Universiteit Utrecht

Environmental Impacts of Biorenewables and Biofuels

Workshop on environmental, social and economic impacts of biofuels
Organized by FAPESP & BE-BASIC
Sao Paulo - Brazil, November 25th, 2010

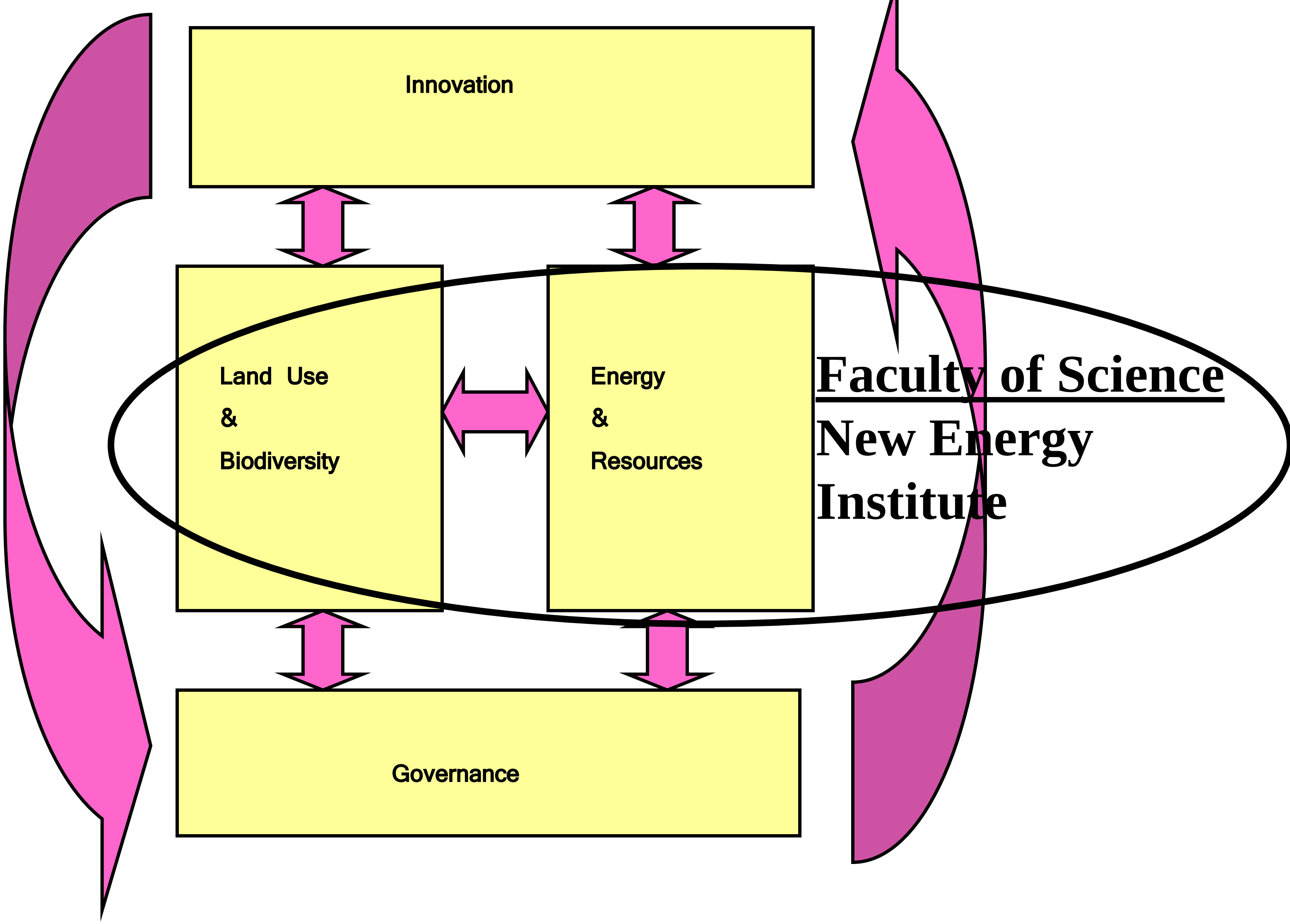
André Faaij

Copernicus Institute - Utrecht University

Task Leader IEA Bioenergy Task 40

Copernicus Institute
Sustainable Development and Innovation Management

Copernicus Institute; key areas of research (Approx. 100 researchers)

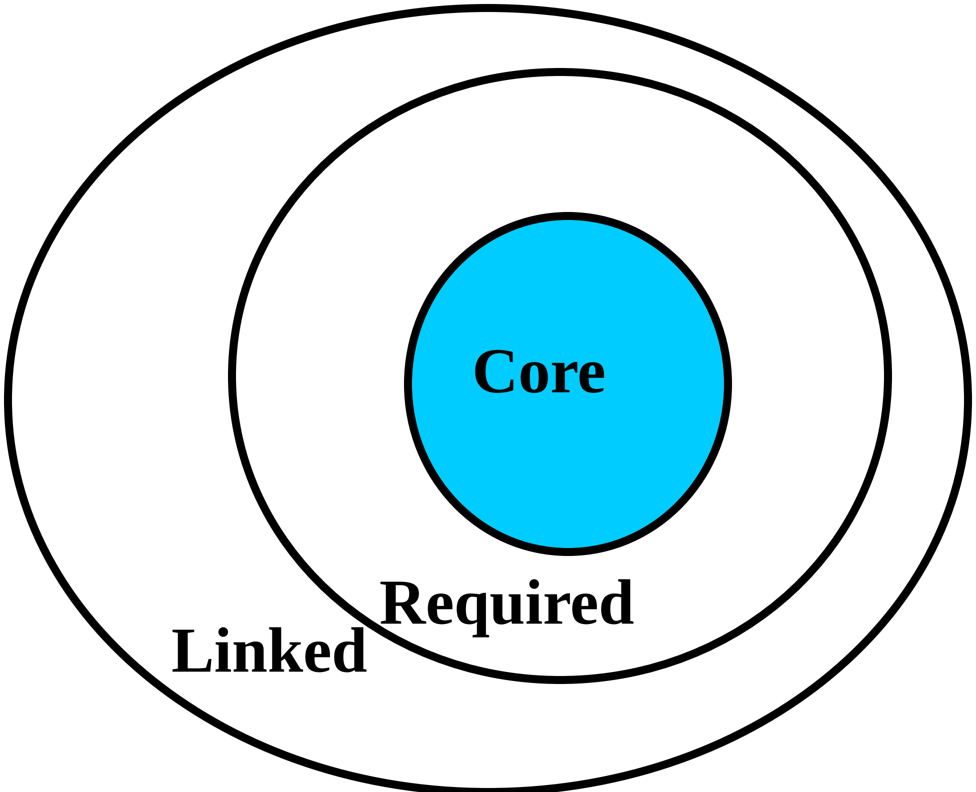


Interlinked concepts for understanding, exploring, monitoring and evaluation.

- *Technologies*: Engineering – Technology Assessment – Technological Learning
- *Impacts*: wide portfolio of methods (environmental / ecological / socio-economic…); how to measure ‘sustainability’?
- *Potential supply*: options, limitations, opportunities.
- *Modeling & uncertainty analysis*: wide range of tools.
- *Implementation*: policy options, energy transition & innovation policies, roadmaps, scenario’s…

Core methods & tools in system analysis

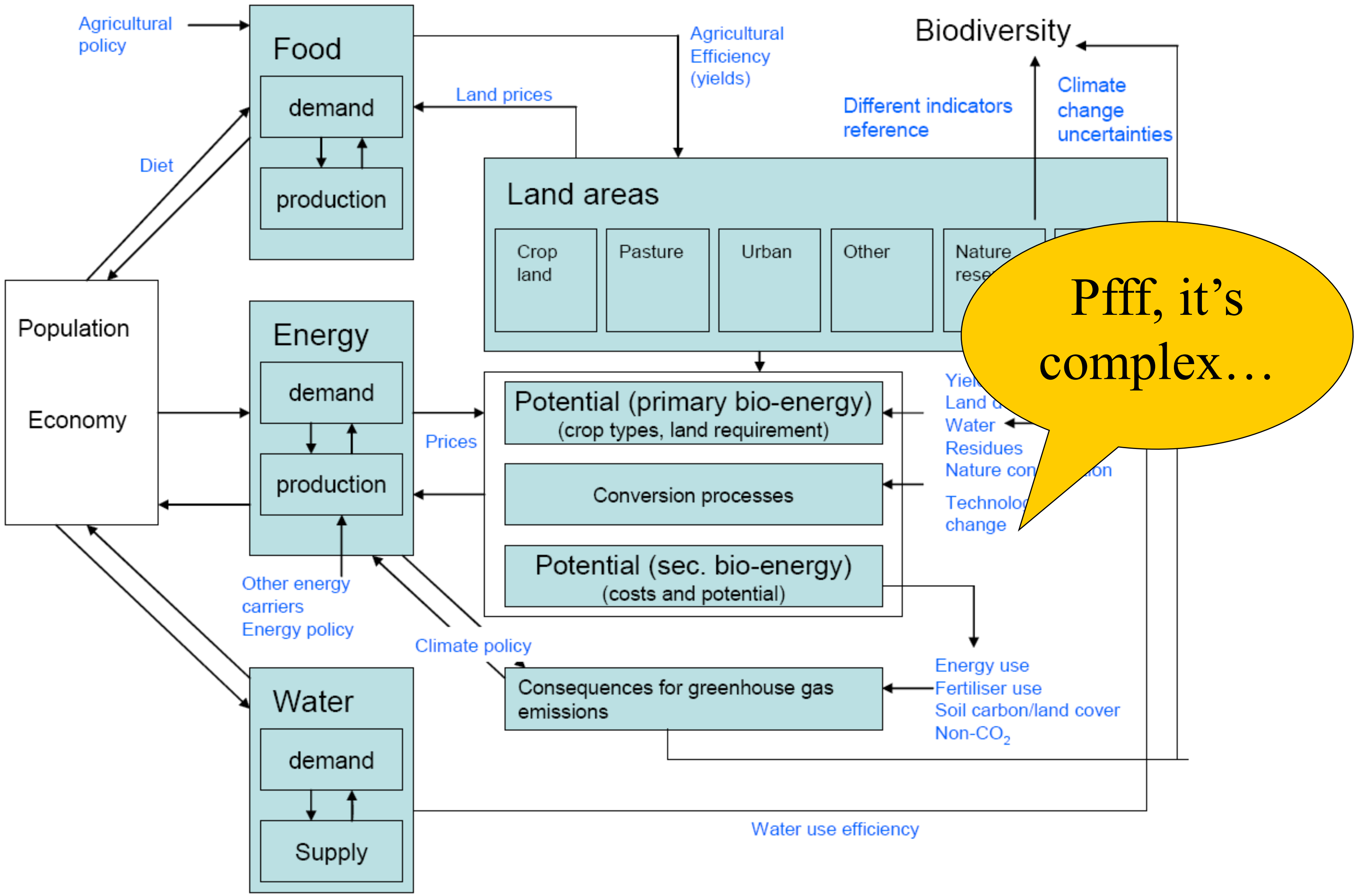
- Process analysis (engineering based)
- Technology Assessment & Technological Learning
- Energy analysis
- Energy system modeling (e.g. MARKAL, GIS support,…)
- Economic analysis / CBA
- LCA / EIA
- Uncertainty & risk analysis
- Scenario analysis
- Chain analysis
- Integrated assessment (e.g. IMAGE/TIMER)
- Participatory methods
- (…)



