# Biofuels and Land Use Change

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**Joint Program on the Science and Policy of Global Change**
**Massachusetts Institute of Technology**

**Transition to a Bio Economy**
**Environmental and Rural Development Impacts**

**Hyatt Regency St Louis at Union Station**
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*Based on collaborative work with Angelo Gurgel (MIT and University of Sao Paulo, Sergey Paltsev (MIT), Jerry Melillo (MBL), David Kicklighter (MBL), and Ben Felzer (Lehigh University) and others in the Joint Program on Global Change

***Questions or comments?***

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# Focus of the Presentation

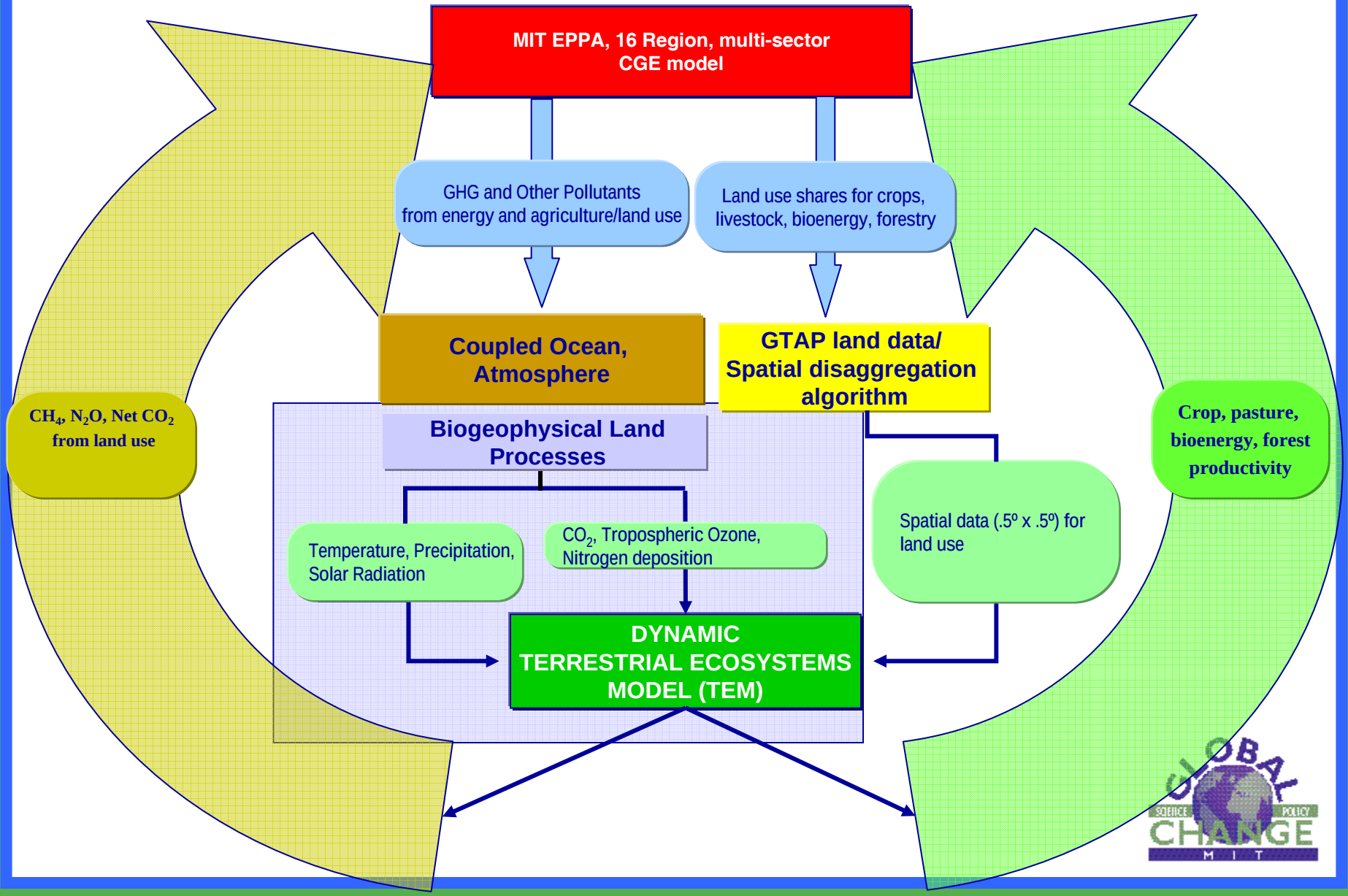
- Can a second generation (cellulosic) biofuel industry fuel the world?
- What areas of the world appear most competitive in such a new industry?
- What are the land use and global food price implications?
- What are the implications for carbon dioxide release from land use change.
- We include in our analysis how changing climate, $CO_2$, and ozone levels will affect yields of crop, pasture, forests, and biofuels but I will not be able to spend much time on showing how those forces affect the future projections.

Note: The presentation draws on some additional material beyond the paper submitted for this conference. The submitted paper draws from a several papers and slightly different model formulations and so the various results I show are not drawn from a consistent model set of model experiments. My goal is to provide some of our general findings

# Economics of Land Use Change

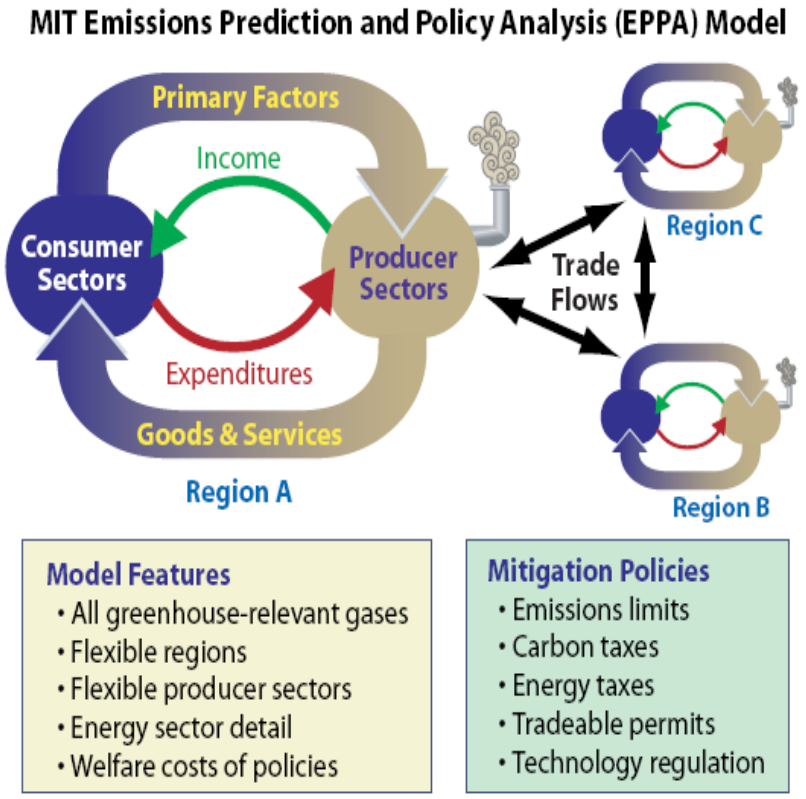
- Extensive Margin—convert new land.
- Intensive Margin—ability to increase intensity of production on existing land.
- With an external forcing (increased demand for land) we expect some movement on both margins and therefore almost certainly a less than 1 for 1 conversion of "virgin" land for every acre (hectare) of new demand.
  - Relative ease/cost/institutional impediments to converting land versus relative ease of intensifying production on existing land.
  - Is that ratio .1, .5, .95?
- Carbon implications of biofuels expansion
  - Energy to improve land, grow crop, convert biofuels
  - Change in carbon stock of land—loss on conversion, possible gain with more intensive management—fertilization, irrigation of degraded or low biomass stock land such as grazing/pasture land
- Obviously…biofuels may not themselves be grown on converted land but may produce a ripple effect.soybeans moves to grazing land, grazing to forest or unmanaged grass land.

# EPPA-Global Land System Interactions



# Emissions Prediction and Policy Analysis (EPPA) Model.

- Computable General Equilibrium (CGE) model of world economy with regional/sectoral detail.
- Fully treats demand/supply, capital/investment, macroeconomy/trade implications of growth, policies, alternative technologies




**Report # 125 @ http://web.mit.edu/globalchange/www/reports.html#pubs**

# EPPA: Detailed Energy Sector in Global Economy Model

## Country or Region

***Developed***
- United States (USA)
- Canada (CAN)
- Japan (JPN)
- European Union+ (EUR)
- Australia/N.Zealand (ANZ)
- Former Soviet Union (FSU)
- Eastern Europe (EET)

***Developing***
- India (IND)
- China (CHN)
- Indonesia (IDZ)
- Higher Inc. East Asia (ASI)
- Mexico (MEX)
- Centr. & S. America (LAM)
- Middle East (MES)
- Africa (AFR)
- Rest of World (ROW)

## Sectors

***Demand Sectors***
- Services (SERV)
- Energy-Intensive (EINT)
- Other Industries (OTHR)
- Commercial Transp. (TRAN)
- Household Transp. (HTRN)
  - *Multiple technologies*
- Hunting and Fishing
- Wildlife Viewing in Reserves
- Other Wildlife Viewing
- Health Services/Air Pollution

***Fuels Supply***
- Coal (COAL)
- Crude Oil (OIL)
- Refined Oil (ROIL)
  - *Multiple Fuels*
  - *Multiple Refinery Processes*
- Natural Gas (GAS)
- Oil from Shale (SYNO)
- Synthetic Gas (SYNG)
- Liquids from Biomass (B-OIL)

***Electricity Generation***
- Fossil (ELEC)
- Hydro (HYDR)
- Nuclear (NUCL)
- Solar and Wind (SOLW)
- Biomass (BIOM)
- Coal with CCS
- Adv. gas without CCS
- Gas with CCS

***Agriculture***
- Crops
- Livestock
- Forest products
- Food Processing

## Factors

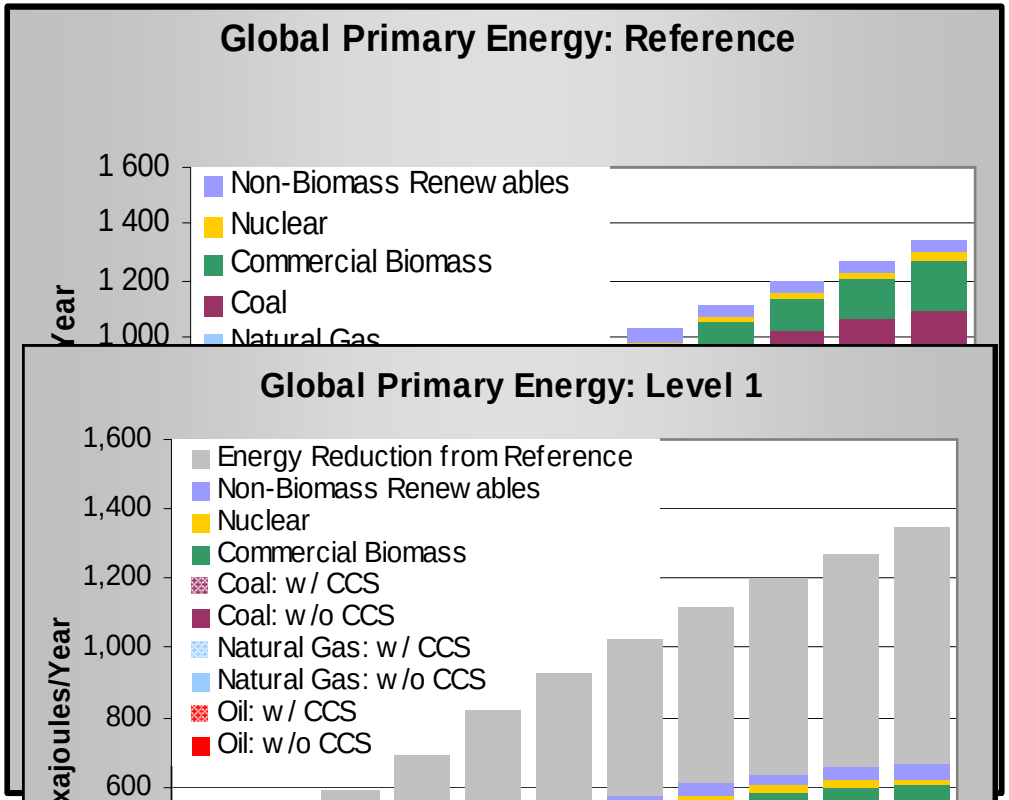
- Capital
- Labor

***Energy Resources***
- Crude Oil
- Natural Gas
- Coal
- Oil Shale
- Oil Sands
- Nuclear
- Hydro
- Wind/Solar

***Land***
- Cropland
- Pastureland
- Managed Forest
- Non-Reserved Natural Forest
- Reserved Natural Forest
- Natural Grassland

# Various versions of land use model

- Land as a single homogeneous input where, following economic theory, its value reflects its productivity.
- Explicit land use types—where land cropland, pasture/grazing land, or managed forest land is "produced" from other types of land through the addition of inputs—or abandoned
- Pure Cost of Conversion Response (PCCR)—"Deforestation scenarios"
- Observed Land Supply Response (OLSR)—"Intensification Scenarios;







In a Reference scenario—no specific biofuel subsidy and no GHG mitigation policy second generation biofuels enters around 2035 and ends up as a substantial part of the energy mix.

Driver is oil price which is rising in our simulation to about $100 by 2050 and to $150 by 2100.

Cost of biofuels depends on land prices, transportation which are endogenous to the model but generally it takes something close to $100 oil and $4.00-$4.50/gal. gasoline to compete.

With strong climate policy—450 ppm stabilization—cellulosic biofuels enters very soon and is the most important source of primary energy.

But this ignores the possible carbon implications of land use change.

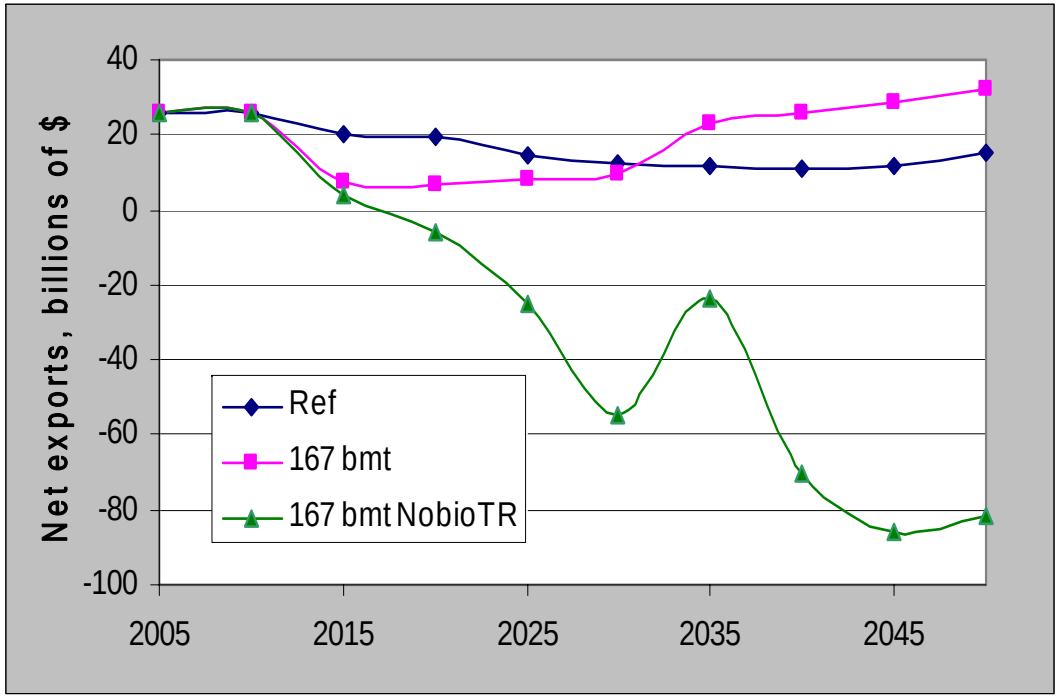
# Again with a GHG policy we find that Latin America and Africa would tend to be the major biofuels producers and the US a net importer of biofuels

**Table 7 Regional biomass production in the policy case (EJ/year)**

| | USA | Mexico | Australia and New Zealand | Latin America | Africa | Other regions | Global |
|---|---|---|---|---|---|---|---|
| 2010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2020 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 2030 | 1 | 0 | 1 | 4 | 19 | 0 | 25 |
| 2040 | 4 | 2 | 2 | 26 | 30 | 5 | 69 |
| 2050 | 13 | 4 | 4 | 54 | 41 | 6 | 122 |
| 2060 | 17 | 4 | 6 | 71 | 48 | 6 | 152 |
| 2070 | 20 | 5 | 8 | 87 | 58 | 7 | 185 |
| 2080 | 24 | 6 | 11 | 107 | 71 | 10 | 229 |
| 2090 | 28 | 7 | 13 | 127 | 85 | 13 | 273 |
| 2100 | 33 | 8 | 16 | 147 | 98 | 18 | 320 |

Note: This is a somewhat different policy—eventually stabilizing $CO_2$ at 550 ppm but with a more aggressive policy early in developed countries

