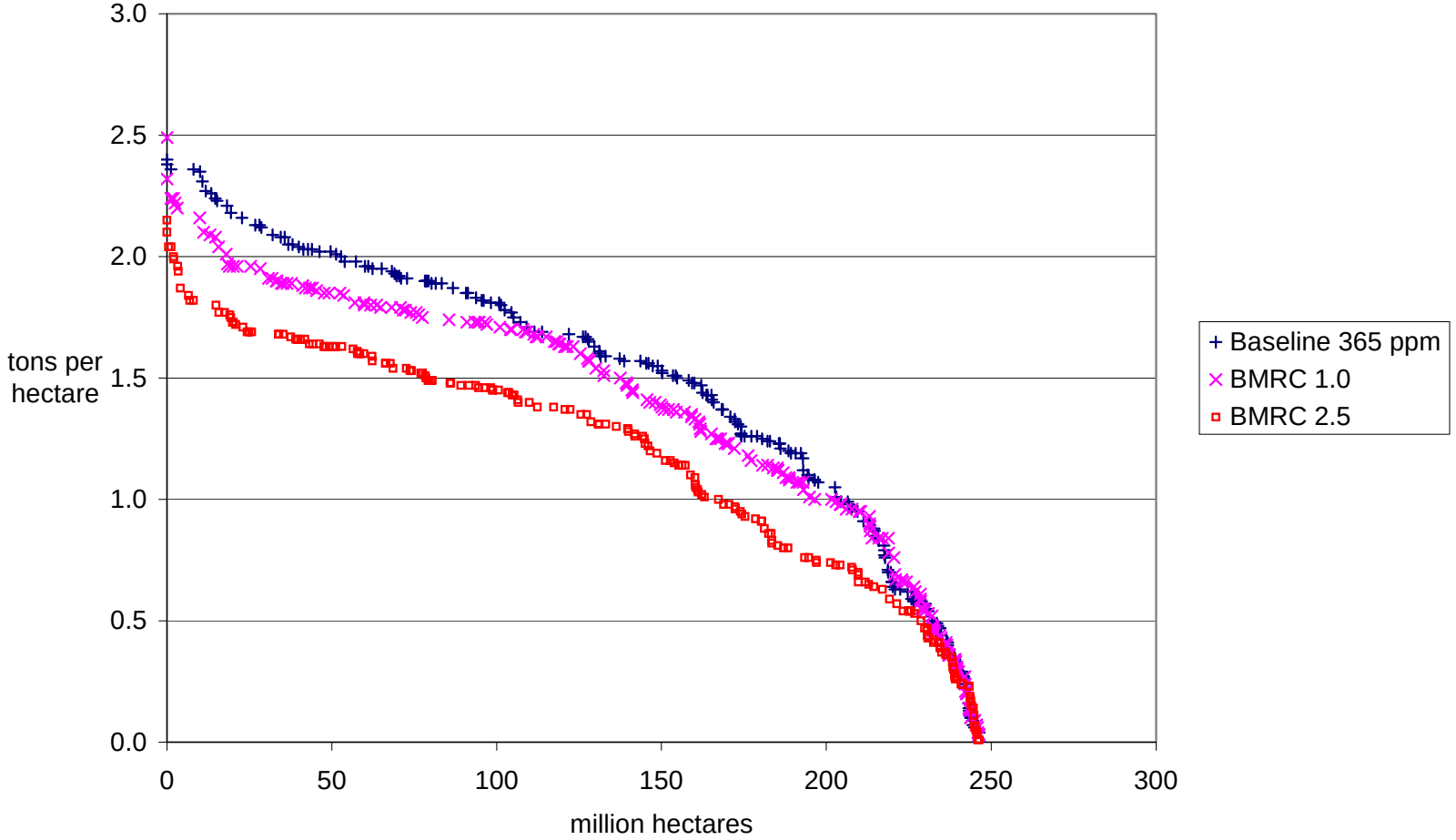
- Climate Scenarios
  - CO_2 at 365 ppmv and 560 ppmv
  - GCMs: UIUC, UIUC+sulfates, BMRC
  - Climate Sensitivity: 1.0 ° C and 2.5 ° C
- EPIC crop growth model to represent managed crops
- BIOME to represent forest, pasture, and biomass productivity

