The challenge of increasing legume production on European farms

Donal Murphy-Bokern

Global Bean Network public meeting

2 September 2025

Funded by the European Union

Legume Futures

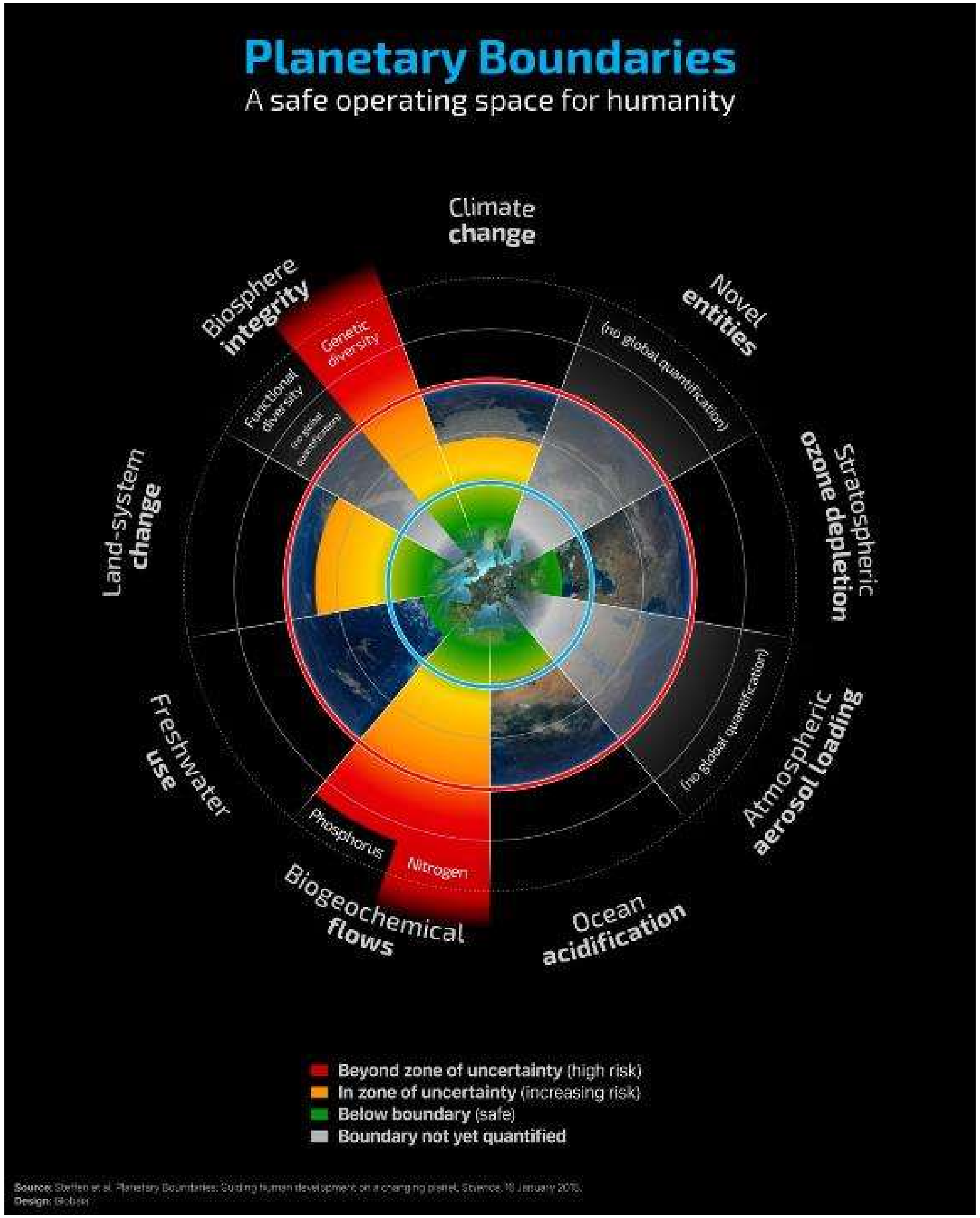
Legume Hub

Legumes Translated

Legume Generation

"How we eat determines, to a considerable extent, how the world is used"

Wendell Berry


Planetary Boundaries
A safe operating space for humanity
Climate change
Novel entities
(no global quantification)
Stratospheric ozone depletion
Atmospheric aerosol loading
(no global quantification)
Ocean acidification
Biogeochemical flows
Nitrogen
Phosphorus
Freshwater use
Land-system change
Biosphere integrity
Genetic diversity
Functional diversity
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified


STOP DE
STIKSTOF
WAANZIN!

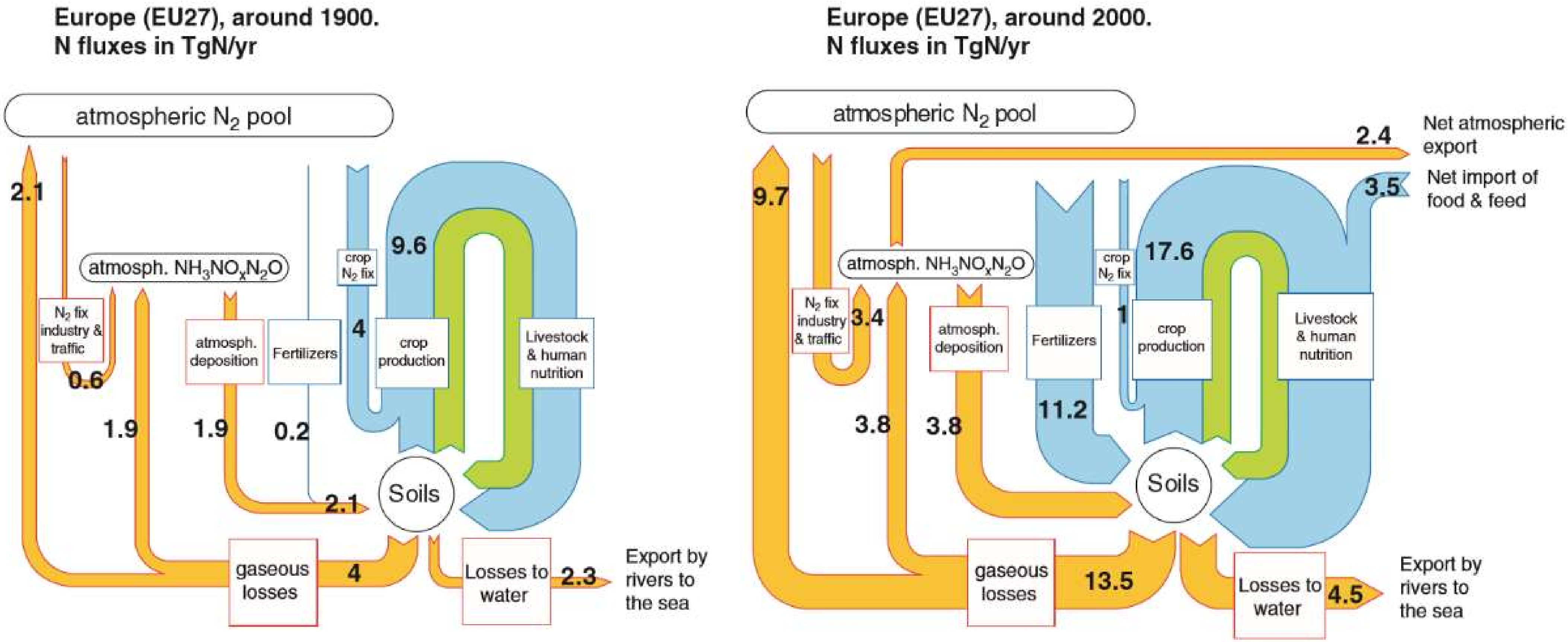
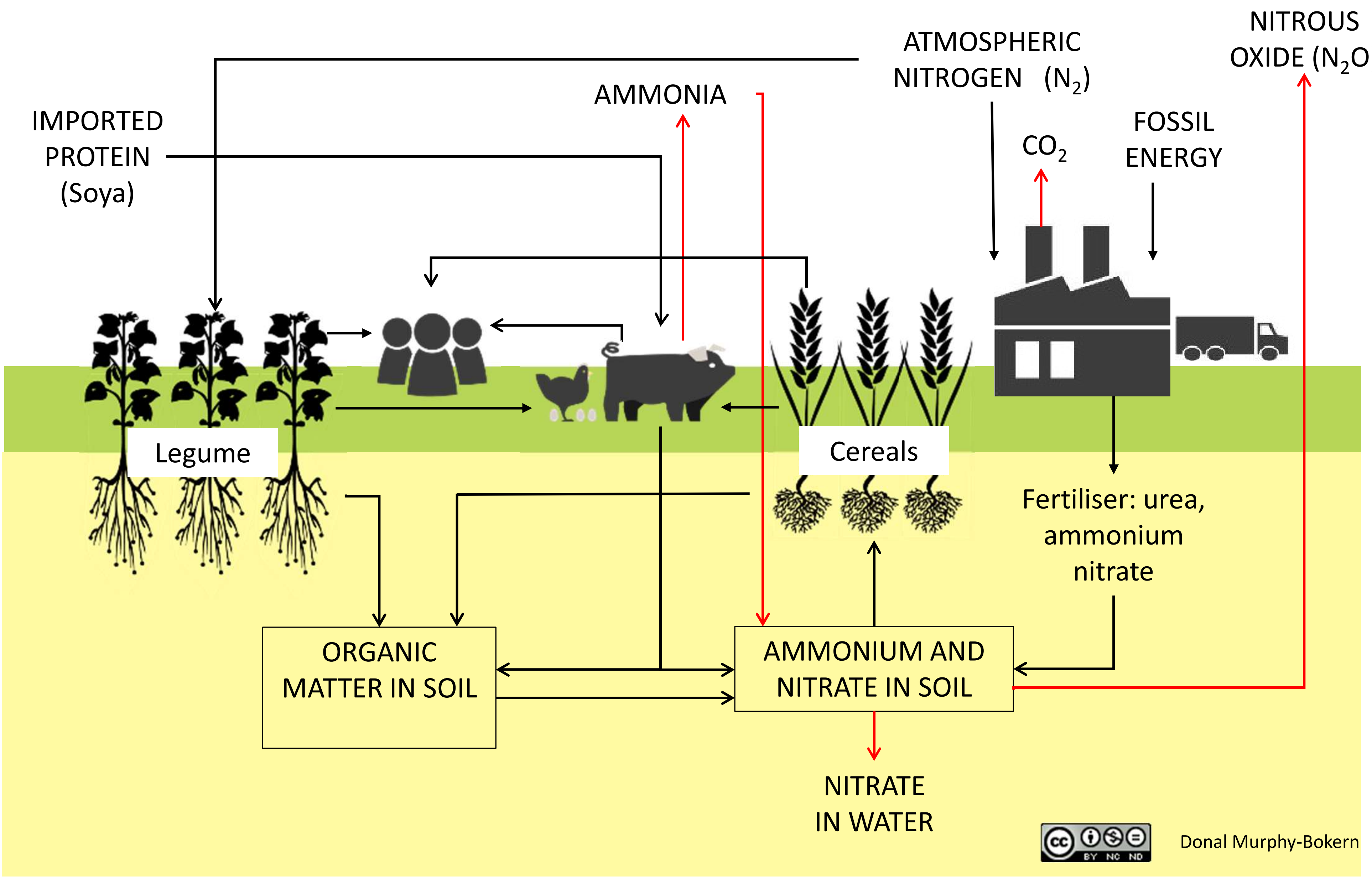
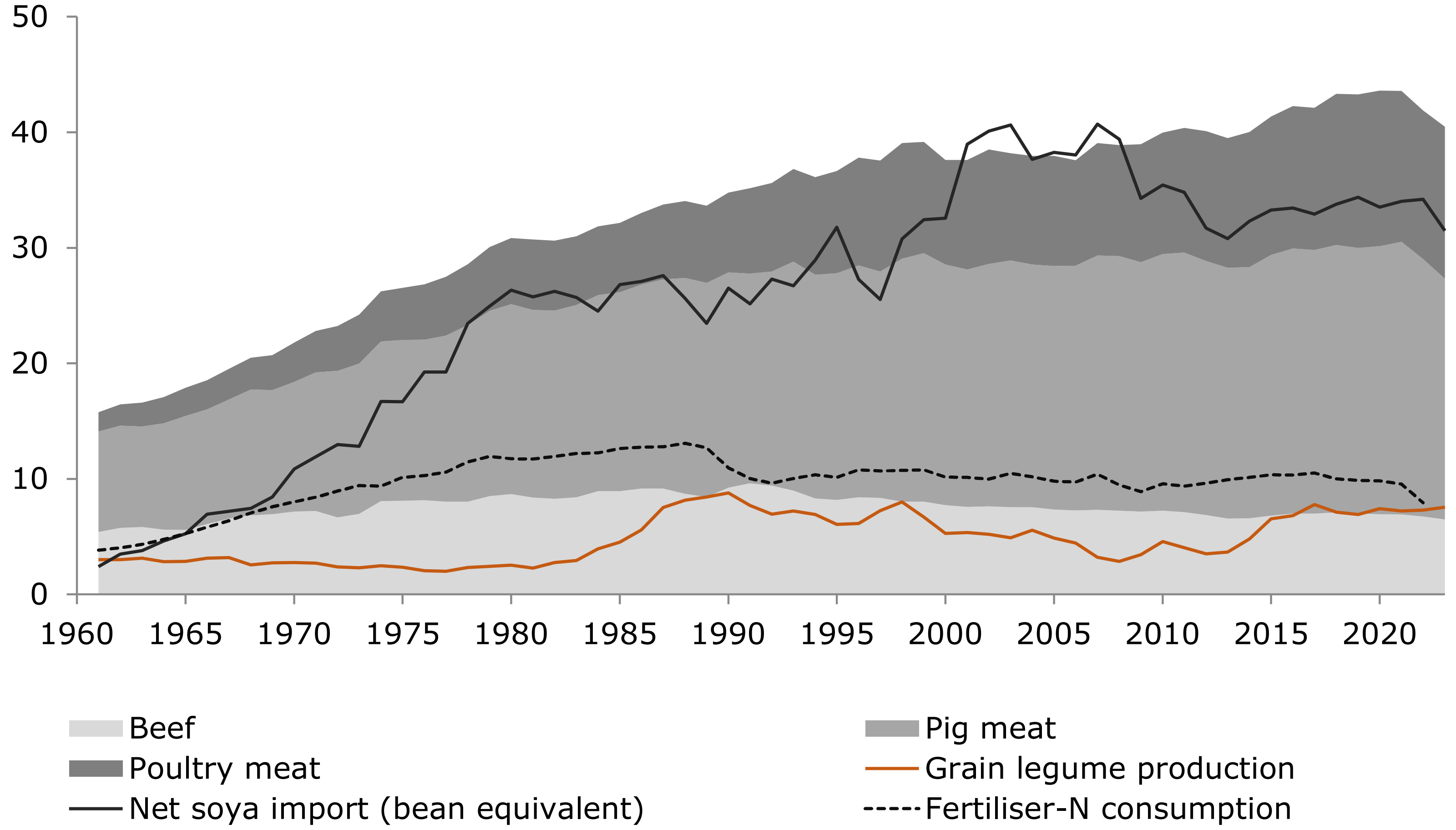


