


Feed legumes for truly sustainable crop-animal systems

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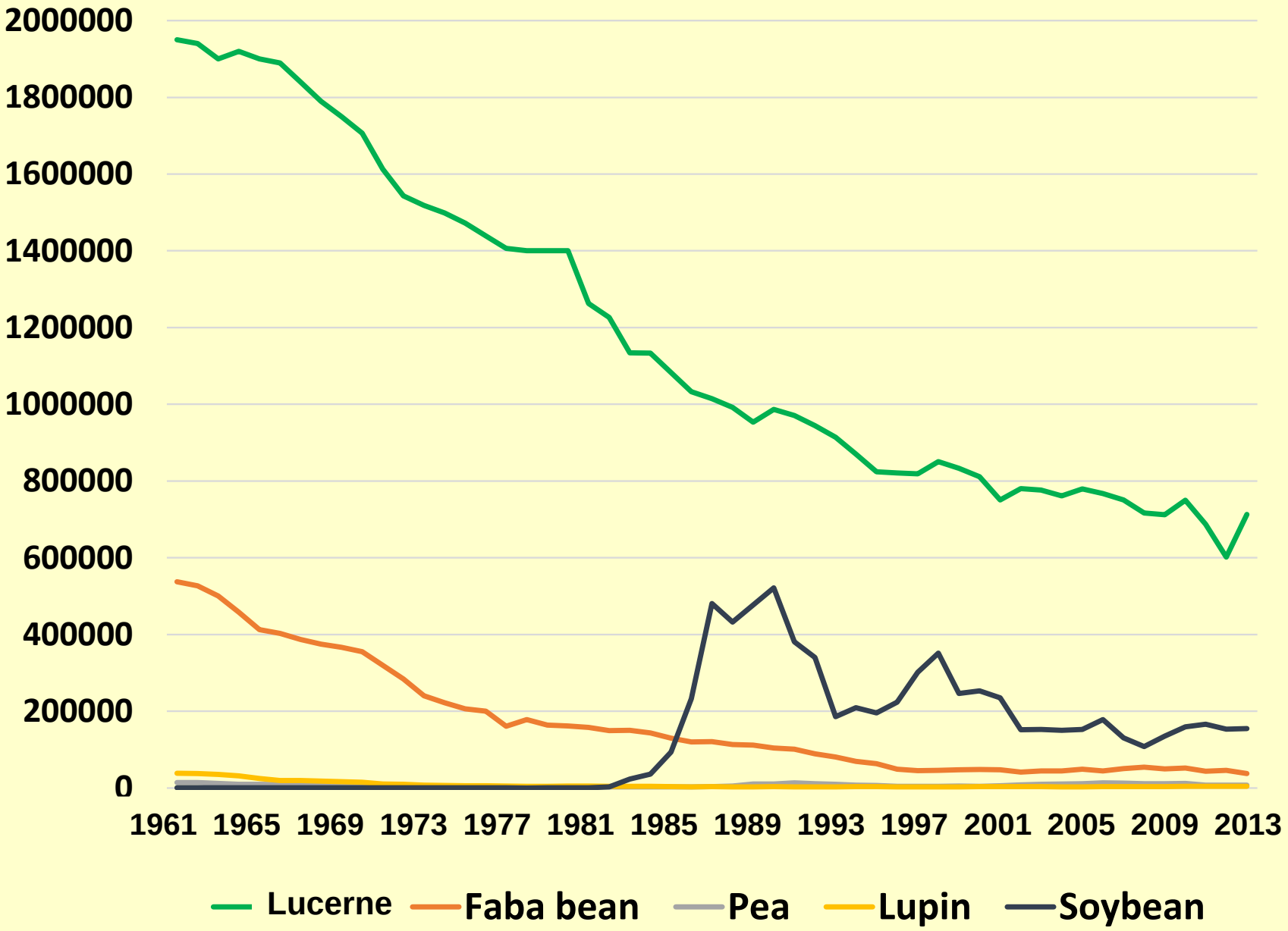
2016 INTERNATIONAL YEAR OF PULSES

Evolution of Italian cropping area for major feed/forage legumes [FAO data]



Current cropping area and market price for major feed/forage legumes in Italy

Species	Cultivated area (ha) [a]	Organic area (%) [b]	Market price (€/t) [c]	Extra price for organic [c]
Lucerne [dehydrated]	670 408 [~80 000]	11.4 [~10.0]	?	?
Soybean	308 979	2.1	361	+90 %
Faba bean	42 157	15.3	206	+62 %
Pea	11 181		268	+32 %
Lupins	4 620	?	?	?

[a] Year 2015 (source: ISTAT) for all crops except lupins, Year 2014 (source: FAO)

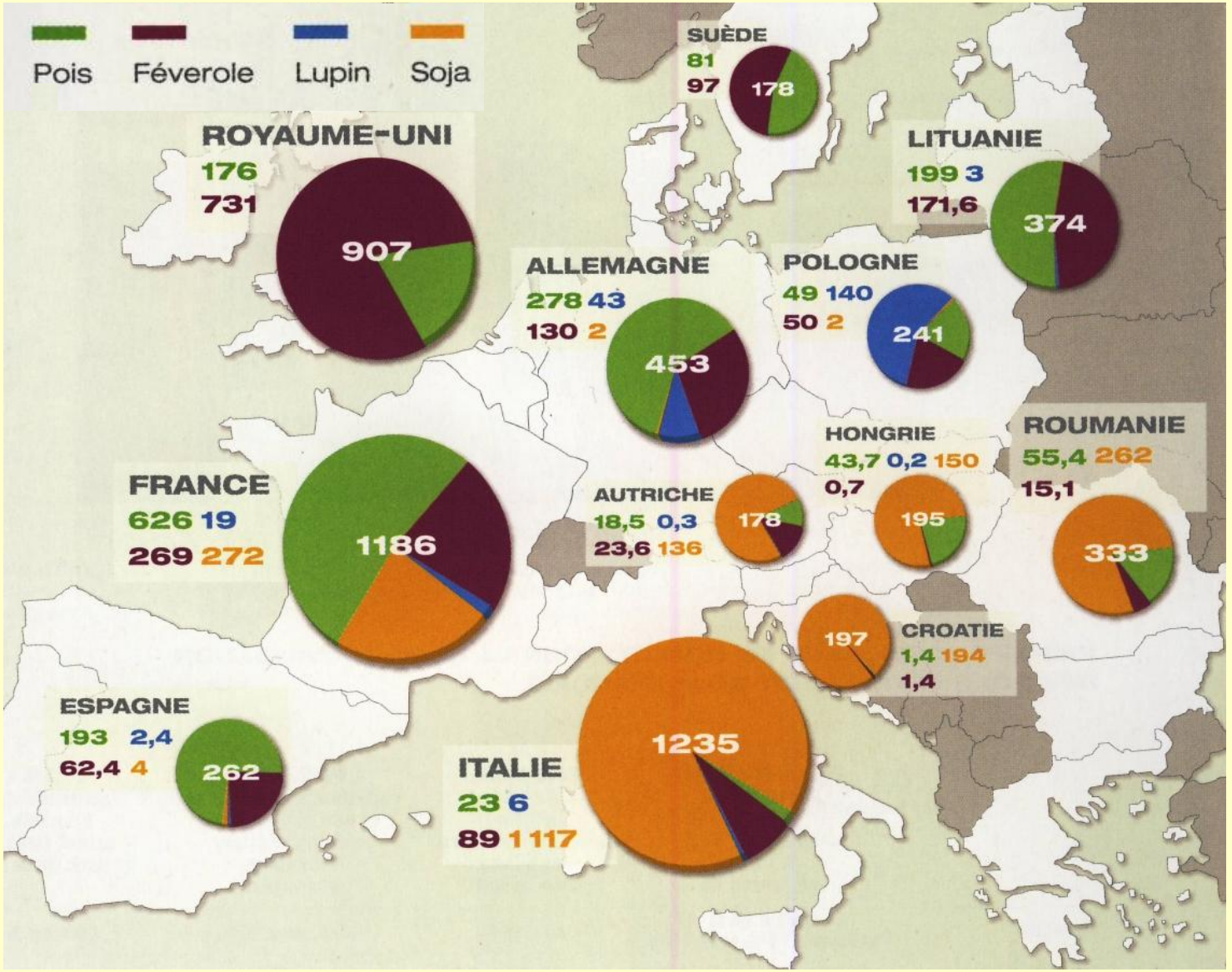
[b] Year 2013 (source: SINAB)

