BioGesteca convegno presentazione risultati – Lodi 13-14 febbraio 2014

Efficienza d’uso dei nutrienti e razionalizzazione delle fertilizzazioni

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Università di Verona

Membro dello Steering Committee del Progetto

L’ Aquila joint statement

There is an urgent need for decisive action to free humankind from hunger and poverty. Food security, nutrition and sustainable agriculture must remain a priority issue on the political agenda, to be addressed through a cross-cutting and inclusive approach, involving all relevant stakeholders, at global, regional and national level. Effective food security actions must be coupled with adaptation and mitigation measures in relation to climate change, sustainable management of water, land, soil and other natural resources, including the protection of biodiversity.

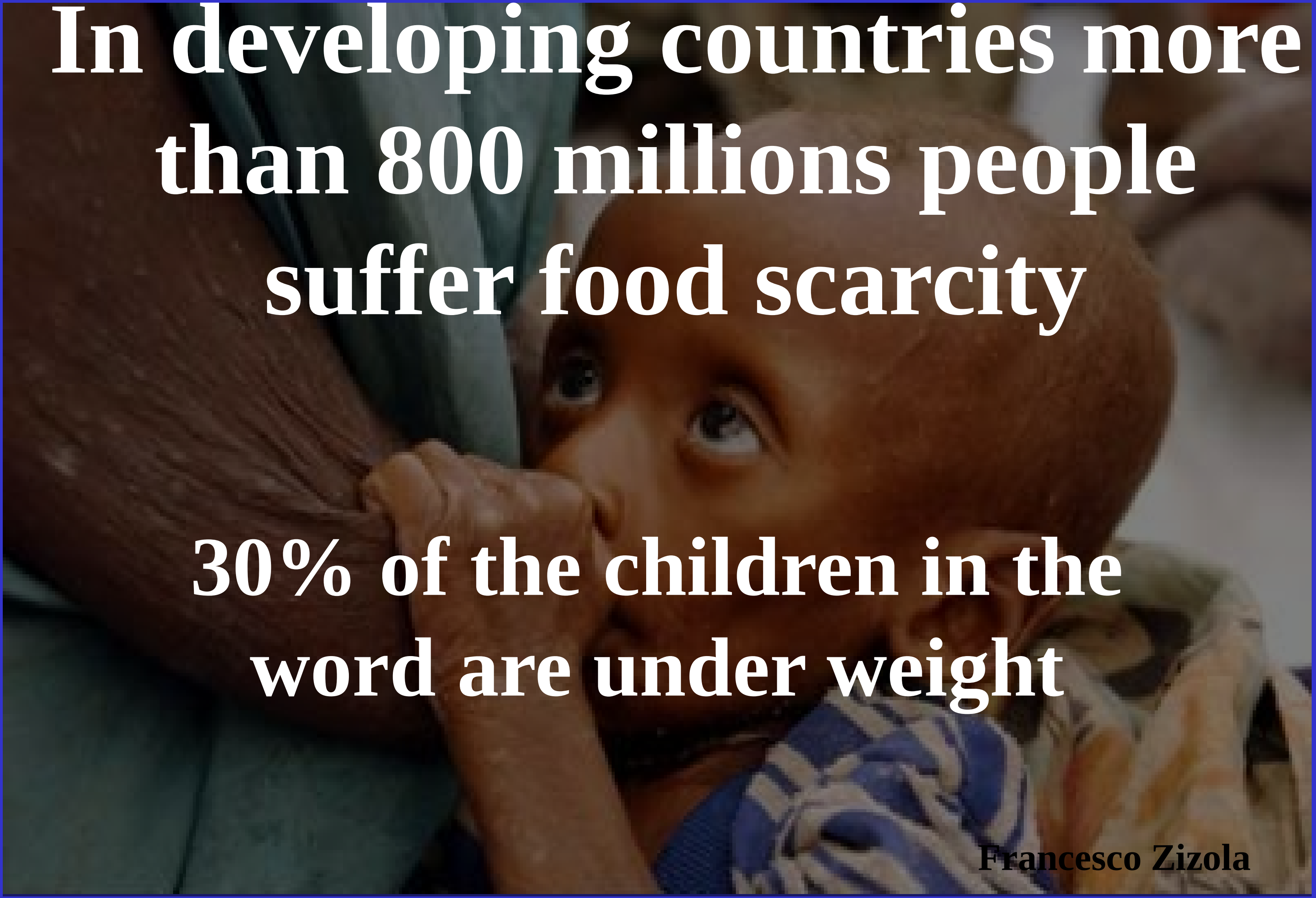
“Vi è un urgente bisogno di un’azione decisiva per liberare l’umanità dalla fame e dalla povertà. La sicurezza alimentare, l’alimentazione di qualità e l’agricoltura sostenibile devono rimanere una questione prioritaria nell’agenda politica, che va affrontata con un approccio trasversale e inclusivo, coinvolgendo tutti gli attori rilevanti a livello mondiale, regionale e nazionale. Le azioni efficaci per la sicurezza alimentare devono essere associate a misure di adattamento e di mitigazione in relazione ai cambiamenti climatici, alla gestione sostenibile delle risorse idriche, dei terreni agricoli, del suolo e di altre risorse naturali, compresa la protezione della biodiversità.”

(*Dichiarazione congiunta sulla sicurezza alimentare globale. G8 L’Aquila, 2009*)

I grandi temi della ricerca in agricoltura

- Food security: soddisfazione quantitativa del fabbisogno alimentare
- Food quality: cibi con elevate caratteristiche qualitative e specifici nell'origine
- Food safety: cibi sani dal punto di vista igienico-sanitario

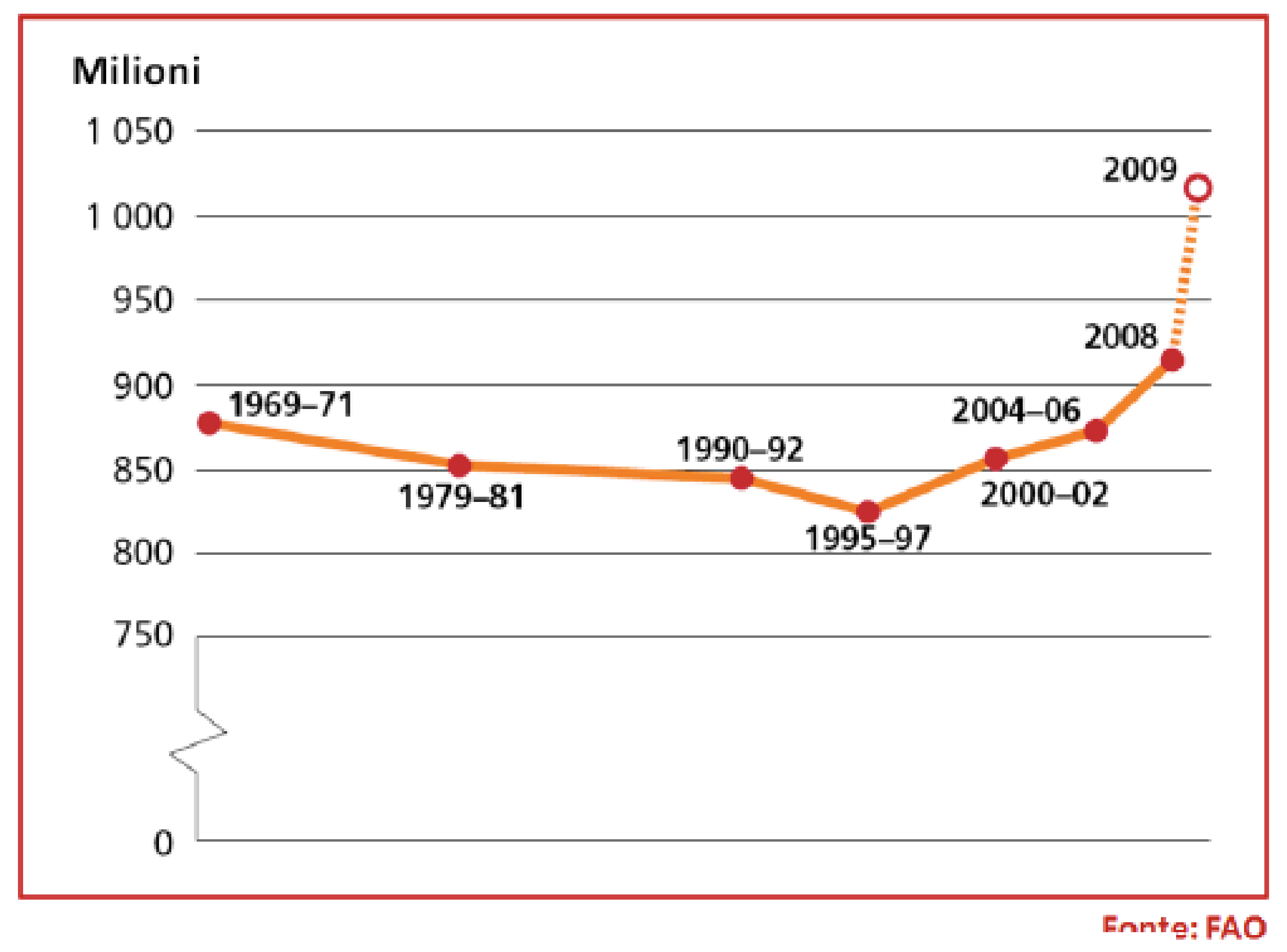
Tutto questo nel rispetto dell'ambiente, della biodiversità e in relazione ai cambiamenti climatici



In developing countries more than 800 millions people suffer food scarcity

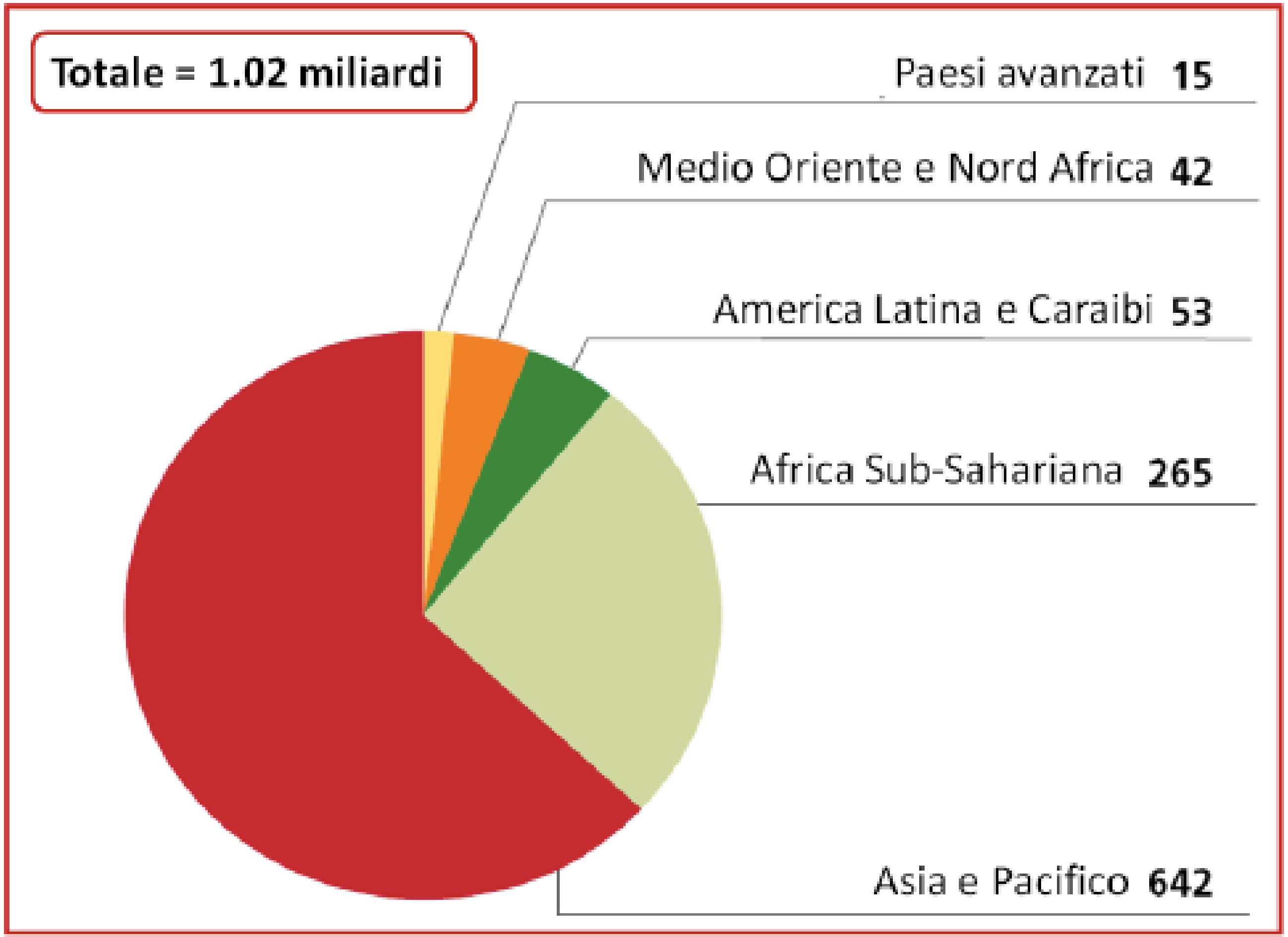
30% of the children in the word are under weight

