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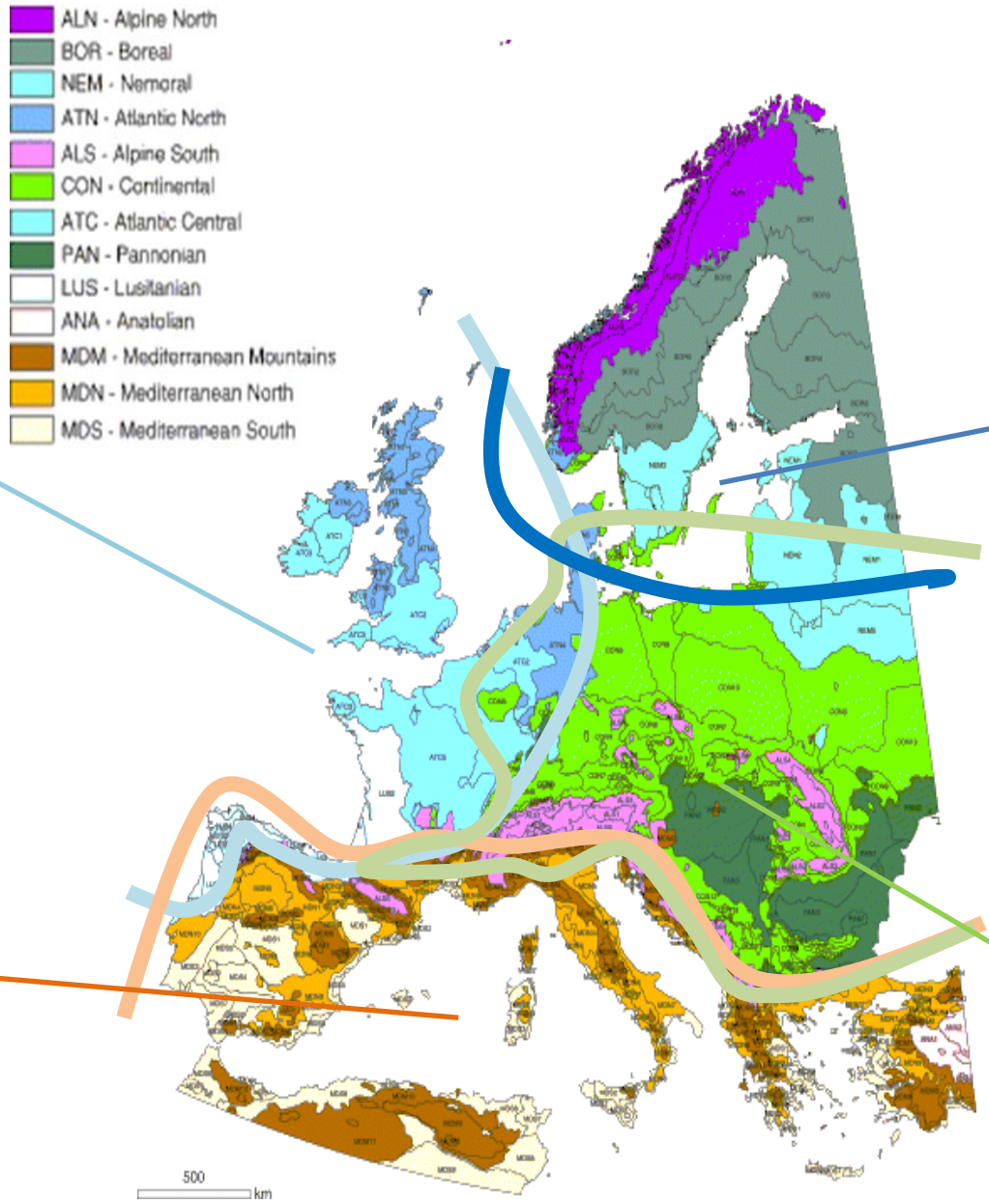
A cropping system assessment framework : applied to legume based cropping systems in Europe

Narrow-leafed lupin (*Lupinus angustifolius* L.)
(photo credit: Reckling, ZALF)

Christine Watson, Moritz Reckling, Johann Bachinger, Göran Bergkvist & Fred Stoddard

Date: June 1, 2018

Environmental Stratification of Europe



NORTH WEST

Autumn-sown pea, faba bean, white lupin; spring-sown pea, faba bean, potentially vetches and lupins

NORTH EAST

Spring-sown, cool-season crops: Pea, faba bean, potentially narrow-leafed lupin, lentil and vetches

