AVEC Workshop, Peyresq, France, September 2003

Land use change in Europe: interpreting regional scenarios from global storylines

Mark Rounsevell & Isabelle Reginster

Department of Geography, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Frank Ewert

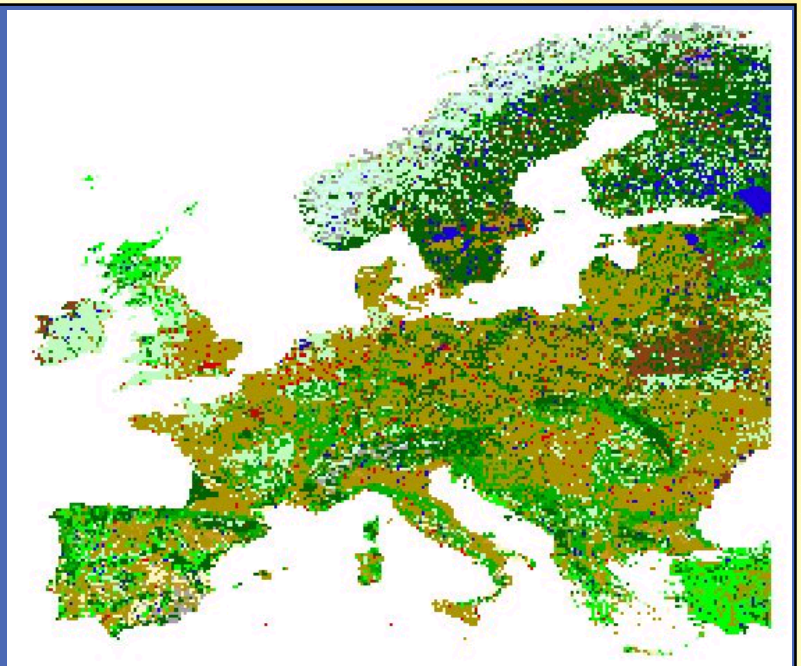
Wageningen University, The Netherlands

UCL Université catholique de Louvain

BELGIUM

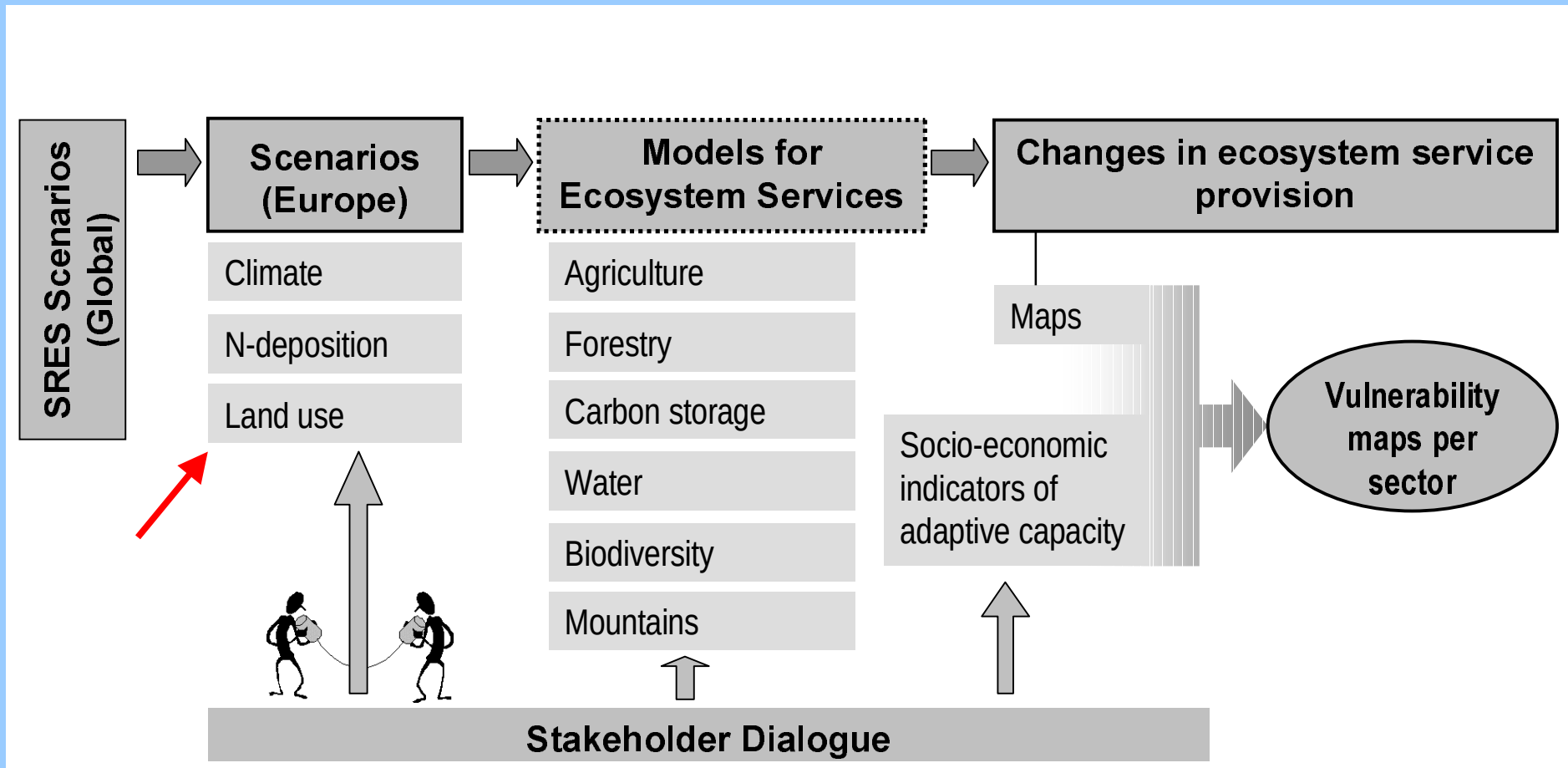
What do we want to do?

- **Develop land use change scenarios for Europe (EU15, Norway and Switzerland)**
- **For urban, agriculture, biofuels & forest land uses**
- **At a spatial resolution of 10 minute lat/long grid**
- **For 2020, 2050 and 2080**
- **Starting with an observed (2000) baseline (PELCOM)**



Spatial window:
11° W, 32° E, 34° N, 72° N
Grid resolution: 10' x 10'
Scenarios planned for the years:
2000, 2020, 2050, 2080.

Concept of the ATEAM project

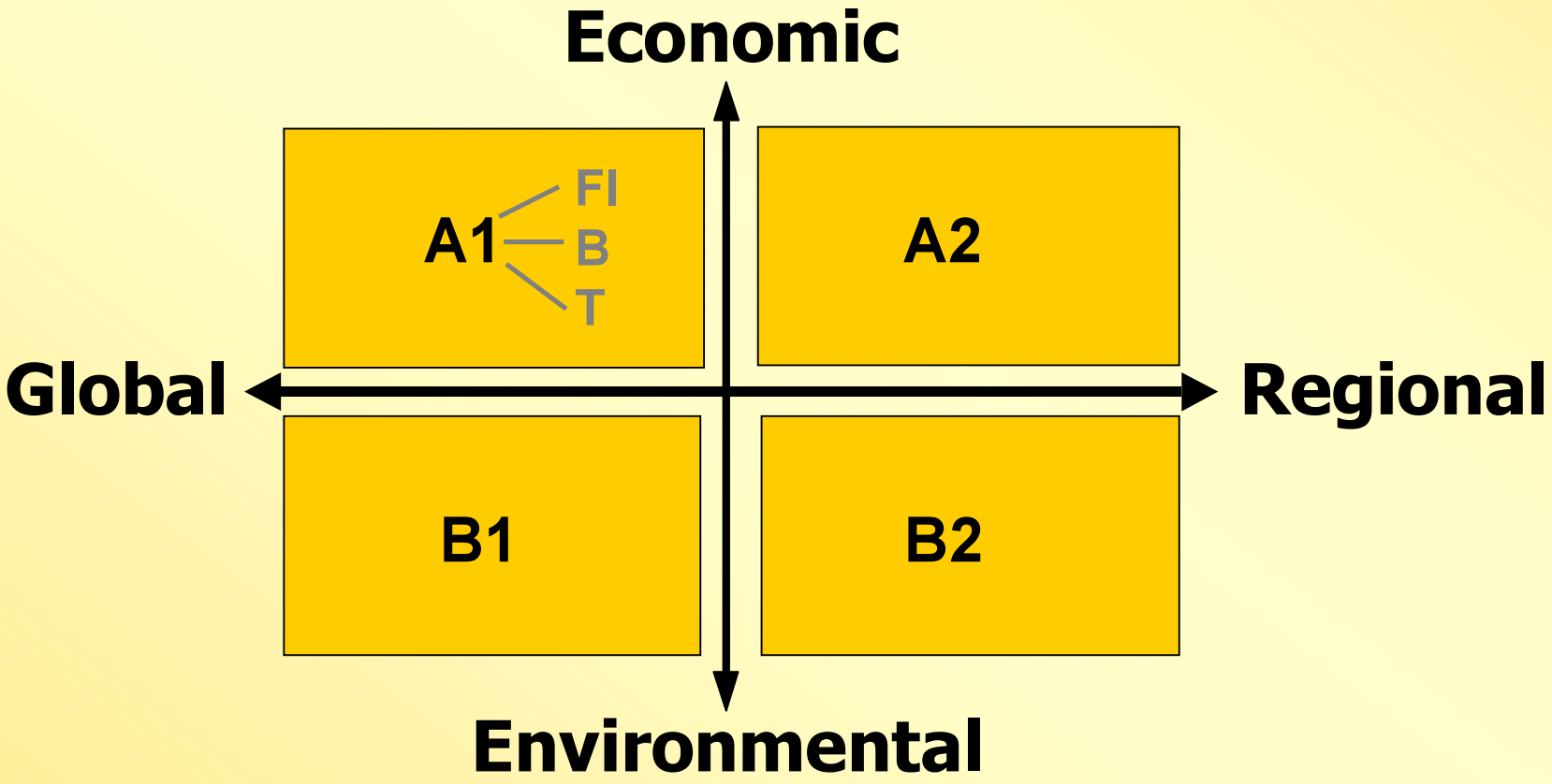


(after Frank Ewert, Wageningen, Uni)

