

WP 5 System analysis

Partner meeting 6/10 2020

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Design system analysis of grass-based biorefineries

"Background system"

Energy systems
in Denmark
and Sweden

"Background system"

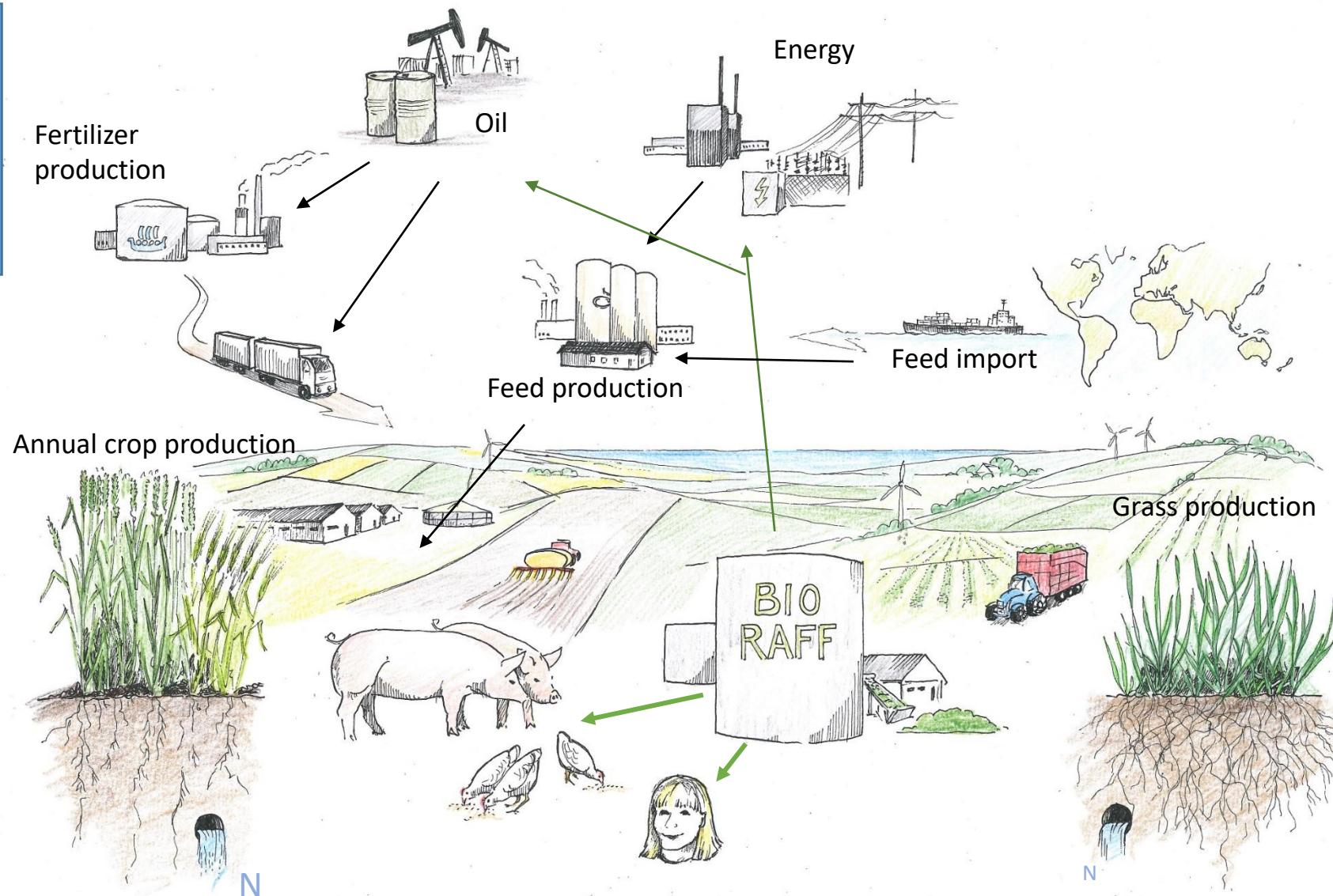
Soybean from
Brazil

"Foreground system"

Intra-landscape
modelling
Data &
indicators

"Foreground system"