SOUTH

Cool-season, autumn-sown crops: pea, faba bean, lentil, chickpea, vetches, lupins; *Irrigated* spring sown soybean, common bean, cowpea

CENTRAL

Warm-season crops: soybean, common bean; Spring-sown pea, faba bean, potentially lupins, lentil and vetches

Stoddard et al. (2018) adapted from Metzger et al. (2005)

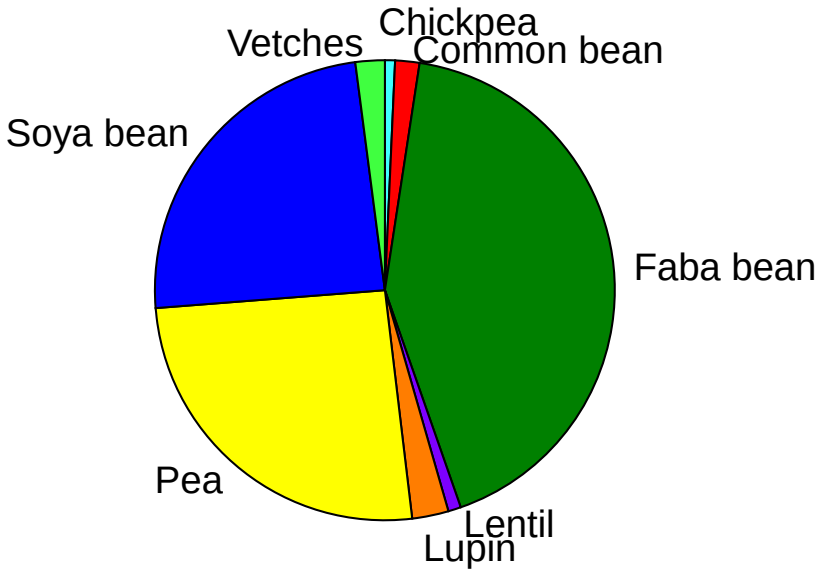
Ecosystem services of legumes (Watson et al. 2017)

- Provisioning services
  - Food and feed
- Supporting and regulating services
  - Biological nitrogen fixation (BNF)
  - Rotational effects
  - Nitrate leaching
  - Nitrous oxide emissions
  - Agro-biodiversity and climate change adaptation
  - Biodiversity
  - Regulating pests, disease and weeds

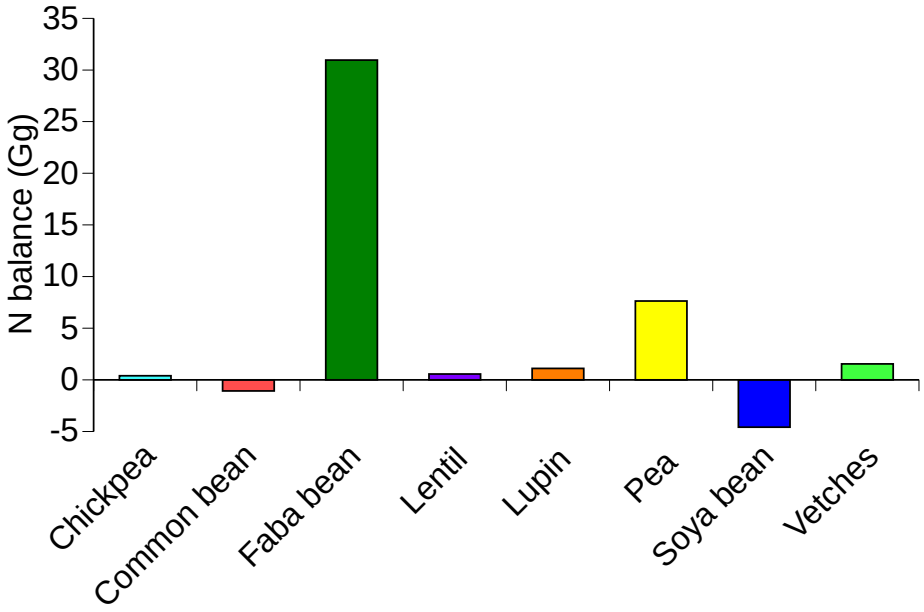
Bumblebee visiting soybean flowers in the field experiment at ZALF (photo credit: Rosner, ZALF)

Watson et al. (2017) Grain legume production and use in European agricultural systems. Advances in Agronomy 144, 235-303.