The basic problem

- How to go from global storylines (SRES) to regional scenarios (of land use)?
- Whilst maintaining plausibility and internal consistency of scenarios

Reminder about SRES (global) I



Reminder about SRES (global) II

Scenario	Population	Economy	Environment	Equity	Technology	Globalization
A1FI						
A1B						
A1T						
B1						
A2						
B2						

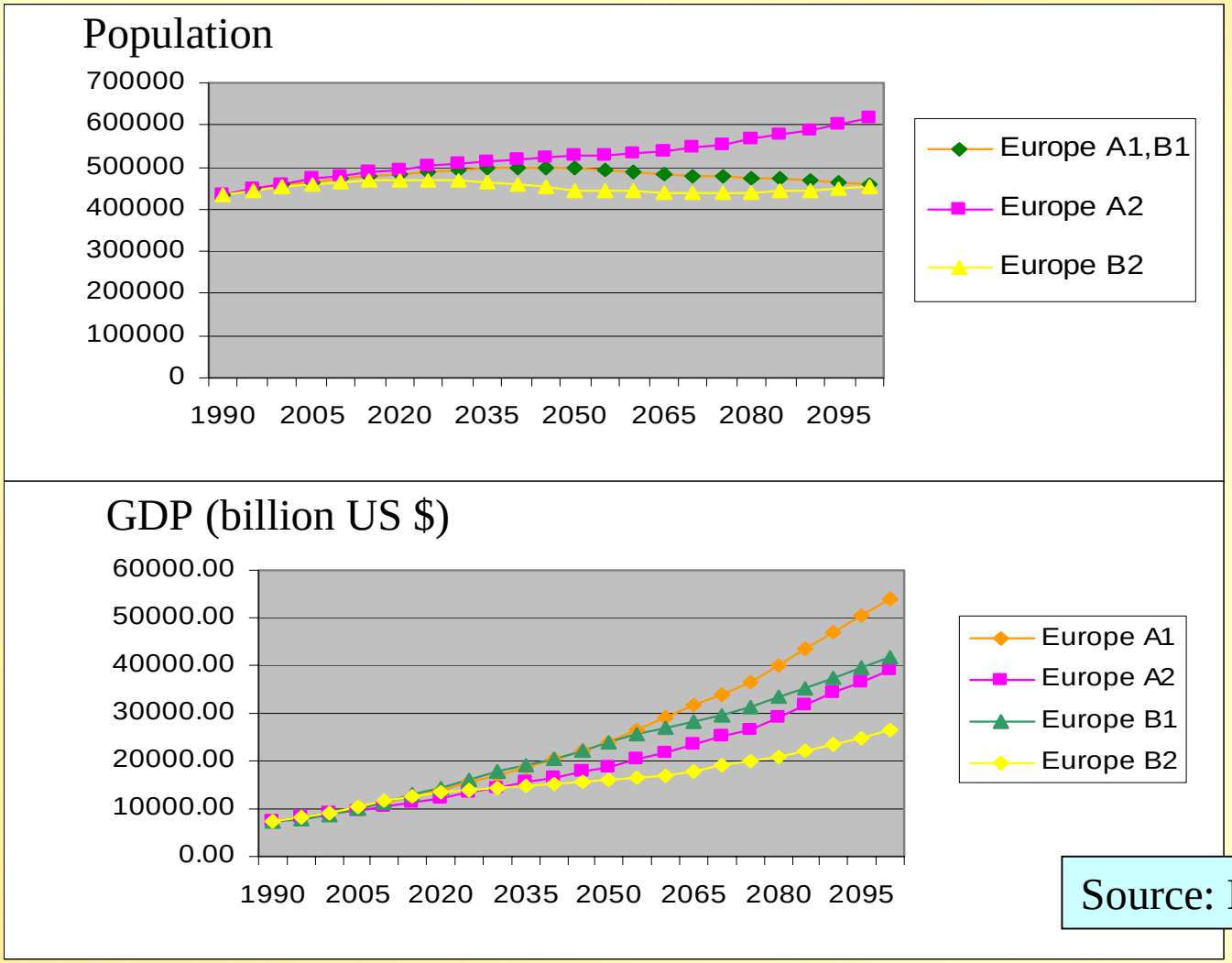
Basic interpretation methodology

- **Identify drivers (qualitative)**
- **Estimate land use demand (quantitative)**
- **Allocate land use demand in space (rule-based)**

European scale drivers (qualitative)

	A1	A2	B1	B2
Economy - GDP	rapid growth, convergence	growth, uneven	growth, convergence	slow growth, uneven
Population	declining	growing	declining	stable
Technological change	rapid	slow and uneven	rapid	uneven
Institutions and government	weak	weak, diverse	strong	weak, except local
Rural development	not a focus area	result of self-reliance	key issue	increase (self-reliance)
Recreation, tourism	increase	increase, decrease resp.	increase, decrease resp	increase, decrease resp
Spatial planning	convergent, less restrictive	heterogeneous	convergent, restrictive	heterogeneous restrictive
EU enlargement	rapid	slow	moderate	stopped

European scale drivers (quantitative)



Source: IIASA & UN

How can we use this information to derive spatially-explicit scenarios?

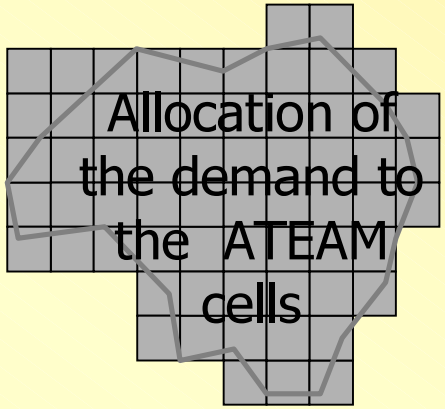
- **Example: which drivers are important for urban land use change?**

Quantity	Spatial location
• Population • GDP (affluence affects household size and industry)	• Planning policy • Accessibility (transport network)

Estimating quantity – a simple empirical approach

NUTS 2 level

ATEAM cell level



Urbanisation processes

1

f(population, GDP)

empirical-statistical model

Potential Transition maps $_{\text{scenario}}$

2

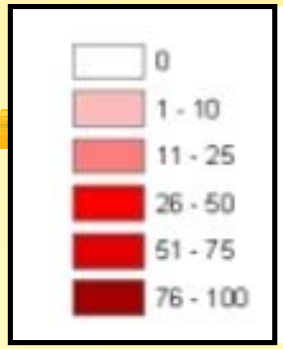
(depending on distance functions)