Figure SPM.3 Simplified comparison of the European nitrogen cycle (EU-27) between 1900 and 2000. Blue arrows show intended anthropogenic nitrogen flows; orange arrows show unintended nitrogen flows; green arrows represent the nearly closed nitrogen cycle of natural terrestrial systems [16.4 and 16 supplementary material].

Sutton and van Grinsven, 2011. European Nitrogen Assessment

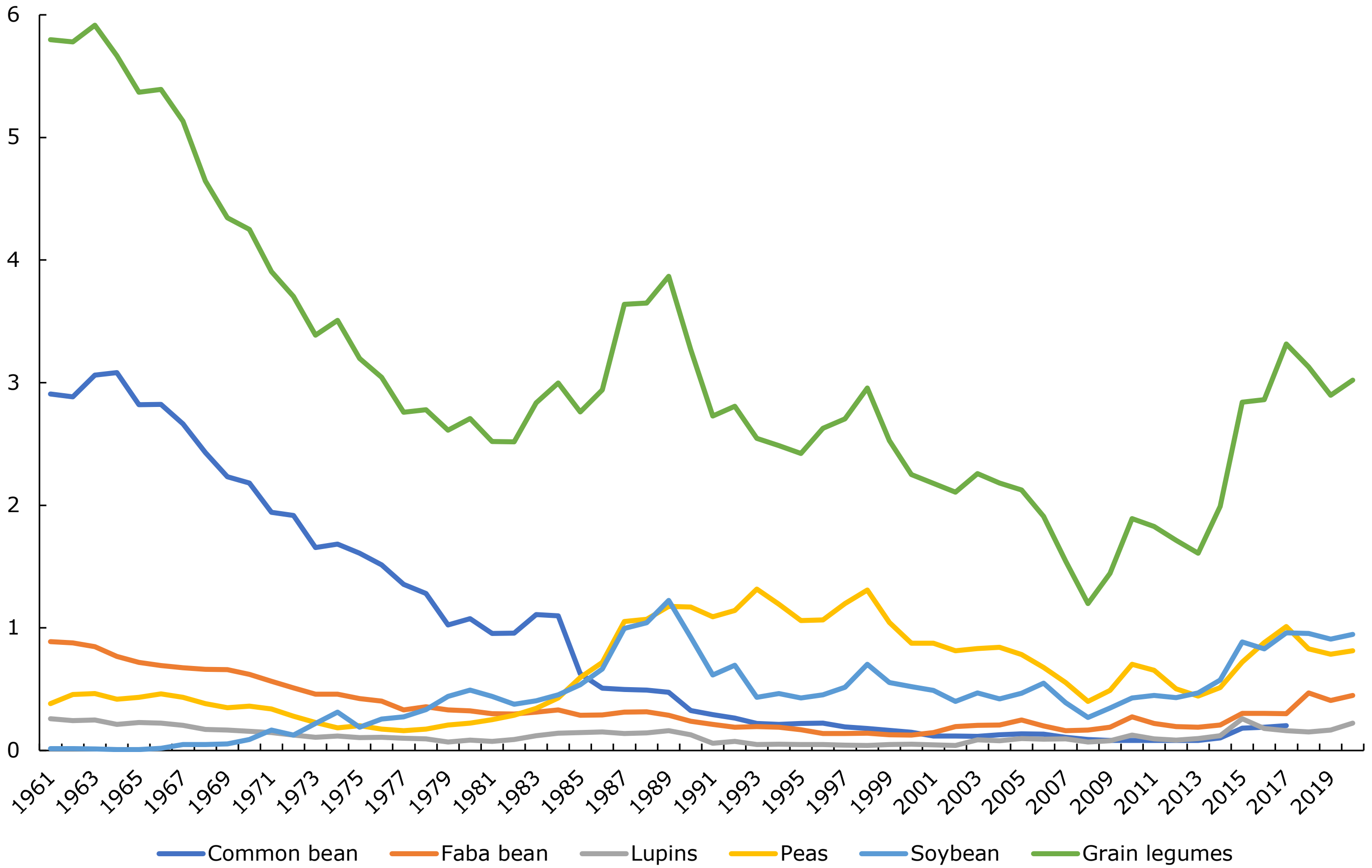

ATMOSPHERIC NITROGEN (N_2)
NITROUS OXIDE (N_2O)
AMMONIA
IMPORTED PROTEIN (Soya)
CO_2
FOSSIL ENERGY
Legume
Cereals
Fertiliser: urea, ammonium nitrate
ORGANIC MATTER IN SOIL
AMMONIUM AND NITRATE IN SOIL
NITRATE IN WATER
Donal Murphy-Bokern

. **Changes (million tonnes) in the production of livestock products, net imports of soya, grain legume (protein crops) and the use of fertiliser nitrogen in the European Union 1961-2023.**



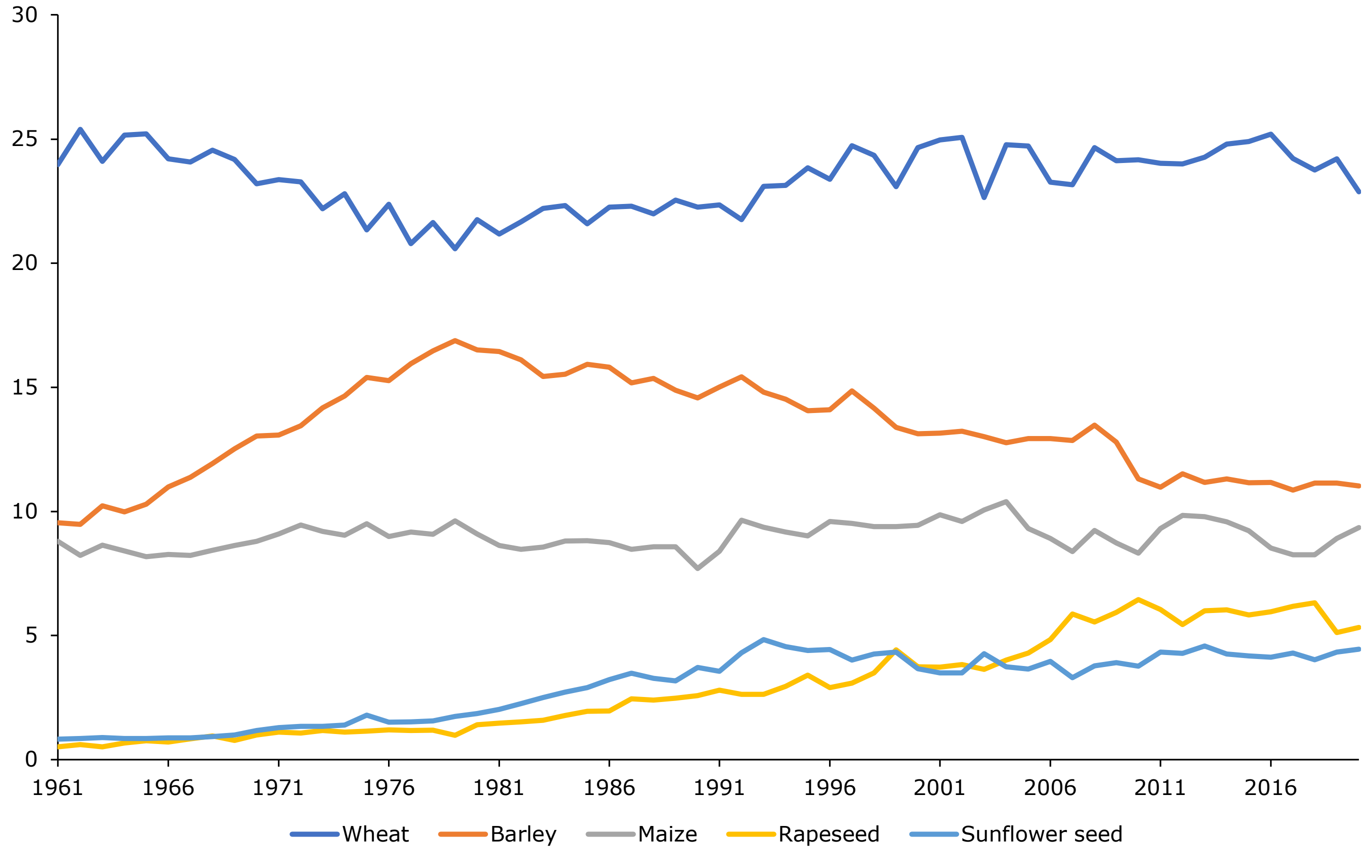
From FAOSTAT

. **Changes (million ha) in the production grain legumes in the European Union 1961-2020.**