[c] BMTI and Camere di Commercio Emilia-Romagna

Cropping area (ha, 2015) of other major grain legumes:

Chick pea	*11 167*
Common bean	*5 870*
Lentil	*3 099*

Production (.000 t) of feed grain legumes in major EU countries



Terres Univia (2015)

Protein yield of forage and feed grain legume crops in Italy

Crop	Protein yield (t/ha)		
	Lombardy	Emilia-Romagna	Tuscany
Lucerne (irrigated)	9.076	-	-
Soybean (irrigated)	1.454	1.134	0.615
Lucerne (rainfed)	-	5.048	2.478
Faba bean (rainfed)	0.676	0.689	0.543
Pea (rainfed)	0.805	0.689	0.501

Based on crop mean yields (ISTAT 2011-2013) and mean protein content

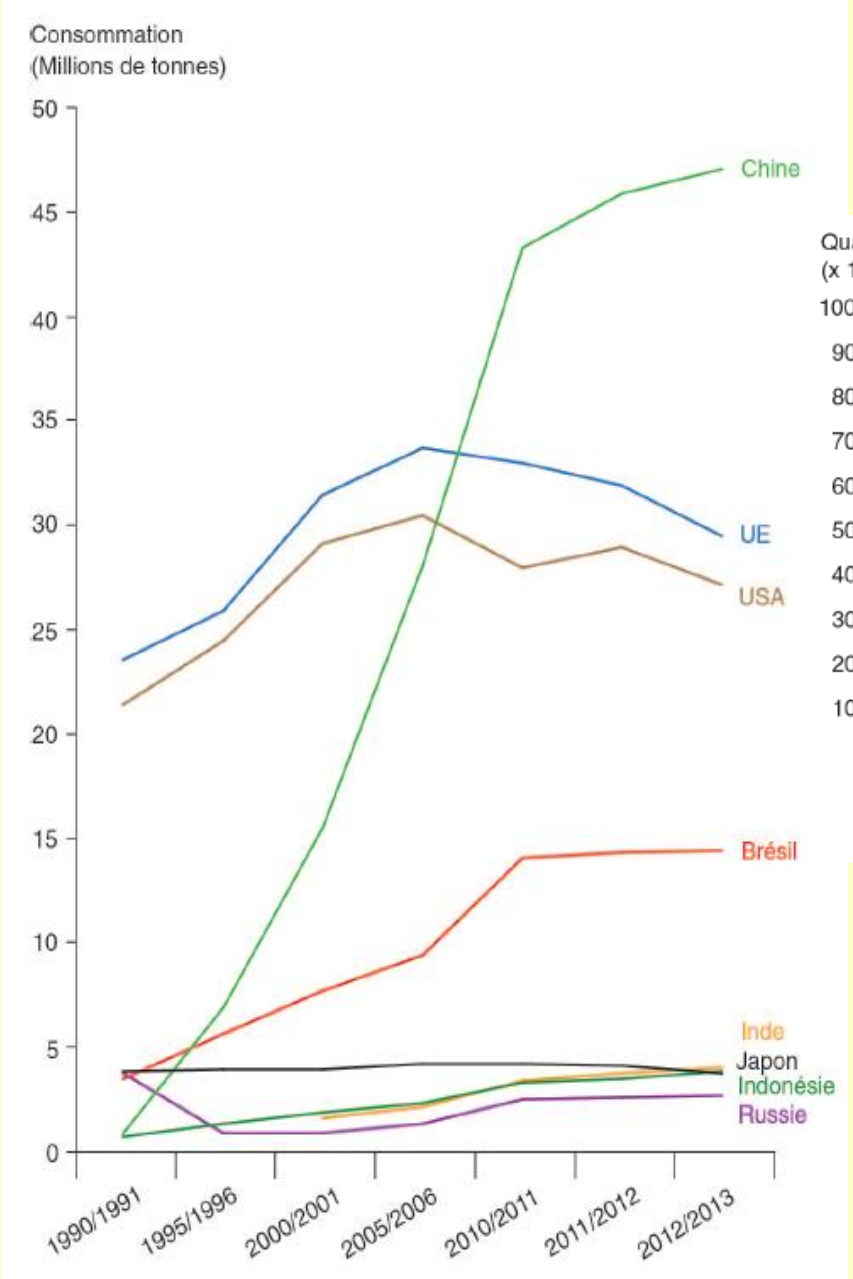
Needed yield increase for feed grain legume crops to match economically the value of benchmark cereals in 2013 in Italy

Crop	Increase (%)		
	Lombardy	Emilia-Romagna	Tuscany
Benchmark crop: maize (irrigated crops)			
Soybean	75	89	135
Benchmark crop: wheat (rainfed crops)			
Faba bean	98	128	51
Pea	30	87	32

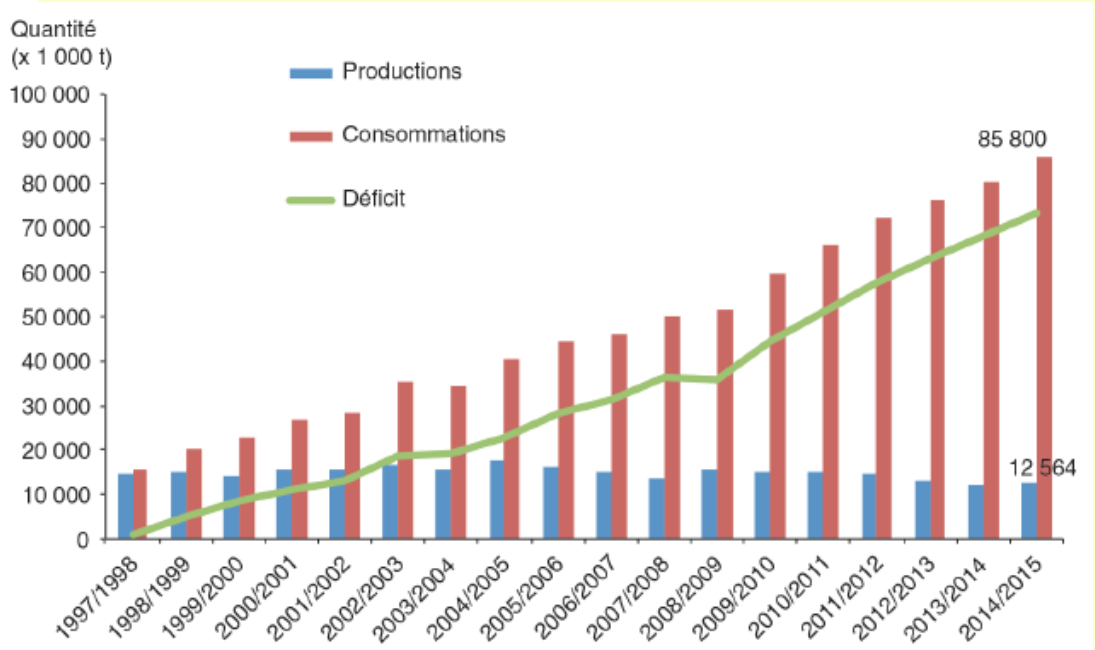
Based on crop mean yields (ISTAT 2011-2013), mean crop contents and international market value of protein, starch and oil

Report EIP-AGRI Focus Group on Protein Crops (2014); De Visser et al. (2014) OCL 21(4): D407

Evolution of world soybean cake consumption [Oilworld]



Evolution of soybean deficit in China (USDA)



World price evolution for:

- soybean cake (above)