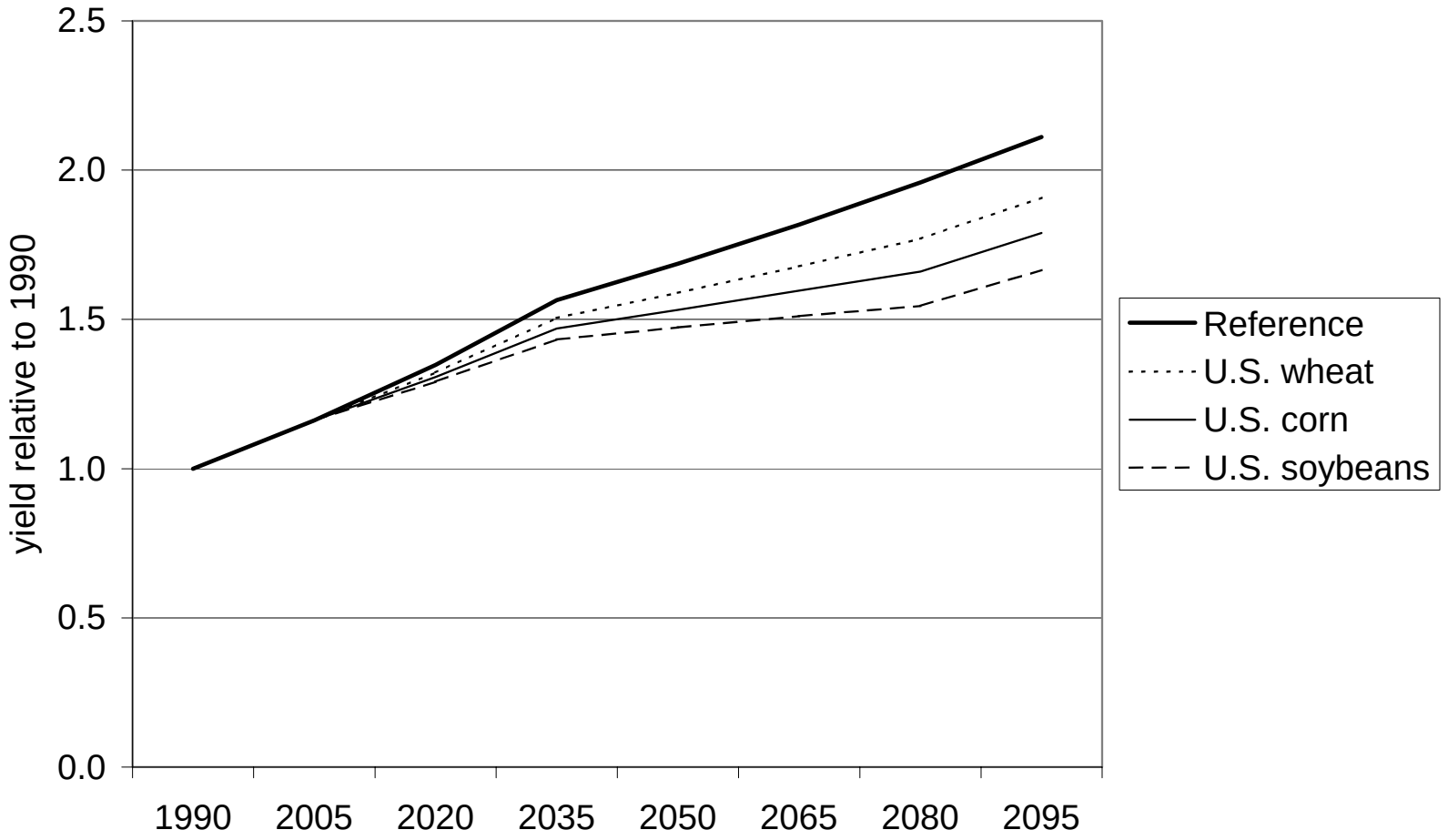
Soybean Yields (tons per ha)

