

# Indirect land use change impacts – Options for an adequate policy response

**Jerry Melillo**

**The Ecosystems Center, Marine Biological Laboratory**

**Woods Hole, MA USA**

+

# A study of direct and indirect effects of global cellulosic biofuels programs

- Used linked economic and terrestrial biogeochemistry models
- Projected direct and indirect effects of a cellulosic biofuels program over the 21<sup>st</sup> century
- Biofuels use promoted in response to a 550ppmv atmospheric CO<sub>2</sub> target with a cap and trade policy

# Summary Points

- Second generation biofuels have the potential to play an important role in the global energy mix in the 21<sup>st</sup> century, but environmental impacts could be large.
- Up to half of the world's forests could be lost.
- Indirect land use will be responsible for substantially more carbon loss (up to twice as much) than direct land use.
- Because of increased fertilizer use, nitrous oxide emissions will be more important than carbon losses in terms of warming potential over the century
- Most biofuels feedstocks will be grown in the tropical regions of the world where land is available and plant productivity is high.
- Africa and Latin America will be major biofuels areas, putting many biodiversity "hot spots" in peril

# Major features of EPPA and TEM

## EPPA

- Multiple regions - Globe divided into 16 economic regions
- Multiple fuels - Fossil, Nuclear, Wind, Solar, Biomass, Biofuels
- Multiple sectors – Industry, Transportation, Households, Agriculture, Forestry

## TEM

- Cycling of carbon, nitrogen, water
- Global land coverage, operates at 0.5°x0.5° spatial scale, monthly time step
- Spatial information on soils, vegetation, climate, elevation, N deposition, atmospheric chemistry (carbon dioxide, tropospheric ozone)

<http://web.mit.edu/globalchange/>

Reports 145 and 168

# Climate Policy

- **An aggressive climate policy – 550 ppmv with specific emissions by region**
- **Cap and Trade:**
  - **developed countries reduce emissions (linearly) to 50% of 1990 levels by 2050;**
  - **Developing countries reduce emissions from 2025 to 2035 to the levels in 2015, and after reduce to 2000 levels;**
  - **CO<sub>2</sub> emissions from land use not considered as part of the cap and trade policy**
- **Emissions 60% of BAU 2010-2050 emissions and 40% of BAU 2050-2100, consistent with 550 ppmv goal**
- **Free trade in biofuels**

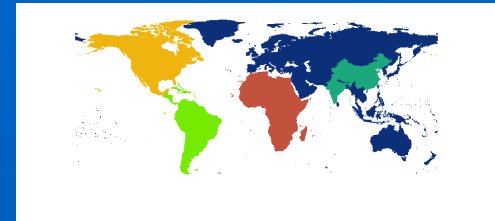
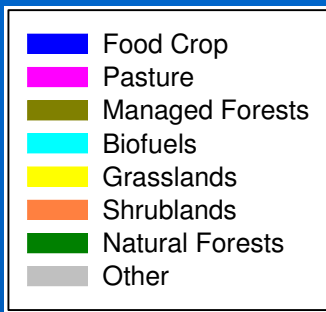
# Two Land-use Options

- **Case 1 - “Deforestation Scenario” - makes land use decisions purely on conversion costs – the value of converting land is greater than the cost of conversion**
- **Case 2 - “Intensification Scenario” - limits land conversion based on observed regional land supply responses (deforestation often not first choice)**

