International Institute for Applied Systems Analysis
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science for global insight

Land use change projections – linking economic constraints and constraints of the physical environment

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[2] *BoKU University (Vienna), CSIRO (Australia), etc.*

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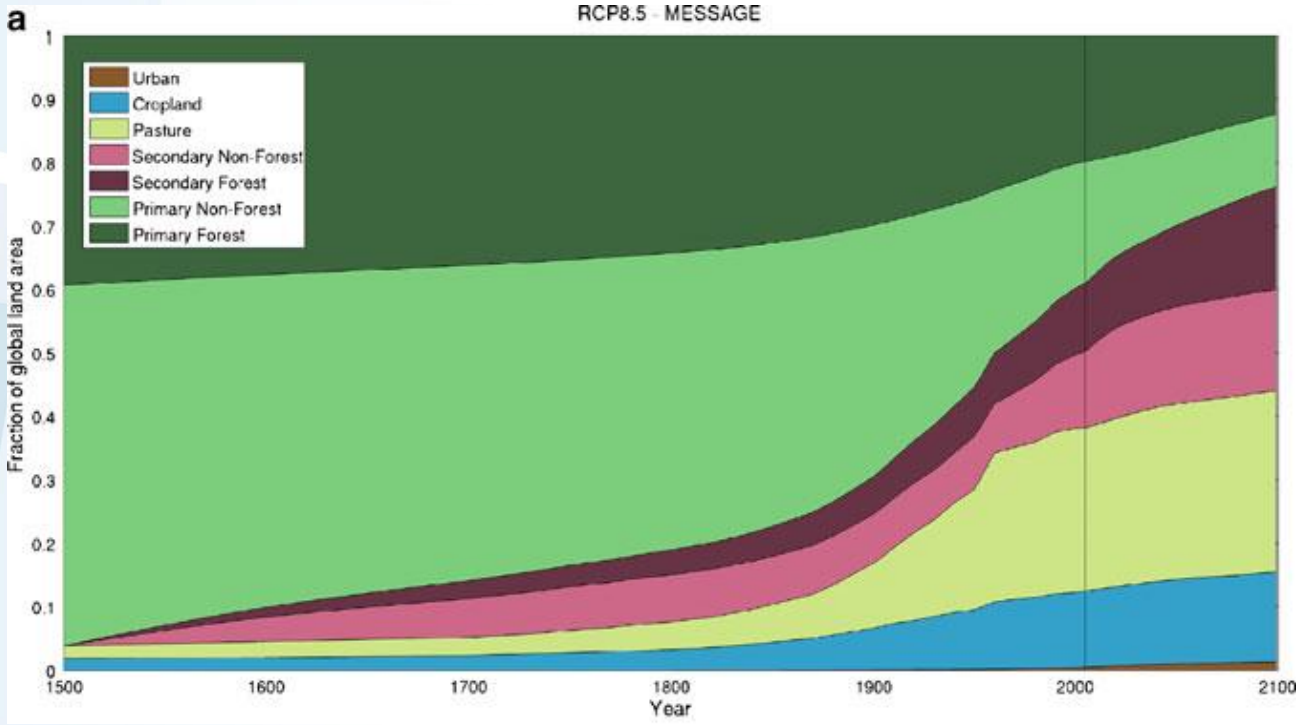
* leclere@iiasa.ac.at

Introduction

- What land use are we talking about?



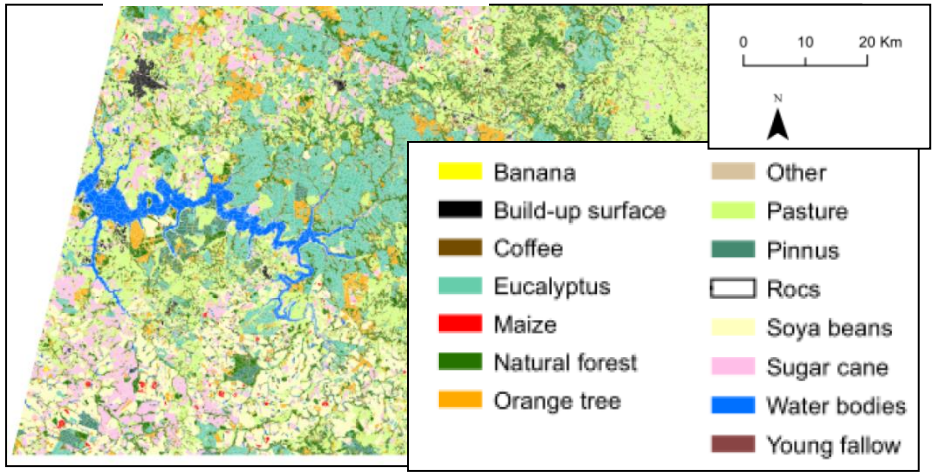
Hurtt et al. (2011)

Introduction

- What land use are we talking about?

JECAM annual report 2015

Sao Paolo site, Dec. 2014



Introduction

- What land use are we talking about?
- Mostly focused on global & long term land use modeling tools
  - Spatial scales: 50 km to global scale
  - Temporal scales: decades, to 2030 or more
  - Thematic scales: most important crops to broad land covers

Introduction

- What land use are we talking about?
- Mostly focused on global & long term land use modeling tools
- An overview of such tools:
  - Key economic & biophysical aspects accounted for?
  - Opportunities & limits in using such projections?

Introduction

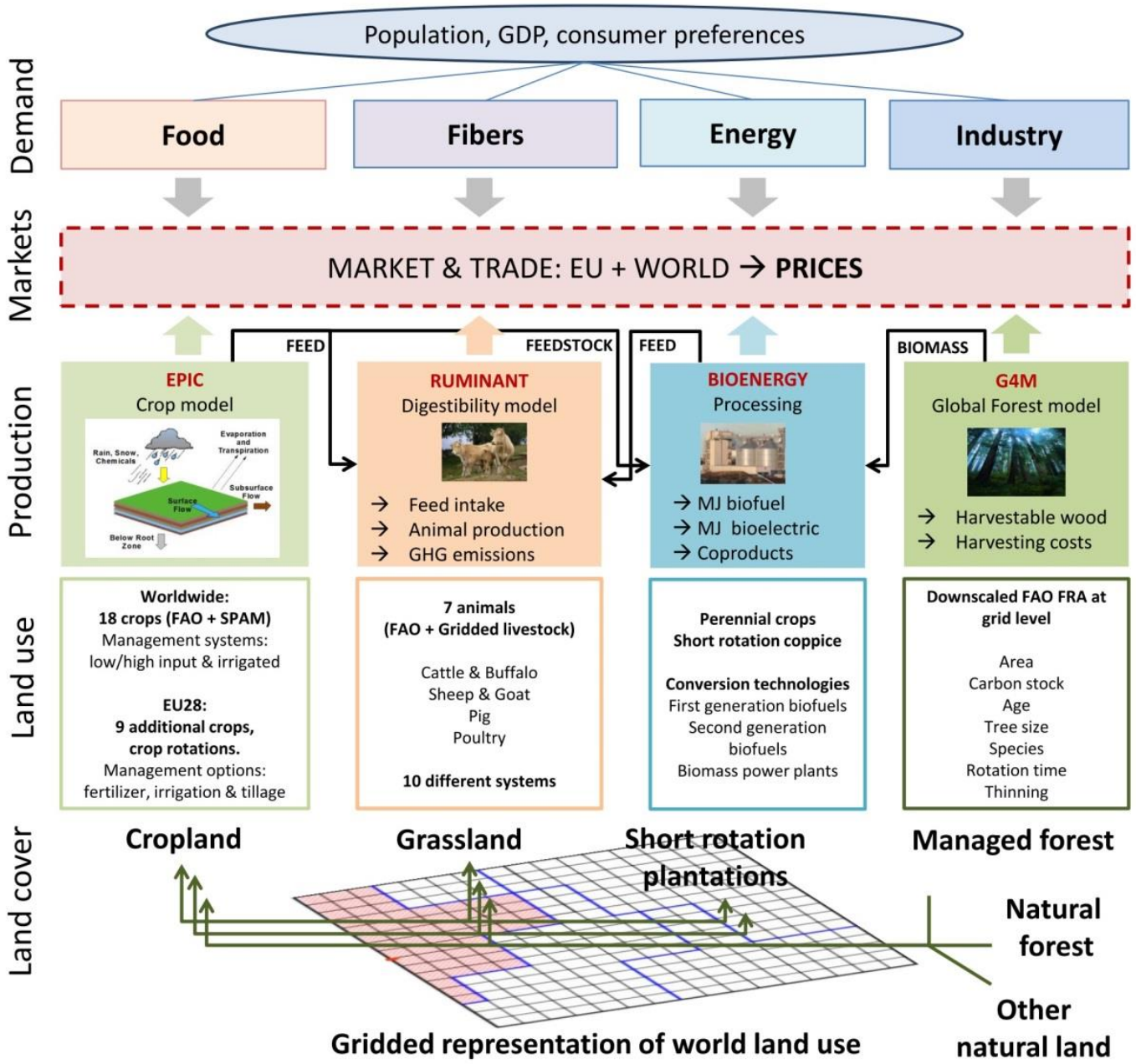
- What land use are we talking about?
- Mostly focused on global & long term land use modeling tools
- An overview of such tools
- Mostly focused on one modeling tool as an example:
  - The GLOBIOM land use model

What are the key economic and biophysical aspects for projecting land use change?

