Optimizing crop rotation using sugar beets

Sustainable regional design

Biethanol seminar

Lelystad, 4 juli 2019

Hans Langeveld (Biomass Research)

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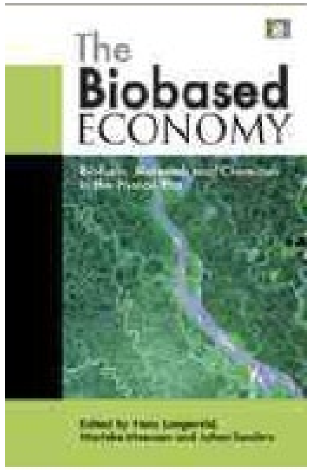
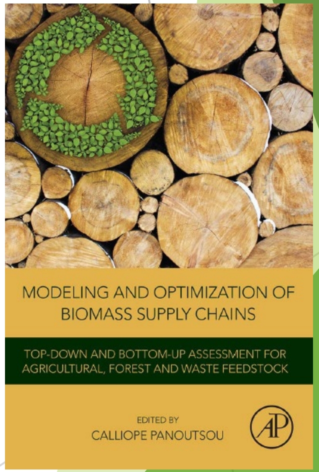
Optimizing crop rotation



Contents

- Bioeconomy
- Crop rotations in the Netherlands
- Landscape design
- Development of a biobased economy



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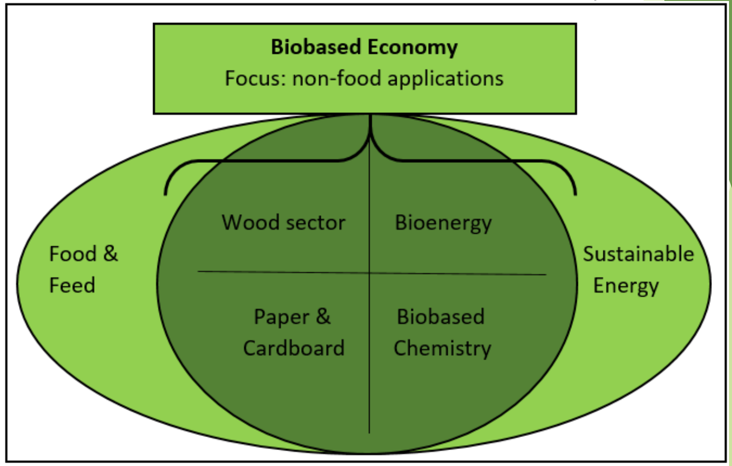
Optimizing crop rotation

Bioeconomy

“The bioeconomy encompasses the **production of renewable biological resources** and **their conversion into food, feed, bio-based products and bioenergy**. It includes *agriculture*, *forestry*, *fisheries*, *food and pulp and paper production*, *as well as parts of chemical*, *biotechnological and energy industries*.



Sustainable Development Goals

- Bioeconomy can contribute to Sustainable Development Goals
- Energy and land use:
  - SDG 1 end hunger, food security
  - SDG 7 affordable, reliable, sustainable and modern energy
  - SDG 12 sustainable production and consumption
  - SDG 15 sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss

SDG	Key wording	Driver	Safe-guard	Land relevance
	End poverty in all its forms everywhere	(✔)	(✔)	moderate
	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	✔	✔	high
	Ensure healthy lives and promote well-being for all at all ages	(✔)	(✔)	low
	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all			
	Achieve gender equality and empower all women and girls			moderate
	Ensure availability and sustainable management of water and sanitation for all	(✔)	(✔)	low
	Ensure access to affordable, reliable, sustainable and modern energy for all	✔	(✔)	high
	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	(✔)	(✔)	moderate
	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	(✔)		moderate
	Reduce inequality within and among countries			
	Make cities and human settlements inclusive, safe, resilient and sustainable	✔	(✔)	high
	Ensure sustainable consumption and production patterns	✔	(✔)	high
	Take urgent action to combat climate change and its impacts	✔	✔	high
	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	(✔)	(✔)	low
	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertifica-tion, and halt and reverse land degradation and halt biodiversity loss	✔	✔	high
	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels		(✔)	low
	Strengthen the means of implementation and revitalise the global partnership for sustainable development	(✔)	(✔)	moderate

Fritsche et al. (2017) GLO report UNCCD

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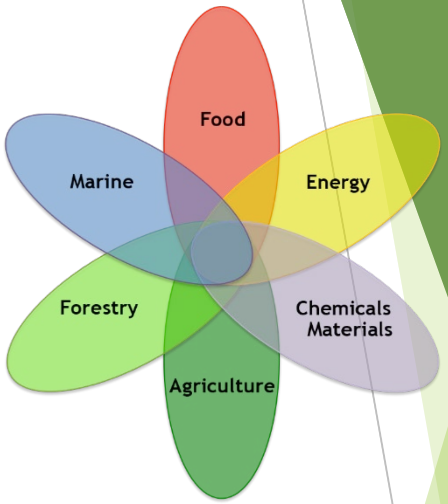
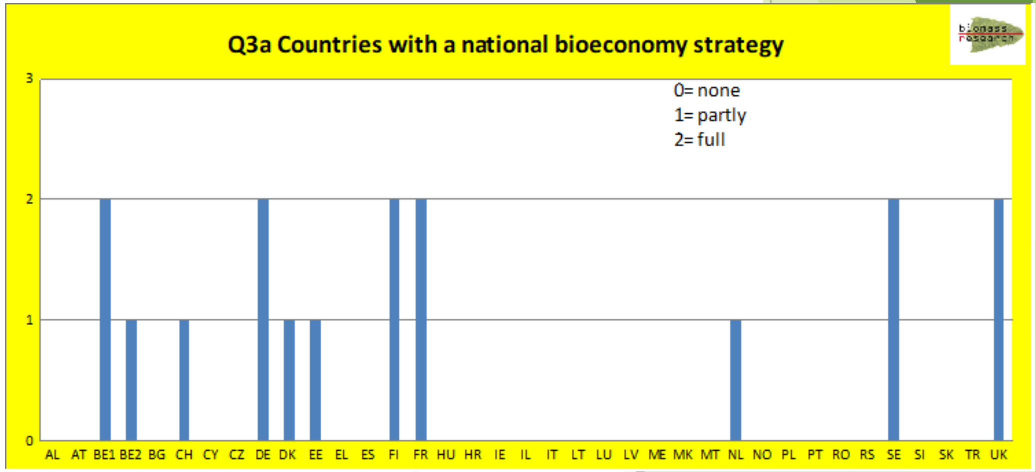
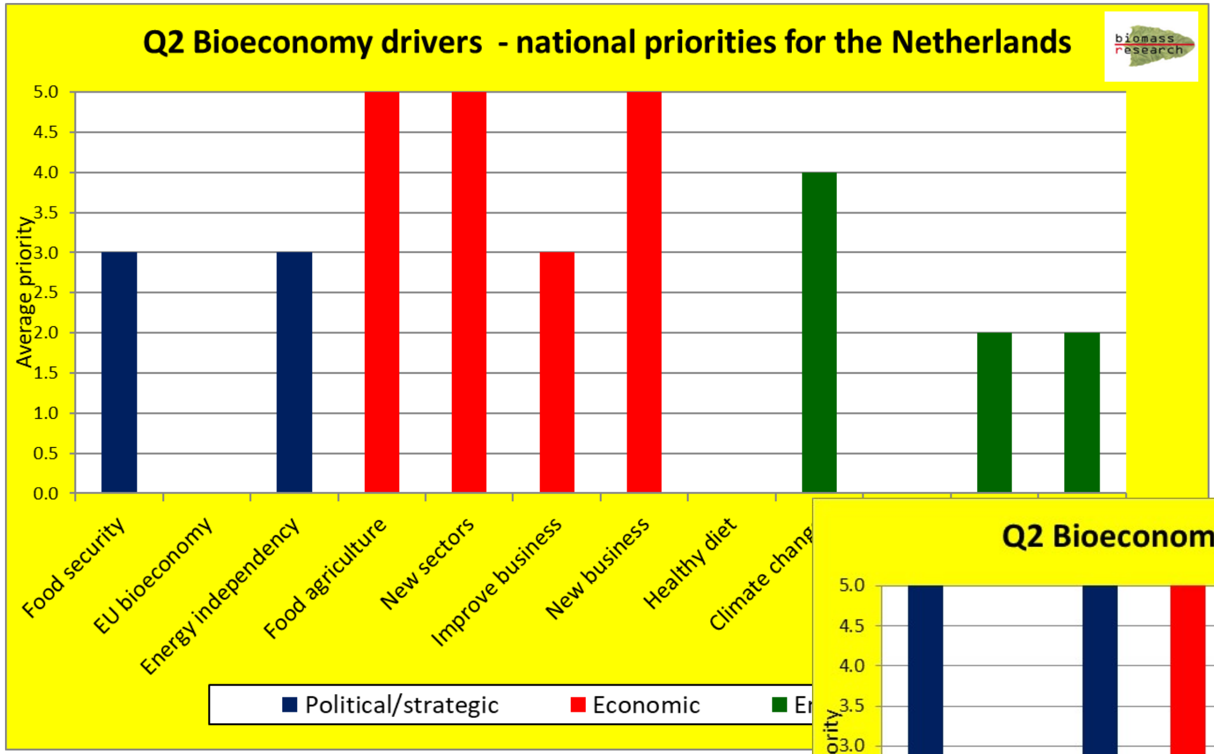
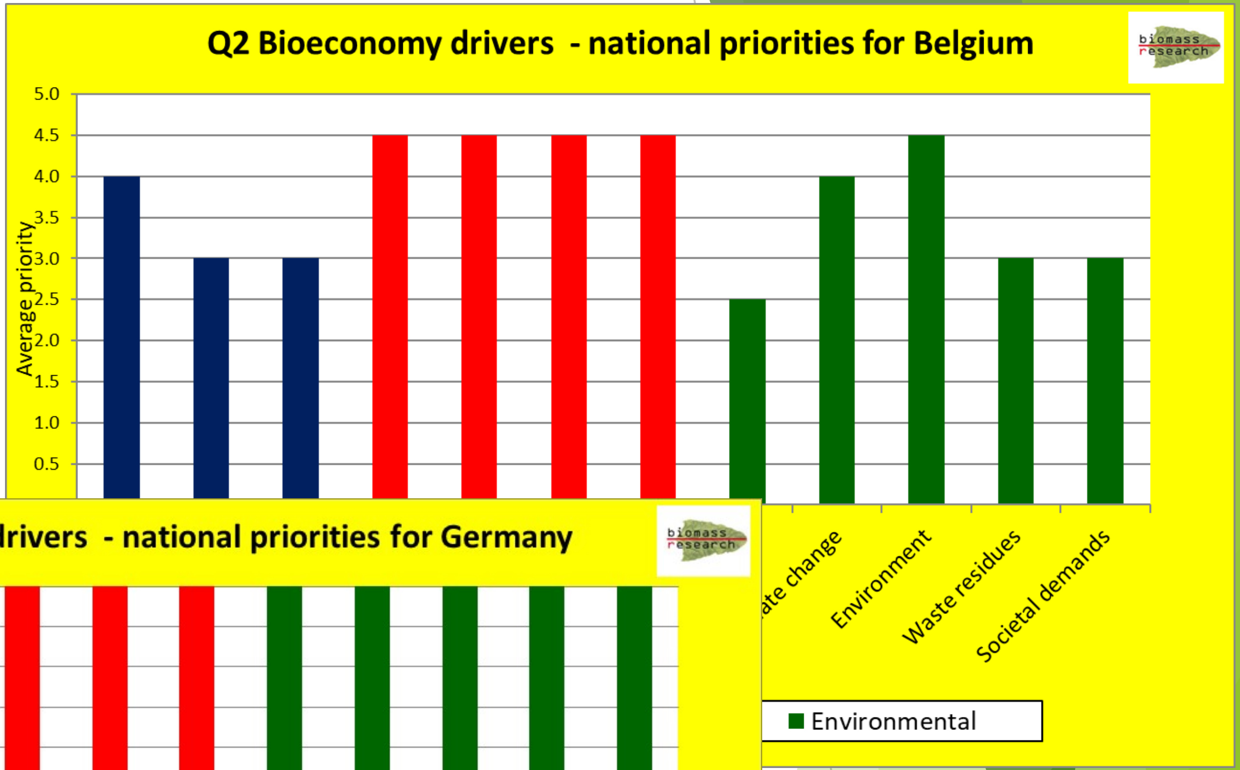
Bioeconomy policy in the Netherlands