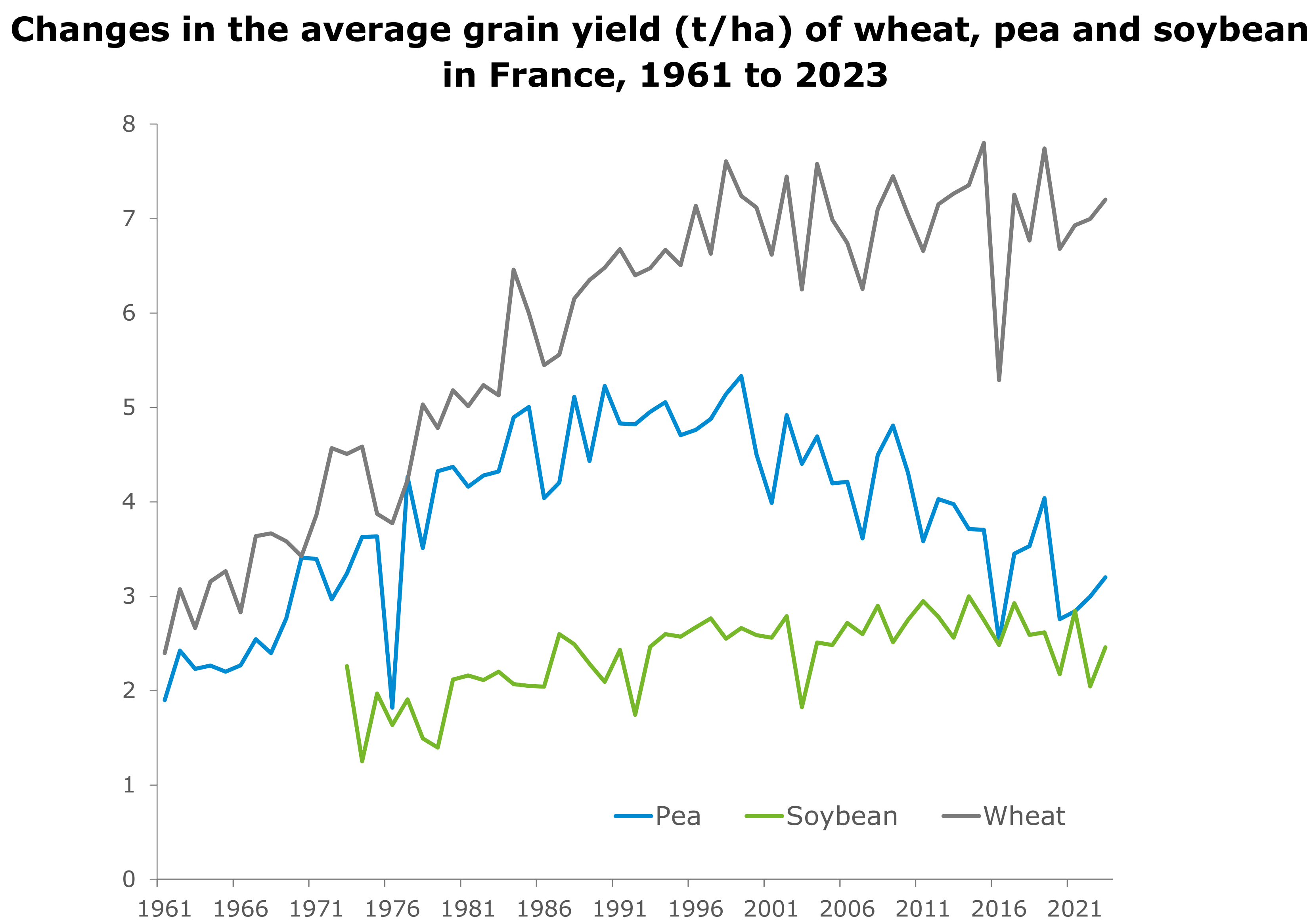


From FAOSTAT

. **Changes (million ha) in the production cereals and oilseeds in the European Union 1961-2020.**



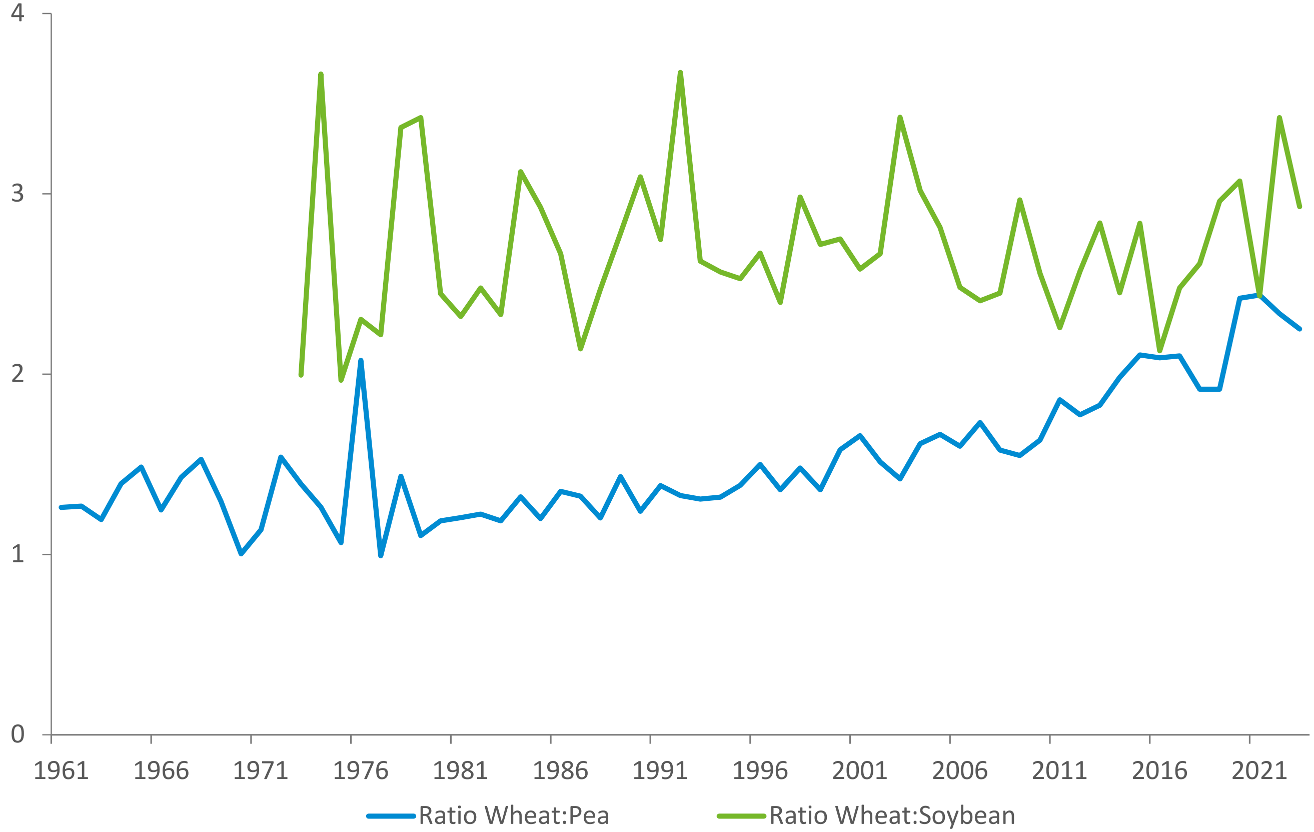
From FAOSTAT



From FAOSTAT

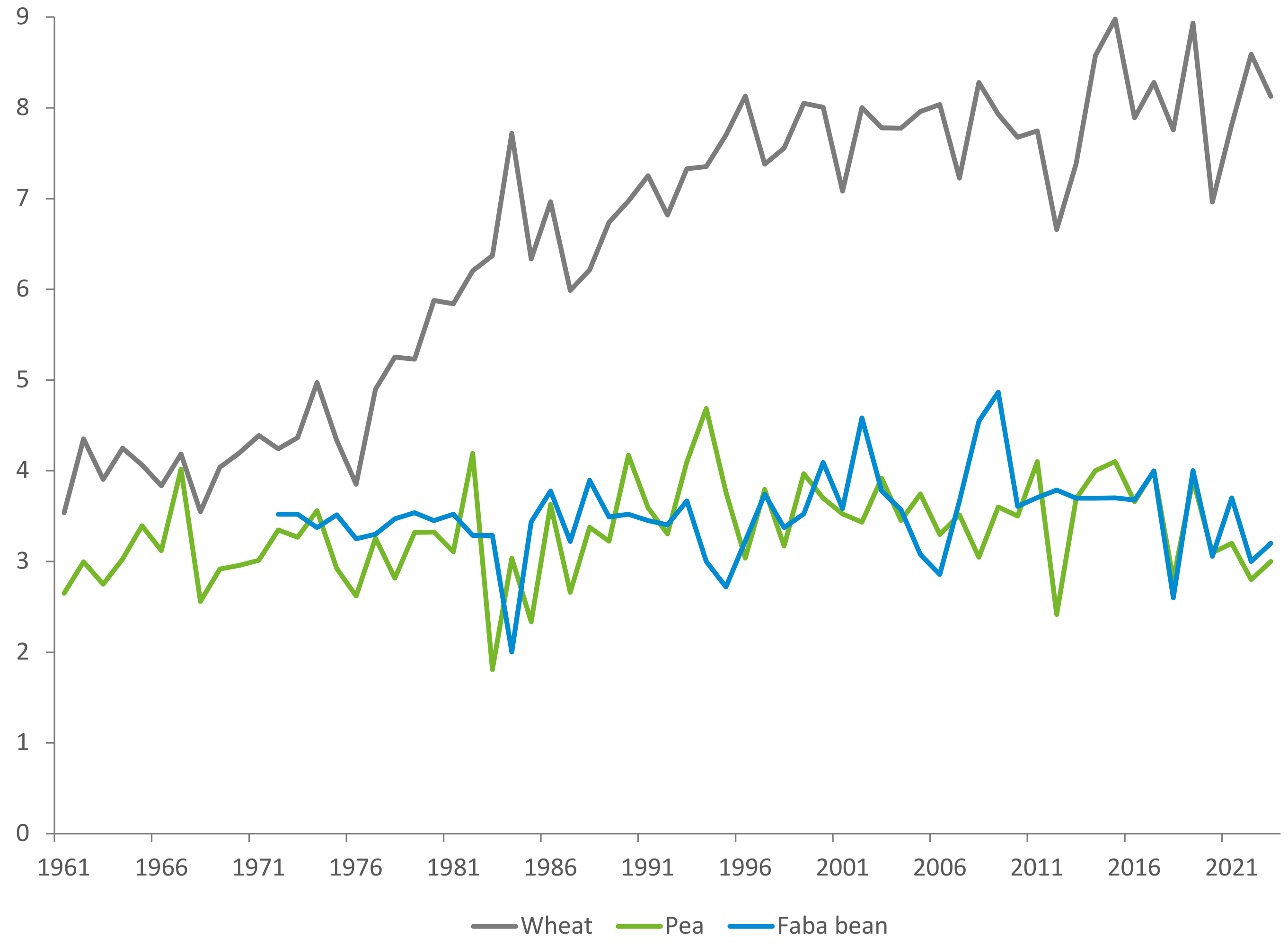
Changes in the ratio of wheat yield to the yield of pea and soybean in France, 1961 to 2023

The competitiveness of wheat has increased from about 1.3 tonnes to about 2.0 tonnes per tonne pea. It has remain steady at about 2.7 t wheat per t soybean