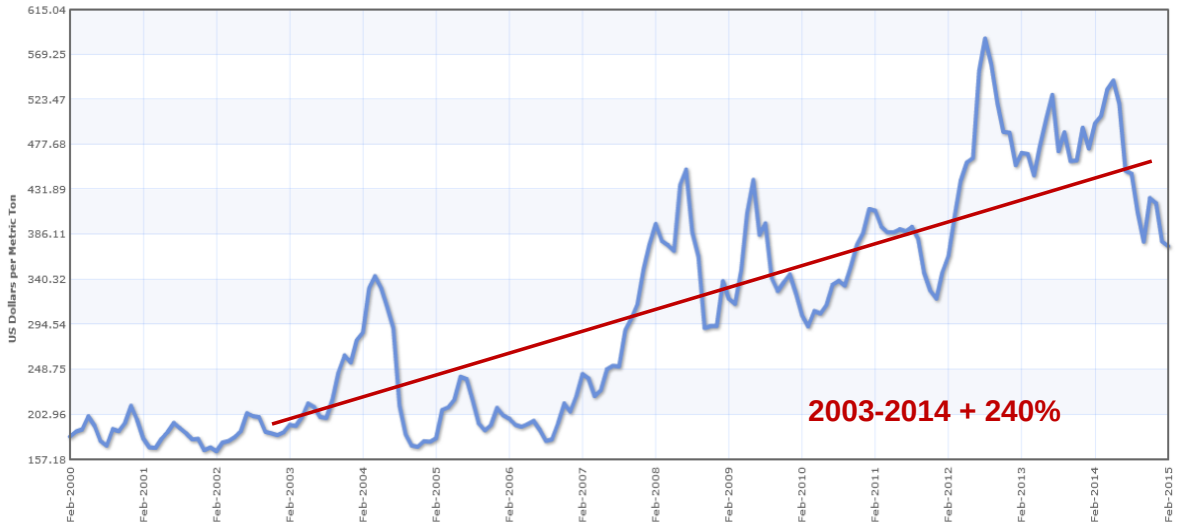
- urea (below)

[Chicago futures]

Soybean Meal Monthly Price - US Dollars per Metric Ton

Range 6m 1y 5y 10y 15y 20y 25y 30y

Feb 2000 - Feb 2015: 193.780 (107.38 %)

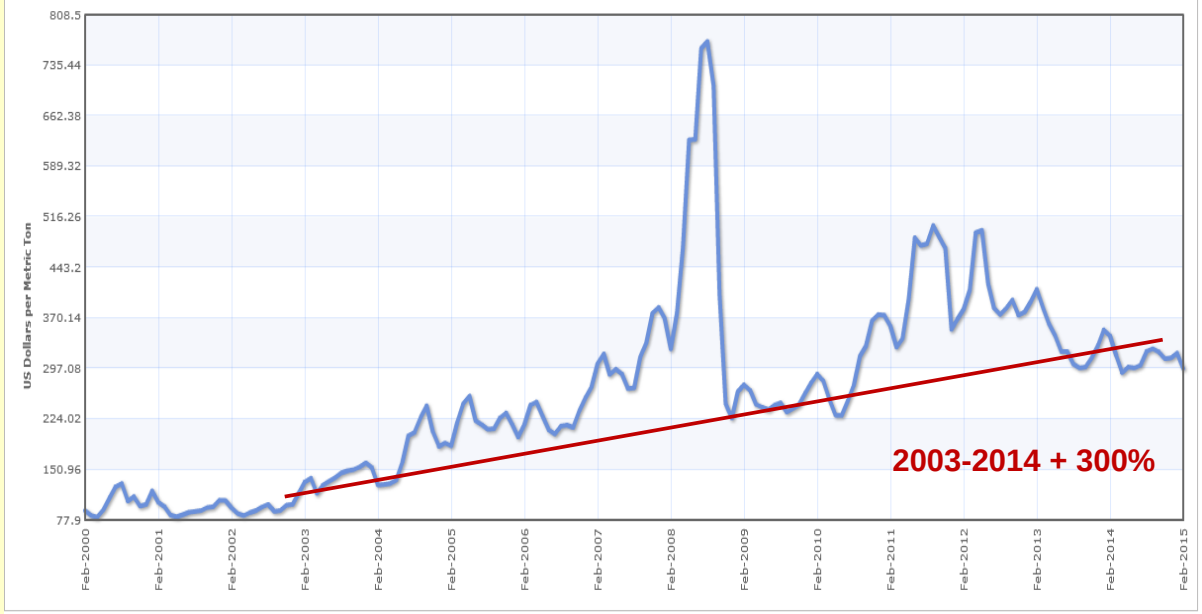


Description: Soybean Meal, Chicago Soybean Meal Futures (first contract forward) Minimum 48 percent protein, US Dollars per Metric Ton

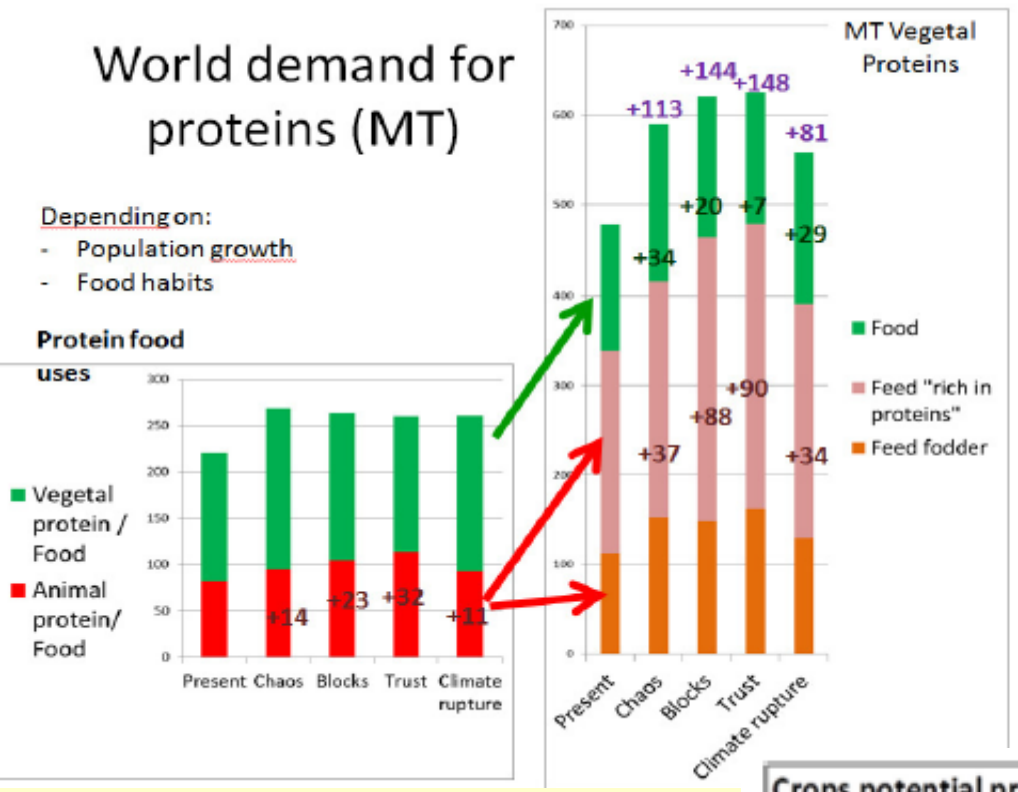
Urea Monthly Price - US Dollars per Metric Ton

Range 6m 1y 5y 10y 15y 20y 25y 30y

Feb 2000 - Feb 2015: 205.620 (225.02 %)



Predicted increase of protein demand for 2030 according to 4 scenarios



- *Demand rises more for protein than oil (limiting rape/sunflower cropping in EU)*
- *Increased protein demand mostly for feed*
- *EU demand for soybean and feed grain increases under any scenario*
- *Possible boost of feed protein extracts from forage legumes*