Total 206 thousand t (Gg) of N fixed in Europe in 2009



N balance across Europe (fixation – harvest, thousand t) in 2009: total 37 Gg



Baddeley et al. (2014) Biological nitrogen fixation by legume crops in Europe. Legume Futures Report 1.5.

Aim of the cropping system framework:

- Assess ecosystem services of legumes in rotations
- Systematically compare cropping systems with and without legumes
- Design novel systems with legumes using multi-criteria analysis

Reckling et al. (2016) A cropping system assessment framework - evaluating effects of introducing legumes into crop rotations. European Journal of Agronomy 76:186-197.

Modelling approach

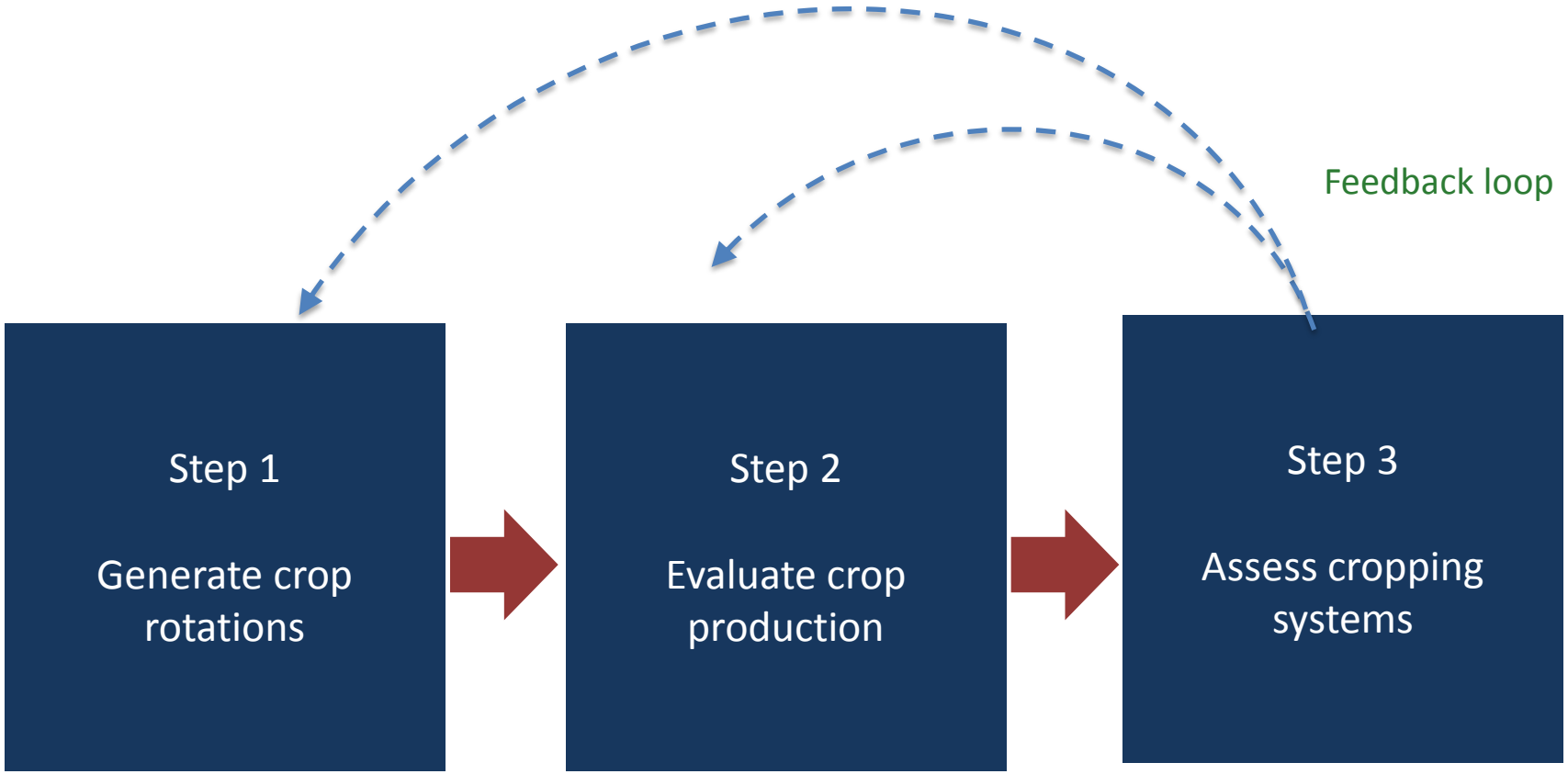
- Rule-based and static model in MS Access
- Algorithms based on literature, IPCC and ROTOR

  (Bachinger and Zander, 2007)
- Data from surveys, statistics and experts from Legume Futures
- Indicators used so far:
  - Economic: gross margin
  - Environmental: N-leaching, N_2O emission, N-fertilizer use
  - Agronomic: pests/disease/weed assessment

Expert knowledge on legumes and crop rotation design

Reckling et al. (2016) A cropping system assessment framework - evaluating effects of introducing legumes into crop rotations. European Journal of Agronomy 76:186-197.