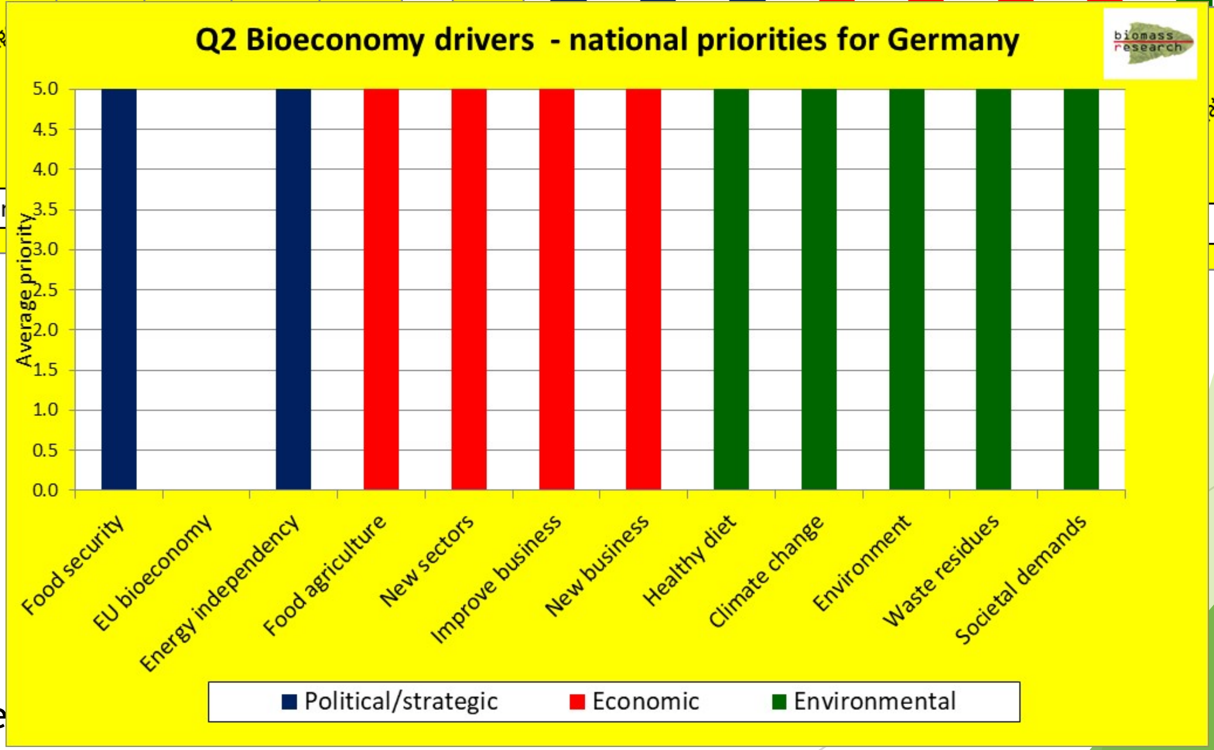
- Early implementation based on green growth policies
- Integration in food, circular and climate policies
- Multiple ministries involved
- Climate accord, stakeholder approach
- Research and innovation, sustainable feedstocks, circular bioeconomy











Source: Langeveld (2015) Results of the

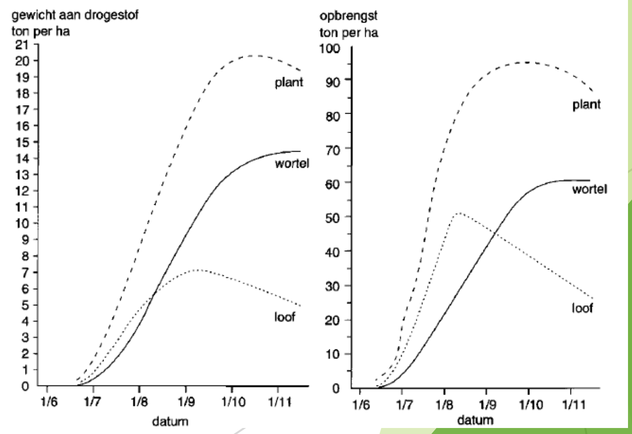
Optimizing crop rotation

Crops in rotation

- Cereals, root- and tuber crops, legumes, feed crops, vegetables
- Input use: fertilizers, agro-chemicals, irrigation
- Impacts: soil organic matter, nutrient emissions (air, soil, water), PM, biodiversity, income, social indicators

Tabel 2 Vruchtwisseling per bedrijfssysteem. In 2001 is in verband met de aaltjessituatie zomergerst geteeld in plaats van waspeen

Jaar	Synthese	Analyse-1	Analyse-2
1.	Aardappel laat	Aardappel laat [1]	Aardappel laat + stro
2.	Suikerbiet	Suikerbiet	Suikerbiet[8]
3.	Triticale	Triticale + hergroei	Zomergerst + zomergerst[2]
4.	Waspeen[3]	Waspeen[3]	Waspeen[3]
5.	Aardappel vroeg[7]	Aardappel vroeg + bladrammenas[5,7]	Aardappel vroeg[7] + bladrammenas[9]
6.	Suikerbiet	Suikerbiet	Suikerbiet[8] + zomergerst
7.	Snijmaïs laat	Snijmaïs laat	Snijmaïs vroeg + zomergerst
8.	Conservenerwt + stamslaboon	Conservenerwt + stamslaboon [3]	Conservenerwt + bladrammenas[6,9]



De Haan et al. (2004) Eindverslag kernbedrijf Vredepeel

De Haan et al. (2018) Effect van organische stofbeheer op opbrengst, bodemkwaliteit en stikstofverliezen op een zuidelijke zandgrond

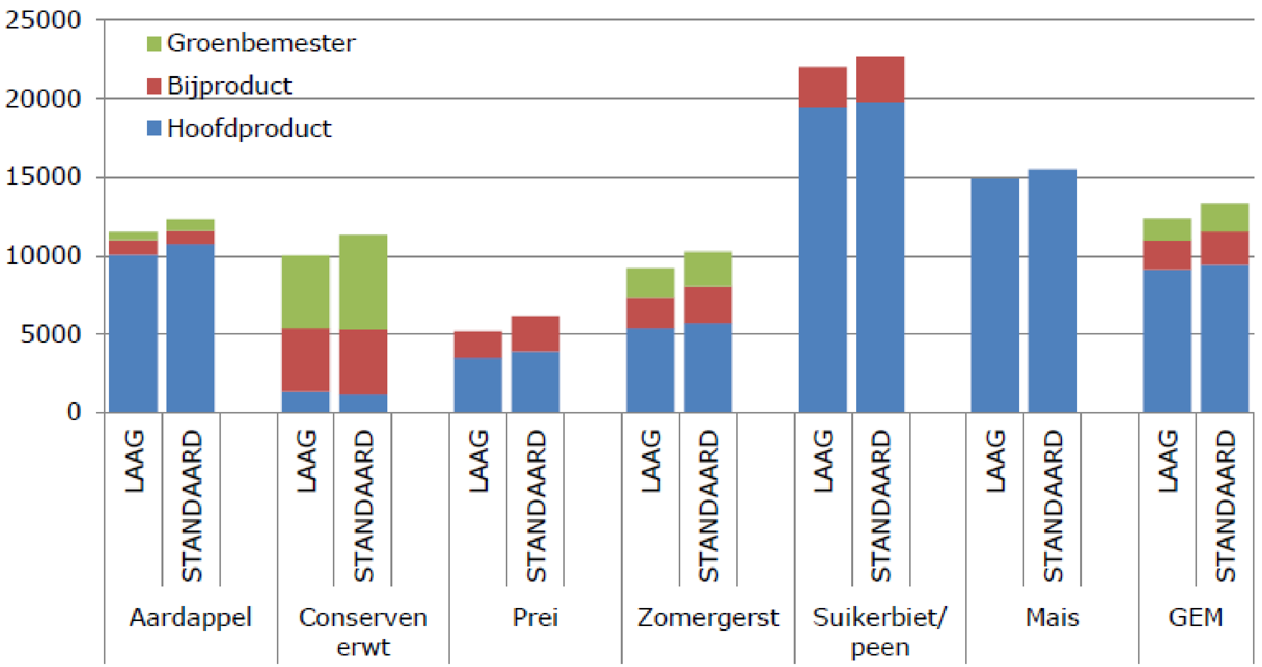
Organic matter

- Production of organic matter
- Main product, by-product
- Fallow crop

2.1.4 Vruchtwisseling

In STANDAARD en LAAG is dezelfde zesjarige rotatie gehanteerd. Van 2011 tot en met 2015 omvatte deze