**Figure 7 Net agricultural exports in the 167 bmt case, with and without biofuels trading**

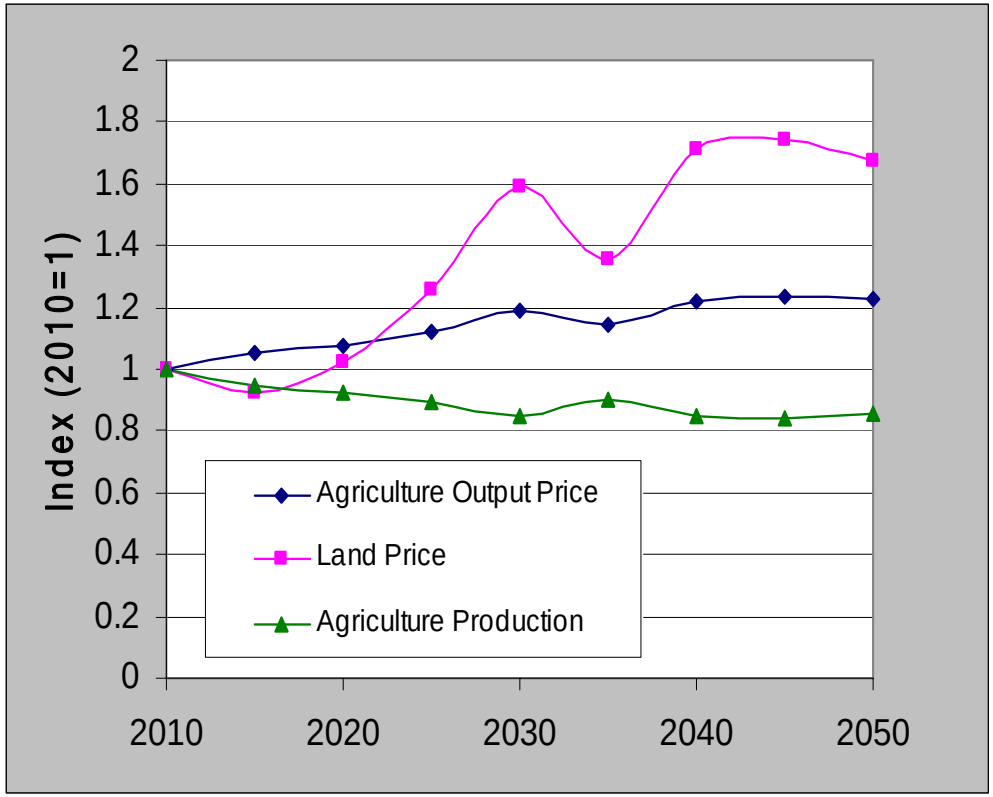



**What if US blocks trade in biofuels relying on our "domestic" energy resource?**

**Answer: We turn into a large food importer**

**167 bmt (billion metric tons) is the allowed carbon dioxide emissions in the US through 2050—this is a policy close to the Warner-Lieberman legislation that was ultimately not passed but similar goals are likely to be reflected in future legislation**

**Figure 8 Indexes of Agriculture Output Price, Land Price, and Agriculture Production in USA in No Biofuel Trading (167bmtNB) Scenario Relative to the Reference (2010 = 1.00)**




**Effects on Food and land Prices relative to Reference,**

**Ag. prices—20% higher.**
**Land prices—60% higher.**
**Ag. Output—down 20%.**

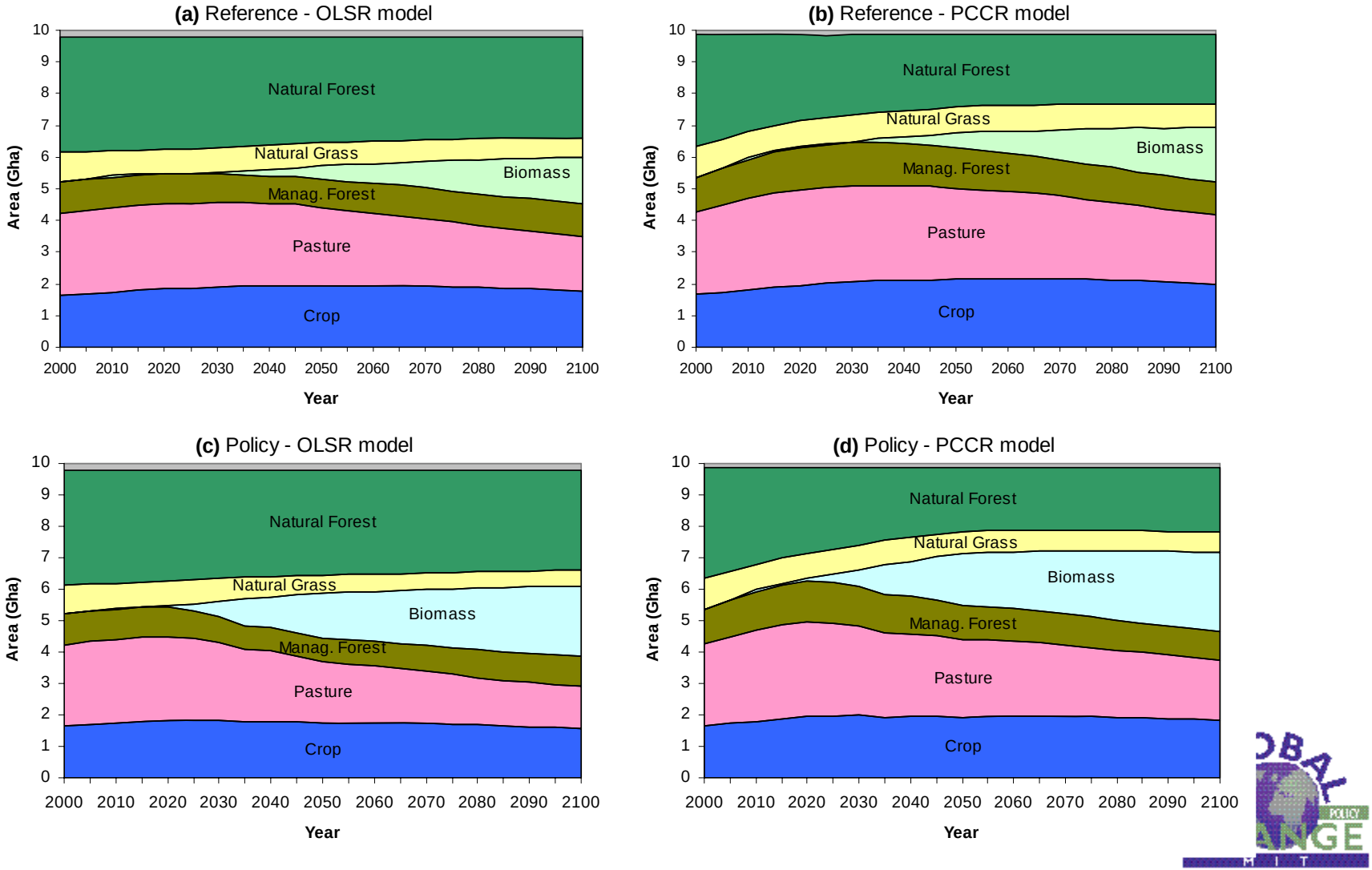
**Assumption of increasing land productivity moderates effects on commodity prices—land a smaller share.**

**NOTE: biofuels are enter in the reference starting around 2040 or so and are already having some impact on land/food prices and so at this point the difference is that effect of biofuels beyond the reference.**

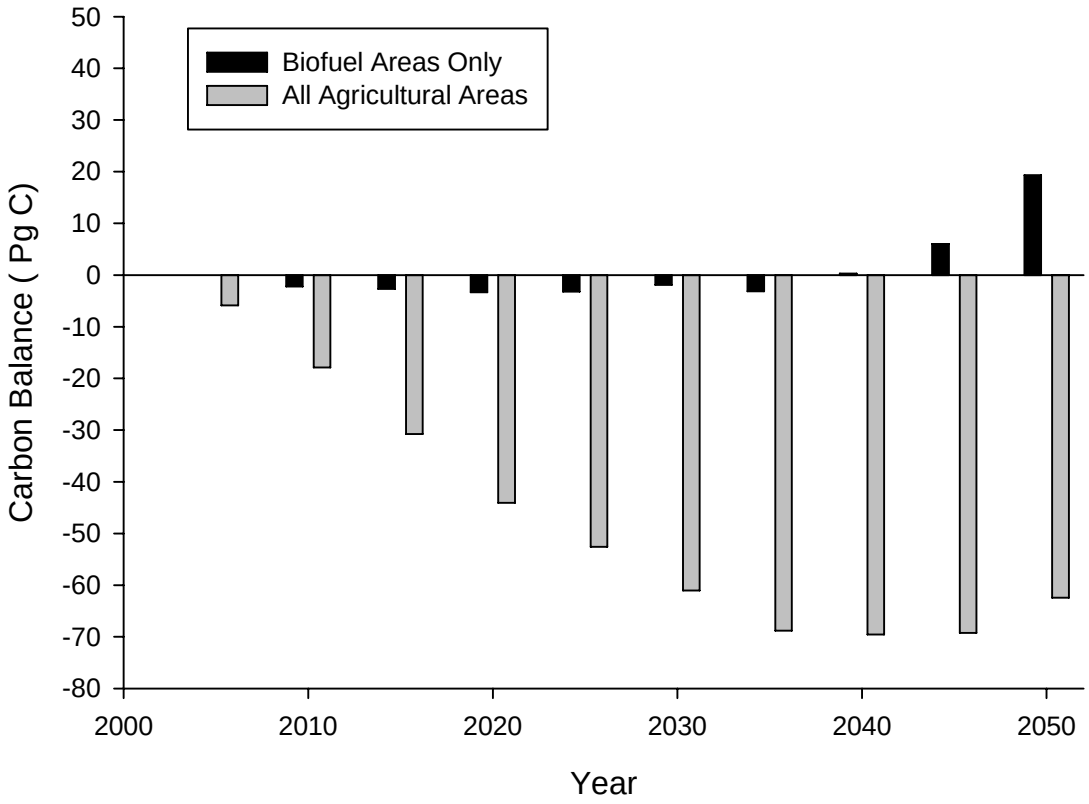
# Results with Enhanced Representation of multiple land types—PCCR and OLSR

- In general, the level of biofuels produced globally is similar in these enhanced versions compared with the simple single land type.
- As expected the OLSR version results in somewhat less biofuels—but the difference is less than 10%.
- Effects on global food prices are relatively small—cost is incurred in “improving land” but because a lot of land improvement occurs the impact on the price of improved land is moderated.
- A main advantage of these enhanced versions is to explicitly represent where and what land is being used—and to track the carbon dioxide emissions of land use change.

# Figure 10 Global Land Use: (a) reference case – OLSR model, (b) reference case – PCCR model, (c) policy case – OLSR model, (d) policy case – PCCR model



Cumulative Net Abatement of Fossil Fuel Carbon with Biofuels using a Pure Conversion Cost Response (PCCR) Model



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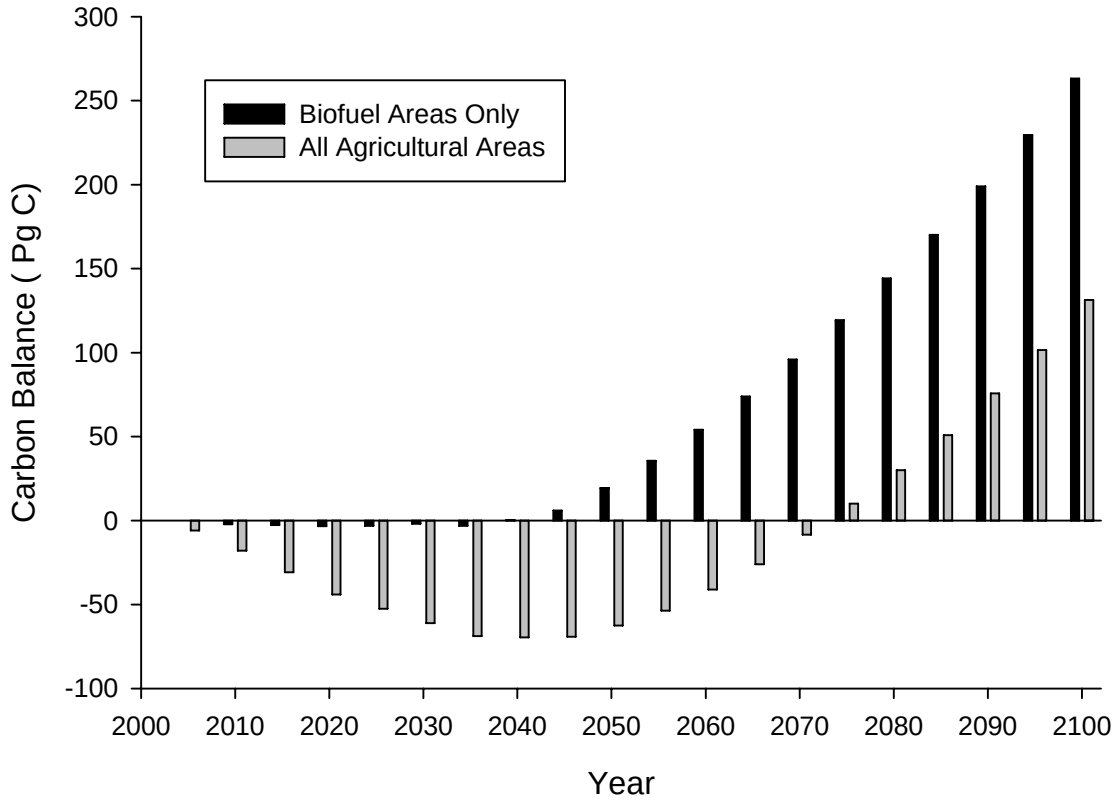
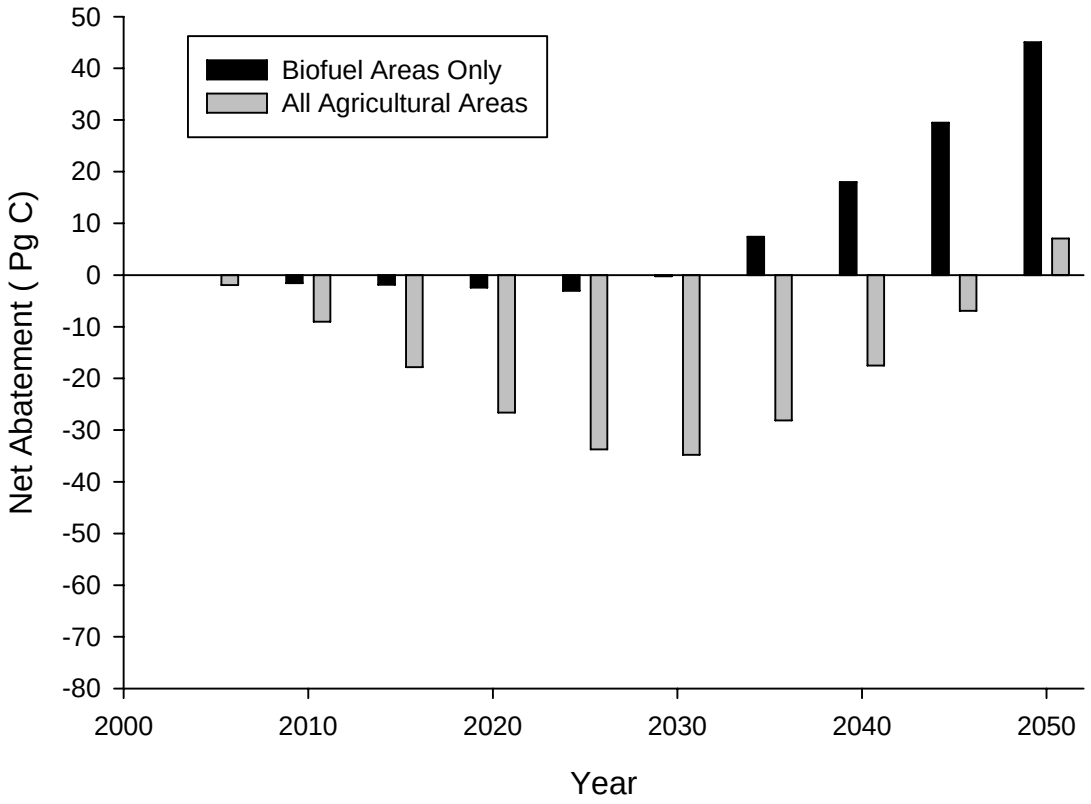


Cumulative Net Abatement of Fossil Fuel Carbon with Biofuels using the Observed Land Supply Response (OLSR) Model