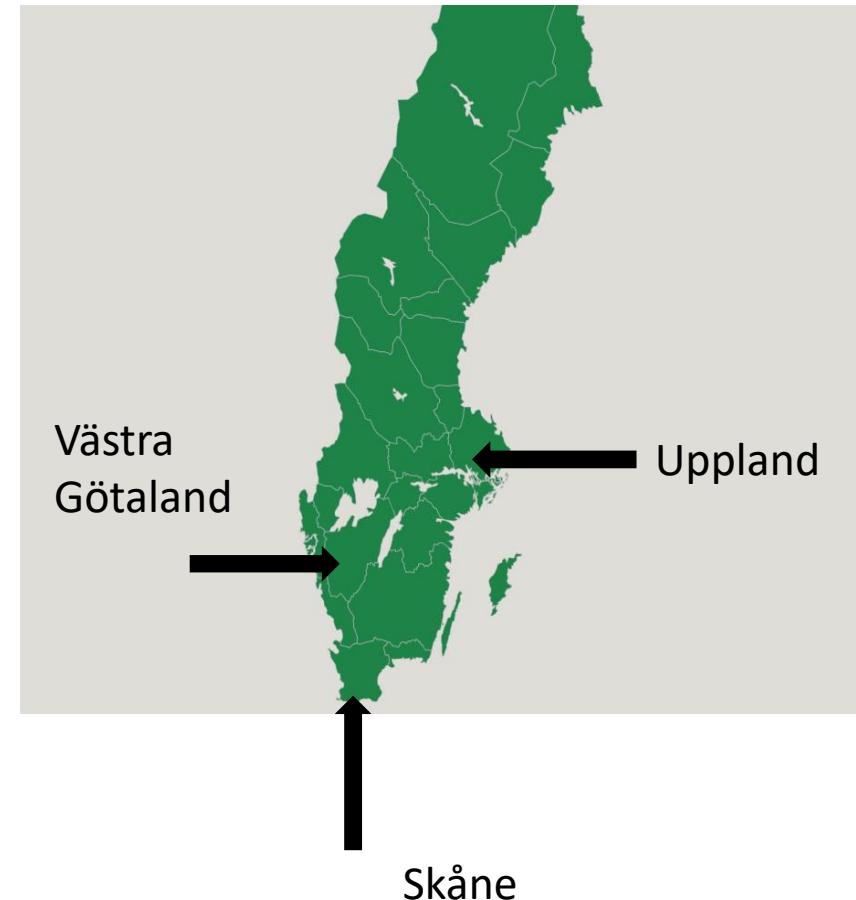
LCA of
production
and use of
products



- Håkan – Economic calculations of crop rotation effects

Economic calculations of crop rotations with and without temporary leys (grass/clover)

- Typical (archetype) crop rotations with and without leys on cereal farms
- Crop rotations and economic calculations for 3 Swedish regions
- Soil preparation, fertilisers, pest control, yields and selected crops differ between the crop rotations



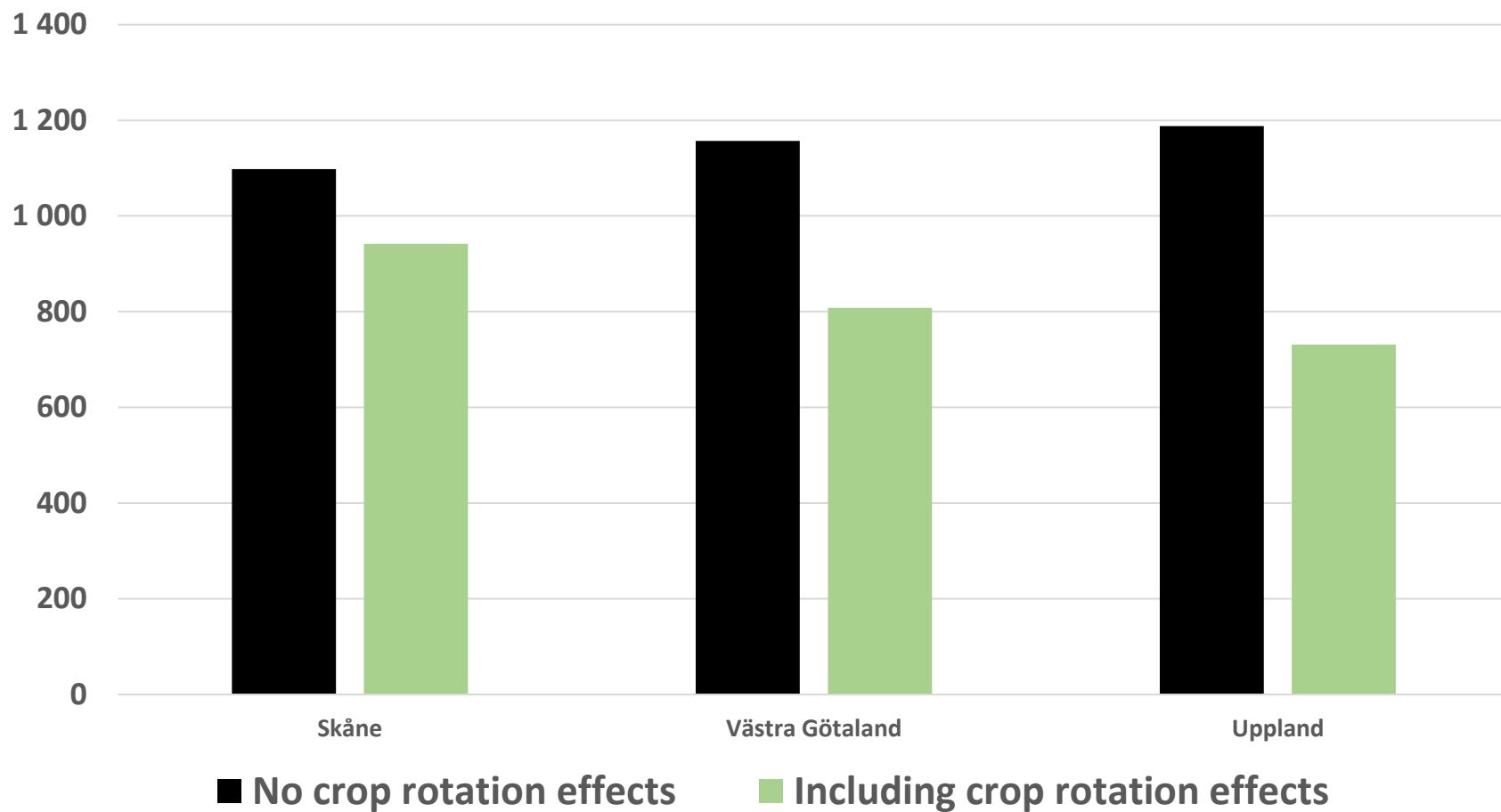
Example of crop rotations Västra Götaland

Year	Cereal-dominated		2 yrs (of 6) with temporary leys	
	Crop	Yield, t/ha	Crop	Yield, t/ha
1	Spring barley	5	Spring barley	5
2	Oats	5	Ley I (grass/clover)	9dm
3	Winter Wheat	6.2	Ley 2 (grass/clover)	6,7dm
4	Winter Rapeseed	3.2	W Rapeseed	3.4
5	W Wheat	6.7	W wheat	7
6	W Wheat	5.5	W wheat	5.8

Including leys in a cereal-dominated crop rotation increases profitability – why?