1. Aardappel – 2. Conservenerwt – 3. Prei (herfst) – 4. Zomergerst – 5. Suikerbiet – 6. Snijmaïs.



Figuur 6 *Droge stofproductie per gewas per systeem, gemiddeld over de jaren 2011-2016, in kg/ha. STND=STANDAARD, GEM= gemiddeld.*

De Haan et al. (2018) Effect van organische stofbeheer op opbrengst, bodemkwaliteit en stikstofverliezen op een zuidelijke zandgrond

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Phytosanitation

- Nematodes
- Tolerance and resistance
- Damage control

→ bietencysteaaltjes

- wit bietencysteaaltje (*Heterodera schachtii*)
- geel bietencysteaaltje (*Heterodera betae*)

→ wortelknobbelaaltjes

- noordelijk wortelknobbelaaltje (*Meloidogyne hapla*)
- graswortelknobbelaaltje (*Meloidogyne naasi*)

Tabel 1. Diagnose van ingestuurde suikerbietenmonsters als percentage van het totaal aantal geïdentificeerde oorzaken (491 monsters) (2017).

diagnose[1]	*(%)*
bladvlekken (o.a. cercospora, meeldauw, pseudomonas, ramularia, roest, stemphylium)	37
aaltjes (o.a. bietencyste-, stengel-, vrijlevende en wortelknobbelaaltjes)	12
nutriëntengebrek en overmaat	12
bodemschimmels (o.a. aphanomyces, phoma, pythium, rhizoctonia, verticillium)	12
insecten (o.a. springstaarten, bietenkever, miljoenpoten, wantsen, zwarte bonenluizen, rupsen, bietenvlieg)	7
herbicidenschade	6
lage pH	4
rhizomanie (resistentiedoorbrekende variant)	4

[1] Schadeoorzaken die minder dan 4% van de diagnoses betroffen, zijn niet vermeld.

opgenomen op de Aanbevelende Rassenlijst. Tussen haakjes staat het totaal aantal onderzochte rassen.

categorie	*aantal rassen doorgegaan*		
	1→2	2→3	3→RL
rhizomanie	6 (16)	3 (3)	1 (1)
aaltjes	4 (20)	6 (8)	3 (3)
rhizoctonia	3 (7)	1 (2)	3 (3)
drievoudig	1 (1)	0 (1)	1 (1)

De Haan et al. (2018) Effect van organische stofbeheer op opbrengst, bodemkwaliteit en stikstofverliezen op een zuidelijke zandgrond

IRS Jaarverslag 2017; IRS (2019) Teelthandleiding

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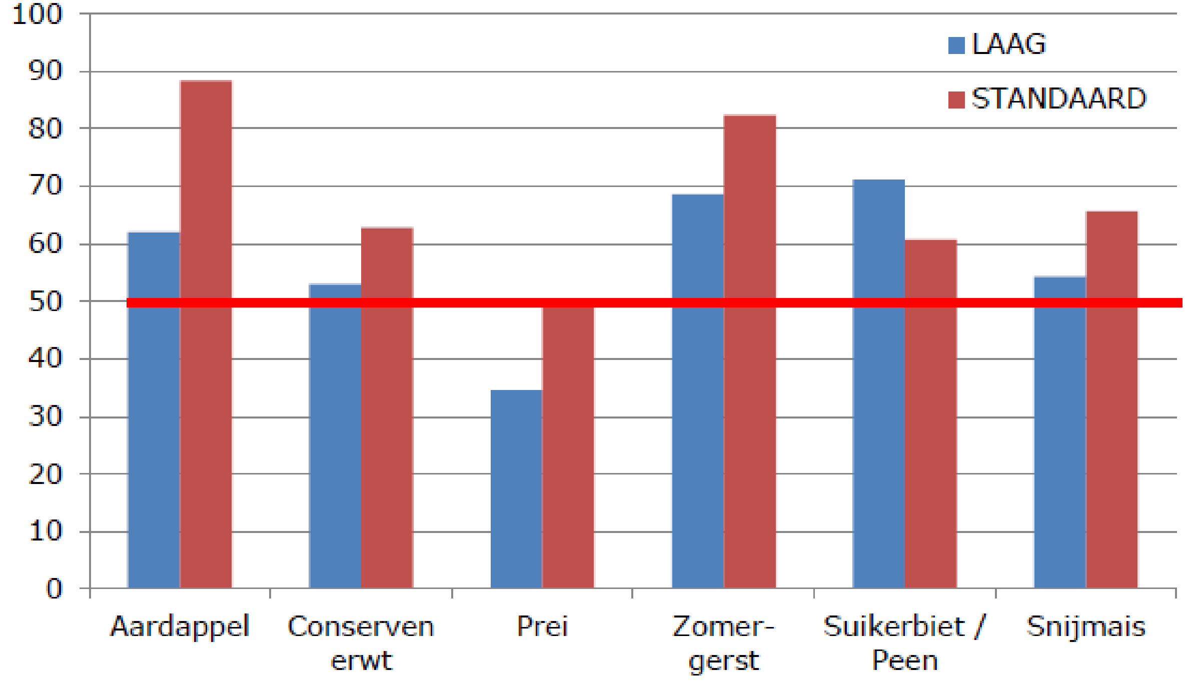
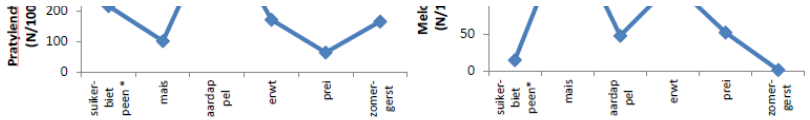


Figuur 15 *Nitraatconcentraties (mg NO_3/l) per gewas per systeem gemiddeld over 2012-2016. De rode lijn geeft de EU-nitraatnorm van 50 mg/l weer.*



Figuur 9 *Gemiddelde (over STANDAARD en LAAG) populatieontwikkeling wortellesieaaltjes (links) en wortelknobbelaaltjes (M. chitwoodi + M. fallax, rechts). Metingen gedaan in januari/februari voorafgaand aan de teelt van het gewas in de periode 2012-2016.*

ı/100 ml grond) voor de belangrijkste plantparasitaire ıpbrengstverliezen (2 (schadepercentages) die rijden van de schadedrempels

			hapla	*Meloidogyne chitwoodi/ fallax*	*Pratylenchus penetrans*	*Paratrichodorus pachydermus*	*Trichodorus similis*
			0 0%)	10 (75-100%)	200 (30-50%)	10 (20)	10 (20%)
			0 0%)	10 (30-50%)	100 (15-30%)	10 (15-35%)	10 (15-35%)
			ıt elijk	niet schadelijk	>1000 (10%)	10 (15-35%)	10 (15-35%)
			ıt elijk	? (<15%)	niet schadelijk	? (<15%)	? (<15%)
			0 0%)	500 (10%)	niet schadelijk	150 (20%)	10 (10%)
Peen (B)	niet schadelijk	niet schadelijk	10 (100%)	10 (100%)	10 (20-40%)	50 (100%)	50 (100%)
Snijmaïs	niet schadelijk	niet schadelijk	niet schadelijk	? (0-15%)	? (15-35%)	? (15-35%)	1 (20%)

De Haan et al. (2018) Effect van organische stofbeheer op opbrengst, bodemkwaliteit en stikstofverliezen op een zuidelijke zandgrond