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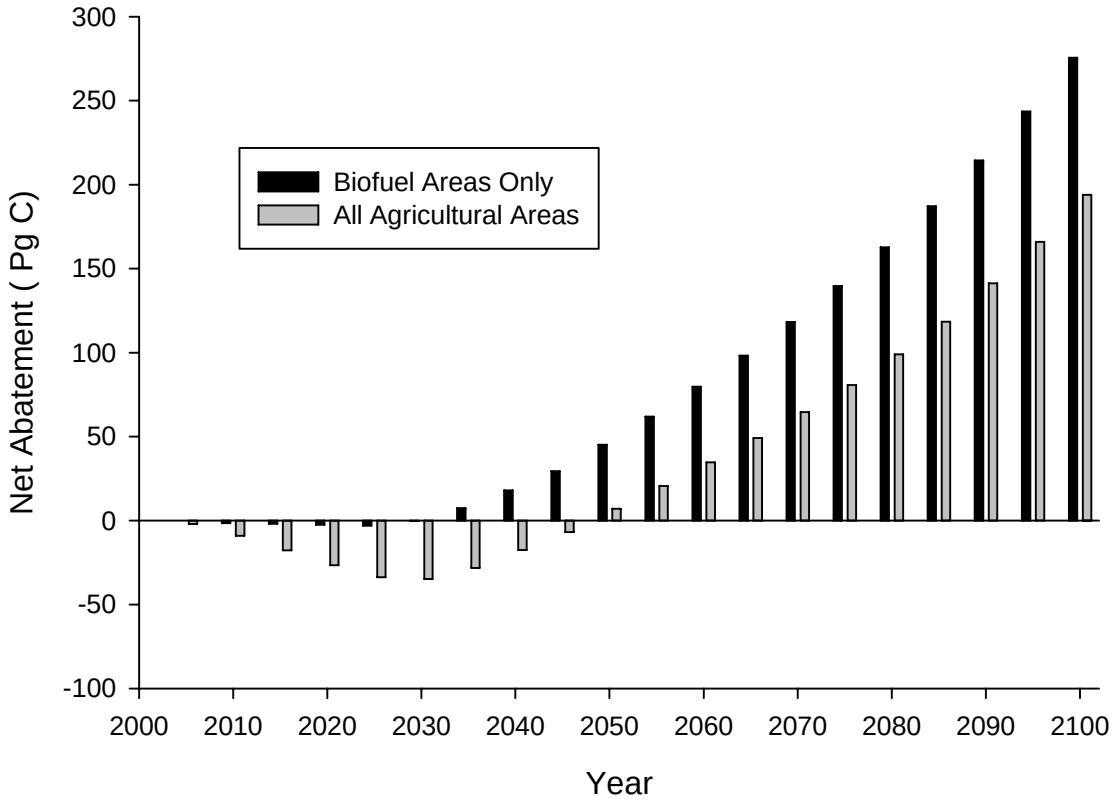
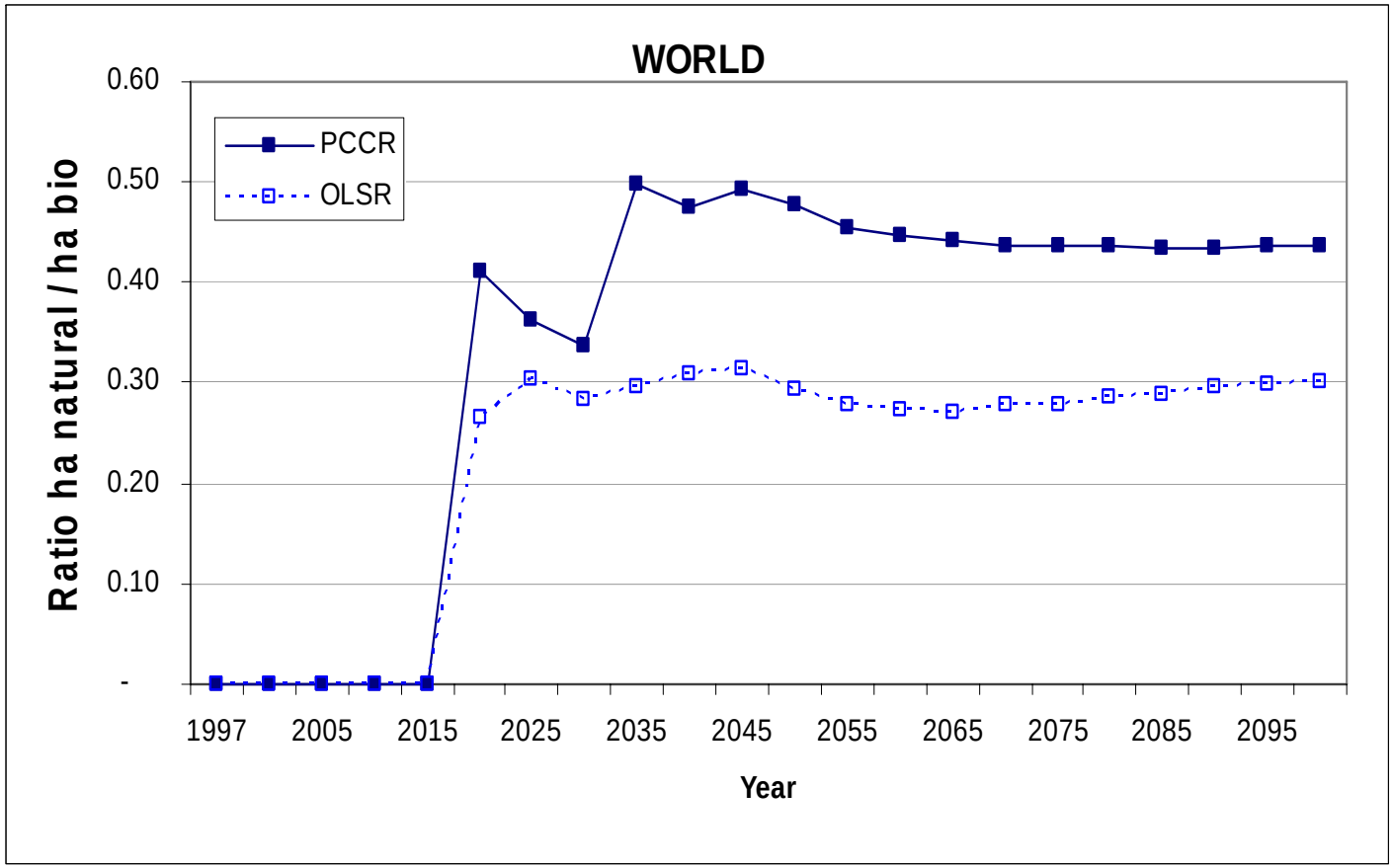


# Cumulative share of land for biofuels from unmanaged forests or grassland

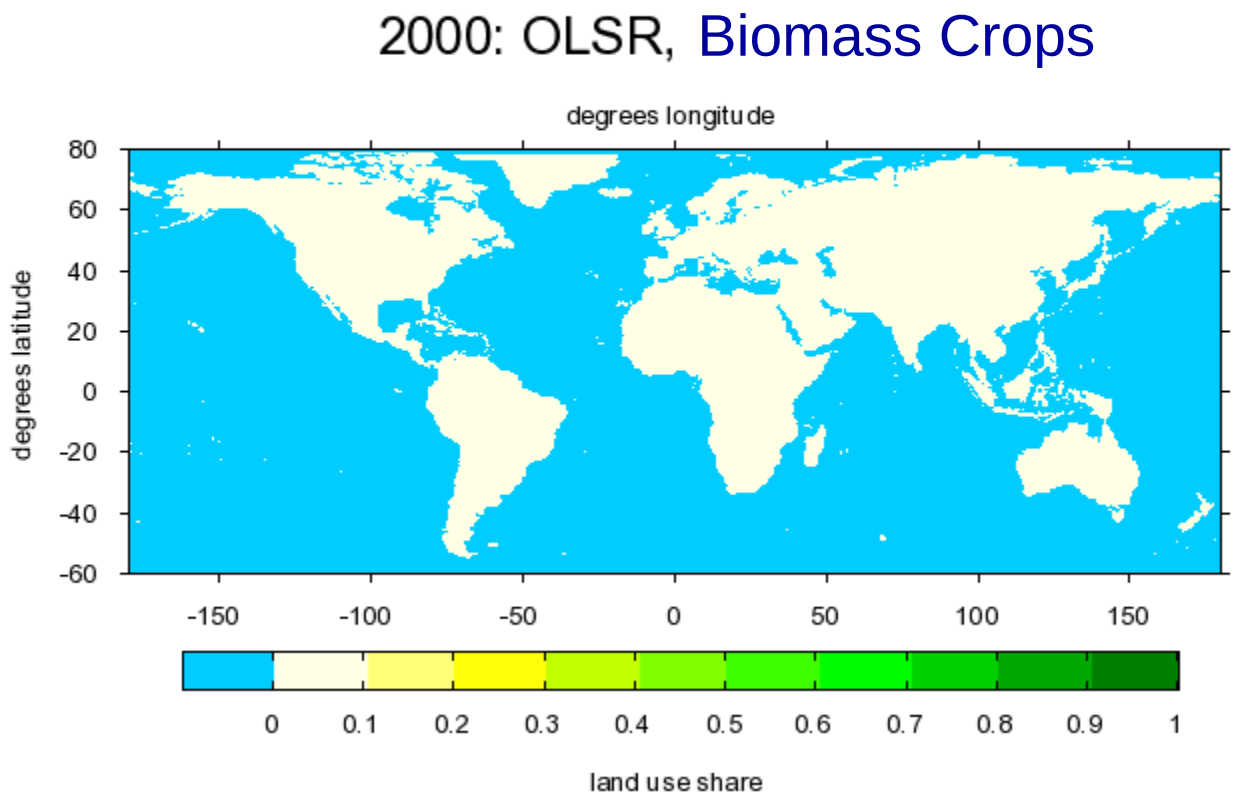


# OLSR (Intensification)

# PCCR (Deforestation)

| | | | |
|---|---|---|---|
| Biomass Crops | Natural Forest | Biomass Crops | Natural Forest |
| Crops | Natural Grass | Crops | Natural Grass |
| Pasture | Crops + Biomass | Pasture | Crops + Biomass |
| Managed Forest | Agriculture | Managed Forest | Agriculture |

# Biomass ("Intensification" Scenario)



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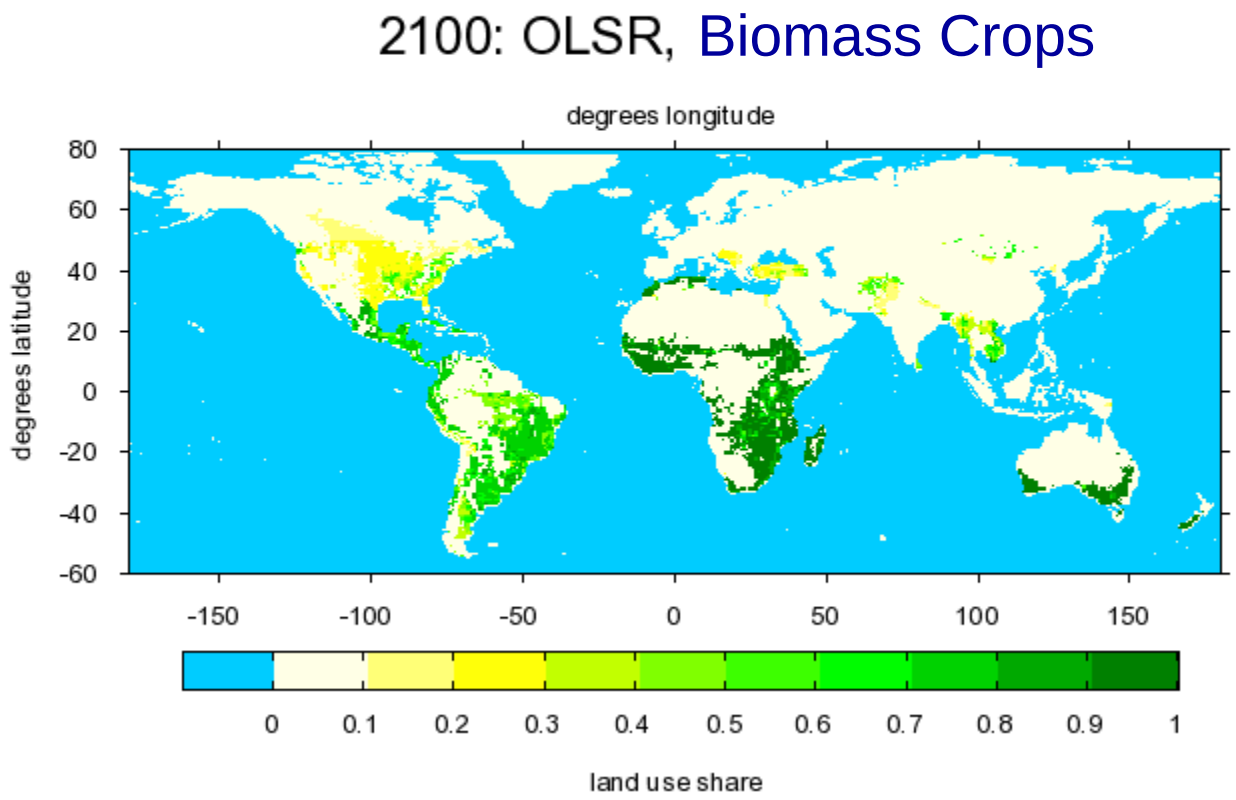
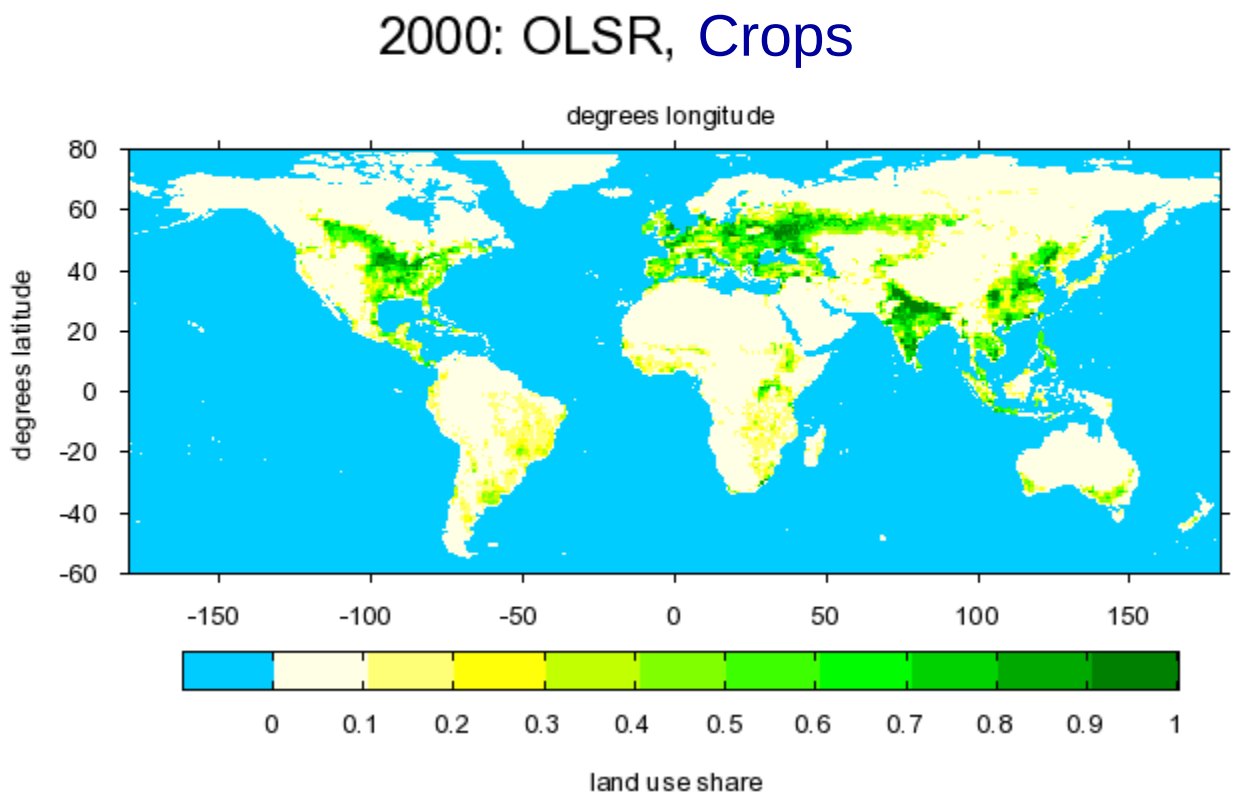


# Crops ("Intensification" Scenario)



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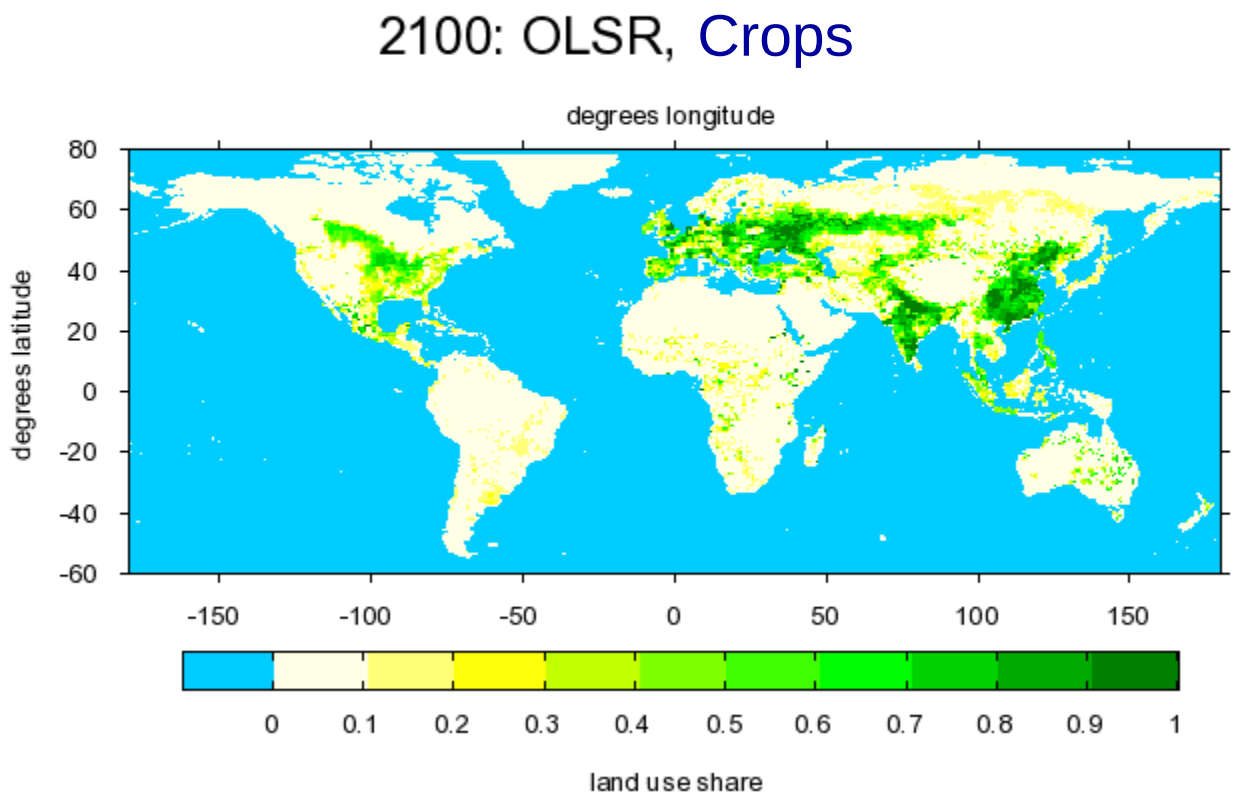