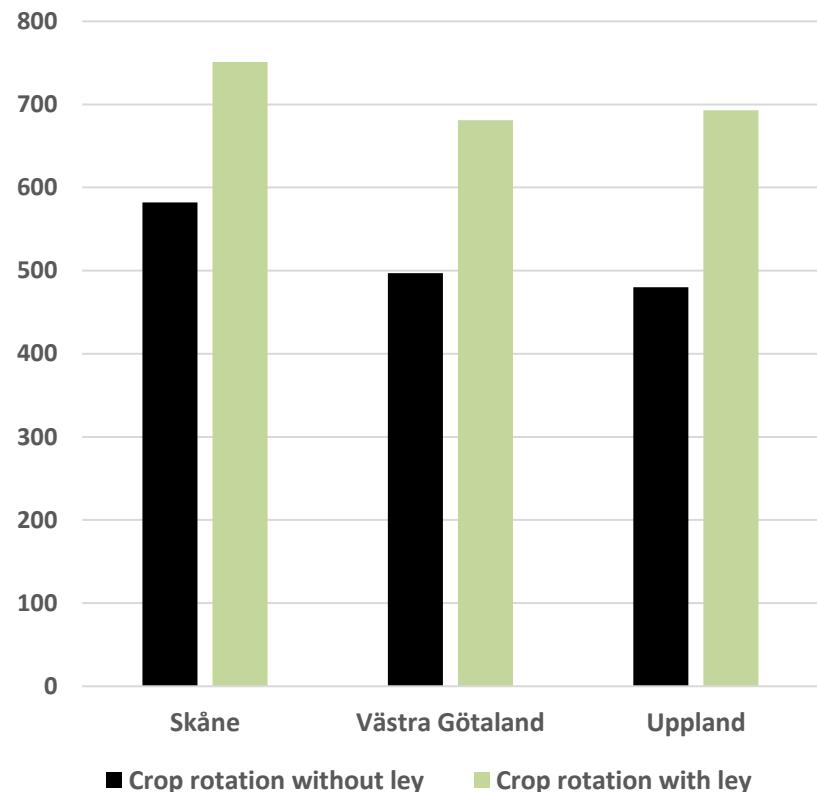
- Removes the less profitable cereal crops and replaces those with grass/clover - it is not the average crop that is replaced
- Yield increase in cereals and oilseeds
- Reduces inputs per ton of cereal/oilseed produced. Both pesticide costs and nitrogen costs decrease per tonne of cereal/oilseed produced

Cultivation cost leys (SEK/ton DM grass&clover) with and without crop rotation effects

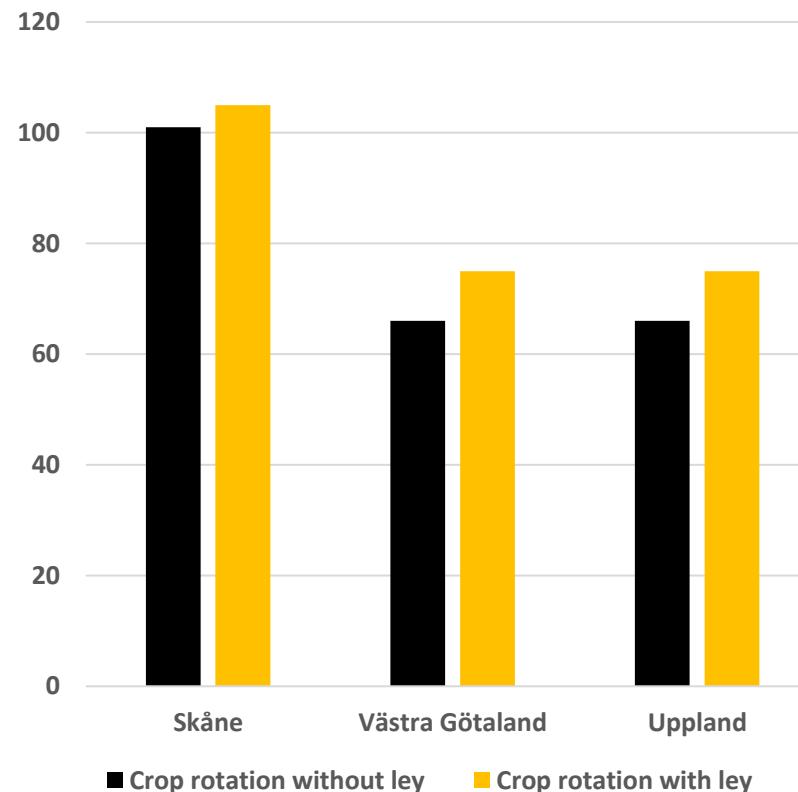


Yield of protein and energy average in overall crop rotations

Protein yield, kg/ha



Energy yield, GJ/ha



- Sebnem – model development

Modelling grass-based biorefinery systems

Motivation and research questions

Overall Motivation – Developing green biorefinery to promote circular green bioeconomy that can use the potential of agriculture

Objective

Modelling and optimization to create a biorefinery development platform and generalised framework to show how refining of the grass(and clover) can deliver sustainable energy and protein

Research questions

- 1.** How can a biorefinery system utilize grass (and clover) to deliver sustainably produced energy products and protein feed?
- 2.** What are the environmental and economic benefits and hot spots of a suggested biorefinery system with grassland integration in agricultural landscapes?
- 3.** How can we quantify the additional agricultural, environmental and economic benefits of establishing more grass(and clover) leys in typical cereal crop production regime by changing crop rotations

Part 1: Economic and Environmental Impacts of Land Use Change to Support Green Biorefinery Development

What would be the total environmental and economic impacts of changing the use of a number of agricultural fields towards grassland in a certain territory?