Key aspects for land use change projections

What is inside 

?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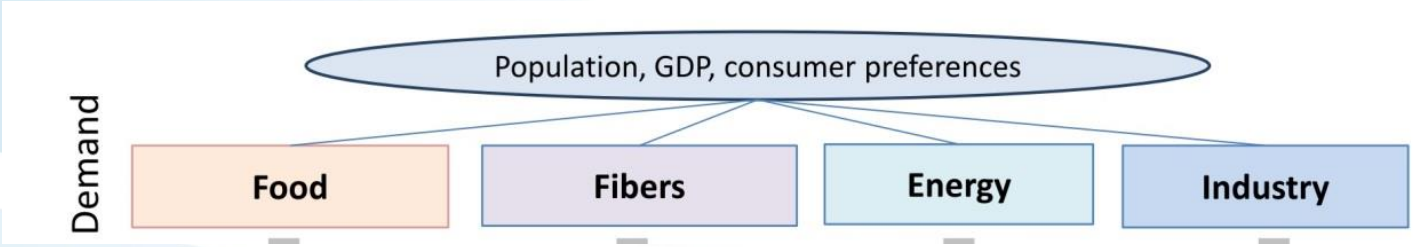
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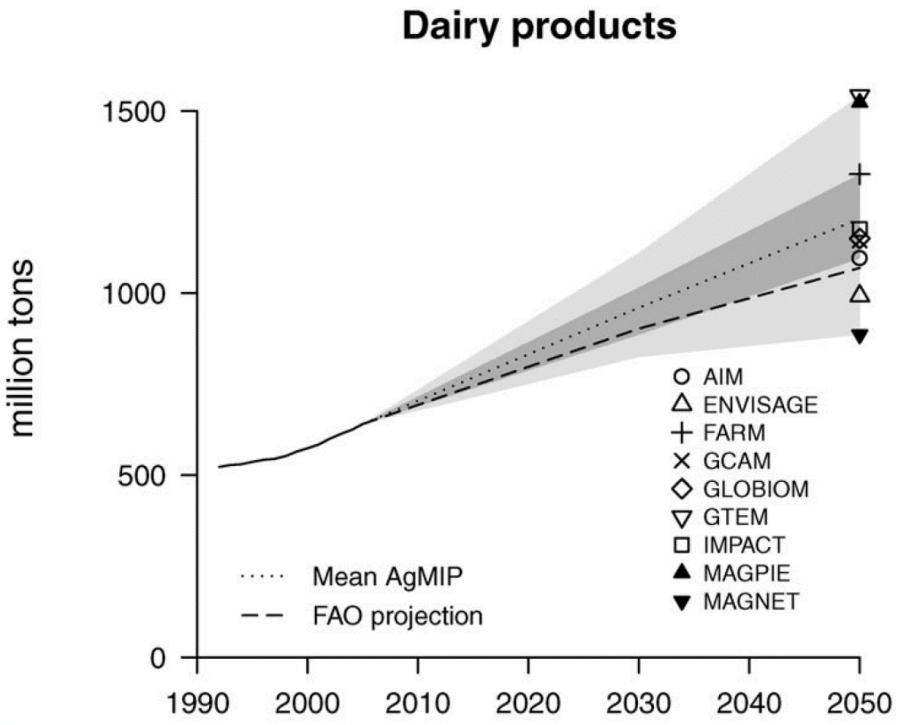
Industry

Key aspects for land use change projections

- demands from land (food, feed, bioenergy, etc.)

Historical statistics + econometric models + Projections (population, GDP)

Valin et al. (2014)



Key aspects for land use change projections

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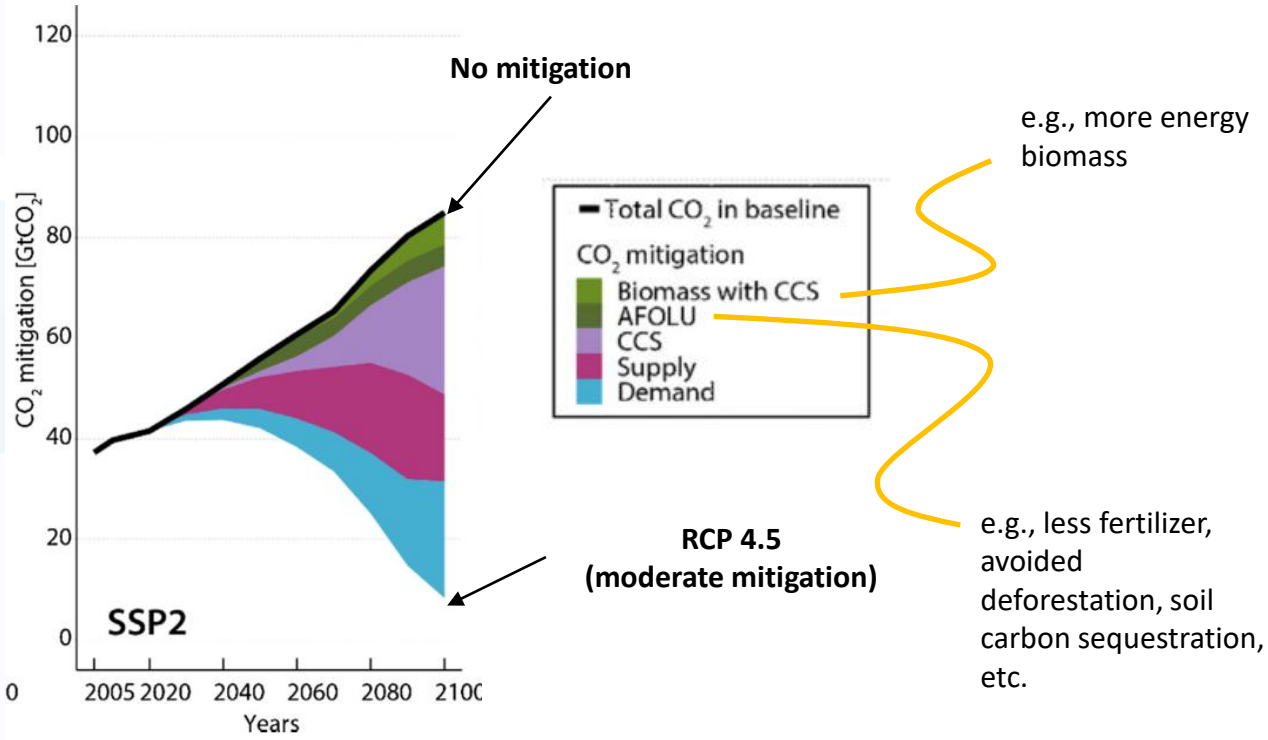
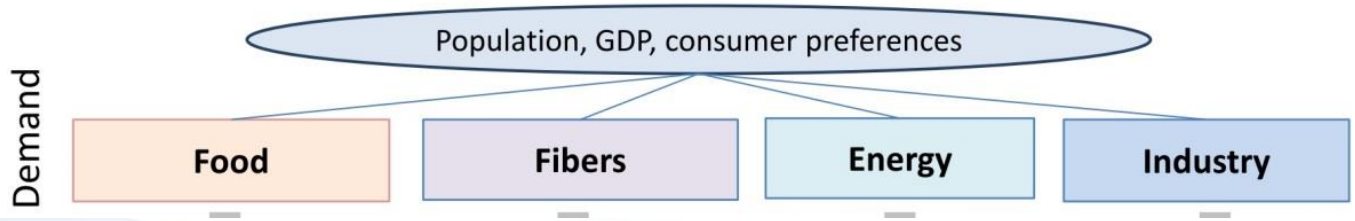
Coupling of land and energy models

Fricko et al. (2016)

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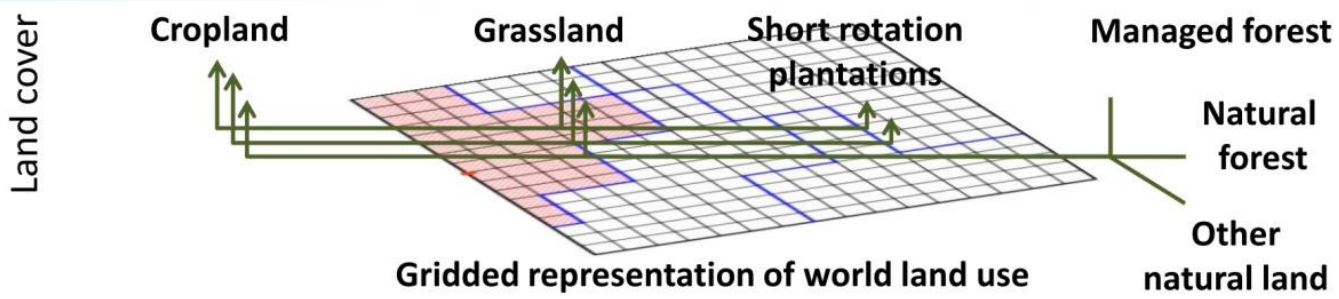
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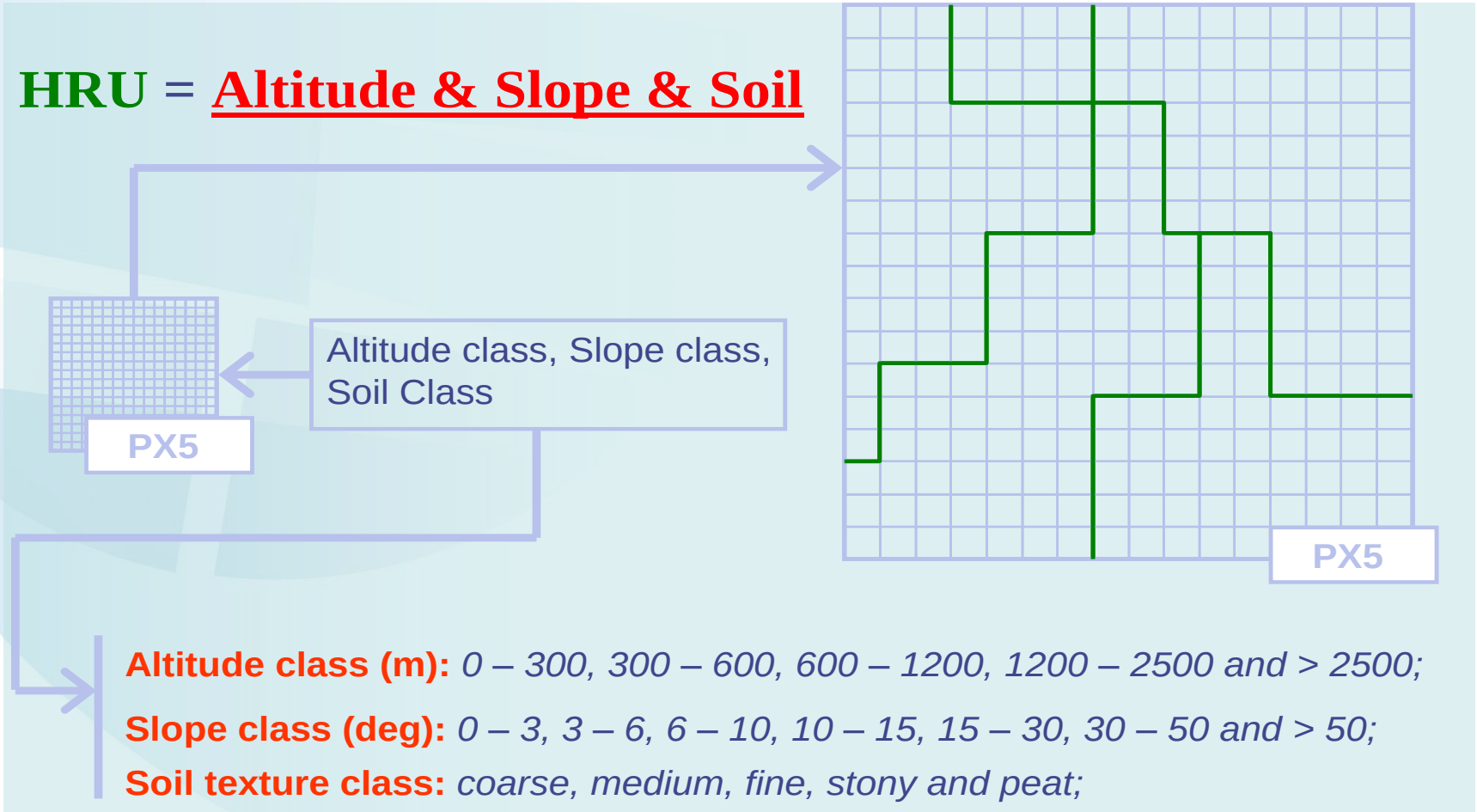
Key aspects for land use change projections