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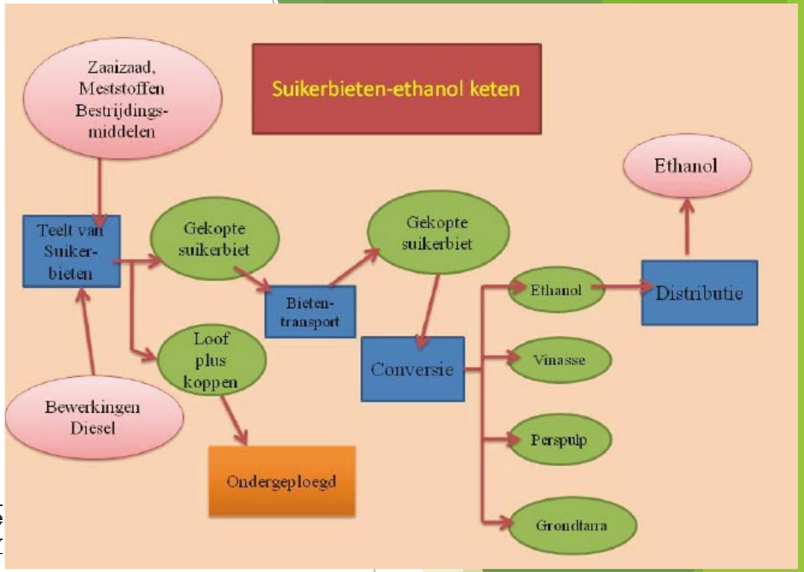
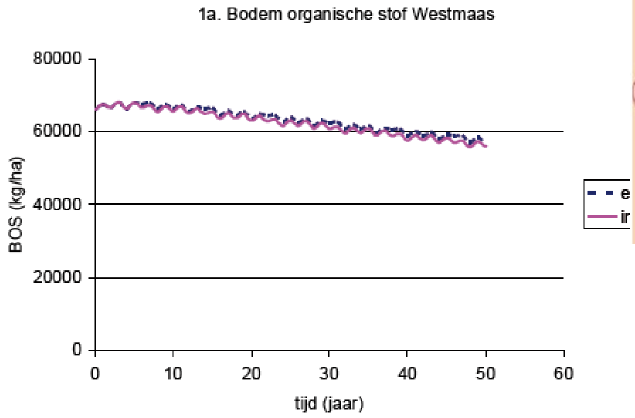
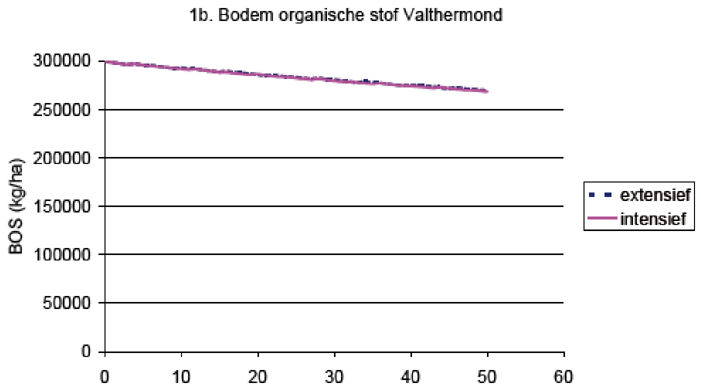
Ethanol chain evaluation

- Ethanol chain (classic)
- Data from PPO, literature
- Modeling development of soil organic matter
- GHG impacts
- Social impacts







De Visser et al. (2008) Effect van organische stofbeheer op opbrengst, bodemkwaliteit en stikstofverliezen op een zuidelijke zandgrond

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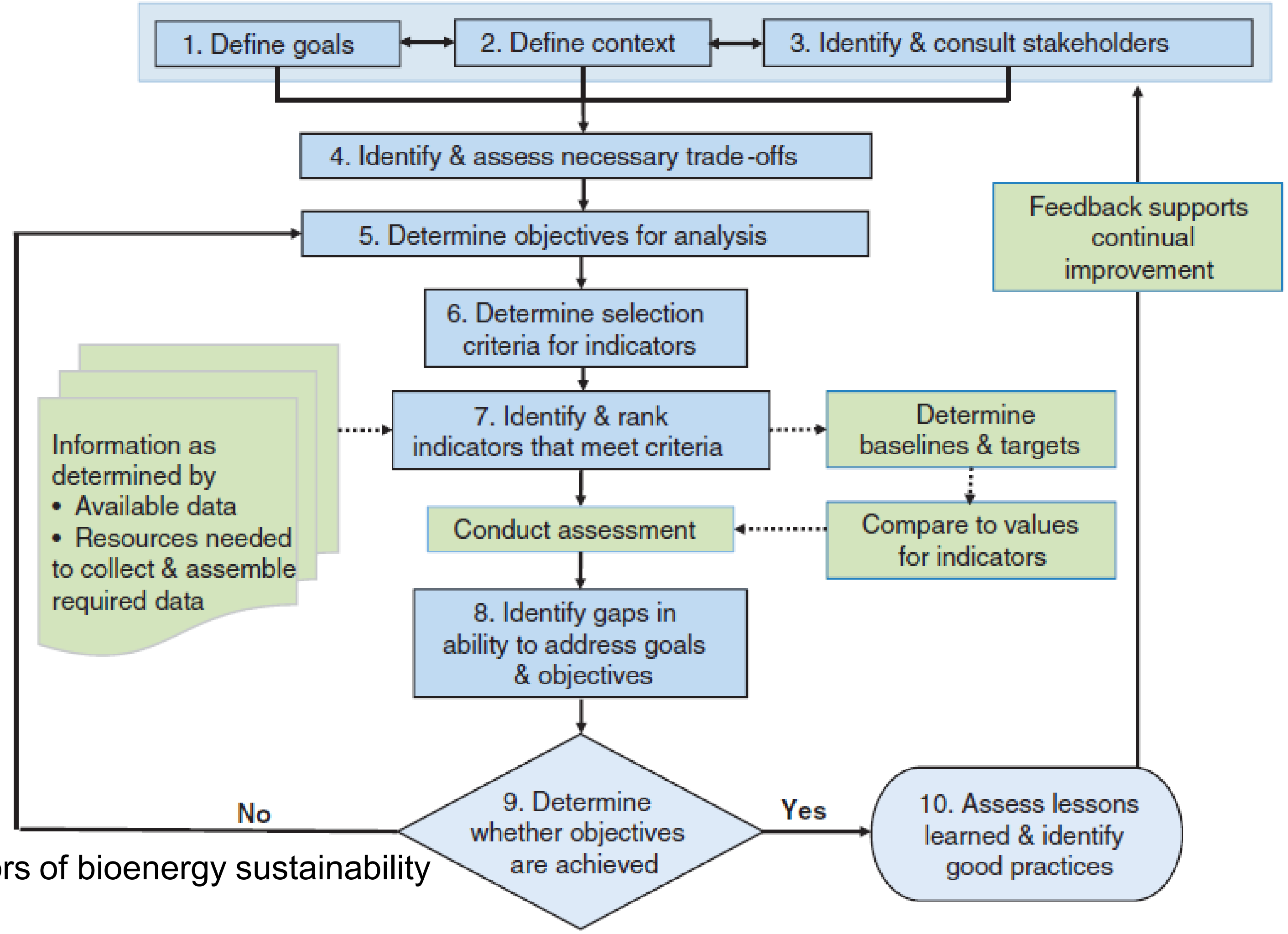
Optimizing crop rotation: process

- Cyclic, interactive
- Data driven
- Impact oriented



Dale et al. (2015) A framework for selecting indicators of bioenergy sustainability

Dale et al. (2015) Integrating biomass supply systems into sustainable landscape designs

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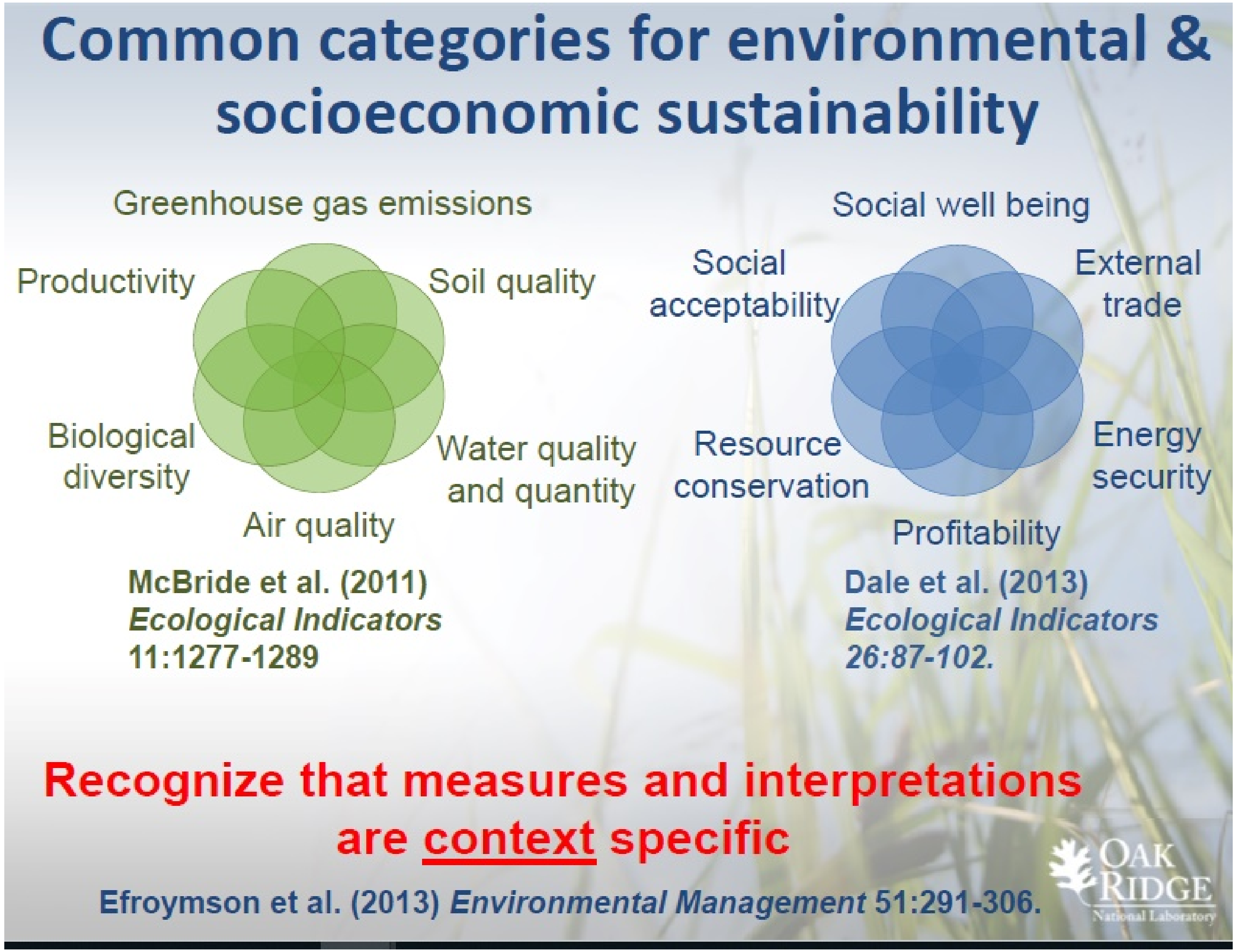
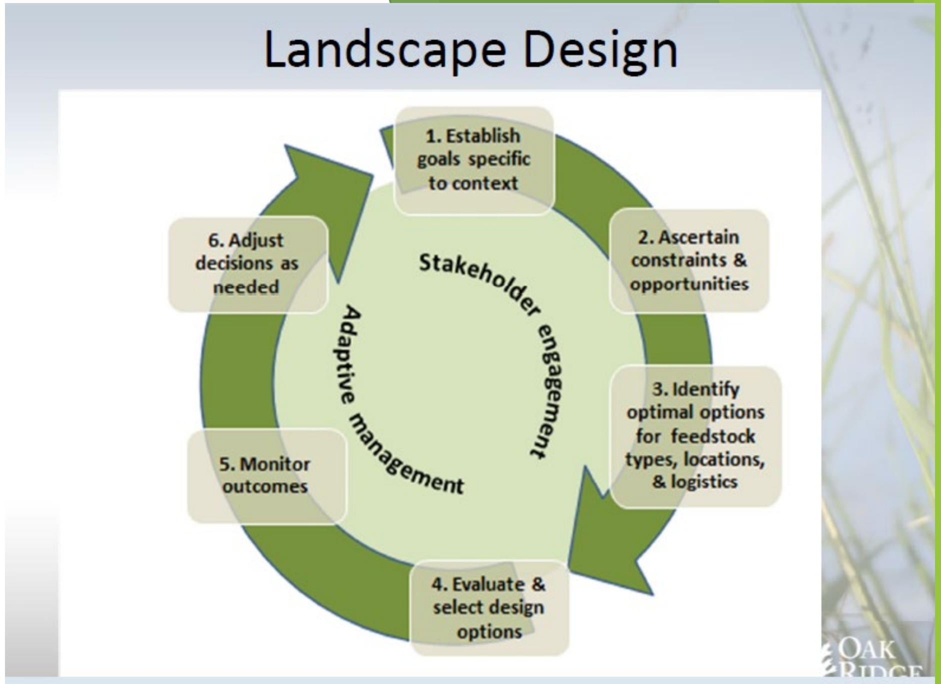