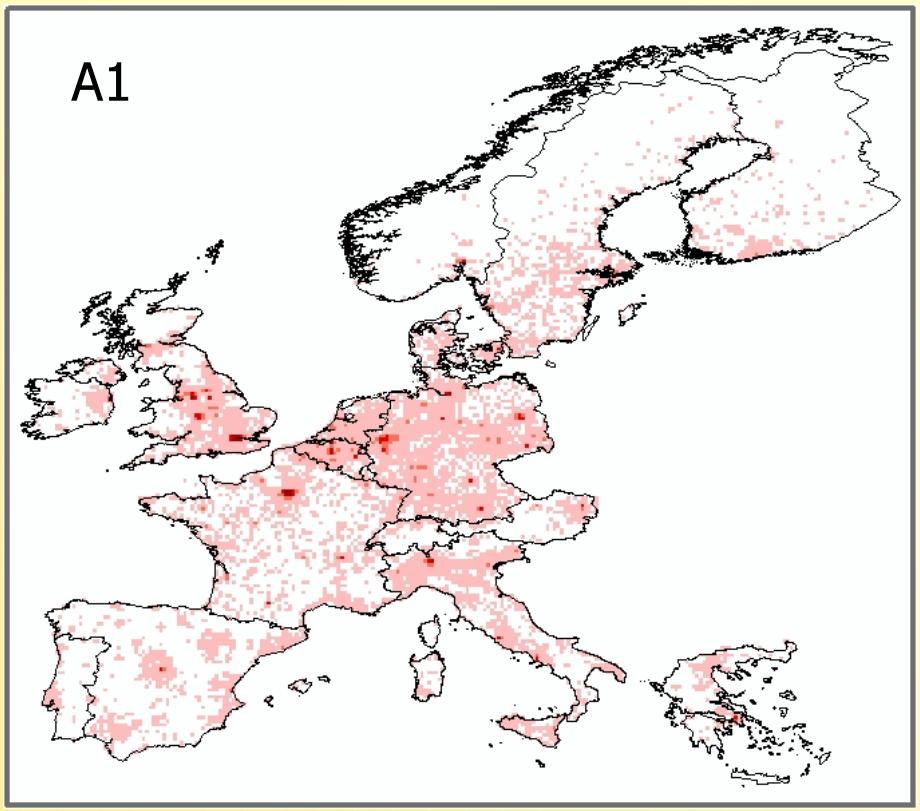
3

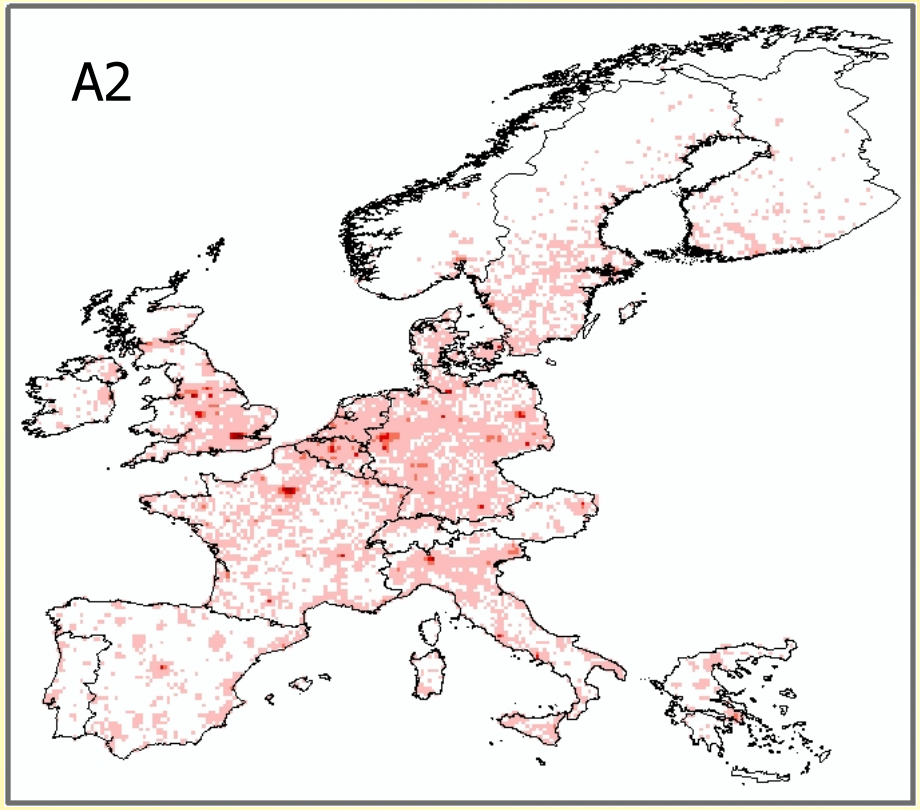
Urban land use maps **scenario, time slice**

Urban maps

Urban land use (%) per ATEAM cell (2080)







Now agriculture: which drivers?

- **You're all « *stakeholders* » (you all consume agricultural goods and services), so what do you think?**

European agricultural drivers

Policy	**Macro-socioeconomics**	
	Demand	**Supply**
Market intervention (subsidies, quotas)	Population (consumption)	Resource competition (e.g. urban)
Rural development (LFAs)	Consumer preferences (meat, organic)	Climate change (Temp, precip, CO_2)
Environmental policy (NVZs, ESAs)	Market liberalisation (WTO)	Technology & management
	EU enlargement	

Micro-socioeconomic drivers?

How to implement the method?

- **Which drivers affect land use quantities and which the spatial allocation (locations)?**
- **Spatial drivers: resource competition, rural and environmental policy & climate change**
- **Non-spatial (quantity) drivers: all the rest**

An agricultural land use (quantity) change model

- **Based on a simple supply and demand function:**

$$\frac{L_t}{L_{t_0}} \propto \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

$$L_t \propto L_{t_0} \cdot \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

L	...	Agricultural land use *[ha]*
t	...	Time
t_0	...	start moment, baseline
D	...	Demand for production *[t]*
P	...	Productivity *[t/ha]*
O	...	Overproduction, relative *[-]*

Unknown Parameters to estimate

Quasi-validation: historic trends (1960-2000)

- Demand change = 1.5
- Oversupply = 1.3 (from 0.9 in 1960 to 1.2 in 2000)
- Technology change (average for Europe) = 2.4
- Estmated land use change factor = 0.81

- Observed change in agricultural land use (based on FAO areas) = 0.85
- Plus, the setaside requirement (no use) = 10% of cereal areas
- Observed change factor = 0.8 to 0.85

Scenario parameter values for quantity estimation

- **Demand**
- **Productivity (climate change, CO_2 effect, technology)**
- **Oversupply**

IMAGE demand values

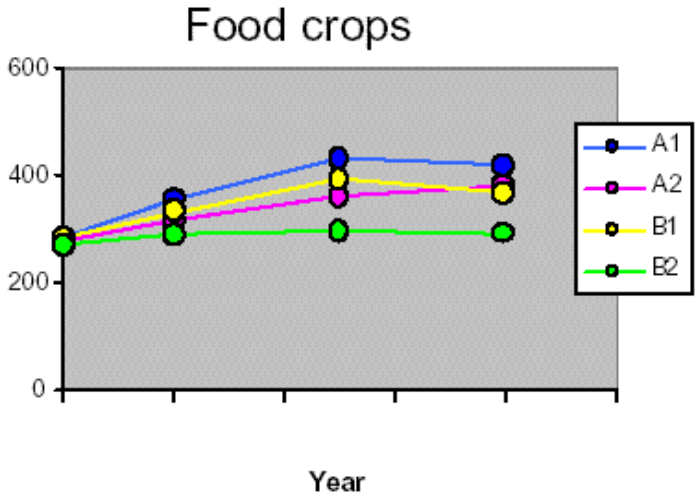
Approach

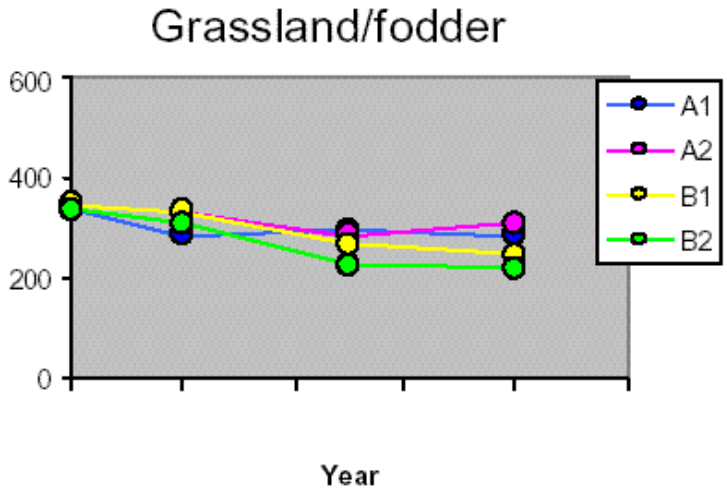
$$\frac{L_t}{L_{t_0}} = \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

IMAGE model

Estimated future demand

1 000 000 Gg/yr





Productivity changes

Approach

$$\frac{L_t}{L_{t_0}} = \frac{D_t}{D_{t_0}} \cdot \frac{P_{t_0}}{P_t} \cdot \frac{O_{r,t}}{O_{r,t_0}}$$

$$P_t = P_{t_0} r_{p\,t-t_0}$$

$$r_{p\,t-t_0} = g(\Delta CO_2, \Delta C, \Delta T)_{t-t_0}$$

P ...	Productivity *[t/ha]*
r_p ...	Relative change in productivity *[-]*
CO_2 ...	Atmospheric CO_2 concentration
C ...	Climate
T ...	Technology

$$P_t = P_{t_0} + ((P_{t,C} - P_{t_0}) + (P_{t,CO_2} - P_{t_0}) + (P_{t,T} - P_{t_0}))$$

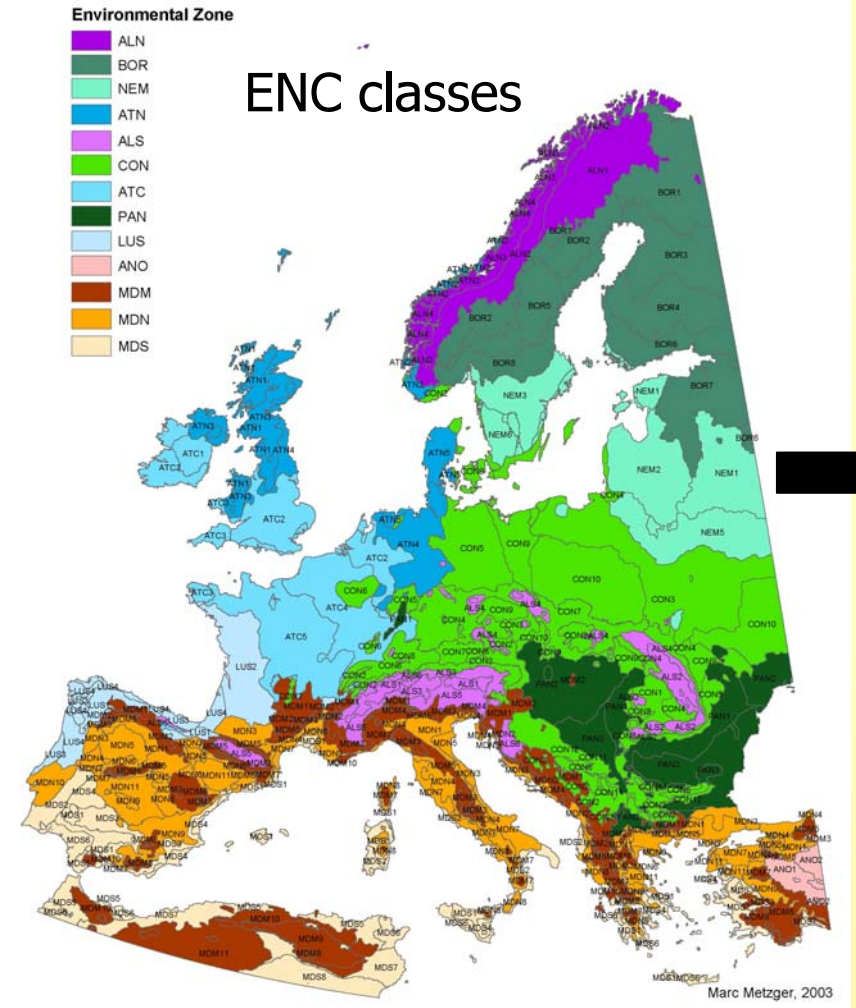
$$\frac{P_{t_0}}{P_t} = \frac{1}{1 + ((P_{t,C}/P_{t_0} - 1) + (P_{t,CO_2}/P_{t_0} - 1) + (P_{t,T}/P_{t_0} - 1))}$$