Francesco Zizola



Fonte: FAO

Persone sottoalimentate nel mondo (dal 1969 al 2009)


Totale = 1.02 miliardi
Paesi avanzati 15
Medio Oriente e Nord Africa 42
America Latina e Caraibi 53
Africa Sub-Sahariana 265
Asia e Pacifico 642

Fonte: FAO

Micronutrient deficiencies (Fe; Zn; I; Vitamin A)

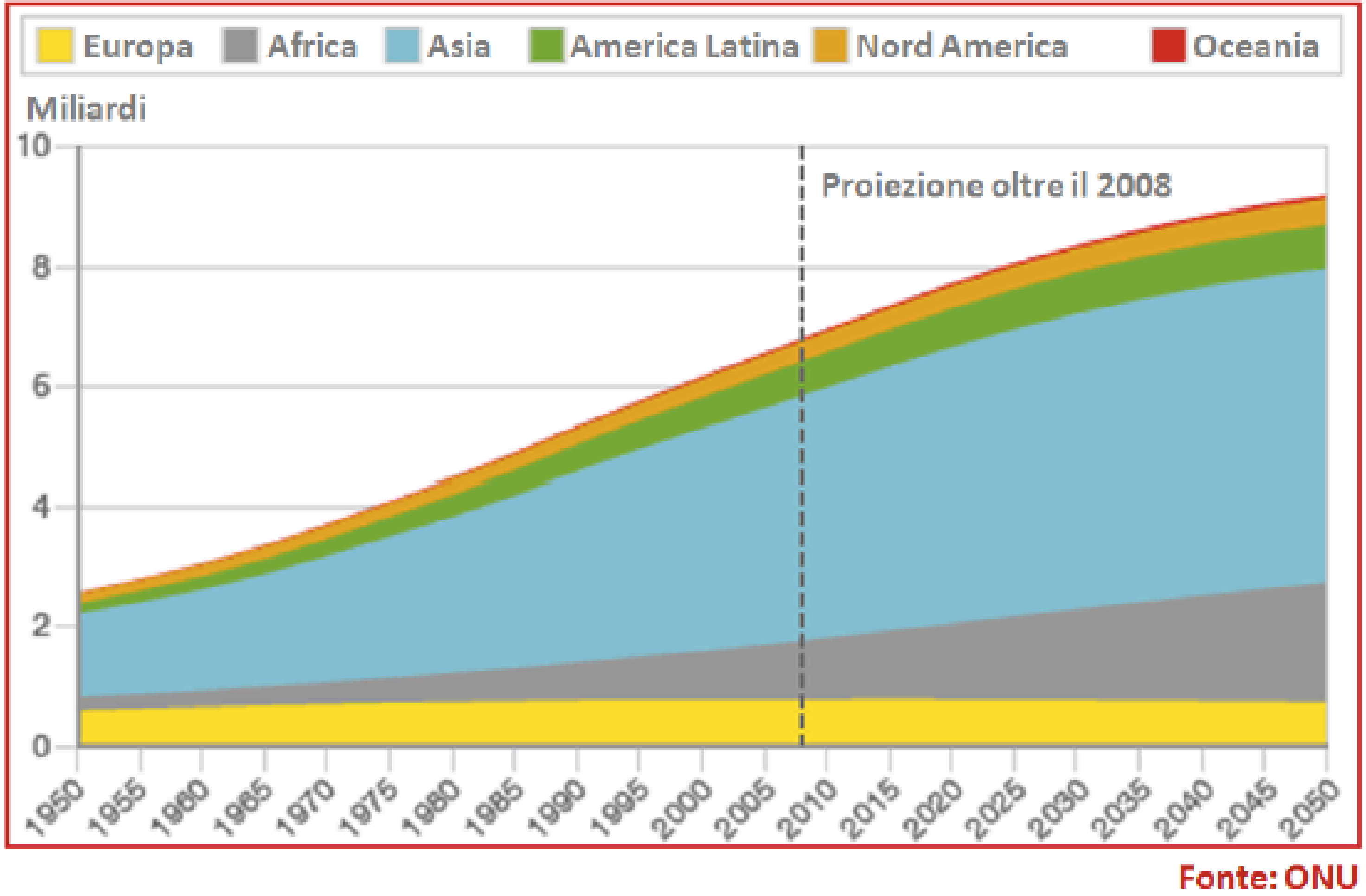
Spread also in industrialized countries

3 billions people

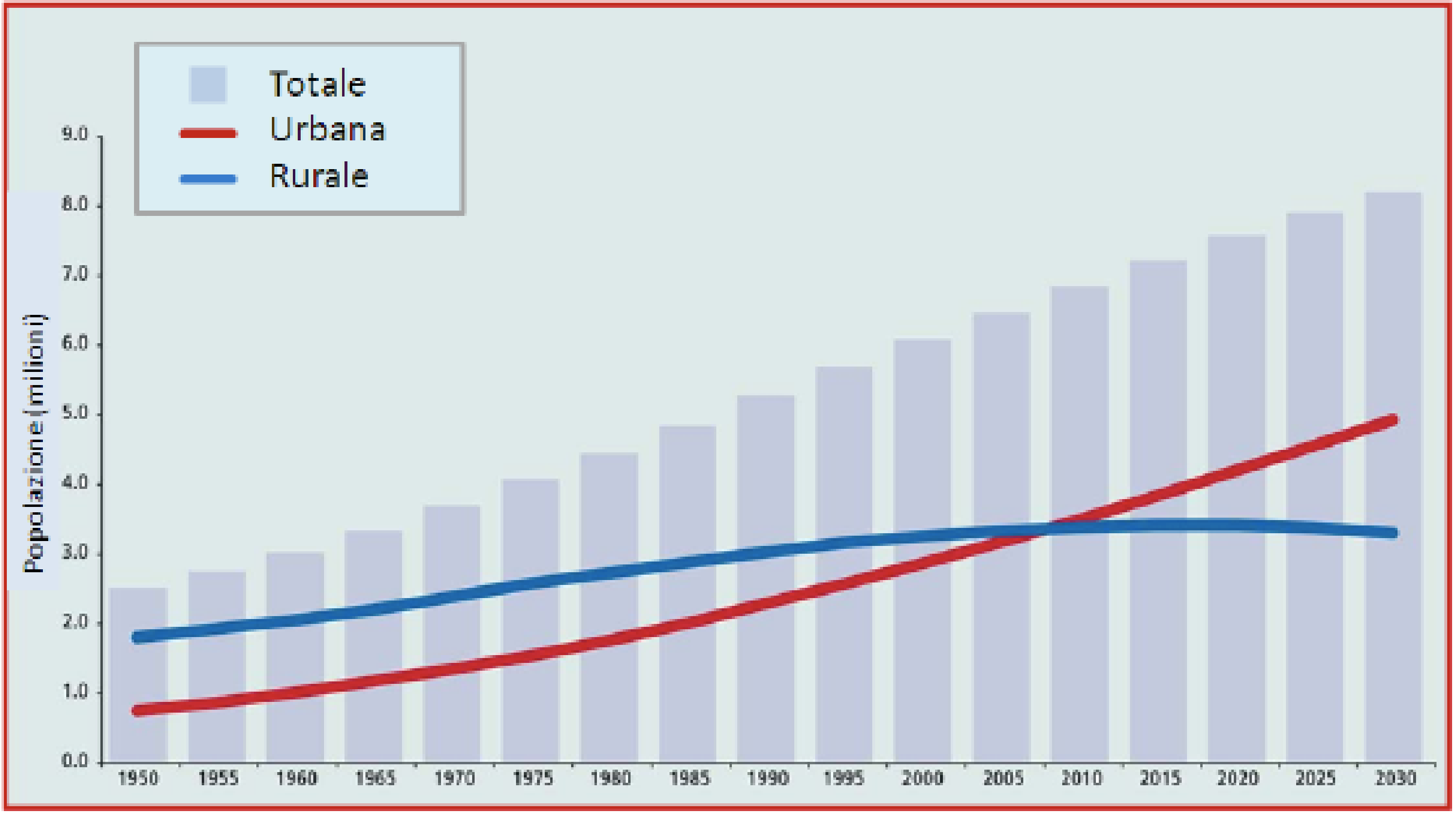
World population

2002, 6 billions

2050, 10 billions

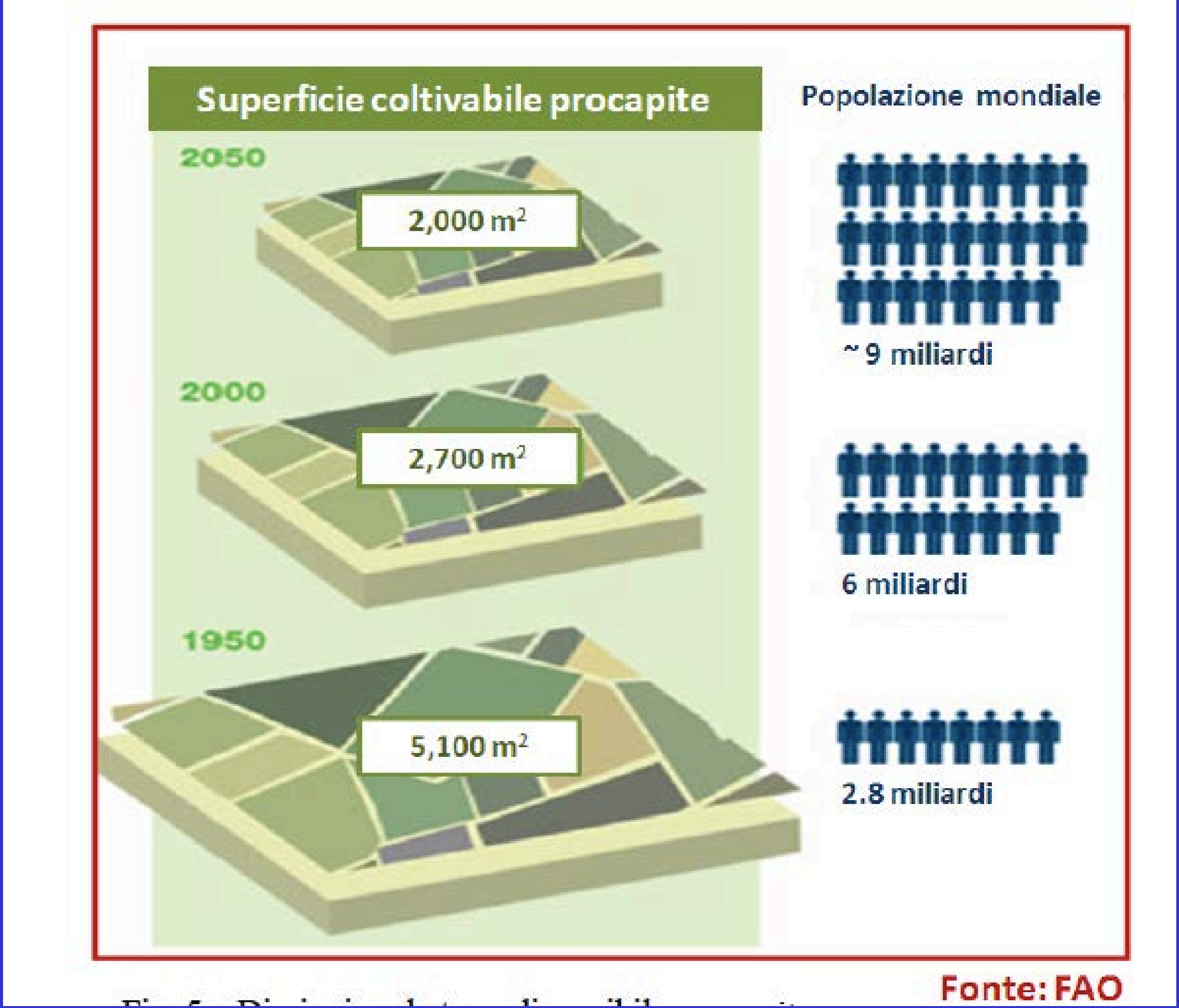


Aumento della popolazione mondiale (dal 1950 al 2050)