Dale, Kline, Buford, Volk, Smith, Stupak (In review) *Renewable & Sustainable Energy Reviews*

Dale et al. (2015) A framework for selecting indicators of bioenergy sustainability

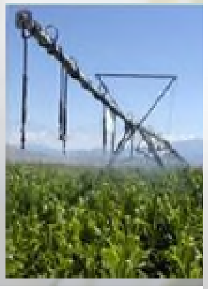
Dale et al. (2015) Integrating biomass supply systems into sustainable landscape designs

Categories of environmental sustainability indicators

Environment	Indicator	Units
Soil quality	1. Total organic carbon (TOC)	Mg/ha
	2. Total nitrogen (N)	Mg/ha
	3. Extractable phosphorus (P)	Mg/ha
	4. Bulk density	g/cm^3
Water quality and quantity	5. Nitrate concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	6. Total phosphorus (P) concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	7. Suspended sediment concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	8. Herbicide concentration in streams (and export)	concentration: mg/L; export: kg/ha/yr
	9. storm flow	L/s
	10. Minimum base flow	L/s
	11. Consumptive water use (incorporates base flow)	feedstock production: m^3/ha/day; biorefinery: m^3/day

Environme
Greenhous gases
Biodiversit
Air quality
Productivit

McBride et al. (2011) *Ecological Indicators* 11:1277-1289



Categories of socioeconomic sustainability indicators

Category	Indicator	Units
Social well-being	Employment	Number of full time equivalent (FTE) jobs
	Household income	Dollars per day
	Work days lost due to injury	Average number of work days lost per worker per year
	Food security	Percent change in food price volatility
Energy security	Energy security premium	Dollars /gallon biofuel
	Fuel price volatility	Standard deviation of monthly percentage price changes over one year
External trade	Terms of trade	Ratio (price of exports/price of imports)
	Trade volume	Dollars (net exports or balance of payments)
Profitability	Return on investment (ROI)	Percent (net investment/ initial investment)
	Net present value (NPV)[2]	Dollars (present value of benefits minus present value of costs)

Category	Indicator	Units
Resource conservation	Depletion of non-renewable energy resources	MT (amount of petroleum extracted per year)
	Fossil Energy Return on Investment (fossil EROI)	MJ (ratio of amount of fossil energy inputs to amount of useful energy output
Social acceptability	Public opinion	Percent favorable opinion
	Transparency	Percent of indicators for which timely and relevant performance data are reported
	Effective stakeholder participation	Number of documented responses to stakeholder concerns and suggestions reported on an annual basis
	Risk of catastrophe	Annual probability of catastrophic event

Dale et al. (2013) *Ecological Indicators* 26:87-102.

OAK RIDGE National Laboratory

Dale et al. (2015) A framework for selecting indicato

Dale et al. (2015) Integrating biomass supply systems into sustainable landscape designs

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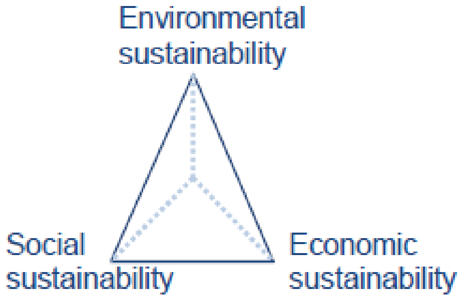
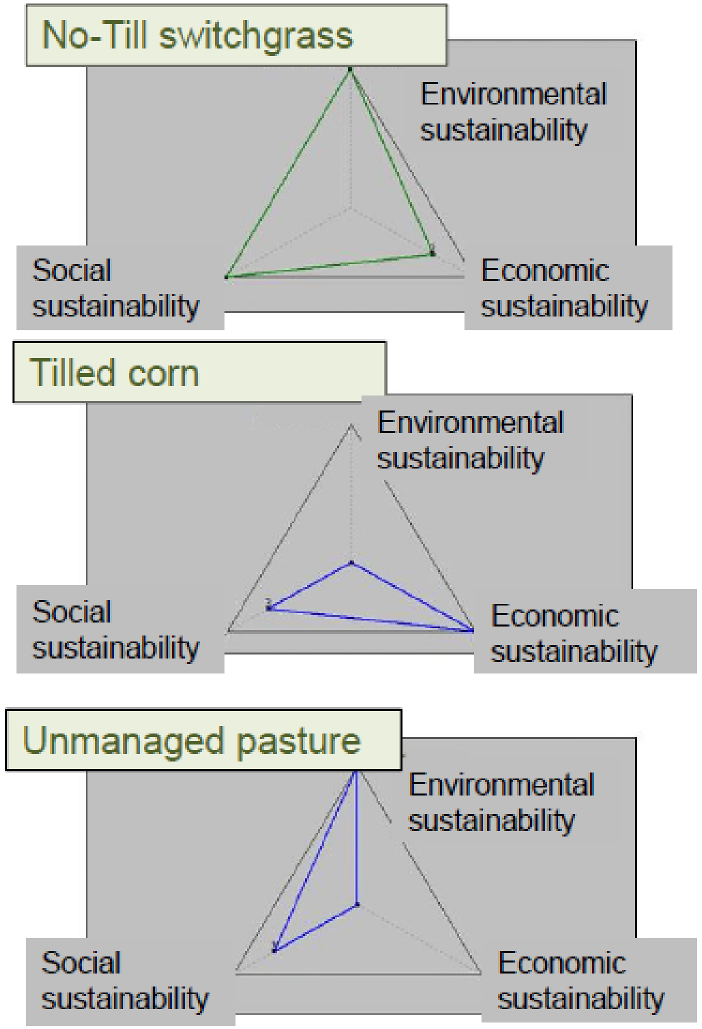
Results: People, planet, profit

Case Study of MADSS Applied to East TN: Determines relative contributions of three "pillars" to overall sustainability

- Switchgras – maize - pasture
- Multi-dimensional evaluation
- Identify strengths and weaknesses

Key to chart





[Parish et al. (In press) Assessing multimetric aspects of sustainability. Ecosphere]

Dale et al. (2015) A framework for selecting indicators of bioenergy sustainability

Dale et al. (2015) Integrating biomass supply systems into sustainable landscape designs

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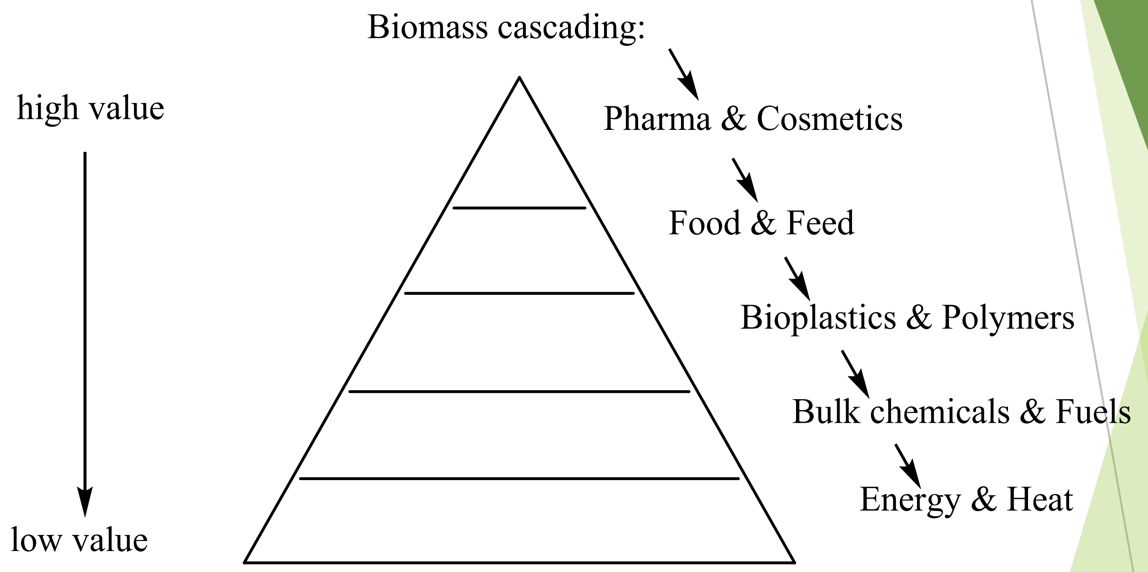
Biocascading: biobased economy