To develop a model to propose a land use pattern in a certain territory by selecting the appropriate agricultural fields and proportions to change into grasslands to supply grass to the biorefinery system to maximize the environmental benefits and e biorefinery profitability in tandem.

To compare the economic and environmental impacts of different land use patterns in the context of biorefinery systems/supply chain design



The Model



Multi objective MILP model solved by ILOG CPLEX optimization software

The main focus;

Max. Biorefinery profitability

Min. Transportation costs

Max. Environmental benefit: Reduced N leakage

Reduced P leakage

Subject to constraints related to;

Total area and yields (normskörd) - Crops and grass

Capacity – Biorefinery and Biomass Hubs

Conversion in biorefinery

Mass balance

The main assumption;

The use of some agricultural lands that are currently utilized for crop production is changed to grasslands to supply grass to biorefinery

Application and Results

SMED Rapport Nr 5 2019

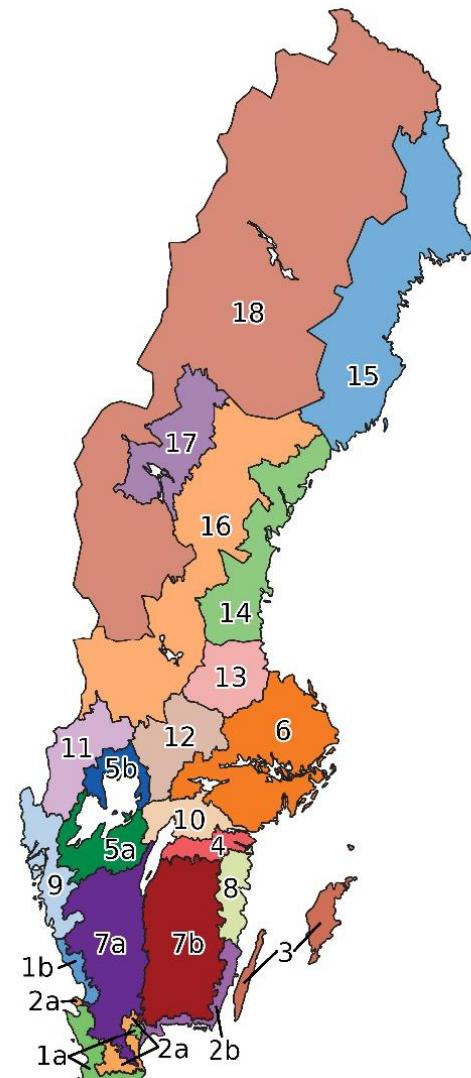


Läckage av näringssämnen från svensk åkermark

Beräkningar av normalläckage av kväve och fosfor för
2016

Holger Johnsson, SLU
Kristina Mårtensson, SLU
Anders Lindsjö, SLU
Kristian Persson, SLU
Ylva Andrist Rangel, SCB
Karin Blombäck, SLU

Lr	Produktionsområde, PO18
1a	Skåne-Hallands slättbygd, 1 (Skånedelen)
1b	Skåne-Hallands slättbygd, 1 (Hallandsdelen)
2a	Sydsvenska mellanbygden, 2 (Skånedelen)
2b	Sydsvenska mellanbygden, 2 (Blekinge-Kalmardelen)
3	Öland & Gotland, 3
4	Östgötaslätten, 4
5a	Vänerslätten, 5 (Södra delen)
5b	Vänerslätten, 5 (Norra delen)
6	Mälar- & Hjälmarbygden, 6
7a	Sydsvenska höglandet, 7 (Västra delen)
7b	Sydsvenska höglandet, 7 (Östra delen)
8	Östsvenska dalbygden, 8
9	Västsvenska dalbygden, 9
10	Södra Bergslagen, 10
11	Västsvenska dalsjöområdet, 11
12	Norra Bergslagen, 12
13	Östra Dalarna, 13
14	Kustlandet i nedre Norrland, 14
15	Kustlandet i övre Norrland, 15
16	Nordsvenska mellanbygden, 16
17	Jämtlandska silurområdet, 17
18	Fjäll- & moränbygden, 18



Figur 6. Läckageregioner (Lr) i Sverige.

Grass supply to biorefinery from;

Scenario 1: at most 10% of current grassland + at most 25% of winter wheat and oats fields change to grassland

Scenario 2: at most 20% of current grassland + at most 10% of oats and 20% of spring barley fields change to grassland

Results 1. Total Environmental Impacts of the Proposed Land Use Patterns

Region	Scenario 1		Scenario 2	
	Reduced N leak. (kg)	Reduced P leak.	Reduced N leak. (kg)	Reduced P leak.
1a Skåne-Hallands slättbygd	462 280	2 737	302 768	1 875
1b Skåne-Hallands slättbygd	152 100	1 499	115 344	1 035
2a Sydsvenska mellanbygden	145 733	730	103 378	678
2b Sydsvenska mellanbygden	56 883	207	39 528	188
3 Öland & Gotland	108 585	143	86 106	191
4 Östgötaslätten	135 525	5 650	33 360	1 462
5a Vänerslätten	498 263	15 095	247 200	7 484
15 Kustlandet i övre Norrland	4 275	204	31 350	1 176
16 Nordsvenska mellanbygden	2 258	174	6 407	462
17 Jämtlandska silurområdet	0	0	2 436	244
18 Fjäll- & moränbygden	0	0	0	0
Total	2 376 550	63 325	1 656 377	44 216