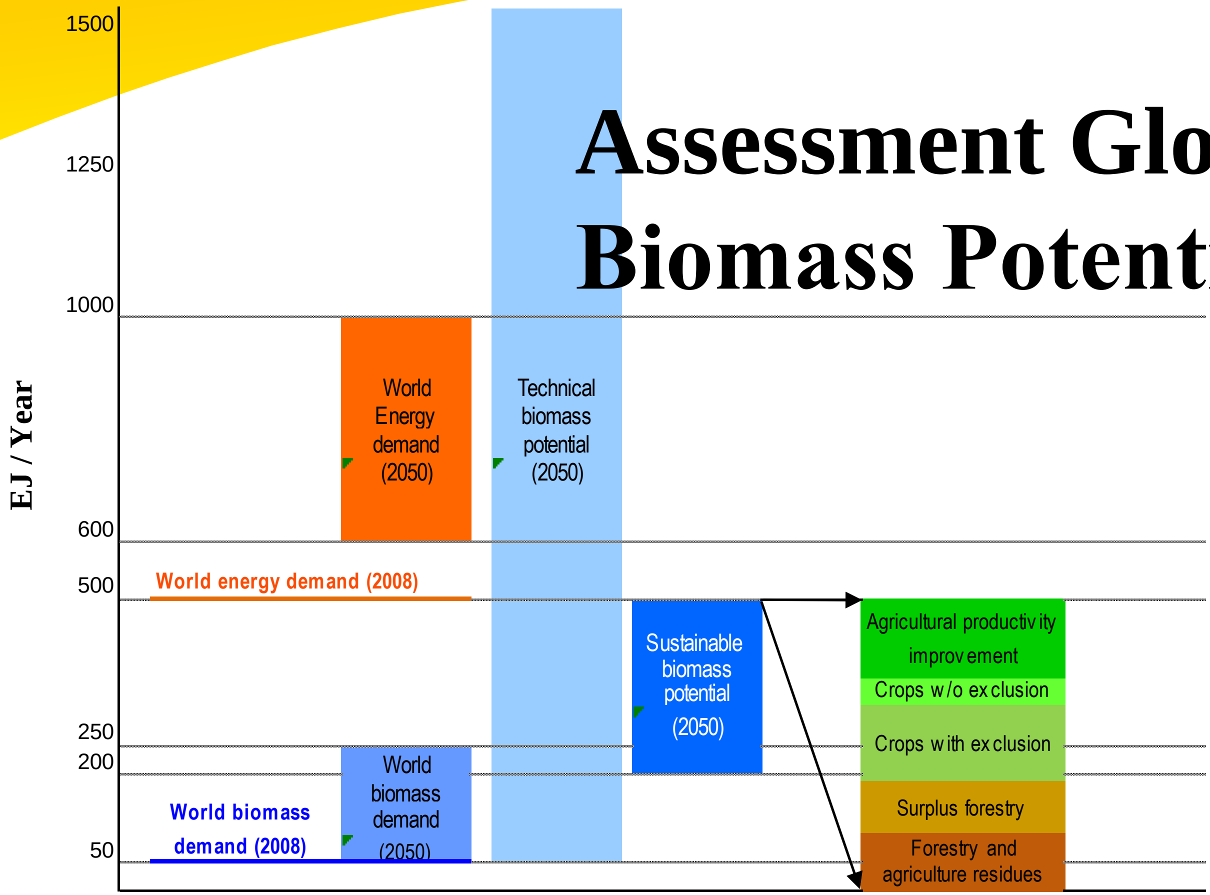
Contents bio-energy research

- *Potentials*: modeling, assessment
- *Sustainability* – full (!) impact analysis & certification.
- *Logistics & conversion;* system studies & optimisation.
- *Technological learning*; improvement potentials and development pathways.
- *Case studies* & implementation.
- *Markets and policy*.

Understanding biomass resource potentials requires integration of many science arena's



Assessment Global *Sustainable* Biomass Potentials 2050…



Current world energy demand (500 EJ/year)

Current world biomass use (50 EJ/year)

Total world primary energy demand in 2050 in World Energy Assessment (600 - 1000 EJ/year)

Modelled biomass demand in 2050 as found in literature studies. (50 - 250 EJ/year)

Technical potential for biomass production in 2050 as found in literature studies. (50 - 1500 EJ/year).

Sustainable biomass potential in 2050 (200-500 EJ/year). *Sustainable biomass potentials consist of: (i) residues from agriculture and forestry; (ii) surplus forest material (net annual increment minus current harvest); (iii) energy crops, excluding areas with moderately degraded soils and/or moderate water scarcity; (iv) additional energy crops grown in areas with moderately degraded soils and/or moderate water scarcity and (v) additional potential when agricultural productivity increases faster than historic trends thereby producing more food from the same land area.*

100-300 EJ achievable… = 1/3 global demand 2050

[*Bioenergy Revisited*: Dornburg et al., Energy & Environmental Science, 2010]

Key factors biomass potentials

Issue/effect	Importance
Supply potential of biomass	
Improvement agricultural management	***
Choice of crops	***
Food demands and human diet	***
Use of degraded land	***
Competition for water	***
Use of agricultural/forestry by-products	**
Protected area expansion	**
Water use efficiency	**
Climate change	**
Alternative protein chains	**
Demand for biomaterials	*
Demand potential of biomass	
Bio-energy demand versus supply	**
Cost of biomass supply	**
Learning in energy conversion	**
Market mechanism food-feed-fuel	**

Dornburg et al., Energy & Environmental Science 2010

Negative vision, ahead of IPCC- SRREN…

Universiteit Utrecht

Low biomass scenario		
Largely follows A2 SRES scenario conditions, assuming limited policies, slow technological progress in both the energy sector and agriculture, profound differences in development remain between OECD and DC's.	High fossil fuel prices expected due to high demand and limited innovation, which pushes demand for biofuels for energy security perspective Increased biomass demand directly affects food markets	Increased biomass demand partly covered by residues and wastes, partly by annual crops. Total contribution of bioenergy about 100 EJ before 2050. Additional crop demand leads to significant iLUC effects and impacts on biodiversity. Overall increased food prices linked to high oil prices. Limited net GHG benefits. Socio-economic benefits sub-optimal.

Positive vision (ahead of IPCC - SRREN…)

Storyline	Key preconditions	Key impacts
High biomass scenario		
Largely follows A1/B1 SRES scenario conditions,	Assumes: well working sustainability frameworks and strong policies well developed bioenergy markets progressive technology development (biorefineries, new generation biofuels, successful deployment of degraded lands.	Energy price (notably oil) development is moderated due to strong increase supply of biomass and biofuels. Some 300 EJ of bioenergy delivered before 2050; 35% residues and wastes, 25% from marginal/degraded lands (500 Mha), 40% from arable and pasture lands 300 Mha). Conflicts between food and fuel largely avoided due to strong land-use planning and aligning of bioenergy production capacity with efficiency increases in agriculture and livestock management. Positive impacts with respect to soil quality and soil carbon, negative biodiversity impacts minimised due to diverse and mixed cropping systems.