Gurgel et al. 2007 <http://bepress.com/jafio/vol5/iss2/art9>

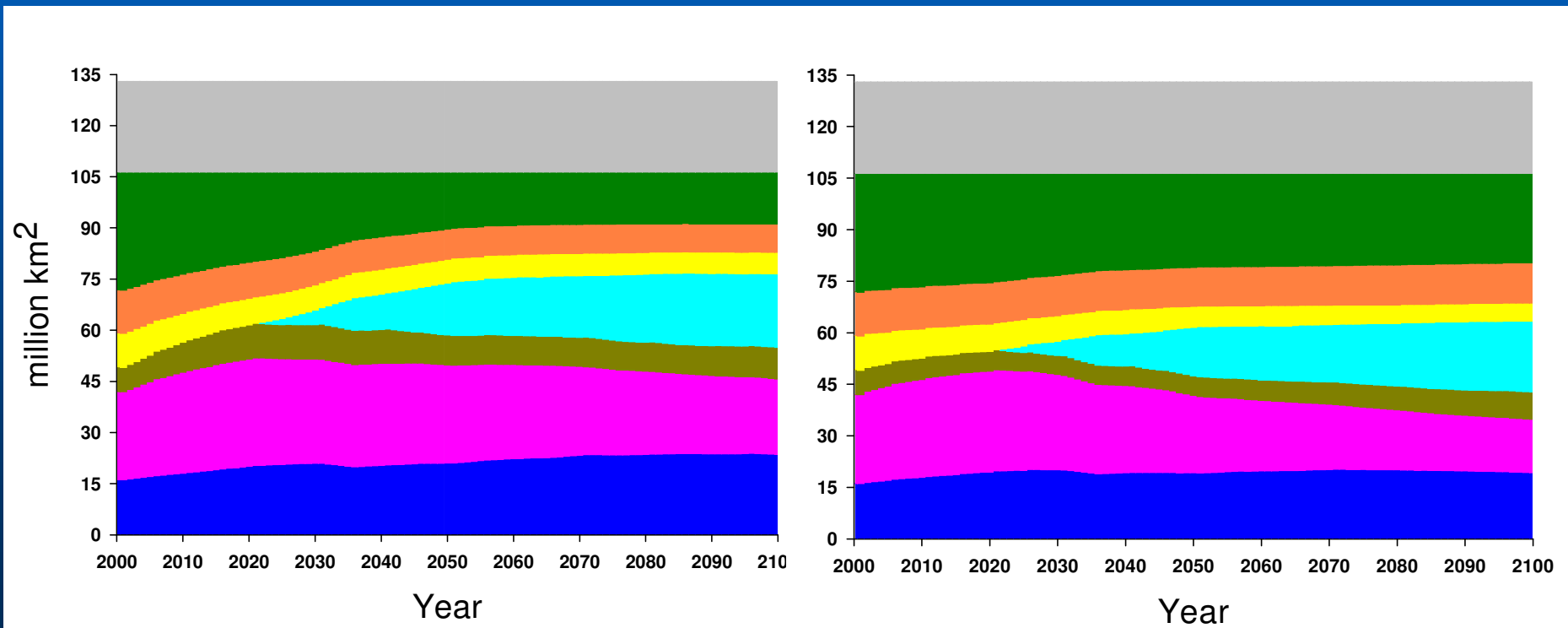
Melillo et al. *Science* 2009

# Global land-share changes (2000-2100)



## Case 1 - Deforestation

## Case 2 - Intensification



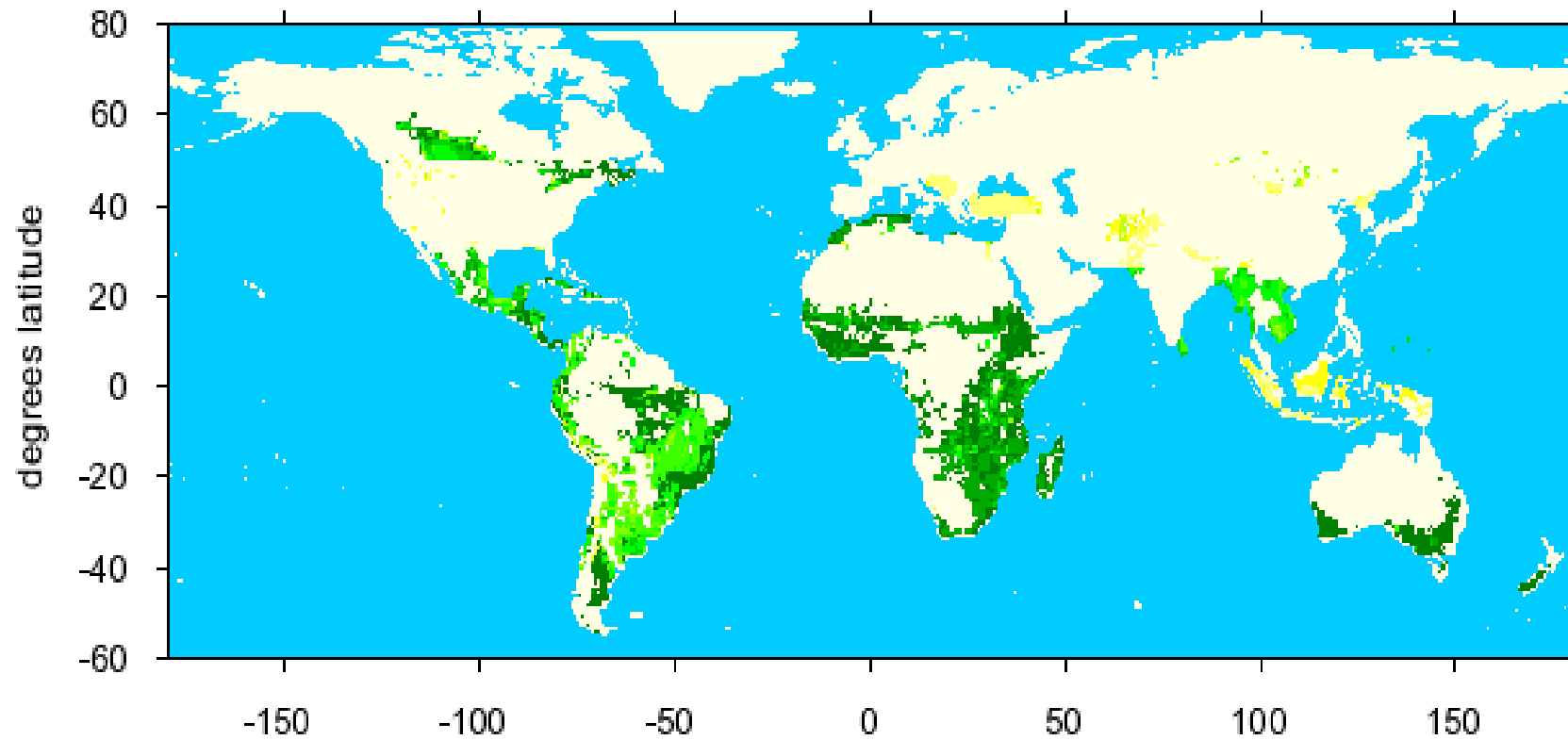
# Case 1- Deforestation: Changes in Land-share Areas Over the 21<sup>st</sup> Century