Framework development

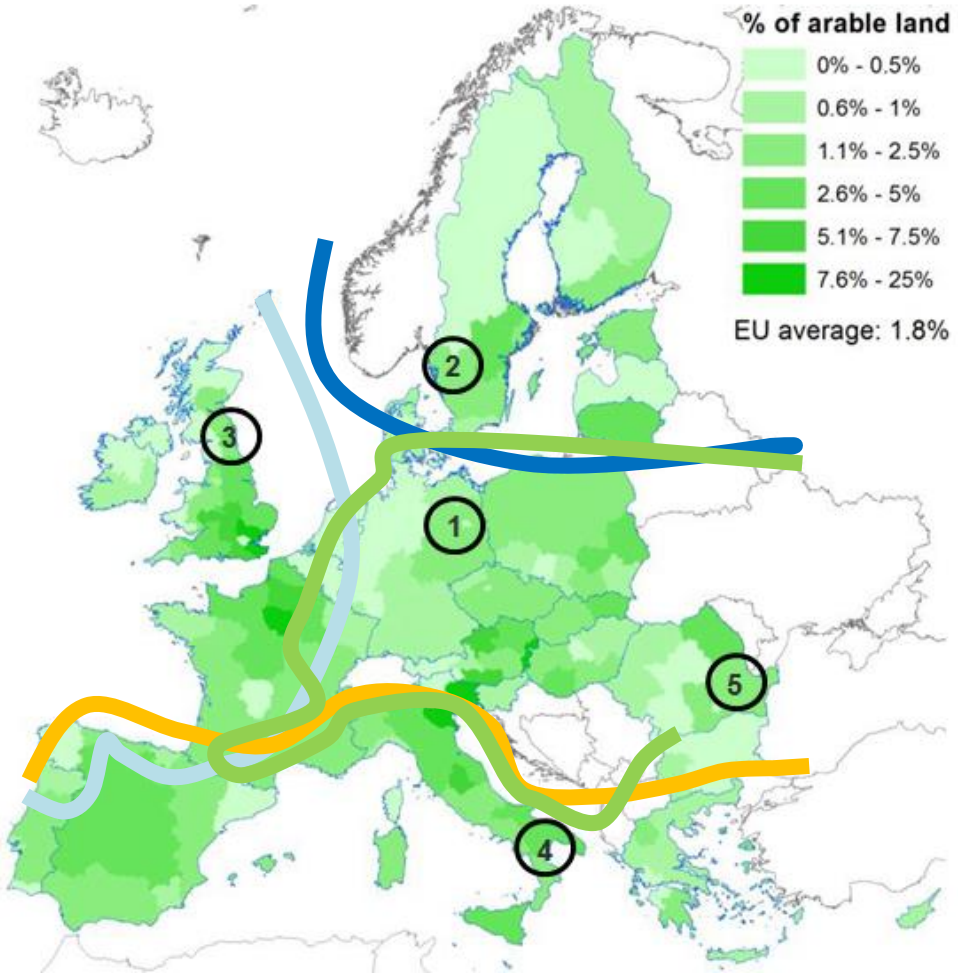


Reckling et al. (2016) A cropping system assessment framework - evaluating effects of introducing legumes into crop rotations. European Journal of Agronomy 76:186-197.

Case studies across Europe

- Case studies
  - ‘Arable systems’ in 5 regions (1-5)
  - ‘Mixed farming’ in 3 regions (1-3)

(1) Brandenburg, Germany
(2) Västra Götaland, Sweden
(3) Eastern Scotland, UK
(4) Calabria, Italy
(5) Sud-Muntenia, Romania



Proportion of EU-27 arable land used for grain legumes in 2010 and the study regions across Europe adapted from Reckling et al. (2016)