From FAOSTAT

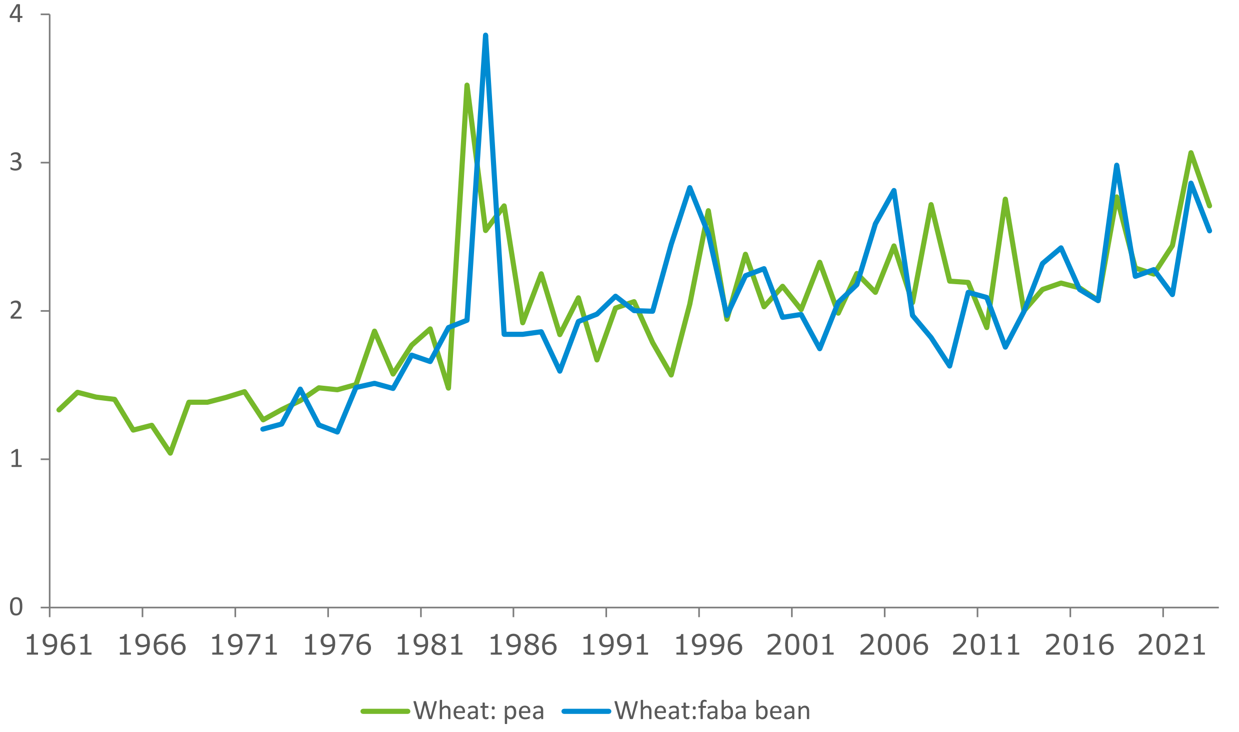
Changes in the average grain yield (t/ha) of wheat, pea and faba bean in the United Kingdom, 1961 to 2023



From FAOSTAT

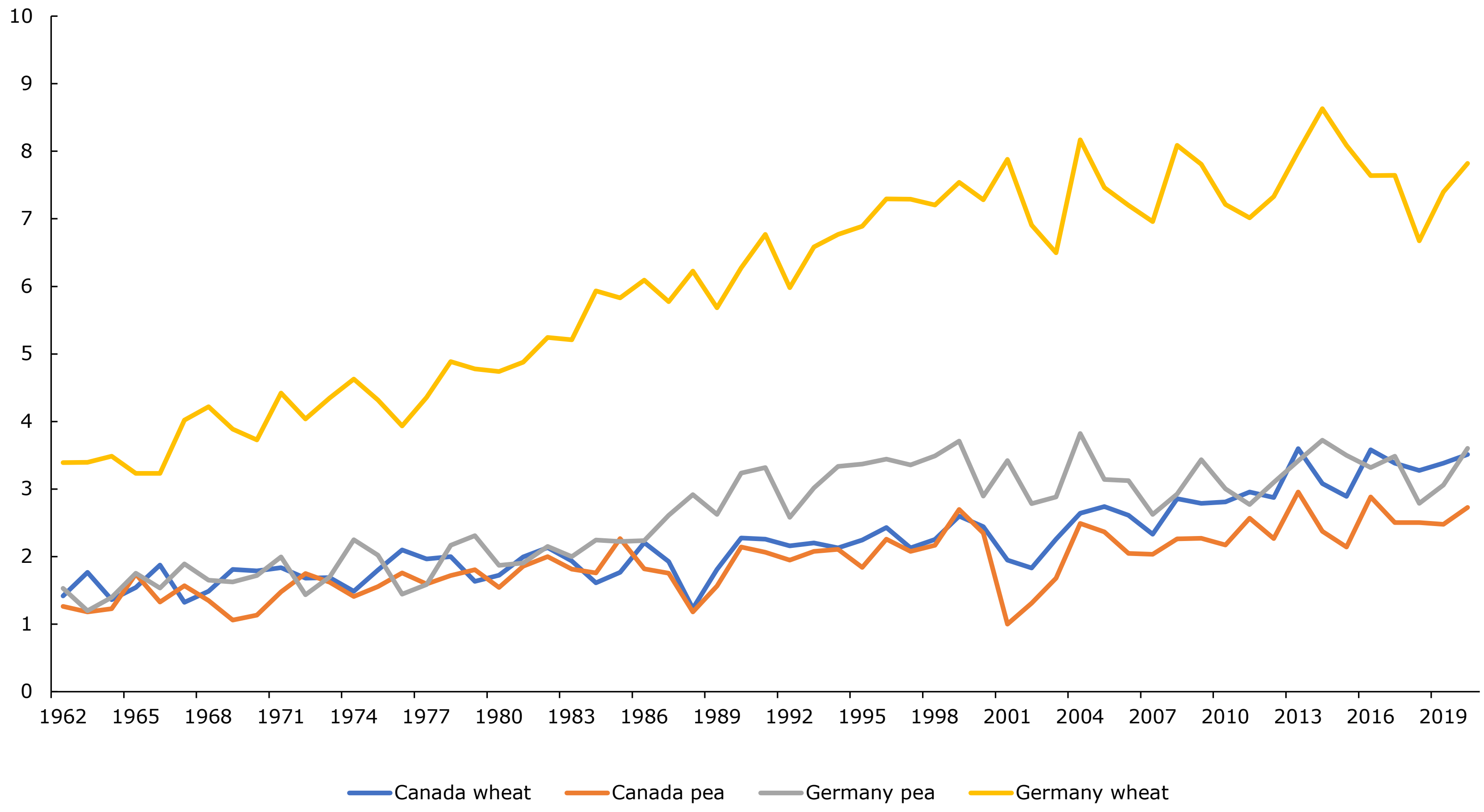
Changes in the ratio of wheat yield to the yield of pea and faba bean in the United Kingdom, 1961 to 2023

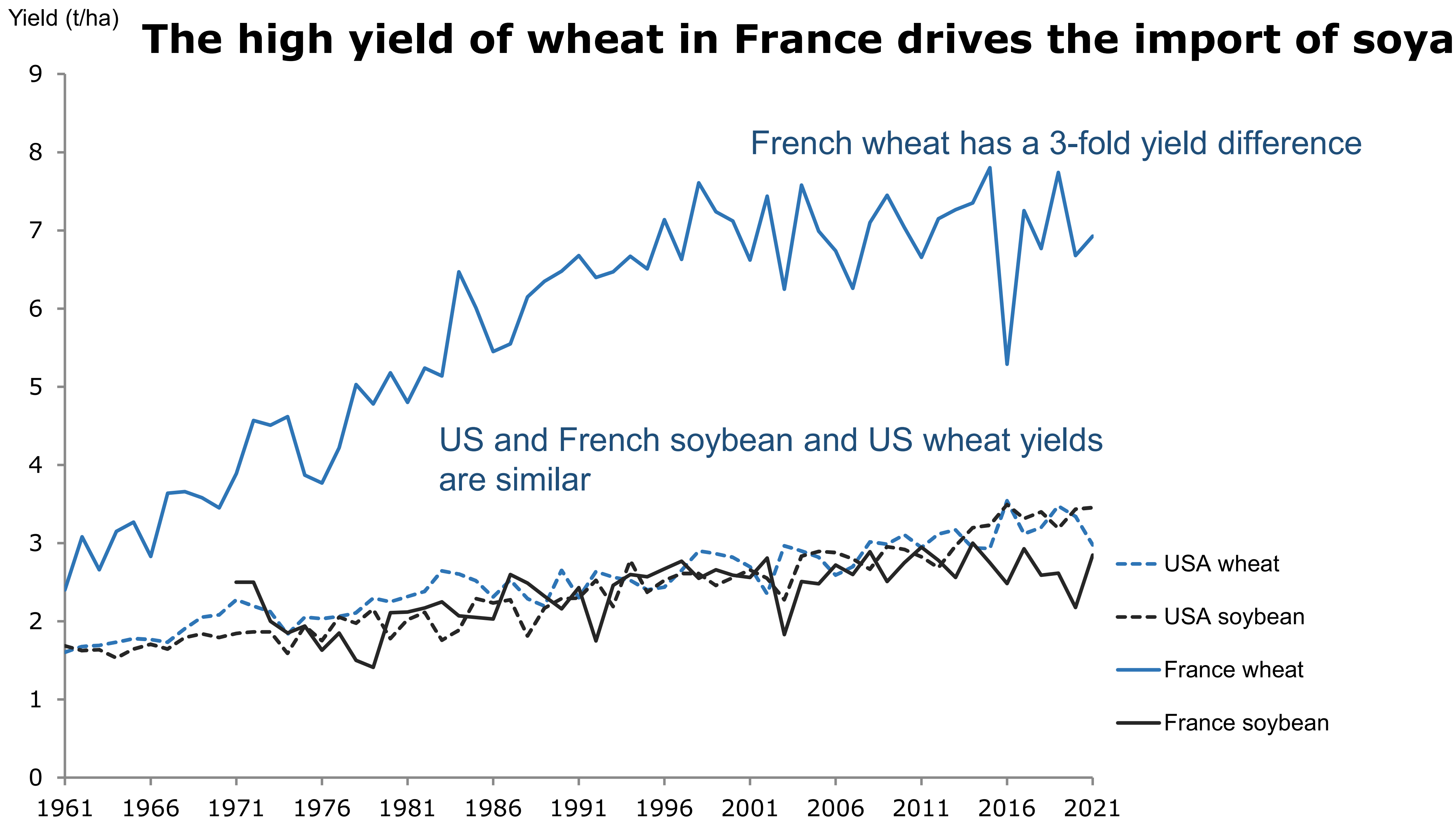
The competitiveness of wheat has increased from about 1.3 tonnes of wheat per tonne pea to about 2.5 tonnes wheat per tonne pea. The pattern for faba bean is similar



From FAOSTAT

Changes in the yield (t/ha) of wheat and pea in Canada and Germany, 1961 to 2023



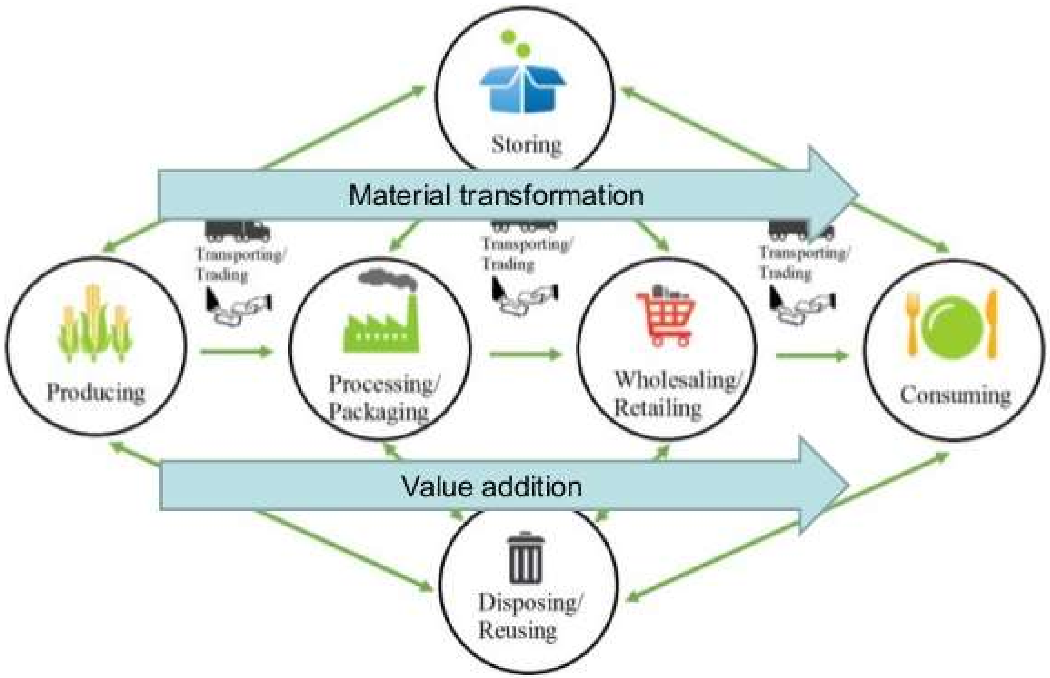

Yield (t/ha)
The high yield of wheat in France drives the import of soya
French wheat has a 3-fold yield difference
US and French soybean and US wheat yields are similar
9
8
7
6
5
4
3
2
1
0
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2011
2016
2021
USA wheat
USA soybean
France wheat
France soybean

Why does trade happen?