(millions of square kilometers)

Year	Food Crops	Pastures	Biofuel Crops	Forests	Shrublands	Grasslands	Other
<b>2000</b>	16.1	25.8	0.0	41.7	12.7	10.0	26.7
<b>2030</b>	20.9	30.6	4.3	33.3	9.9	7.4	26.7
<b>2050</b>	21.0	28.8	15.3	25.5	8.9	6.9	26.7
<b>2080</b>	23.6	24.4	20.0	23.6	8.4	6.4	26.7
<b>2100</b>	23.6	22.1	21.6	24.4	8.4	6.3	26.7

2100: PCCR

degrees longitude



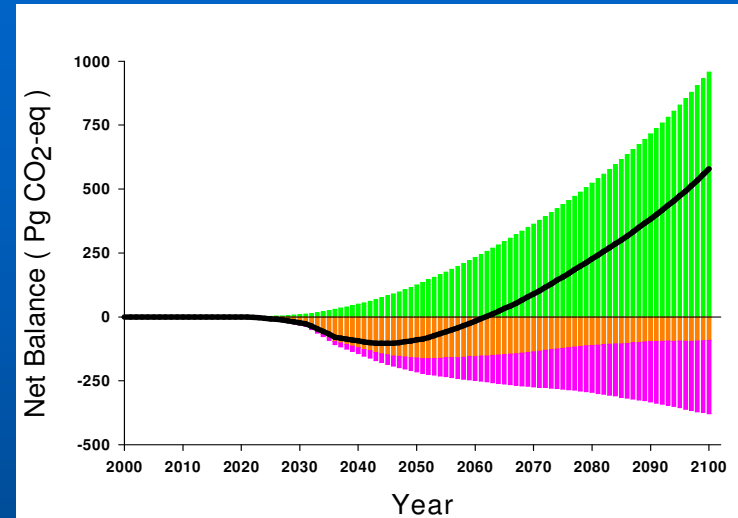
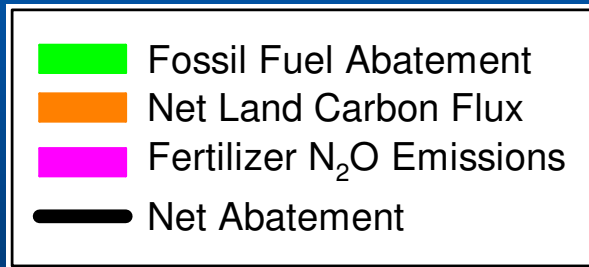
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