- Value pyramid
- Cascading: highest value (economic, environmental, social) first
- Volumes vs value



Farma
Fun
Food
Feed
Functional chemical
Fibre
Fermentation
Fuel
Fertilizer
Fire
Flare
fill

Design for the bioeconomy

- Protein transition
- Crops and fractions

Table 1 Development rules for a sustainable bioeconomy

Every project should follow the principles of *People, Planet, Profit*
The aim is to improve overall energy efficiency of the entire system
Increase field yield but keep plant components on the field that are required for soil fertility
Use all biomass components and choose the right raw material
Use each component at its highest value: (molecular) structure is much better than caloric
Reduce capital cost to speed up innovation and to benefit from small scale without the disadvantages

Table 2 Protein production in Europe (Mtonne of dry matter per year)

Crop	Mha	Actual yield	2050 potential	Protein (% of dry matter)	Actual protein yield	Potential protein yield
Maize	13.5	61	145	10	6.1	14.5
Barley	14.5	61	89	10	6.1	8.9
Wheat	56	170	340	10	17	34
Sugar beet	3.6	160	180	2	3.2	3.6
Rape seed	8.1	22	28	25	5.5	7
Grass	69.4	140	500	16	22.4	80

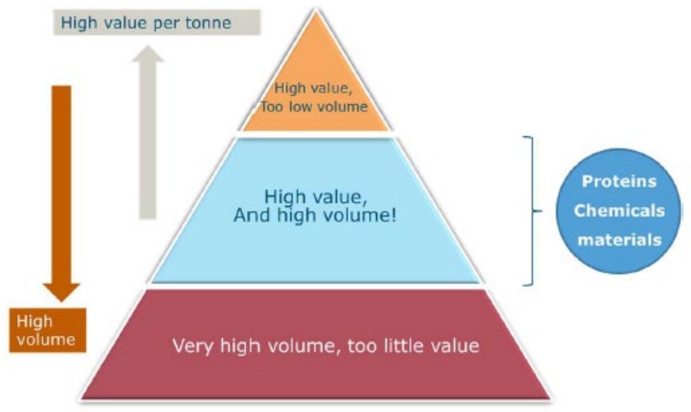


Figure 1. Eco-pyramid

Sanders en Langeveld (2019) Development perspectives for the biobased economy. In: Chalanakis (ed.) Biobased products and industries

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Design for the bioeconomy

- Regional or national approach
- Stepwise development (transition)
- Multi-purpose output

Table 21.2 *Substitution of fossil fuels and value created by biomass on 25 per cent of Dutch agricultural acreage devoted to production of biomass*

	Step 1: 100% biomass used generate to power or fuels	*Step 2: 10% biomass to chemicals*	*Step 3: 20% biomass to chemicals*
Substitution of fossil fuels (PJ):	0	50	100
		135	120
		185	220
		6	7
		500	1000
		200	180
		340	300
		1040	1480
		2330	3331

…wheat equals ca. €1700.

Table 21.3 *Substitution of fossil fuels, and value created by biomass in Brazil*

	Step 1: 100% biomass used to generate power or fuels			*Step 2: 10% biomass to chemicals*			*Step 3: 20% biomass to chemicals*		
Unit	*mln tonnes*	*PJ*	*mln €/y*	*mln tonnes*	*PJ*	*M €/y*	*mln tonnes*	*PJ*	*mln €/y*
Proteins	24		7200	42		12,600	40		12,000
Cattle feed	24		240	42		1050	36		900
Pig feed				24		2400	24		2400
Biodiesel	12	420	4800	9	315	3600	6	210	2400
Bioethanol				36	790	7200	72	790	14,400
Electricity		pm			pm			pm	
Chemicals							12	600	6000
Total		420	12,240		1105	29,250		2390	38,100
Output per hectare (€/ha)		510			1219			1588	

Langeveld and Sanders (2010) Chapter 21 The Biobased Economy

Biobased options

- Added value
- Market size
- Price
- Potential impact
- Employment
- Development

Table 1. Main development perspective of biobased products.†

Product	Feedstocks	Market size	Market price	Potential biobased share	Potential biobased production size	Potential impact for local producers	Potential local employment	Prospects for development
Pharmaceuticals	Selective crops	Very small	Very high	Very high	Very low	Very low	–	Very poor
Bulk chemicals	Starch, sugar crops, proteins	Very large	Low	Modest	Very low	Very low	–	Poor to modest
Fine chemicals	Oil, starch, sugar crops, straw	Very small	Average to good	Low	Low	Modest	Very limited	Modest to good
Solvents	Oil, starch, sugar crops, straw	Small	Low	Very low	Very low	Very low	Very limited	Very poor
Surfactants	Various	Small	Low	Modest	Low	Low	Very limited	Poor
Lubricants	Oil crops	Very small	Low	Modest to high	Low	Low	Good	Modest to good
Polymers	Mostly starch & sugar crops	Very large	Very low	Low	Modest	Very low	Very limited	Very limited
Fibers	Lignocellulosic crops, residues, grasses	Modest	Rather low	Low	Modest	Low	Good	Modest to good

†Source: composed by the authors using data on market size and price and projections of potential market share and size as well as expected perspectives (employment, income) for local biomass producers and laborers.

Langeveld et al. (2010) *Crop Science*

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Sustainability – transparency - responsibility

- People – planet - profit
- SDG’s
- Technical, economic and environemental performance
- Social responsibility

Standards	GHG emissions	Environment	Biodiversity	Social well-being	Competition with food	Economic prosperity	Traceability & crop management	(total)
SQF 2000	0	1	0	1	1	0	1	4
EUREPGAP	2	2	2	1	0	0	2	9
ISO 14001	1	1	0	1	0	0	1	4
FSC	1	1	2	2	1	1	2	10
Eugene	1	1	0	0	0	0	0	2
Cerflor	0	1	1	2	0	2	2	8
EU regulation 2092/91	1	2	2	1	0	0	2	8
IFOAM	1	2	2	2	0	2	2	11
ILO	0	1	1	1	0	0	0	3
EMAS	2	2	2	1	0	0	0	7
ETI	0	0	0	1	0	0	0	1
Green Gold Label	0	1	1	1	0	0	1	4
RSPO	0	1	1	1	1	1	1	6
RTRS	1	1	1	1	0	1	0	5
(total scores)	11	23	19	21	4	9	19	

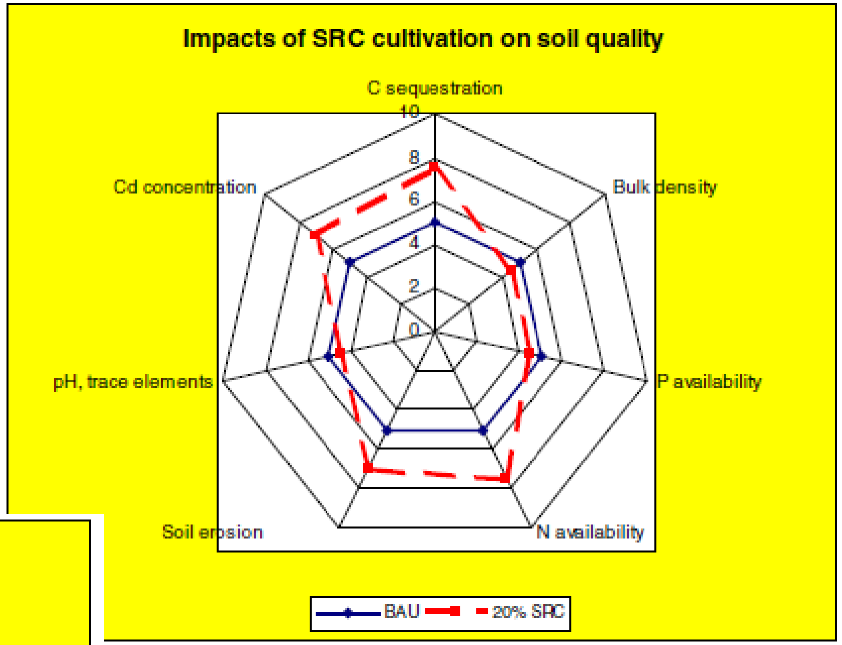
Notes: 0. Not included; 1. Partly included; 2. Included.