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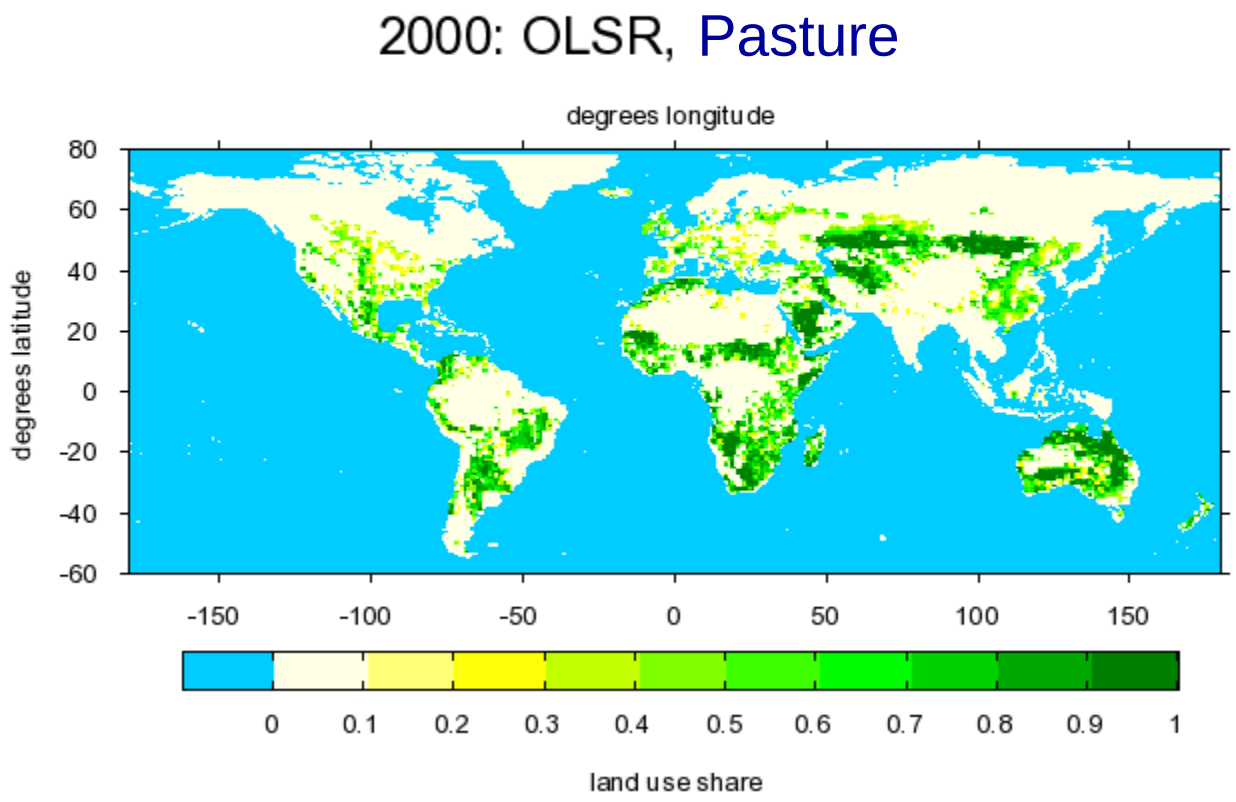

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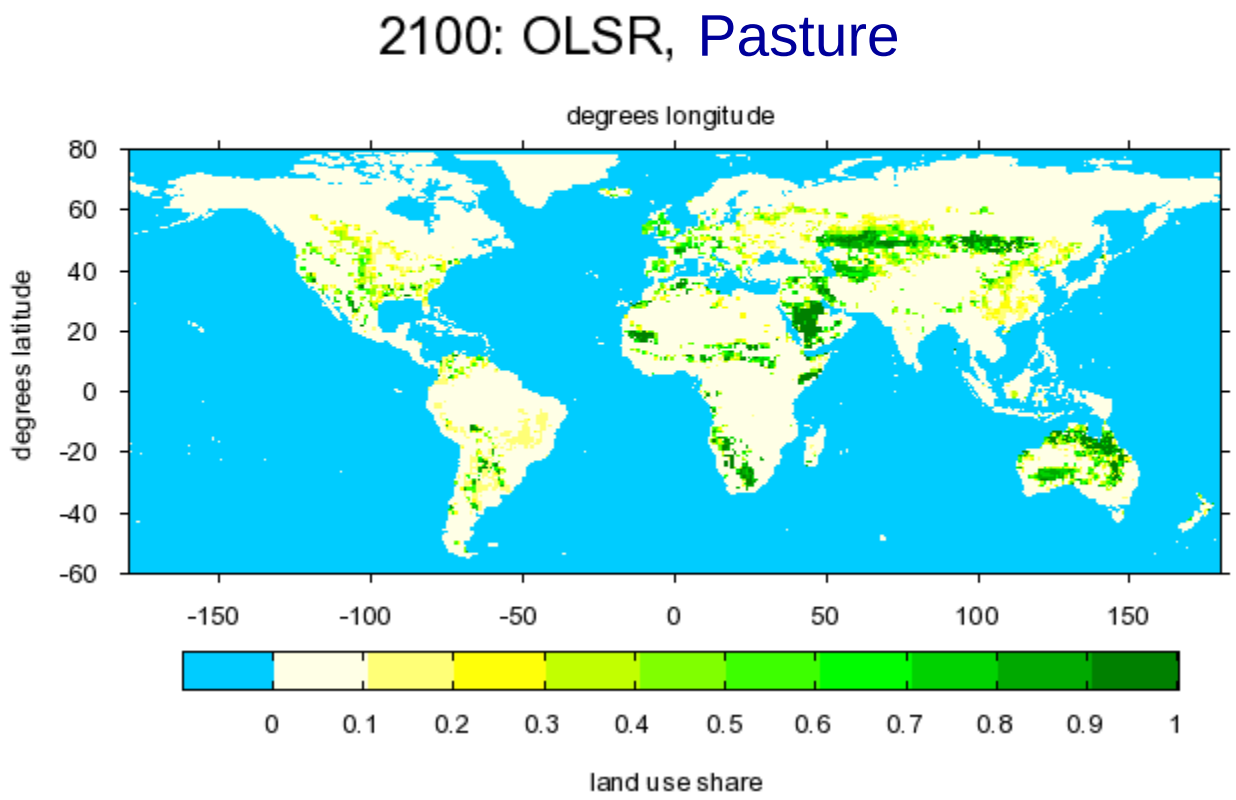
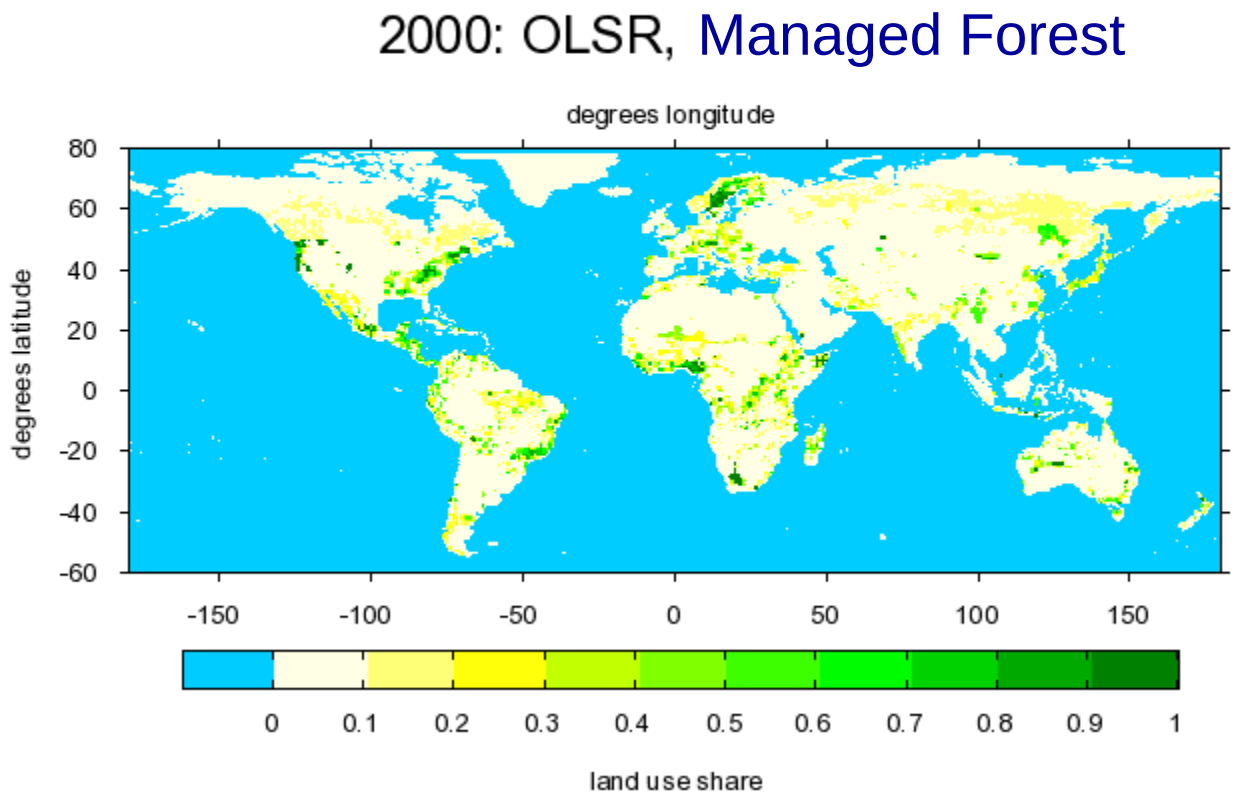


# Managed Forest ("Intensification" Scenario)



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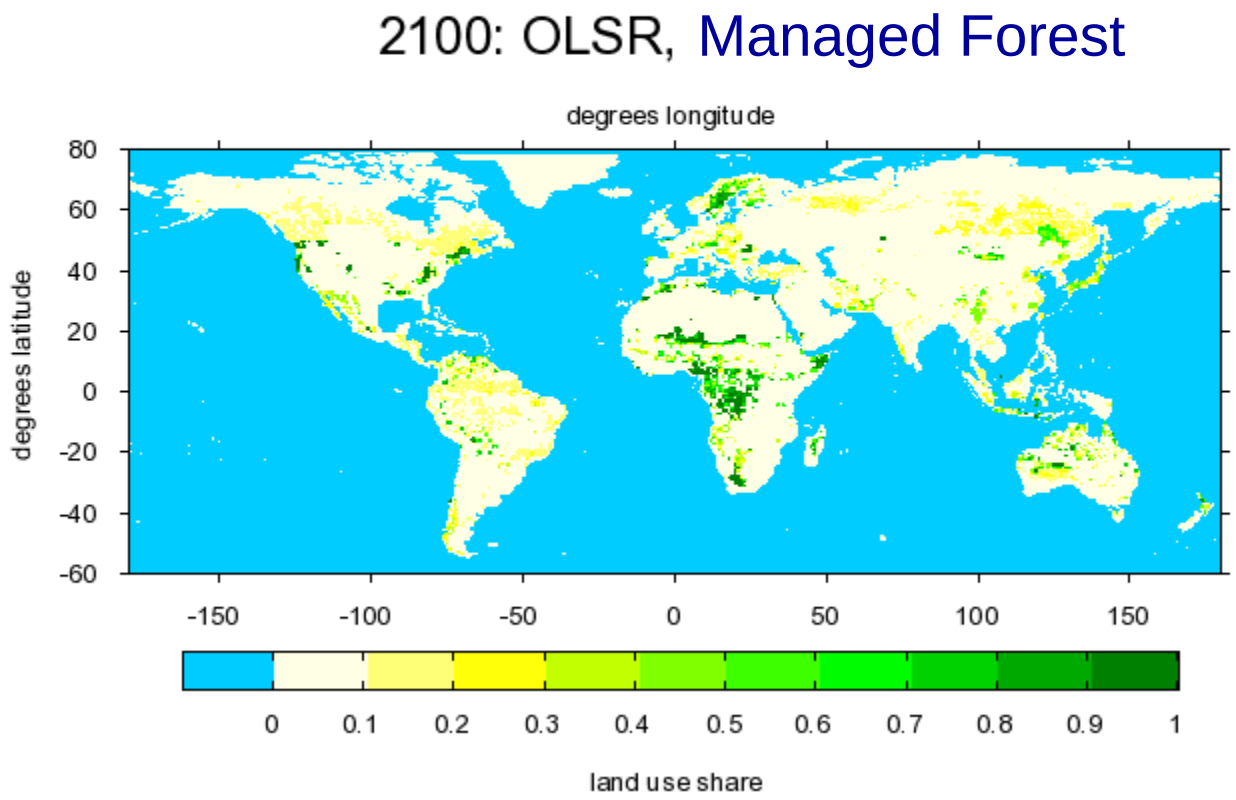

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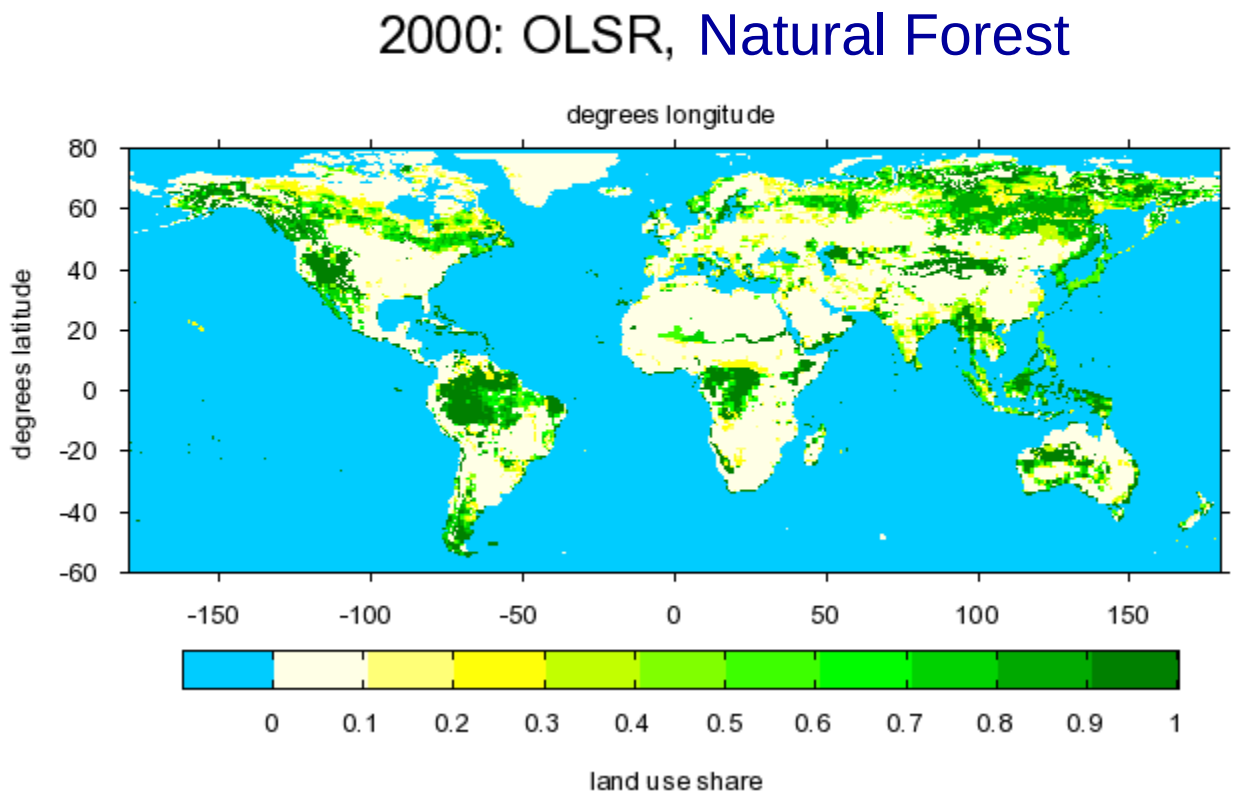