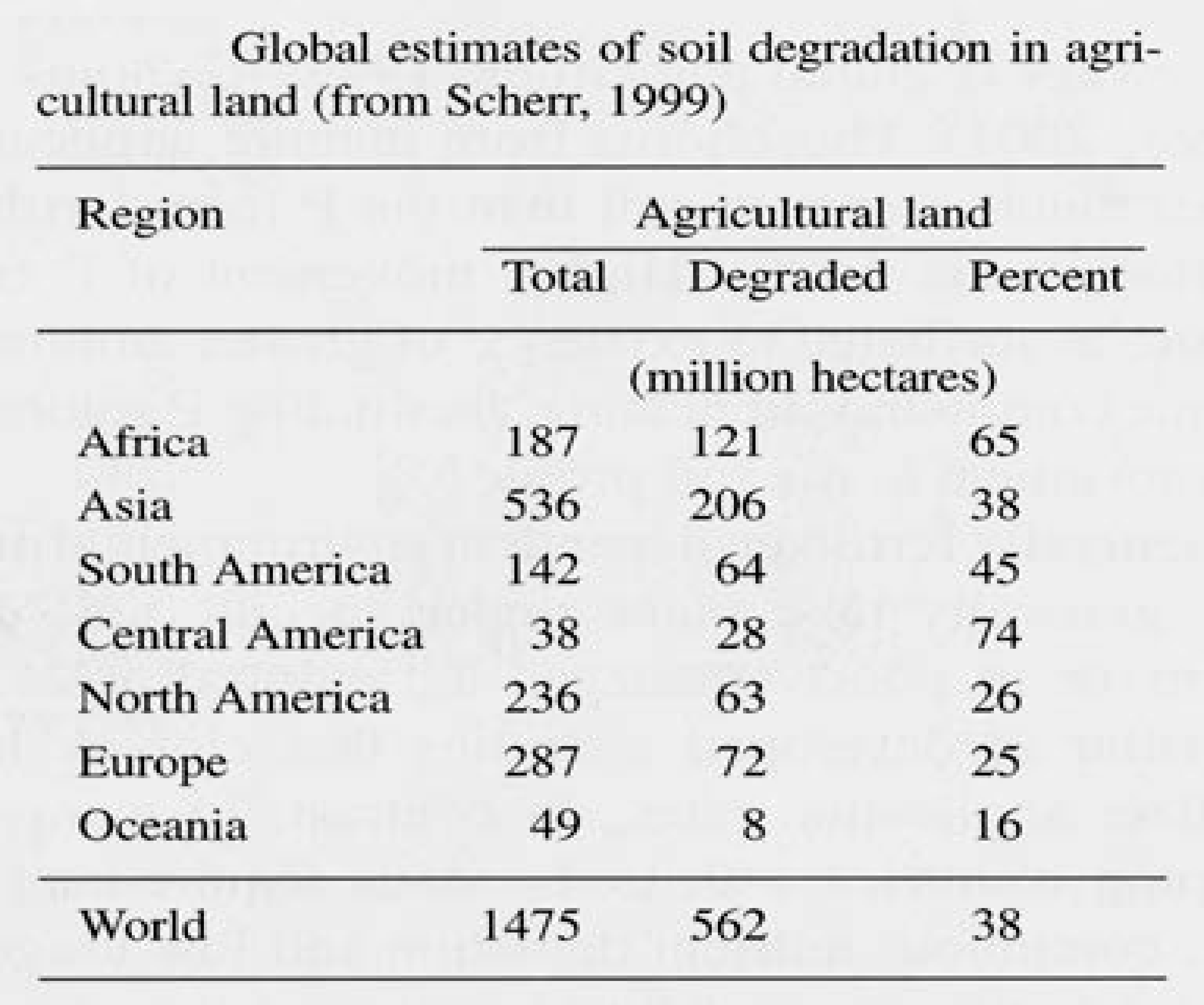
Fonte: ONU

Popolazione mondiale, urbana e rurale (dal 1950 al 2050)



Fonte: FAO

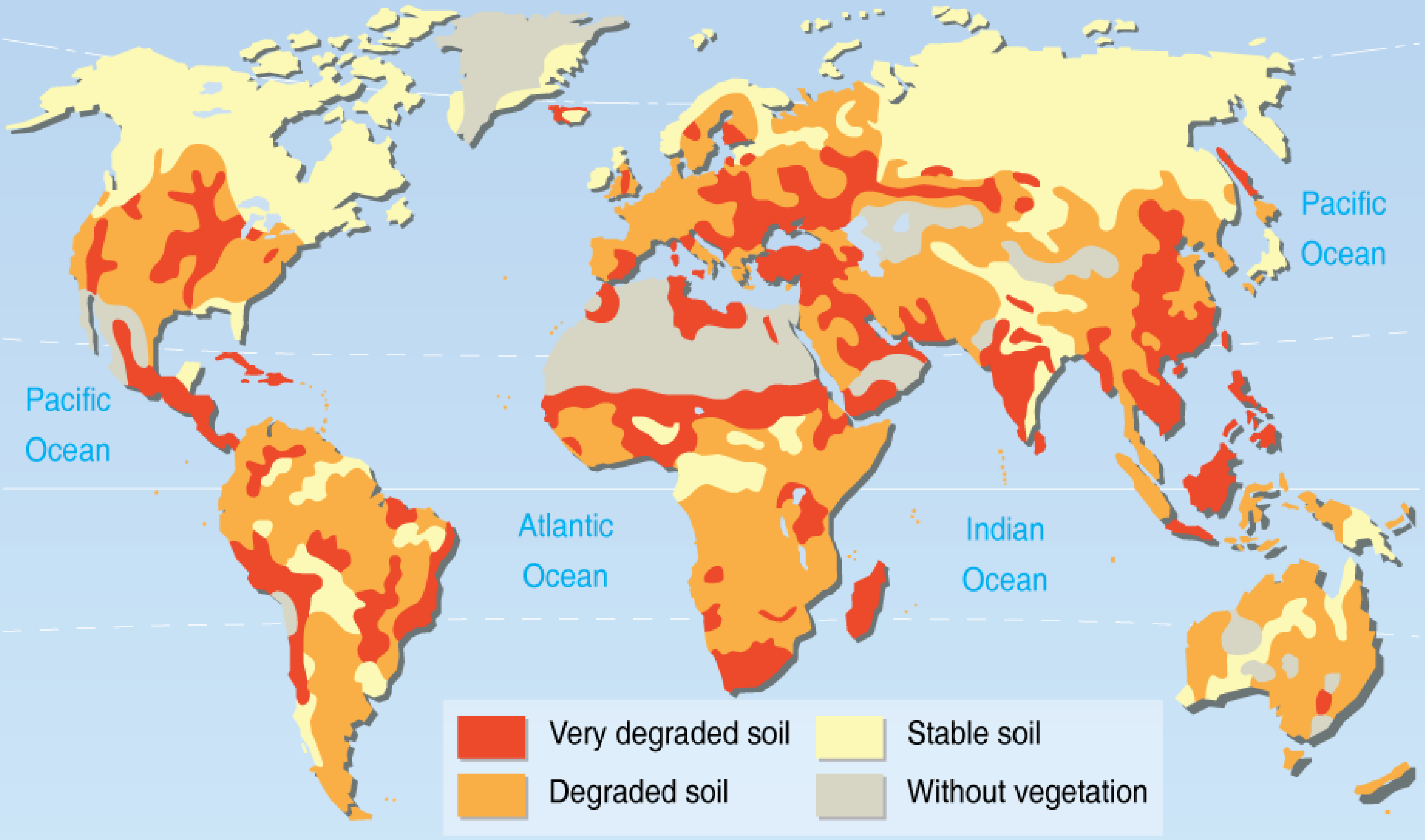
Terra disponibile procapite dal 1959 al 2050



Global estimates of soil degradation in agricultural land (from Scherr, 1999)

Region	Agricultural land		
	Total	Degraded	Percent
	(million hectares)		
Africa	187	121	65
Asia	536	206	38
South America	142	64	45
Central America	38	28	74
North America	236	63	26
Europe	287	72	25
Oceania	49	8	16
World	1475	562	38

Soil degradation



Source: UNEP, International Soil Reference and Information Centre (ISRIC), World Atlas of Desertification, 1997.

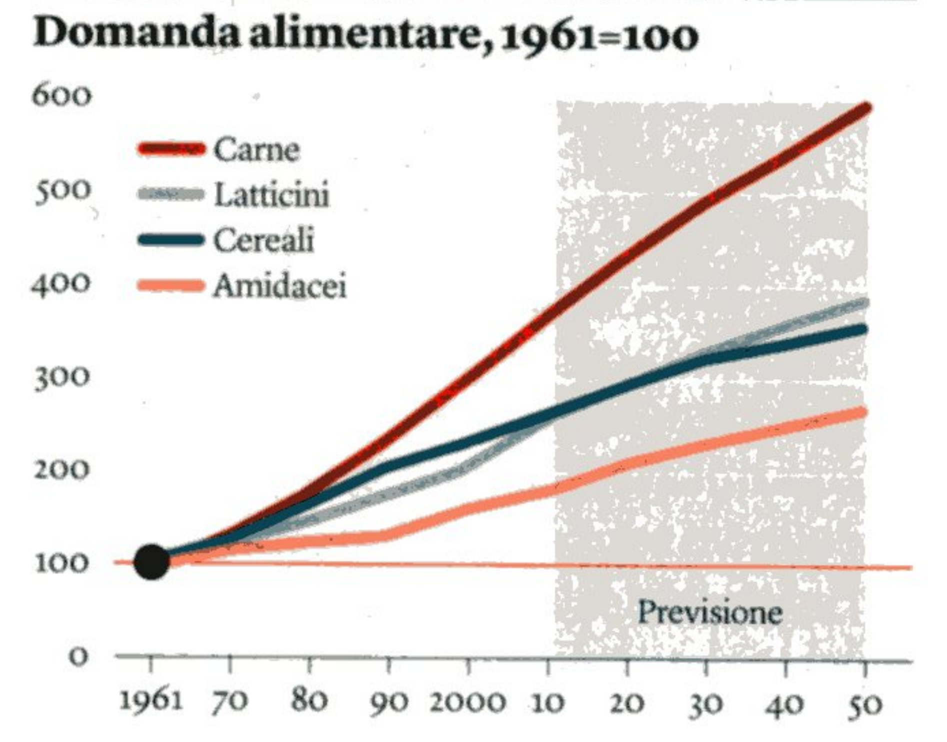
Philippe Rekacewicz, UNEP/GRID-Arendal

Le otto minacce per il Suolo
(Direttiva quadro per la protezione del suolo - C.E. 22/09/2006)

1. Erosione idrica ed eolica
2. Impoverimento della sostanza organica
3. Contaminazione ed inquinamento
4. Consumo di suolo (impermeabilizzazione in seguito ad urbanizzazione e industrializzazione)
5. Compattamento e altre forme di degradazione fisica (croste superficiali impermeabilizzazione)
6. Perdita di produttività e biodiversità
7. Salinizzazioine e sodicizzazione
8. Frane e smottamenti

Secondo dati FAO per soddisfare il fabbisogno mondiale di alimenti la produzione complessiva dovrebbe aumentare del 50% entro il 2030
e raddoppiare entro il 2050

Questo in considerazione anche delle migliorate abitudini alimentari delle classi emergenti che porta ad un maggior consumo di carne.