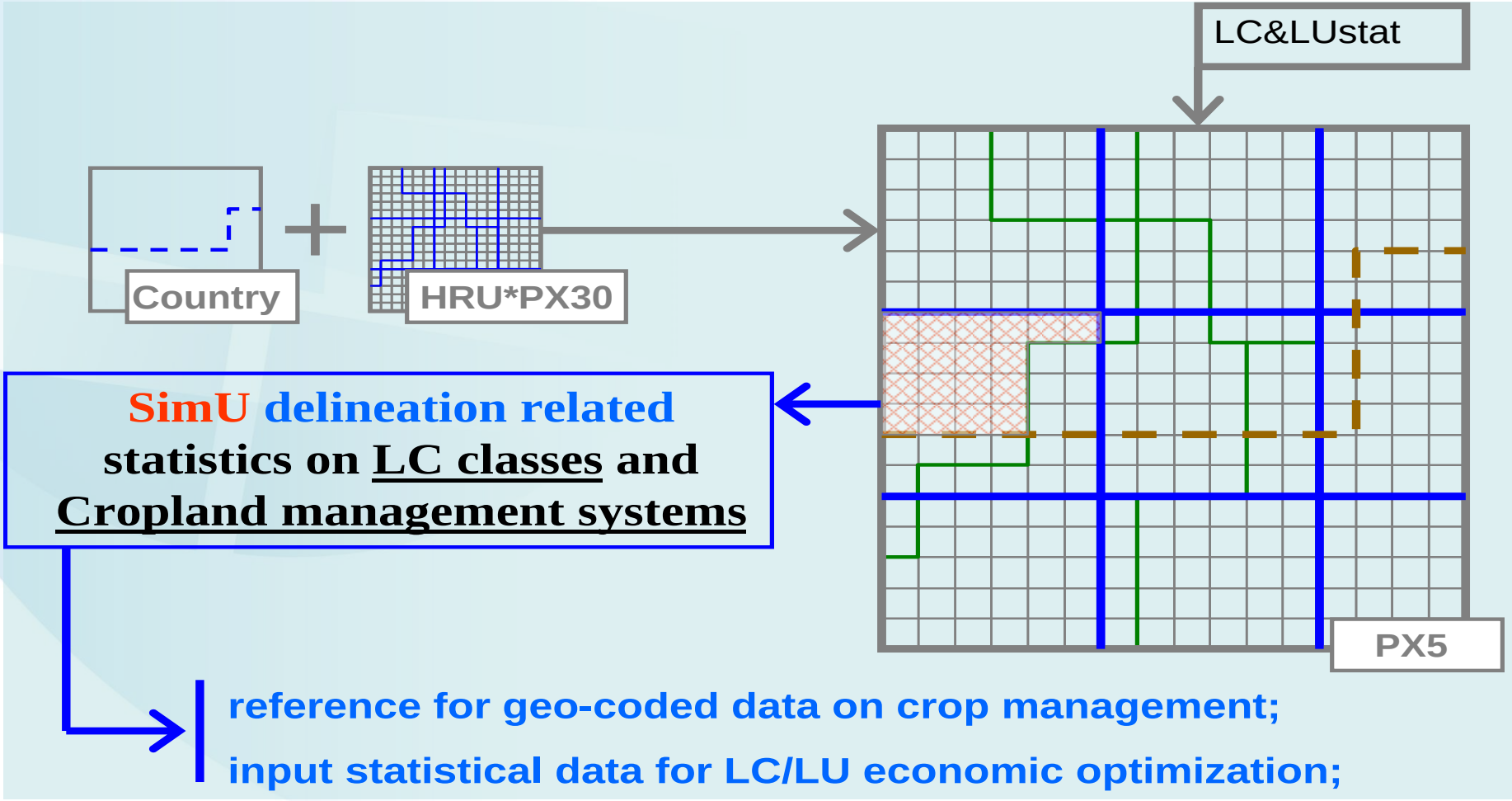
Homogeneous response units (HRU) – clusters of 5 arcmin pixels



Skalský et al. (2008)

Key aspects for land use change projections

Simulation Units (SimU) = HRU & PX30 & Country zone



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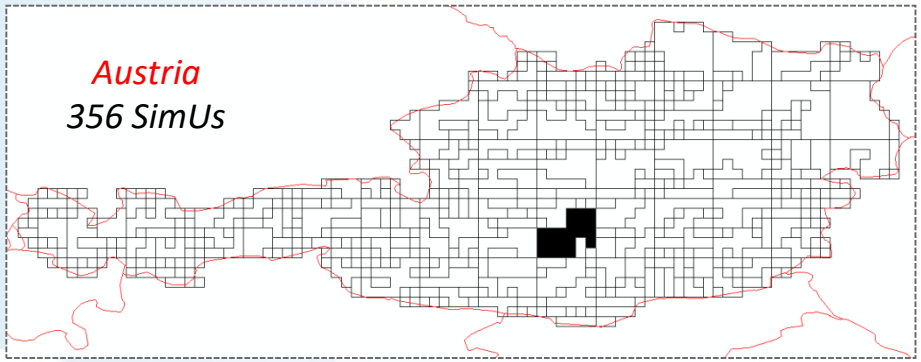
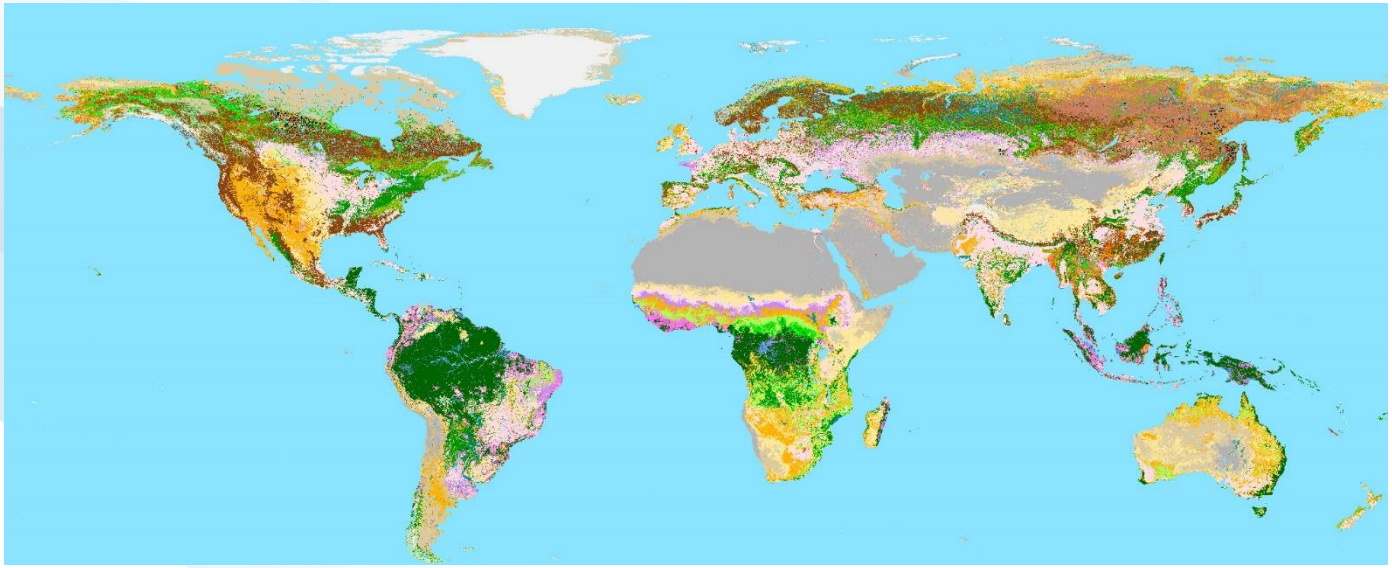