Read David Ricardo

Trade happens along the value chain

Plant breeding → Seed multiplication → Farm inputs →



From John Ingram, University of Oxford (adapted)

Changes in protein and metabolisable energy (ME) production of grain legumes, wheat and barley in the EU 28 as affected by eight legume production scenarios.

Scenario	Description	Protein production (million tonnes)	Energy (million GJ)	Protein change: soybean equivalents (million tonnes)	ME change: wheat equivalents (million tonnes)	Change in nitrogen fertiliser requirements (million tonnes)
	Baseline	23.79	2,874			10.77
1.	3x	23.96	2,726	+0.51	-10.83	-0.71
2.	3x-SFB	24.33	2,748	+1.62	-9.26	-0.71
3.	3x-PCE	24.51	2,794	+2.12	-5.88	-0.61
4.	3x–SFB-PCE	24.88	2,815	+3.21	-4.31	-0.61
5.	5x	24.71	2,565	+2.71	-22.72	-0.93
6.	5x–SFB	25.46	2,607	+4.89	-19.58	-0.93
7.	5x–PCE	25.93	2,714	+6.28	-11.73	-0.71
8.	5x–SFB-PCE	26.68	2,757	+8.47	-11.69	-0.71

Economic, environmental, and production effects of changing reference rotations to legume-supported rotations.

	Study area; reference rotation	Rotation with legume	GM (standard)	GM (feed value)	GM (subsidies)	GM (CO2-tax)	N fertilizer use	N_2O emissions	Nitrate leaching	Biodiversity	Yield stability	Protein yield	Energy yield
Arable cropping systems	***Central East Europe***												
	BG, BG 31; WW-GM-SF	BG 31#1: FP-WW-GM-SF	-22%	-5%	-14%	-22%	-28%	-24%	-16%	-2%	0p.p.	+4%	-10%
		BG 31#2: WW-SF-FP-GM	-17%	+1%	-12%	-15%	-29%	-23%	-11%	0%	0p.p.	+1%	-13%
	BG, BG 32; WOR-WW-SF-GM	BG 32#1: SY-WW-SF-WW	-2%		+2%	+1%	-54%	-45%	-13%	+16%	-6p.p.	0%	-25%
	BG, BG 33; WOR-WW-SF-GM	BG 33#1: CB-WW-SF-WW	-112%		-107%	-118%	-5%	+1%	+84%	+18%	-6p.p.	-23%	-37%
	RO, RO 11; GM-WW	RO 11#1: GM-WW-SY	-4%		+23%	+1%	-37%	-31%	-8%	+4%	+3p.p.	+13%	-16%
	RO, RO 21; GM-SF-WW	RO 21#1GM-WW-SY	+12%		+25%	+13%	0%	+8%	+21%	-6%	-1p.p.	+44%	+6%
	RS, RS 12; GM-WW	RS 12#1: GM-WW-SY	+70%			+78%	-19%	-7%	-11%	+3%	0p.p.	+57%	+8%
	UA, Kyiv oblast; GM-SF-WW	UA #1: GM-SY-SF-WW	+5%			+6%	-20%	-12%	+11%	-1%	0p.p.	+16%	-11%
	Central West Europe												
	AT, AT 11; GM-GM-WW	AT 11#1: SY-WW-GM	+56%			+68%	-41%	-31%	-2%	+10%	-5p.p.	+24%	-19%
	AT, AT 12; GM-WW-SF	AT 12#1: GM-WW-SY	+7%			+9%	-16%	-6%	+32%	-1%	0p.p.	+39%	-3%
	DE, DE 11; WW-WB-WT	DE 11#1: WW-WB-FP-WT	-21%	+1%	+23%	-19%	-29%	-24%	-12%	-6%	+2p.p.	-3%	-13%
	DE, DE 11; SU-WW-WB-GM	DE 11#2SU-WW-WB-FB	-35%	-20%	-13%	-36%	-38%	-20%	+79%	+8%	+2p.p.	0%	-15%
	DE, DE 13 (Kies); GM-GM-WW-WOR	DE 13#1: GM-GM-SY-WW-WOR	-13%		+10%	-11%	-22%	-19%	-1%	+5%	0p.p.	+7%	-11%
	DE, DE 13 (Löss); GM-GM-WW-WOR	DE 13#2: GM-GM-SY-WW-WOR	-8%		+2%	-7%	-22%	-18%	+2%	+6%	0p.p.	+8%	-10%
	DE, DE 40 (soil type 2); WW-WB-WOR	DE 40#1: WW-FP-WW-WB-WOR	-14%	-5%		-13%	-23%	-19%	-18%	+1%	+1p.p.	+3%	-13%
		DE 40#2: WW-SY-WW-WB-WOR	-4%			-2%	-23%	-19%	-14%	+2%	-1p.p.	+12%	-5%
	DE, DE 40 (soil type 3); WR-WR-WOR	DE 40#3: WR-FP-WR-WOR	-15%	-5%		-14%	-27%	-21%	-17%	-1%	+1p.p.	+5%	-8%
		DE 40#4: WR-L-WR-WOR	-16%	-11%		-15%	-27%	-21%	-15%	-2%	-2p.p.	+10%	-9%
	DE, DE 73; WOR-WW-WW-SB	DE 73#1: WOR-WW-FP-WW-SB	-24%	-6%	+20%	-25%	-21%	-17%	-16%	-1%	-1p.p.	+6%	-7%
	North-West Europe												
	GB, UKM 7; WOR-WB-WO-SB-WB	UKM 7#1: WOR-WB-WO-FP-WB	0%	+4%		+2%	-30%	-23%	-24%	-1%	-1p.p.	+10%	-3%
		UKM 7#2: WOR-WB-WO-FB-SB	+1%	+6%		+3%	-26%	-25%	-28%	0%	-1p.p.	+16%	-6%
	IE, IE 05, IE, 06; WB-WO-WW-WB-WOR-WW	IE 05, 06#1: WB-WO-WW-FB-WW	-7%	+17%	+4%	-6%	-22%	-19%	-23%	-2%	-2p.p.	+14%	-2%
	IE, IE 05, IE, 06; SMB-SO-SFB-SMB-SMB	IE 05, 06#2: SMB-FB-SO-SFB-SMB	+7%	+43%	+24%	+10%	-20%	-14%	-8%	-3%	-2p.p.	+25%	-4%
	Southern Europe												
	IT, ITH 4; GM-GM-GM	ITH 4#1: GM-SY	+93%		+105%	+134%	-54%	-63%	-30%	+24%	-2p.p.	+35%	-20%
Forage cropping systems	***Central West Europe***												
	DE, DE 40; WW-WR-SM-SM-SM	DE 40#5: WW-WR-AF-AF-AF	-14%			-12%	-72%	-31%	-63%		+1p.p.	+55%	-13%
	North-West Europe												
	GB, UKM 9; GR-GR-GR-SB	UKM 9#1: GC-GC-GC-WW	+108%			+140%	-25%	-13%	+22%			+10%	+5%
		UKM 9#2: GC-GC-GC-SB-FP/SB-WW	+70%			+95%	-36%	-20%	+39%			-7%	-7%
		UKM 9#3: GC-GC-GC-SB-FP-WW	+64%			+88%	-36%	-21%	+33%			-5%	-7%
		UKM 9#4: GC-GC-GC-SB-FB-WW	+133%	+159%		+172%	-38%	-25%	+30%			-5%	-11%
		UKM 9#5: AF-AF-AF-SB	-96%			-97%	-87%	-61%	-36%			-19%	-29%
		UKM 9#6: WW-GC-GC-GC-SB	+66%			+88%	-23%	-12%	+51%			-3%	-3%

Notz et al., 2023, Transition to legume-supported farming in Europe through redesigning cropping systems. Agronomy for sustainable development

Growing degree days to maturity for winter wheat and soybean

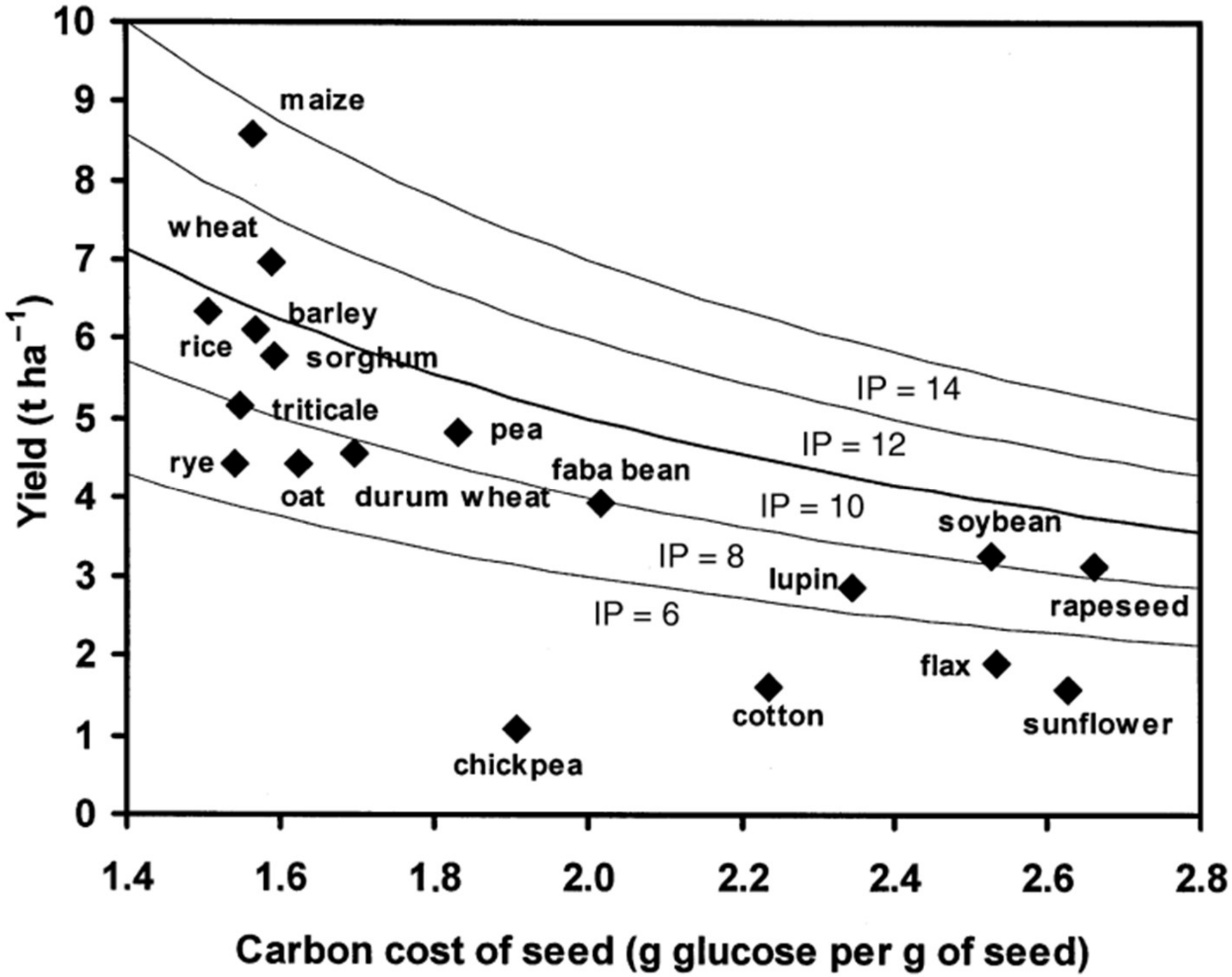
Winter wheat:
1800 – 2200 (base 0°C
1300 – 1600 (base 5°C)

1000 – 1300 (base 10°C)

A 25-30% variation in progress to maturity in wheat

200+% variation in soybean

Maturity group (MG)	Growing degree days (base 10°C)
OOO	1000 - 1200
OO	1100 - 1300
O	1200 - 1400
I	1300 - 1500
II	1400 - 1600
III	1500 - 1700
IV	1600 - 1800
V	1700 - 1900
VI	1800 - 2000
VII	1900 - 2100
VIII	2000 - 2200
IX	2100 - 2300
X	2200 - 2400



Relationship between carbon cost of seed production for many species (Sauvant *et al*. 2002) and their yield (http://epp.eurostat.cec.eu.int; http://faostat.fao.org). In order to compare crop production performances, various isoproduction curves (IP), expressing the product of the energy cost of 1 g of seed by the yield, have been indicated.
Munier-Jolain and Salon