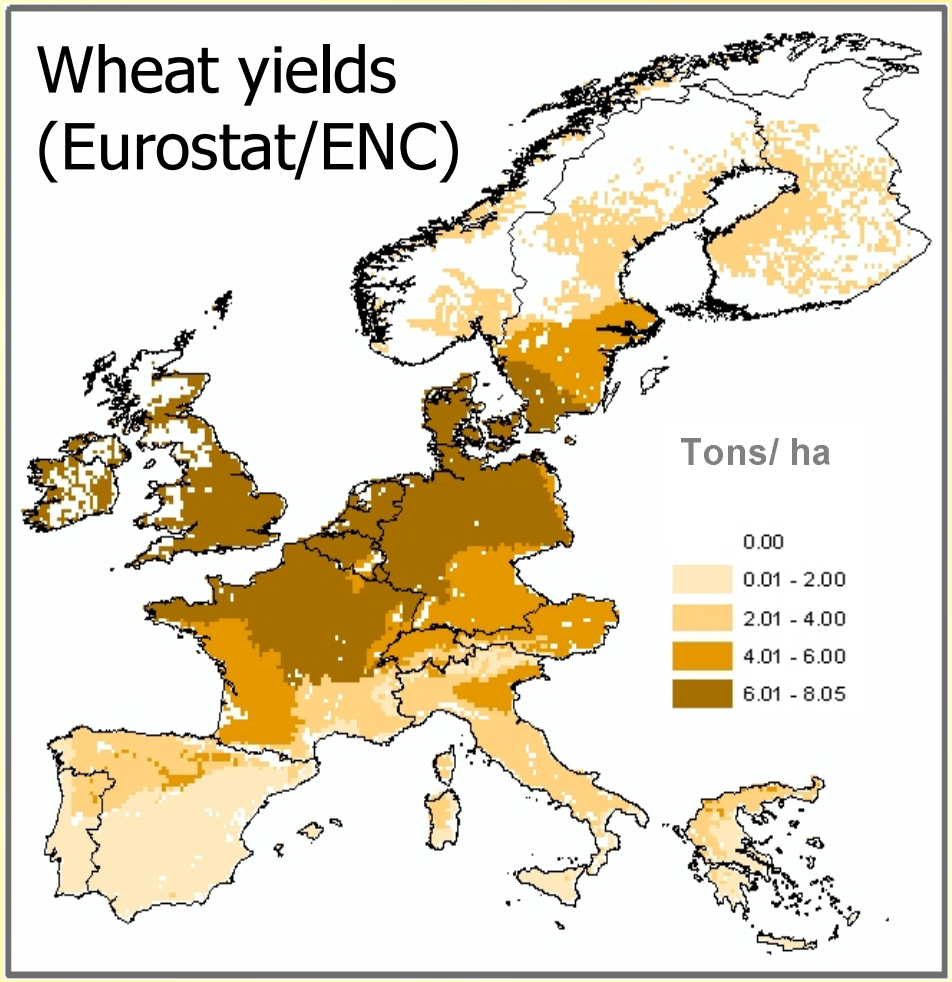
CO_2 estimates

- **Values for the effect of CO_2 on crop/grass yields estimated from the literature (baseline = 1.00)**

Scenario	2020	2050	2080
A1F1	1.04	1.16	1.32
A2	1.04	1.13	1.27
B1	1.04	1.09	1.11
B2	1.04	1.11	1.15

Estimating climate effects





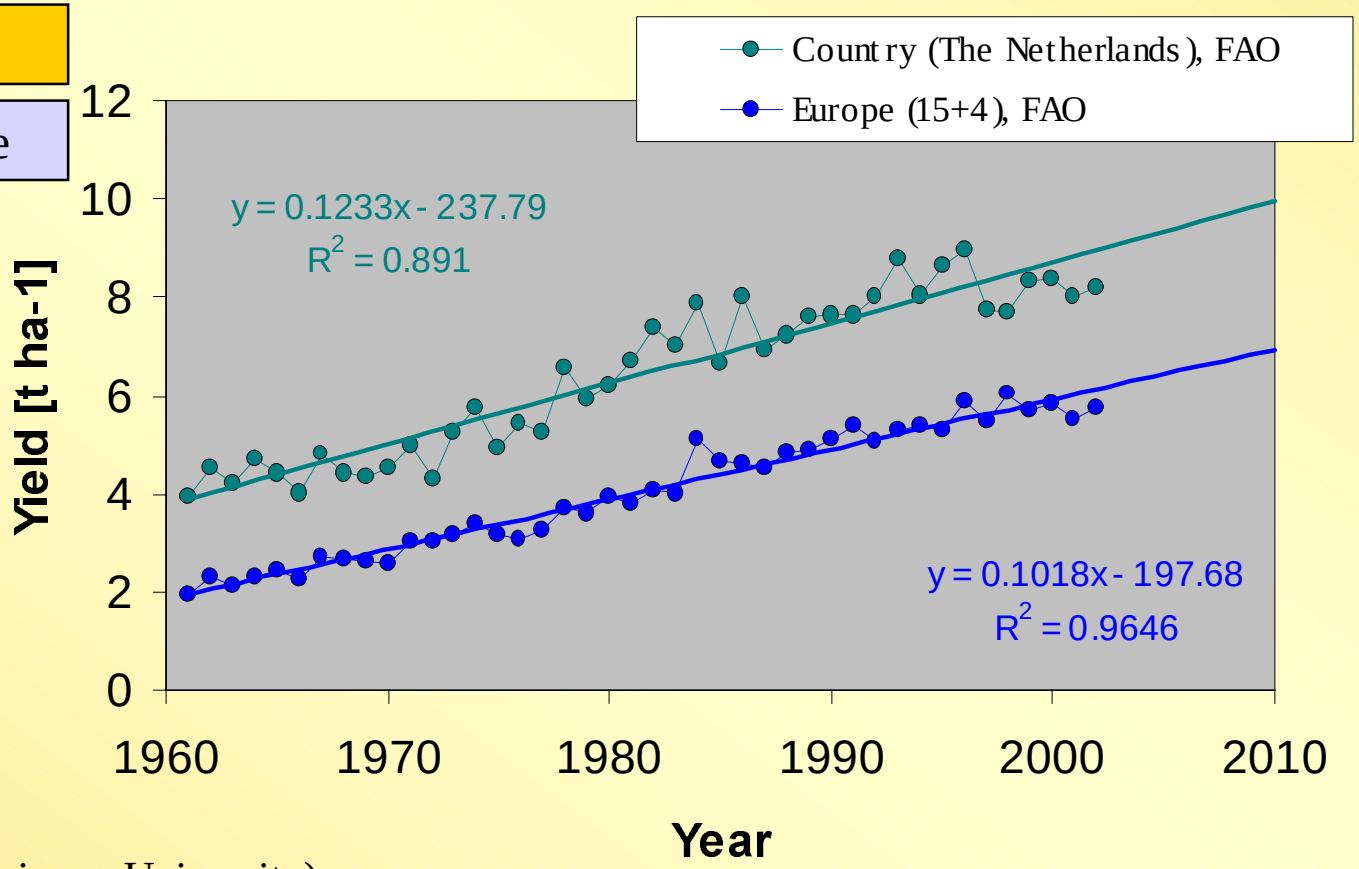
Technology effect

- How to quantify future changes in crop yields arising from technology and management change (e.g. plant/animal breeding, GM crops, pesticides, etc.)
- How to interpret technology changes per scenario? A1 is assumed to be more innovative, but what about protected markets … ?