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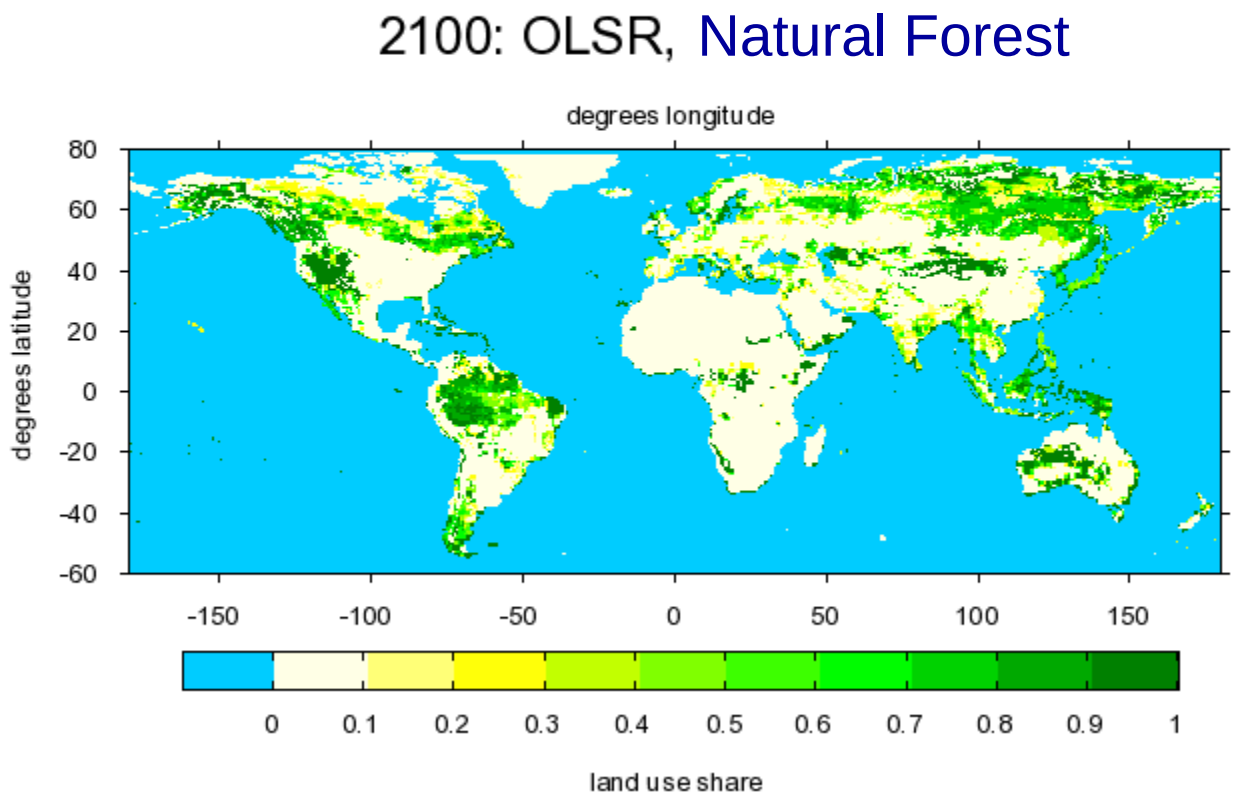
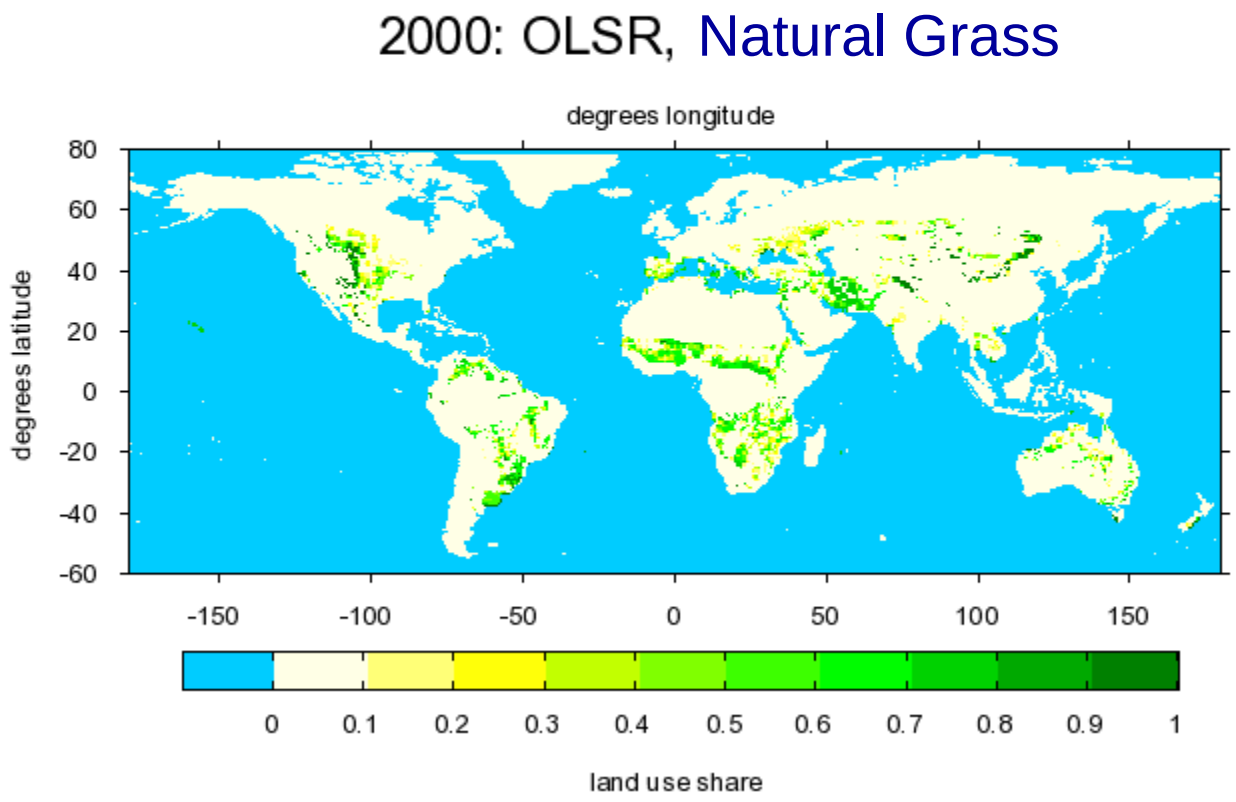


# Natural Grass ("Intensification" Scenario)



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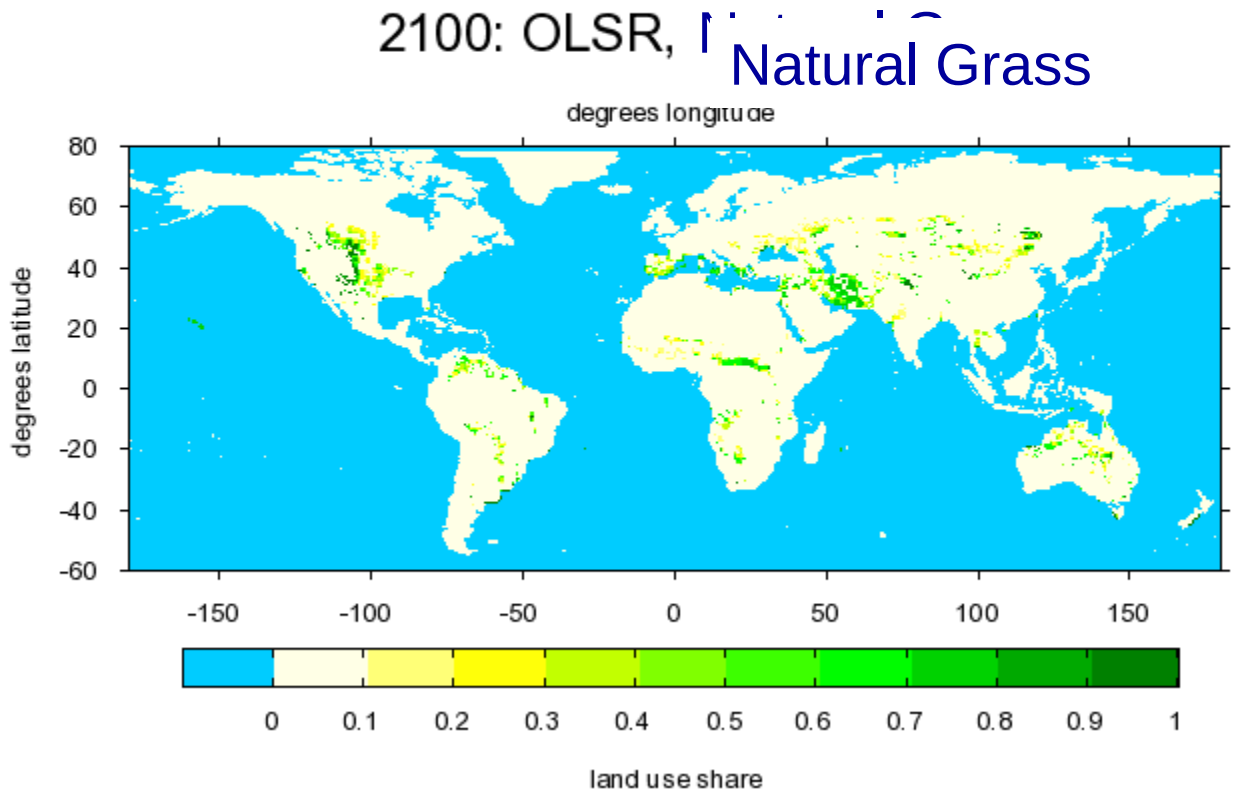
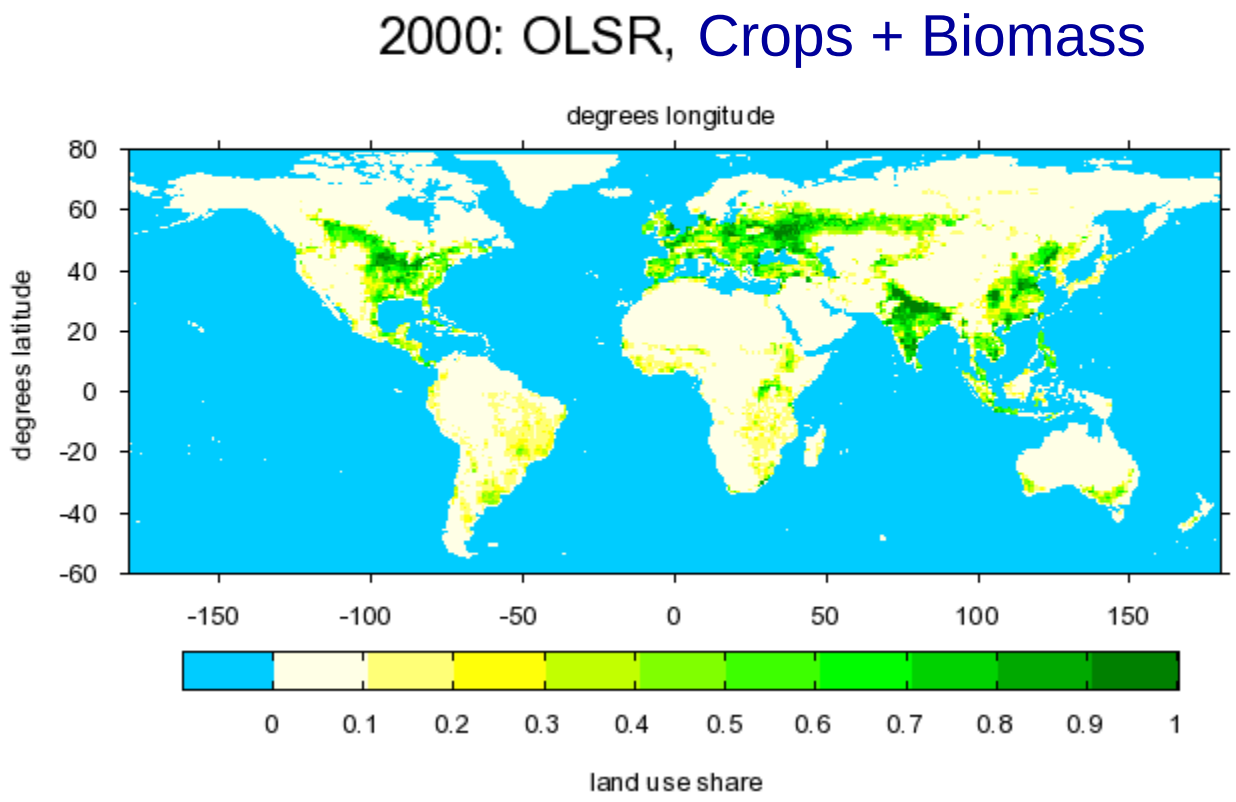


# Crops + Biomass ("Intensification" Scenario)



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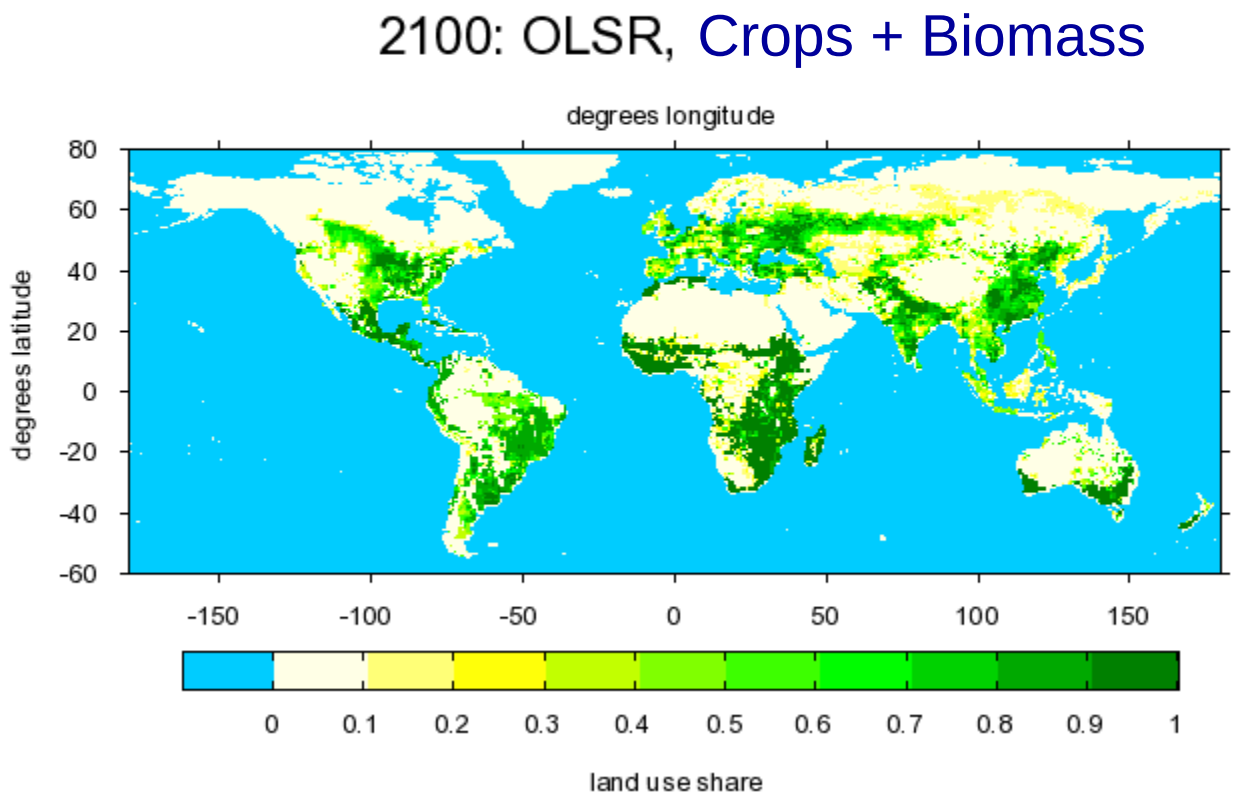
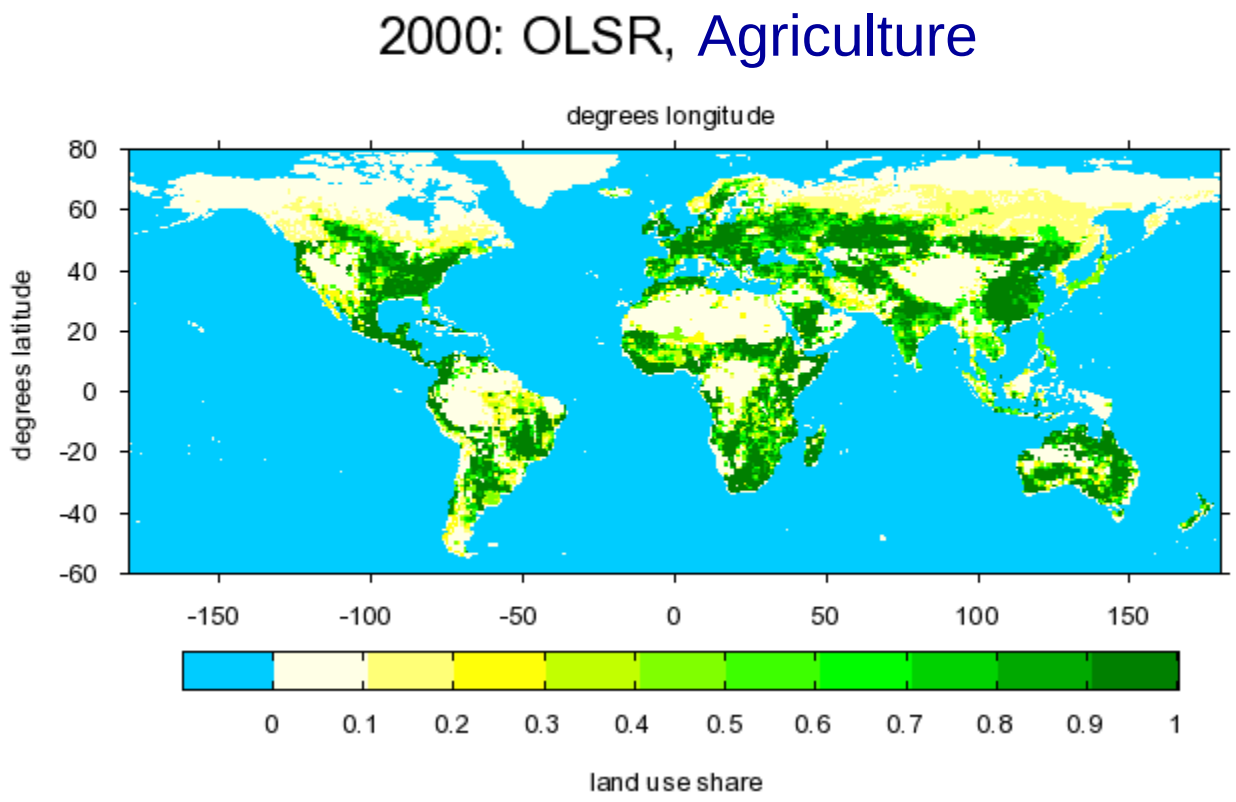