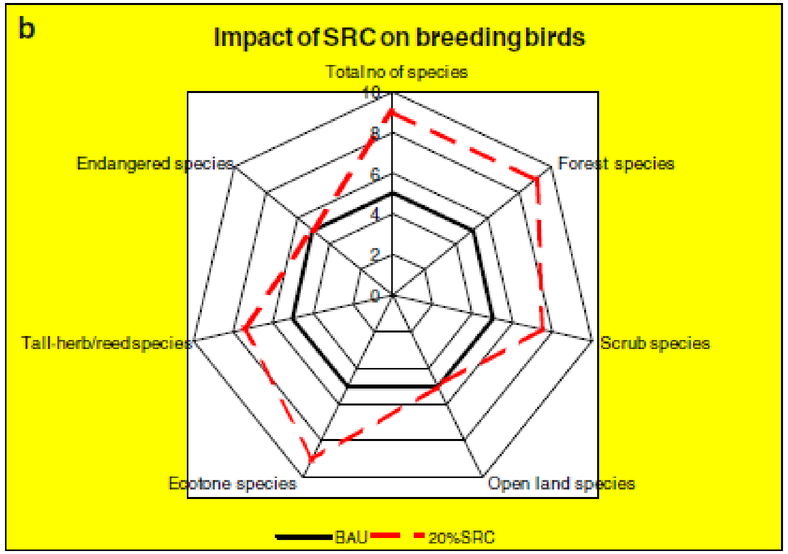
Langeveld et al. (2010) Journal of Forest Energy

Optimizing rotations anc regions

- New crops or applications
- Regional optimization
- Quantification of effects
- Development process

Fig. 1 Impacts of SRC cultivation on soil quality. Figure based on data collected and analysed in Dimitriou et al. [31] and Baum et al. [70]





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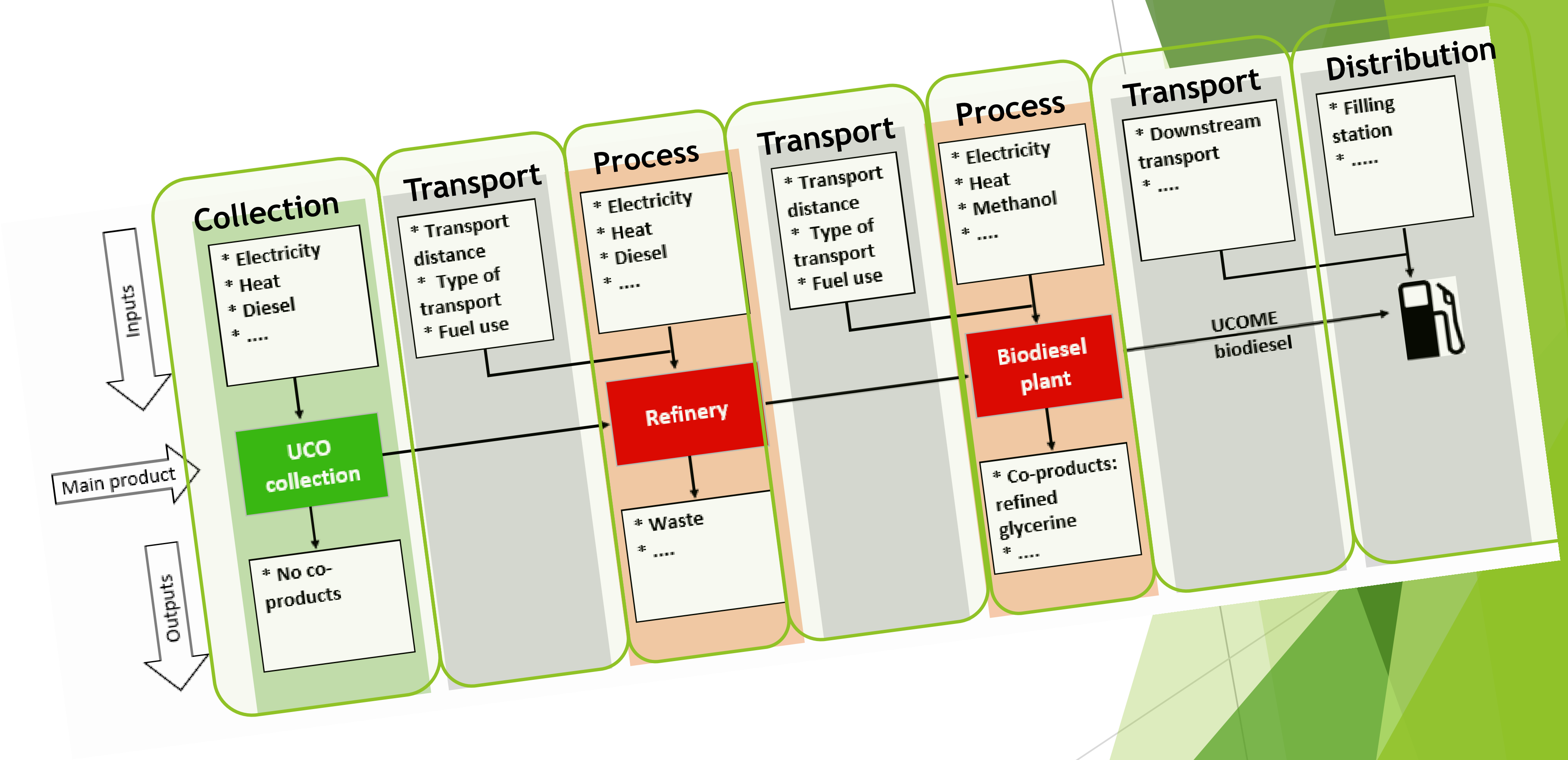
biomass research

Chain assessment and certification

- Steps by step
- Quantification of inputs and outputs
- Identification of chain partners and roles



Chain design ISCC

Chain assessment and certification

Table 1 Internal flows and external transfers associated with harvesting corn stover for bioenergy production

Sphere	Bioenergy	Nitrogen	Carbon	Labour	Money
Local (farm)	Stover collection	Additional fertilizer needs, involuntary *N* losses	Reducing the replenishment of soil organic matter	Jobs on the farm (stover collection)	Higher farm income
Regional (sector)	Stover transport, conversion to bioenergy	Fertilizer transport, nutrient leaching or runoff, water pollution	Emissions from land use change within the region, additional erosion risks	Jobs in the region (stover transport, ethanol production)	Higher regional incomes and tax revenues
Outer (nation)	Replacement of fossil fuels	Increasing demand for fertilizers, nutrient leaching or runoff beyond the region	Offsets by emission indirect l the regio	[illegible]	educed expenditure and dependence on imported oil

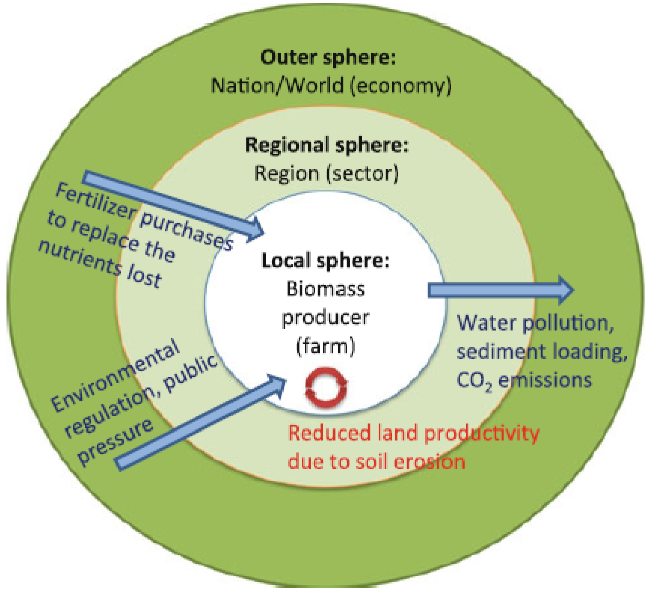


Fig. 2 Potential transfers and interaction among spheres due to soil erosion caused by stover removal

- Emissions and interactions
- Modelling impacts

Gan et al. (2013) *Environmental Management*

Role of fertilizers and soils

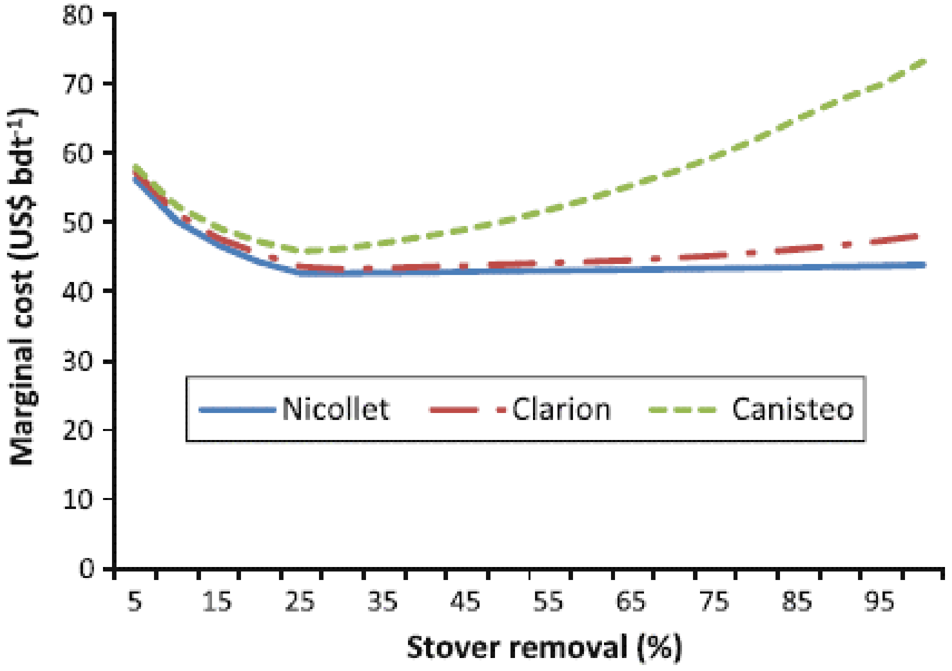


Fig. 3 Total marginal cost of corn stover removal by soil type in Palo Alto County, Iowa (including the costs of soil erosion, nutrient loss, and stover harvesting)