Characterisation of European legume crops

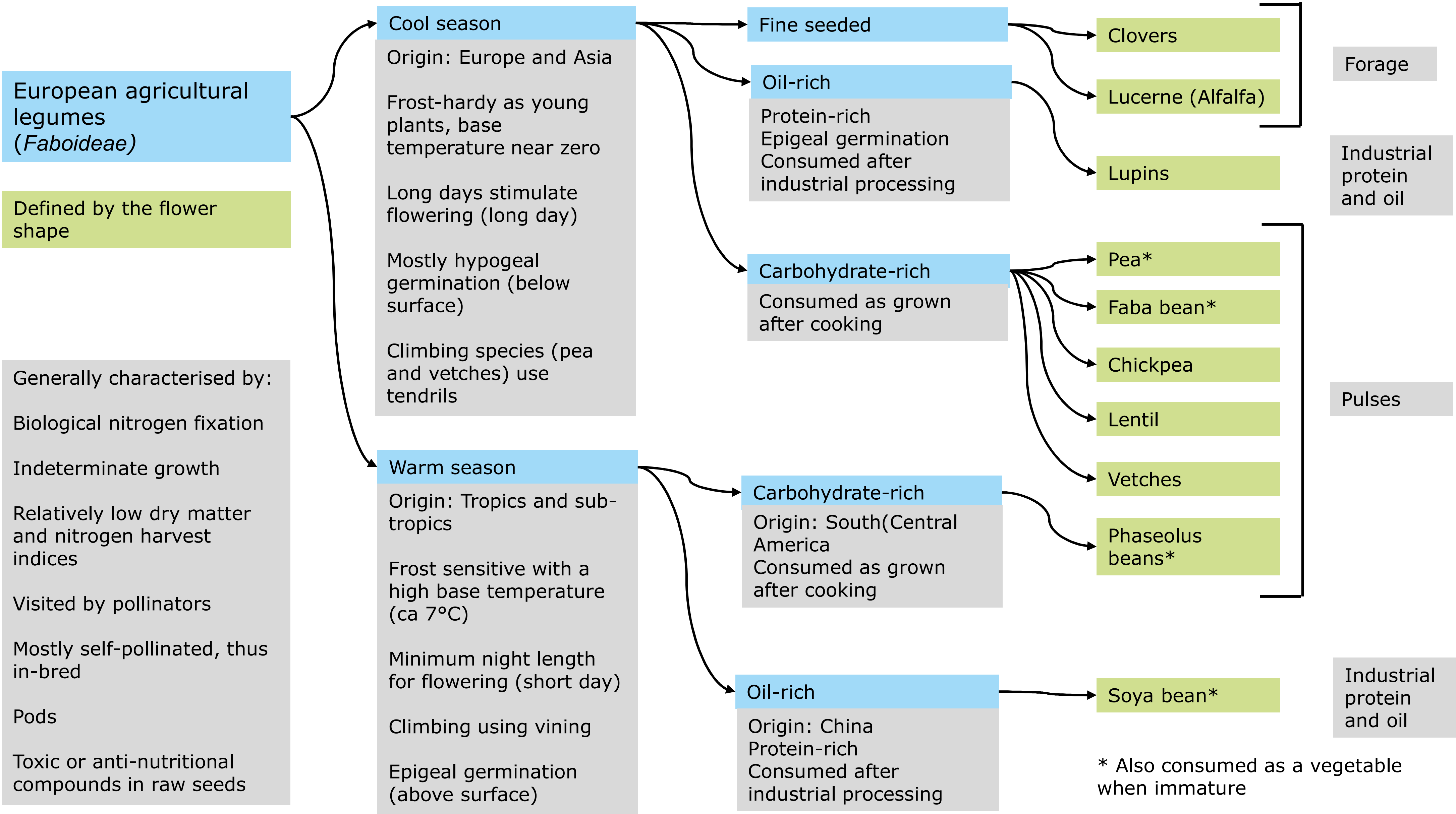

European agricultural legumes (*Faboideae)*
Defined by the flower shape
Generally characterised by:
Biological nitrogen fixation
Indeterminate growth
Relatively low dry matter and nitrogen harvest indices
Visited by pollinators
Mostly self-pollinated, thus in-bred
Pods
Toxic or anti-nutritional compounds in raw seeds
Cool season
Origin: Europe and Asia
Frost-hardy as young plants, base temperature near zero
Long days stimulate flowering (long day)
Mostly hypogeal germination (below surface)
Climbing species (pea and vetches) use tendrils
Warm season
Origin: Tropics and sub-tropics
Frost sensitive with a high base temperature (ca 7°C)
Minimum night length for flowering (short day)
Climbing using vining
Epigeal germination (above surface)
Fine seeded
Oil-rich
Protein-rich
Epigeal germination
Consumed after industrial processing
Carbohydrate-rich
Consumed as grown after cooking
Carbohydrate-rich
Origin: South(Central America
Consumed as grown after cooking
Oil-rich
Origin: China
Protein-rich
Consumed after industrial processing
Clovers
Lucerne (Alfalfa)
Lupins
Pea*
Faba bean*
Chickpea
Lentil
Vetches
Phaseolus beans*
Soya bean*
Forage
Industrial protein and oil
Pulses
Industrial protein and oil
* Also consumed as a vegetable when immature

Photo: Fred Eickmeyer

The top ten legume crops

Faba bean

Photo: Carola Blessing, The Legume Hub

Pea

Photo: AgroBioInstitute (Bulgaria),
The Legume Hub

Photo: Carol Blessing, LTZ
Semi-leafless pea

Soya bean

Photos: Donal Murphy-Bokern,

Lupins

Photo: Moritz Reckling, ZALF

Chickpea

Photo: Donal Murphy-Bokern

Lentil

Photo: Pulse Australia

Photo: Elizabeth Ninou

Phaseolus beans

P

Vetches

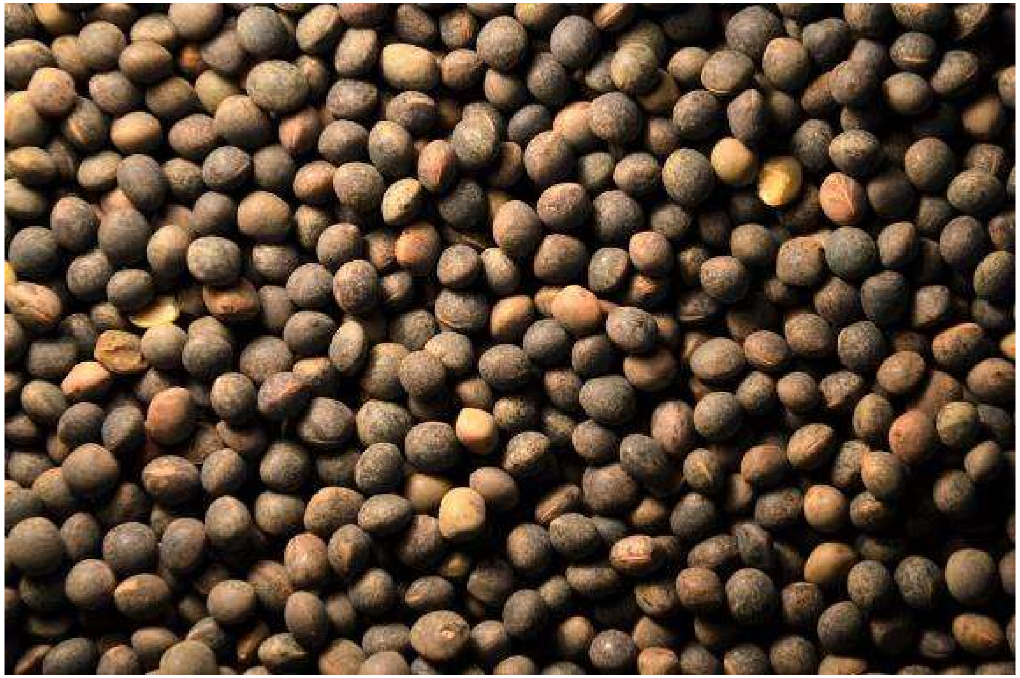
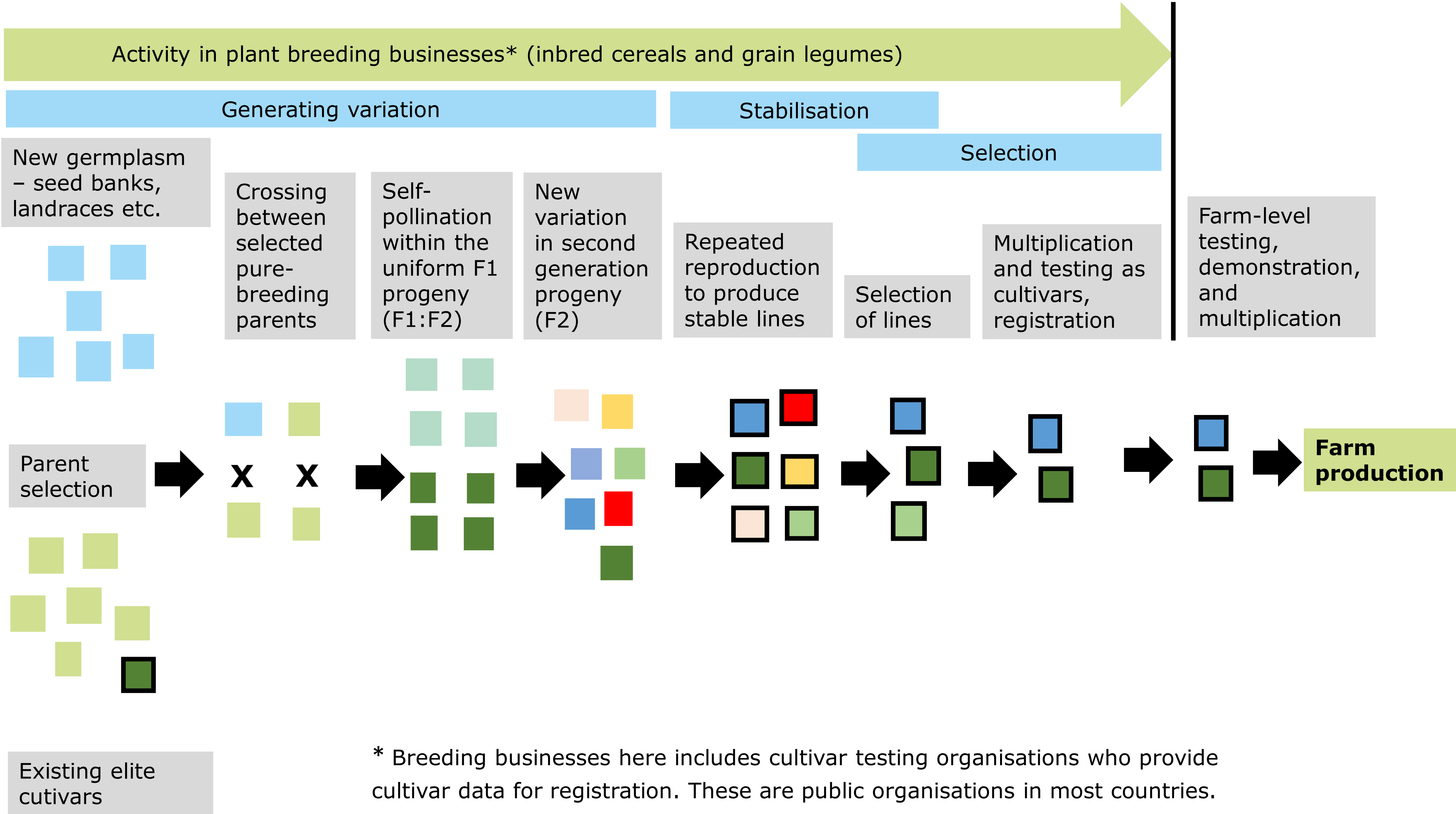