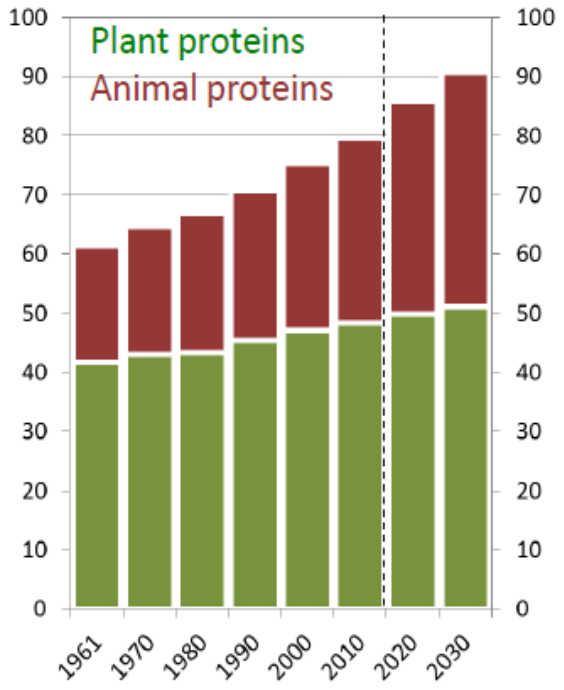
Pilorgé & Muel (2016) OCL

DOI: 10.1051/ocl/2016030

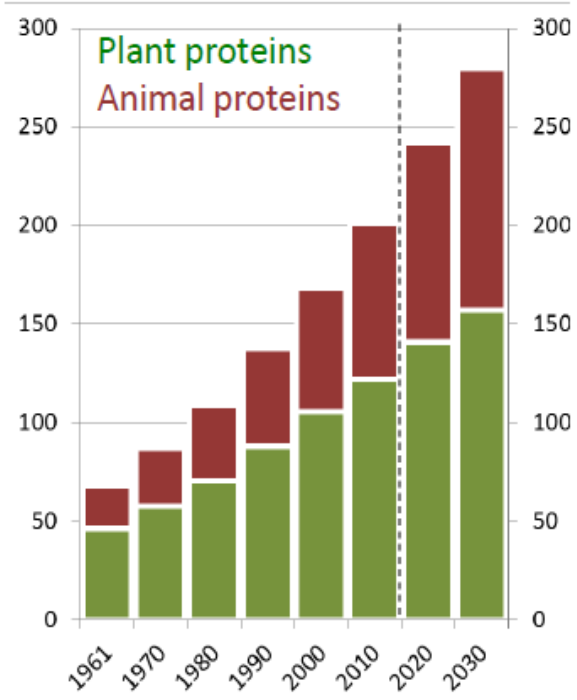
Crops potential progression by 2030	SC1 Chaos	SC2 Blocks	SC3 Trust	SC4 Climate rupture
WORLD				
Rapeseed	-	++	+	-
sunflower	-	+	+	-
Soyabean	++	+++	++	++
Grain legumes	++	+++	++	+
EUROPE				
Rapeseed	-	-	=	--
sunflower	-	--	-	--
Soyabean	+++	+++	++	+++
Grain legumes	+	+++	+++	+++

Predicted increase of world demand for plant protein

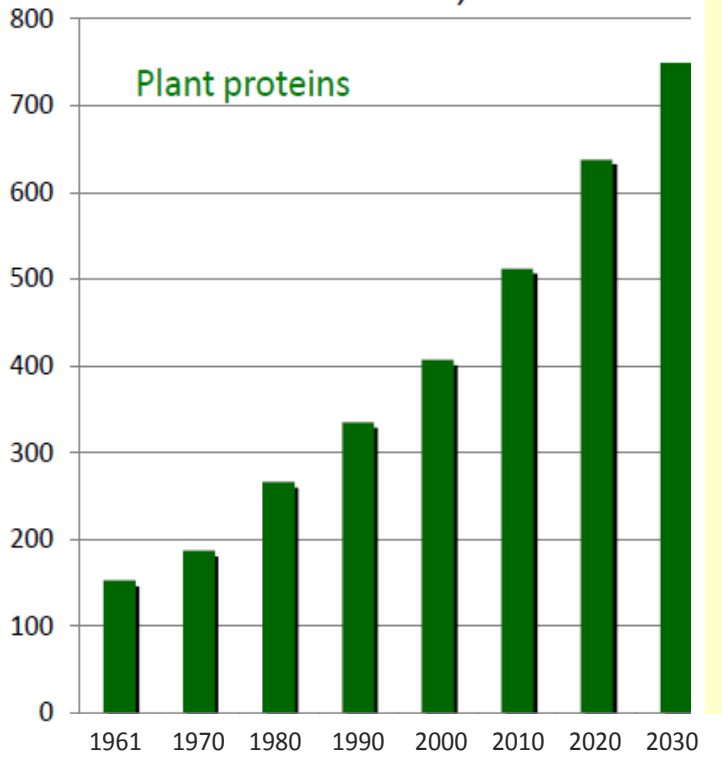
Mean daily consumption (g/hab/day) *(from FAO)*



Annual world demand of proteins (Mt/year) *(from FAO)*



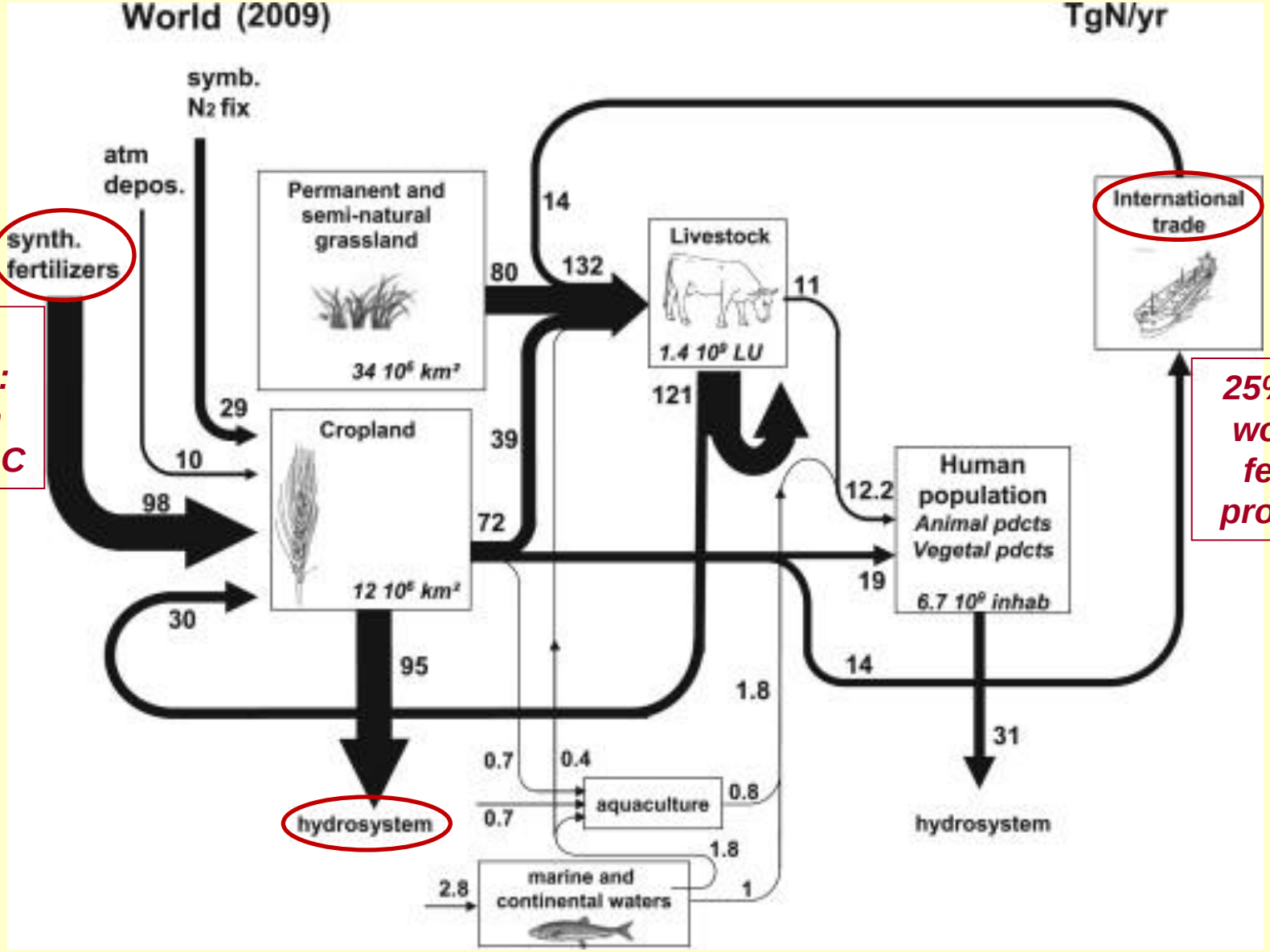
Estimated annual world demand of plant proteins considering the 4.9 coefficient for animal proteins (Mt/year) *(own calculations)*



By Christian Huyghe, based on FAO data [seminar in Lodi, 2015].

Overall plant protein demand based on protein efficiency of animal productions (0.10, beaf meat; 0.30, pig meat; 0.36, chicken meat; 0.43, cow milk; etc.)