Past changes in crop yields

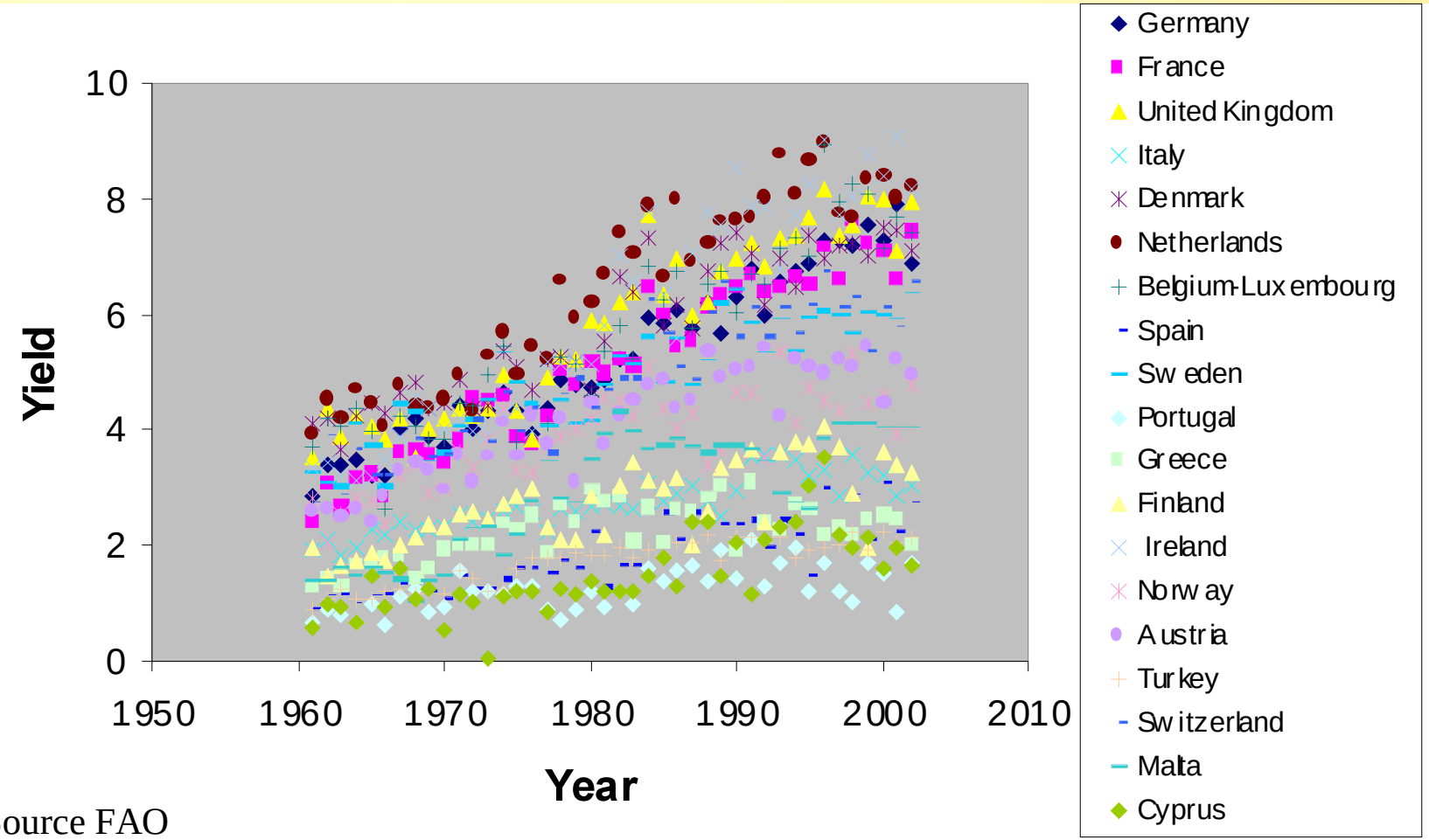
Europe, 1961-2002

Wheat yield vs. time



Source FAO
(after Frank Ewert, Wageningen University)

Wheat yield differences between countries

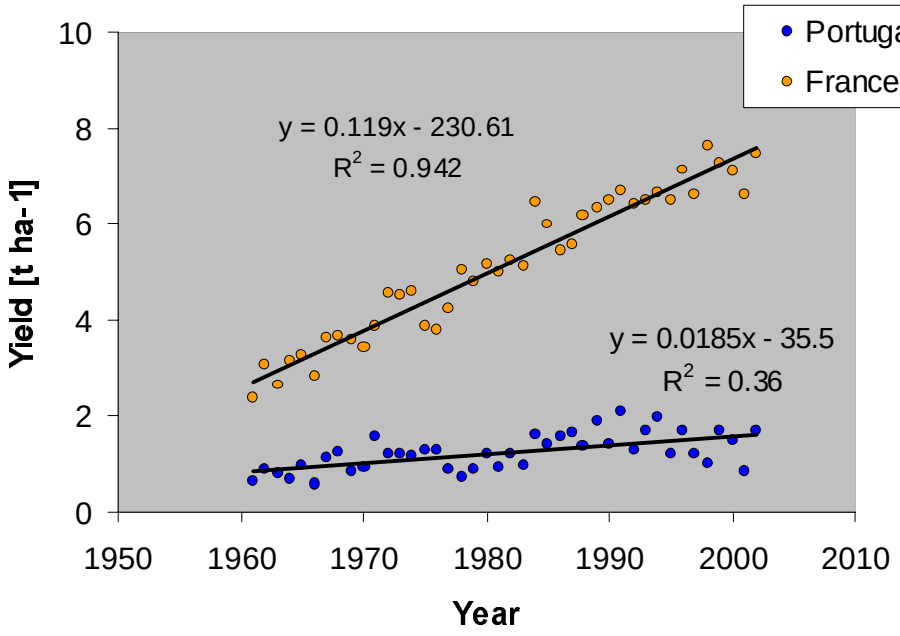


Source FAO
(after Frank Ewert, Wageningen University)

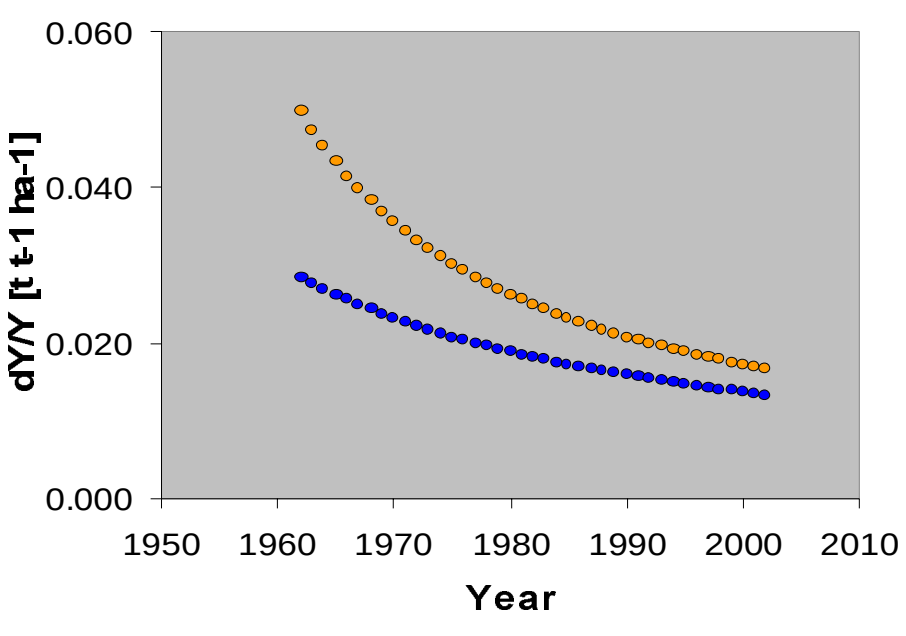
Relative change in yields

France and Portugal, 1961-2002

Wheat yield [t/ha] vs. time [yr]



Relative change in yield, dY/Y, vs. time

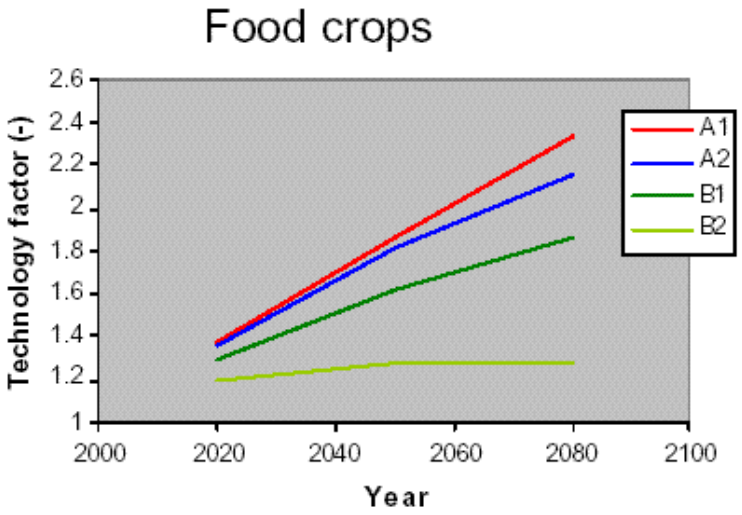


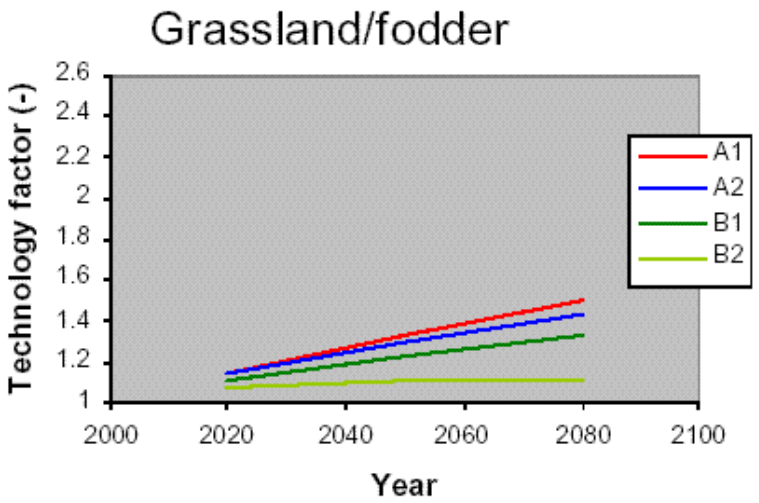
Technology change factors

Approach

$$\frac{P_{t_0}}{P_t} = \frac{1}{1 + ((P_{t,C} / P_{t_0} - 1) + (P_{t,co_2} / P_{t_0} - 1) + (P_{t,T} / P_{t_0} - 1))}$$