Photo: Thuenen Institute

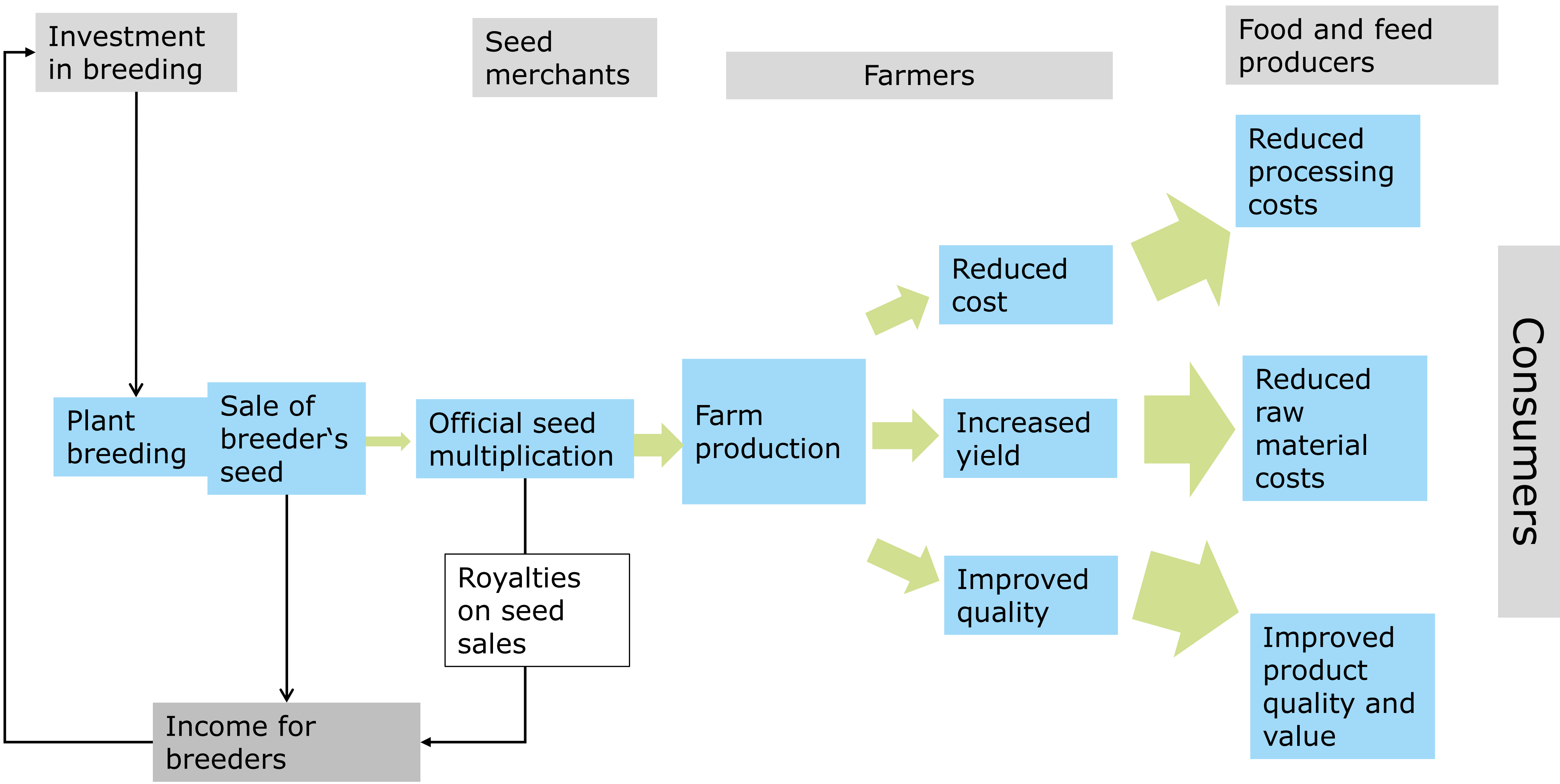
Lucerne

Photos: Bernadette Julier, INRAE

Clovers


Activity in plant breeding businesses* (inbred cereals and grain legumes)
Generating variation
Stabilisation
Selection
New germplasm – seed banks, landraces etc.
Crossing between selected pure-breeding parents
Self-pollination within the uniform F1 progeny (F1:F2)
New variation in second generation progeny (F2)
Repeated reproduction to produce stable lines
Selection of lines
Multiplication and testing as cultivars, registration
Farm-level testing, demonstration, and multiplication
Parent selection
X
X
Farm production
Existing elite cutivars
* Breeding businesses here includes cultivar testing organisations who provide cultivar data for registration. These are public organisations in most countries.

The generation and distribution of value from plant breeding



Euphytica 17 (1968): 385–403

THE BREEDING OF CROP IDEOTYPES

C. M. DONALD

Waite Agricultural Research Institute,
The University of Adelaide, South Australia

Received 17 November, 1967

SUMMARY

Most plant breeding is based on "defect elimination" or "selection for yield". A valuable additional approach is available through the breeding of crop ideotypes, plants with model characteristics known to influence photosynthesis, growth and (in cereals) grain production. Some instances of the successful use of model characters of this kind are quoted.



Priority 1 Breeding for yield

Fundamental rather than incremental change needed

Extending the growing season – frost tolerance

Harvest index

Canopy function

Groundbreaking ideas

We must focus on crop productivity

‘Resource capture’

Euphytica 17 (1968): 385–403

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Pea grand designs: changing pea plant architecture

RELATED PAGES

Germplasm Resource Unit (GRU)

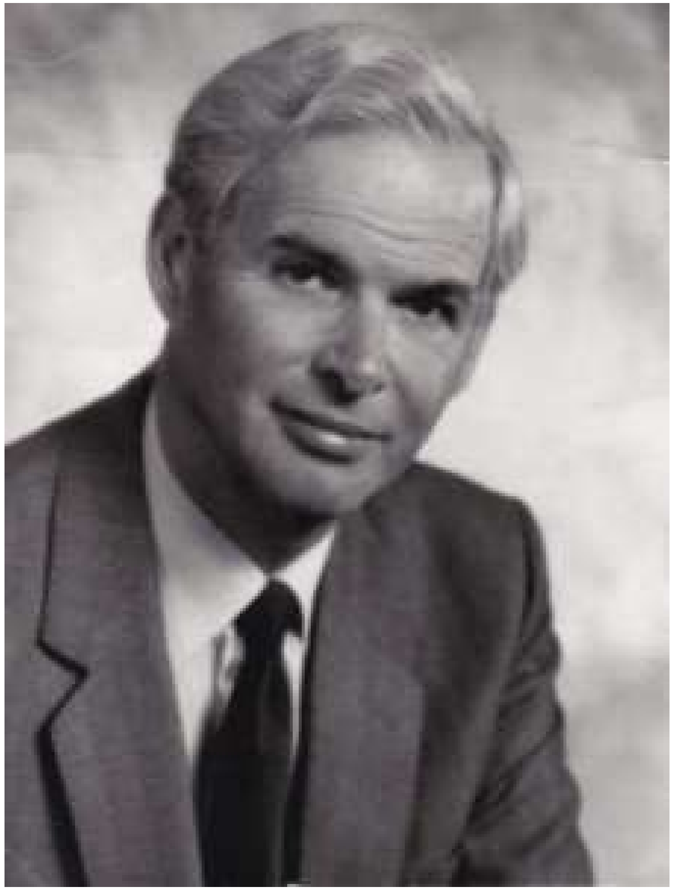
The history of plant science and microbial science at the John Innes Centre

In the late 1960s, many vining pea crops were being bypassed by the harvesters because of the slow throughput of the harvesting machinery.

Throughout Europe there was a demand for crops with acceptable yields but less stalks and stems. In response to this, a research programme was initiated at the John Innes Institute in 1969, led by Brian Snoad, to investigate stalk and stem reduction and modification.

Snoad and his team began cross-breeding two known genes (capable of producing this morphological change) into cultivar pea types. The *af* gene replaces leaflets with branching tendrils, and the *st* gene (first observed in 1923 by scientists Pellew and Sverdrup at the John Innes Institute) greatly reduces the size of leaf-like appendage on leaves, called stipules.

Read John Monteith



Breeding for climate change

How does climate change affect plants

These are annual plants: climate and weather

Warmer or colder?

Drier or wetter?