Representation of land heterogeneity

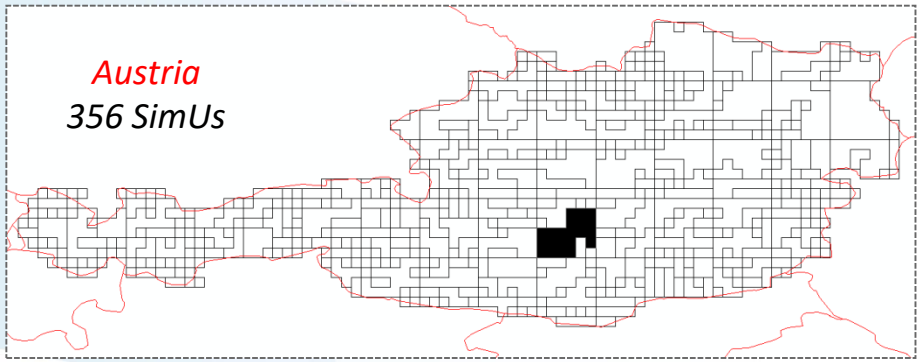
> 200,000 Simulation units globally



Initial land cover

Global Land Cover (GLC) 2000 *JRC*

Key aspects for land use change projections



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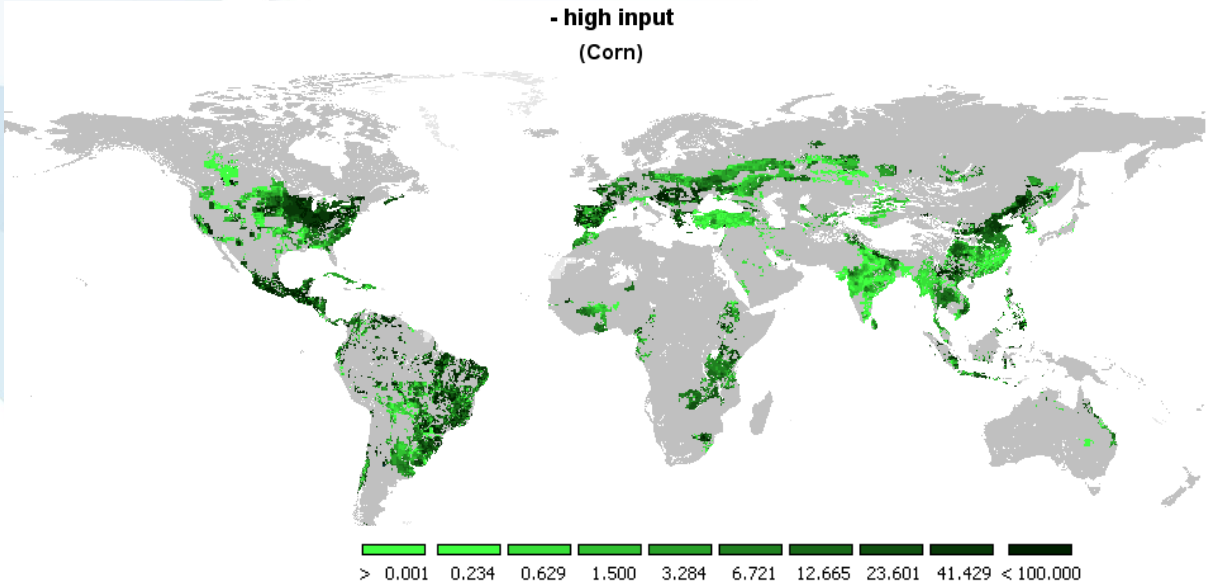
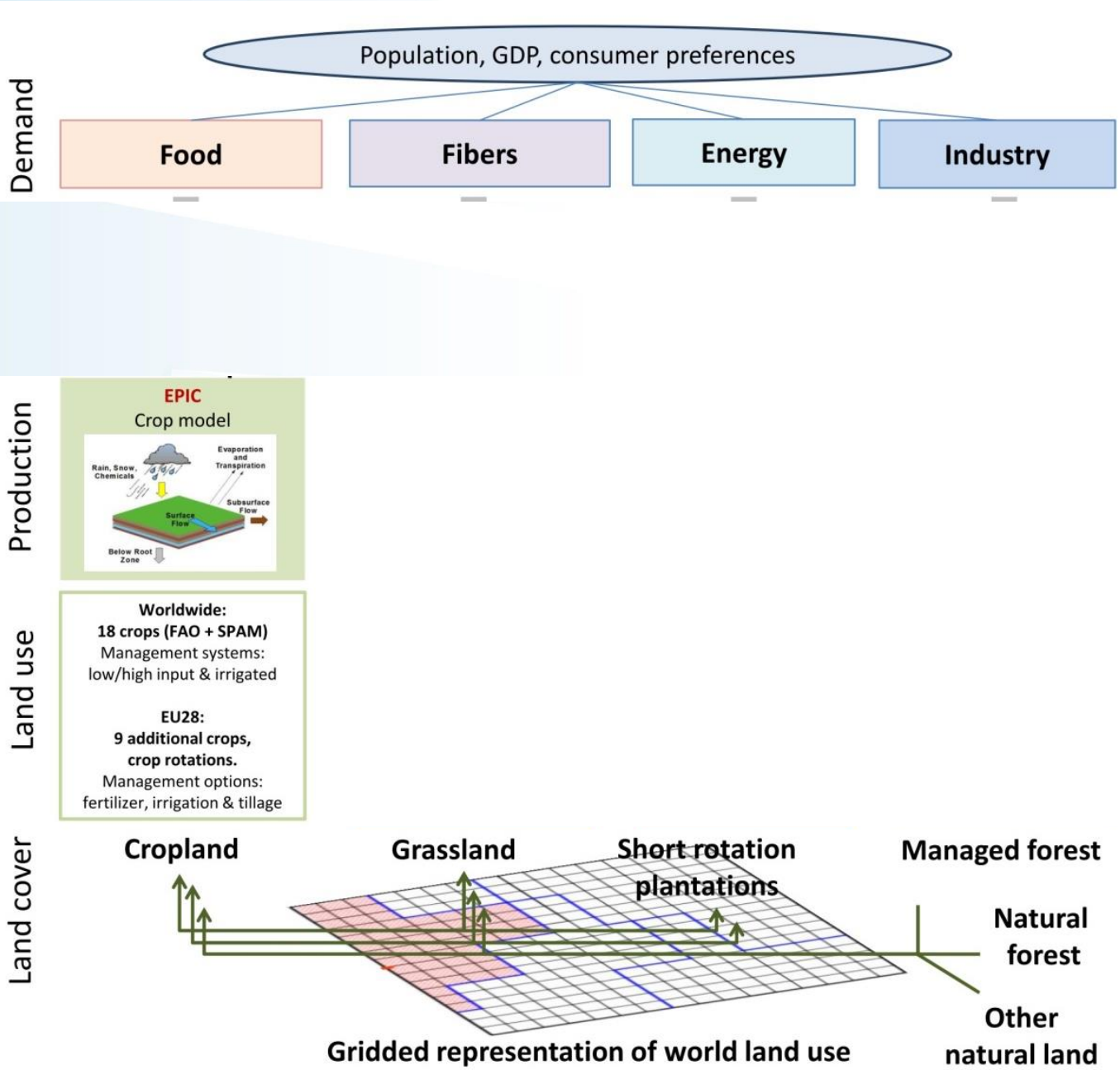


Initial land use

SPAM database
[18+ crops,
4 management
systems]

You & Wood (2006)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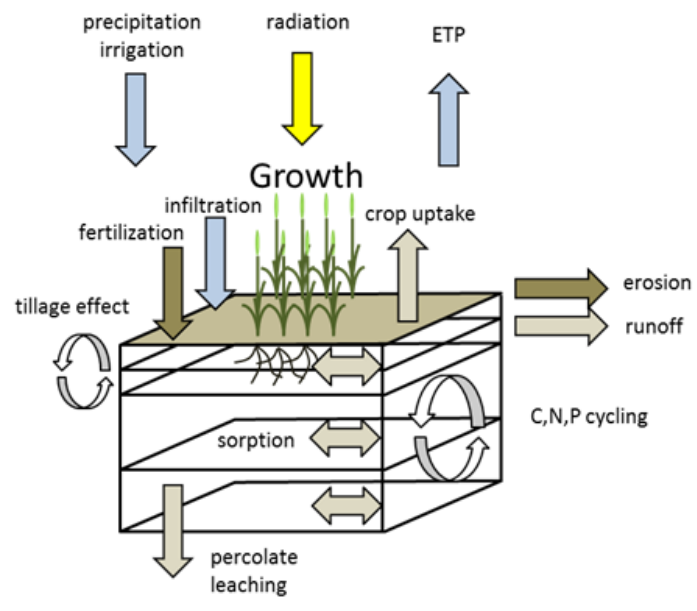
Key aspects for land use change projections

Williams et al. (1990)



EPIC Crop growth model

Weather

Hydrological cycle

Nutrient (N,P,K) and C cycle

Soil temperature and moisture

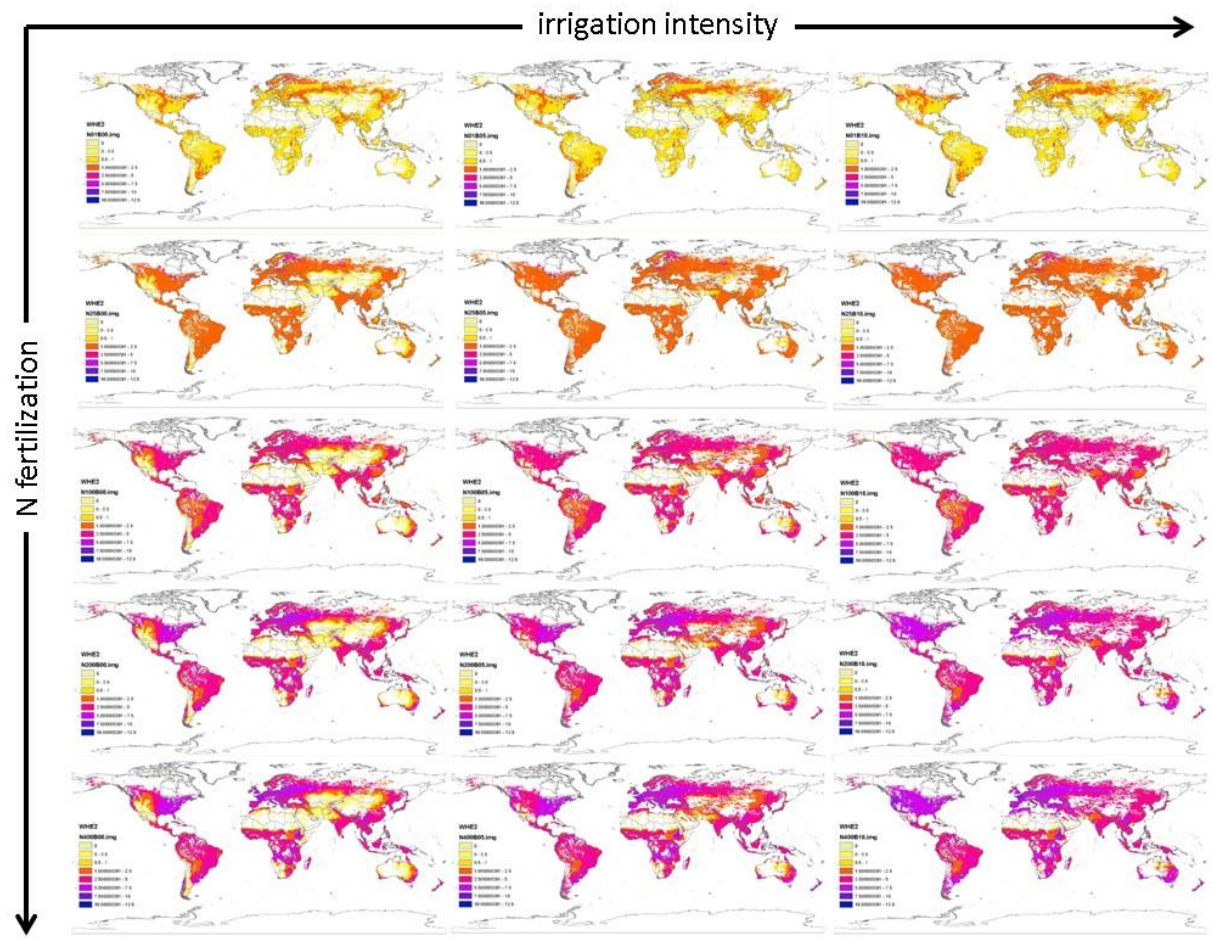
Soil erosion

Management operations

- crop rotations,
- tillage/cultivation practices,
- fertilization,
- irrigation,
- liming,
- pesticides,
- drainage,
- etc.