biofuel land use share  
biofuel land use share

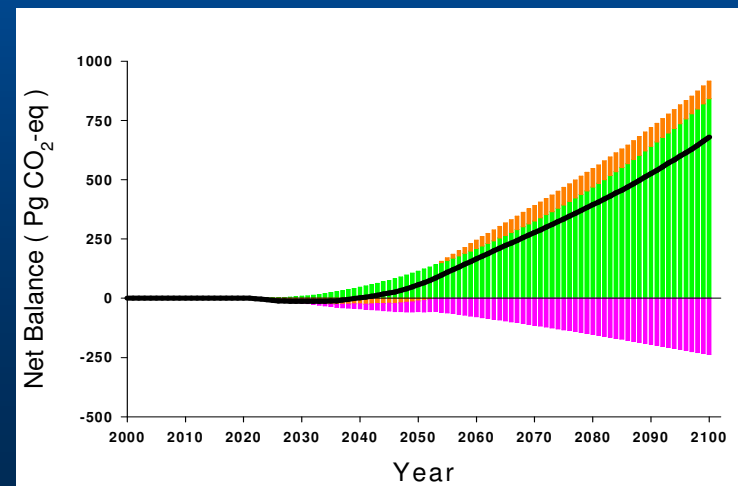


# GHG Balance - global

## Case 1 - Deforestation Scenario



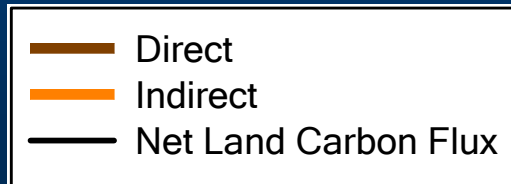
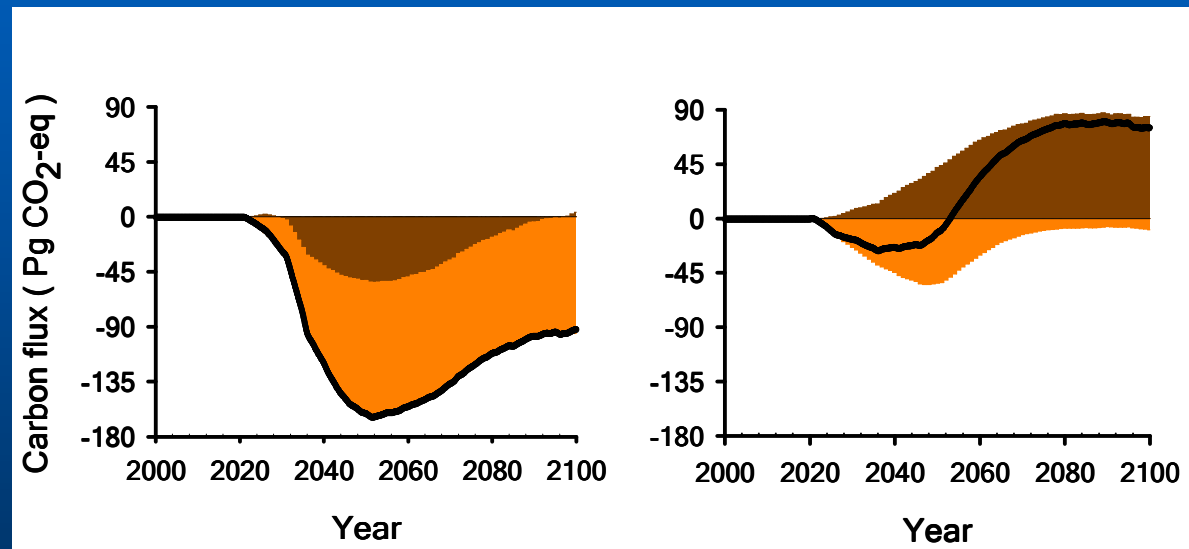
## Case 2 - Intensification Scenario



# Partitioning of Net Land Carbon Flux

Case 1

Case 2



# Conclusions

- **Second generation biofuels have the potential to play an important role in the global energy mix in the 21<sup>st</sup> century, but environmental impacts could be large.**
- **Up to half of the world's forests could be lost.**
- **Indirect land use will be responsible for substantially more carbon loss (up to twice as much) than direct land use.**
- **Because of increased fertilizer use, nitrous oxide emissions will be more important than carbon losses in terms of warming potential**
- **Most biofuels feedstocks will be grown in the tropical regions of the world where land is available and plant productivity is high.**
- **Africa and Latin America will be major biofuels areas, putting many biodiversity "hot spots" in peril**