Bottlenecks (I): improve key insights and data:

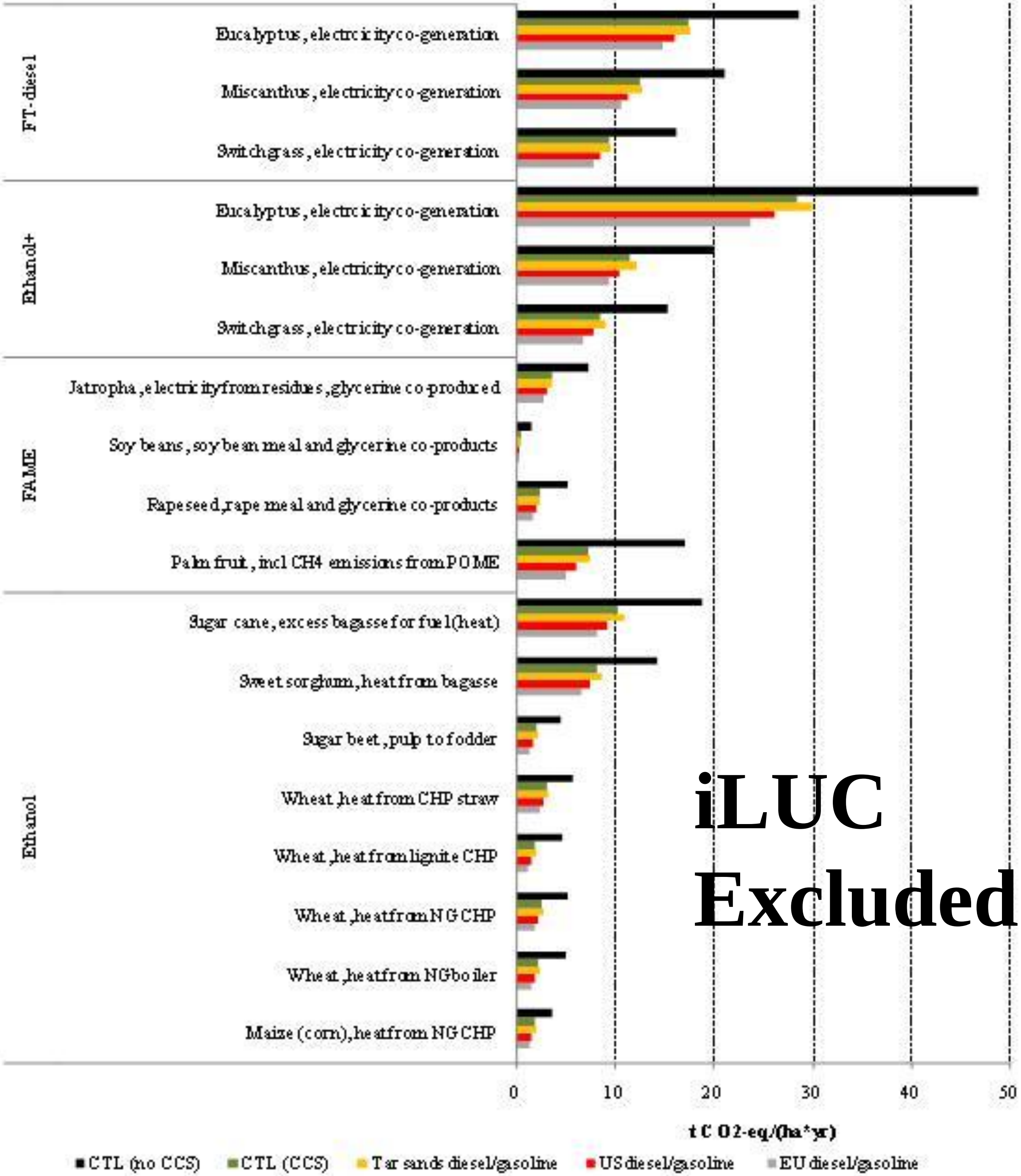
- Embed technological learning of bioenergy systems properly in models (production, supply and conversion systems). [Bottom-up]
- Learning of agricultural and livestock management (in relation to prices, settings and policies). [Bottom-up]

Bottlenecks (II): Biophiscal models ~ environment:

- Water [regional level; bottom-up]
- Biodiversity (resolve methodological issues; management options and reference situations).
- Proper incorporation of residues and wastes.
- Marginal and degraded lands [data!!!]

Bottlenecks (III): modeling frameworks:

- Integrate biophysical and macro-economic models (partly tackled: IFPRI, UU/PBL/LEI - IMAGE/GTAP).
- Feedbacks prices (and policies) on learning and intensification.
- New advanced scenario's: policy driven, sustainability incorporated.
  - Key additons:
  - 2nd (+) generation options
  - Biomaterials
  - Non-agricultural lands (forest, marginal, degraded, etc.)
- Backed by concrete examples; model verification



Universiteit Utrecht

Lifecycle greenhouse gas emissions saved per hectare land for different fossil reference fuel types.

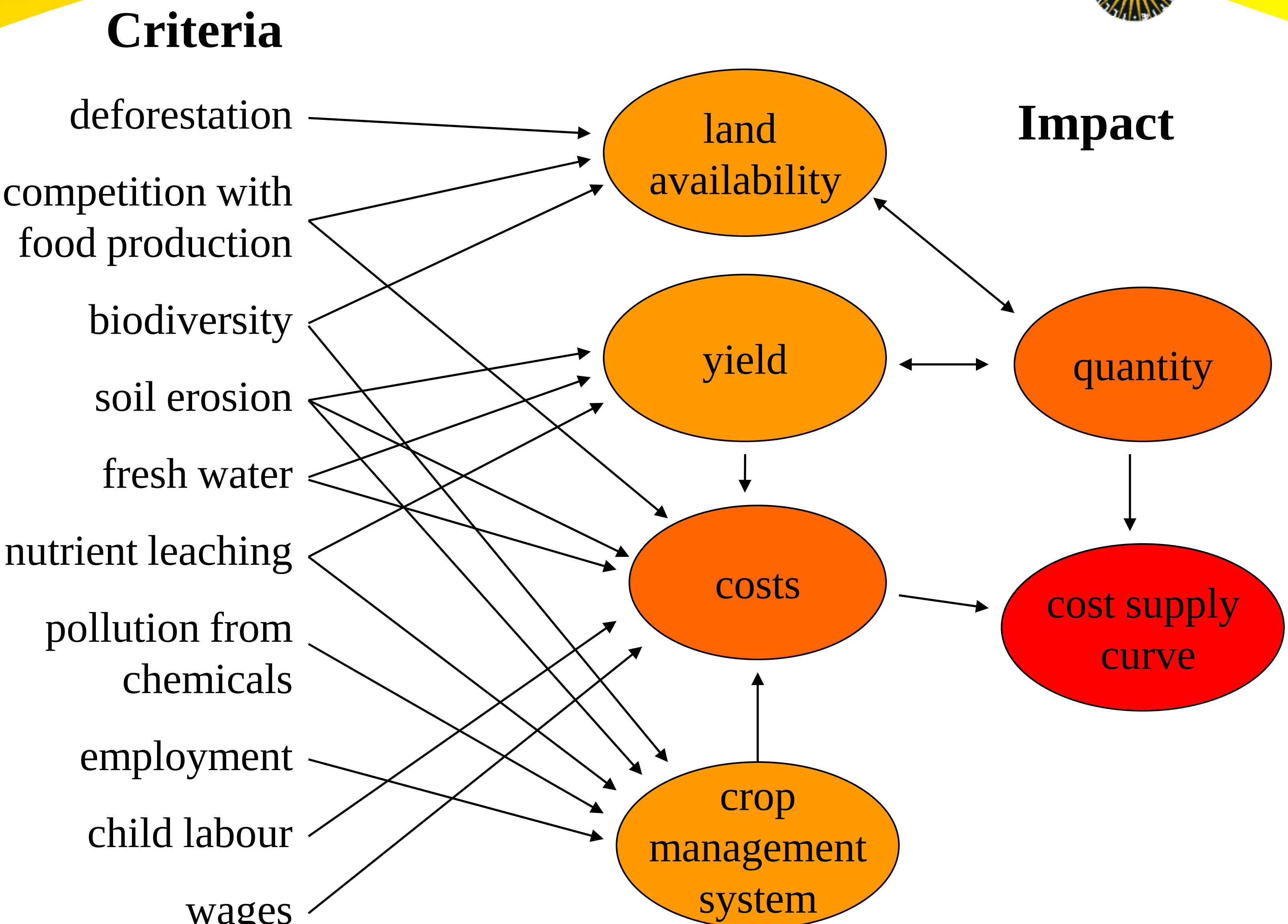
Hoefnagels et al., Renewable & Sustainable Energy Reviews, Feb 2010.

iLUC factors…

- Searchinger: 1
- Later global (macro-economic) analyses: 0.3 -> 0.2.
- More detailed regional studies: depends highly (Fully…) on rate of improvement in agricultural and livestock management (e.g Apola, et al. PNAS, 2010)
- This was *also & already* the case in Hoogwijk, Smeets, REFUEL, etc.etc.
- iLUC is a **reactive** concept while we actually want to be **proactive** in avoiding it altogether…