18 crops (>75% of harvested area)

Key aspects for land use change projections



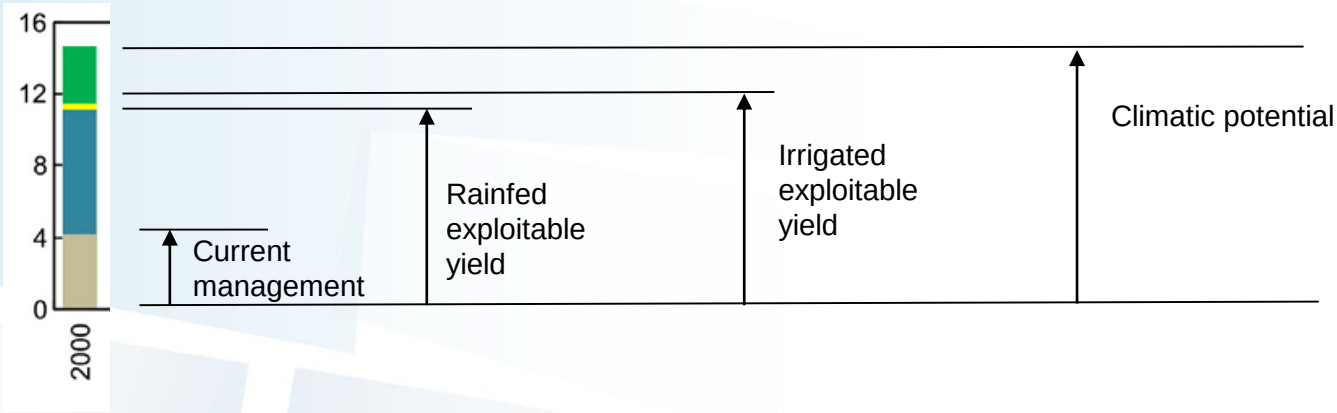
Spatially explicit diagnosis of production potentials

wheat yield [tDM/ha]

- 0
- 0 - 0.5
- 0.5 - 1
- 1.000000001 - 2.5
- 2.500000001 - 5
- 5.000000001 - 7.5
- 7.500000001 - 10
- 10.00000001 - 12.5

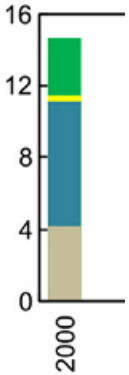
Key aspects for land use change projections

Total wheat production (Mt) over current cropland, depending on the management:

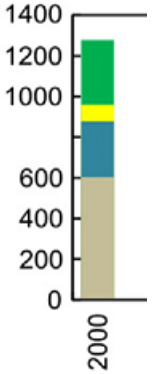


Spatially explicit diagnosis of production potentials

Southern Africa

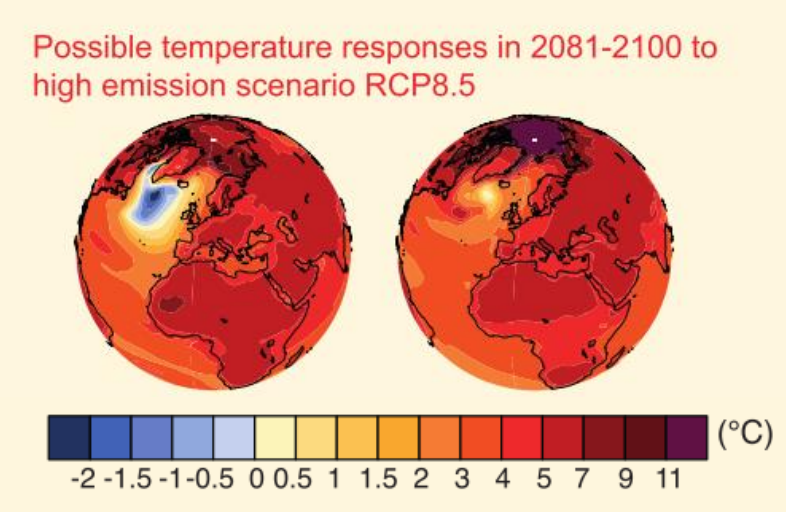


World



Balkovič et al. (2014)

Key aspects for land use change projections

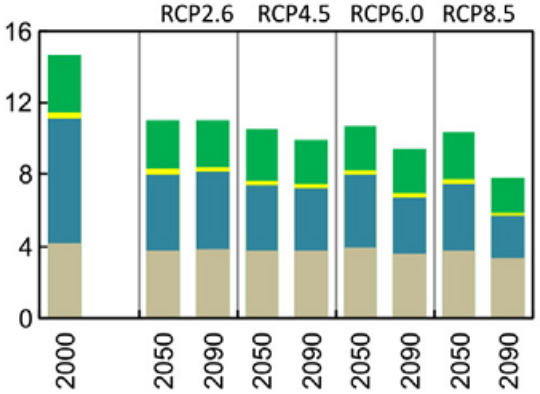


IPCC AR4

Spatially explicit diagnosis of production potentials

Including climate change impacts

Southern Africa



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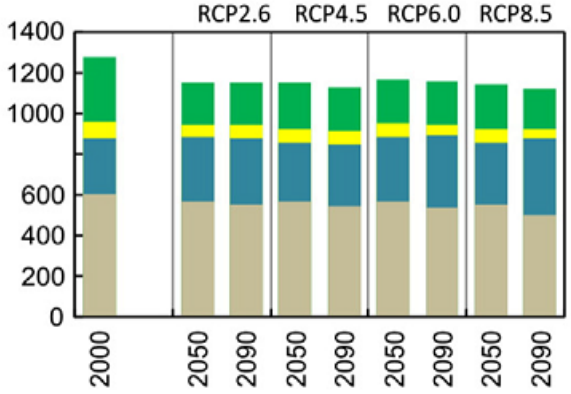