# Agriculture ("Intensification" Scenario)



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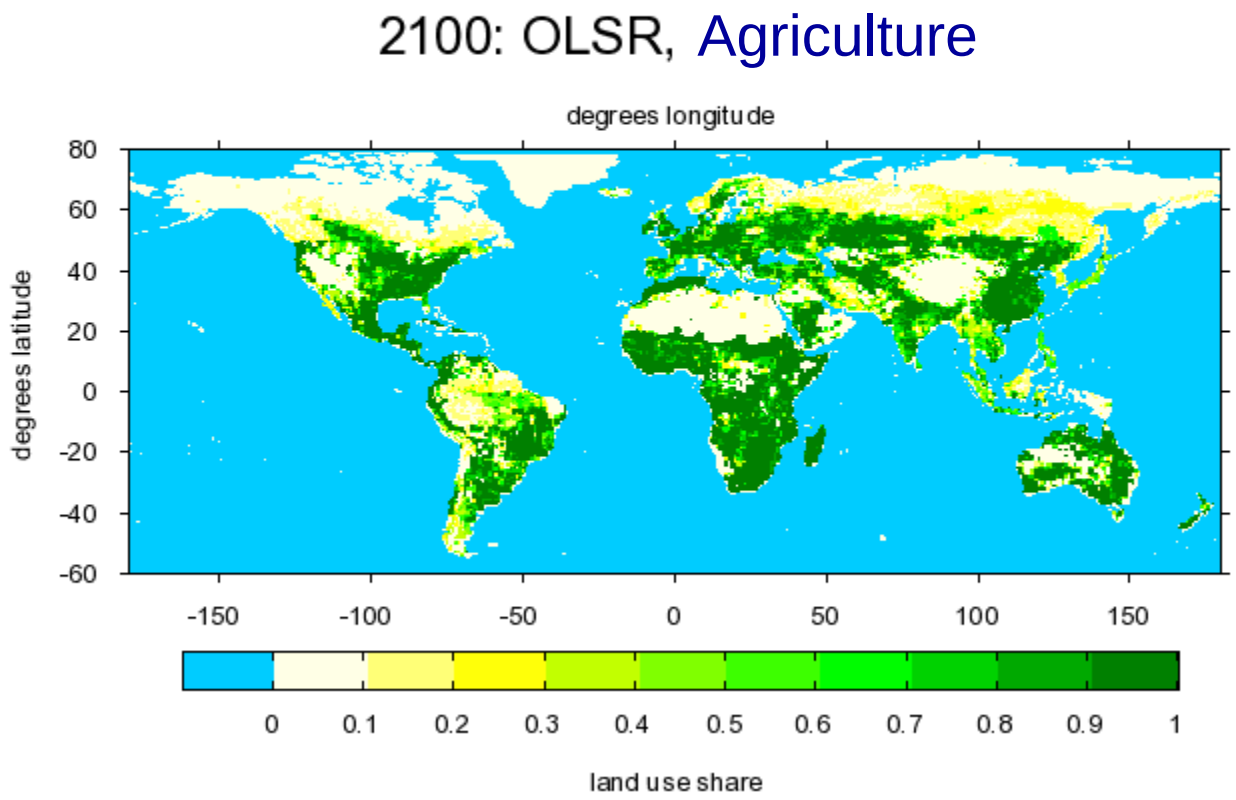
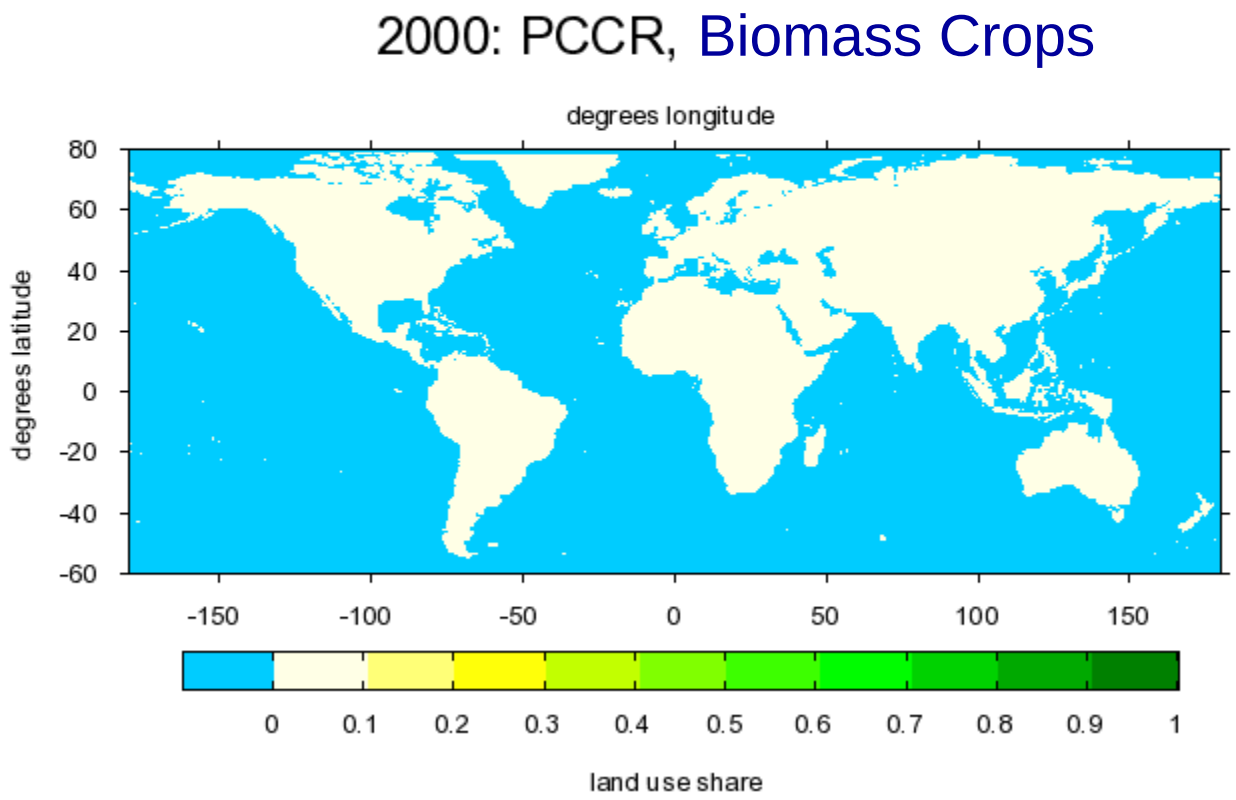
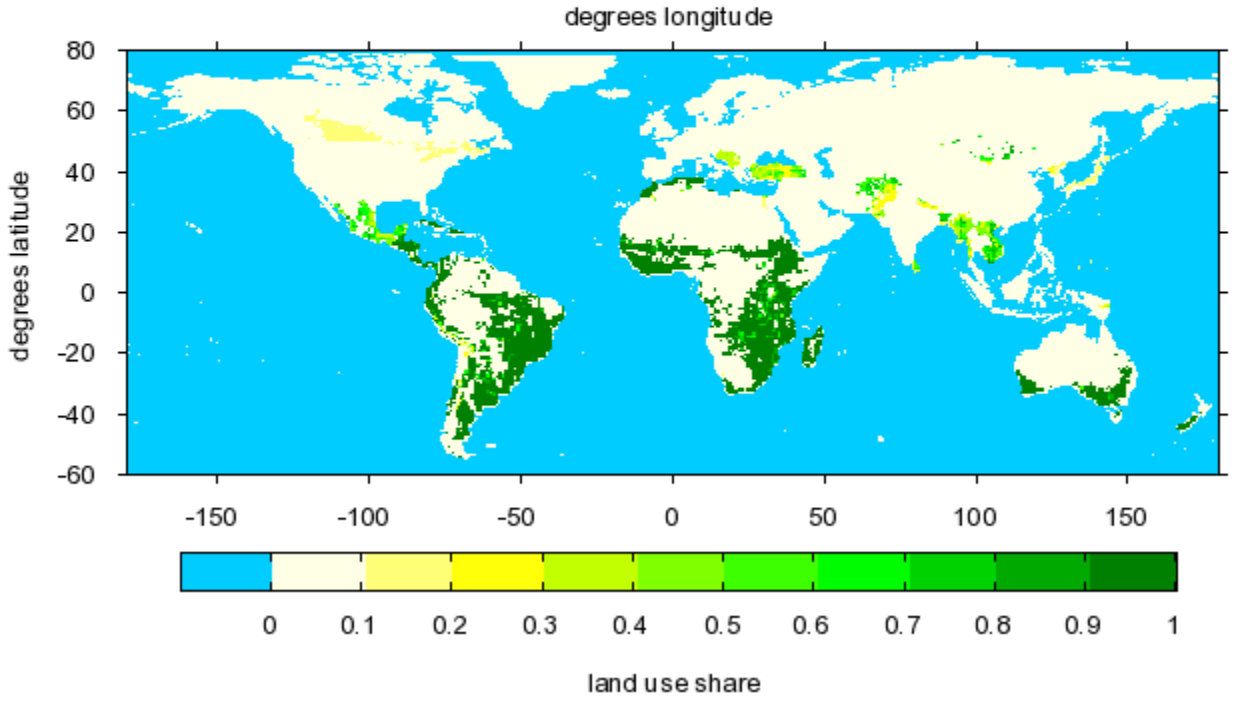


# Biomass ("Deforestation" Scenario)

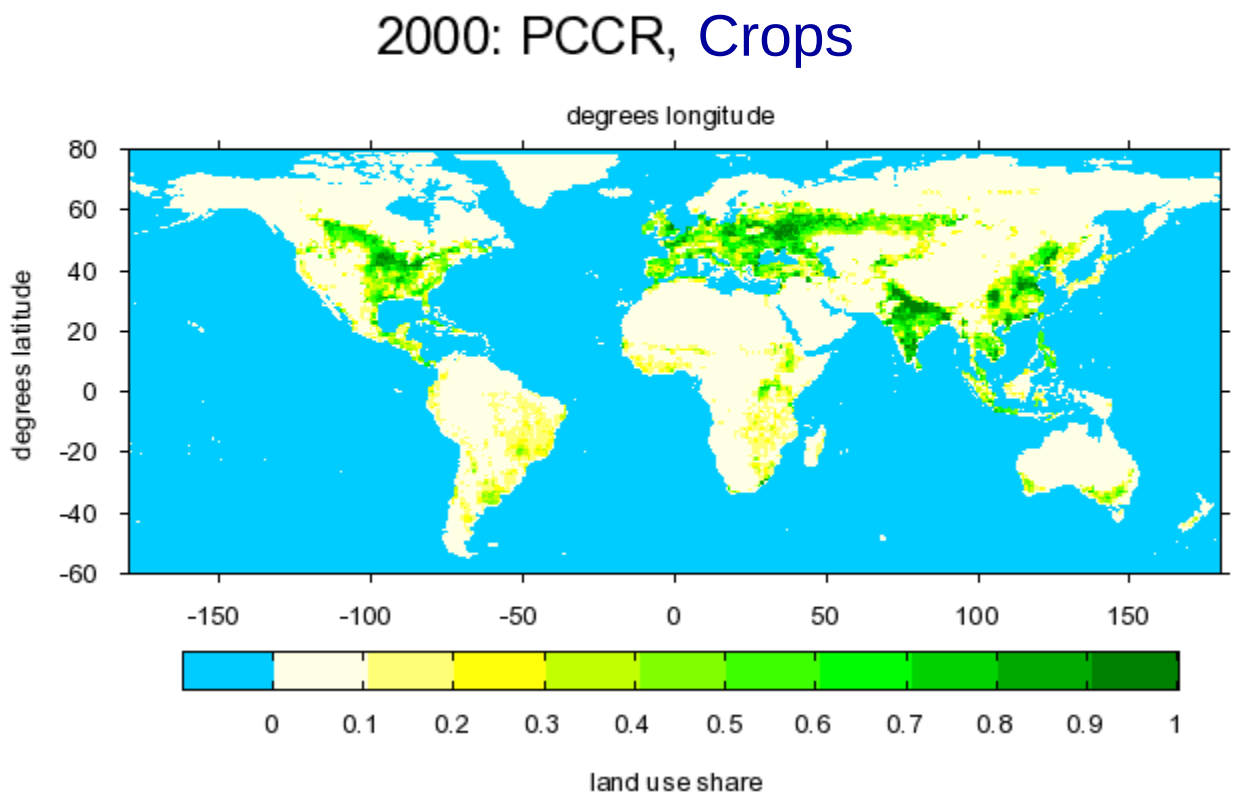


# Biomass ("Deforestation" Scenario)

2100: PCCR, Biomass Crops



# Crop ("Deforestation" Scenario)



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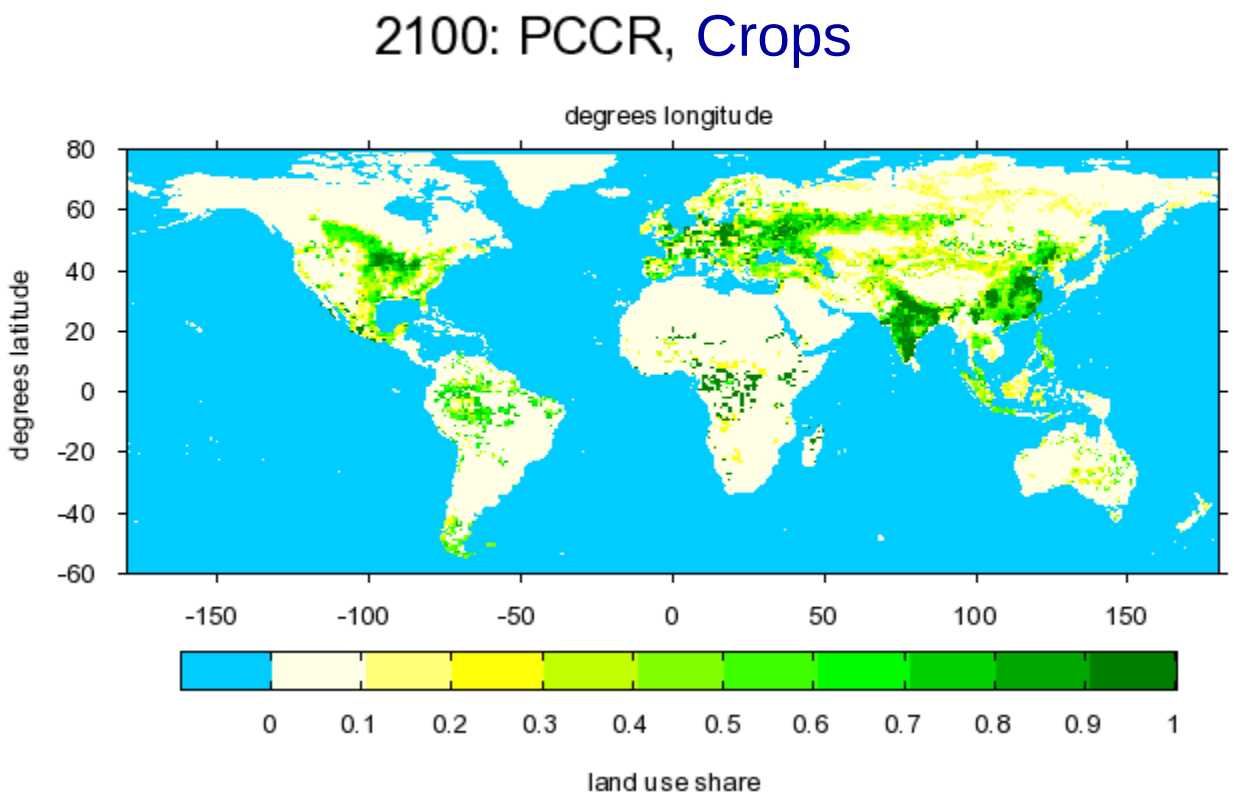
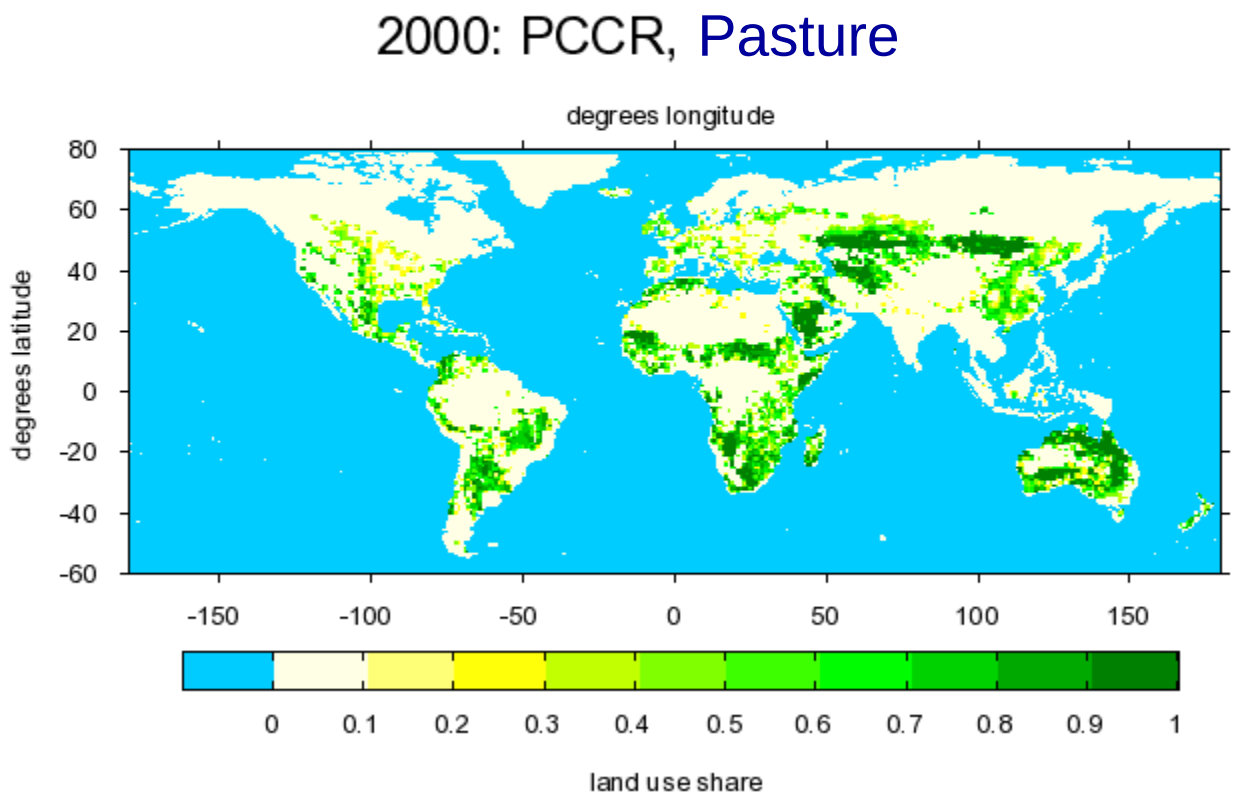