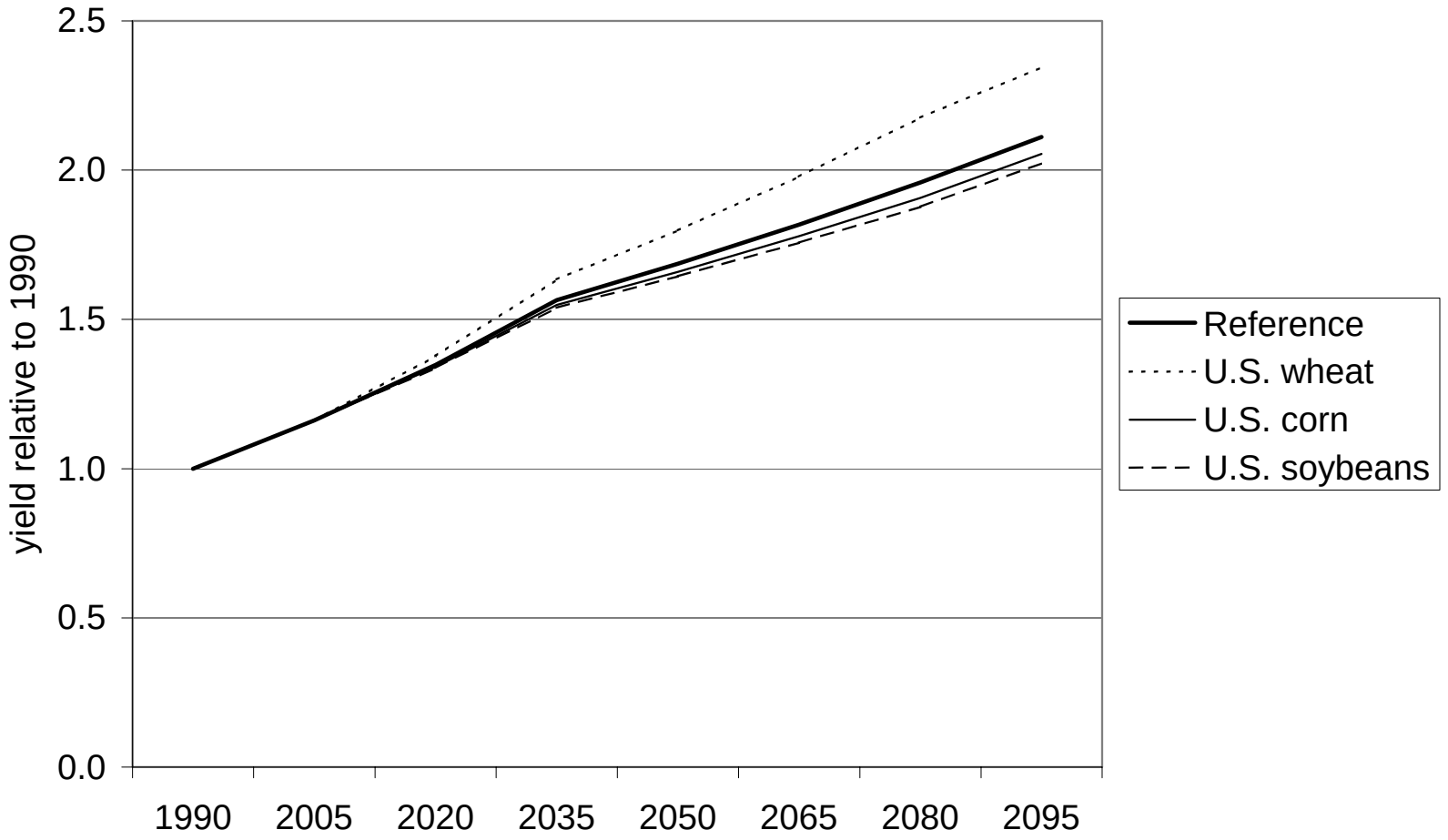
	dryland		irrigated	
	365 ppmv	560 ppmv	365 ppmv	560 ppmv
Baseline	1.56	1.88	1.87	2.17
BMRC 1.0	1.45	1.76	1.80	2.10
BMRC 2.5	1.23	1.49	1.58	1.85
UIUC 1.0	1.53	1.84	1.80	2.09
UIUC 2.5	1.44	1.72	1.63	1.90
UIUC 1.0 + sulfates	1.53	1.84	1.80	2.09
UIUC 2.5 + sulfates	1.47	1.77	1.68	1.95

Yields are an average across 204 hydrologic unit areas in the United States, with agricultural land used as weights.