Adapted from: Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

Results

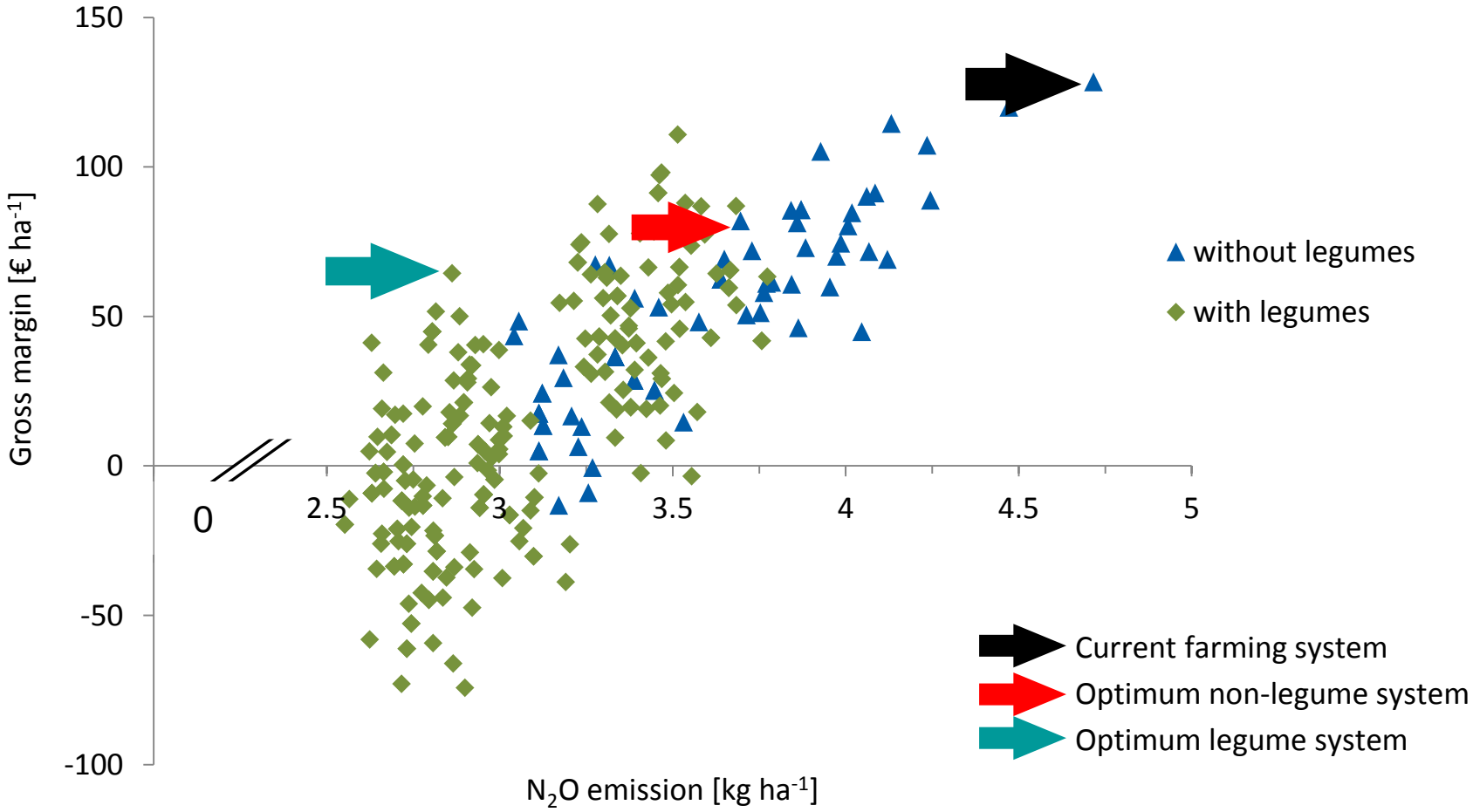
Economic & environmental impacts of introducing legumes into cropping systems

- Trade-offs were reduced between economic and environmental impacts
- Varying impacts per region

Indicators	Arable systems	Mixed farming systems
	Effect (%)	
N_2O emissions	-12 to -30	-23 to -52
N-fertilizer use	-17 to -40	-27 to -58
Nitrate-N leaching	-24 to +3	-50 to +5
Gross margins	-73 to +29	0 to +62