Fluxes of nitrogen characterising the global agro-food system in 2009

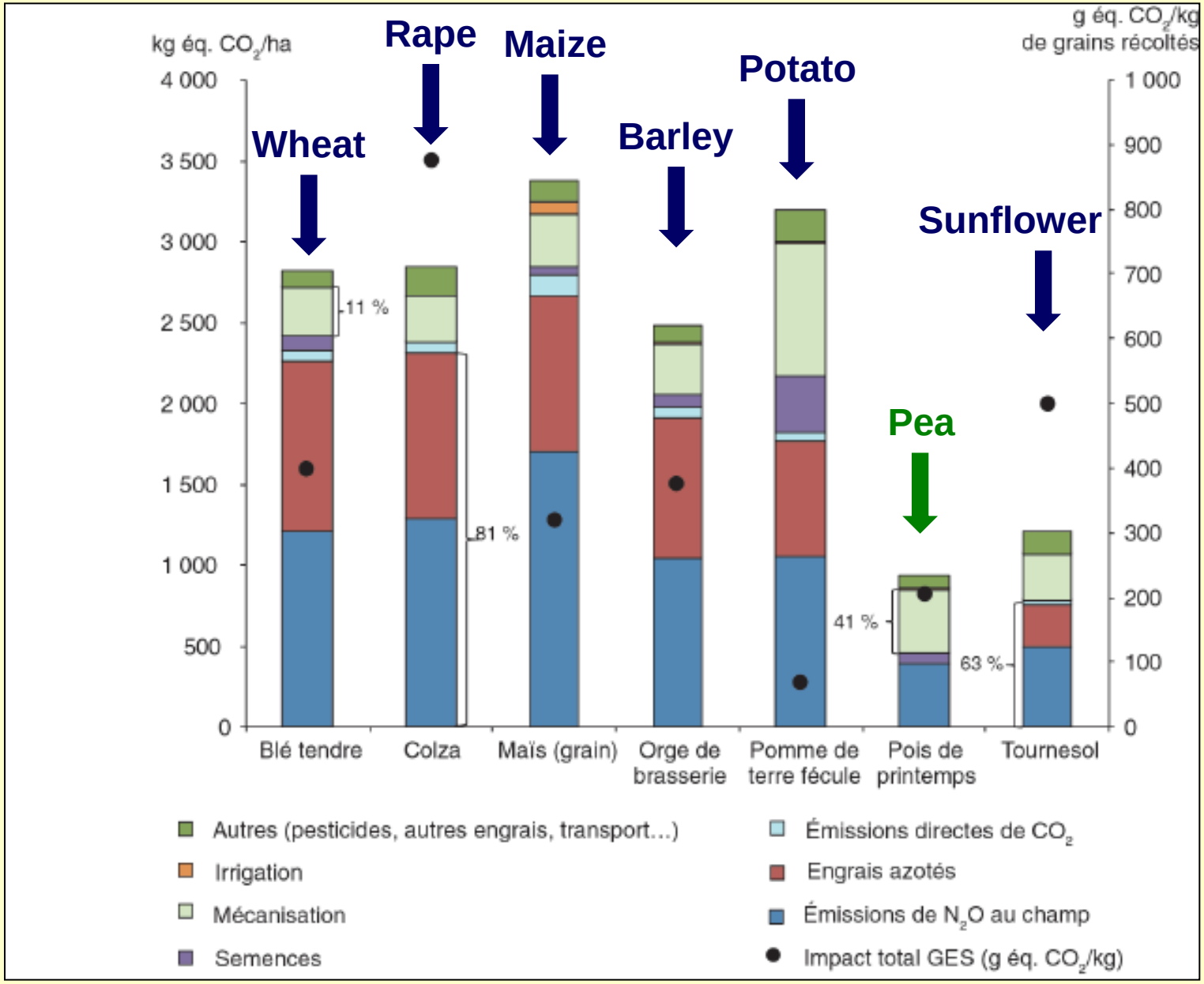


Haber process: 200 atm 400-600° C

25% of world feed protein

Billen et al. (2014) Glob. Food Sec. 3: 209-219

Impact on GHG emission per ha (bar) and kg of grain (dot) for crops in France



Willmann et al. (2014) Proc. LCA Food 2014, USA, pp. 1541-1550

Legumes (particularly grain ones) have been marginal in EU, owing to:

- simplification and specialization of farming
- greater focus on/support to cereals (also due to Europe-USA agreements)
- low cost of N fertilizer, feed proteins, international transportation
- neglecting environmental costs
- accepting huge virtual cropping areas and associated problems (e.g. land grabbing)

Truly sustainable agricultural systems (forced by events) will imply:

- greater exploitation of symbiotic N fixation
- recovering a manageable complexity of farming (greater feed protein self-sufficiency; synergy/complementarities between farmers; cereal-legume mixed cropping; etc.)
- prizing crop ecological services
- credible effort on legume research and its interfacing with stakeholders
- national feed protein plans (favouring integration of crop-animal production chains, contracts of cultivation, etc.)

Exploiting innovative farmers' experience

Example: maize, Alsace

Co-design of new cropping sustems

Maize monoculture

⬇

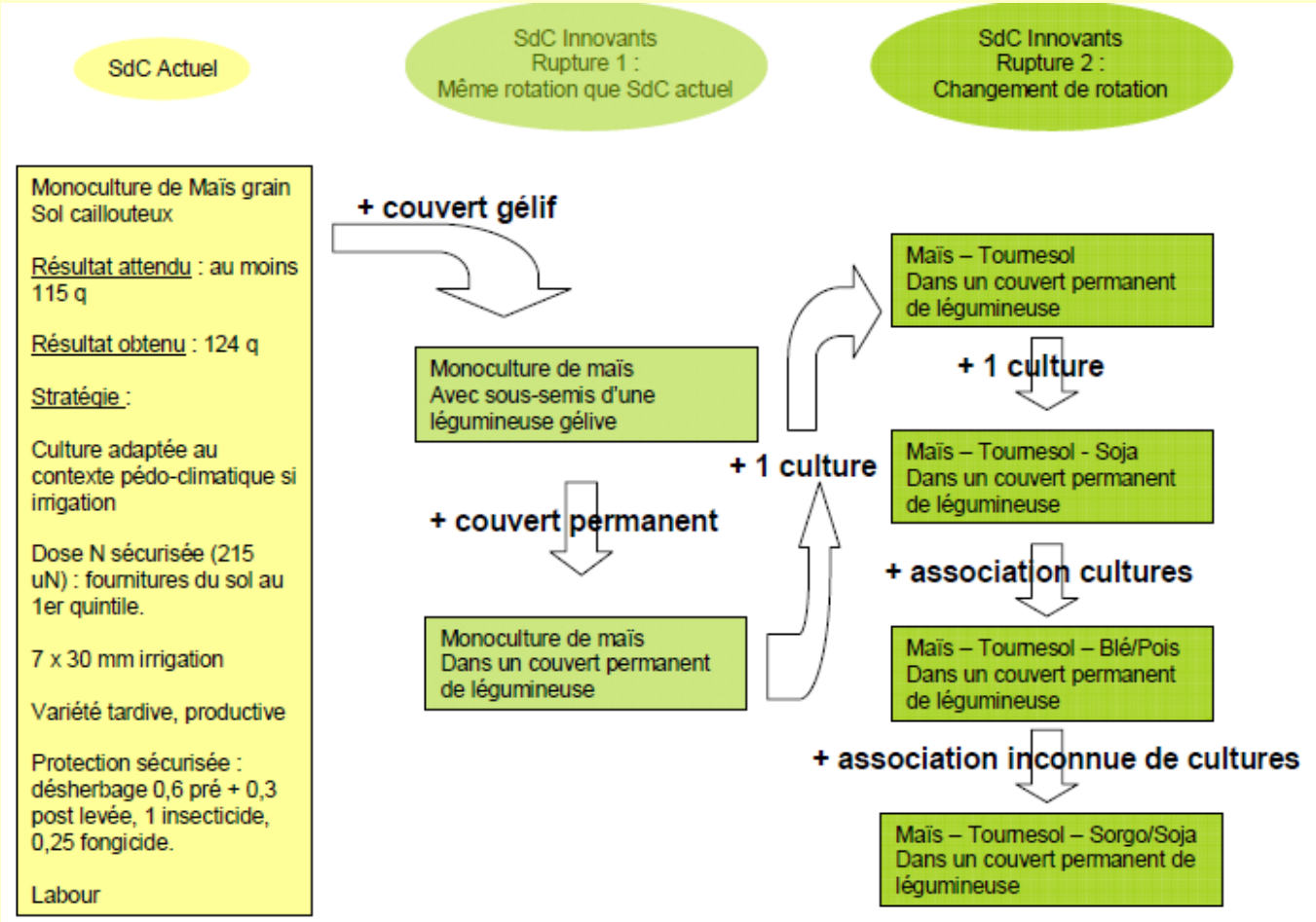
Maize in permanent legume

⬇

Inclusion of soya and sunflower

⬇

Soya-sorgo association



Reau et al. (2012) Innov. Agron. 20: 5-33

Example: farmer-participatory evaluation of innovative legume-based forage crops in Sardinia ***Melis et al. (2016) – this conference***