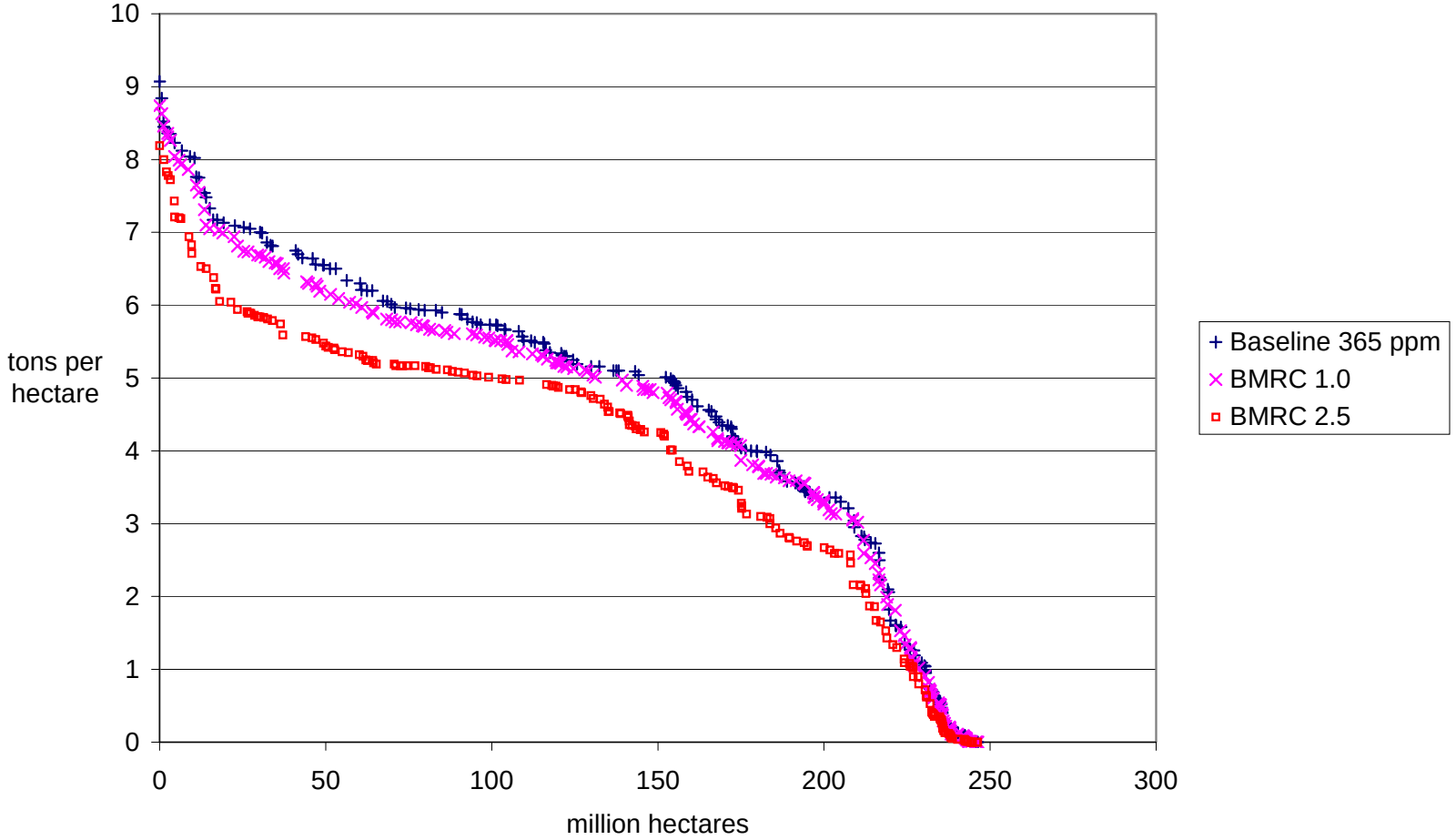
Soybean Yield (USA)