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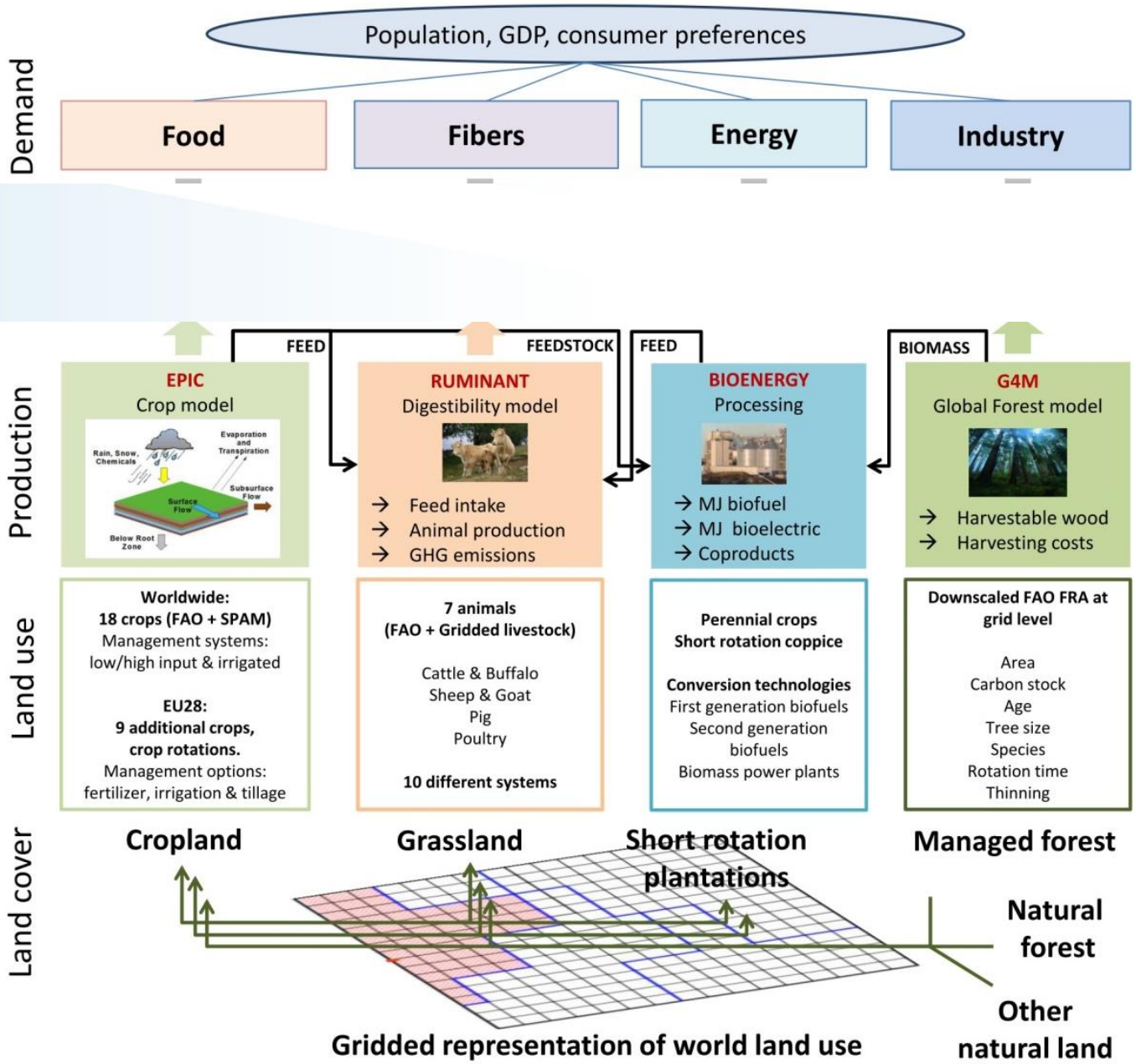
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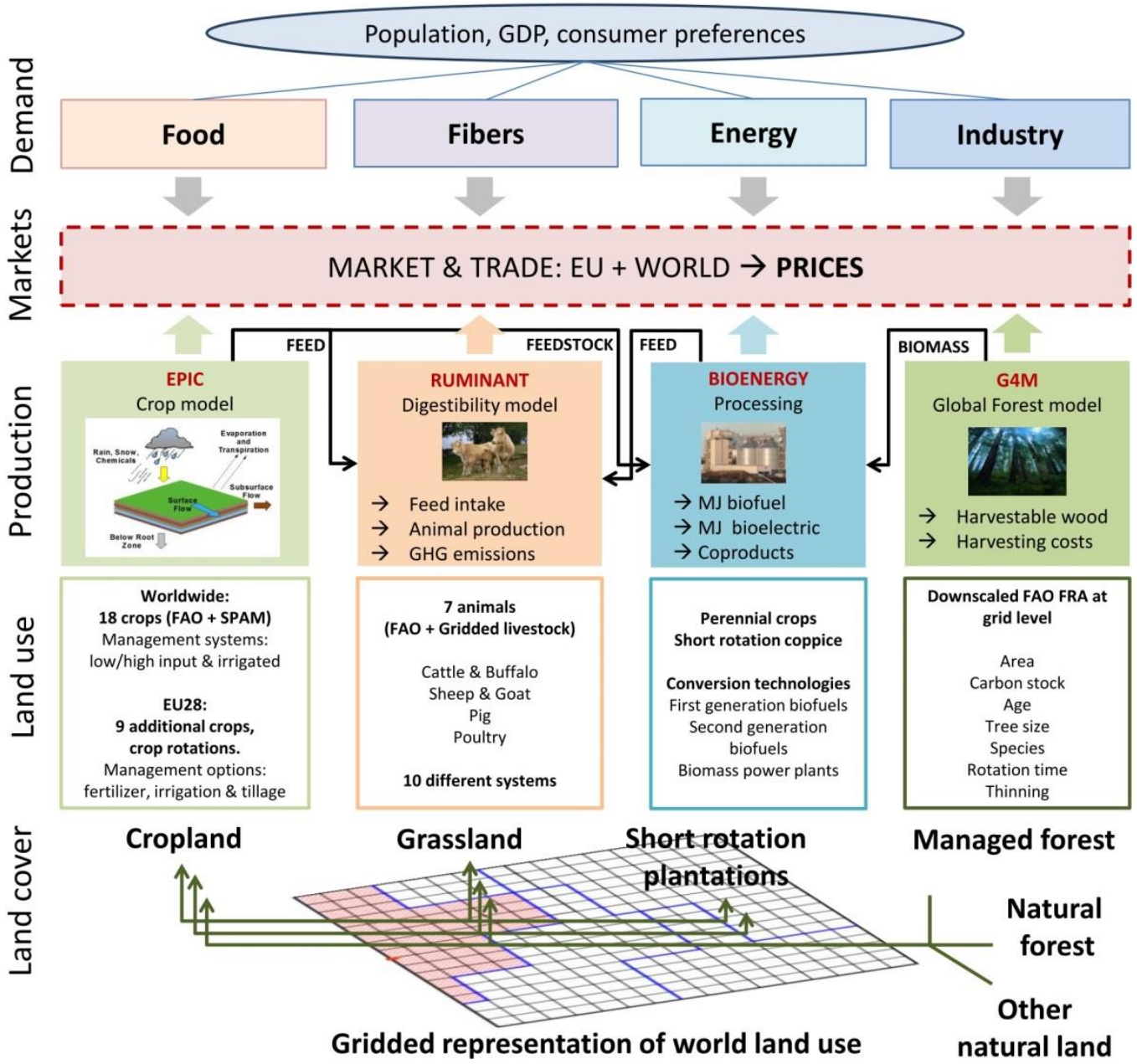
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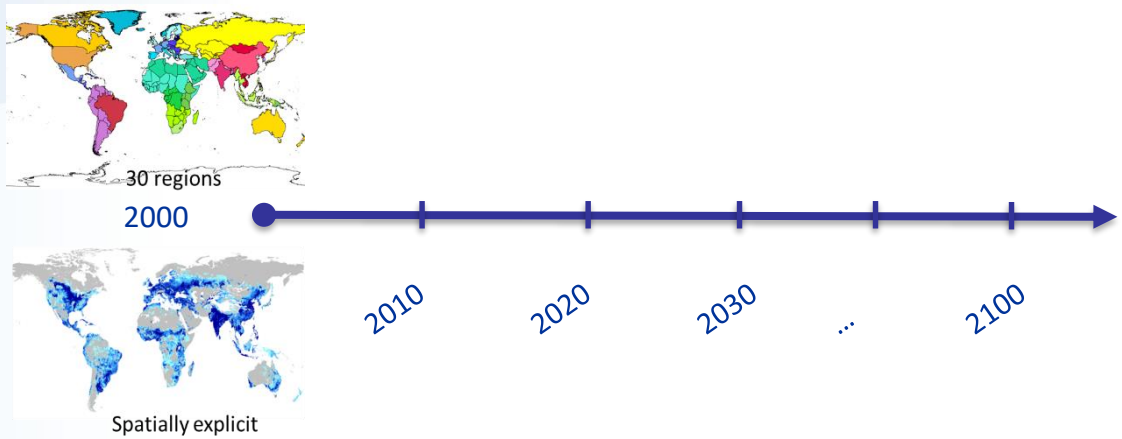
Key aspects for land use change projections

A recursive dynamic global partial equilibrium model of Agriculture, Forest and Bioenergy sectors

Based on linear spatial equilibrium mathematical programing.

Solves, recursively at a **10 year** time step:

- **producers' behavior** at high resolution (> 200 k spatial units, 18 crops, 7 livestock, etc.)
- **consumers' behavior** and **bilateral trade** at regional scale (30 regions, 30 products)
- **market interactions** between consumers, producers of various regions & sectors

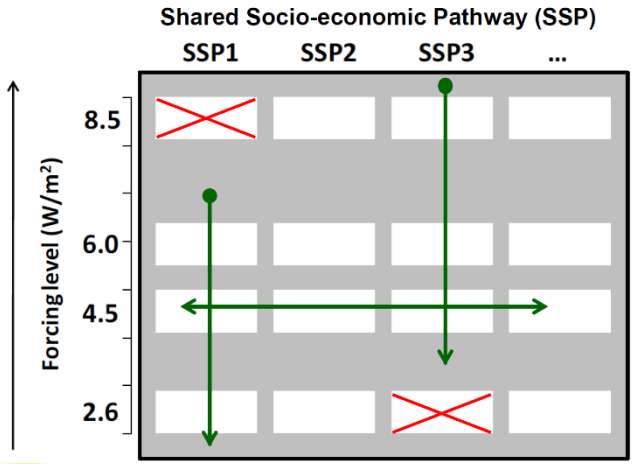


Havlík et al. (2011, 2014)

Opportunities & Limits

Long-term projections of land cover & use

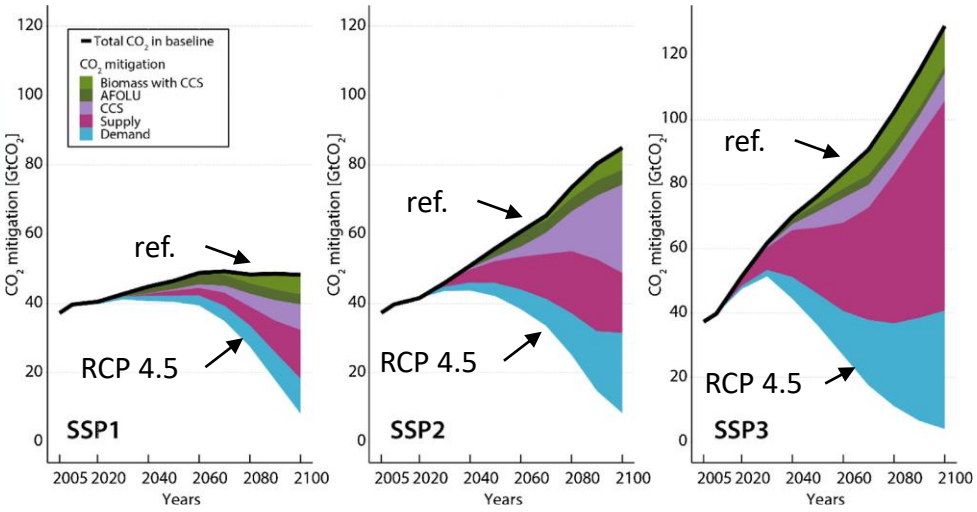
Fricko et al. (2016)