2. Economic Impacts of the Entire System

2.1. Farmers' perspective

Region	Farmer-Current	Scenario 1		Scenario 2		Income (SEK/year)	Cultivation Cost (SEK/year)		
		Farmer-New		Farmer-New					
		Income (SEK/year)	Cultivation Cost (SEK/year)	Income (SEK/year)	Cultivation Cost (SEK/year)				
1a Skåne-Hallands slättbygd	1 644 249 147	1 254 286 381	1 487 786 570	1 078 848 898	1 528 557 851	1 108 797 489			
1b Skåne-Hallands slättbygd	466 086 372	355 545 746	421 734 776	305 815 436	433 291 989	314 304 800			
2a Sydsvenska mellanbygden	599 471 364	413 691 071	473 713 922	355 669 126	486 047 639	364 863 445			
2b Sydsvenska mellanbygden	287 935 065	198 702 010	227 531 884	170 833 202	233 455 952	175 249 371			
3 Öland & Gotland	464 356 562	293 340 615	303 692 536	281 943 192	310 443 655	286 260 843			
4 Östgötaslätten	753 147 125	602 694 608	630 274 066	505 686 044	661 579 093	536 506 946			
13 Östra Dalarna	182 786 750	124 225 438	97 166 235	119 302 233	97 474 946	118 801 415			
17 Jämtländska	78 446 995	12 204 837	9 252 415	12 204 837	9 070 201	11 386 981			
18 Fjäll- & moränbygden	32 381 700	0	0	0	0	0	0		
Total	10 774 196 901	7 578 835 437	7 565 341 983	6 086 507 371	7 739 148 994	6 241 310 201			

2.2. Biorefinery Investor perspective (Scenario 1)

Region	Income (SEK/year)	Investment cost	Operational Cost	Feedstock cost	Profit (SEK/year)
		(SEK)	(SEK/year)	(SEK/year)	
1a Skåne-Hallands slättbygd	388 379 768	1 239 321 600	26 606 477	97 094 942	215 105 485
1b Skåne-Hallands slättbygd	109 422 900	787 564 800	8 896 928	27 355 725	41 667 655
2a Sydsvenska mellanbygden	158 400 000	605 721 600	10 264 320	39 600 000	84 306 816
2b Sydsvenska mellanbygden	77 215 478	583 387 200	7 397 532	19 303 869	27 178 588
3 Öland & Gotland	140 880 465	562 003 200	9 136 959	35 220 116	74 043 262
4 Östgötaslätten	278 368 838	988 099 200	16 645 409	69 592 209	152 607 251
14 Kustlandet i nedre Norrland	55 791 125	365 587 200	4 150 158	13 947 781	23 069 698
15 Kustlandet i övre Norrland	70 813 238	355 291 200	4 532 821	17 703 309	34 365 459
16 Nordsvenska mellanbygden	33 060 281	345 470 400	3 237 237	8 265 070	7 739 158
17 Jämtländska silurområdet	22 926 313	345 470 400	2 914 977	5 731 578	460 942
Total	3 102 038 893	11 255 428 800	197 771 557	775 509 723	1 678 540 461

3. Changed landscape, biorefinery configuration and output (Scenario 1)

Region	Area-grassland (ha) (changed from cropland)	Total area-grassland (ha) (to supply grass to bioref.)	Biorefinery Scale	Protein (ton)	Press Cake (ton)	Brown Juice (ton)
1a Skåne-Hallands slättbygd	20 320	24 130	Large	13 205	54 373	10 098
1b Skåne-Hallands slättbygd	5 760	6 840	Small	3 720	15 319	2 845
2a Sydsvenska mellanbygden	6 668	10 859	Small	5 385	22 176	4 118
2b Sydsvenska mellanbygden	3 203	5 216	Small	2 625	10 810	2 007
6 Mälar- & Hjälmarbygden	36 113	41 385	Large	16 157	66 528	12 355
7a Sydsvenska höglandet	4 125	16 665	Large	7 721	31 792	5 904
7b Sydsvenska höglandet	3 800	15 352	Small	5 385	22 176	4 118
8 Östsvenska dalbygden	1 330	3 914	..	0	0	0
9 Västsvenska dalbygden	4 378	10 352	Small	5 047	20 781	3 859
13 Östra Dalarna	2 100	5 340	Small	1 952	8 038	1 493
14 Kustlandet i nedre Norrland	570	6 422	Small	1 897	7 811	1 451
15 Kustlandet i övre Norrland	475	7 695	Small	2 407	9 914	1 841
Total	146 298	246 671	4 L, 1 M, 14S	105 469	434 285	80 653

Capacity levels (ton DM /year)

Small scale-31680

Medium scale - 63360

Large scale - 95040

Other results

- Transportation/storage decisions (optimized distribution amounts, biomass hubs, environmental impacts...)
- Soy substution analysis (economic and environmental impacts of soy-protein replacement)
- Sensitivity analyses... Impact of changes in prices (crop, grass, biorefinery products) and yields
- Impacts of incentives for farmers and biorefinery system

Future research

Overall Model with Bioenergy/Biofuel Production

To develop a comprehensive approach for modelling, optimization and analysis of the overall system with biorefinery and bioenergy facilities

An extended modelling approach with additional environmental and energetic concerns

- GHG from farm operations, biorefinery operations and transportation

- SOC changes

- Energy balance

Västra Götaland application

- Marie – energy efficiency in green protein proteins

Green proteins: An energy-efficient solution for increased self-sufficiency in protein in Europe

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Received June 30 2018; Revised January 18 2020; Accepted February 28 2020;
View online March 27, 2020 at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.2098; *Biofuels, Bioprod. Bioref.* 14:605–619 (2020)