Main crops object of genetic improvement research at CREA-FLC of Lodi

Pea

Italy

rainfed

White lupin

Italy (low-lime soil)

rainfed

Soybean

north Italy

mostly irrigated

(summer cycle)

Faba bean

centre & south Italy

rainfed

Lucerne (Alfalfa)

(~88% hay or silage;

~12% dehydrated)

Italy

mostly rainfed

Prioritazing rainfed, autumn-sown feed grain legume species for Italy

Mean grain, crude protein and energy (Milk Feed Units) yield of 4 rainfed grain legumes across Italian subcontinental- and Mediterranean-climate sites

Species	Yield (t/ha)	Protein (%)	Crude protein (t/ha)	Milk Feed Units / ha
Pea	4.43	22.8	1.01	5080
Faba bean	3.44	29.4	1.01	3806
White lupin	3.55	38.8	1.38	4339
Narrow-leafed lupin	3.10	30.6	0.95	3807

Species represented by the locally top-yielding cultivar out of 49 pea, 24 faba bean, 11 white lupin and 16 narrow-leafed lupin varieties

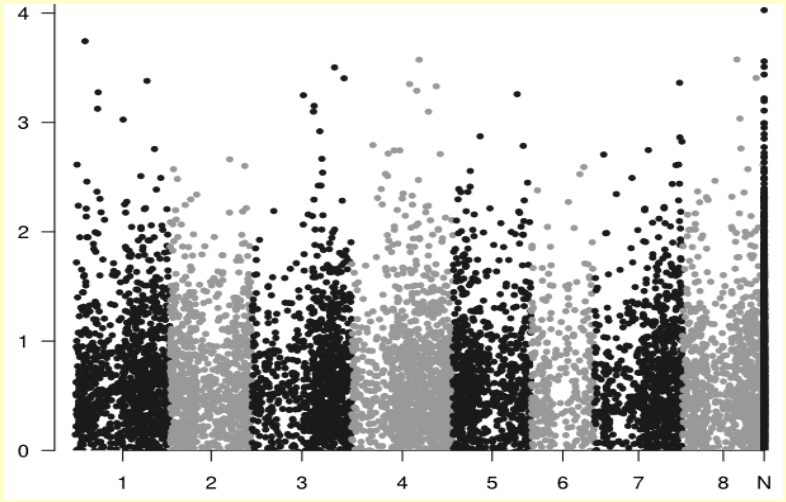
Annicchiarico (2008) Agron. J. 100: 1647-1654

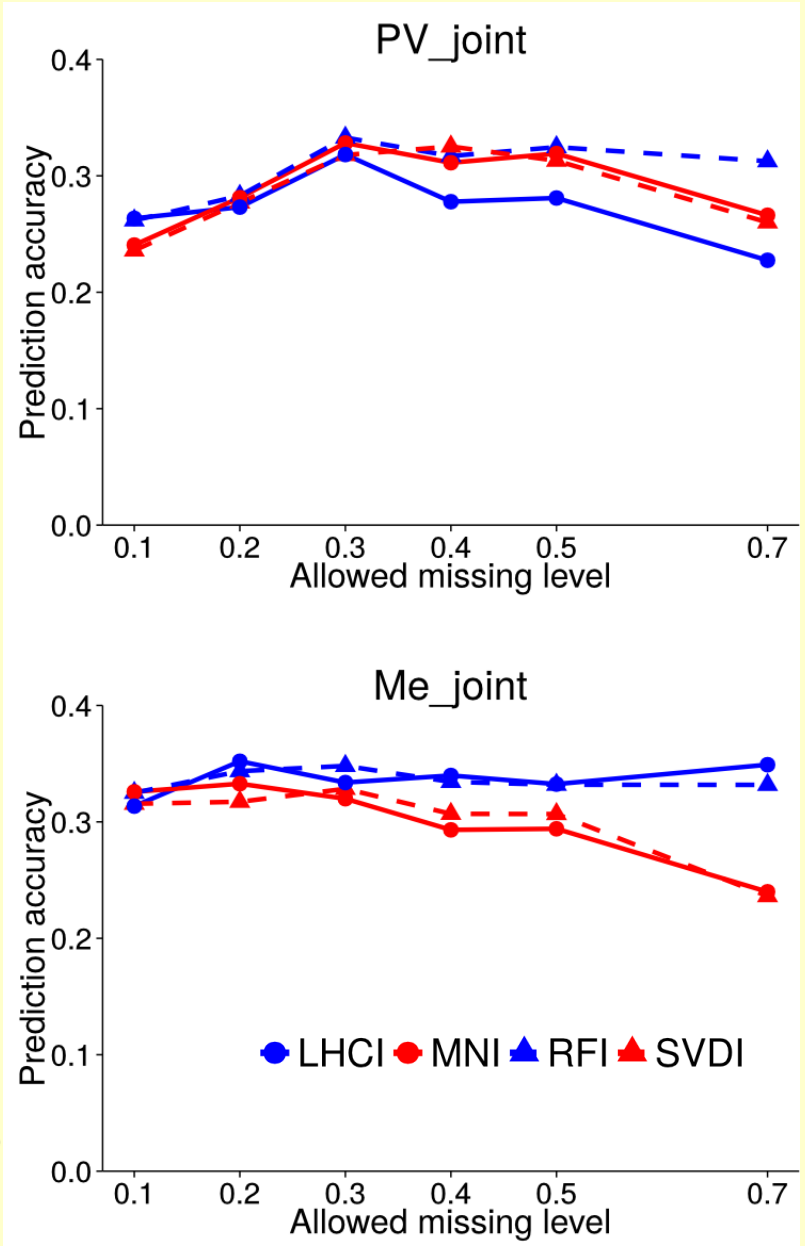
CREA-FLC improvement strategies I. Genomic selection (using GBS markers)

Lucerne: Accuracy of genomic selection for breeding value (as forage yield) in semi-dormant (PV) and Mediterranean (Me) germplasm

(4 models; 6 genotype missing data thresholds; up to 21000 SNPs)

QTLs from GWAS of 6453 M. truncatula-aligned SNPs (Manhattan plot)





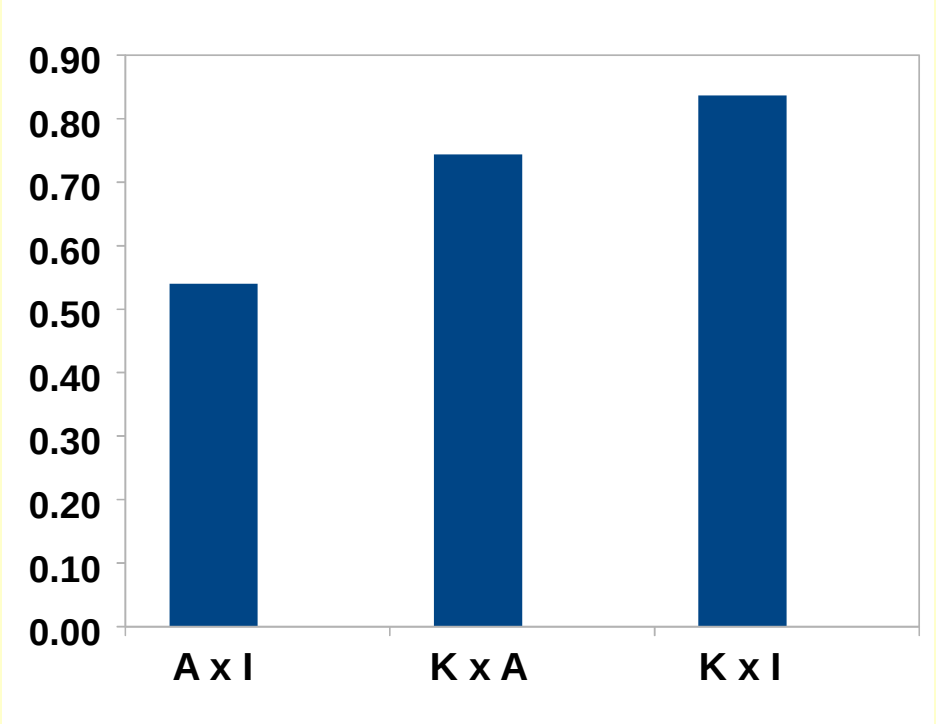
Annicchiarico et al. (2015) BMC Genomics 16: 1020