Per produrre 1kg di carne occorrono circa 10 kg di cereali

Quantità di fertilizzante azotato (Mengel 1993):

1 t di proteine di soia = 400 Kg di N (50% efficienza del fertilizzante N)

1 t di proteine di maiale = 6 t proteine di soia (17% eff.)
= 2400 Kg di N
Una proteina contiene approssimativamente il 16% di N. Nell’ambiente rimangono ($2400_{Nutilizzato}$-$160_{Nrecuperato}$)
2240 Kg di N

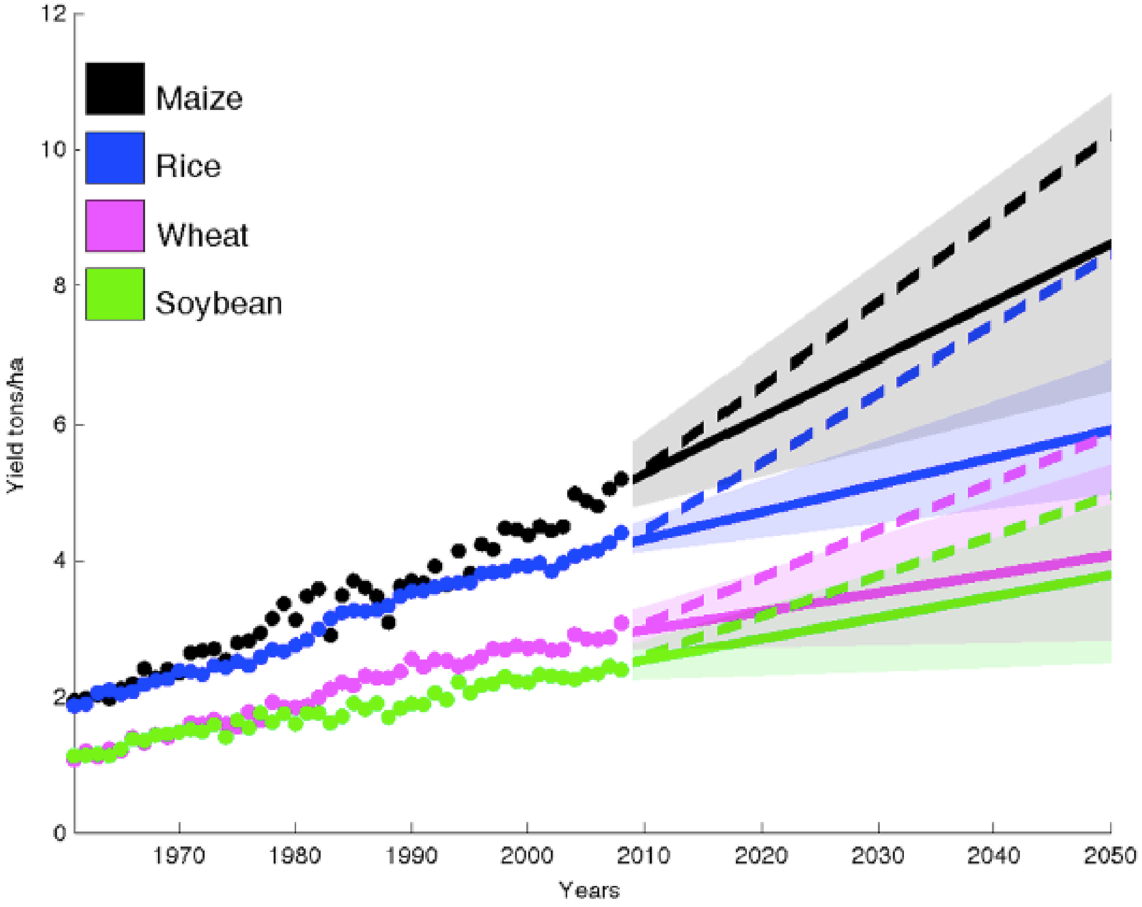
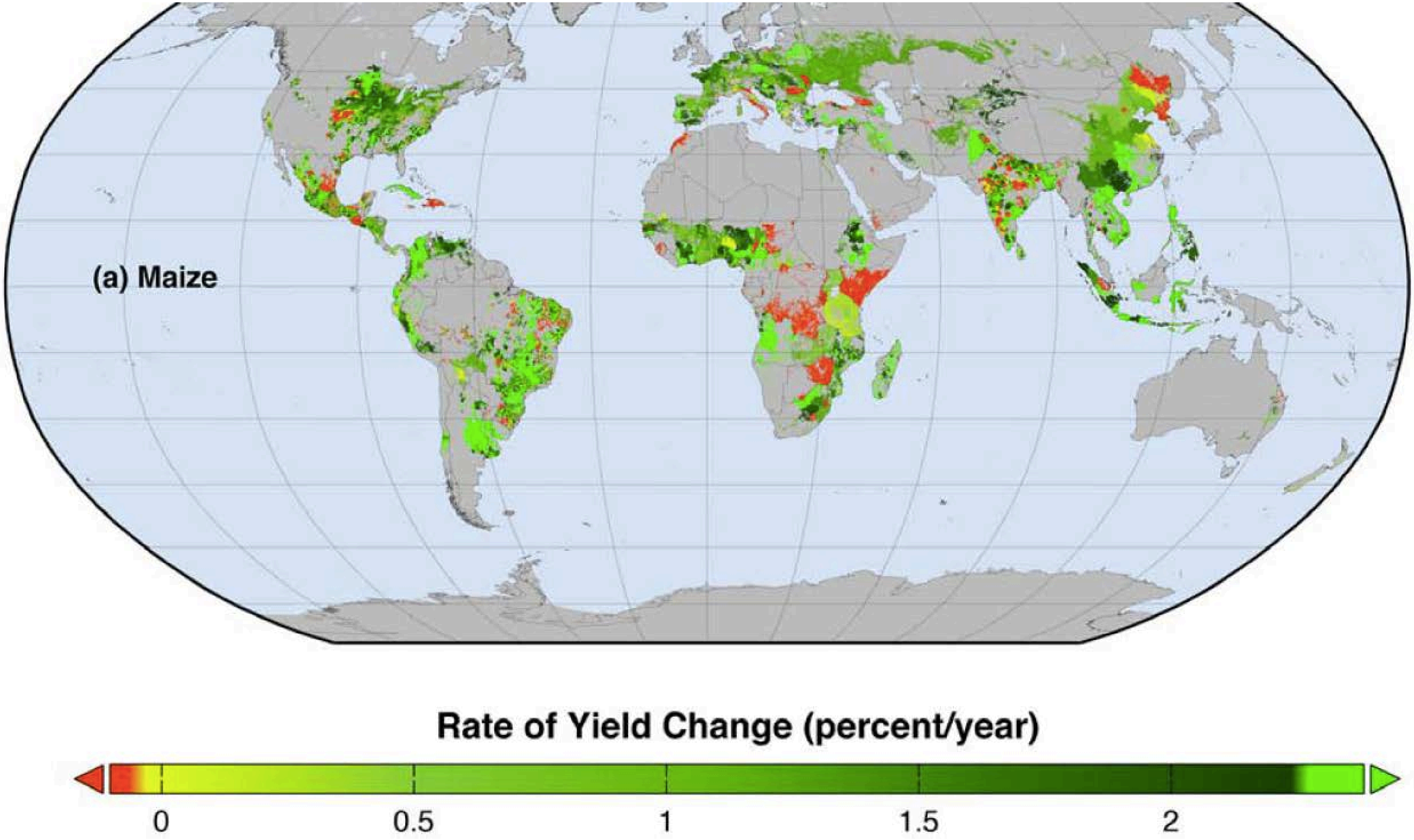


Figure 1. Global projections. Observed area-weighted global yield 1961–2008 shown using closed circles and projections to 2050 using solid lines for maize, rice, wheat, and soybean. Shading shows the 90% confidence region derived from 99 bootstrapped samples. The dashed line shows the trend of the ~2.4% yield improvement required each year to double production in these crops by 2050 without bringing additional land under cultivation starting in the base year of 2008.
doi:10.1371/journal.pone.0066428.g001

Ray et al. 2013


(a) Maize
Rate of Yield Change (percent/year)
0
0.5
1
1.5
2

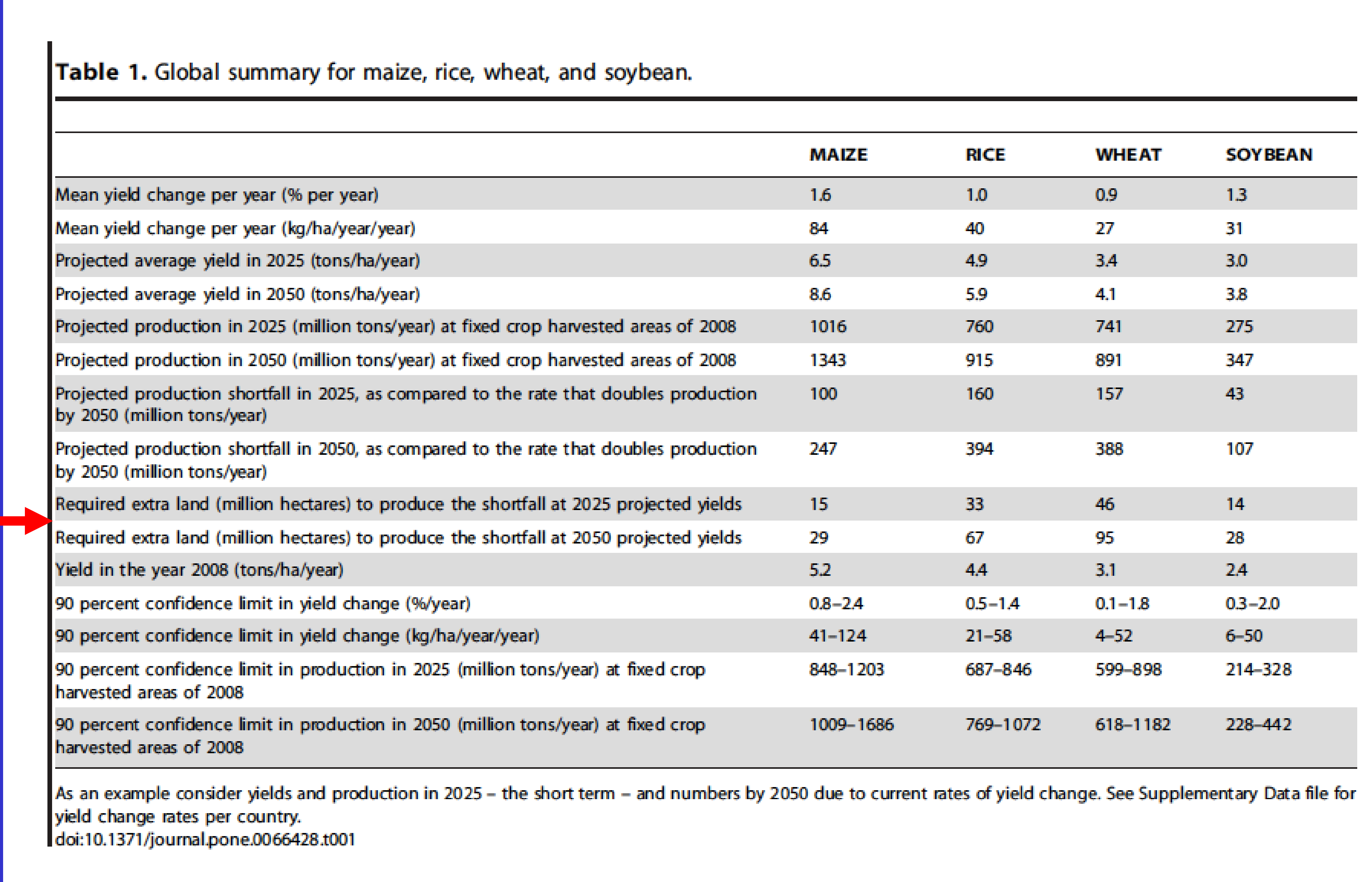


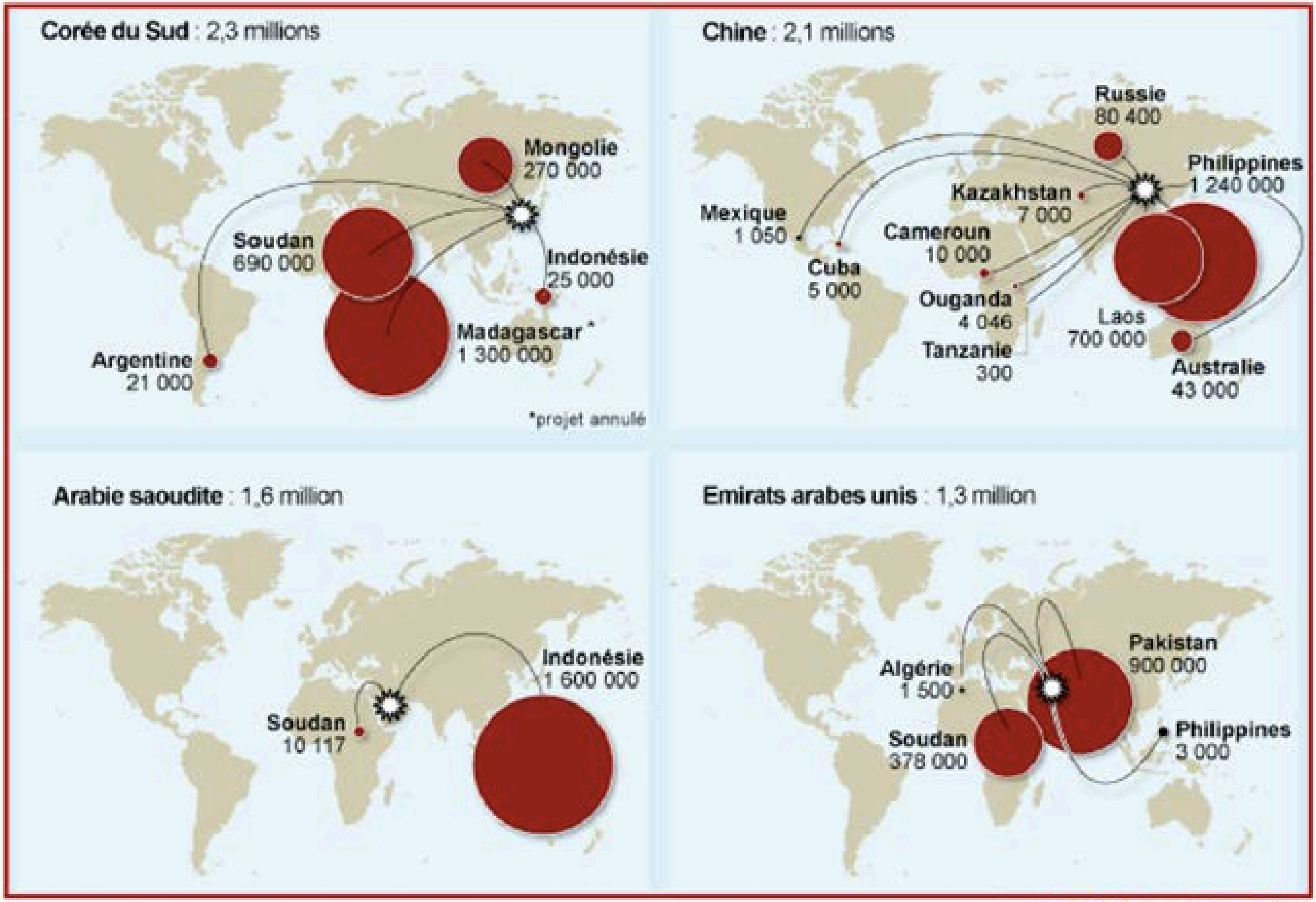
Table 1. Global summary for maize, rice, wheat, and soybean.