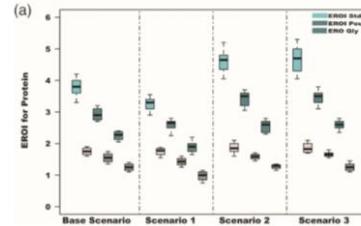


Abstract: The heavy reliance of the livestock industry of the European Union (EU) on feed protein imports has initiated a transition to alternative protein sources such as grass proteins. Green biorefineries (which process grass into protein and other related bio-products) are gaining interest in the EU as the EU searches for ways to cut its import of feed proteins, to reduce its reliance on fossil fuels, and to combat climate change. However, the vulnerability of green biorefineries to fossil energy constraints has not been studied. We estimated the energy conversion efficiencies (EE) and the energy return on investment (EROI) of bio-products from standalone (SGBR) and integrated grass refinery (IGBR) systems using scenario and energy analysis. The base scenario assumes an SGBR that processes grass into protein, fiber, and brown juice. The three IGBR scenarios assume that grass is processed into protein, fiber, and biomethane (Scenario 1); into protein, fiber, heat, and electricity (Scenario 2); or into protein, fiber, heat, and biomethane (Scenario 3). We found that the EE of the IGBR (83%–85%) largely exceeded that of the SGBR (77%) in all cases. Energy returns on investment were lower for grass than for clover-grass because of the high fertilizer needs of the former. The standard EROIs ($EROI_{std}$) for grass protein ranged from 1.6 to 5.4 over the various feedstocks and scenarios evaluated. The $EROI_{std}$ decreased when the system boundary was expanded to the point of use ($EROI_{pou}$), or when they were adjusted for quality ($EROI_{qj}$). Other bioproducts from both SGBR and IGBR also had high $EROI_{std}$, and showed similar patterns to that of grass protein (i.e., $EROI_{std} > EROI_{pou} > EROI_{qj}$). Although Scenario 1 had a high EE relative to the base scenario, its heavy reliance on auxiliary energy inputs reduced the EROIs of its products. Our analysis showed the strong impacts of brown-juice recycling in the energy performance of green biorefinery. It thus deserves close attention when designing and implementing a green biorefinery in a given region.

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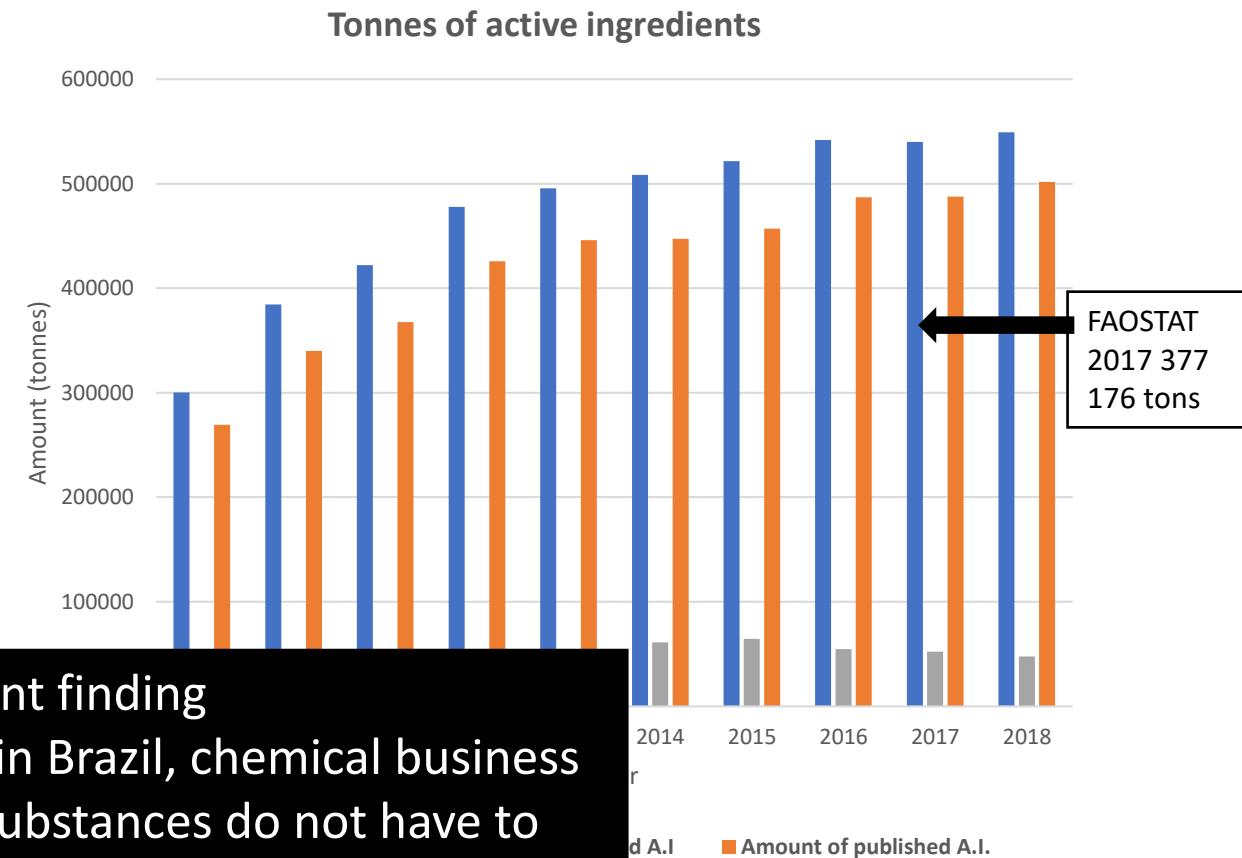
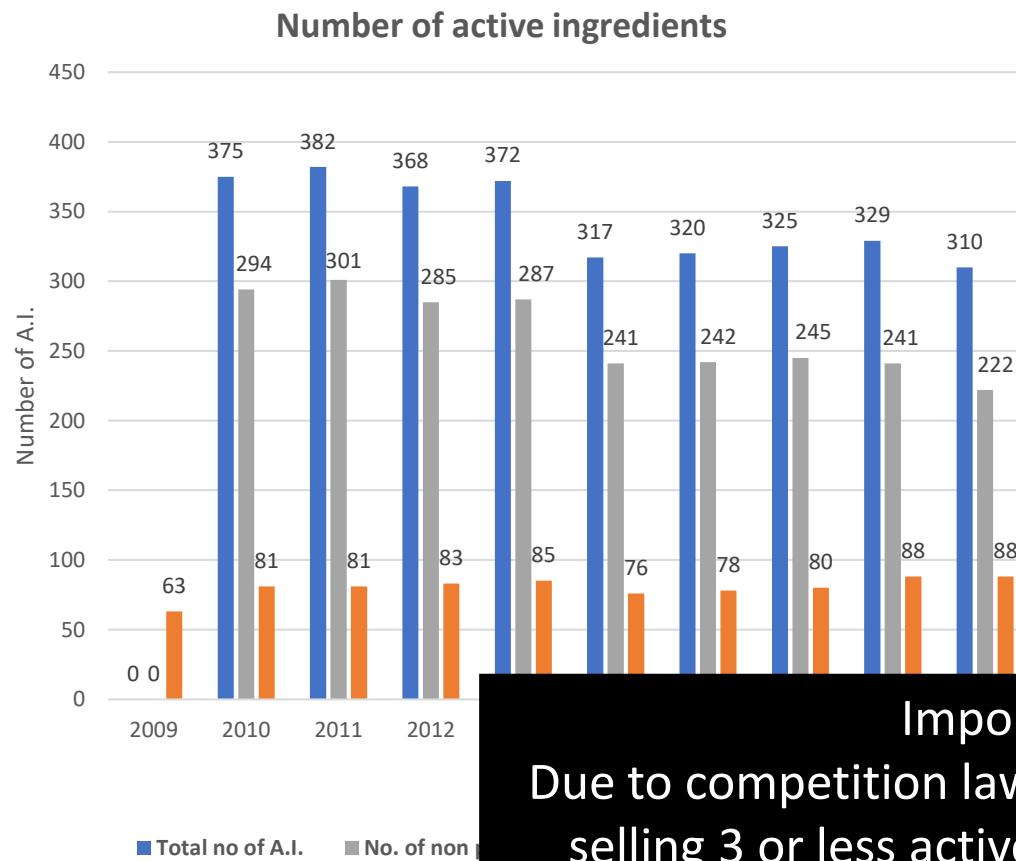
MAIN FINDINGS