CREA-FLC improvement strategies I. Genomic selection (using GBS markers)

Pea: accuracy of genomic selection for grain yield under severe terminal drought in 3 crosses

(105 lines per cross; rrBLUP model; 4000-4800 SNPs)

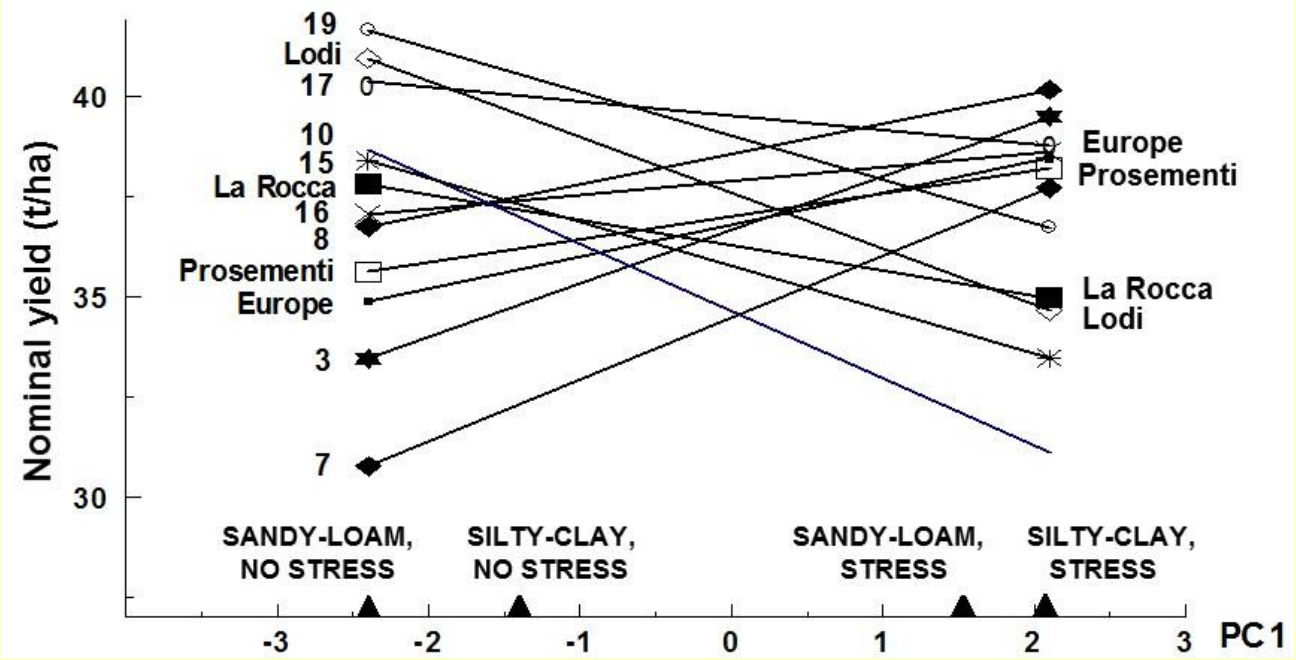
One of CREA-FLC phenotyping platform



Annicchiarico et al.
The Plant Genome (submitted)

CREA-FLC improvement strategies II. Exploiting plant adaptation

Lucerne: artificial selection environments that mimic AMMI modelled cultivar responses in northern Italy



SILTY-CLAY SOIL, NO DROUGHT STRESS (Subregion B)

SANDY-LOAM SOIL, DROUGHT STRESS

SILTY-CLAY SOIL, DROUGHT STRESS (Subregion C)

SANDY-LOAM SOIL, NO DROUGHT STRESS (Subregion A)

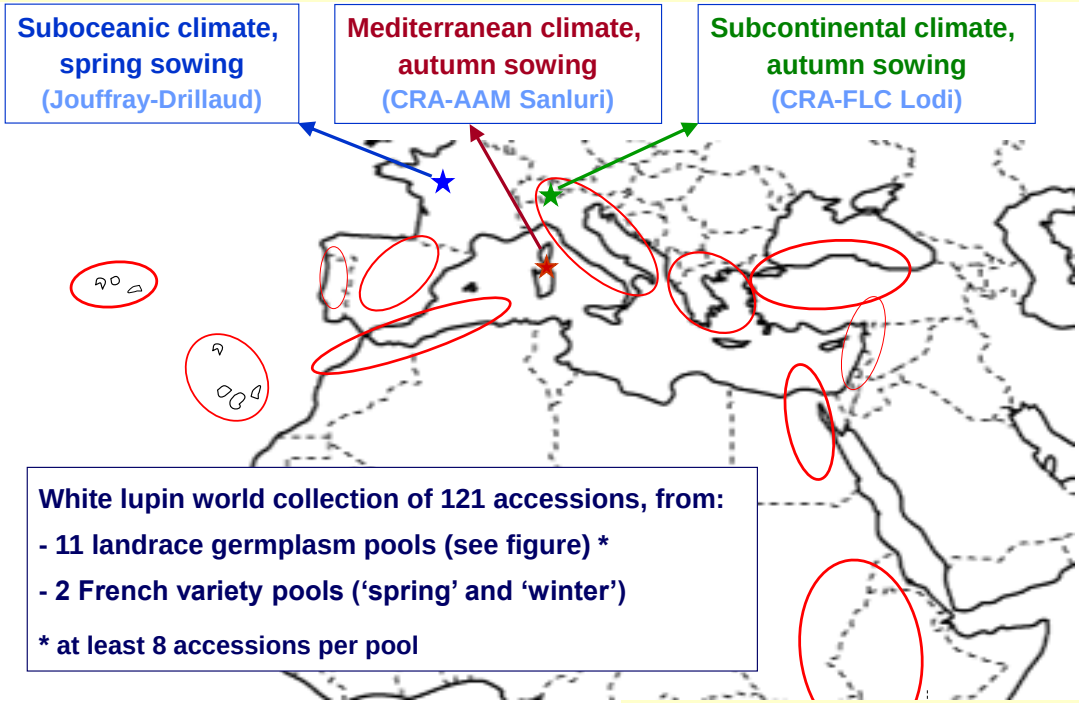
Annicchiarico & Piano (2005) Theor. Appl. Genet. 110: 219-227