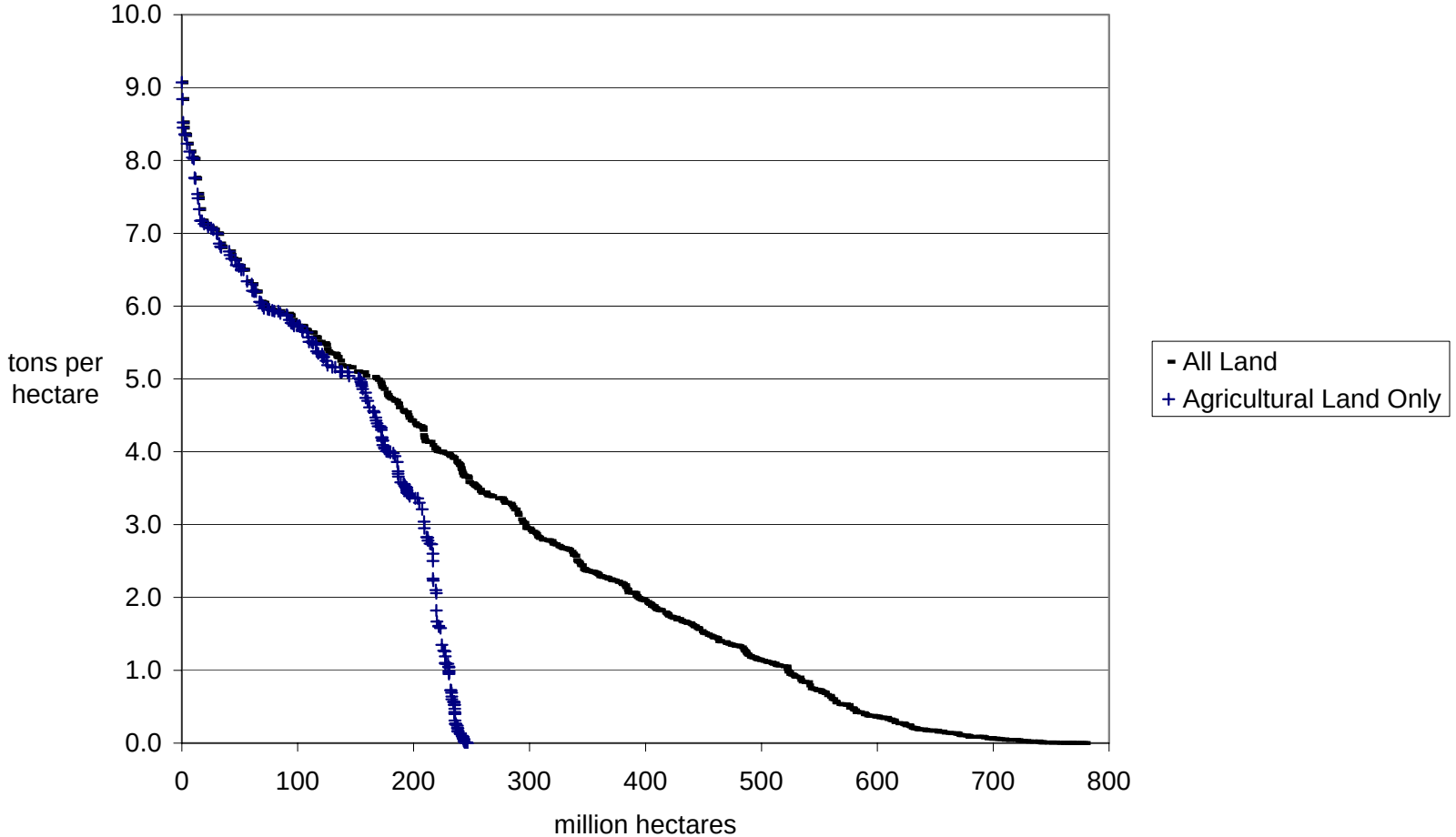

U.S. Crop Yields (BMRC 2.5; 365 ppm)
yield relative to 1990
2.5
2.0
1.5
1.0
0.5
0.0
1990
2005
2020
2035
2050
2065
2080
2095
Reference
U.S. wheat
U.S. corn
U.S. soybeans


U.S. Crop Yields (BMRC 2.5; 560 ppm)
yield relative to 1990
2.5
2.0
1.5
1.0
0.5
0.0
1990
2005
2020
2035
2050
2065
2080
2095
Reference
U.S. wheat
U.S. corn
U.S. soybeans