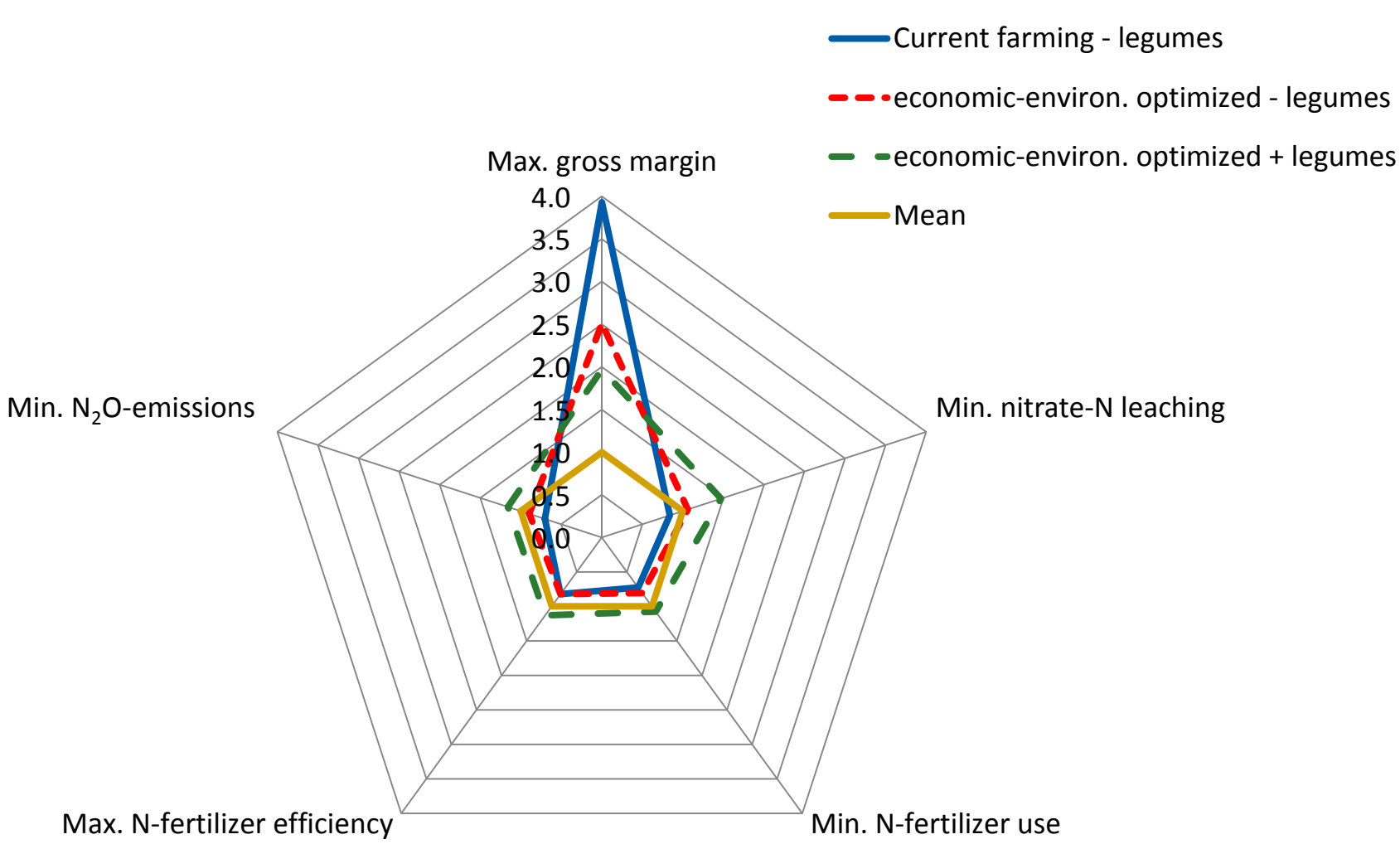
Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

Results



Nitrous oxide emissions plotted against gross margins for CS with and without legumes in Brandenburg for arable systems

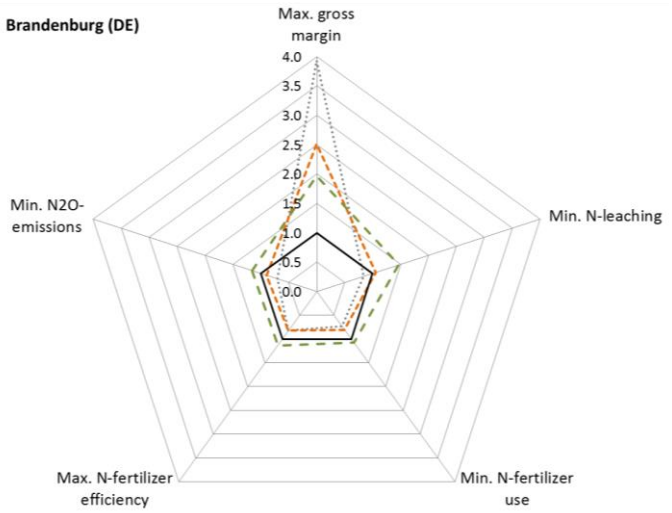
Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

