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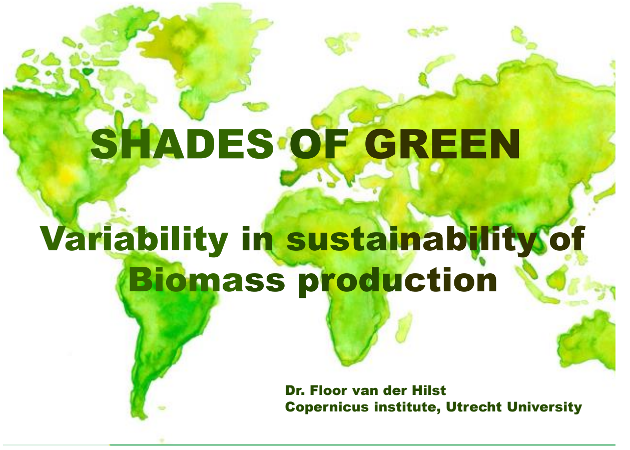
Copernicus Institute of Sustainable Development

Energy & Resources

Shades of Green: Variability in sustainability of biomass production

E&R seminar series 29 January 2015

Dr. Floor van der Hilst
Copernicus institute, Utrecht University



SHADES OF GREEN

Variability in sustainability of Biomass production

Dr. Floor van der Hilst
Copernicus institute, Utrecht University

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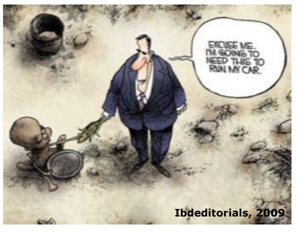
Sustainability concerns

- Large scale deployment of biomass could have implications:
  - GHG emissions
  - Deforestation
  - Loss of biodiversity and other ecosystem functions
  - Water depletion
  - Impacts on soil quality
  - Competition with food
  - Impacts on local prosperity and social well being
  - Etc.



Ibdeditorials, 2009

Bioenergy is ‘the silver bullet’

Bioenergy is ‘the root of all evil’

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Rationale

Sustainability of biomass supply chains depend on:

- Design of the supply chain
- Management of supply chain
- Biophysical and socio-economic conditions of the regions

It is context specific: context varies over space and time… Therefore:

Sustainability of biomass supply chains should be assessed in a spatially explicit and temporal way

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Demonstration: Mozambique

High bioenergy potential:
- Favorable climate and soil conditions
- Low population density (29 p/km2)

Vicinity of ocean
- Facilitates trade

Many incentives for biofuel production
- High import expenditures
- Stimulation rural development
- Biofuel strategy and policy

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Demonstration: Mozambique

1. **Land use change model** → potential land availability for biomass production
2. **Dynamic cost supply curve** → given the location and characteristics of the available land, what are the cost of the biomass supply chains
3. **Impact assessment** → given the location of land availability for biomass productions and the biophysical and socio-economic conditions in those regions, what are the environmental and socio-economic impacts.

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Land use change modeling

- Land for bioenergy crops should not compete with other land use functions.
- The amount of land available for bioenergy depends on the land required for:
  - Settlements
  - Food, feed, fiber production
  - Livestock production
  - Nature conservation
  - Excluded areas (not suitable)
- Land requirements for land use functions change over time.

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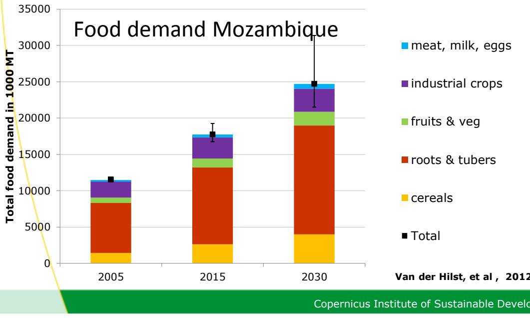
Land use change modeling: Drivers of land use change



Van der Hilst, et al , 2012

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Land use change modeling: 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 goats 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. Wood demand met by wood plantations.
Policy	**Current** policy framework	Highly **effective policies** on efficient and sustainable production

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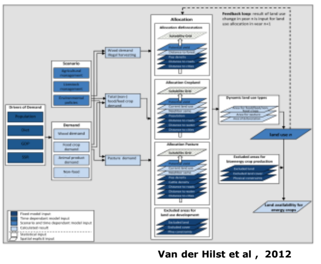
Land use change modeling: Approach

- Land use change model
  - Allocates land requirements for each year (to 2030)
  - Based on suitability factors
  - Excludes no-go areas



Van der Hilst et al , 2012

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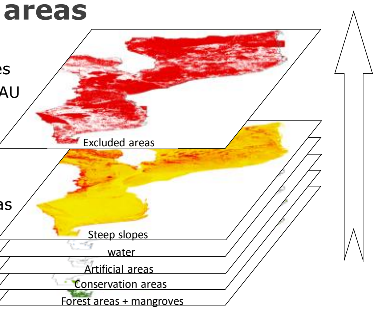
Land use change modeling: Excluded areas

- For all land use changes
  - Forest areas (not in BAU scenario)
  - Mangroves
  - Conservation areas
  - Urban areas
  - Regularly flooded areas
  - Steep slopes



