Società Italiana di Agronomia
XLV Convegno Nazionale

A.D. MDLXII

La ricerca agronomica verso il 2030: gli obiettivi globali di sviluppo sostenibile

Università degli Studi di Sassari
Dipartimento di Agraria

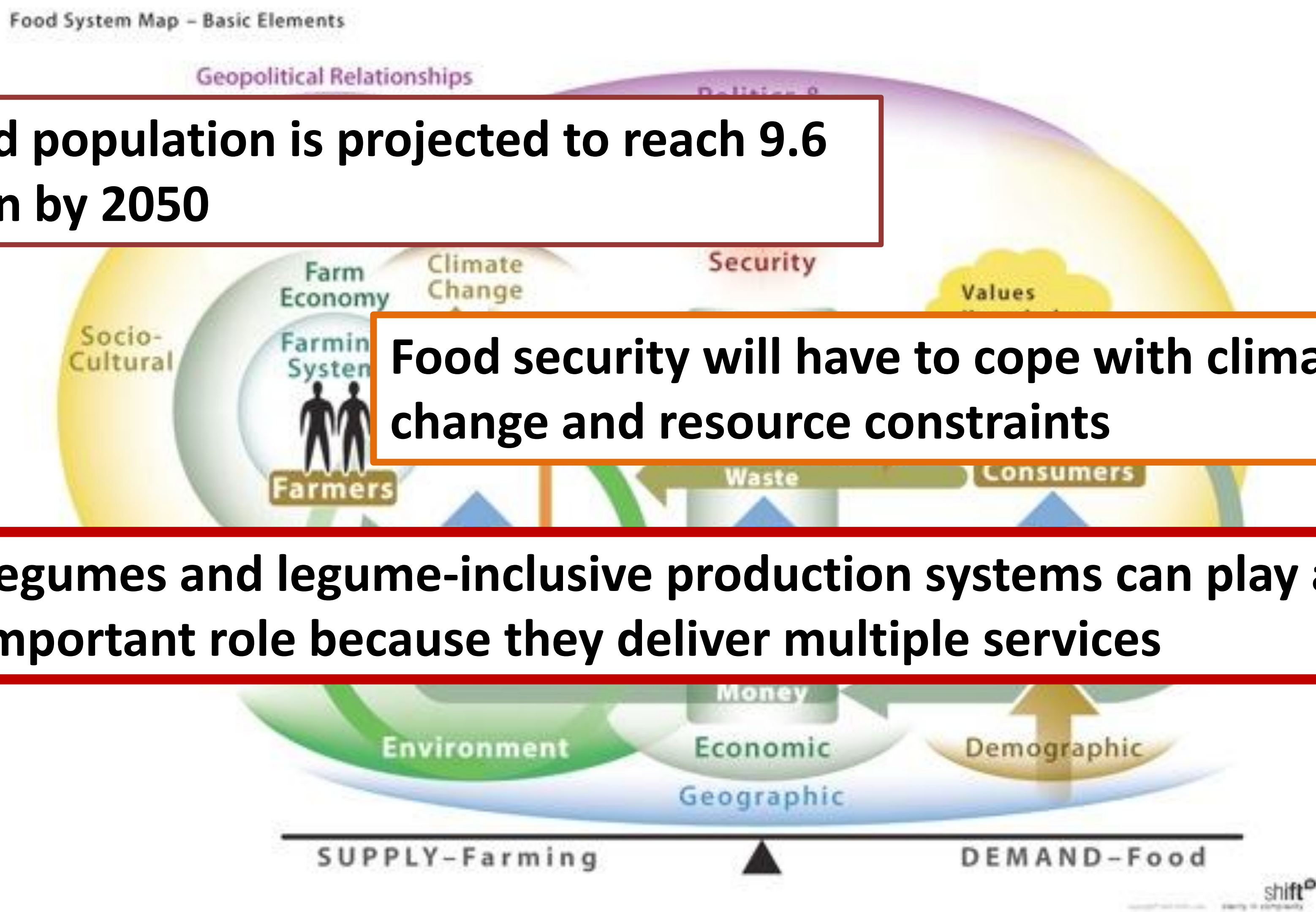
Grain legumes and sustainable cropping system: an overview