Breeding targets (traits) for climate change

Timing of harvest – earlier or later

Insensitivity to long days

Early growth and vigour under cool conditions: lower base temperature

Tolerance of summer chilling

Tolerance and survival of heat stress

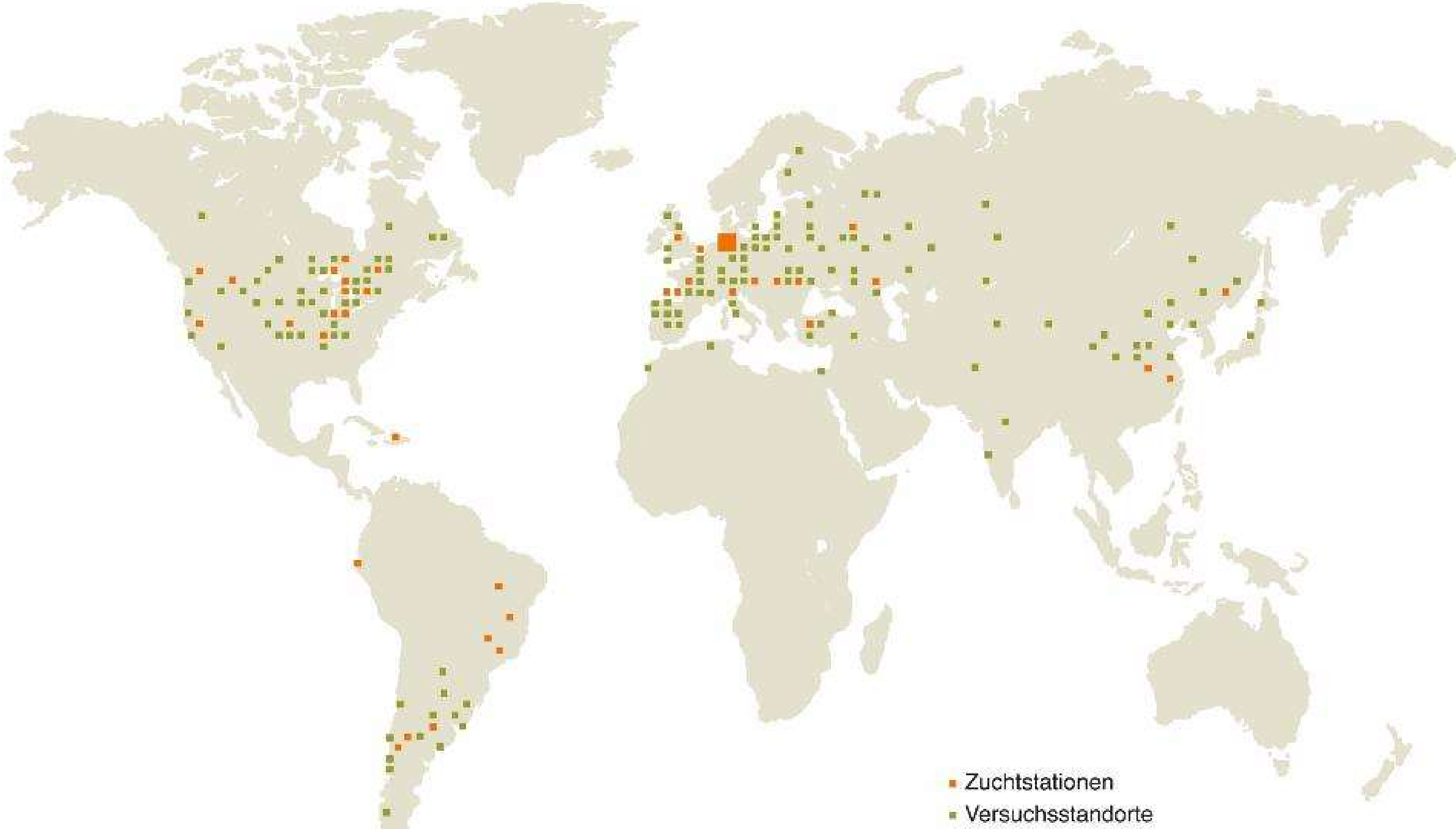
Tolerance of drought and water-logging

Very significant trade-offs between traits relevant to climate change

Breeding for climate change

Züchtungs- und Vertriebsaktivitäten der KWS Gruppe in über 70 Ländern

KWS



Participatory breeding

Participatory plant breeding

and

Participatory varietal selection

Donau Soja Protein Strategy for Europe

Taking responsibility

Short term: Sustainable imports and consumption

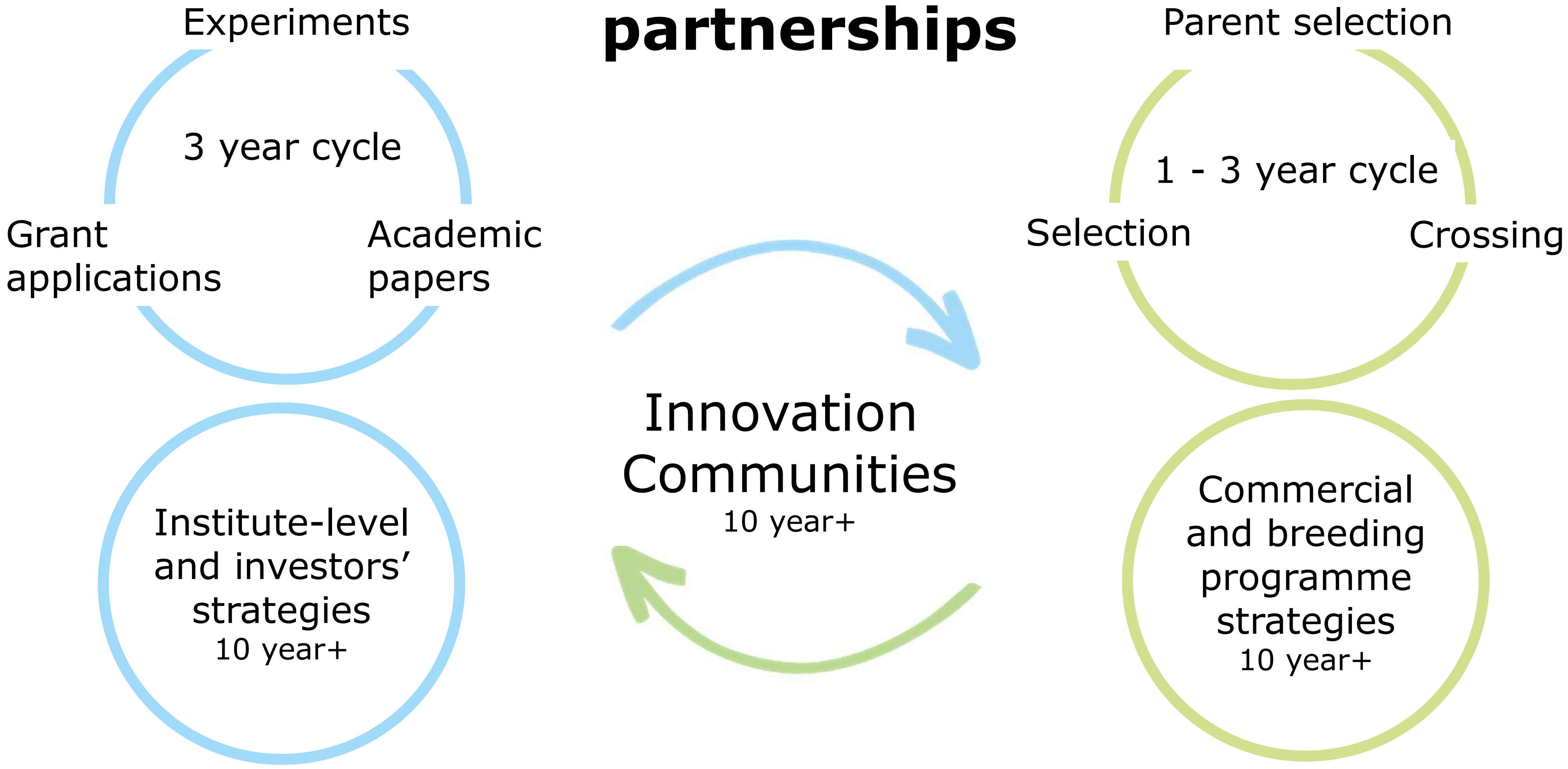
Medium term: Agricultural innovation and policy

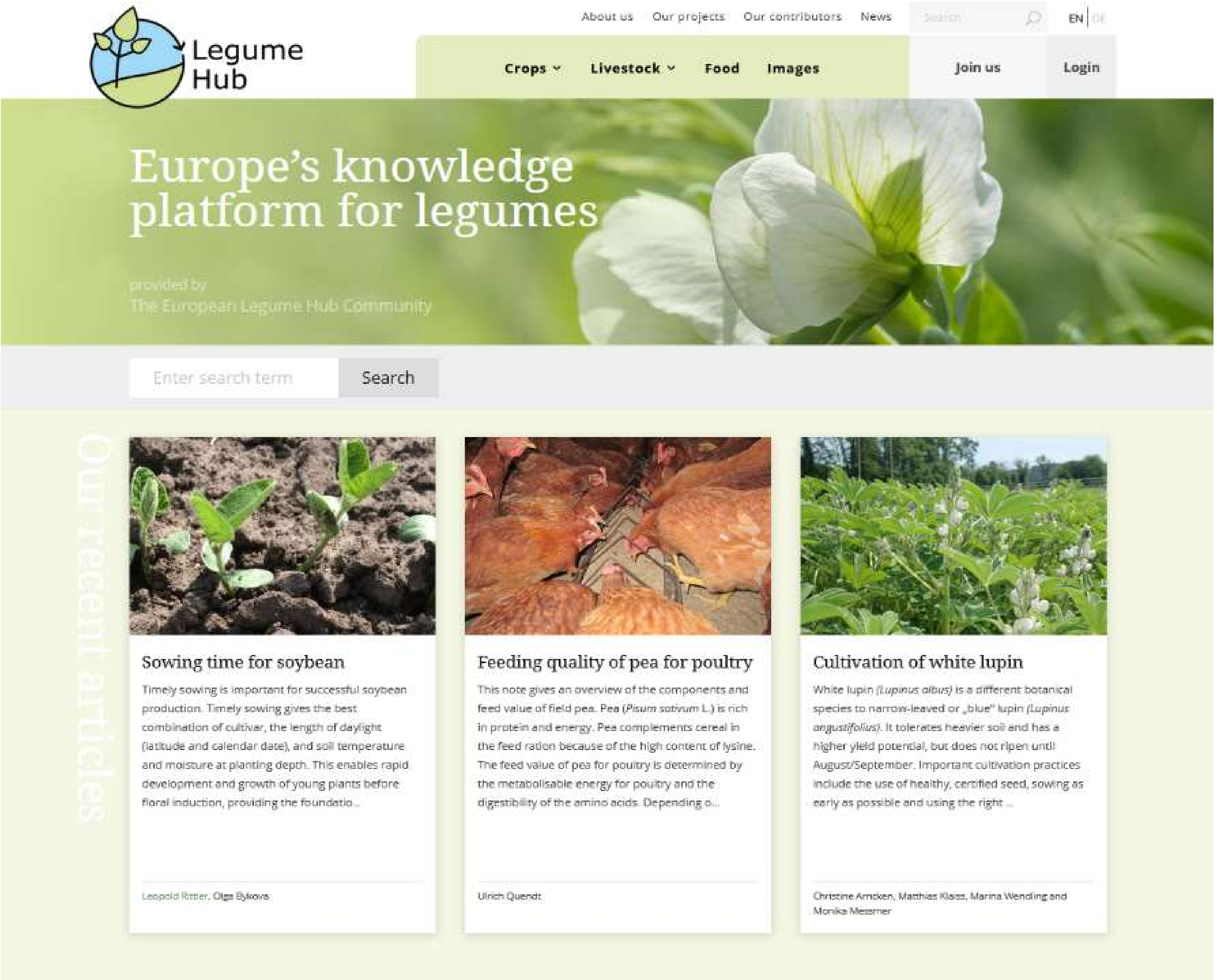
Long term: Breeding and value chain infrastructure

Empowerment

Knowledge is power, but understanding empowers

We need deep long-term partnerships

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provided by
The European Legume Hub Community
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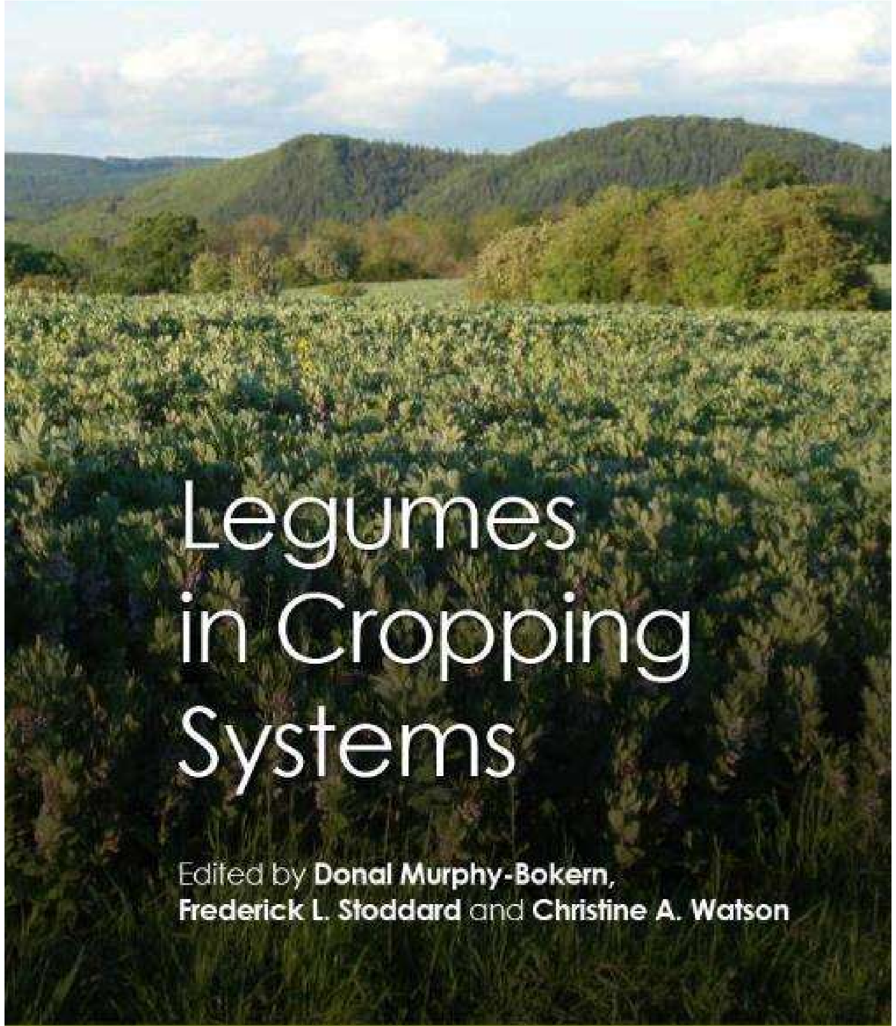
Sowing time for soybean
Timely sowing is important for successful soybean production. Timely sowing gives the best combination of cultivar, the length of daylight (latitude and calendar date), and soil temperature and moisture at planting depth. This enables rapid development and growth of young plants before floral induction, providing the foundatio...
Leopold Rittler, Olga Bykova
Feeding quality of pea for poultry
This note gives an overview of the components and feed value of field pea. Pea (Pisum sativum L.) is rich in protein and energy. Pea complements cereal in the feed ration because of the high content of lysine. The feed value of pea for poultry is determined by the metabolisable energy for poultry and the digestibility of the amino acids. Depending o...
Ulrich Quendt
Cultivation of white lupin
White lupin (Lupinus albus) is a different botanical species to narrow-leaved or „blue" lupin (Lupinus angustifolius). It tolerates heavier soil and has a higher yield potential, but does not ripen until August/September. Important cultivation practices include the use of healthy, certified seed, sowing as early as possible and using the right ...
Christine Arncken, Matthias Klaiss, Marina Wendling and Monika Messmer



Legumes in Cropping Systems

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OPINION

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Developing legume-supported cropping systems in Europe: Have we overlooked something?

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Abstract

Why are legume crops rare in Europe even though they grow well there? This opinion paper brings together concepts from crop physiology, classical economics and sociotechnical theory to address this question. It argues for increased focus on research and innovation on crop performance. The starting point is that trade policy no longer explains the marginalisation of legumes. A more recent premise that mutually supporting social, technical and agricultural factors have combined over time to establish and maintain the current cropping systems is also incomplete. However,

Legume Generation

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