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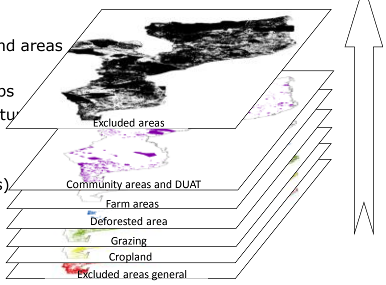
Land use change modeling: Excluded areas

- For energy crops
  - All of the excluded land areas
    - Previous slide
  - Land required for crops
  - Land required for pastu
  - Deforested areas
  - Farm areas
  - DUAT (land use rights)
  - Community areas



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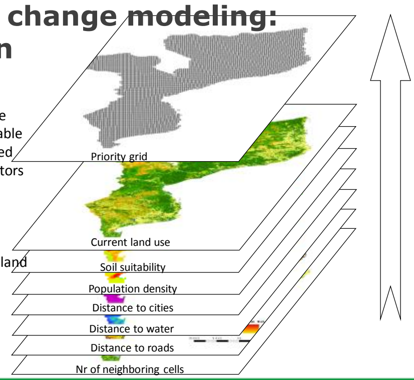
Land use change modeling: Allocation

Land is allocated to a land use function when it is most suitable for that specific function based on several land suitability factors

Example:
suitability for cropland

Also done for other dynamic land use classes



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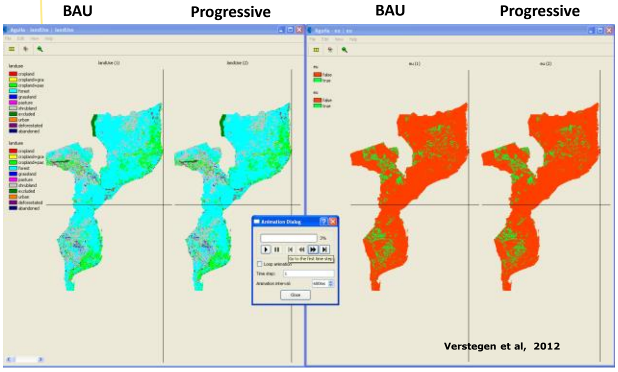
2005

BAU | Progressive | BAU | Progressive



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2006

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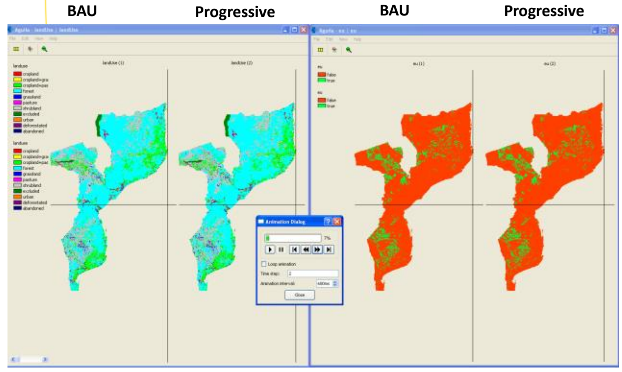

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2007

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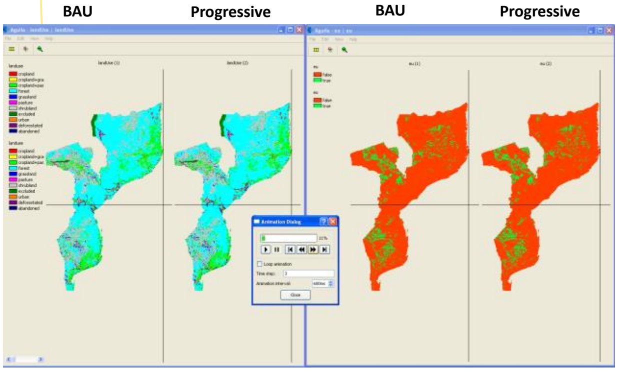

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2008

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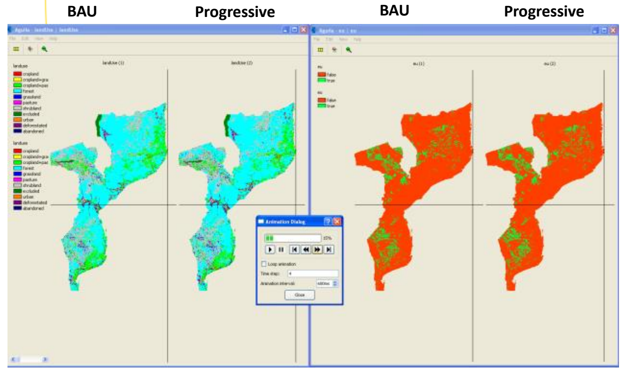

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2009

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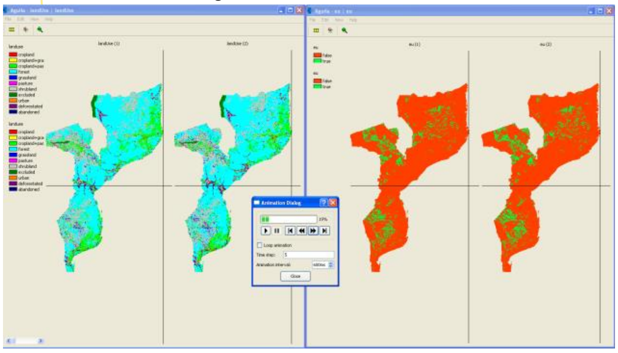