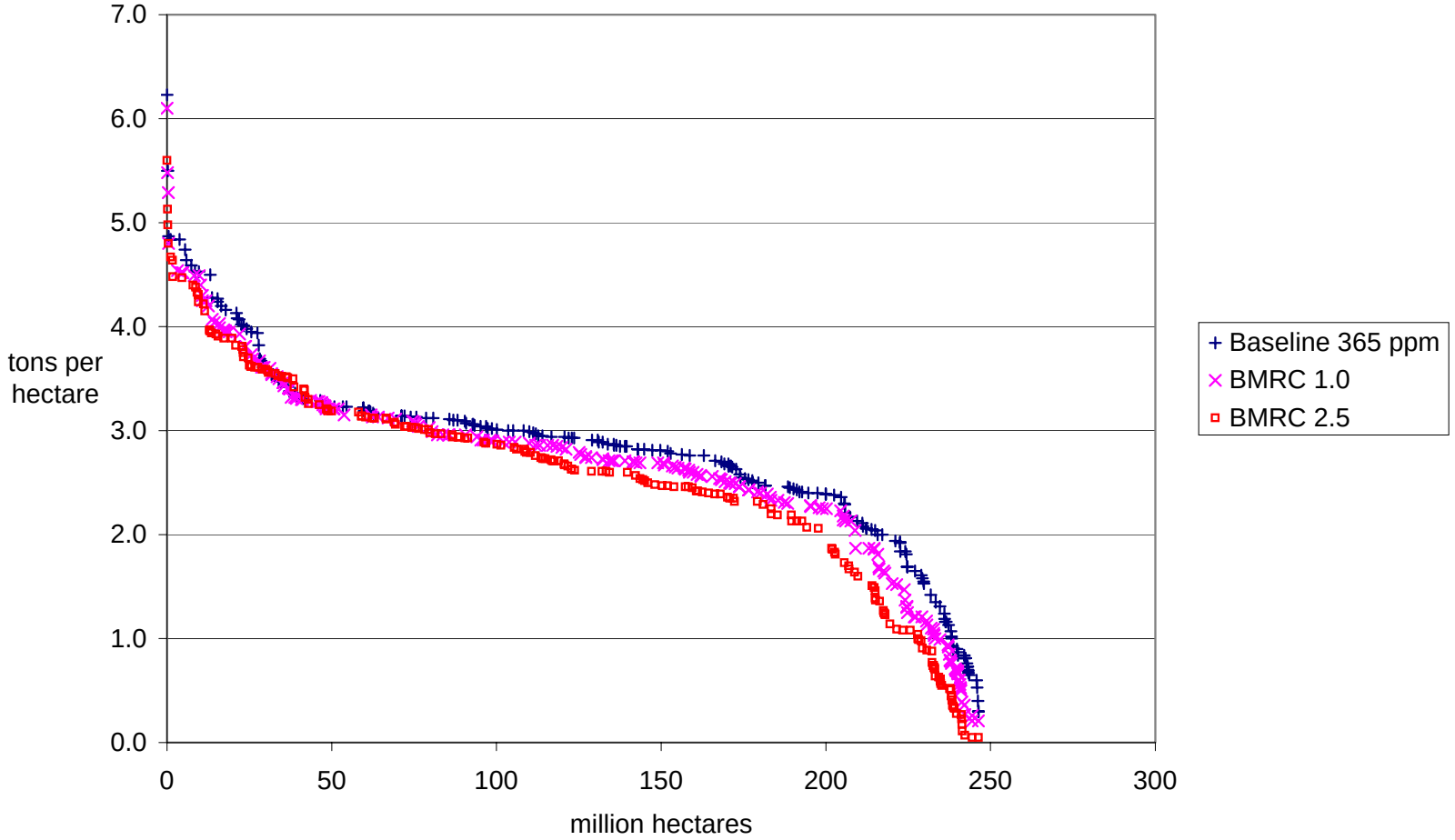
Corn Yield (USA)