# Conclusions 2

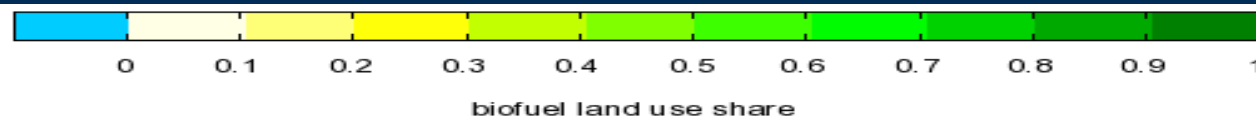
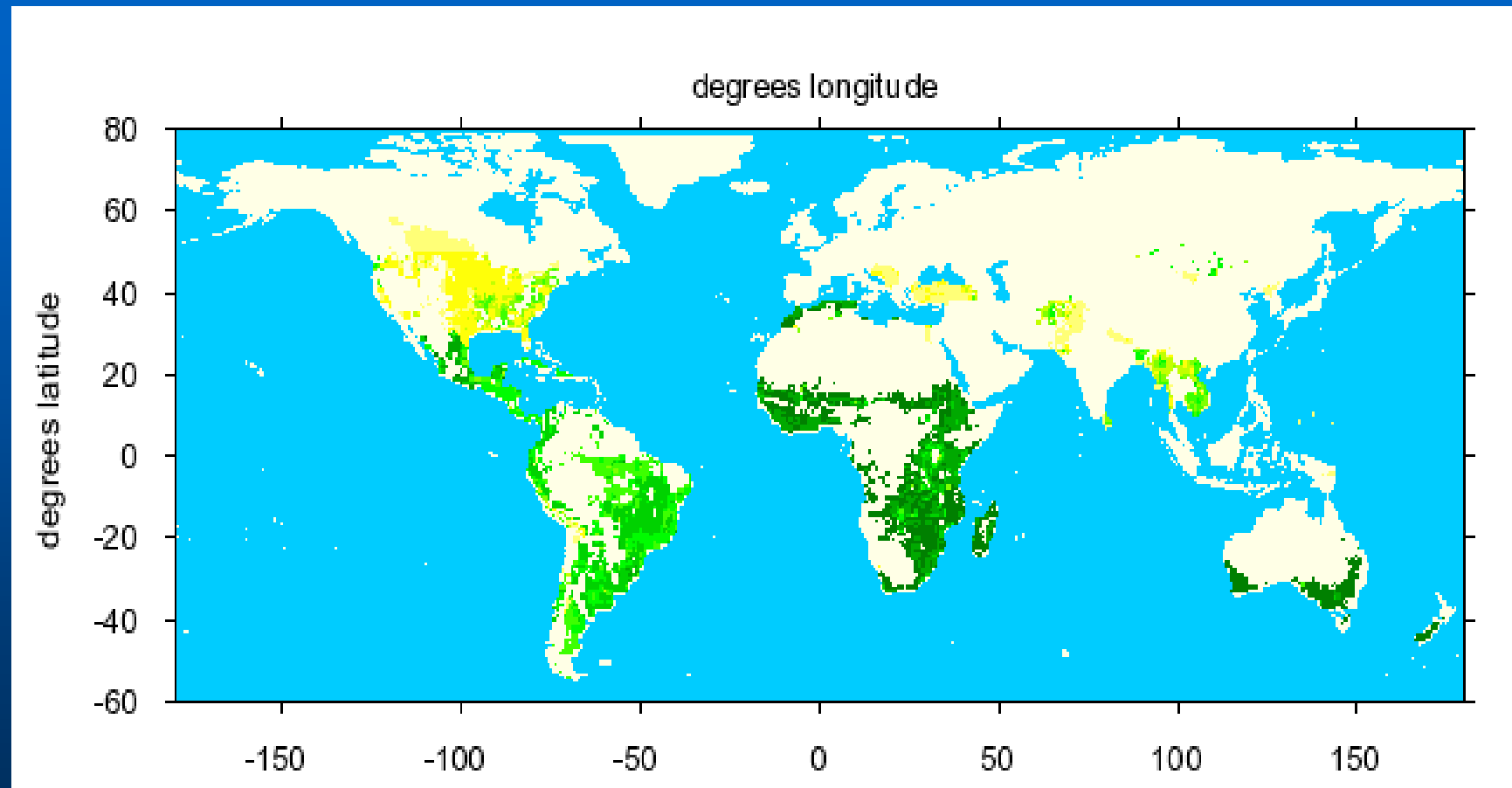
- **Where, what and how biofuels feedstocks are grown determines environmental impacts:**
  - **Avoid clearing of forests to grow feedstocks so a large “carbon debt” is not incurred**
  - **Realize that the use of abandoned or marginal lands for growing biofuels feedstocks may require substantial inputs of nutrients (e.g., nitrogen) and water, and these must be part of cost/benefits analyses**
  - **Appropriate selection of feedstocks can reduce input requirements (e.g., jatropha in drier places)**