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2010

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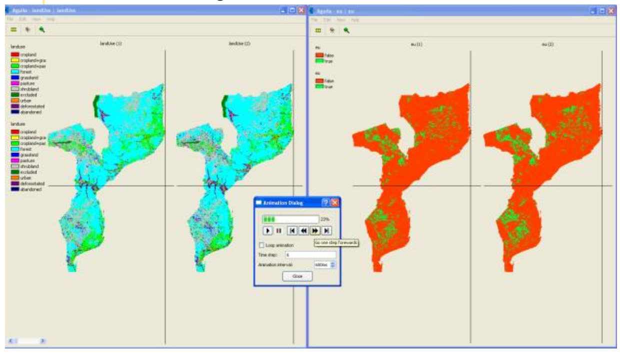

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2011

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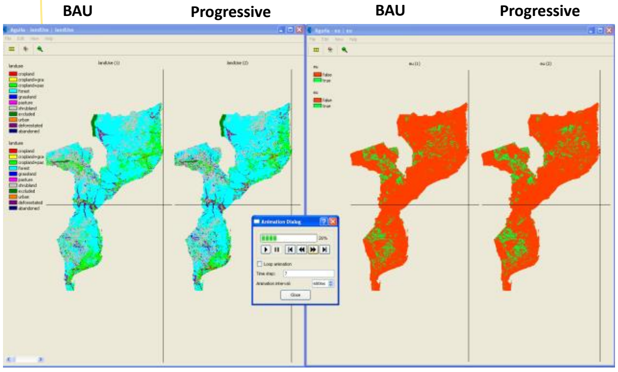

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2012

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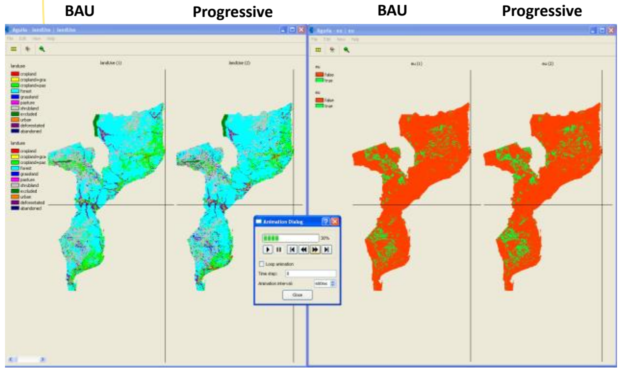

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2013

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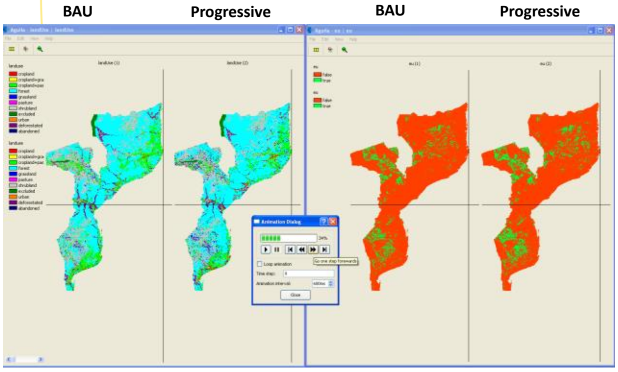

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2014

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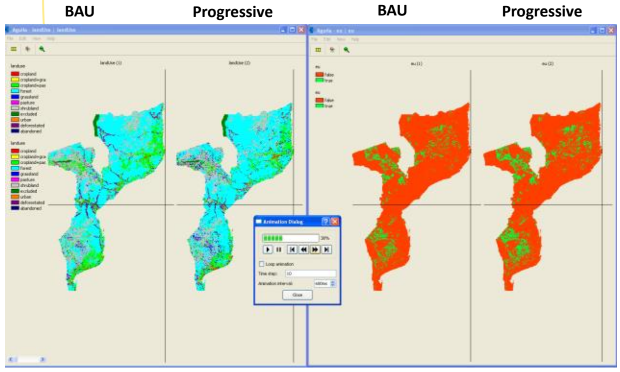

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2015

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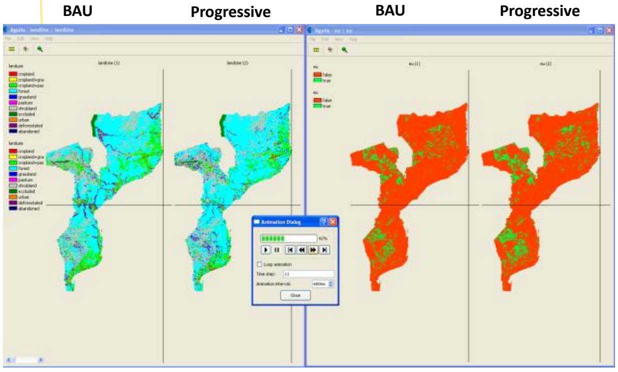