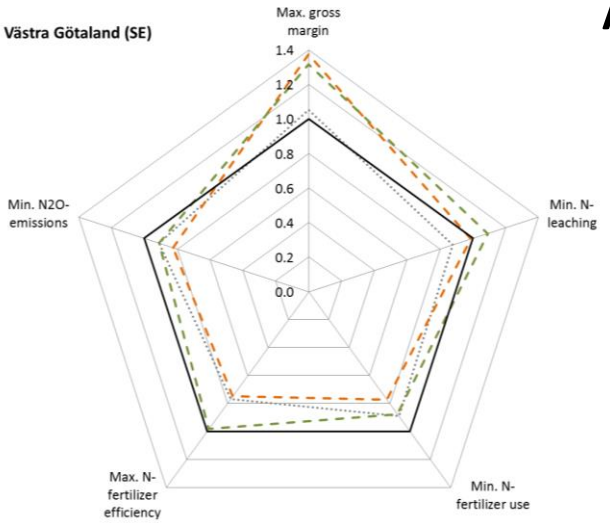


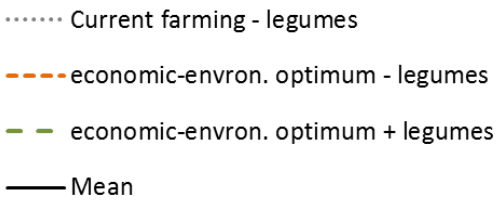
Multi-criteria assessment of arable cropping systems in Brandenburg, with and without legumes. Values are the ratio of the single impact relative to the average impact (positive impacts outside)

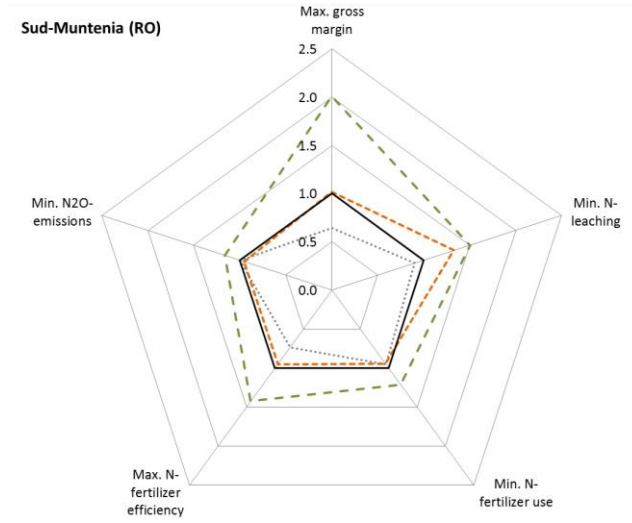
Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