# Case 2 - Intensification: Changes in Land-share Areas Over the 21<sup>st</sup> Century (millions of square kilometers)

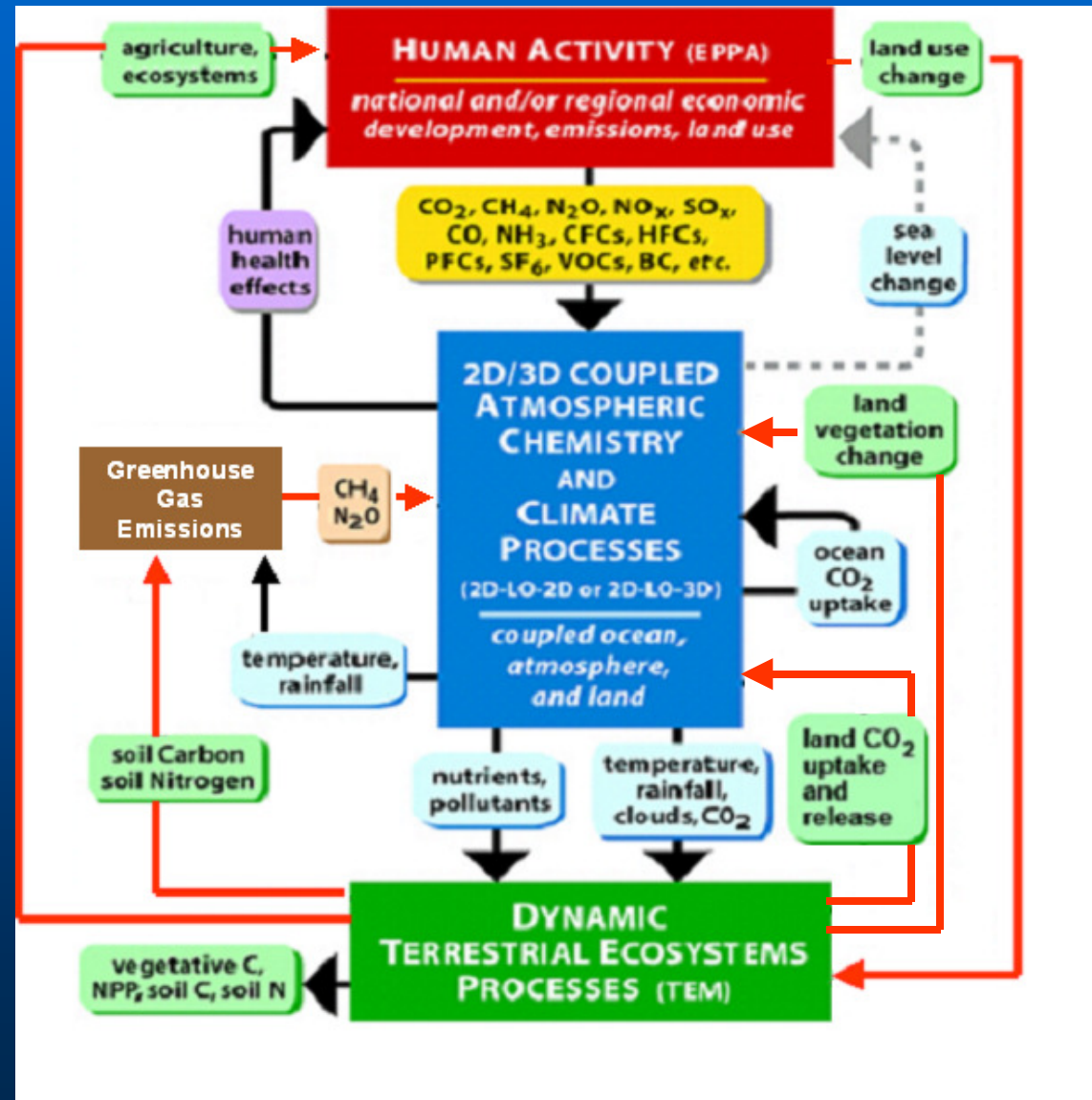
Year	Food Crops	Pastures	Biofuel Crops	Forests	Shrublands	Grasslands	Other
2000	16.1	25.8	0.0	41.7	12.7	10.0	26.7
2030	20.1	27.8	4.2	35.2	11.7	7.4	26.7
2050	19.2	22.6	14.1	32.9	11.4	6.1	26.7
2080	20.1	17.5	18.3	33.4	11.5	5.4	26.7
2100	19.2	15.5	20.6	33.9	11.7	5.3	26.7