	MAIZE	RICE	WHEAT	SOYBEAN
Mean yield change per year (% per year)	1.6	1.0	0.9	1.3
Mean yield change per year (kg/ha/year/year)	84	40	27	31
Projected average yield in 2025 (tons/ha/year)	6.5	4.9	3.4	3.0
Projected average yield in 2050 (tons/ha/year)	8.6	5.9	4.1	3.8
Projected production in 2025 (million tons/year) at fixed crop harvested areas of 2008	1016	760	741	275
Projected production in 2050 (million tons/year) at fixed crop harvested areas of 2008	1343	915	891	347
Projected production shortfall in 2025, as compared to the rate that doubles production by 2050 (million tons/year)	100	160	157	43
Projected production shortfall in 2050, as compared to the rate that doubles production by 2050 (million tons/year)	247	394	388	107
Required extra land (million hectares) to produce the shortfall at 2025 projected yields	15	33	46	14
Required extra land (million hectares) to produce the shortfall at 2050 projected yields	29	67	95	28
Yield in the year 2008 (tons/ha/year)	5.2	4.4	3.1	2.4
90 percent confidence limit in yield change (%/year)	0.8–2.4	0.5–1.4	0.1–1.8	0.3–2.0
90 percent confidence limit in yield change (kg/ha/year/year)	41–124	21–58	4–52	6–50
90 percent confidence limit in production in 2025 (million tons/year) at fixed crop harvested areas of 2008	848–1203	687–846	599–898	214–328
90 percent confidence limit in production in 2050 (million tons/year) at fixed crop harvested areas of 2008	1009–1686	769–1072	618–1182	228–442

As an example consider yields and production in 2025 – the short term – and numbers by 2050 due to current rates of yield change. See Supplementary Data file for yield change rates per country.

doi:10.1371/journal.pone.0066428.t001

Ray et al. 2013



Fonte: grain.org

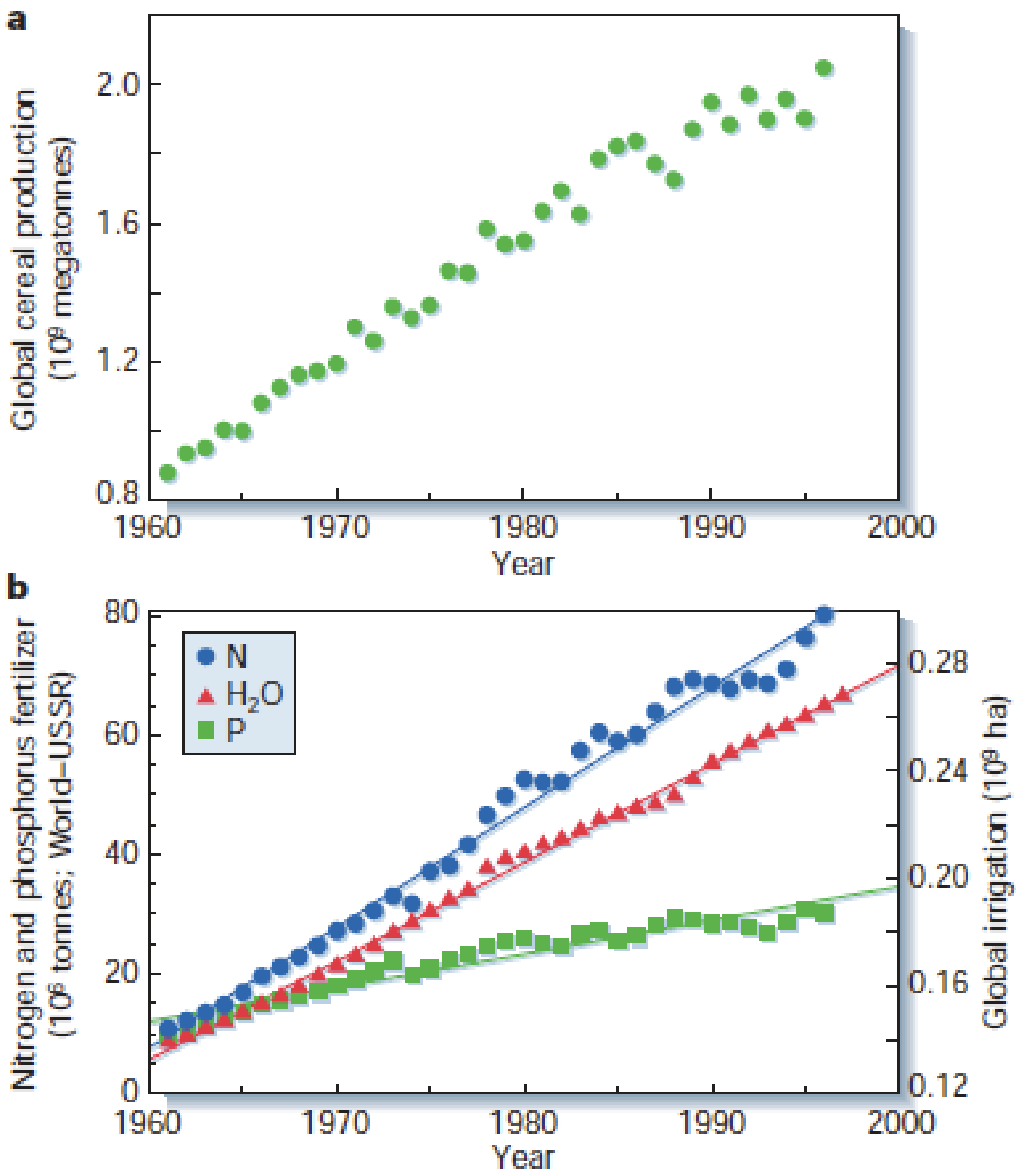
Acquisizione uso terre coltivabili da alcuni paesi (ha)

Aumentare la produttività:

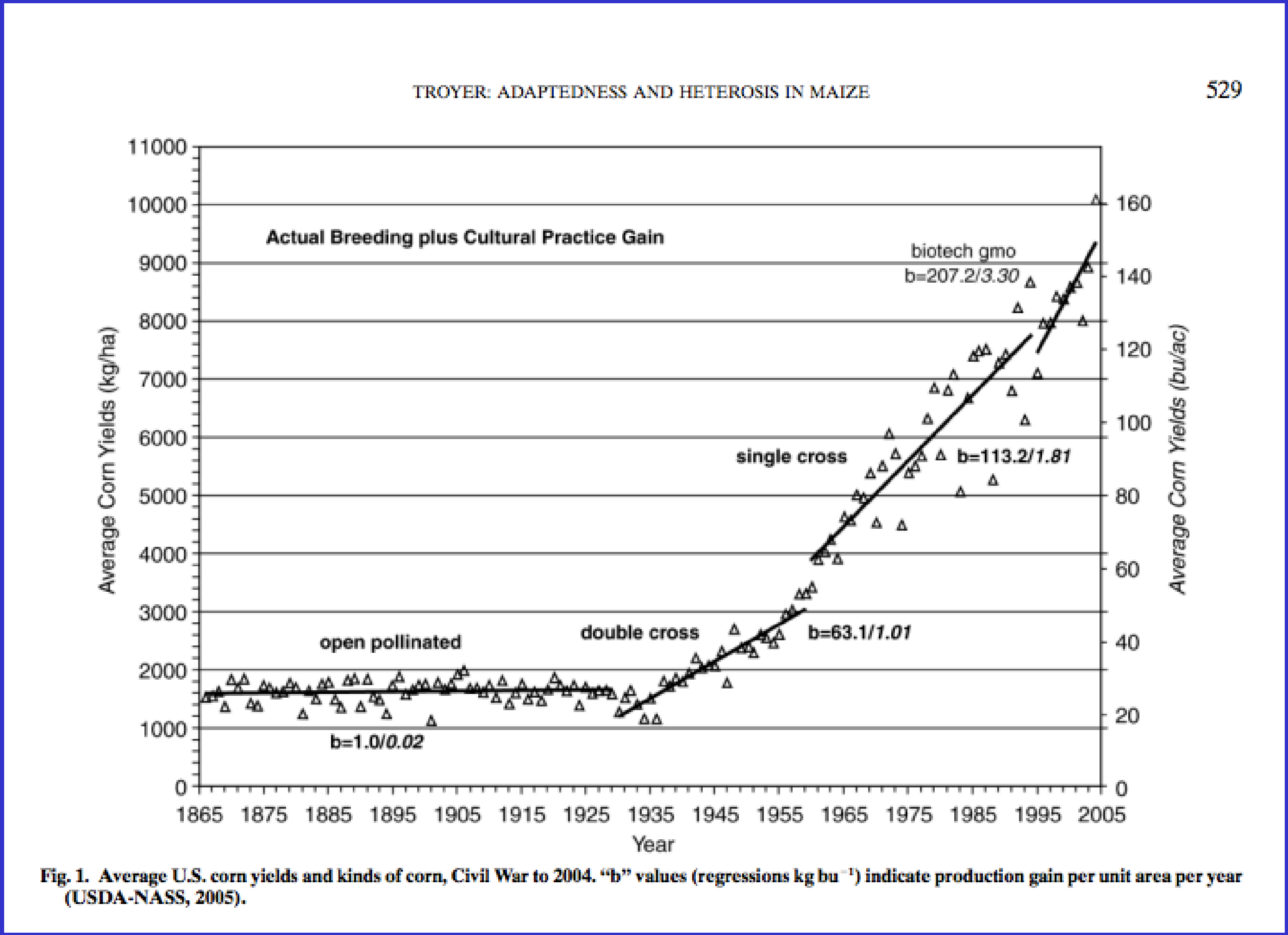
Input “chimici”, acqua …

Migliorare le piante….