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2016

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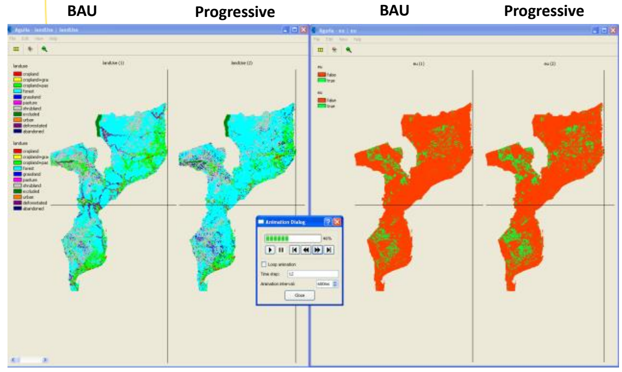

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2017

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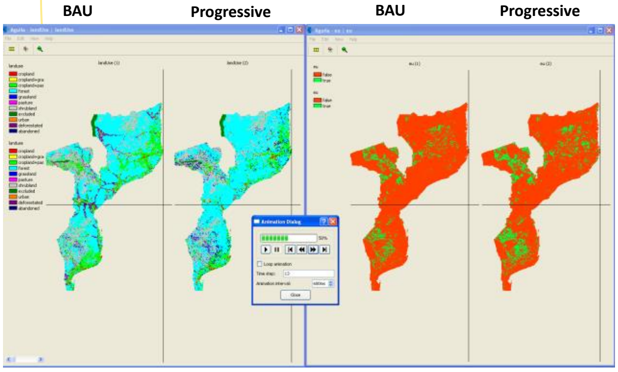

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2018

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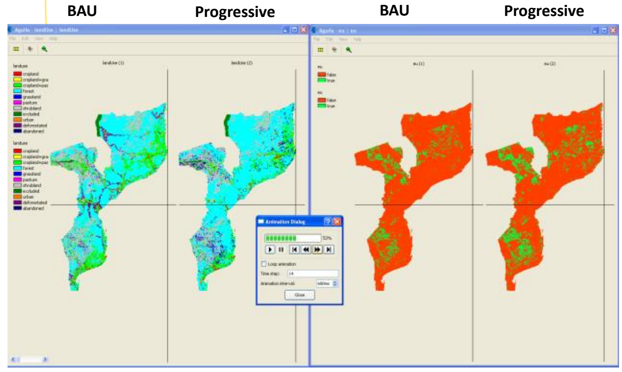

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2019

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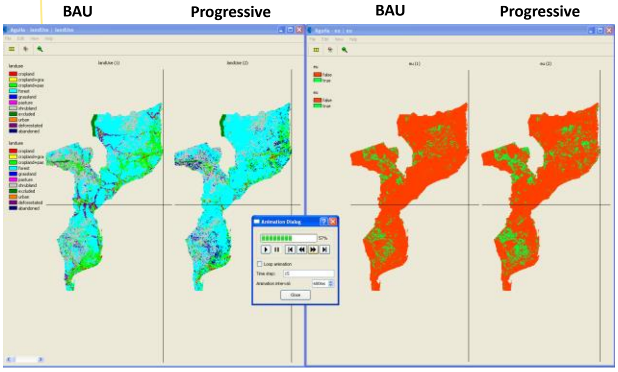

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2020

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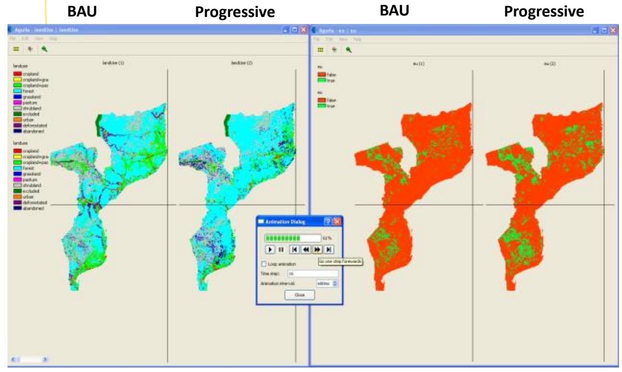

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2021

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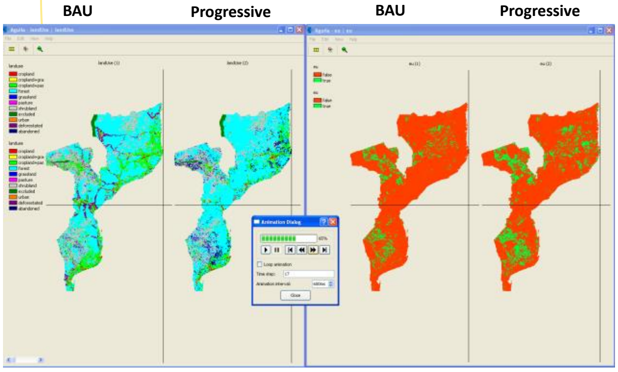

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2022

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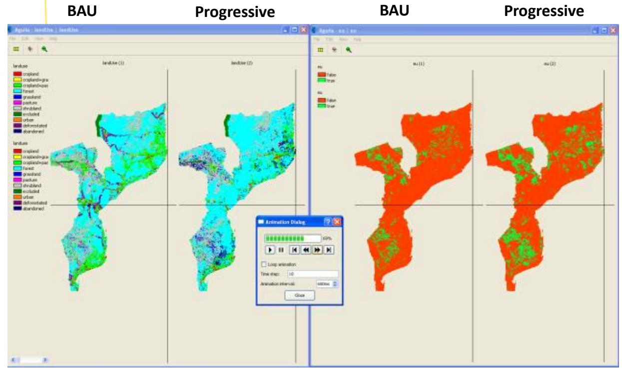