Operationalisation of sustainability criteria

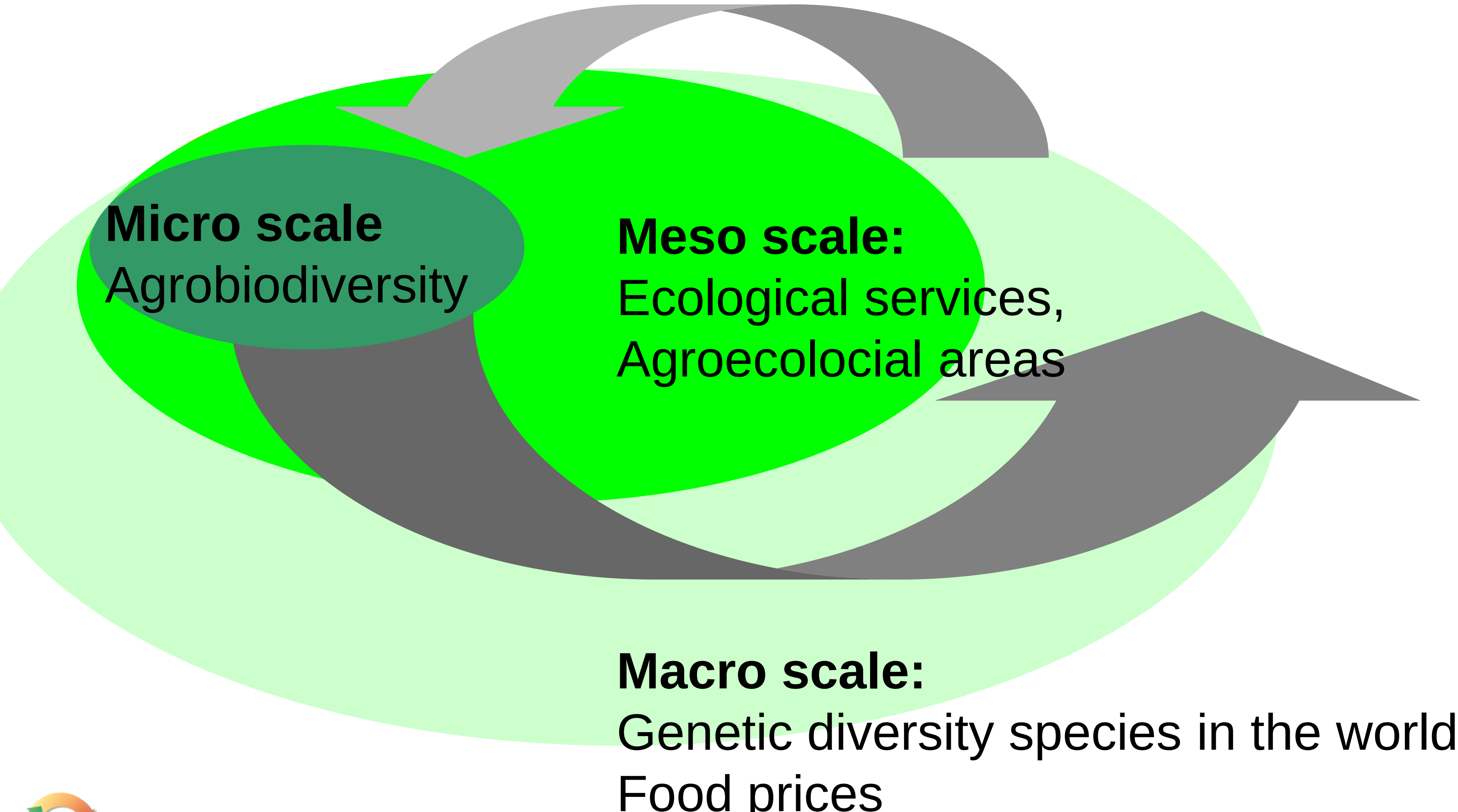
Universiteit Utrecht



[Smeets et al., Biomass & Bioenergy, 2010]

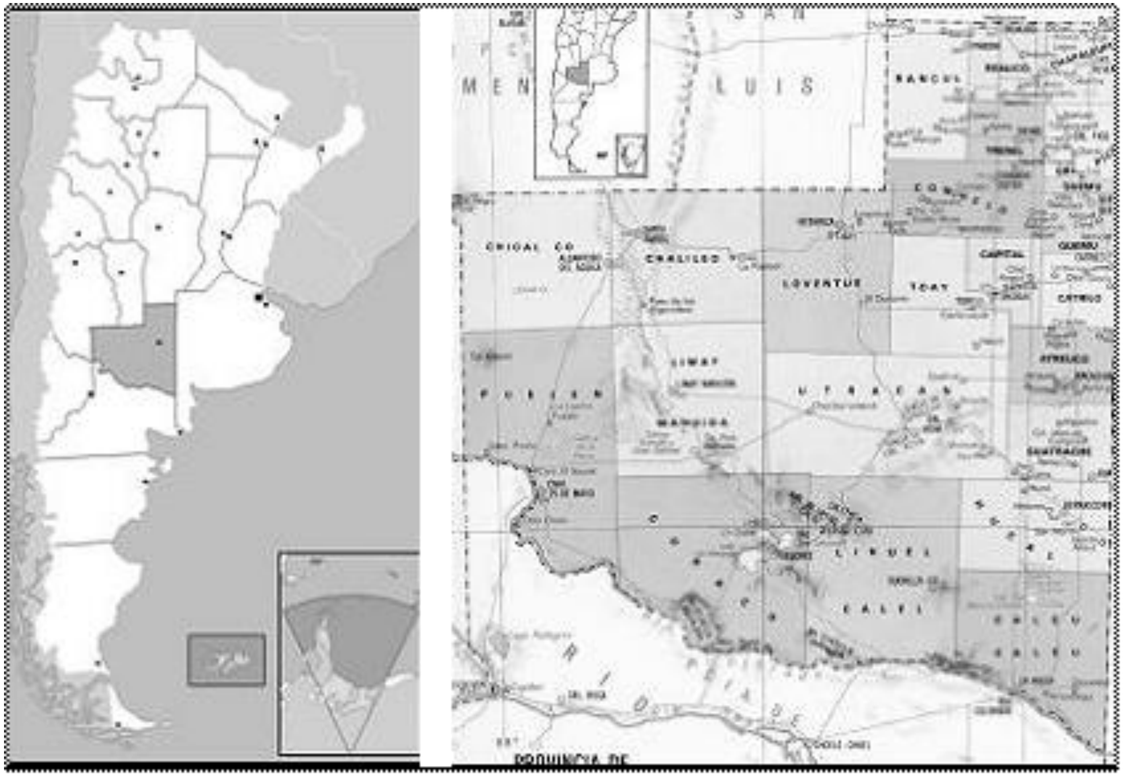
Macro-meso-micro level

<u>Examples are: Impacts of </u>Biodiversity, water, socio-economic impacts…



Van Dam et al., RSER 2010

Argentina; example full impact analysis



Van Dam et al., 2009 (forthcoming)

Different ***scenario's*** for land-use and agricultural management

Compares soybean (biodiesel) to switchgrass (pellets)

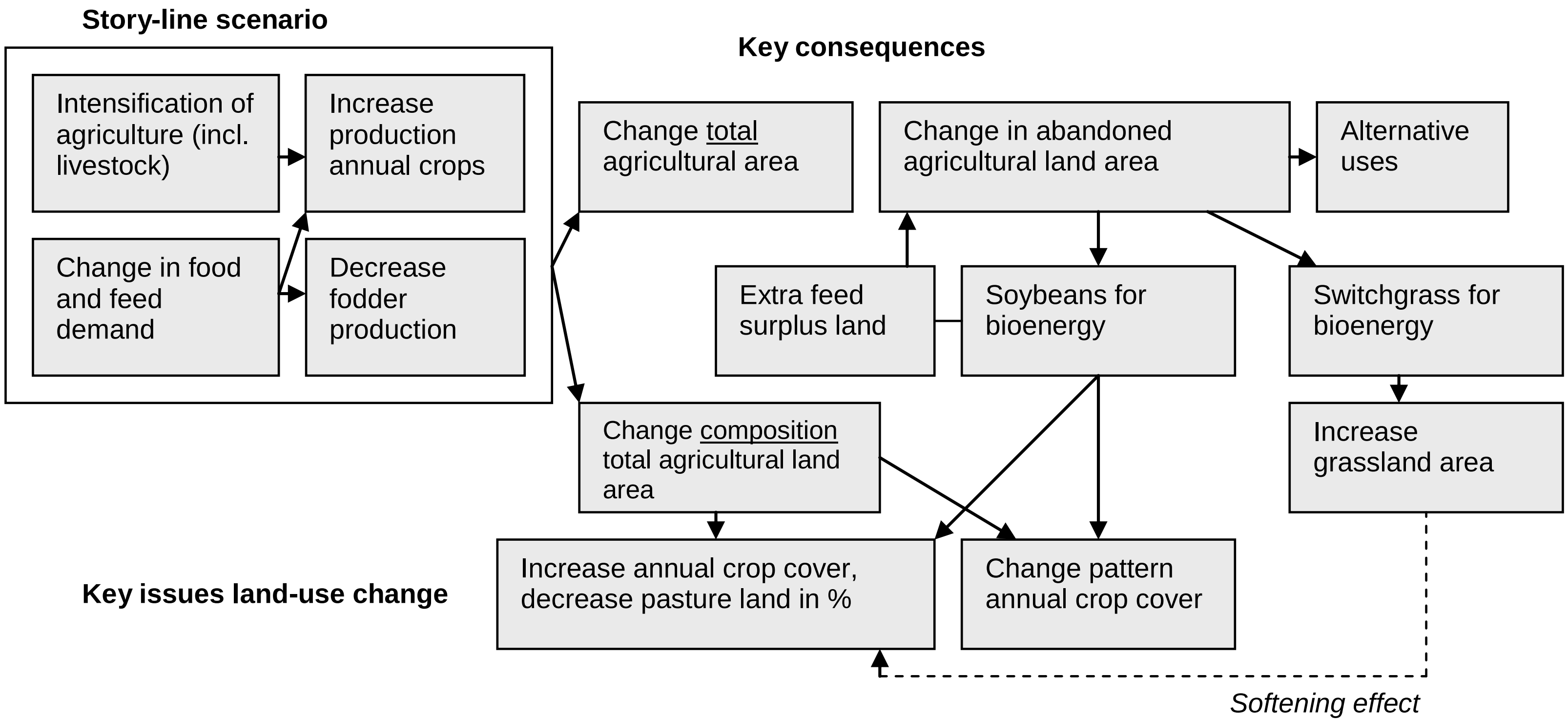
Focus on more marginal area in one province (La Pampa)

Follows main principles of Cramer framework

Van Dam et al., 2009 Renewable & Sustainable Energy Reviews

Criteria: Issues related to land-use change
Land-use changes and changes in land and food/feed prices

Figure: Key consequences and expected direct land-use changes in scenarios according to story lines