Technology factors



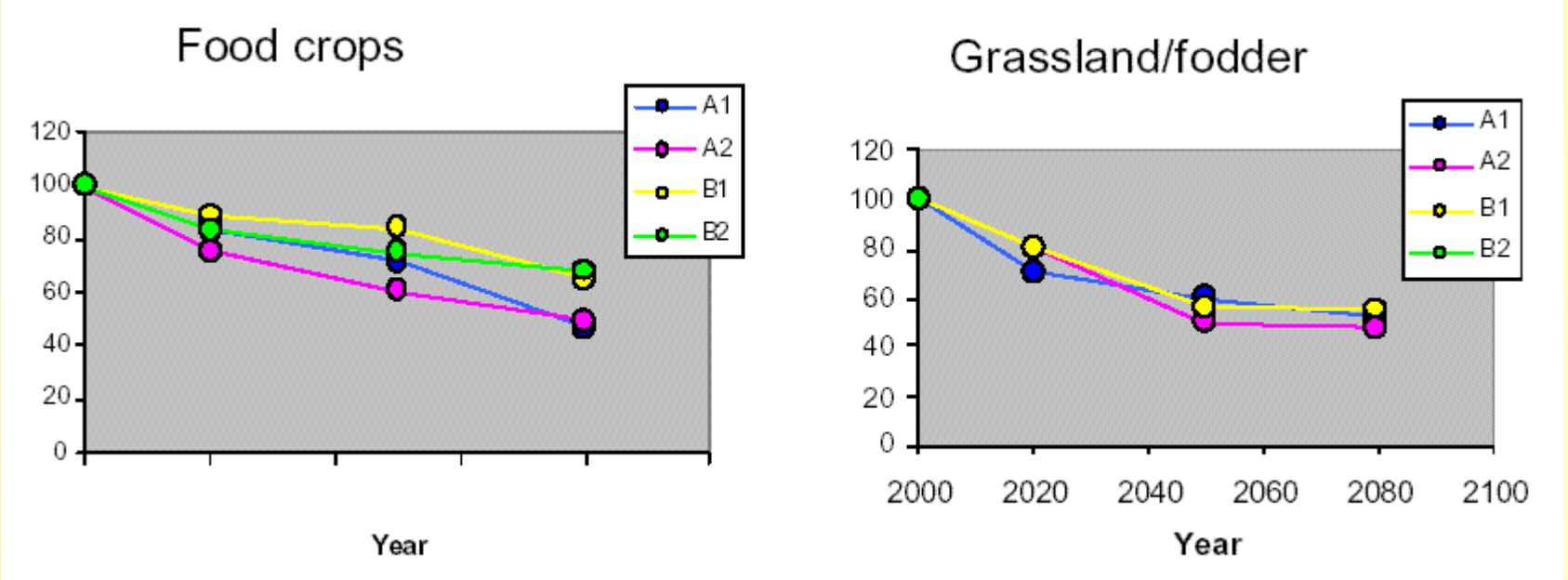


Oversupply factors (Baseline = 1.00)

Scenario	Food crops			Grassland		
	2020	2050	2080	2020	2050	2080
A1F1	0.90	0.90	0.90	1.00	1.00	1.00
A2	0.90	0.90	0.90	1.00	1.00	1.00
B1	1.00	1.00	1.00	derived	derived	derived
B2	derived	derived	derived	derived	derived	derived

European change quantities

- **50% declines in agricultural (food) production areas by 2080!**
- **BUT, what about the spatial allocation of these quantities?**



Scenario spatial allocation rules

A1

No oversupply
Optimal locations
(non LFAs)

No oversupply
Equal spatial change
(regional)

A2

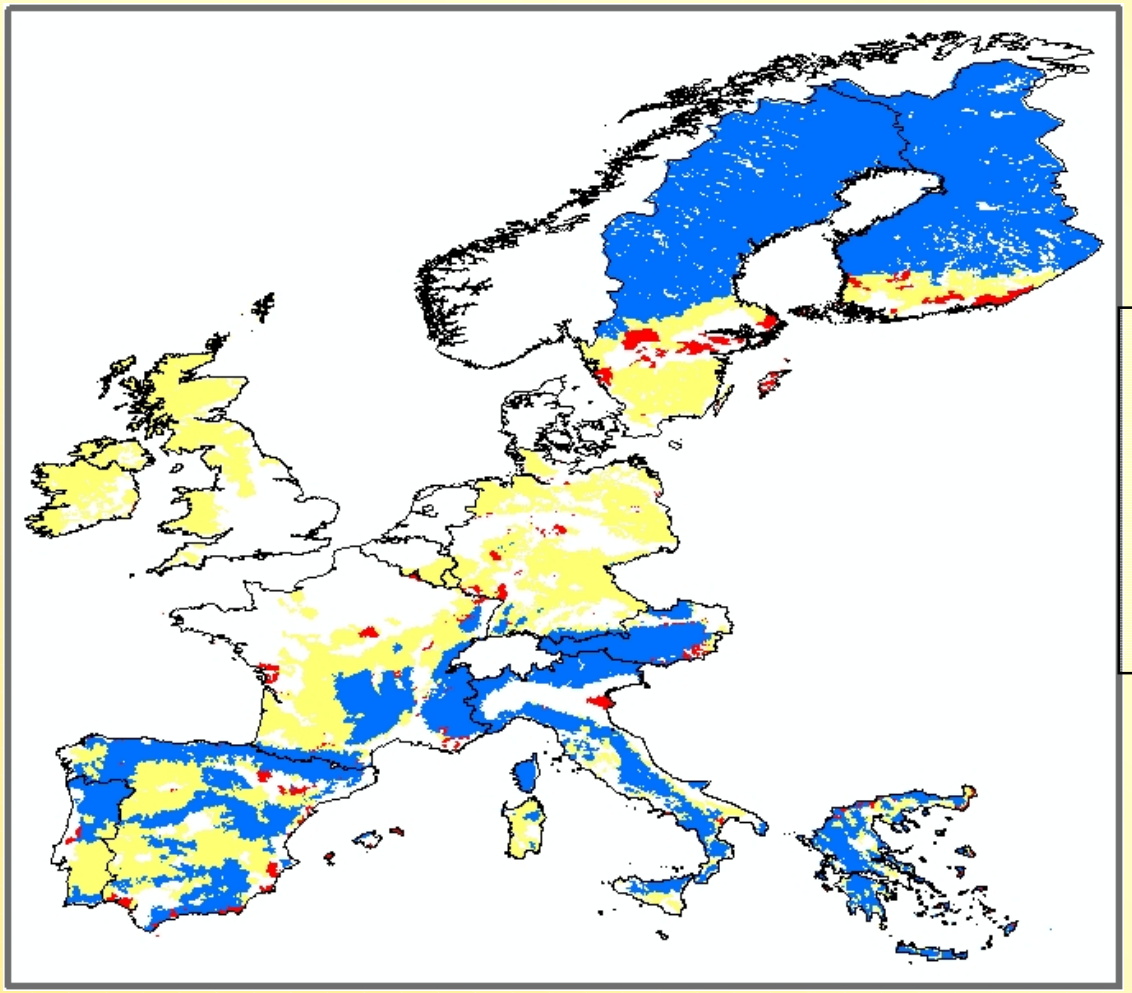
B1

Oversupply
Optimal location of arable
No change in grassland

Oversupply
No change in areas
(discussed later)

B2

Less Favoured Areas

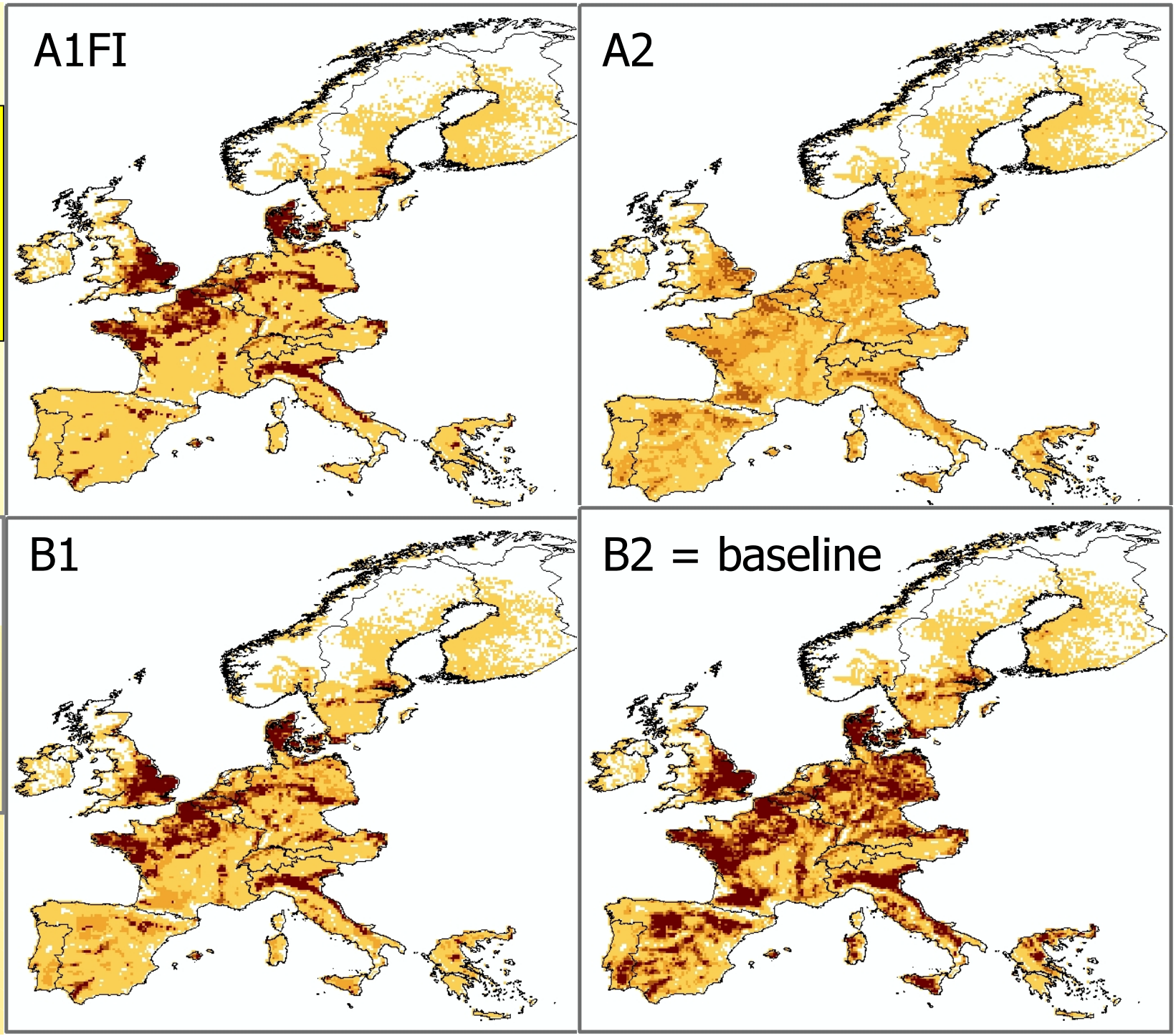


Non-optimal locations?