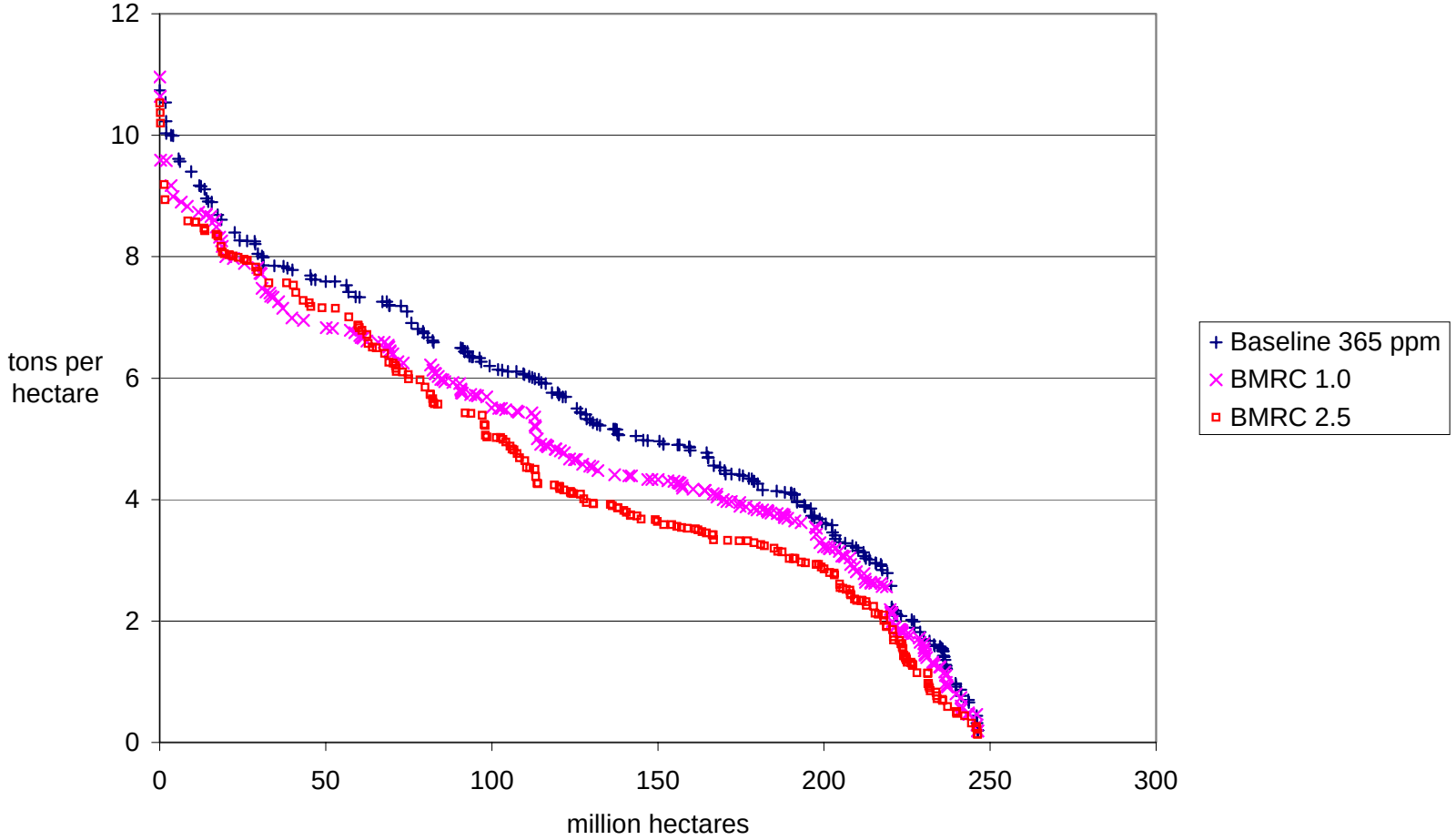
Full-Out Corn Production (United States)