Van Dam et al., 2009 Renewable & Sustainable Energy Reviews

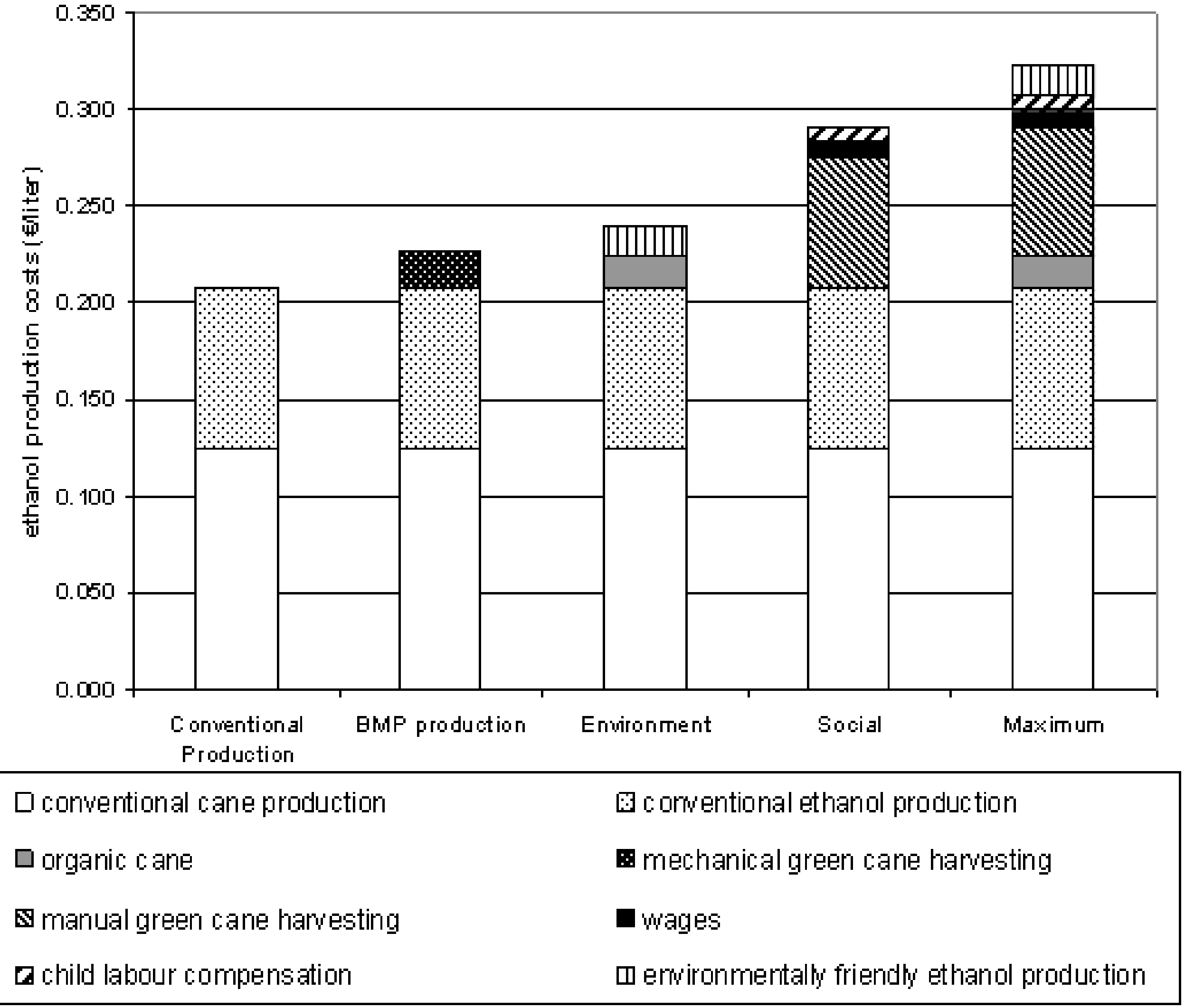
relative sustainability performance switchgrass and soybean bioenergy chain

	Switchgrass bioenergy chain								Soybean bioenergy chain							
Principles	CUR		A		B		C		CUR		A		B		C	
	S	mS	S	mS	S	mS	S	mS	S	mS	S	mS	S	mS	S	mS
Reference land- use	C	D	C	D	G	D	C	D	C	D	C	D	G	D	C	D
Soil carbon balance	++	+	++	+	+	+	++	+	0	--	0	--	--	--	0	-
GHG balance	++	++	++	++	++	++	++	++	++	+	++	+	+	0	++	+
Land-use change																
- Change in land-use	≈0+	≈0+	≈0+	≈0+	≈0+	≈0+	≈0+	≈0+	≈0-	≈0-	≈0-	≈0-	≈0-	≈0-	≈0-	≈0-
- Rise land prices	0	0	-	0	+	0	+	0	0	0	-	-	0	0	-	-
- Rise food prices	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0	≈ 0
Biodiversity	+	0	+	0	+	0	+	0	0	-	0	-	-	-	0	-
Soil quality and quantity																
Soil erosion	++	++	++	++	-	++	+	++	0	-	0	-	--	++	0	++
Soil nutrients	≈++	≈+	≈++	≈+	≈+	≈+	≈++	≈+	≈0/-	≈--	≈0	≈--	≈--	≈--	≈0	≈-
Water quality and quantity																
- Water quality	++	+	++	+	-	+	++	+	0	--	0	--	--	--	0	--
- Water quantity	≈ 0+	≈ 0-	≈ 0+	≈ 0-	≈ 0+	≈ 0	≈ 0+	≈ 0	≈ 0	≈ 0-	≈0	≈ 0-	≈ 0+	≈ 0-	≈ 0+	≈ 0-
Air quality	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Local prosperity	++	+	++	+	++	+	++	+	+	0	+	0	+	0	+	0
Social well-being	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+

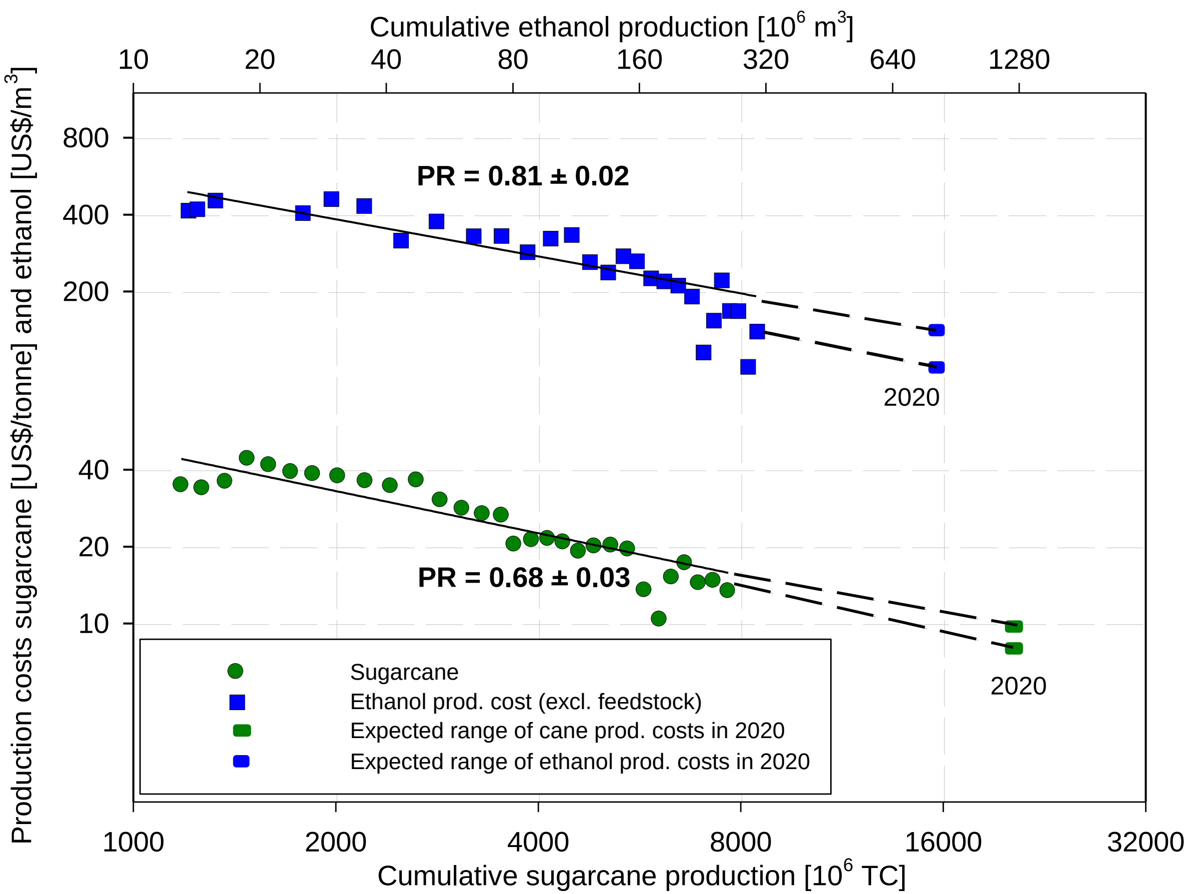
Van Dam et al., 2009 Renewable & Sustainable Energy Reviews

Ethanol in Brazil; the costs of compliance with various sustainability criteria compared to the reference situation

[Smeets, Junginger, Faaij, Walter, Dolzan, 2008]



Estimated future costs of sugarcane and ethanol production assuming 8% annual growth