Michele Pisante, Fabio Stagnari, Albino Maggio*

Faculty of Biosciences and Technologies for Agriculture Food and Environment, University of Teramo, Italy

*Department of Agricultural Science, University of Naples Federico II, Portici, Italy

Sustainability of production/consumption is central in future food systems



World population is projected to reach 9.6 billion by 2050

Food security will have to cope with climate change and resource constraints

Legumes and legume-inclusive production systems can play an important role because they deliver multiple services

Multiple services of legume crops

- Excellent source of protein for humans
- Fundamental component of husbandry
- **Mitigate greenhouse gases**
- **Require less energy and can contribute to bio-energy**
- **Improve soil properties**

Stagnari et al., 2016. MULTIPLE BENEFITS OF LEGUME CROPS FOR AGRICULTURE SUSTAINABILITY. CBTA, submitted.

Trends in world total legume area (million hectares)

	1962	1972	1982	1992	2002	2012
Cool-season legumes						
Chickpea	12.2	10.5	10.3	9.3	10.4	12.1
Pea	10.3	8.0	7.4	7.2	6.0	6.3
Faba bean	6.1	4.2	3.3	2.9	2.7	2.4
Lentil	1.6	1.8	2.6	3.3	3.6	4.2
Vetches	2.4	1.7	1.0	1.0	0.9	0.6
Lupins	1.4	0.8	0.6	1.2	1.2	0.9
Warm-season legumes						
Common bean	23.5	22.8	26.2	24.8	27.5	28.8
Cowpea	2.7	4.2	3.9	8.5	9.9	10.7
Pigeonpea	2.7	2.7	3.4	4.2	4.4	5.3
Major cereals, for comparison						
Wheat	207.6	213.8	238.5	222.5	213.8	216.7
Rice	119.5	132.2	141.6	147.4	147.6	163.5
Maize	103.5	114.9	124.4	136.8	137.6	177.0

Rubiales and Mikic (2015) - Source: FAOSTAT, 2013

Legumes and climate change

- Lower the emissions of the key greenhouse gases carbon dioxide (CO_2) and nitrous oxide (N_2O) compared to N-fertilized systems

- Reduce the fossil energy used in the production of food and forage

- Contribute to the sequestration of carbon (C) in soils

- Can provide a viable source of biomass for biofuels

Legumes are lower yielding/higher protein concentrations than cereals, which have resulted in less interest in their use for biofuels.

A potential for biorefinery (up to now the only the legume used to a certain extend for protein feed and biodiesel is soybean).

CO_2

Globally between **350 and 500 Tg CO_2** could be emitted as a result of the 33 to 46 Tg N that is biologically fixed by agricultural legumes each year.

This compares to around **300 Tg CO_2** released annually from the manufacture of 100 Tg fertilizer N.

CO_2 respired from the nodulated roots of N_2-fixing legumes originates from photosynthesis and does not represent a net contribution to atmospheric concentrations of CO_2, whereas the CO_2 generated during the synthesis of N fertilizer is derived from fossil fuels.

Jensen et al., 2012. Agronomy for Sustainable Development. 32(2): 329–364.

- Soils under **legumes** emitted **1.29 kg N_2O–N ha^{-1}** during a growing season (averages across 71 site-years of data)

- **N-fertilized crops and pastures** emitted a mean of **3.22 kg N_2O–N ha^{-1}** (67 site-years)

- **Unplanted soils or unfertilized non-legumes** emitted **1.20 kg N_2O–N ha^{-1}** (33 site-years of data

Rates of N_2O losses can increase:

- Following termination of legume-based pastures
- When legumes had been green- or brown-manured (rapid build-up of high concentrations of nitrate in soil.)
- The asynchrony between N supply and demand/utilization from the following crops (fallow period follows legumes crop or during winter and early spring in cold wet soils)

Legume crops and legume-based pastures require less fossil energy

- Legumes use 35% to 60% less fossil energy than N-fertilized cereals or grasslands.

- Inclusion of legumes in cropping sequences reduces the average annual energy usage over a rotation by 12% to 34%.