# Pasture ("Deforestation" Scenario)



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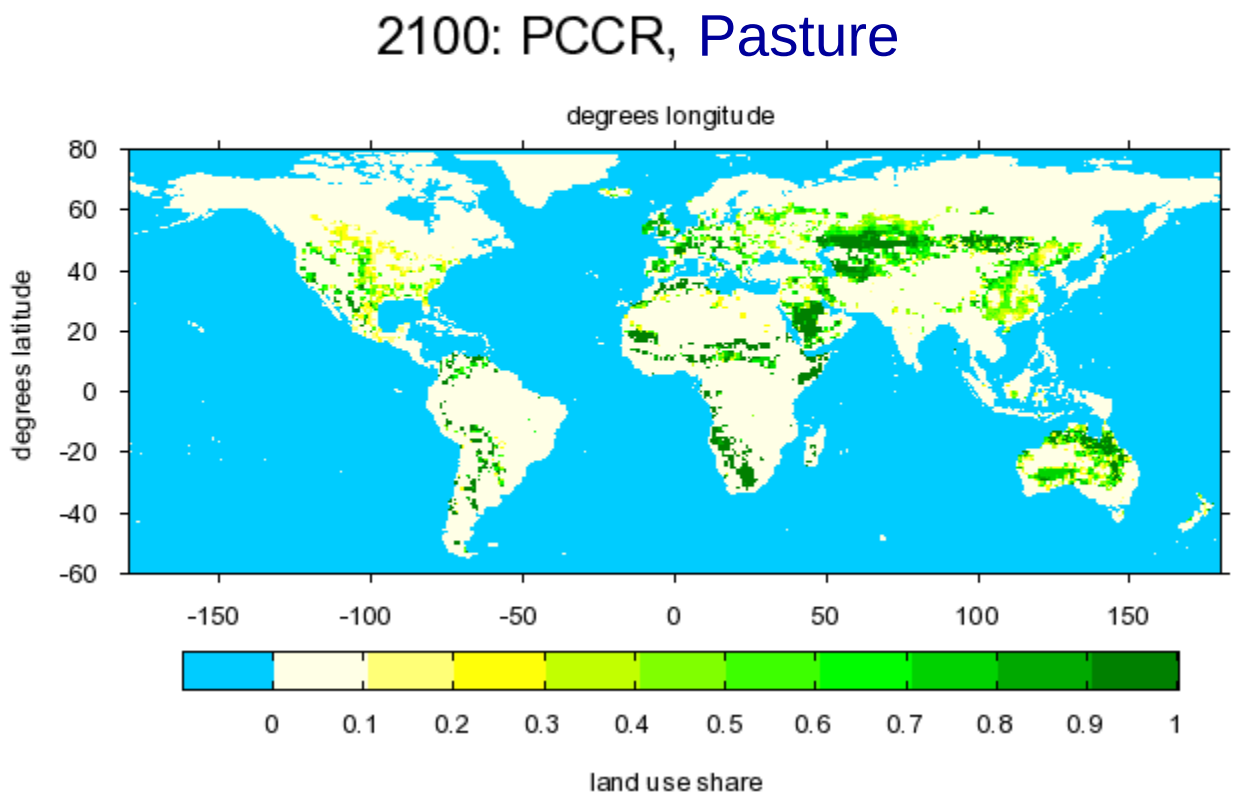
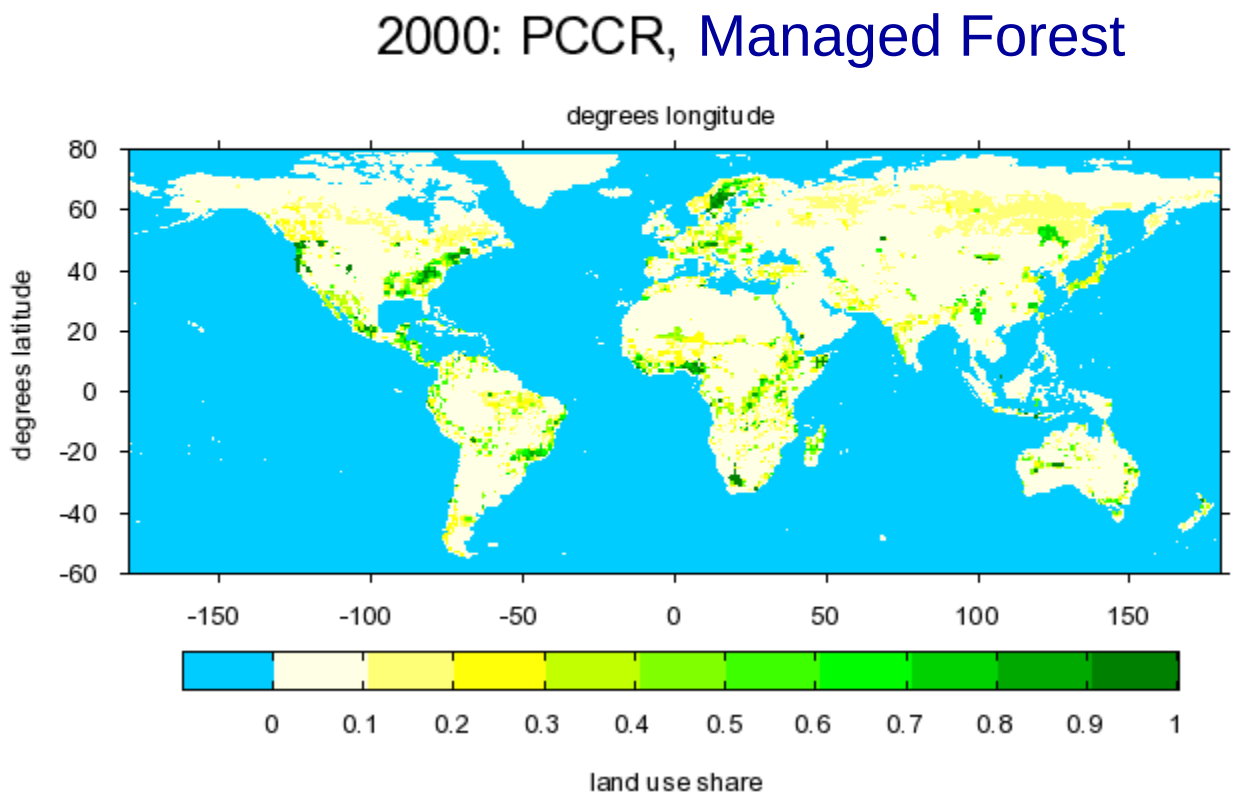


# Managed Forest ("Deforestation" Scenario)



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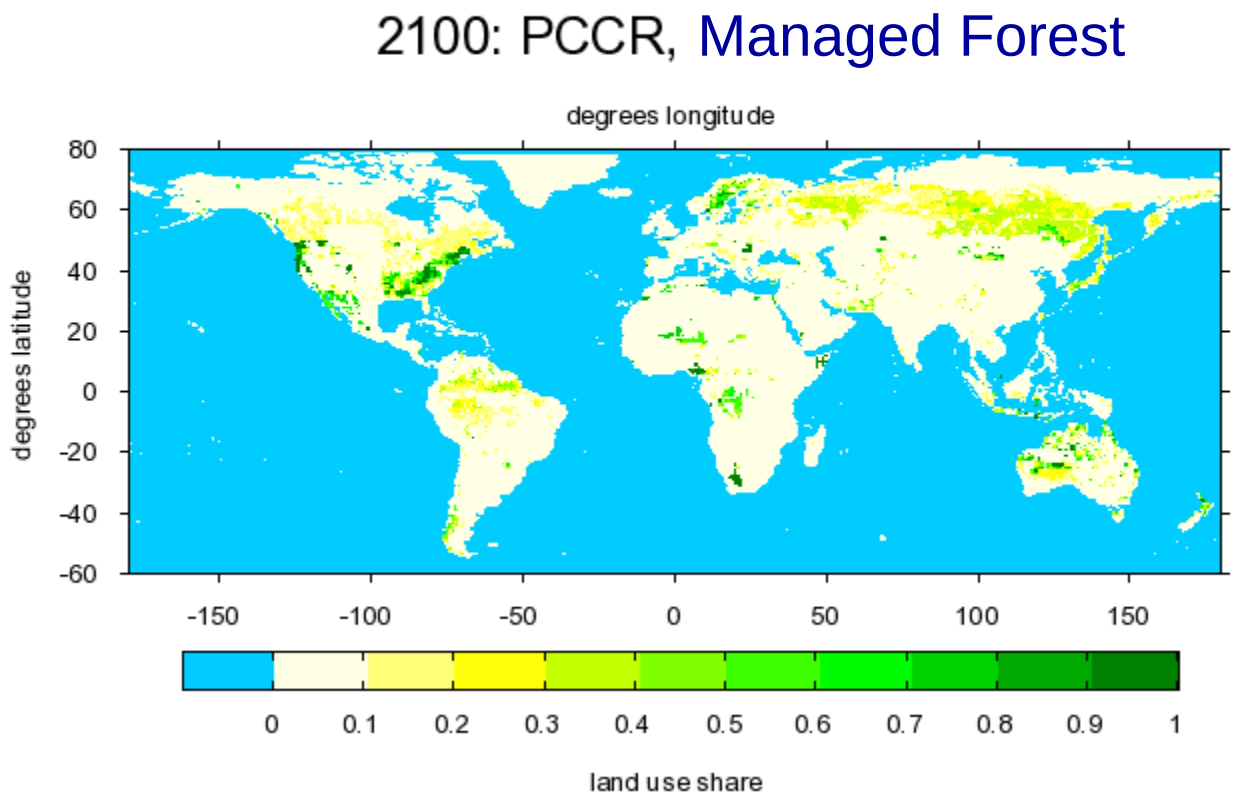

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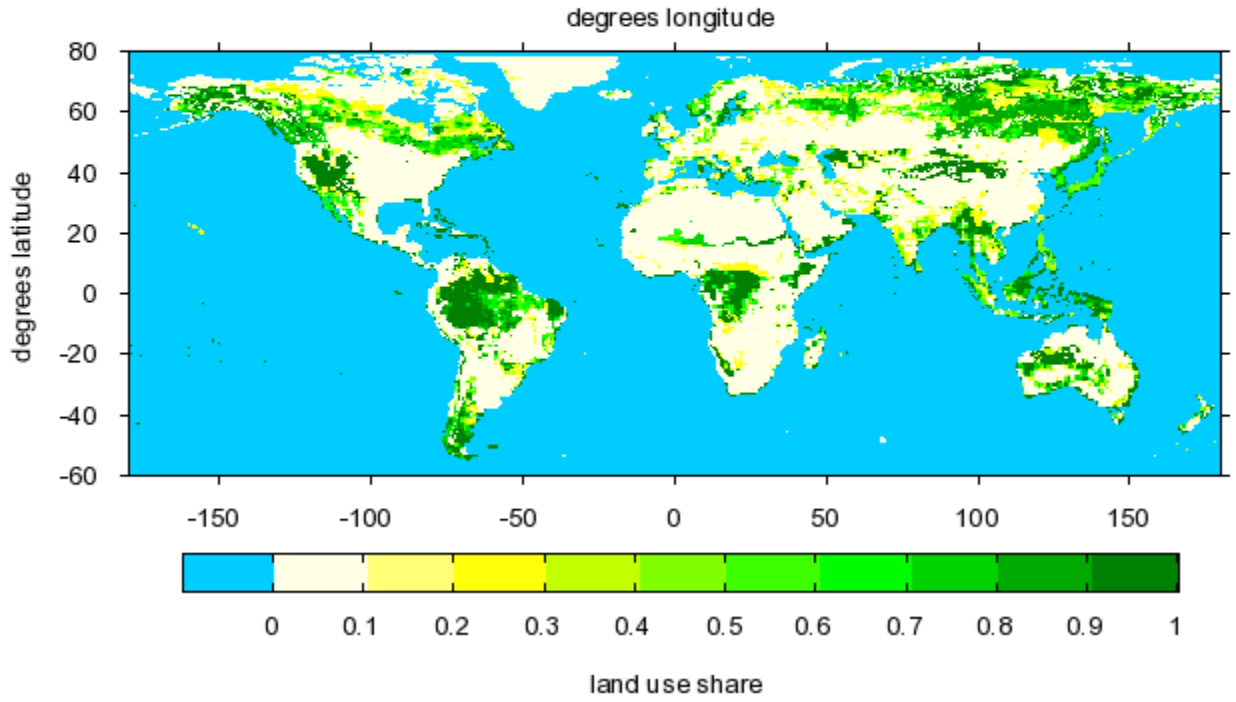

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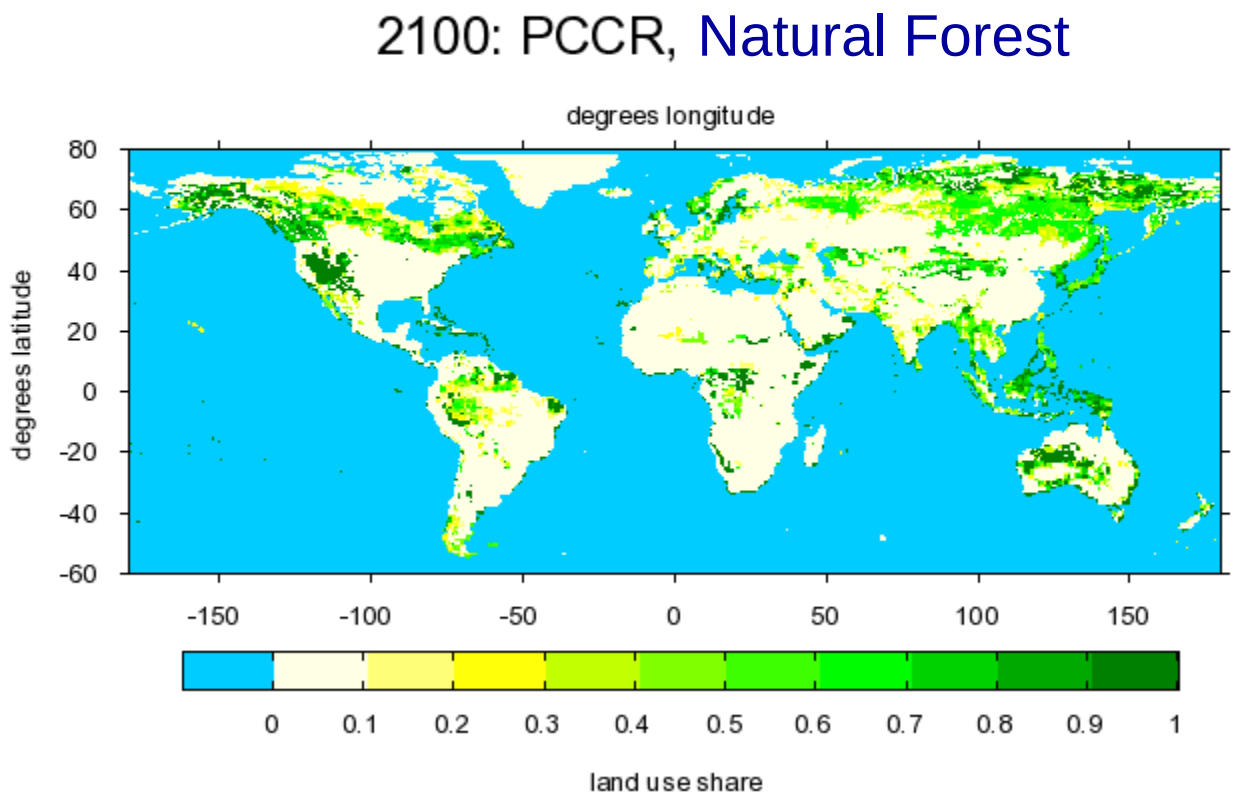