# Biofuels land share in 2100

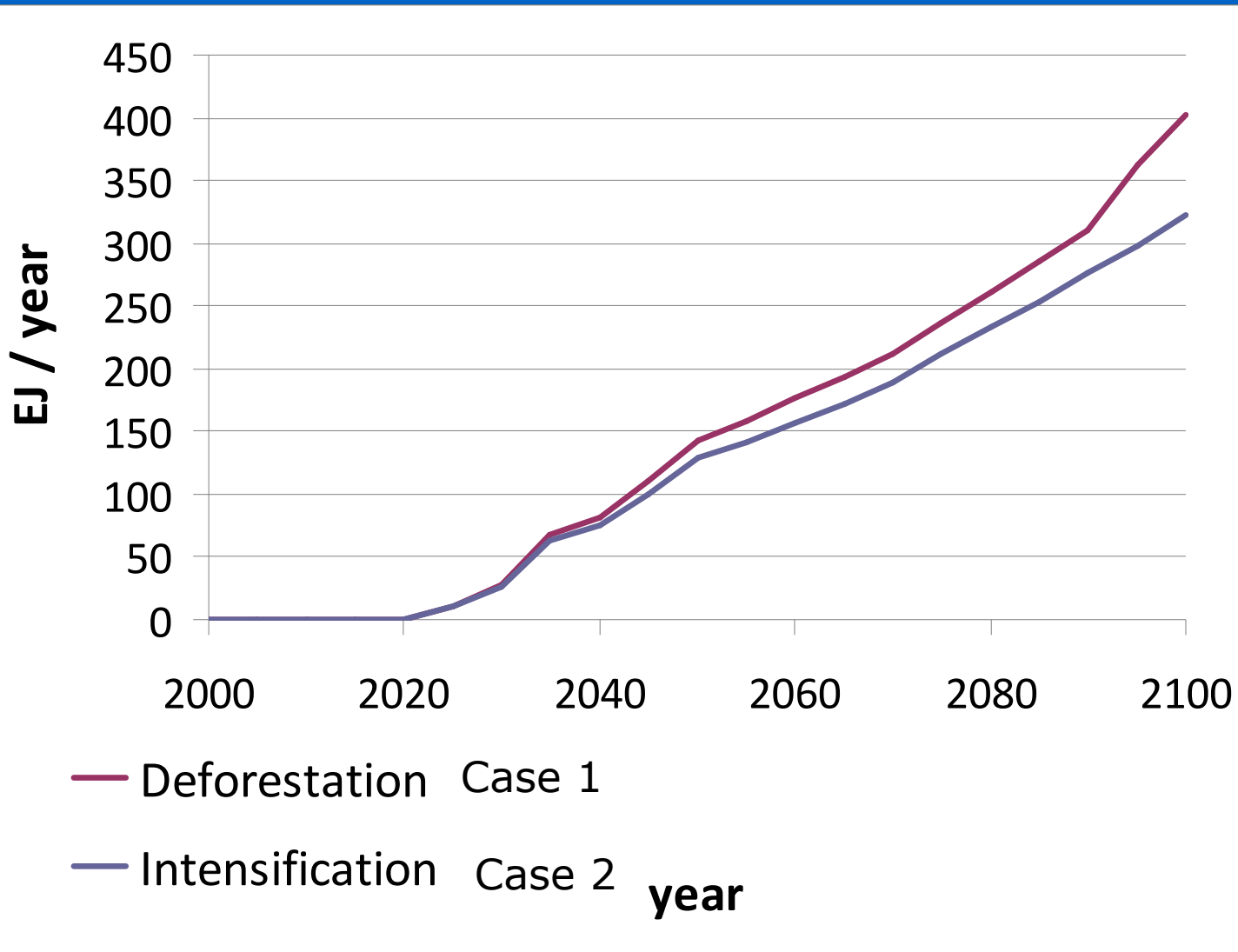
Case 2 - Intensification



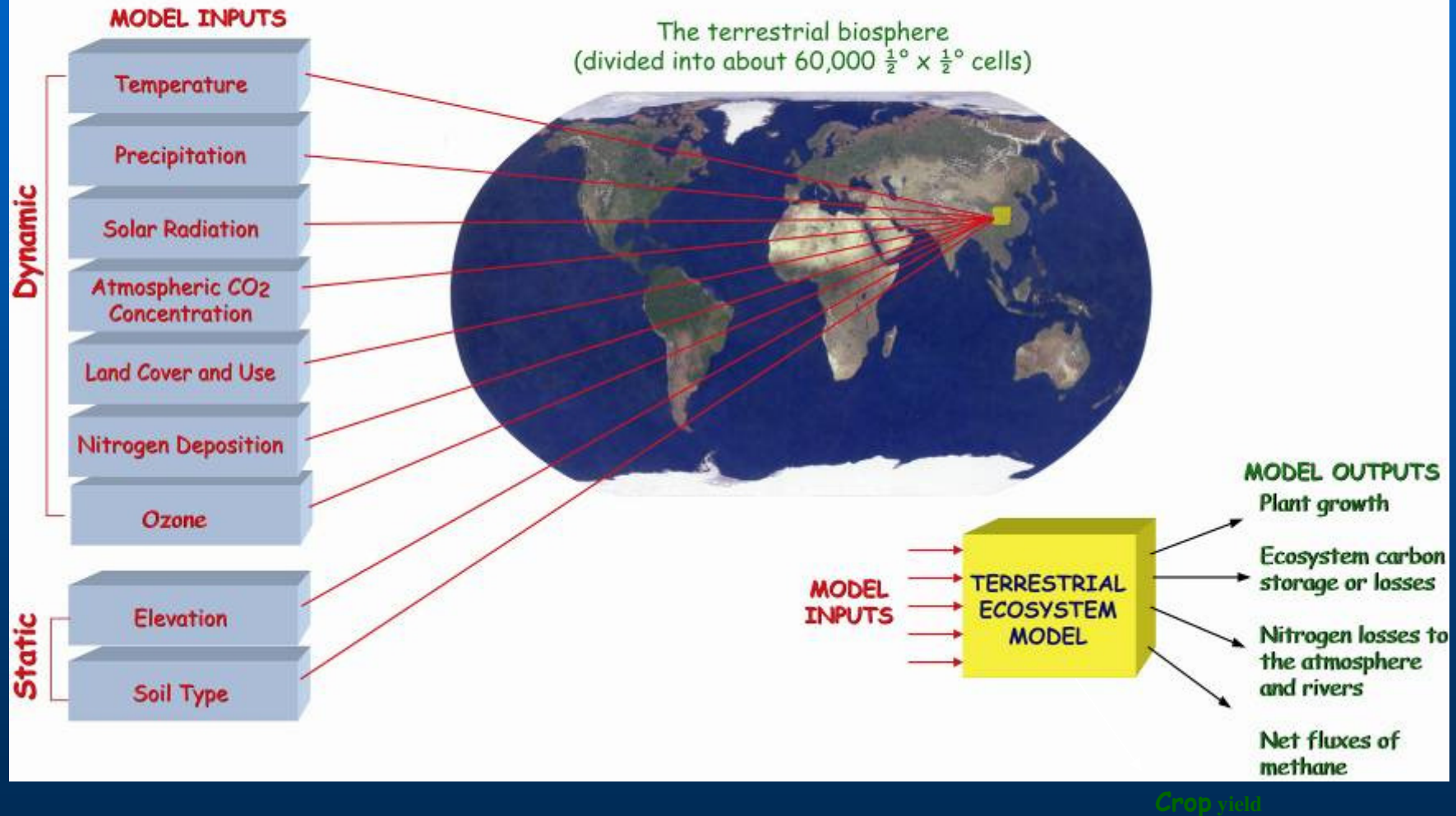
# MIT Integrated Global System Model



# Energy from Biofuels

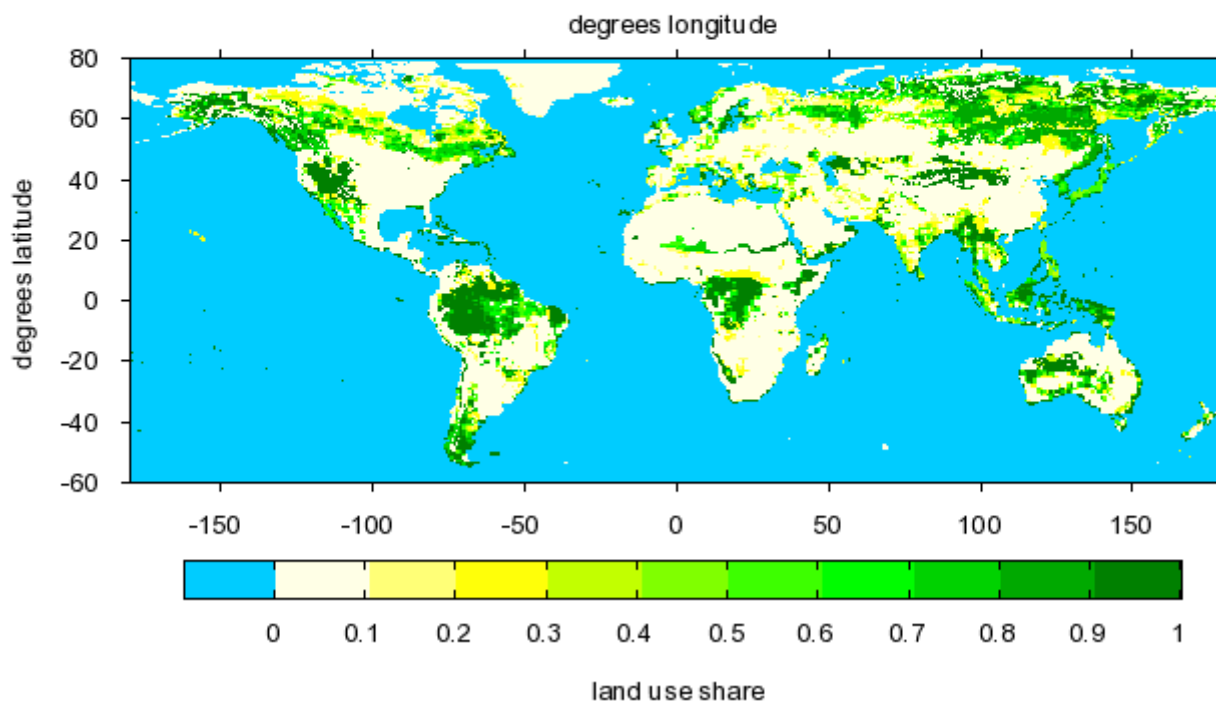


# MODELING GLOBAL BIOGEOCHEMISTRY



# Natural Forest (Melillo et al. 2009)

2000: PCCR, Natural Forest



11<sup>th</sup> Annual Conference on Global Economic Analysis



# Natural Forest (“Deforestation” Scenario)

2050: PCCR, Natural Forest