Dual effect:

1) Reduced energy use primarily due to less need for N fertilizers

2) Lower N fertilizer requirements for crops that follow legumes

Legumes improve soil carbon sequestration

For a change in land use to result in a net increase C sequestration in soil, the inputs of C remaining in plant residues need to exceed the CO_2 respired by soil microbes during the decomposition of plant residues or soil organic C, and the C lost through wind or water erosion.

Data collected from pasture, cropping, and agroforestry systems all indicated that **legumes are excellent providers of the additional organic N required to encourage the accumulation of soil C** at rates greater than can be achieved by cereals or grasses even when they were supplied with N fertilizer.

Competitive advantage of legumes

The elemental composition of SOC tends to be very similar in almost all soils

Since:

1) **<u>The C/N ratios and amounts of N provided per megagram of C in legume residues are generally much closer to that of soil organic matter than non-legume species</u>**

2) Leguminous organic matter tends to have higher P concentrations than other species

The inclusion of legumes in farming systems might be expected to be more conducive to C sequestration and the build-up of SOC over time

Role of grain legumes in cropping systems

Legume-derived additional N

- Additional N-nitrate available to wheat crops following legumes instead of cereals, averaged around **37 kg N ha^{-1}** (Australia)

- Nitrogen uptake in crops that follow legume crops has been reported to increase by **23-59%** after field pea and narrow-leafed lupin on different soil types (Denmark)

- Only **14-15%** for durum wheat following vetch in a semi-arid Mediterranean environment.

- Increased N uptake of crops after grain legumes reached up to **61% or 36 kg ha^{-1}** for a vetch-barley rotation (Cyprus)

‘nitrogen effect’ and ‘break crop effect’ components

- The *nitrogen effect* component is a result of the N provision from legumes biological fixation (BNF)

- The break crop effect includes non-legume-specific benefits:
  - improvements of soil organic matter and structure (Hernanz et al., 2009),
  - phosphorus mobilization (Shen et al., 2011)
  - soil water retention and availability (Angus et al., 2015),
  - reduced pressure from diseases and weeds (Robson et al., 2002)

(highest benefits in cereal based rotations)

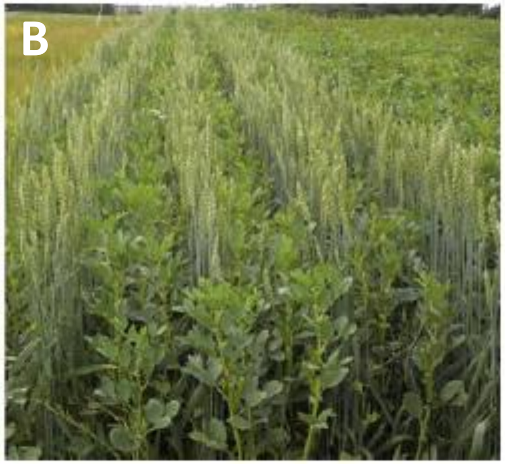
Intercropping systems

Intercropping is widely used in developing countries or in low-input and low-yield farming systems

- better pest control
- competitive yields with reduced inputs
- pollution mitigation
- more stable aggregate food or forage yields per unit area
- Improving competition for weeds
- Mutual benefits: cereals benefit of legumes-fixed N and increase Fe and Zn bioavailability to the companion legumes