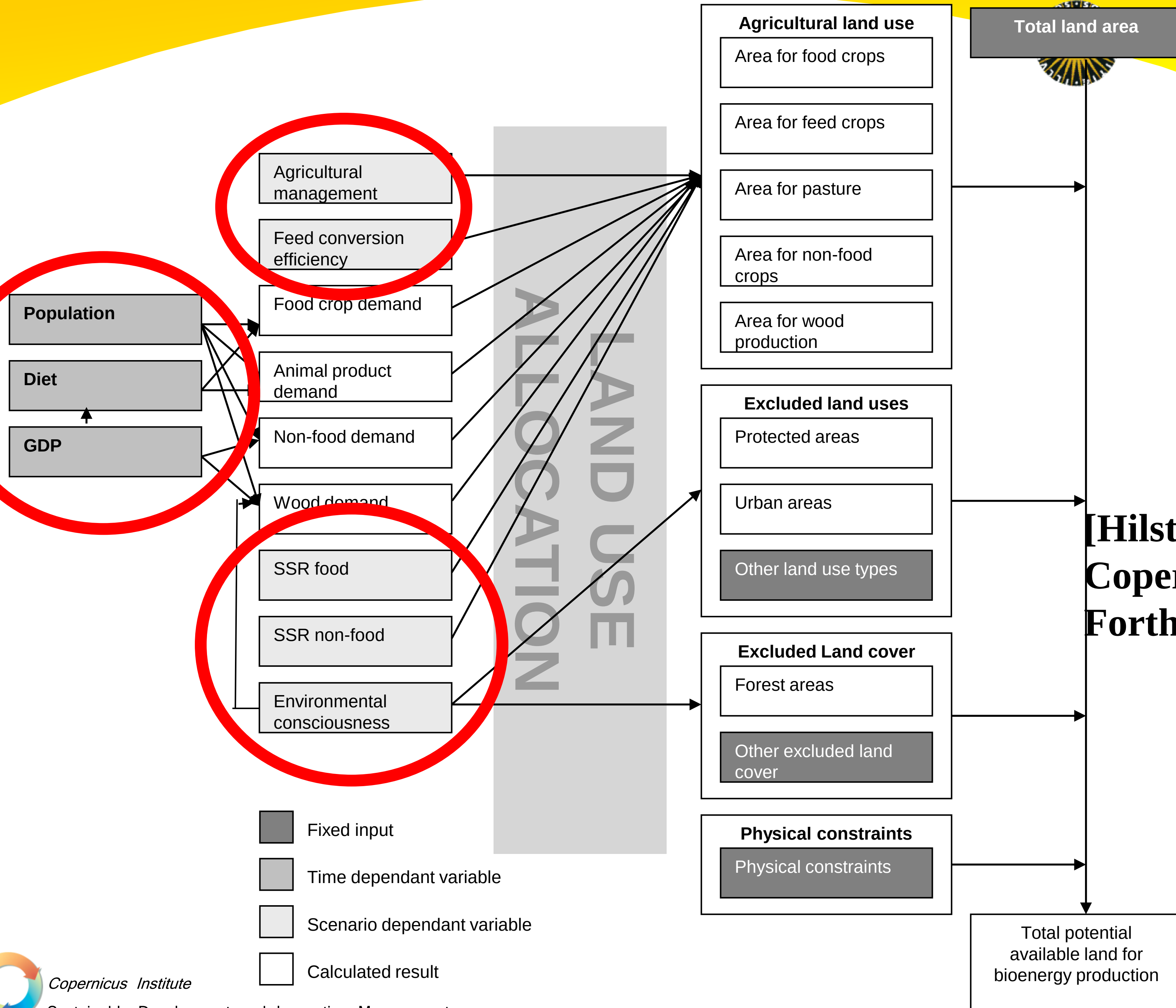


Explaining the experience curve:

Cost reductions of Brazilian ethanol from sugarcane

J.D. van den Wall Bake, M. Junginger, A. Faaij, T.Poot, A. da Silva Walter

Biomass & Bioenergy, 2008

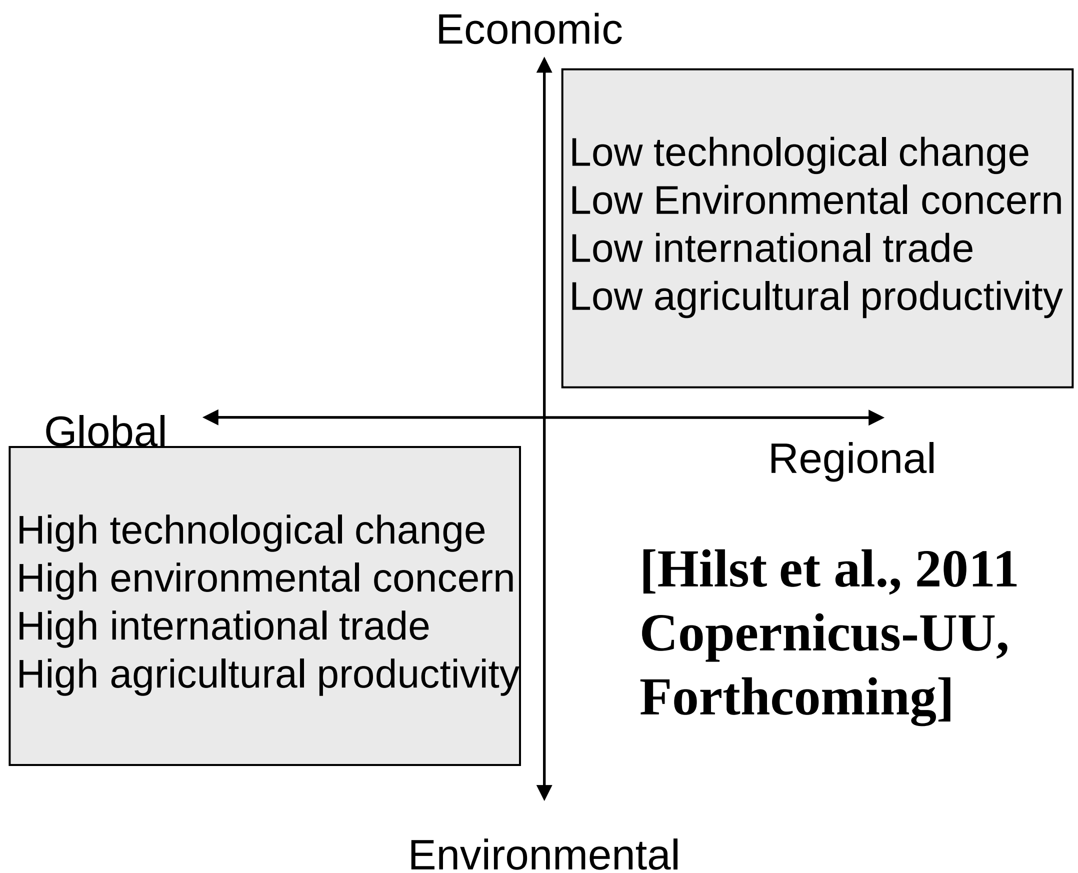


[Hilst et al., 2011 Copernicus-UU, Forthcoming]

Land use developments

Land use developments can not be predicted…

But future land use developments can be explored by means of a scenario approach.



[Hilst et al., 2011 Copernicus-UU, Forthcoming]

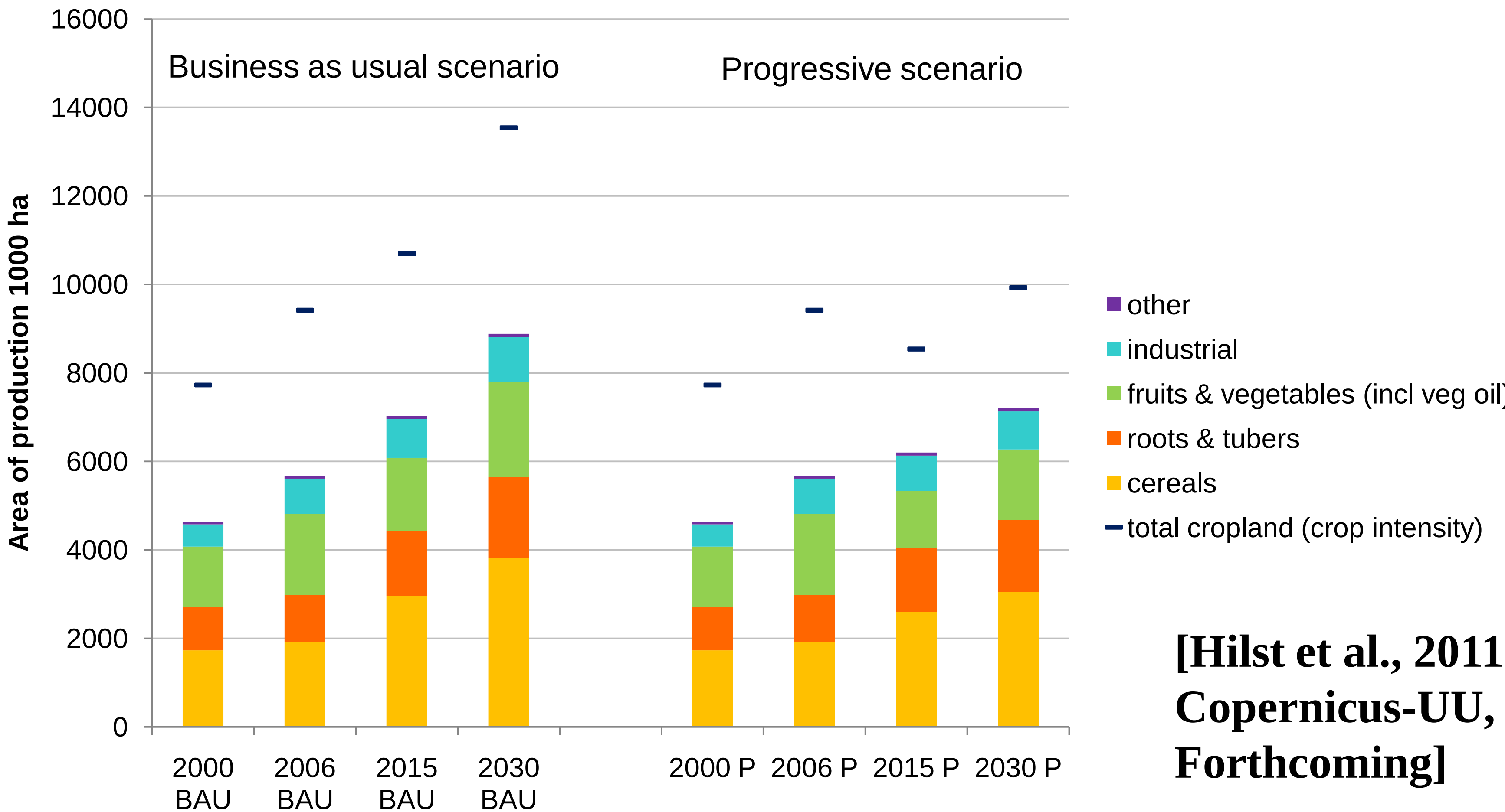
Scenarios

	Business as Usual scenario	Progressive scenario
Farm	Mainly subsistence farming	Shift towards commercial farming
Technology	Low adoption of improved seeds, fertilizers pesticides and mechanisation. Low yield increase.	Strong increase in use of improved seeds, fertilizers, pesticides and mechanisation. High yield increase
Livestock	Cattle and goat mainly in pastoral systems	Shift towards mixed systems (higher efficiency)
Wood	Deforestation due to illegal logging and high demands for fuel wood	Decrease in deforestation. Due to regulated logging and decreased fuel wood demand related to higher implementation of improved stoves.
Policy	Less effective policies on efficient an sustainable production	Highly effective policies on efficient and sustainable production