- Mountain/hill areas
- Areas with specific handicaps
- Less Favoured Areas

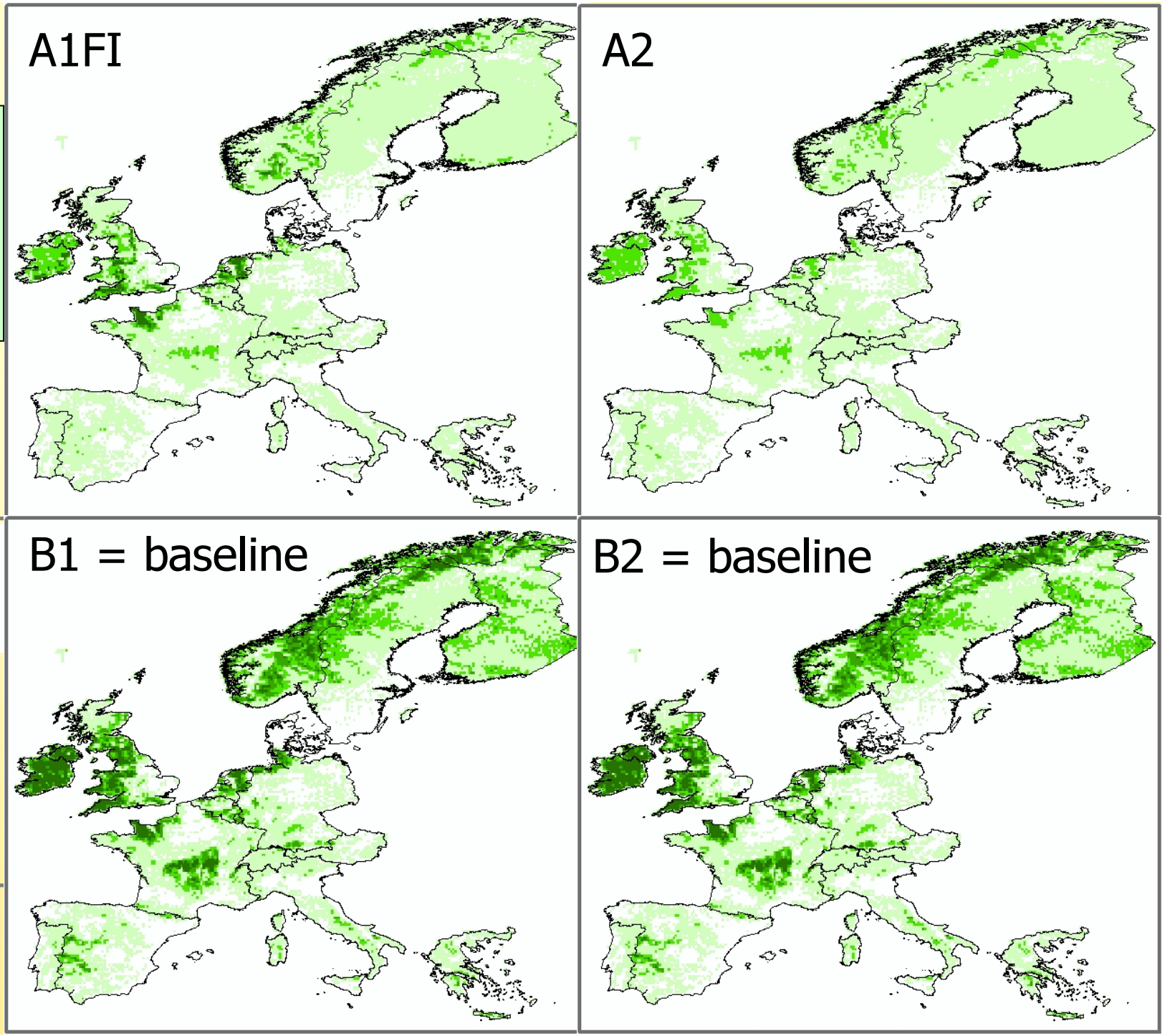
Source: EC DG Agriculture

Arable land in 2080 (HADCM3)



Grass land in 2080

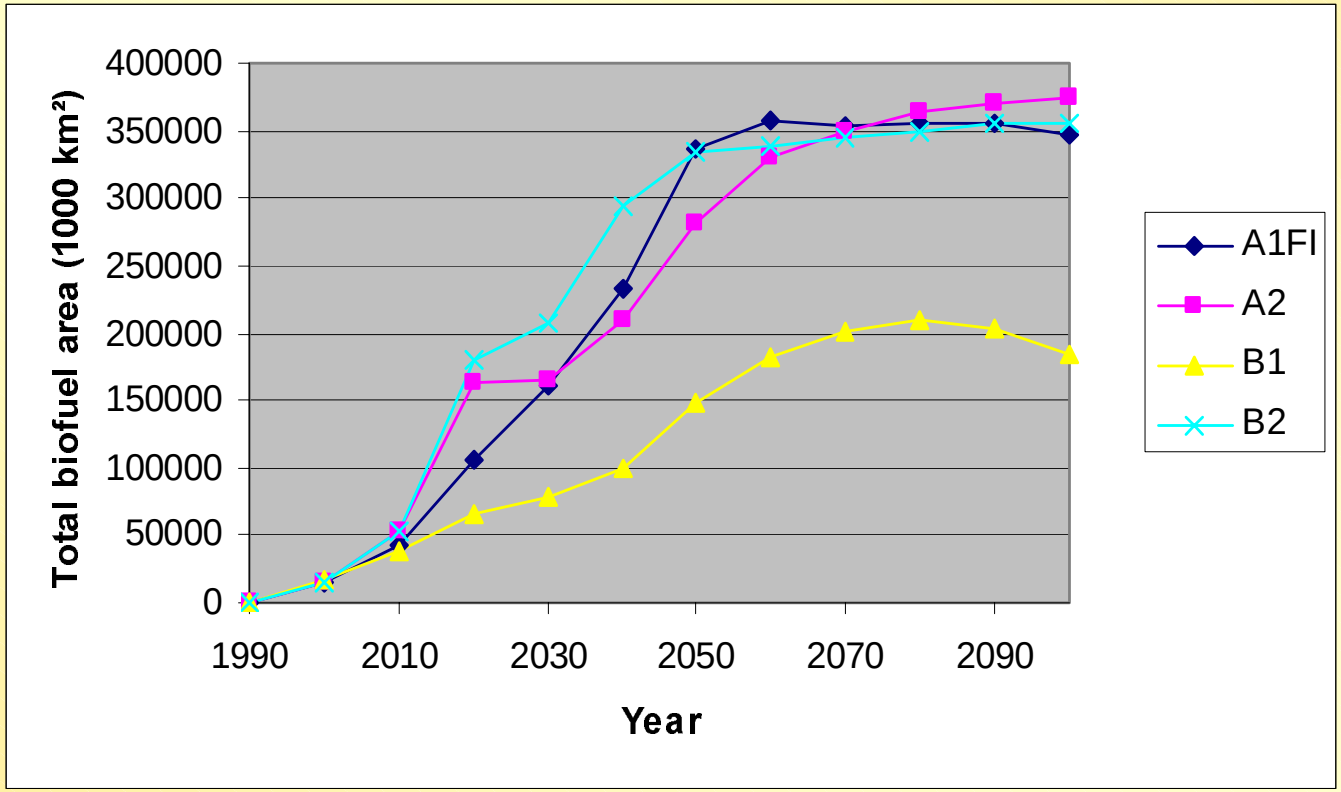
(HADCM3)



So what happens to all the spare land?

- Can we subsitute food production for energy production on agricultural land?
- How much (IMAGE area data)?
- Where to allocate it? Spatial allocation rules and suitabilities

Potential biofuel areas



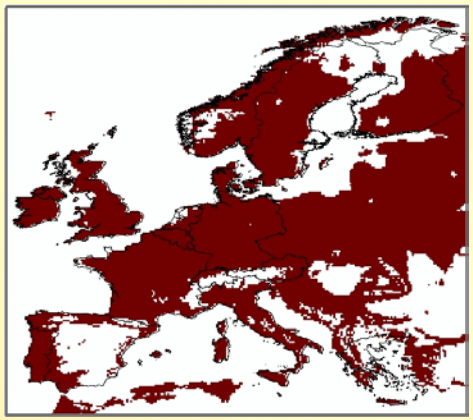
source: IMAGE 2.2

Potential biofuel locations (in red)