Nel rispetto della sostenibilità


a
Global cereal production (10^9 megatonnes)
0.8
1.2
1.6
2.0
1960
1970
1980
1990
2000
Year
b
Nitrogen and phosphorus fertilizer (10^6 tonnes; World–USSR)
0
20
40
60
80
● N
▲ H_2O
■ P
Global irrigation (10^9 ha)
0.12
0.16
0.20
0.24
0.28
1960
1970
1980
1990
2000
Year

(Tilman, 2002)

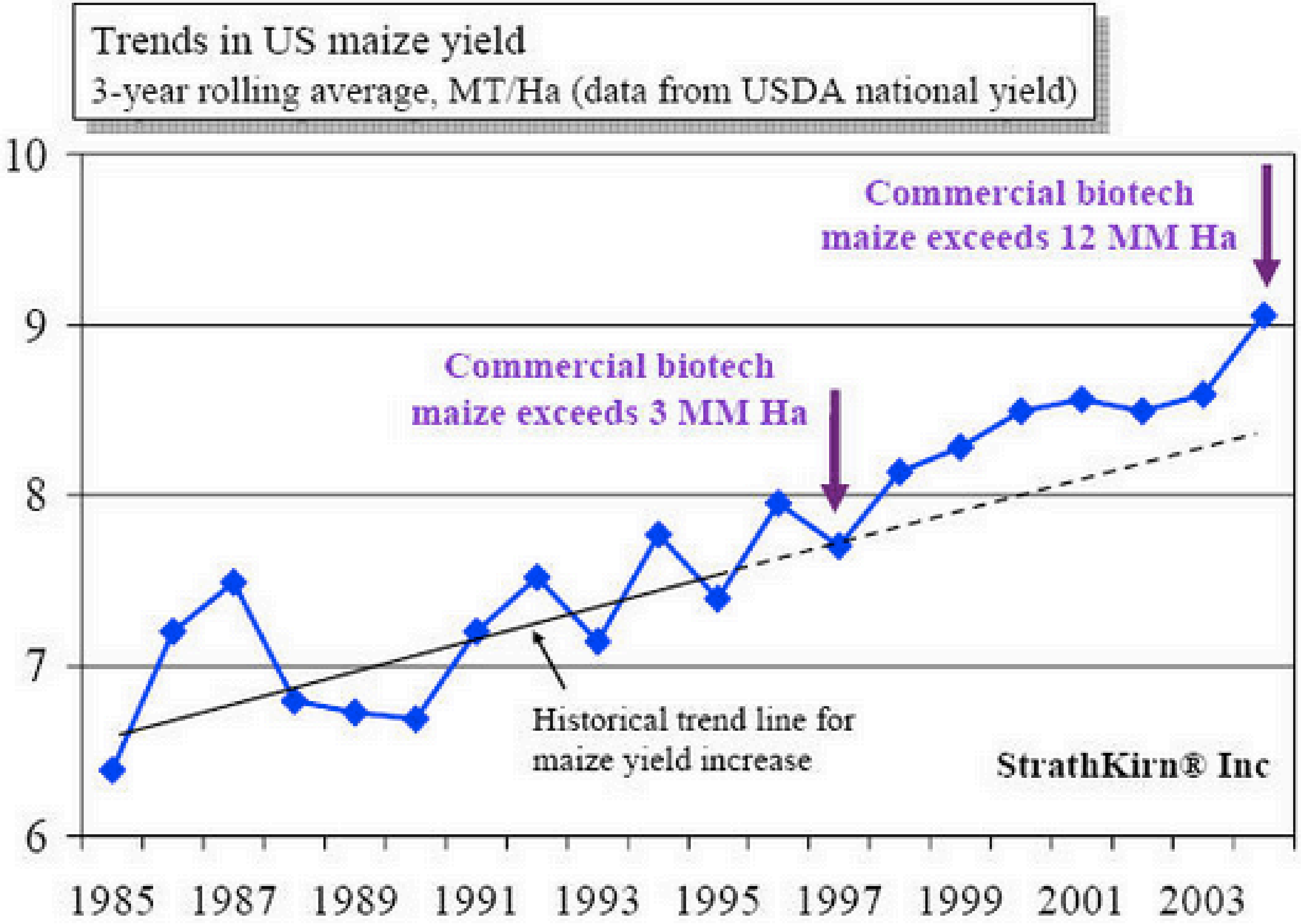


TROYER: ADAPTEDNESS AND HETEROSIS IN MAIZE 529

Fig. 1. Average U.S. corn yields and kinds of corn, Civil War to 2004. "b" values (regressions kg bu^{-1}) indicate production gain per unit area per year (USDA-NASS, 2005).

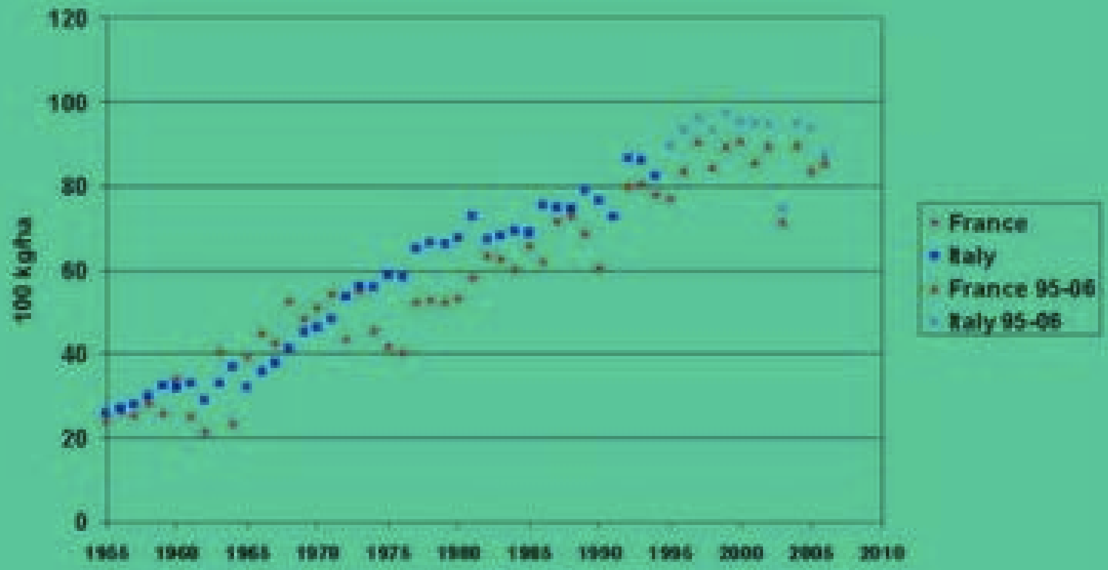
Troyer 2006

Si considera che metà dell' aumento produttivo realizzato a partire dagli anni 50 ad oggi sia dovuto all' aumento/miglioramento nell' uso di mezzi tecnici, l' altra metà al miglioramento genetico



We analyzed the annual US maize yields, using published USDA data, and found that from around 1997 onwards: A) the yield increase trend was above the historical trend line, B) annual yield variability appeared to be much less. The adoption of the first biotech maize is associated with these changes.

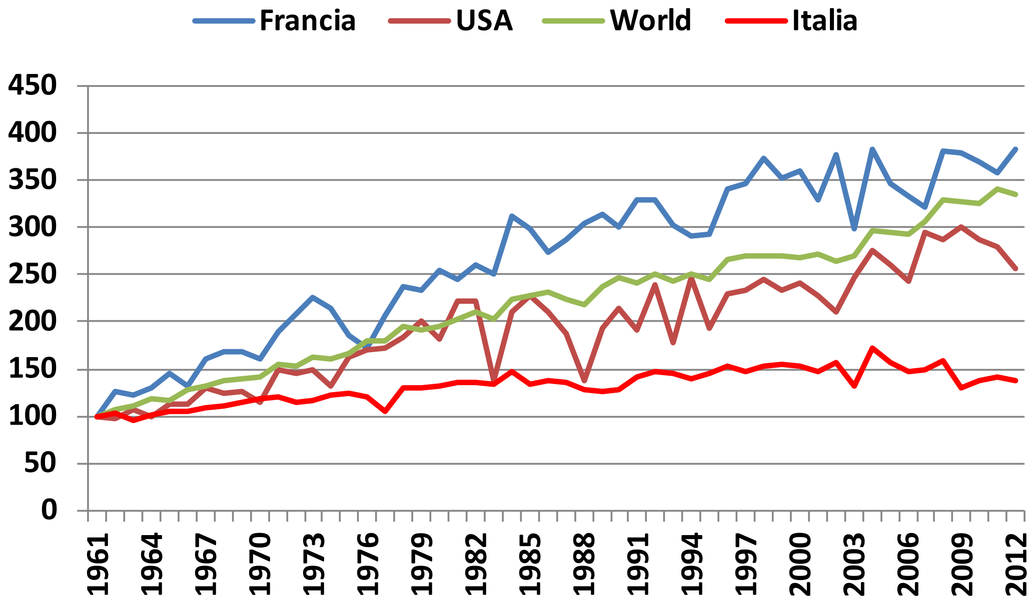
corn yields in France and Italy in the last 10 years fail to show the same trend



Source, Eurostat

Evoluzione dei cereali: situazioni a Confronto (indice 1961=100)

FAO STAT (2013)



Importazione delle principali colture (2012)

INEA (2013)

Coltura	**Importazione (%)**
Frumento tenero	64
Frumento duro	37
Mais	21
Riso	●
Orzo	48
Totale*	45

* comprensivo di soia, girasole e colza

La produzione nazionale di cereali è simile da 50 anni a fronte di un aumento dei consumi del 70%

Il sistema agro-alimentare è sempre più dipendente dalle importazioni

Reyneri e Blandino (2013)

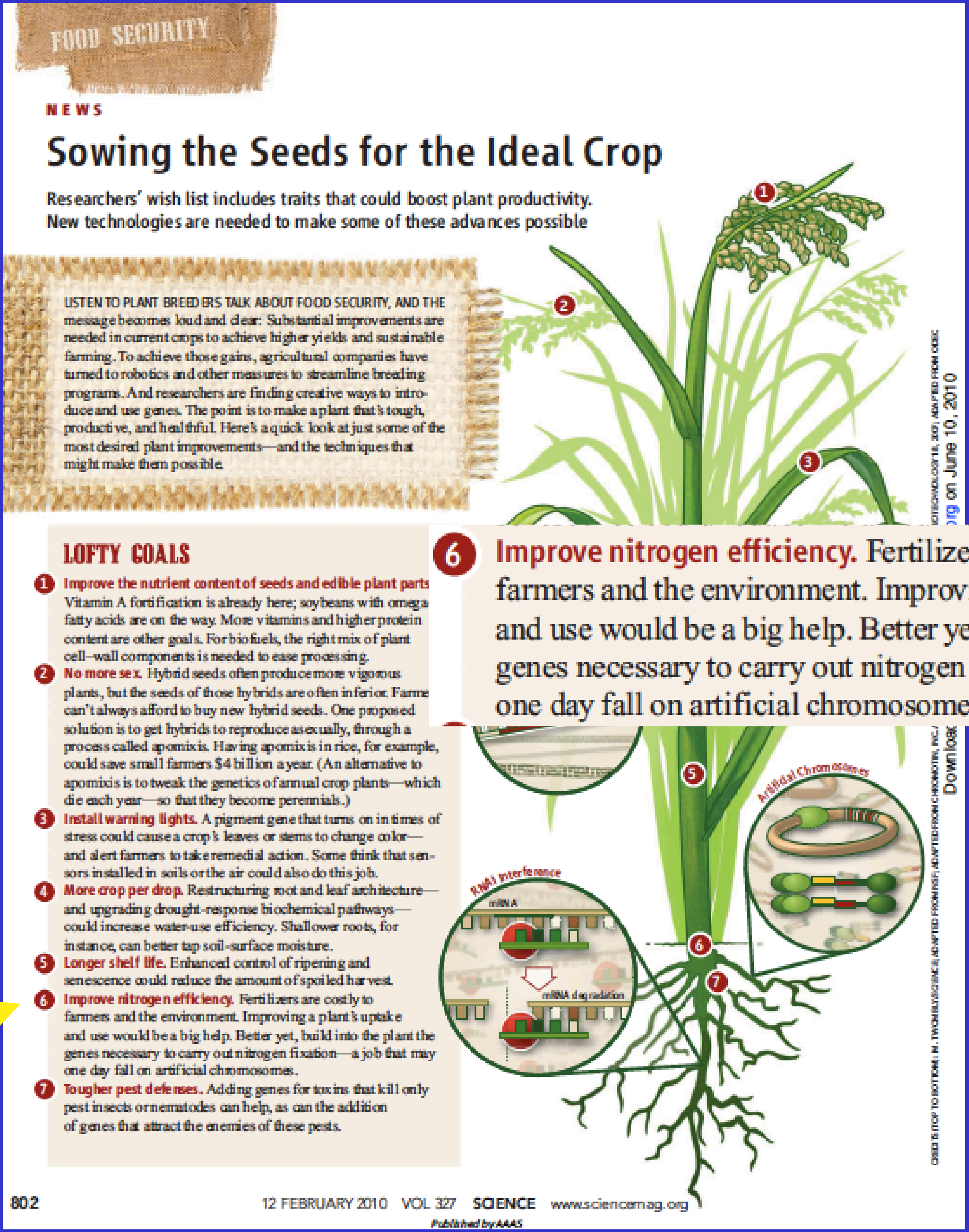
Per far fronte alle richieste alimentari e prevenire la degradazione dell' ambiente occorrono piante con:

- Capacità di raggiungere livelli produttivi adeguati anche in condizioni ambientali sfavorevoli

- Maggior capacità di accumulo di nutrienti

- Maggior efficienza d' uso dei nutrienti

Questi obiettivi richiedono la comprensione dei meccanismi con cui le piante acquisiscono gli elementi nutritivi dal suolo e li utilizzano al loro interno



NEWS

Sowing the Seeds for the Ideal Crop

Researchers' wish list includes traits that could boost plant productivity. New technologies are needed to make some of these advances possible

LISTEN TO PLANT BREEDERS TALK ABOUT FOOD SECURITY, AND THE message becomes loud and clear: Substantial improvements are needed in current crops to achieve higher yields and sustainable farming. To achieve those gains, agricultural companies have turned to robotics and other measures to streamline breeding programs. And researchers are finding creative ways to introduce and use genes. The point is to make a plant that's tough, productive, and healthful. Here's a quick look at just some of the most desired plant improvements—and the techniques that might make them possible.