[Hilst et al., 2011 Copernicus-UU, Forthcoming]

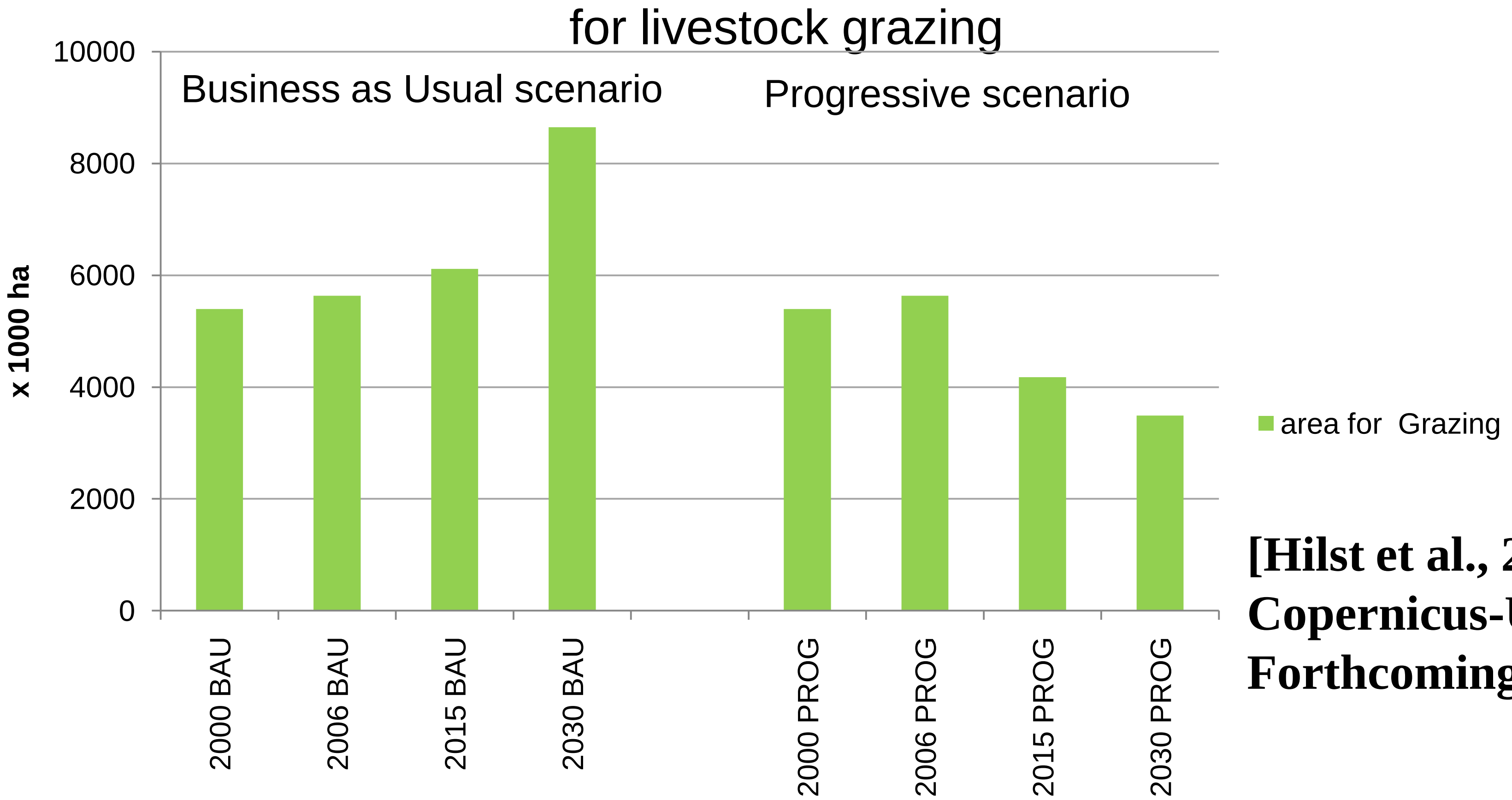
Land requirements

for crop production



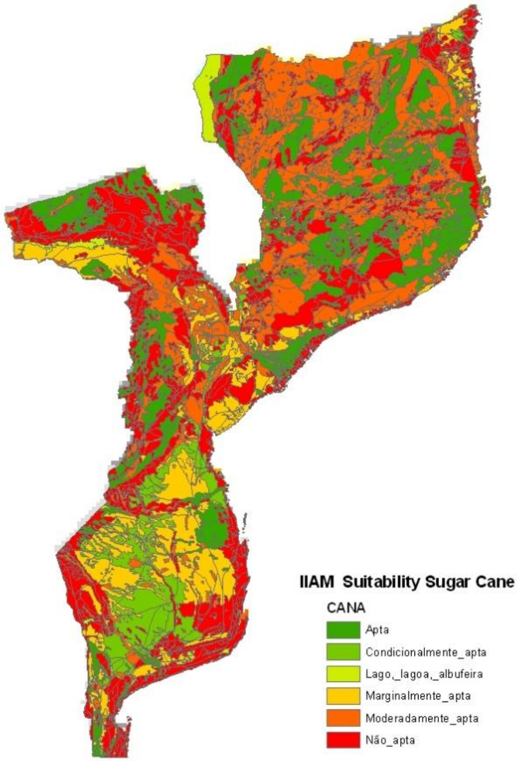
[Hilst et al., 2011 Copernicus-UU, Forthcoming]

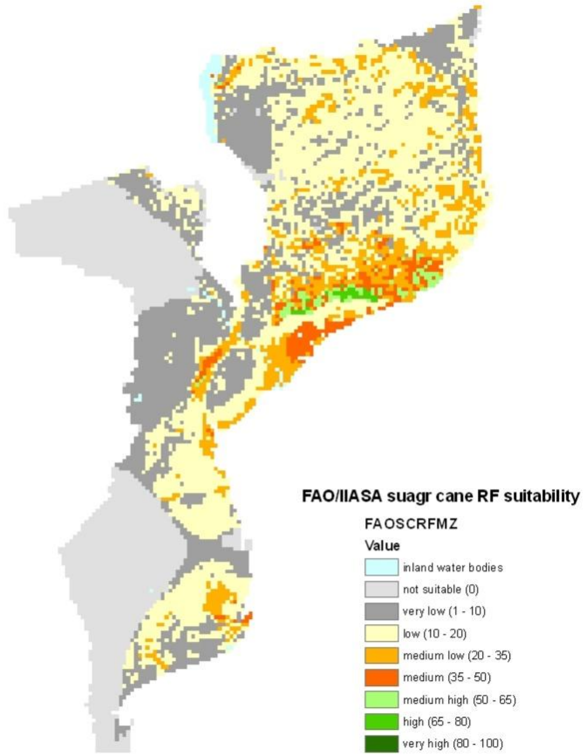
Land requirements

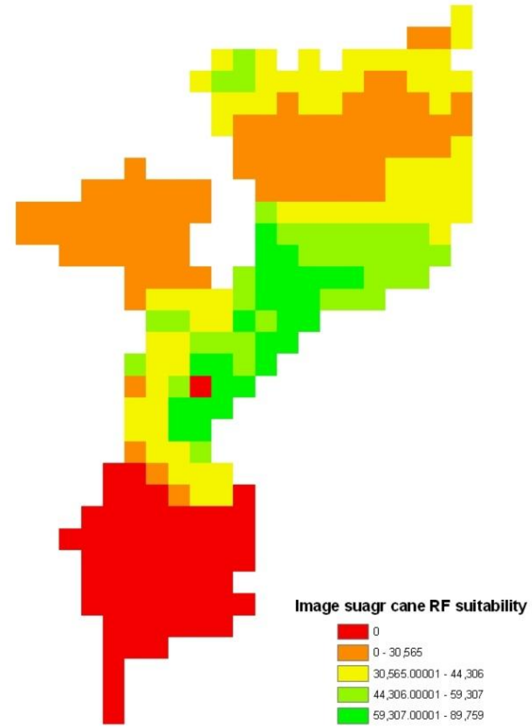


[Hilst et al., 2011 Copernicus-UU, Forthcoming]

In progressive scenario, higher share of food from food crops and higher grass production per ha. Therefore a decrease in required land area for grazing







[Hilst et al., 2011 Copernicus-UU, Forthcoming]