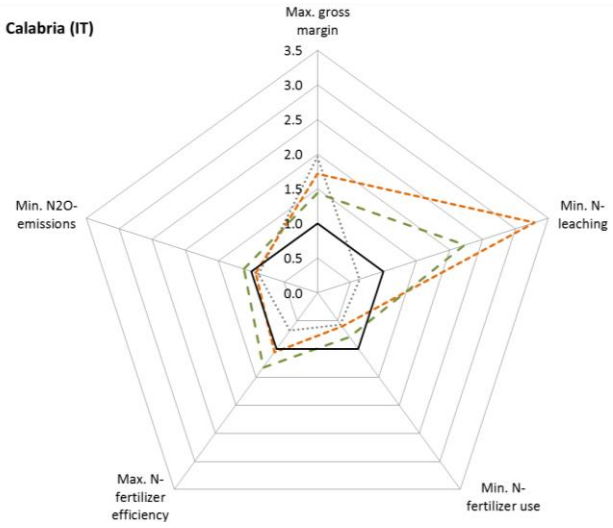
Arable farming systems

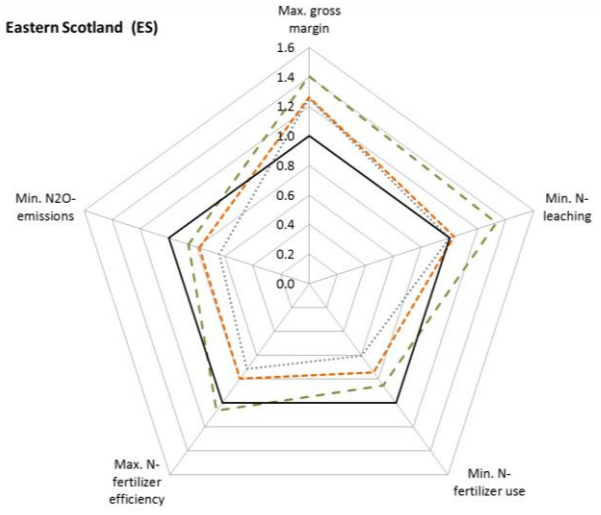












Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

TABLE 2 | Average economic and environmental impacts for cropping systems with and without legumes.

Region	Site	Legume	Generated systems [no.]	Gross margin [€/ha]	NO_3-N leaching [kg/ha]	N fertilizer use [kg/ha]	N_2O emissions [kg/ha]
ARABLE CROPPING SYSTEMS							
BB	Type 2	+legume	249	14	21	88	3.0
		-legume	68	51	23	114	3.6
CB	Type 1	+legume	328	195	24	32	1.3
		-legume	12	263	23	53	1.9
ES	Type 1/2	+legume	1237	637	23	107	4.1
		-legume	227	600	30	132	4.6
SM	Type 1	+legume	220	476	13	86	3.0
		-legume	20	369	13	108	3.6
VG	Type 1	+legume	10,127	420	30	100	3.5
		-legume	1756	452	31	121	4.0
FORAGE CROPPING SYSTEMS							
BB	Type 3	+legume	102	130	18	53	2.2
		–legume	89	80	37	126	4.7
ES	Type 3	+legume	18	733	24	220	7.4
		-legume	23	715	30	311	9.7
VG	Type 1	+legume	146	482	15	146	4.7
		-legume	108	483	14	201	6.1

BB, Brandenburg; CB, Calabria; ES, Eastern Scotland; SM, Sud-Muntenia; and VG, Västra Götaland. Types represent different land capabilities.

Reckling et al. (2016) Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science 7:669.

Forward look

- Geographical spread: testing this in more NUTS-2 regions
- Impact spread: adding other environmental impacts such as pollinator support or soil carbon effects
- Interpretation depth: Making systems changes requires communication, as we all make mistakes in our first attempt with a crop
- Uncertainty: Adding a fuzzy-logic component to allow for yield instability of different classes of crop

Publications

Europ. J. Agronomy 76 (2016) 186–197

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A cropping system assessment framework—Evaluating effects of introducing legumes into crop rotations

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Chapter Four - Grain Legume Production and Use in European Agricultural Systems

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Trade-Offs between Economic and Environmental Impacts of Introducing Legumes into Cropping Systems

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Thank you!

Legume Futures

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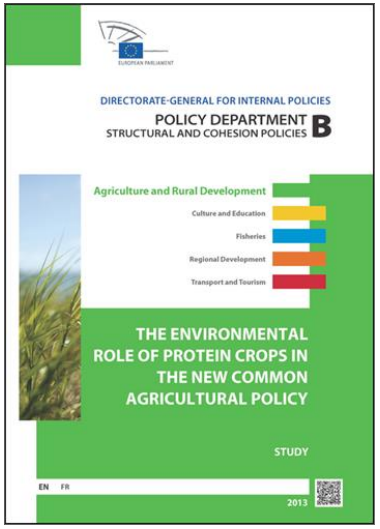
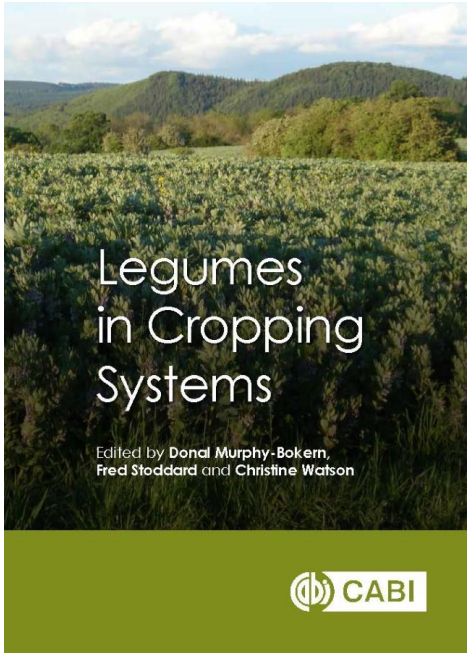


Bues et al. 2013



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