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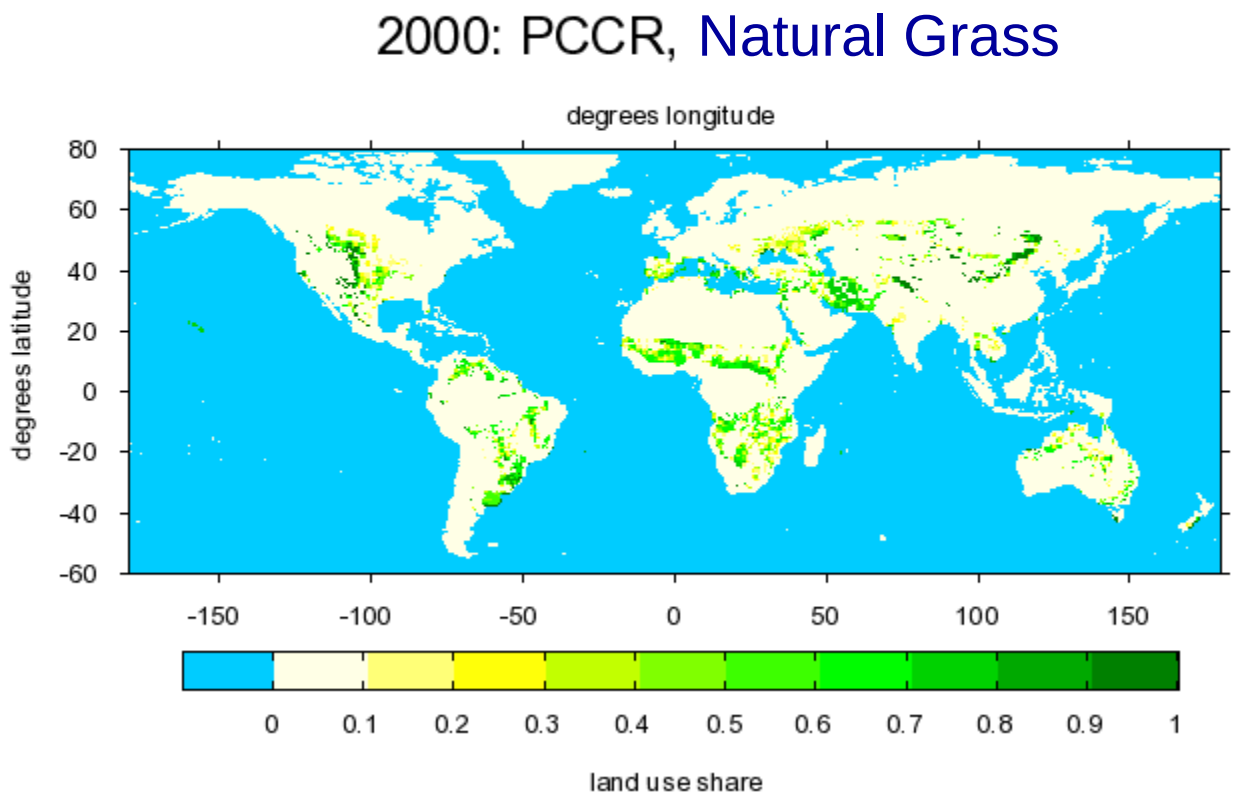

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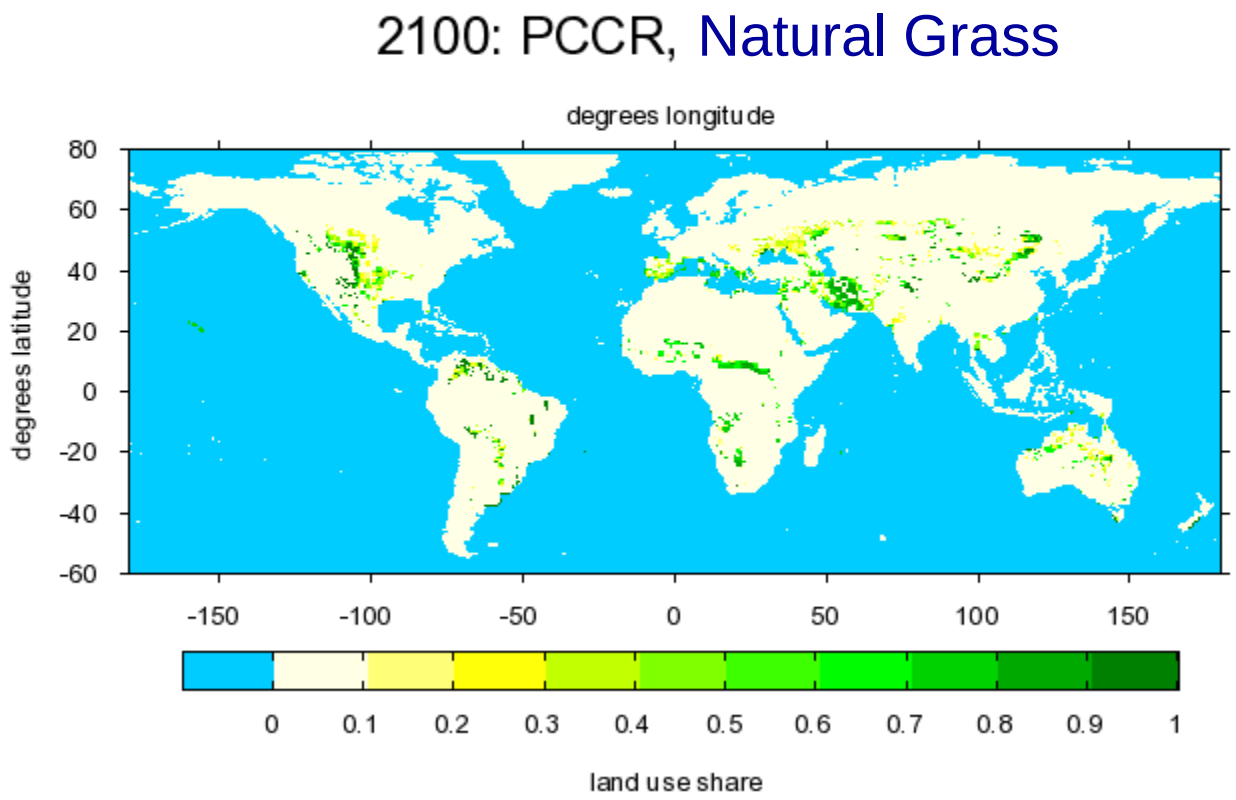
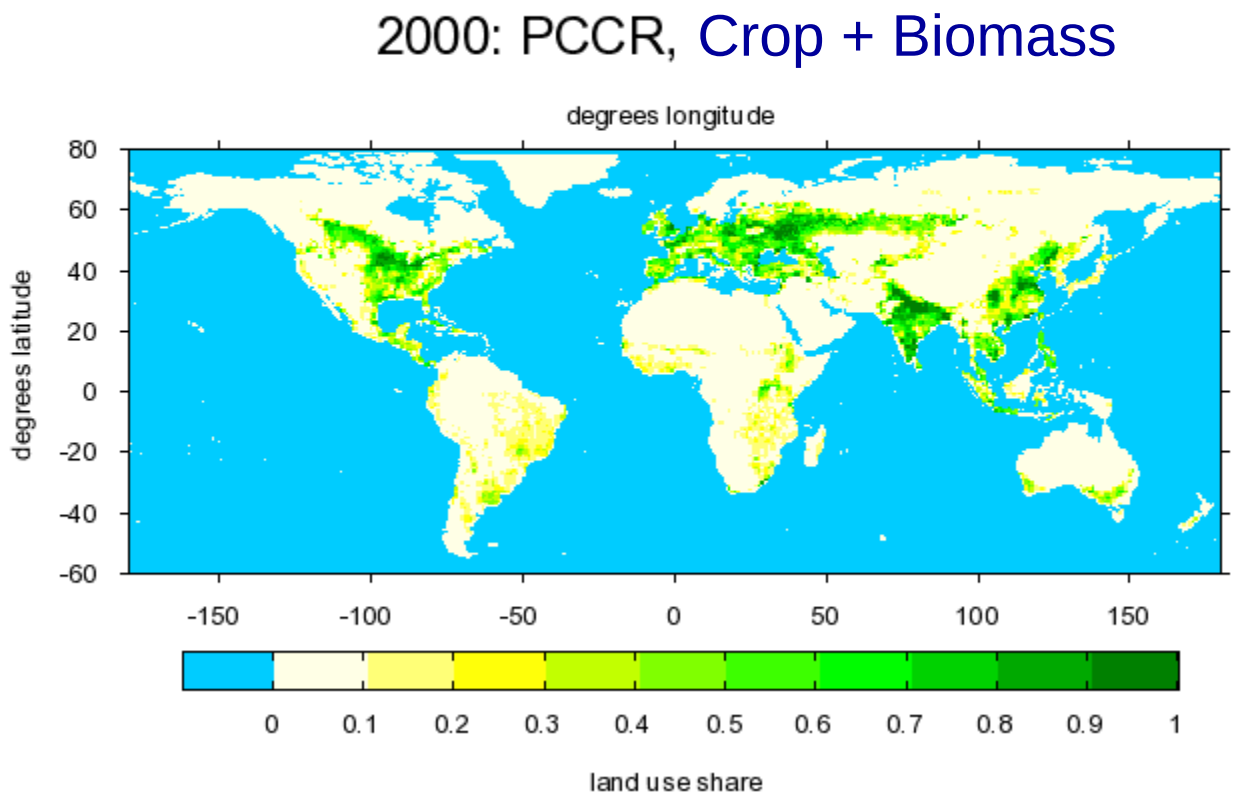
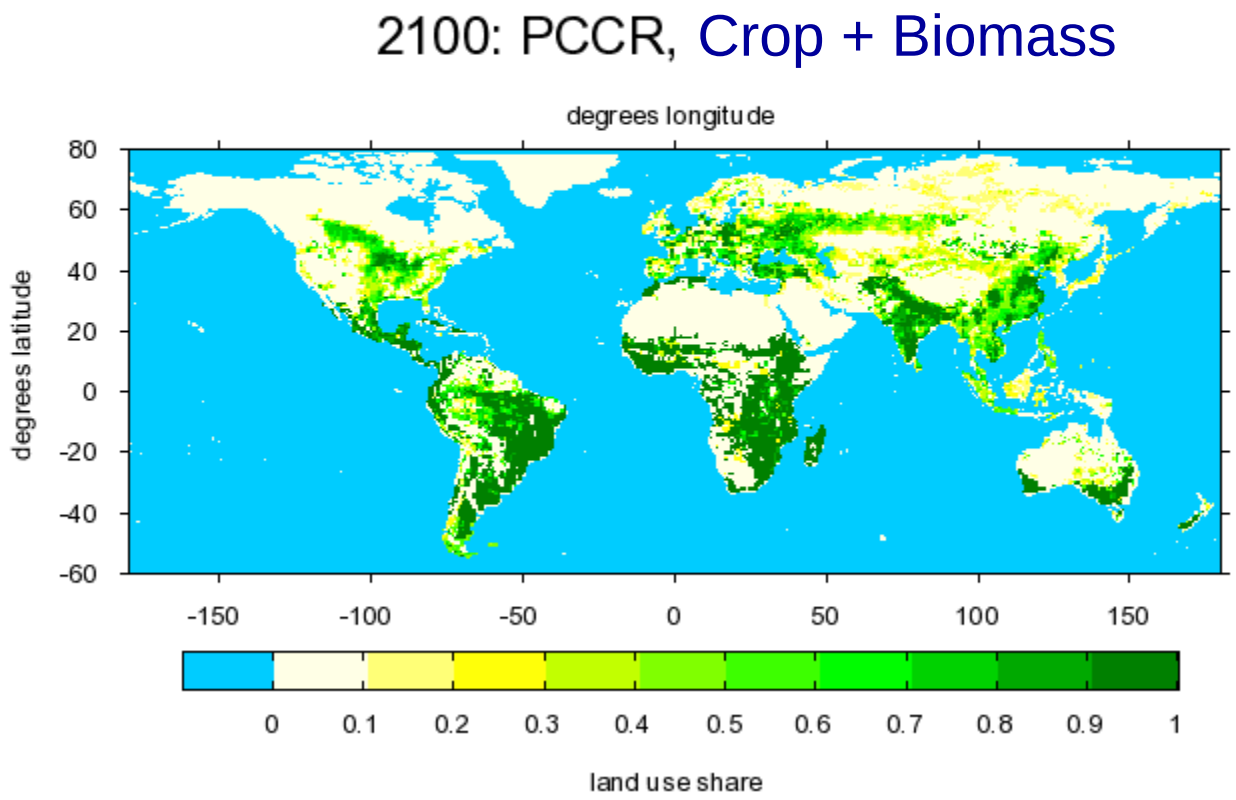


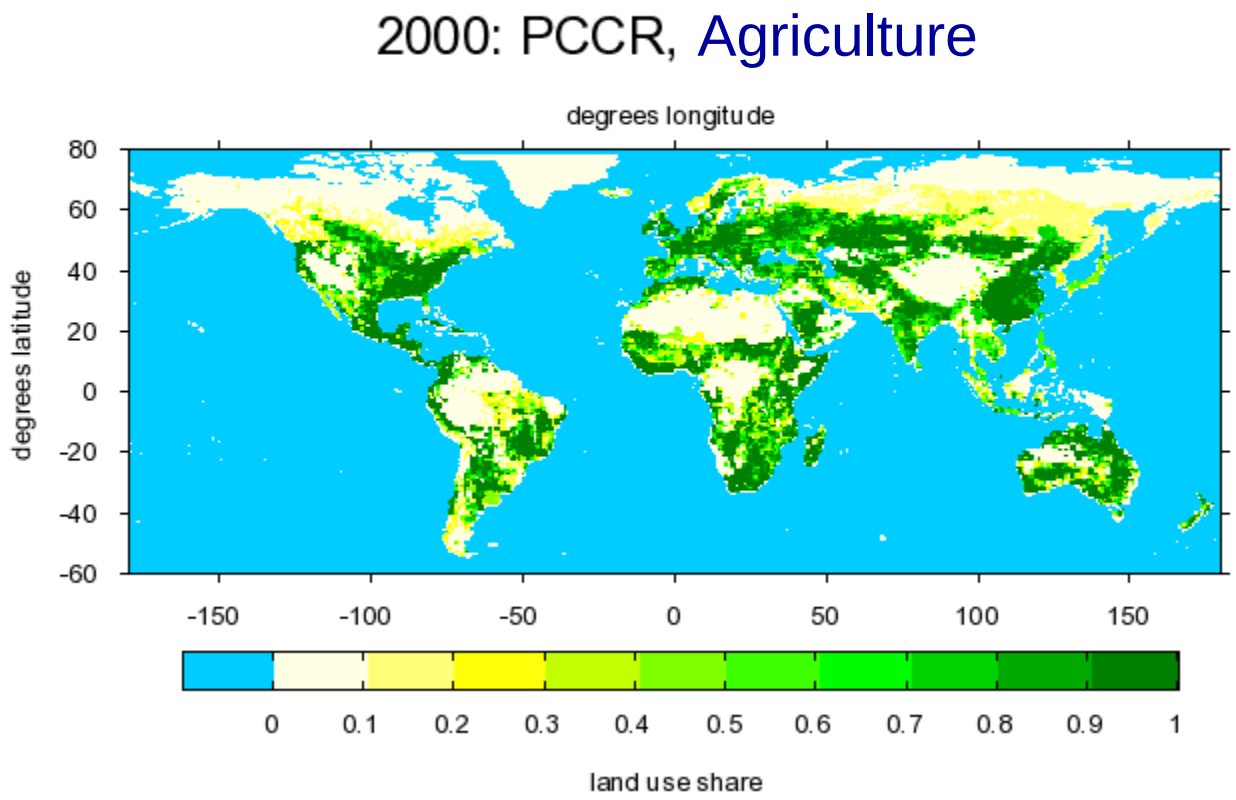
# Crop + Biomass ("Deforestation" Scenario)



# Crop + Biomass ("Deforestation" Scenario)



# Agriculture ("Deforestation" Scenario)



# Agriculture ("Deforestation" Scenario)