LOFTY GOALS

① **Improve the nutrient content of seeds and edible plant parts** Vitamin A fortification is already here; soybeans with omega fatty acids are on the way. More vitamins and higher protein content are other goals. For biofuels, the right mix of plant cell–wall components is needed to ease processing.

② **No more sex.** Hybrid seeds often produce more vigorous plants, but the seeds of those hybrids are often inferior. Farme can't always afford to buy new hybrid seeds. One proposed solution is to get hybrids to reproduce asexually, through a process called apomixis. Having apomixis in rice, for example, could save small farmers $4 billion a year. (An alternative to apomixis is to tweak the genetics of annual crop plants—which die each year—so that they become perennials.)

③ **Install warning lights.** A pigment gene that turns on in times of stress could cause a crop's leaves or stems to change color—and alert farmers to take remedial action. Some think that sensors installed in soils or the air could also do this job.

④ **More crop per drop.** Restructuring root and leaf architecture—and upgrading drought-response biochemical pathways—could increase water-use efficiency. Shallower roots, for instance, can better tap soil-surface moisture.

⑤ **Longer shelf life.** Enhanced control of ripening and senescence could reduce the amount of spoiled harvest.

⑥ **Improve nitrogen efficiency.** Fertilizers are costly to farmers and the environment. Improving a plant's uptake and use would be a big help. Better yet, build into the plant the genes necessary to carry out nitrogen fixation—a job that may one day fall on artificial chromosomes.

⑦ **Tougher pest defenses.** Adding genes for toxins that kill only pest insects or nematodes can help, as can the addition of genes that attract the enemies of these pests.

Published by AAAS

⑥ **Improve nitrogen efficiency.** Fertilizers are costly to farmers and the environment. Improving a plant's uptake and use would be a big help. Better yet, build into the plant the genes necessary to carry out nitrogen fixation—a job that may one day fall on artificial chromosomes.

NATURE|Vol 466|29 July 2010

AN UNDERGROUND REVOLUTION

Plant breeders are turning their attention to roots to increase yields without causing environmental damage. **Virginia Gewin** unearths some promising subterranean strategies.

Desirable plant characteristics for a sustainable soil-plant system

- High uptake rates at low nutrient concentration in soil solution

- Efficient solubilization of sparingly available nutrient at the rizosphere

- Architecture of root system able to optimize nutrient capture

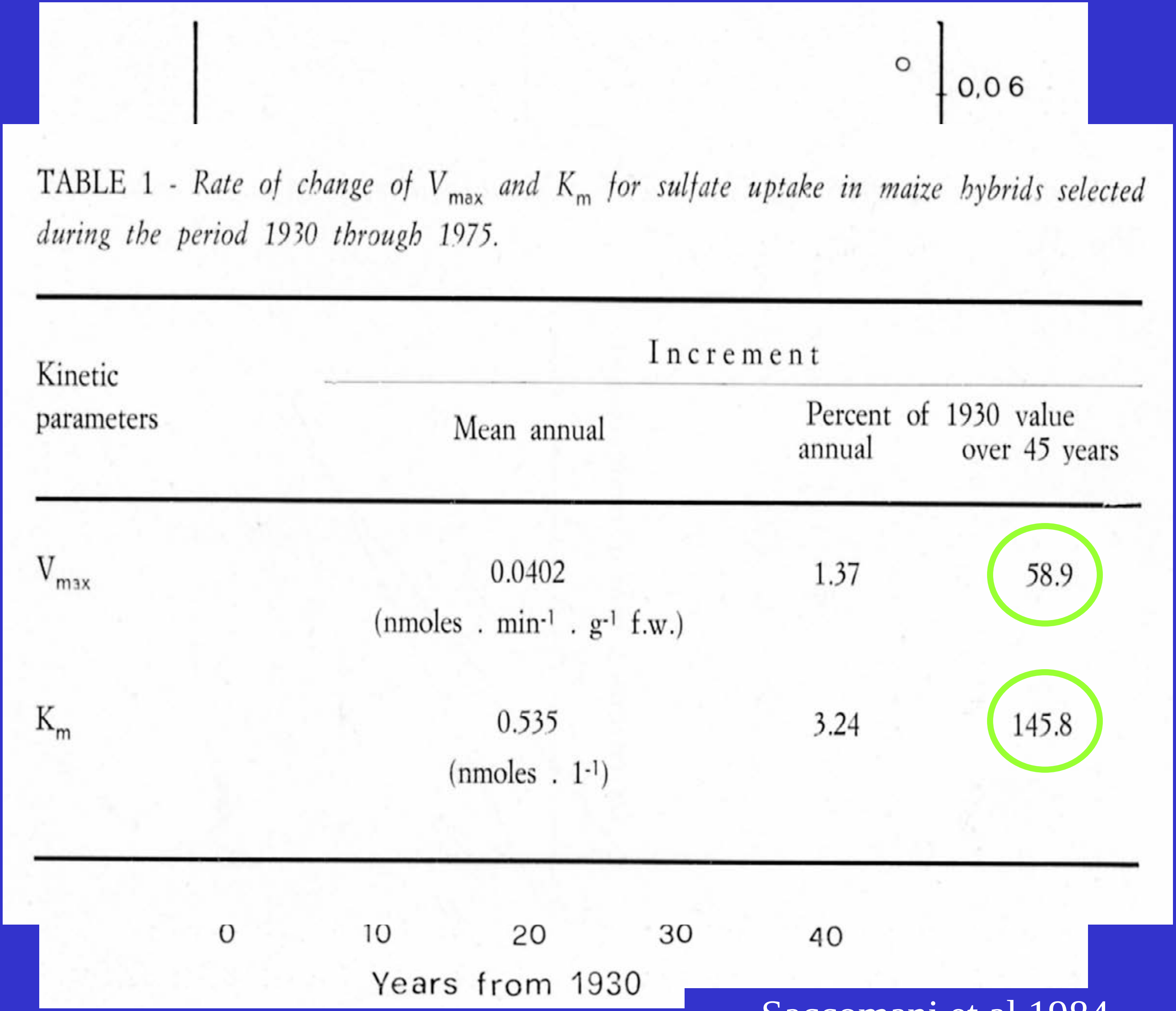
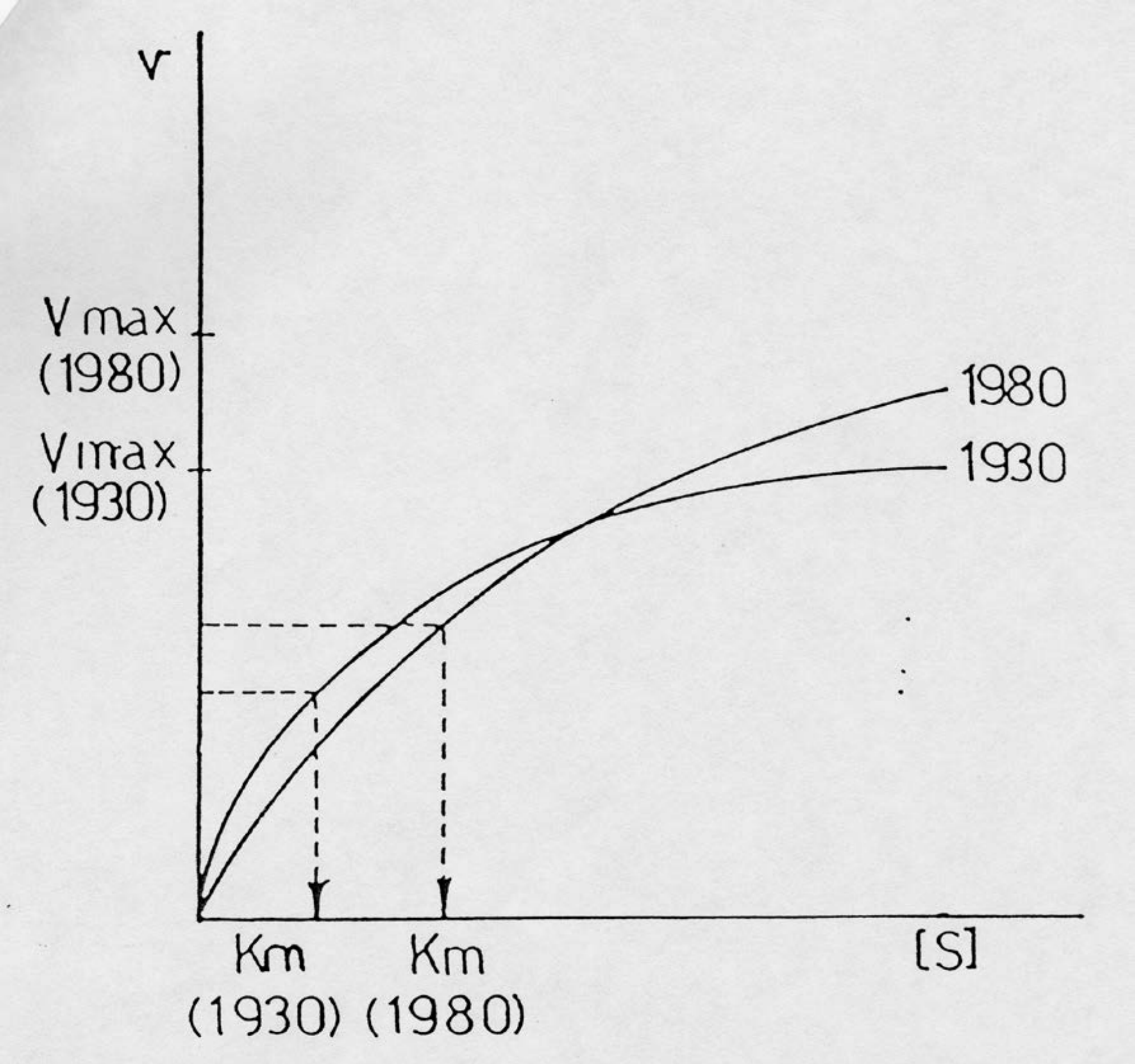


TABLE 1 - *Rate of change of V_{max} and K_m for sulfate uptake in maize hybrids selected during the period 1930 through 1975.*

Kinetic parameters	Increment		
	Mean annual	Percent of 1930 value annual	Percent of 1930 value over 45 years
V_{max}	0.0402 (nmoles . min^{-1} . g^{-1} f.w.)	1.37	58.9
K_m	0.535 (nmoles . 1^{-1})	3.24	145.8

Saccomani et al 1984

Sulphate transport rate



Il caso dell’azoto

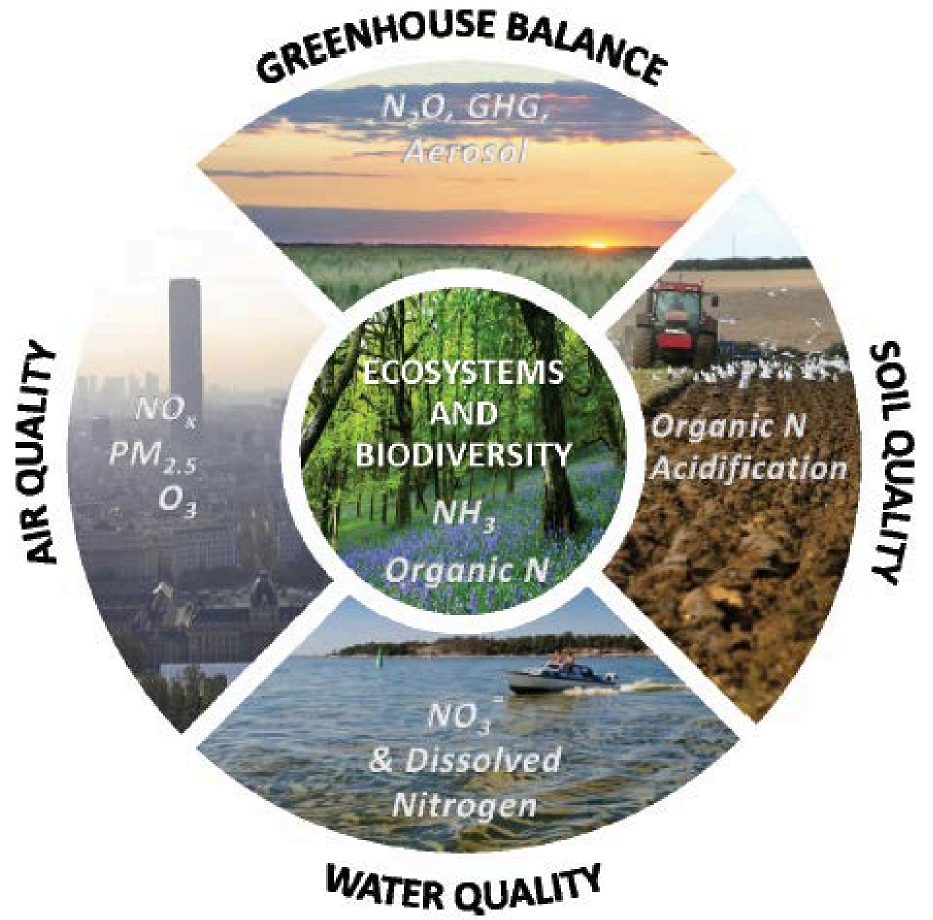


Figure SPM.7 Summary of the five key societal threats of excess reactive nitrogen, drawn in analogy to the 'elements' of classical Greek cosmology. The main chemical forms associated with each threat are shown [5.4]. *Photo sources*: Shutterstock.com and garysmithphotography.co.uk.