A1FI
2080
HADCM3

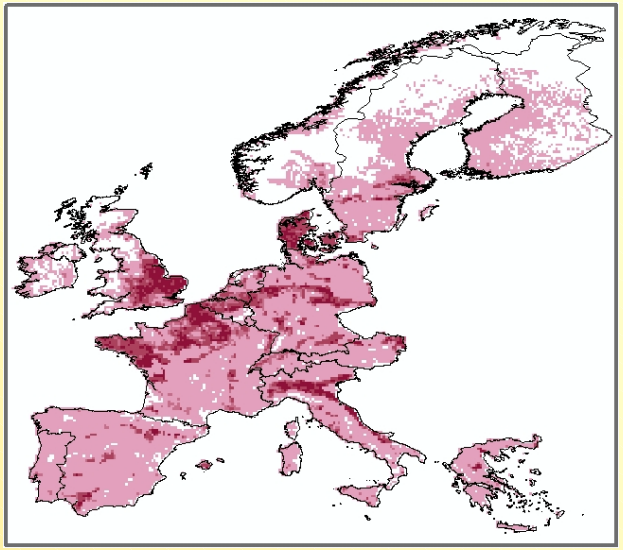
Liquids | Non-woody | Woody

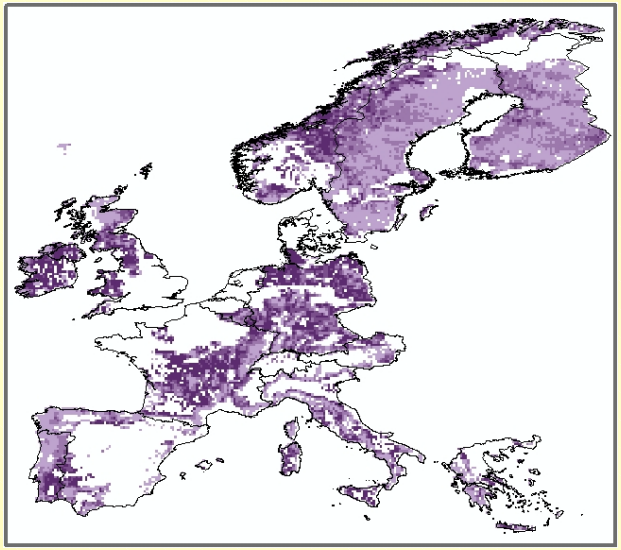
A2
2080
HADCM3

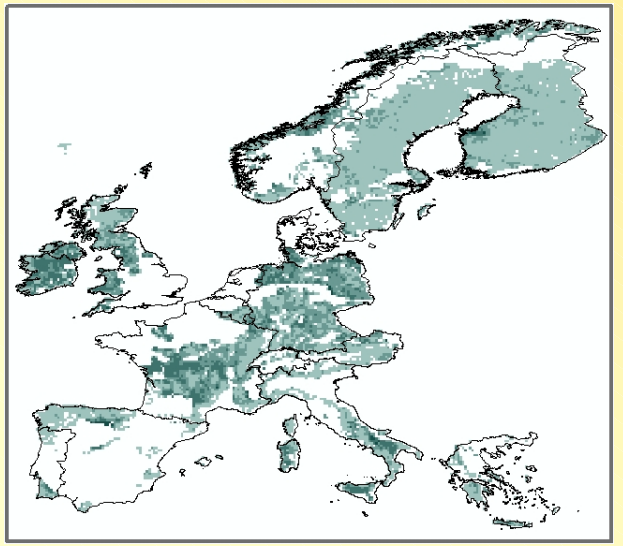


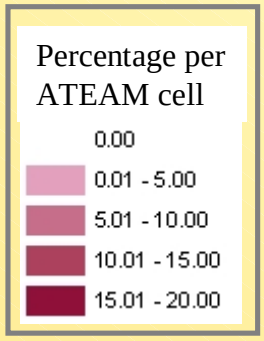
Source: Gill Tuck, Rothamsted Experimental Station, maps prepared by Isabelle Reginster, UCL

Biofuel areas – A1F1 2080

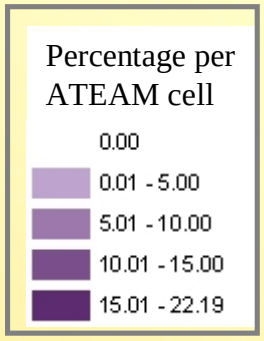




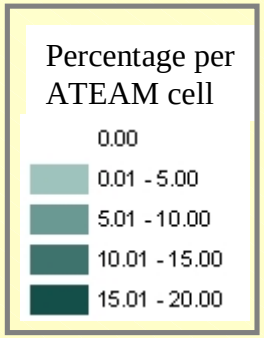




Liquids



Non-woody



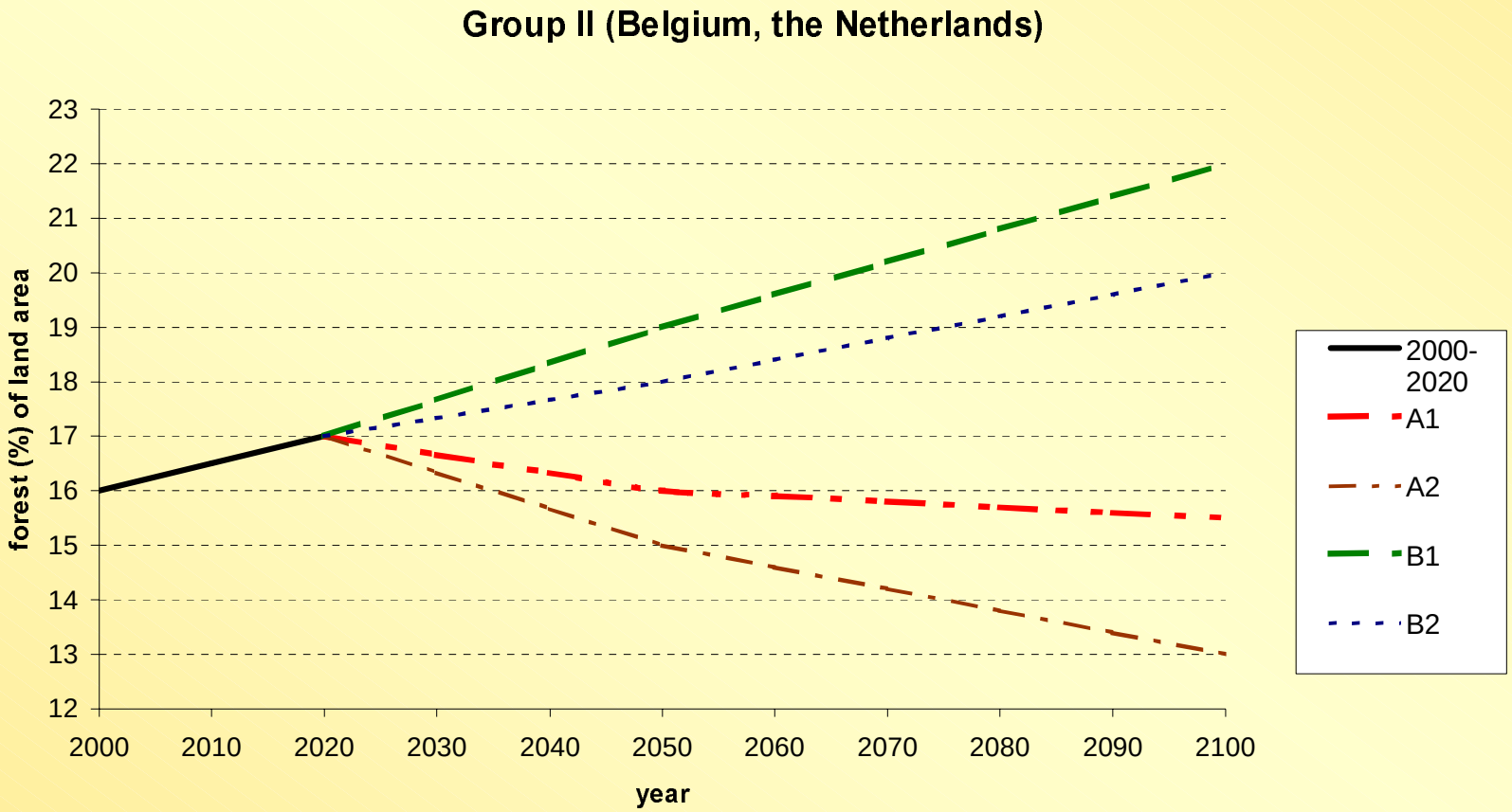
Woody

Source: Gill Tuck, Rothamsted Experimental Station, maps prepared by Isabelle Reginster, UCL

But, biofuels still don't account for all of the surplus land!

- So, grow more trees …

Forest scenarios



Source: Tim Carter & Susanna Kankaanpää, Finnish Environment Institute

What happens to what's left?

- Even more trees?
- Adandonement (i.e. more trees anyway)
- Special areas for nature conservation and/or recreation
- What do you think?
- And, who pays?

Conclusions I

- The scenarios suggest large declines in the surface areas of agricultural land use (especially grassland) for the A (economic scenarios)
- The principal cause of these reductions is the assumptions about the role of technological development
- The reductions seem only partly compensated for by increasing biofuel production and forest land use
- It is unclear what might happen to the large areas of surplus land

Conclusions II

- Declines in agricultural areas are less for the B (environmental scenarios) than for the A's
- This assumes, however, that the pressures toward declining agricultural areas are counterbalanced by policy mechanisms that seek to limit crop productivity
- This could include measures to promote extensification or organic production, or
- The substitution of food production by energy production and the planting of trees, or
- An acceptance of overproduction (as with the current CAP)

Finally, food for thought …

- Scenarios are (themselves) models of the real-world – sometimes, descriptive/qualitative, sometimes conceptual, sometimes quantitative
- Scenarios can be interpreted from storylines in many different ways – there is no correct answer, and many possibilities
- Scenarios allow us to explore our understanding and preconceptions of how the world works – I didn't know that technology was potentially so important for agricultural land use (there's no literature on this!)
- Scenarios force us to confront (policy) questions about the future, and to plan now

Some discussion questions I

- How do the presented scenarios of land use change compare with your responses to the questionnaire (of Tim Carter)?
- If there are differences, what are they and why?

Some discussion questions II

For your study region:

- **Are there additional 'divers' of importance for land use change? [start with the presented list of European-scale drivers]**
- **What are the possible solutions to the surplus land issue? [start by addressing whether this is a plausible scenario]**
- **What are the consequences of the presented scenarios for goods and services? [start by making a list of the goods and services that will be affected by land use change in your region]**

Acknowledgements

- Thanks to the European Commission for the cash (funding of the ATEAM and ACCELERATES projects)
- Thanks to my colleagues too numerous to mention ….