- To assess the energy aspects of green biorefineries, we estimated the energy conversion efficiencies (EE) and the energy return on investment (EROI) of bio-products from grass refinery systems using energy analysis.
- We found that the EE of biorefineries integrated with biogas plants (83%–85%) largely exceeded that of the standalone (77%) in all cases.
- Energy returns on investment (EROI) were lower for highly fertilized grass (450 kg N/ha) than for unfertilized clover-grass because of the high fertilizer needs of the former.
- Our analysis showed the strong impacts of brown-juice recycling in the energy performance of green biorefinery. It thus deserves close attention when designing and implementing a green biorefinery in a given region.



- Christel – pesticide use and impacts in Brazilian soybeans (the “background system”)

Pesticide reporting in Brazil – total statistics at national level (results from H Pollak Master thesis)



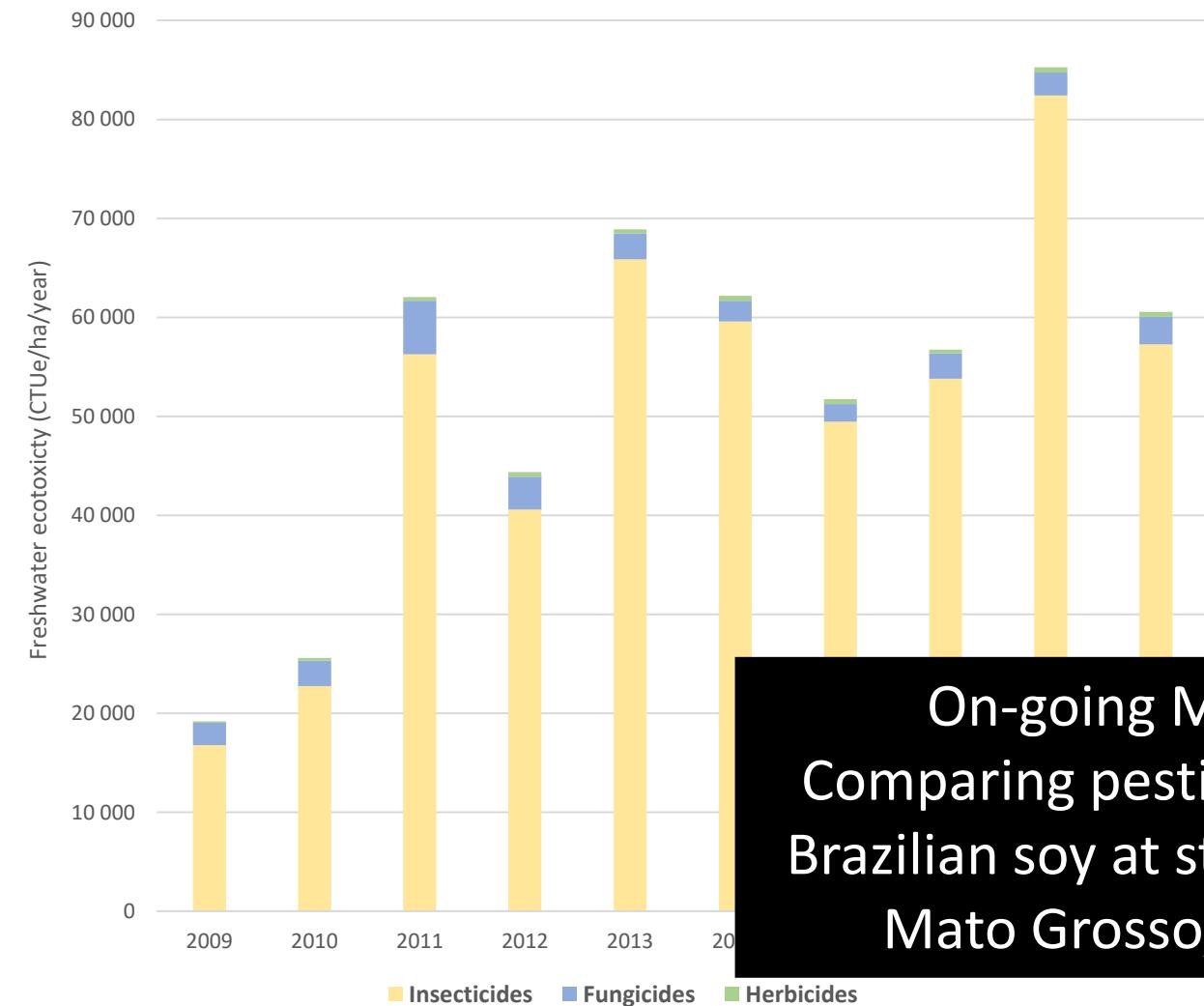
Important finding
Due to competition laws in Brazil, chemical business
selling 3 or less active substances do not have to
report the individual active ingredients, only total sale