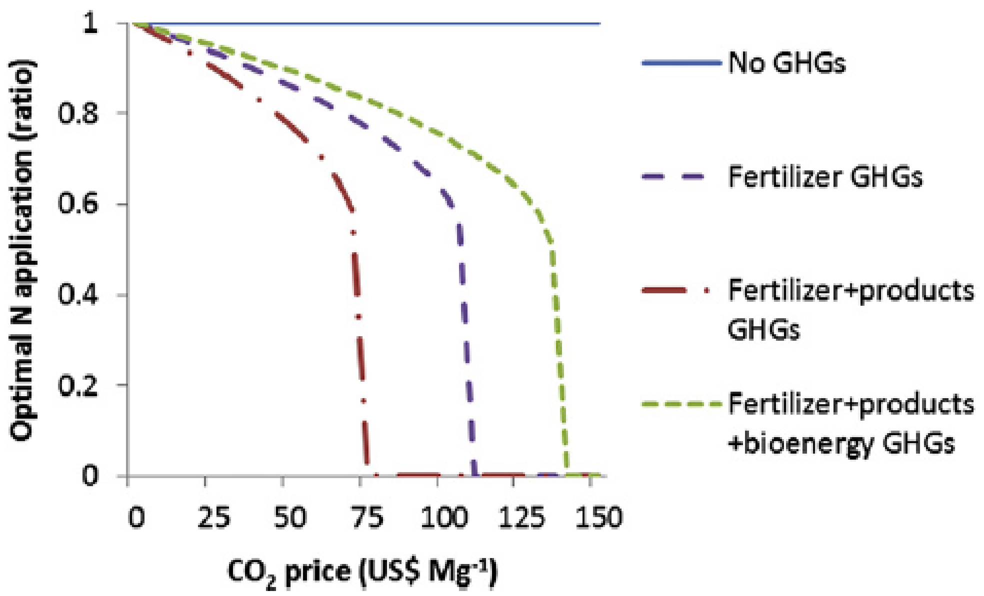


Fig. 5. Optimal fertilizer application intensity at different CO_2 prices for different modelled scenarios. 'No GHGs': GHGs excluded, 'Fertilizer GHGs': GHGs from fertilizer included, 'Fertilizer + products GHGs': GHGs from fertilizer, wood and paper products included, and 'Fertilizer + products + bioenergy GHGs': GHGs from fertilizer, wood and paper products, and bioenergy included.

Gan et al. (2012) *Journal of Environmental Management 113*

Gan et al. (2013) *Environmental Management*

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Emission calculations

- RED defined approach
- Chain steps and pa
- Quantification
- Certification

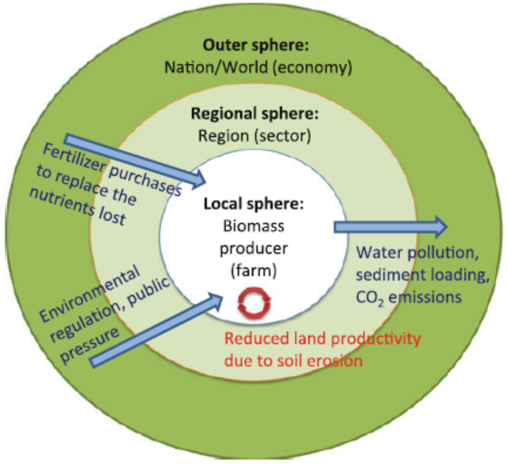
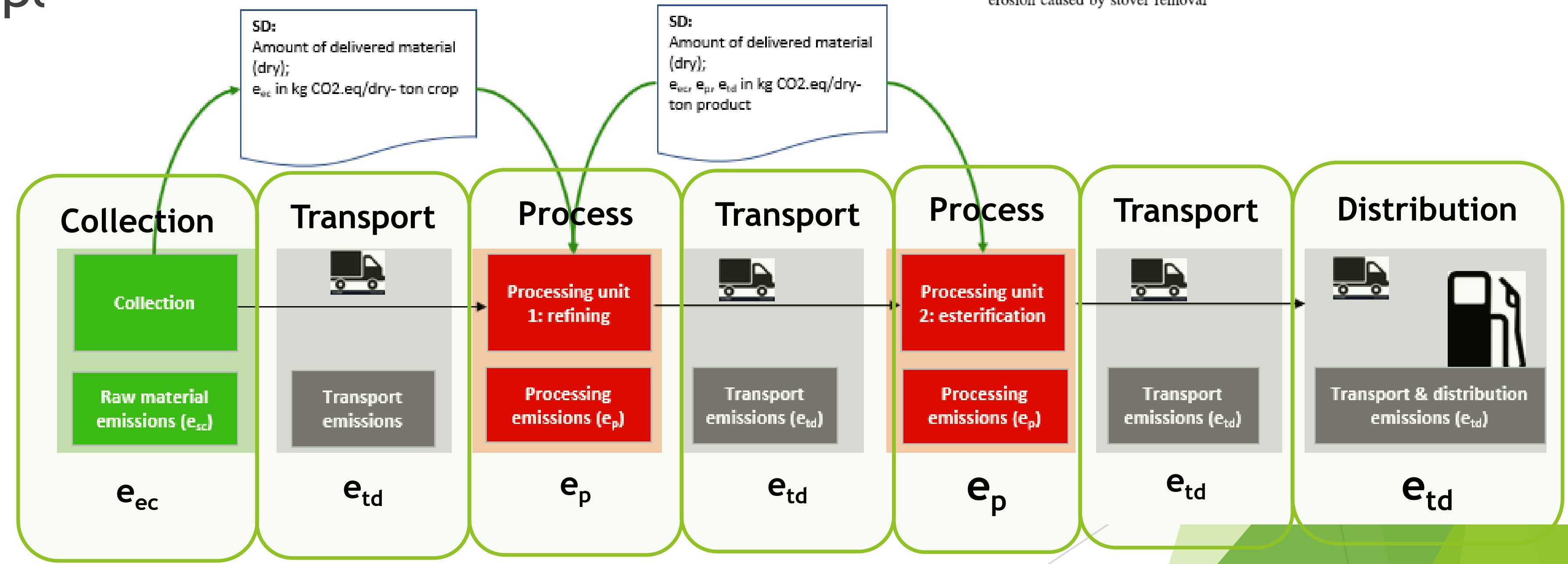


Fig. 2 Potential transfers and interaction among spheres due to soil erosion caused by stover removal



Chain design ISCC

Gan et al. (2013) *Environmental Management*

Federatie Bio-economie Nederland

FBN

- Representation of companies, boards, and individuals
- Develop a sustainable bioeconomy
- Give input to policy, debate and research

Van links naar rechts: Roel, Dorette en Hans

Federatie Bio-economie Nederland

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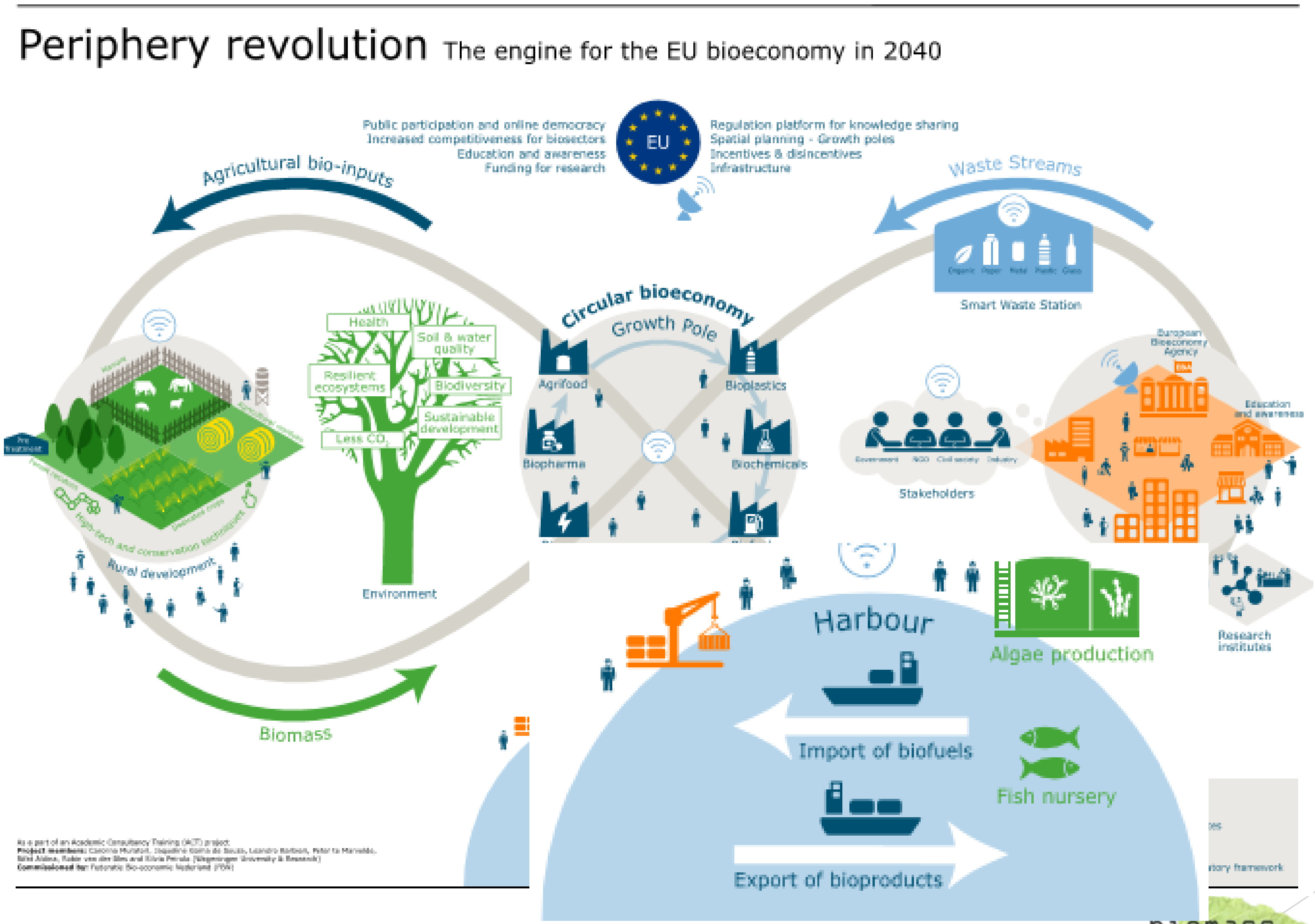

Aldina et al. (2018) Periphery revolution: the engine of the bioeconomy

Thank you for your attention

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