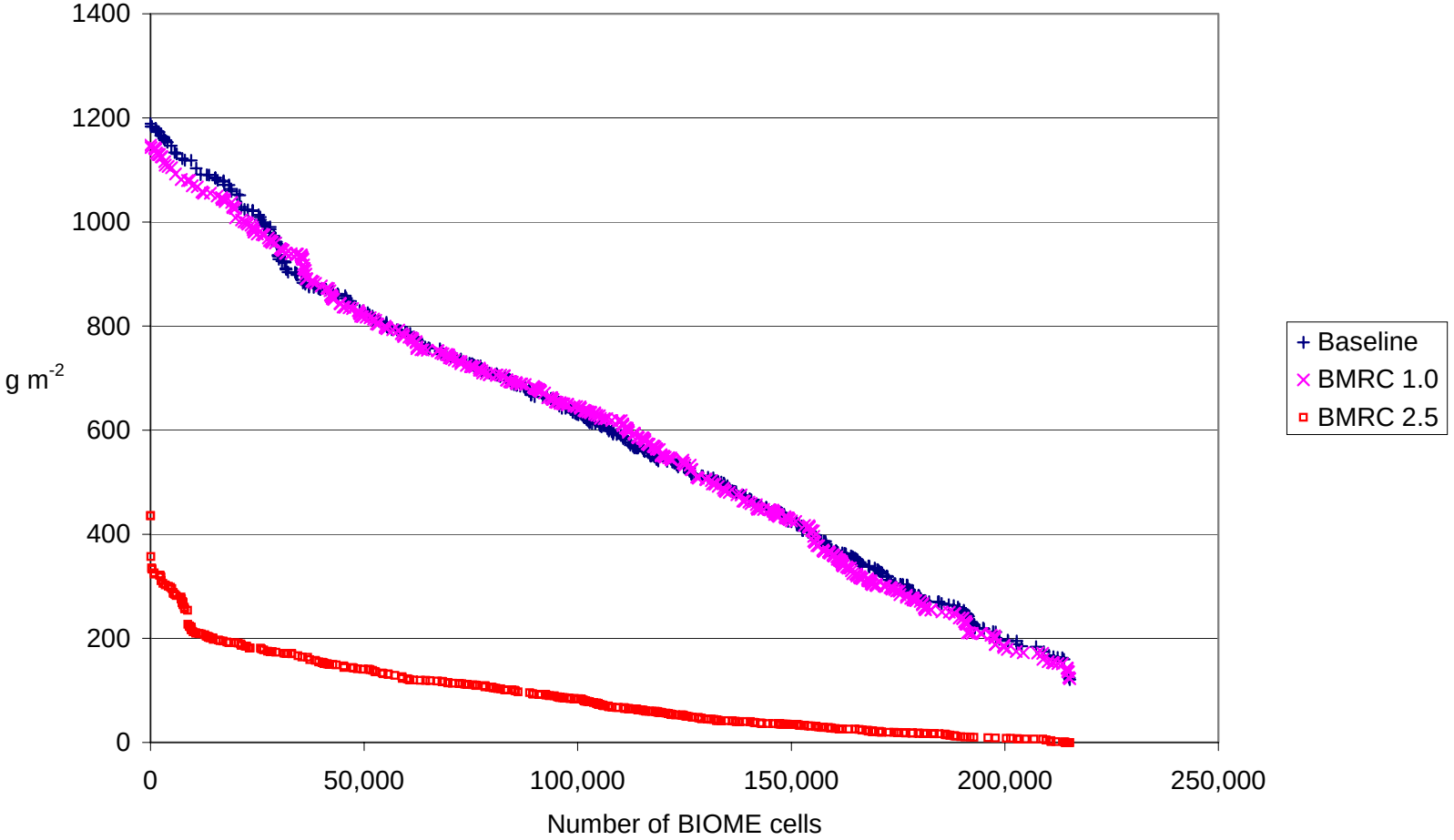
Winter Wheat Yield (USA)



Hay Yield (USA)



Annual Net Primary Productivity (USA)



Intended Uses of AgLU

- Carbon Emissions from Land Use Change and Changes in Land Management
  - Interaction with carbon policy through biomass
  - Carbon sequestration in soils and forests
- Climate Impacts
  - ENSO study for North America
  - Change in crop yields from EPIC and General Circulation Models
- Non-CO_2 Greenhouse Gases
  - Tracking emissions from agriculture over time
  - Mitigation options

Conclusion

- Recent Progress
  - Sensitivity Analysis on Global Scale
  - Detailed Crop Simulation for USA
- Model Development
  - Crop Simulation outside of USA
  - Irrigated Agriculture
  - Embed in Computable General Equilibrium Framework