FAOSTAT
2017 377
176 tons

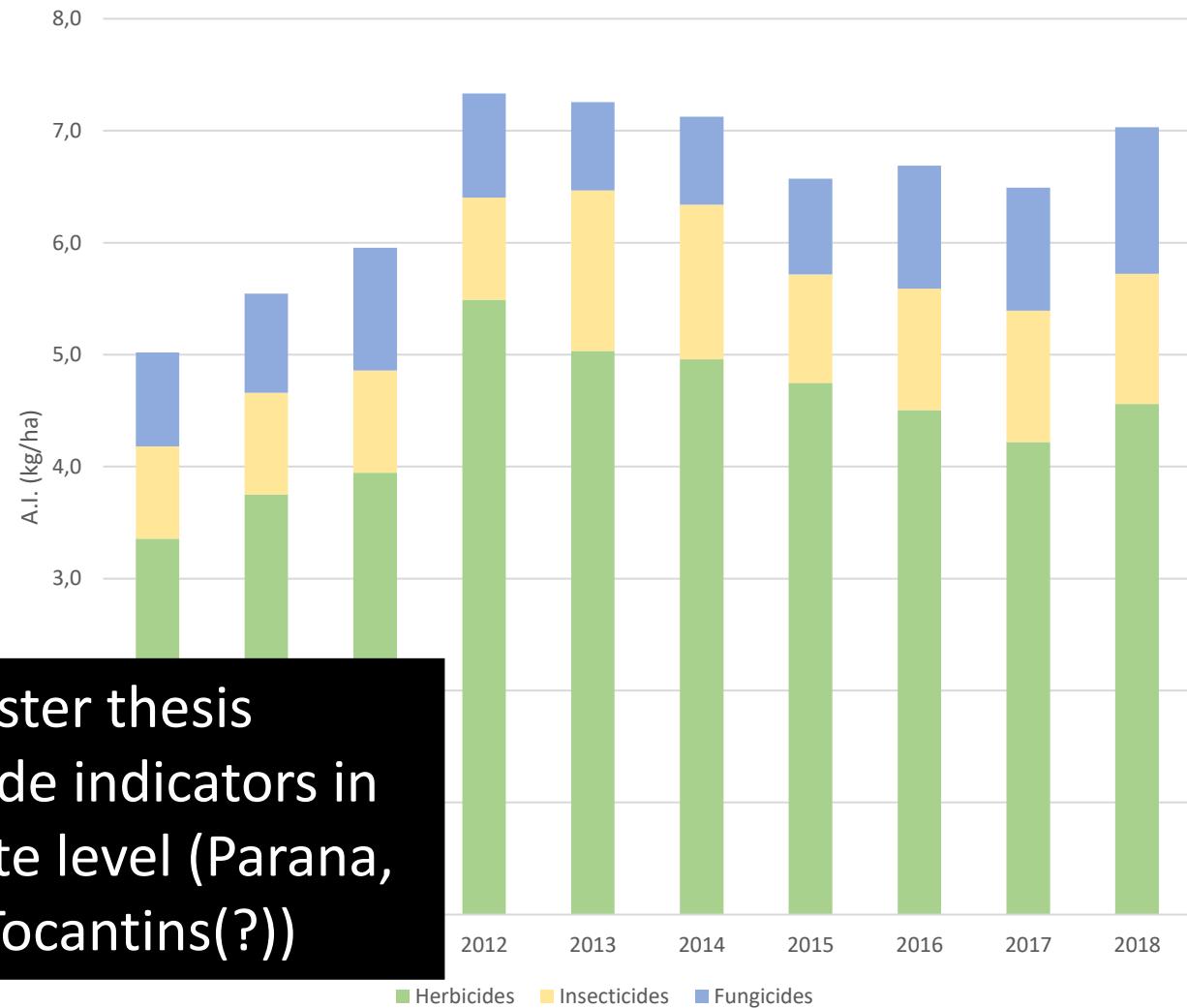
Pesticide indicators in Brazilian soybeans

(results from H Pollak's Master thesis)

Freshwater ecotoxicity, impact indicator per ha soybeans



Use of pesticides, pressure indicator, kg A.I. per ha soybeans



On-going Master thesis
Comparing pesticide indicators in
Brazilian soy at state level (Parana,
Mato Grosso, Tocantins(?)

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