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2023

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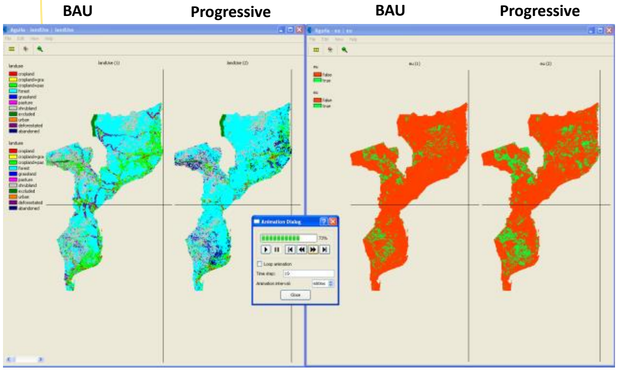

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2024

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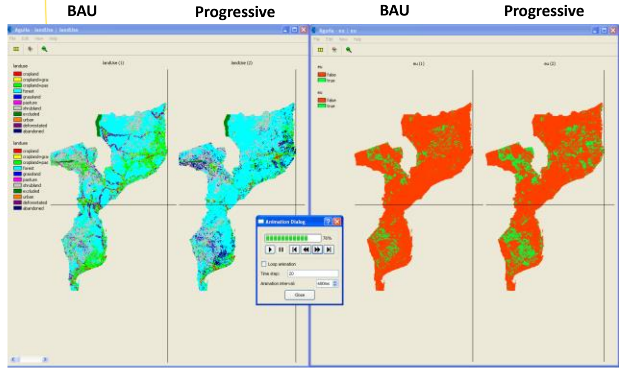

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2025

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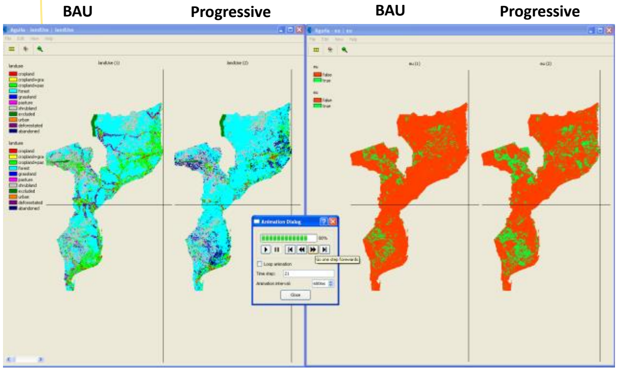

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2026

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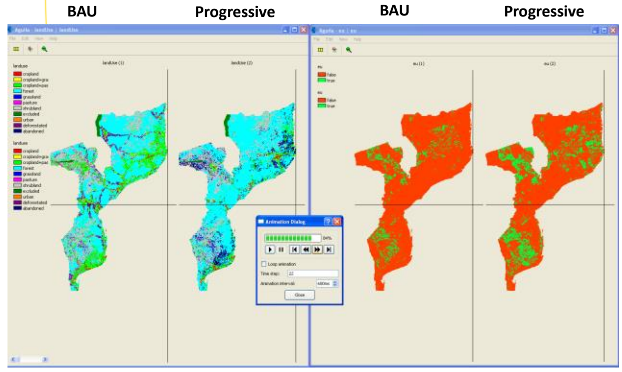

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2027

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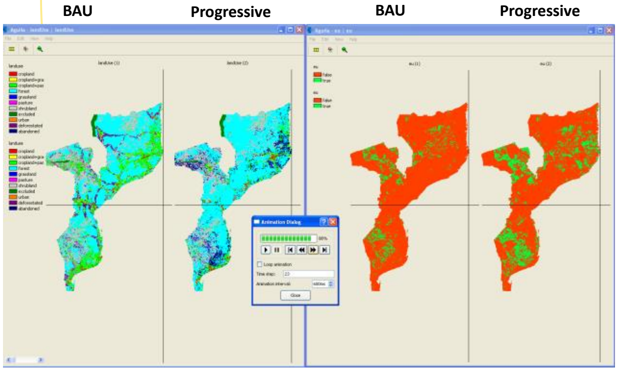

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2028

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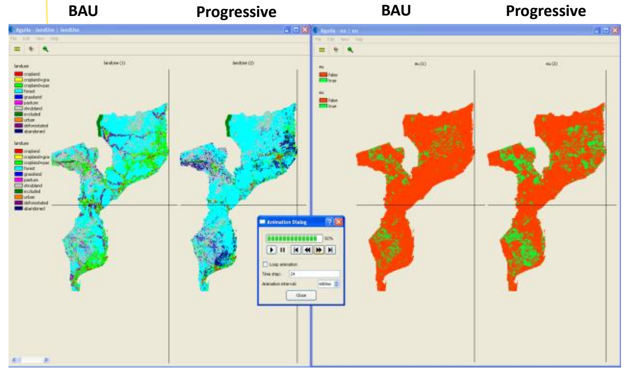