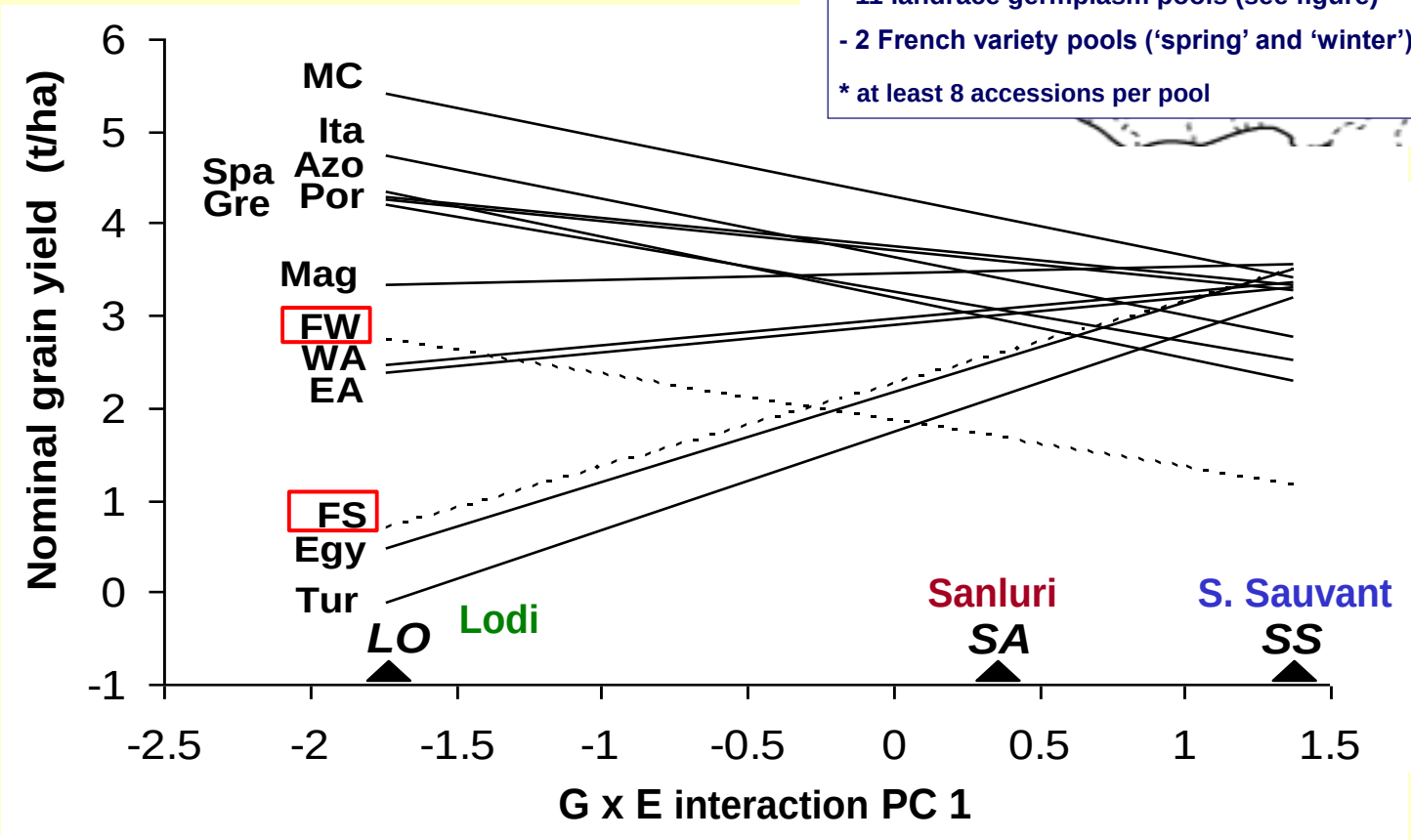
CREA-FLC improvement strategies

III. Exploiting world germplasm collections

White lupin: world landrace collection evaluated in 3 sites

Annicchiarico et al. (2010)
Field Crops Res. 119: 114-124





EA = East Africa
MC = Madeira & Canaries
Mag = Maghreb
WA = West Asia

Azo = Azores
Egy = Egypt
Gre = Greece
Ita = Italy

Por = Portugal
Spa = Spain
Tur = Turkey

FS = French spring
FW = French winter

CREA-FLC improvement strategies IV. Farmer participatory and evolutionary approaches

Pea: development, application and test of selection indexes based on trait importance attributed by organic farmers and by breeders

Importance of traits: 5 = high, 0 = nil

Trait	Breeder	Farmer	P	
Visual agronomic score	5	5	ns	←
Grain yield	4.83	4.61	ns	←
Biomass	3.33	1.86	*	
Cold tolerance	4.08	4.03	ns	←
Lodging tolerance	4.58	4.22	ns	←
Antracnose tolerance	3.75	2.22	*	
Fusarium tolerance	3.08	2.19	ns	
Early flowering	3.33	2.83	ns	
Early maturity	3.17	3.17	ns	
Plant height (flowering)	2.83	2.33	ns	
Semi-leaflessness	4.50	2.56	*	
Seed size	0.83	0.86	ns	
Yellow seed	1.00	0.00	*	
Green seed	0.67	1.19	ns	
Brown seed	0.33	0.14	ns	
Grain protein content	3.92	4.22	ns	←
First pod height	3.67	3.45	ns	

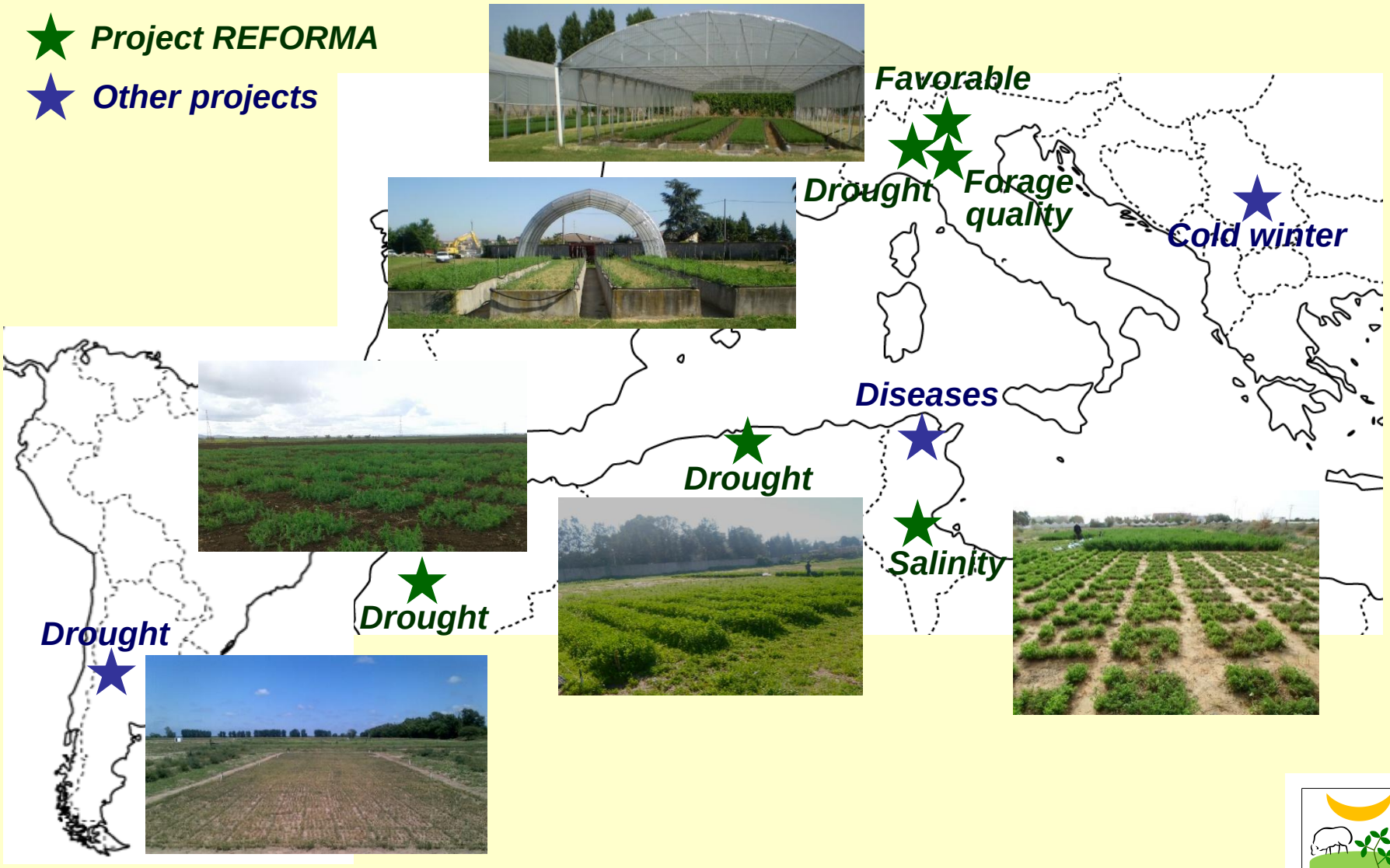
Annicchiarico et al. (unpublished)

AIAB farmers from north (above) and centre Italy (below) assigning visual agronomic scores to 315 replicated pea breeding lines

Coordinating Organic Plant Breeding Activities for Diversity
COBRA

CREA-FLC improvement

Focus on stress tolerance, exploiting international cooperation (example: lucerne)



Main international projects and funding bodies supporting CREA-FLC research

FP7-ArimNet REFORMA **"Resilient, water- and energy-efficient forage and feed crops for Mediterranean agricultural systems"** *http://reforma.entecra.it/*

FP7 LEGATO **"Legumes for the agriculture of tomorrow"** *http://www.legato-fp7.eu/*

FP7-Core Organic COBRA **"Coordinating organic plant breeding activities for diversity"** *http://www.coreorganic2.org/*

Italy-USA bilateral project GENALFA **"Genomic selection in alfalfa"**
http://centroflc.entecra.it/index.php/current-projects/117-genalfa

Thank you for your attention!