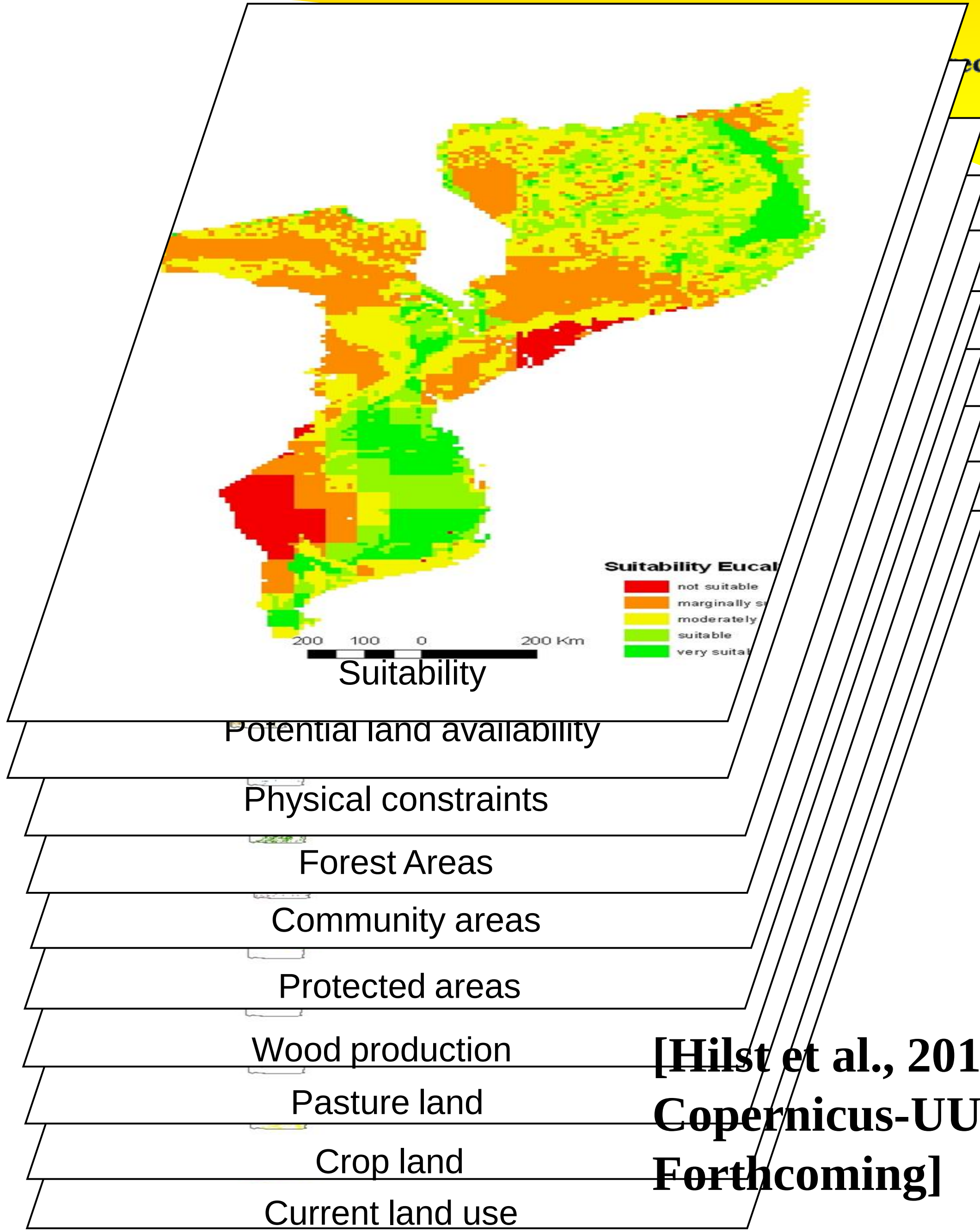
Land availability scenario dependent

Excluding land for:

- Food production
- Non-food production
- Nature preservation
- Livelihoods
- non-suitable land

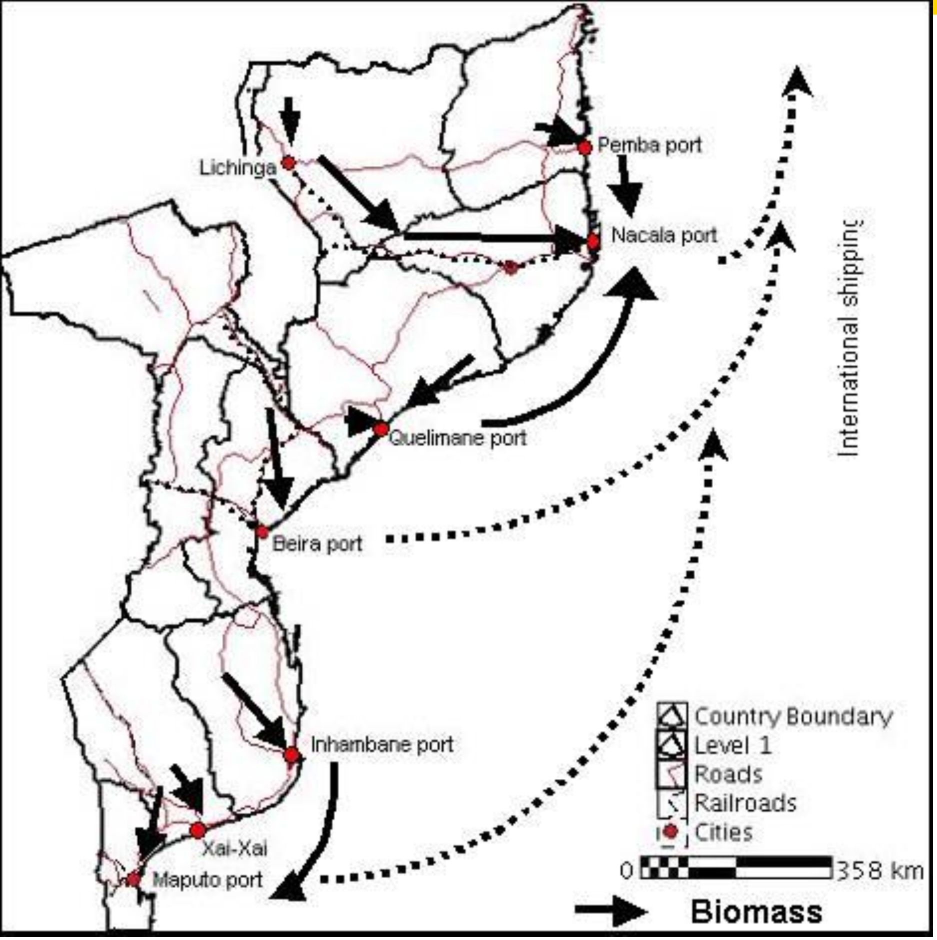
Taking in consideration:

- suitability for crops

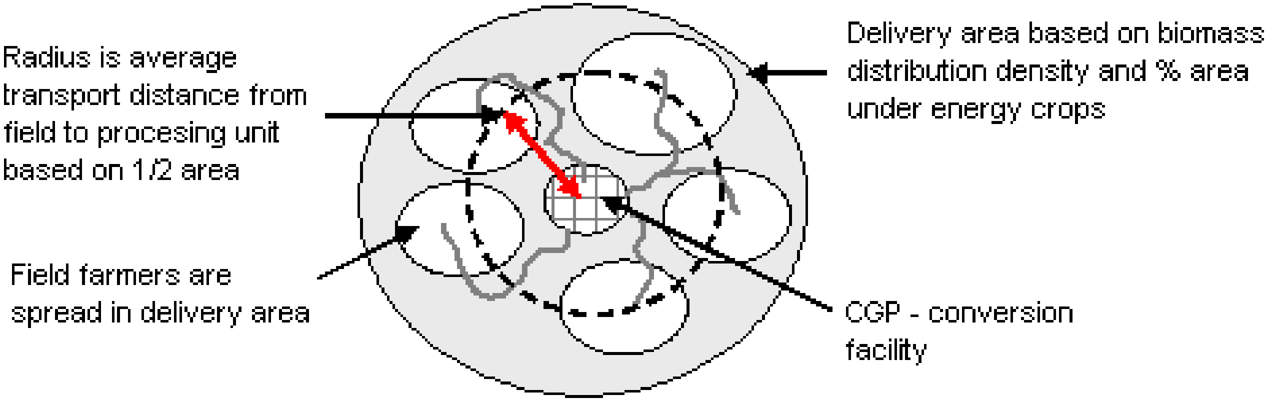


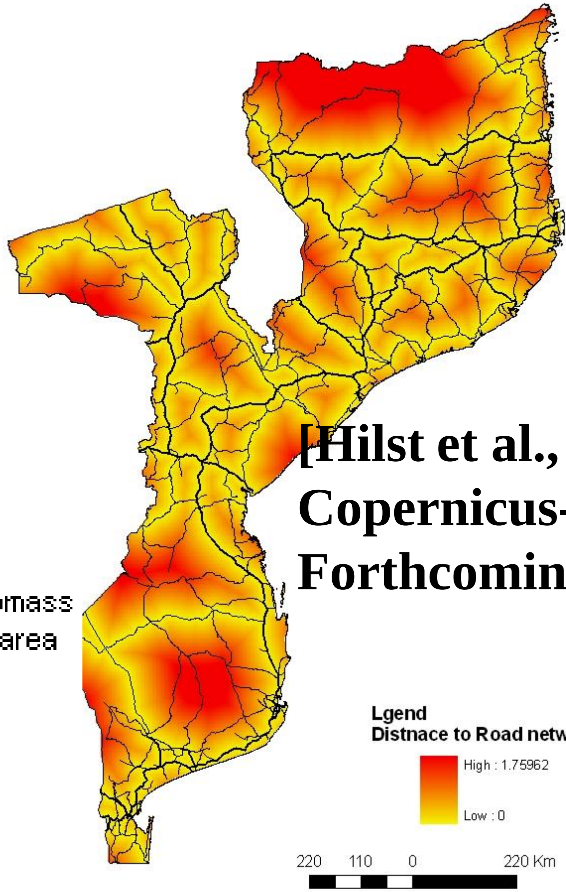
[Hilst et al., 2011 Copernicus-UU, Forthcoming]

Logistics for export….



Batidzirai & Faaij, 2006





[Hilst et al., 2011 Copernicus-UU, Forthcoming]

Key work BE-BASIC (Flagship 9)

- Detailed regional analysis on land-use (potentials, dynamics).
- LCA/EIA/economics/optimisation over time of advanced biobased supply chains.
- Methodology development & demonstration regional impacts water & biodiversity.
- Socio-economic impacts on regional level.

Fully integrated with (senior researcher capacity):

- Macro-economic analysis methods (LEI)
- Remote sensing (TUD)
- Stakeholder perspectives (TUD, univ A'dam)

Final remarks

Universiteit Utrecht

- **Not mentioned:**
  - major work on biomaterials & biochemicals (e.g. Dr. Martin Patel, links to biocatalysis)
  - integral energy system studies & scenario's (e.g. MARKAL/TIMES)
  - Transport systems (WTW) & modelling

- **Major efforts Copernicus – UU on:**
  - new generation modelling framework (IMAGE-TIMER/GTAP based)
  - Full impact analyses; improved methods, remote sensing linked **(BE-Basic).**
  - Detailed regional/country studies (Southern Africa, Latin America, Eastern Europe, SE Asia, North America)
  - International biomass and biofuel markets.
  - Bio-CCS and advanced biorefining concepts.

- **MANY opportunities** for exchange and collaboration!

Universiteit Utrecht

Thanks for your attention

For more information, see e.g:

www.bioenergytrade.org

And sciencedirect/scopus

Copernicus Institute
Sustainable Development and Innovation Management