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2029

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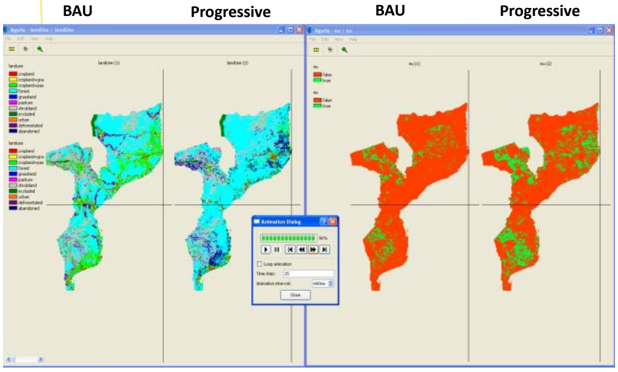

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2030

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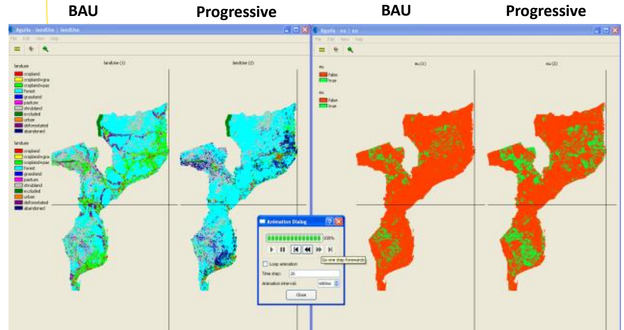

Verstegen et al, 2012

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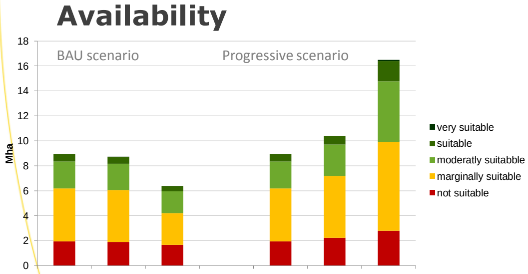
Land use change modeling: Availability



Development of land availability over time differentiated for suitability classes for the BAU scenario (left) and the Progressive scenario (right).

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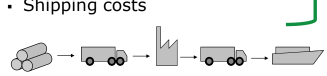
Cost of Biomass supply chains

- Example:
  - Sugar cane ethanol
  - Eucalyptus torrefied pellets
- Total costs include:
  - Feedstock production costs
  - Primary transport costs
  - Conversion costs
  - Secondary transport costs
  - Shipping costs

Spatially and temporally variable



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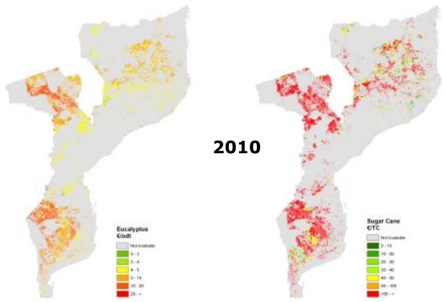
Cost of Biomass supply chains: Feedstock



Eucalyptus **Sugarcane**

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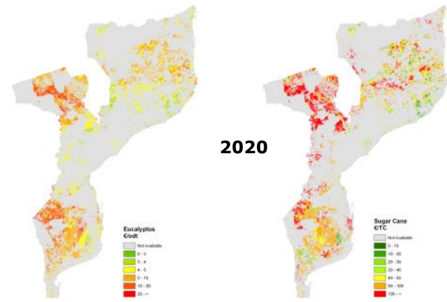
Cost of Biomass supply chains: Feedstock



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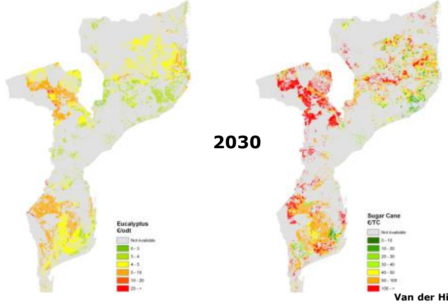
Cost of Biomass supply chains: Feedstock



Eucalyptus **Sugarcane**

Van der Hilst et al, 2012b

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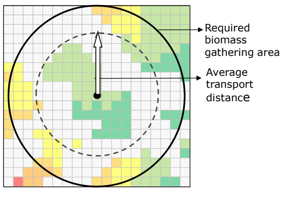
Cost of Biomass supply chains: Primary transport

- The cost for primary transport (field to plant) in year *y* at location *a* depend on:
  - The **capacity** of the plant (I)
  - The spatial distribution of the **land availability** at location *a* in year *y*
  - The **productivity** of the available land at location *a* at time *y*



Van der Hilst et al, 2012b

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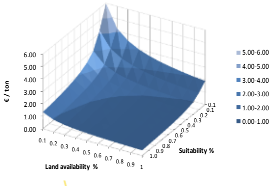
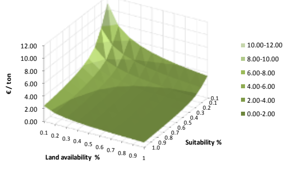
Cost of Biomass supply chains: Primary transport