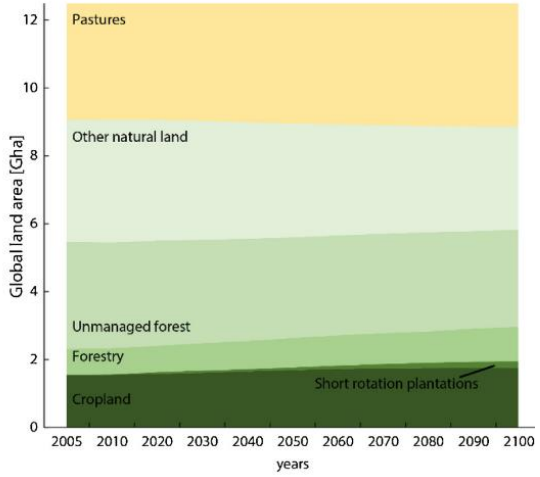
scenarios

MESSAGE-GLOBIOM Integrated Assessment model

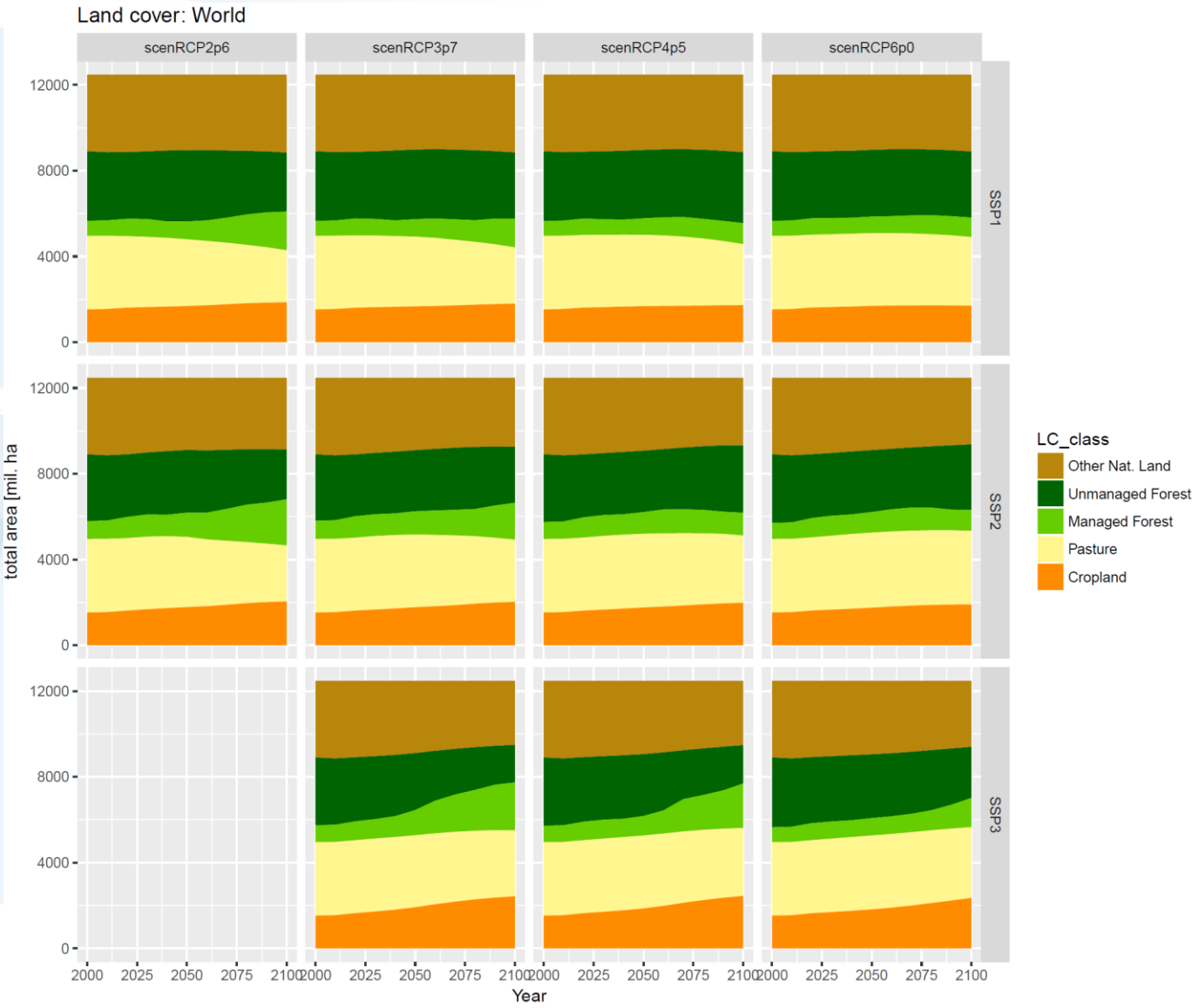
Δ land use (regional)



SSP2, RCP 4.5 land use (global scale)

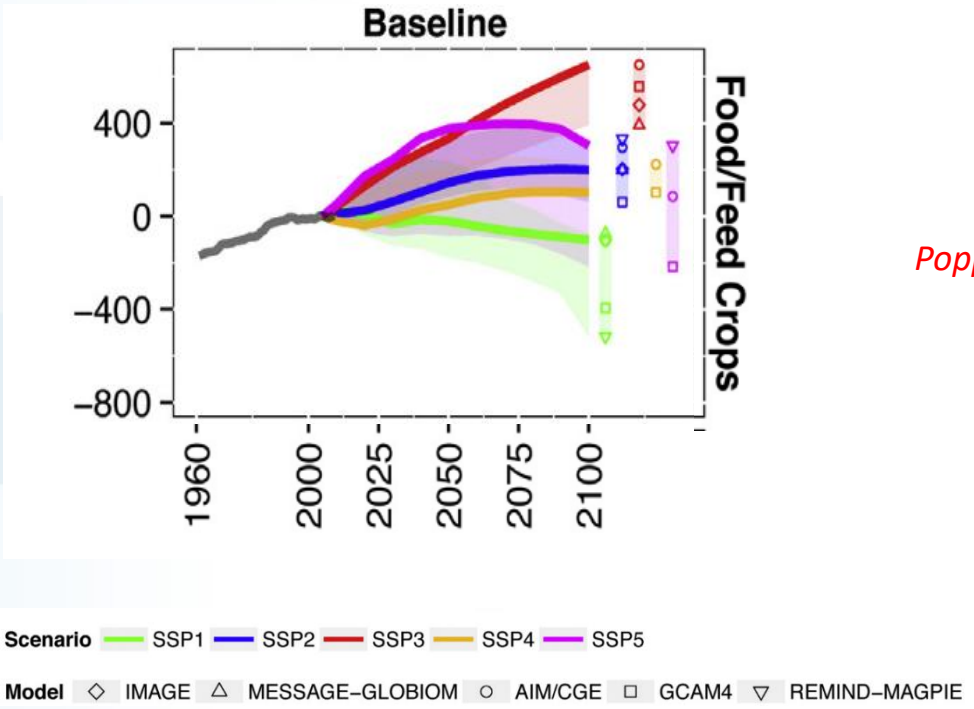


Long-term projections of land cover & use



Long-term projections of land cover & use

- Challenges:
  - (IAM) long-term land use projections are uncertain



Popp et al. (2017)

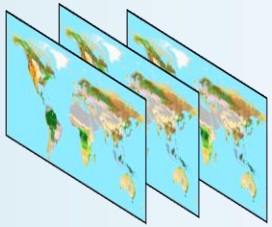
Long-term projections of land cover & use

- Challenges:
  - (IAM) long-term land use projections are uncertain
  - Worse as we go:
    - Far in the future
    - Towards high spatial resolution
    - Towards high thematic resolution & little used land covers

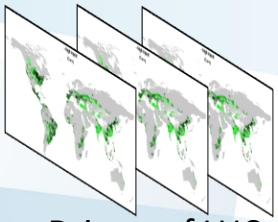
Long-term projections of land cover & use

- Challenges
- Among the promising avenues:
  - Model intercomparisons
  - Regional studies
  - Econometric & interdisciplinary approaches
  - Adequate end-use methods for dealing with uncertainties

Econometric land use downscaling model



LUC Data 2000-2010



Drivers of LUC

Krisztin et al., in prep.

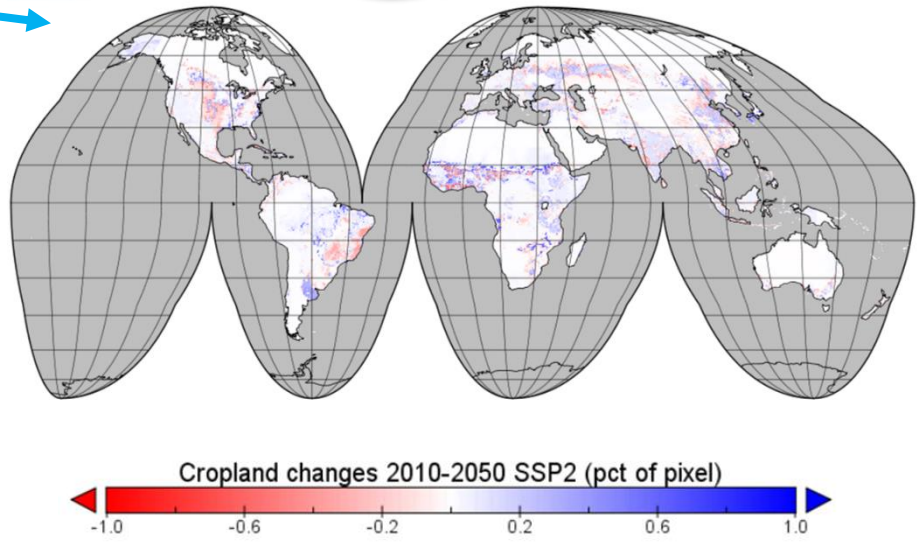
$$\Pr(y_i = j) = \frac{\exp(\mu_{i,j})}{1 + \sum_{j=1}^{J} \exp(\mu_{i,j})}$$

$$\boldsymbol{\mu}_j = \boldsymbol{X}\boldsymbol{\beta}_j + \boldsymbol{W}(\phi)\boldsymbol{X}\boldsymbol{\theta}_j + \boldsymbol{\iota}_N \alpha_j$$

Econometric Model

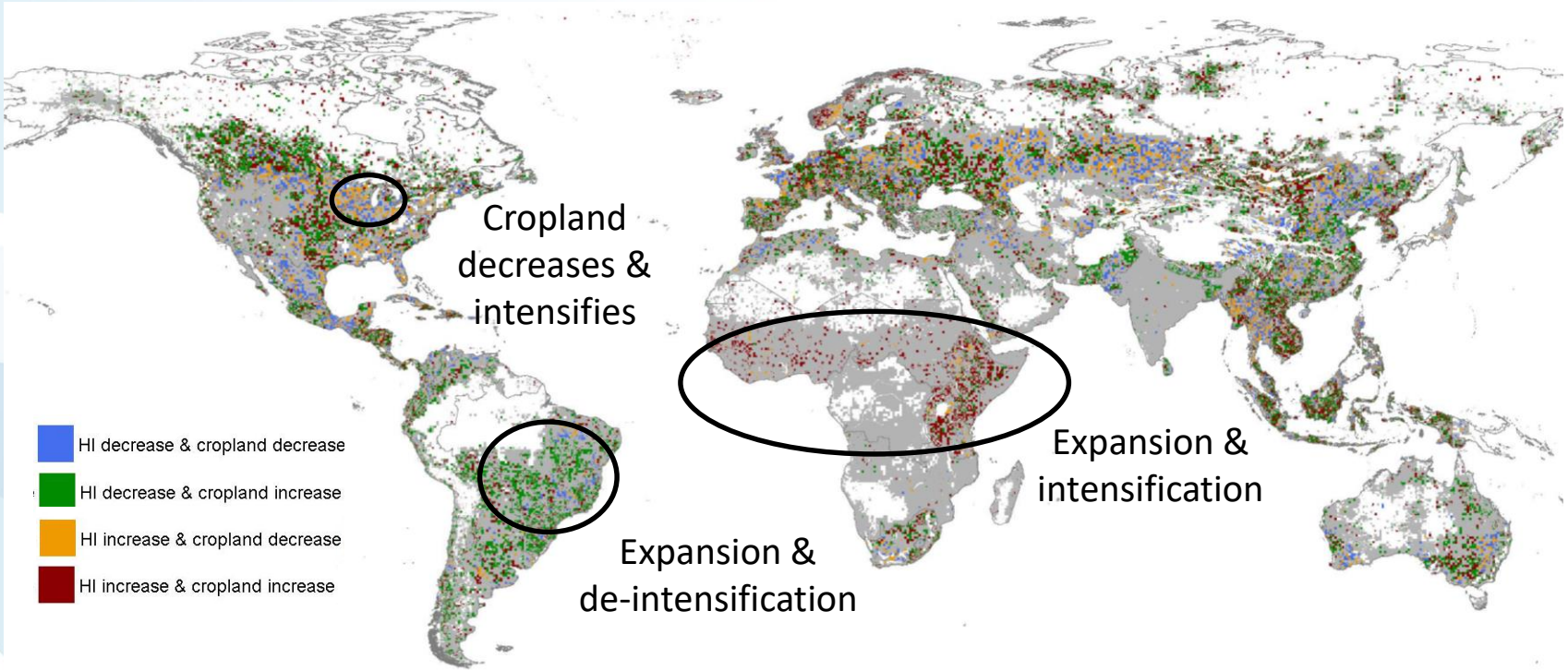
Δ land use (regional)

Δ land use high res.