Legumes can contribute up to 15% of the N in an intercropped cereal

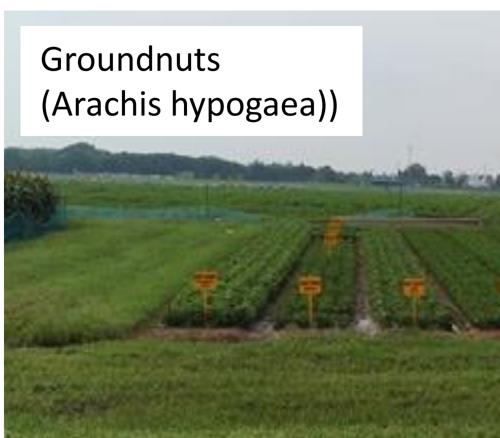
A=pea-barley
B= faba bean-spring wheat



A recent visit at ICRISAT

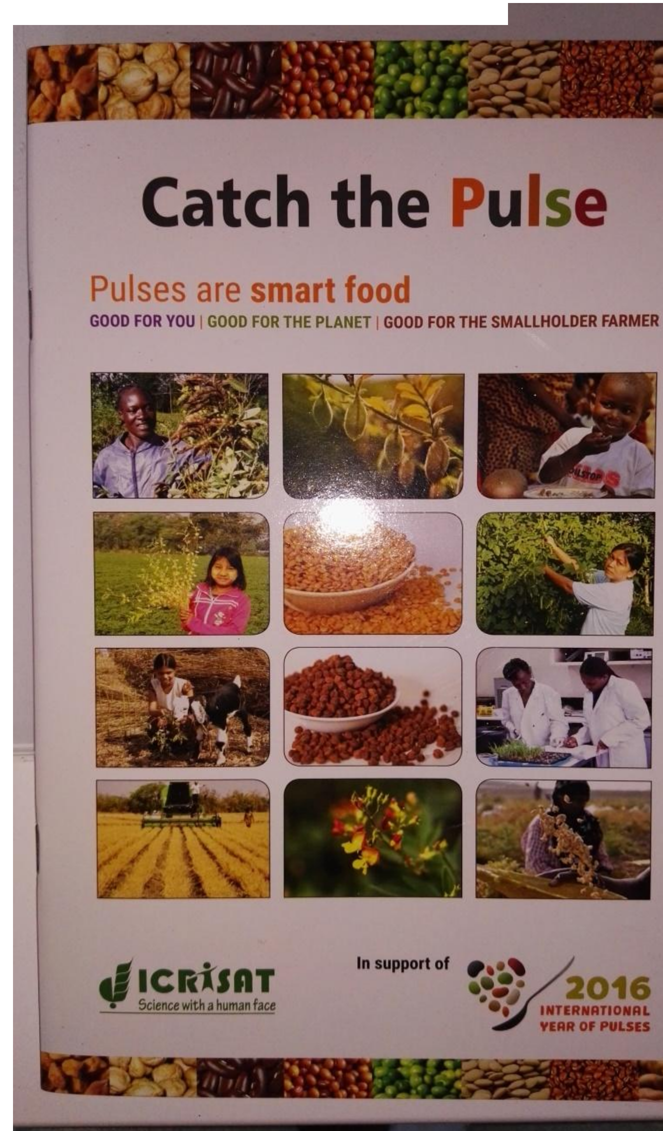
Less than 2% of legumes genetic resources are used

Pigeon pea
(Cajanus cajan)



Groundnuts
(Arachis hypogaea))

Phenotyping facility



Resource and Environmental effects of legumes arising from key agroecological processes operating at four levels

Process	Protein crop	Farm	Agri-food system	Global
Biological nitrogen fixation (BNF)	No N fertiliser required Reduced N_2O emissions Below ground biodiversity changes	Reduced N fertilizer requirement	Reduced fossil energy (natural gas) use Reduced CO_2 emissions from industry	Reduced global GHG emissions
Grain protein synthesis	Lower crop yield (compared with cereals) due to resource demands of protein synthesis	Increased on-farm supply of protein	Increased diversity of 'protein' crop commodity supplies	Reduced demand for globally traded soya Reduced direct land-use change pressures
N transformation in soil	Reduced N_2O emissions	Effect in both direction on nitrate leaching		Reduced global GHG emissions
Soil development		Improved water infiltration, reduced cultivation energy, increased crop yields		
Phosphorous transformations	Increased mobilisation of soil P	Reduced optimum levels of plant-available P		Reduced mining of phosphate rock (minor effect)
Soil carbon transformations	Positive soil carbon balance	Increased soil organic matter, higher and more stable crop yields		Increased soil carbon sequestration (minor effect)
Weed, pest and disease development		Increased cropping system yield. Reduced emissions of pesticides to water		
Species interactions	Increased pollen and nectar provision. Increased soil fauna diversity	Larger population of insects supporting wider wildlife		

Reckling et al. (2014)