Eucalyptus



Sugar cane

Van der Hilst et al, 2012b

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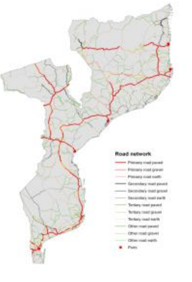
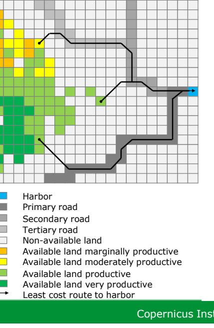
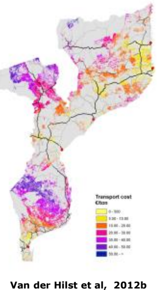
Cost of Biomass supply chains: Secondary transport







Van der Hilst et al, 2012b

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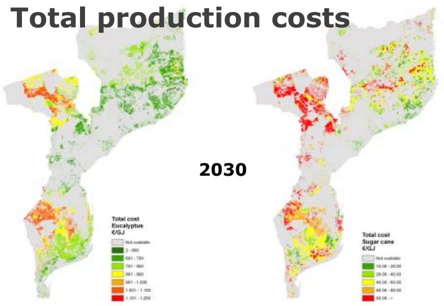
Total production costs



Van der Hilst et al, 2012b

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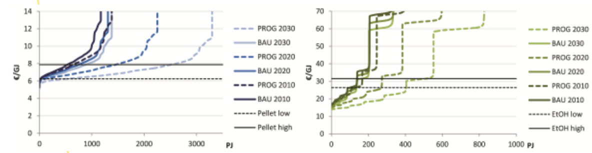
Total production costs



Cost supply curves for eucalyptus pellets and sugar cane ethanol in timeframe 2010-2030 for 2 scenarios

Van der Hilst et al, 2012b

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Next steps

- Now we have information on:
  - The amount, the location and the timeline of **land availability** for energy crops in Mozambique
  - The development in **potential of biomass** production (actual yield levels)
  - The development in **economic viability** of biomass supply chains
  - The most **favorable areas** for biomass production from **economic point of view**
- We want to know:
  - What are the most **favorable areas** for bioenergy production from a sustainability point of view?

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Impact assessment

1. **Land use change model** → potential land availability for biomass production
2. **Dynamic cost supply curve** → given the location and characteristics of the available land, what are the cost of the biomass supply chains
3. **Impact assessment** → given the location of land availability for biomass productions and the biophysical and socio-economic conditions in those regions, what are the environmental and socio-economic impacts.

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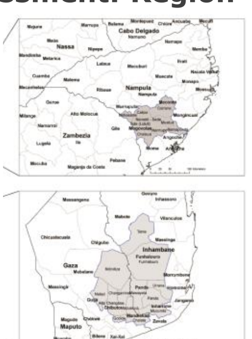
Impact assessment: Region selection

Nampula
- Low land availability
- High population density
- High agro-ecological suitability
- Close to infrastructure

Gaza-Inhambane
- High land availability
- Low population density
- Low to moderately suitable
- Remote



Van der Hilst et al, 2013

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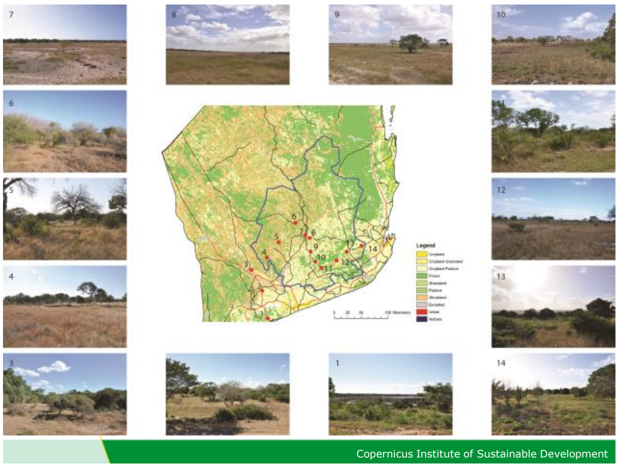

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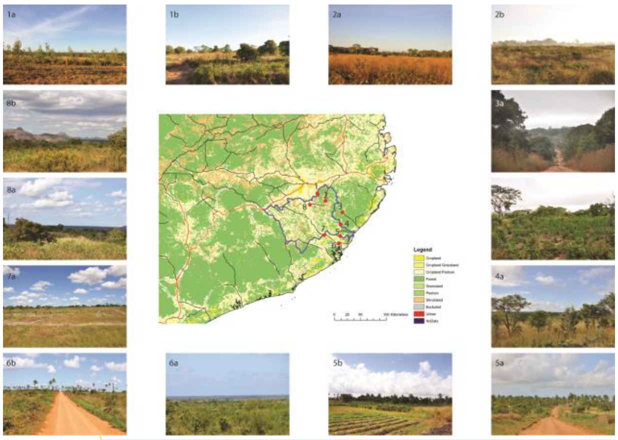

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Impact assessment

	Issue	EU-RED	CSBP	GBEP	RSB	ISCC	NTA8080	RFTO	MOZ
Environmental impacts	GHG emissions	√	√	√	√	√	√	√	√
	Biodiversity	√	√	√	√	√	√	√	√
	Soil		√	√	√	√	√	√	√
	Water		√	√	√	√	√	√	√
Socio- economic impacts	Legality				√		√		√
	Land right								√
	Food security	√		√			√		√
	Economic viability			√	√				√
	Local prosperity			√	√		√		√
	Social well being			√	√	√		√	√
	Labour conditions		√	√	√	√	√	√	√
	Gender		√	√	√	√	√	√	√