Posterior projections of results along scenarios, 2010-2100 @ 5 arcminutes, 10 years

Long-term projections of land cover & use



Leclère et al., in prep.
(preliminary results)

Countryside Species-Area model

Δ land use high res.

Leclère et al., in prep.

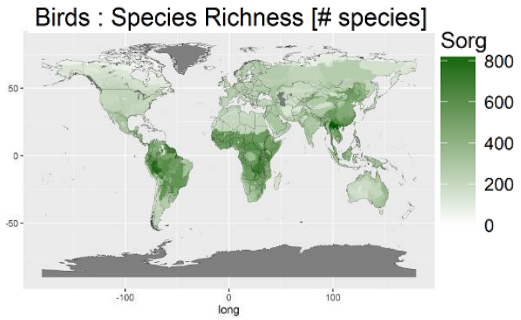
Δ habitat
Δ species richness
…

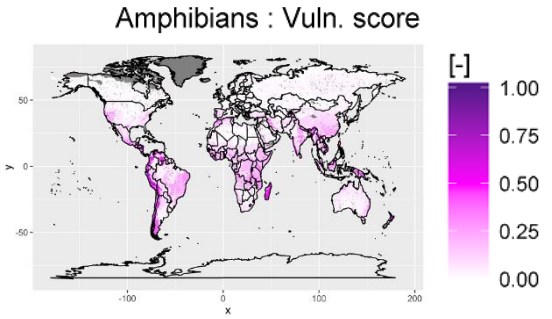
cSAR model

Translates land use into habitat quality, species richness & extinction risk

- $Species\ Richness = c \cdot (Habitat\ Size)^z$
- $Habitat\ size = total\ area \cdot \sum_{LCC} a_{LCC} \cdot h_{LCC}$
- *Affinity h_{LCC} of species for each land cover/use class LCC*
- *A refined version of Chaudhary et al. (2015) to account for LCC transitions & time dynamics of recovery*

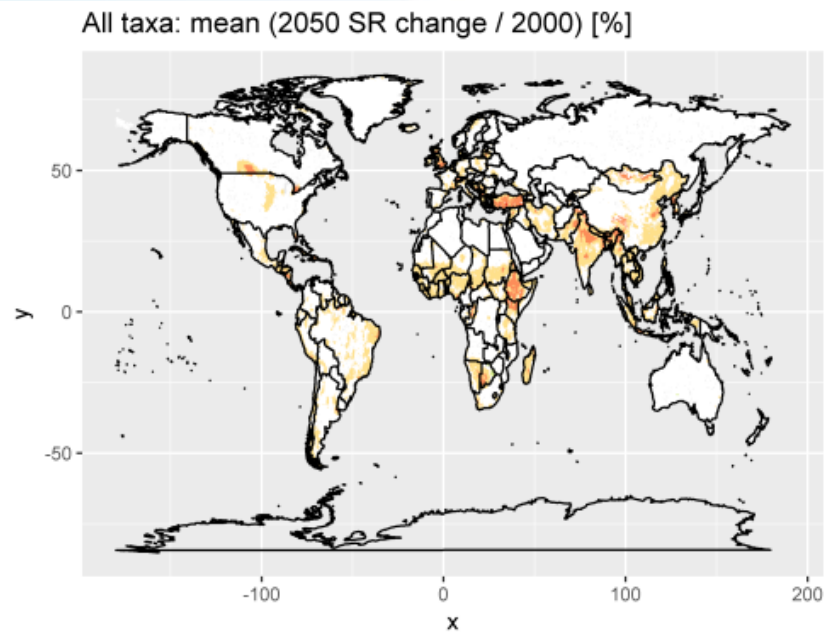
Parameters for 5 taxa (Amphibians, Birds, Mammals, Reptiles, Plants) at the scale of WWF ecoregions

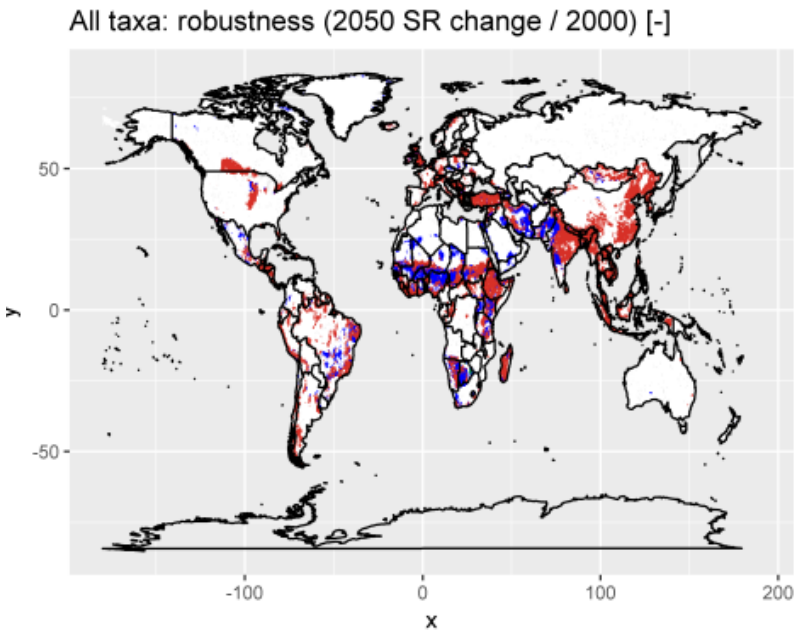


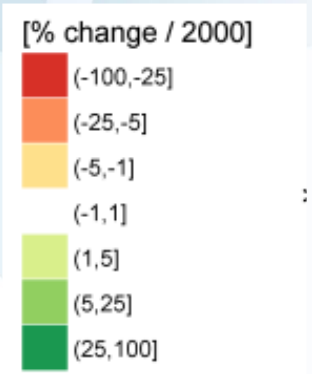


Projections of habitat change, species richness change and extinction of endemic species at risk in year 2000
@ 5 arcminutes spatial resolution, 10 years time step

Results – biodiversity impact (hotspot mapping)







Leclère et al., in prep.
(preliminary results)

Concluding remarks

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- Global land use models include:
  - Detailed geographical & biophysical description of land
  - Detailed but flexible scenarios about future drivers
  - Sound modeling of interactions between components
- Resulting global land use projections:
  - High degree of linkage across scales, sectors & regions
  - Rather good at exploring plausible futures, options for transformative change & integrated outcomes, but not predictive models
- Rapid methodological developments:
  - Econometric methods to refine LULCC projections
  - Regional studies have much lower uncertainties
  - Reduction & better communication of uncertainties

Thank you!

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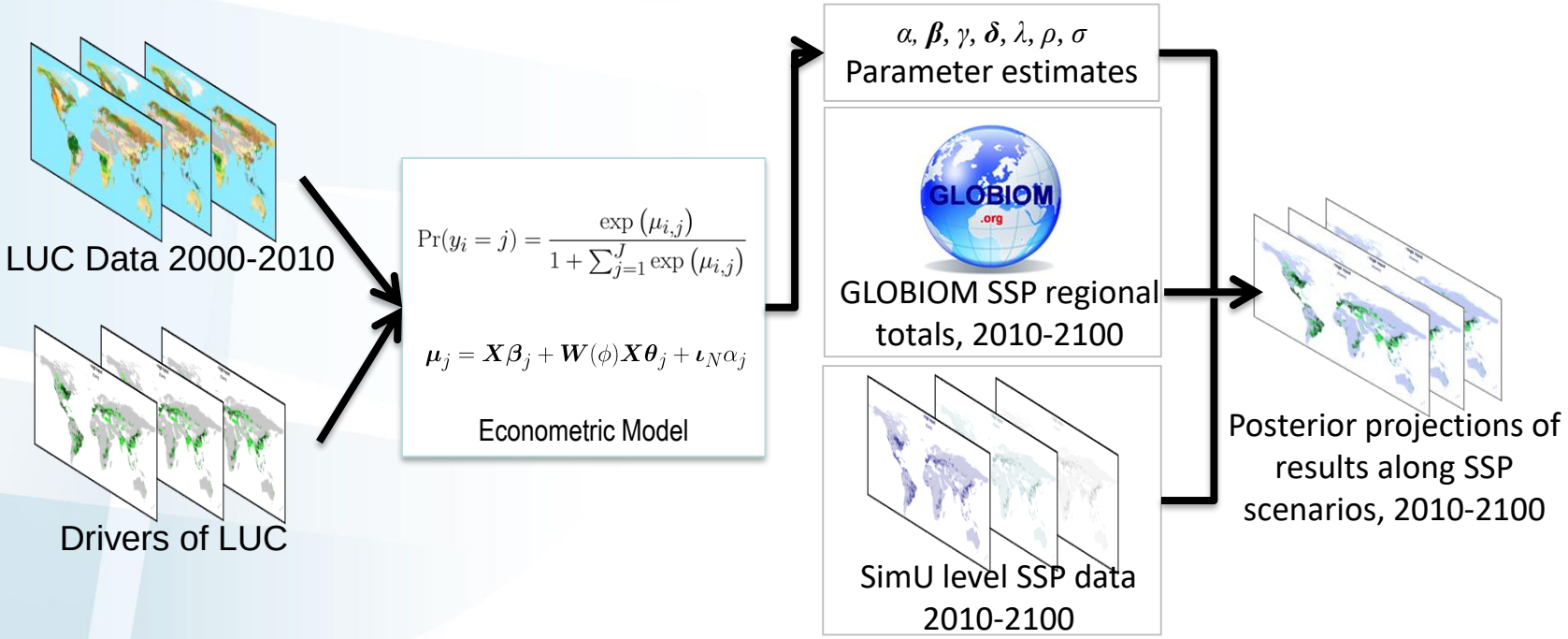
Developing downscaling



Overall regional results equal GLOBIOM, for each time period *t* and SSP scenario

Variables influencing the specific spatial distribution:

- land-use change in previous periods *t-1*;
- physical characteristics of land (soil type, altitude, climate)
- expected yields of land at time *t*;
- projected economic state and population density at *t*
- Neighboring SimUs are forced to have similar land-use change