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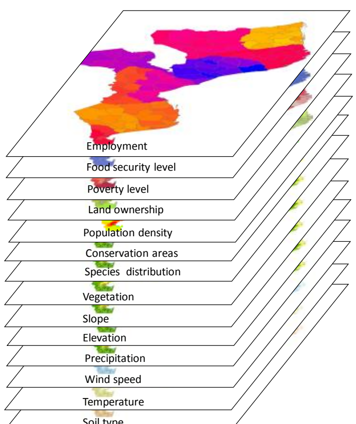
Impacts

Impacts depend on the biophysical and socio-economic conditions of the region of supply



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Overall results – Environmental Impacts

	Impact	Unit	Gaza-Inhambane BAU EU	Gaza-Inhambane BAU SG	Gaza-Inhambane PROG EU	Gaza-Inhambane PROG SG	Nampula BAU EU	Nampula BAU SG	Nampula PROG EU	Nampula PROG SG
Environmental Impacts	**GHG Emission [b]**									
	Life cycle	Kg CO_2-eq /$GJ_{biomass}$	2.3	3.9	2.3	3.9	2.2	3.6	2.2	3.6
	LUC related emissions	Kg CO_2-eq /$GJ_{biomass}$	11.9	34.2	-20.4	-15.4	10.6	29.0	-27.3	-22.3
	Total emissions	Kg CO_2-eq /$GJ_{biomass}$	14.2	38.2	-18.2	-11.5	12.9	32.6	-25.1	-18.7
	Total avoided emissions	Kg CO_2-eq /GJ_{EtOH}	-36	24	-117	-100	-39	10	-134	-118
	Soil [c]									
	Soil Organic Carbon	Δ kg C /$GJ_{biomass}$	0.0	-2.1	-1.3	-3.3	0.0	-2.1	-1.5	-3.9
	Wind Erosion	Qualitative	-	0	+	++	-	0	+	++
	Water [d]									
	Water use efficiency	$Odt_{biomass}$/ l water	0.7	0.7	0.9	0.9	0.8	0.9	0.8	0.9
	Water depletion	mm/season	426	-96	426	-96	523	-237	523	-237
	Biodiversity [e]									
	MSA	ΔMSA x100 /$GJ_{biomass}$	-0.4	-0.5	-0.1	-0.1	-0.3	-0.3	-0.1	-0.1

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Overall Results – Socio-economic Impacts

Van der Hilst et al, 2013

	Impact	Unit	Gaza-Inhambane BAU EU	Gaza-Inhambane BAU SG	Gaza-Inhambane PROG EU	Gaza-Inhambane PROG SG	Nampula BAU EU	Nampula BAU SG	Nampula PROG EU	Nampula PROG SG
Socio-economic Impacts	**Legality [f]**		*No ex-ante analysis possible, recommendations to comply with national law are provided see*							
	Land rights [g]									
	Land right risk	Qualitative	+	+	+	+	-	-	+	+
	Food security [i]									
	Food security	Qualitative	+/-	+/-	+	+	-	-	+	+
	Economic viability [j]									
	Feedstock	$/$GJ_{biomass}$	2.44	3.05	1.29	1.54	1.84	2.01	1.03	1.31
	End product	$/$GJ_{EtOH}$	14.18	16.62	11.32	12.86	12.96	14.38	10.93	12.63
	Local Prosperity [k]									
	Total jobs	X 1000 jobs	9.7	6.9	8.0	5.9	4.8	2.3	7.1	4.7
	Local labour	%	100	100	100	100	100	100	100	100
	Total investment	M$	260	297	208	230	157	127	201	226
	Total wages	M$	10.1	7.1	8.3	5.8	4.9	2.4	7.4	4.9
	Social well-being [l]									
	Total no of people affected	X 1000 people	49	34	40	28	24	12	36	24
	Labour conditions [m]		*No ex-ante analysis possible, recommendations to comply with (inter-) national*							

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Discussion and conclusion

- No general conclusion about the sustainability of biomass supply chains
- But general applicable methods can be developed to assess and quantify sustainability
- Identification of 'Go' and 'No-go' areas
- Important information for:
  - Investors
  - Policymakers
  - Certification bodies
- Avoid negative impacts, optimise positive impacts

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Ongoing research

- Improvements in land use modelling
  - Calibration, validation, uncertainty
- Improvements optimisation of supply chains
  - Tech-change, multi-objective optimisation
- Environmental impact assessment
  - Biodiversity, hydrology, carbon
- Socio-economic impacts
  - Disaggregation I/O models, CGE models, bottom-up, food security
- Integrated assessments
  - Model collaboration, local-global, trade-offs, identify strategies

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Contact:
F.vanderhilst@uu.nl

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1) Questions and comments on the presentations?

2) Open invitation for further cooperation: what are new & further possibilities to work together on the Bio-Based Economy within the department of IMEW, the Geoscience faculty and Utrecht University at large?

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Statements for discussion

- Can use of wood pellets for electricity production help to mobilize sustainable forestry resources and achieve short-term GHG emission reductions?
- Should biomass feedstock production for the biobased economy be maximized in the EU before relying on imports?
- Is it wishful thinking that indirect effects of feedstock production can be avoided or mitigated?