Sutton et al 2011

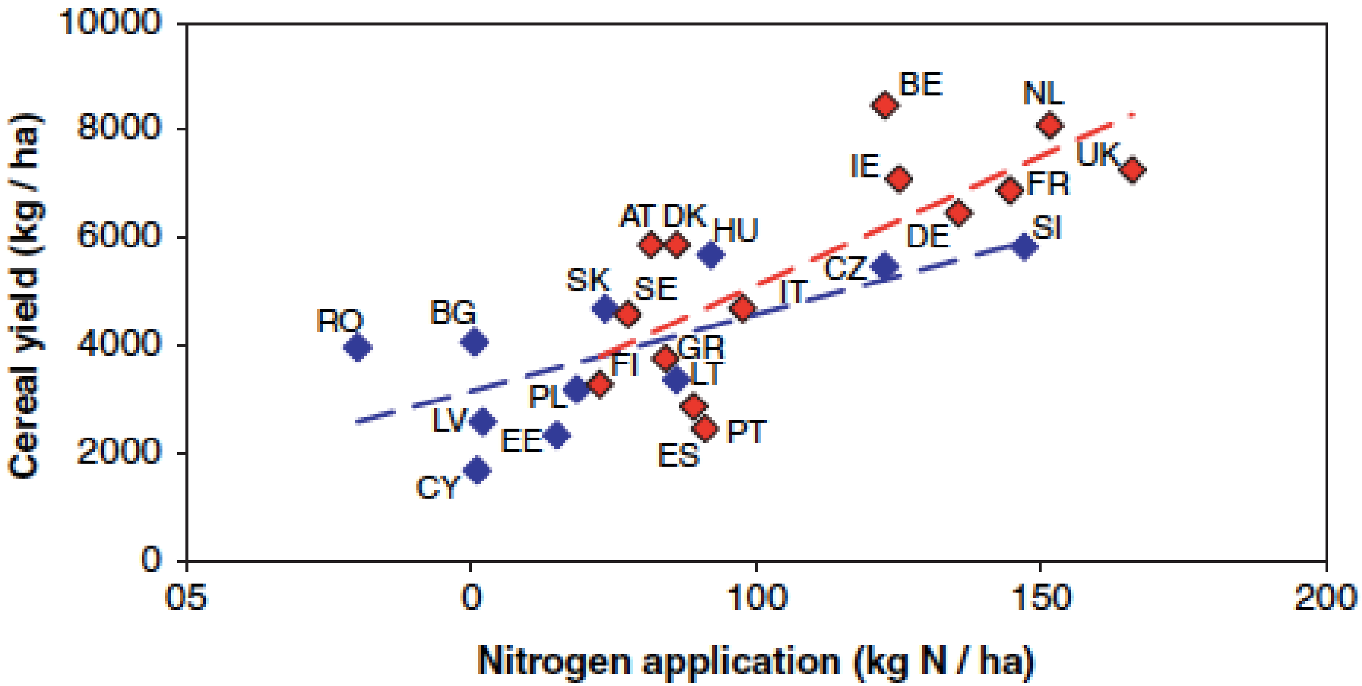
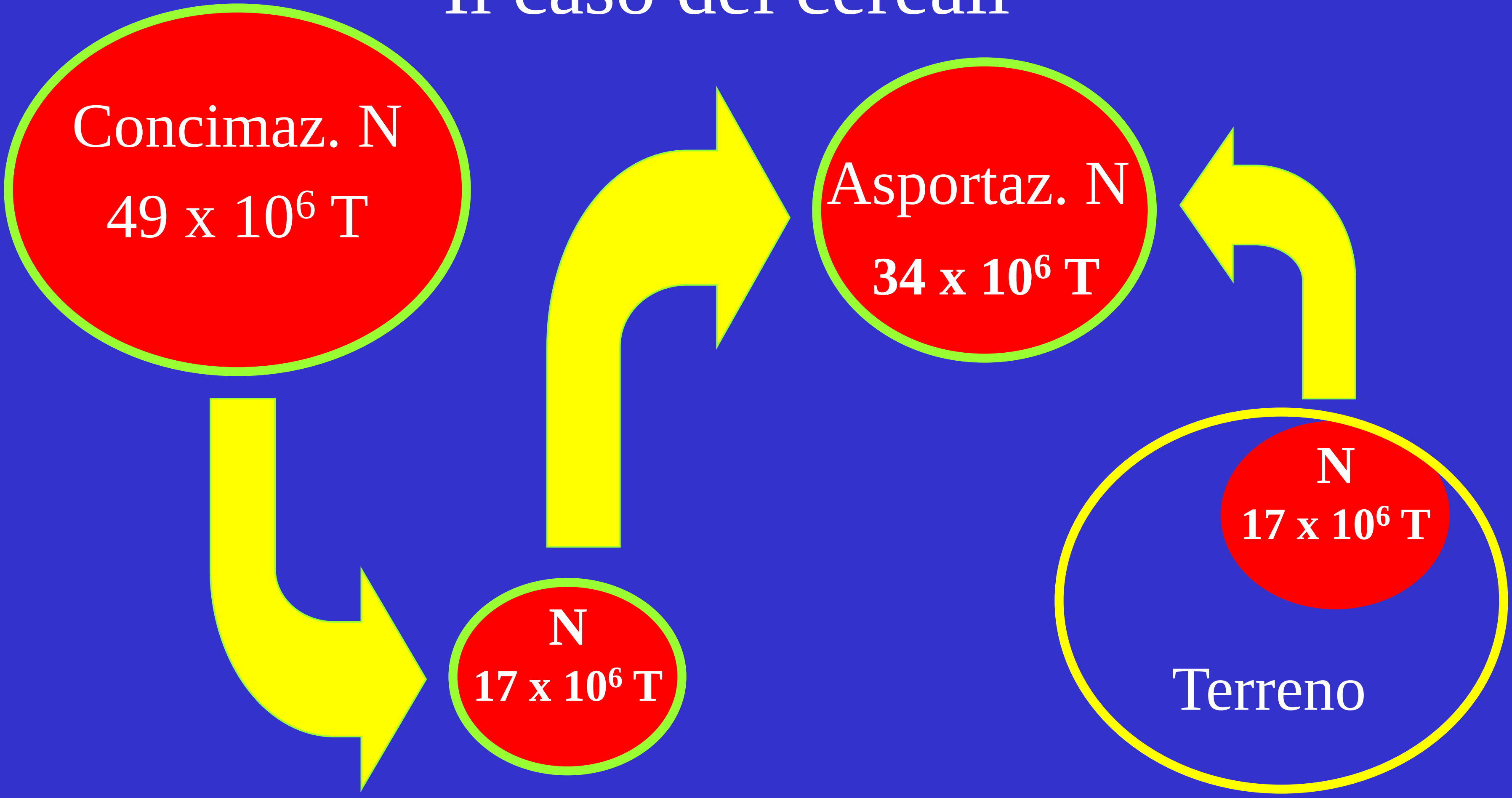


Figure SPM.5 Variation of nitrogen fertilizer use on winter wheat across the European Union (EU 15: blue, EU 12: red) around the year 2000. The variation indicates that there is substantial scope to increase performance and reduce environmental effects [3.2].

Sutton et al 2011

Il caso dei cereali



Concimaz. N

49×10^6 T

Asportaz. N

34×10^6 T

N

17×10^6 T

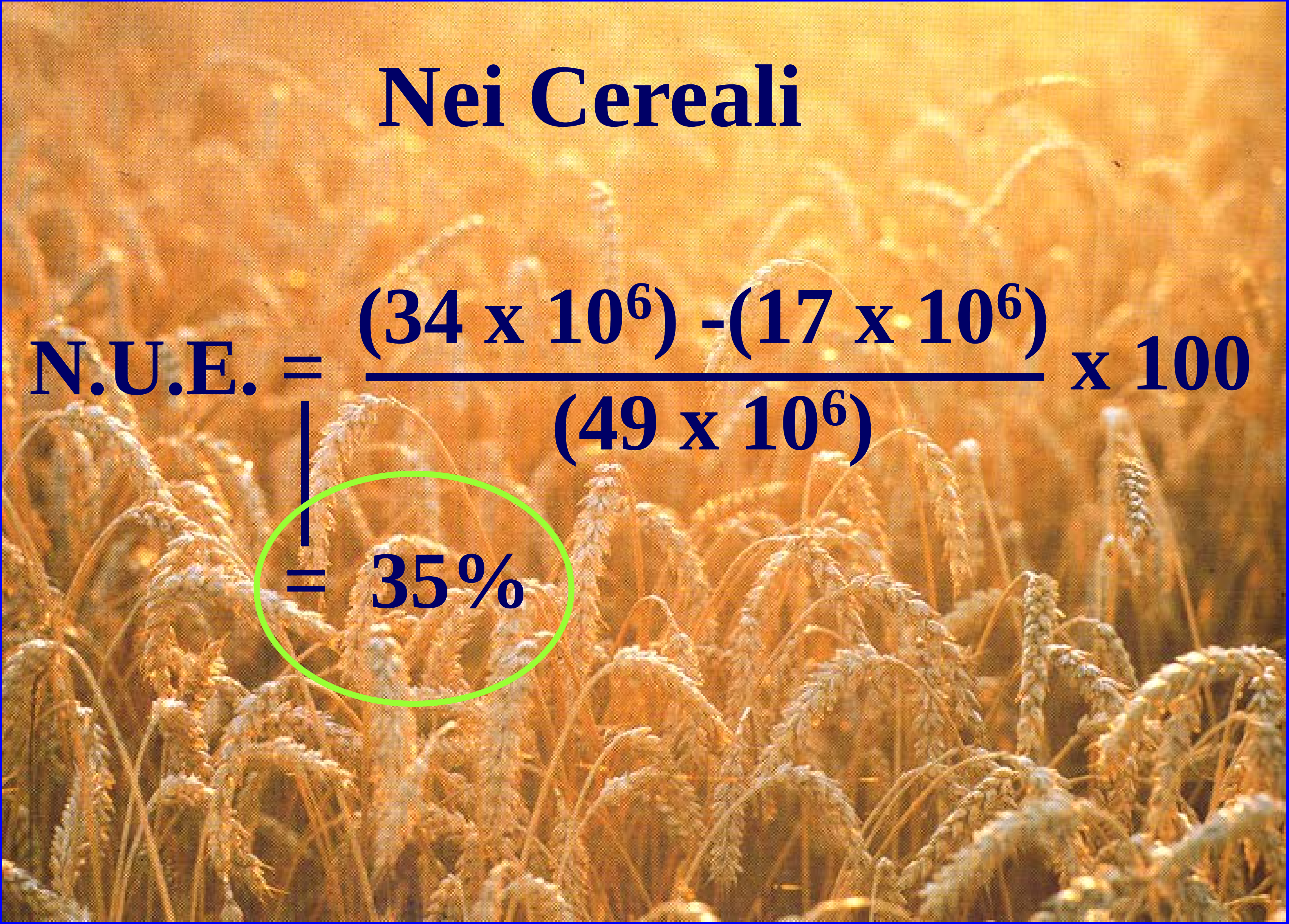
N

17×10^6 T

Terreno

$$\text{N.U.E.} = \frac{(\text{N}_{\text{tot. asport.}}) - (\text{N}_{\text{dal terreno}} + \text{N}_{\text{depositato con eventi atm.}})}{(\text{N}_{\text{fornito con le fertilizzazioni}})}$$

Nei Cereali

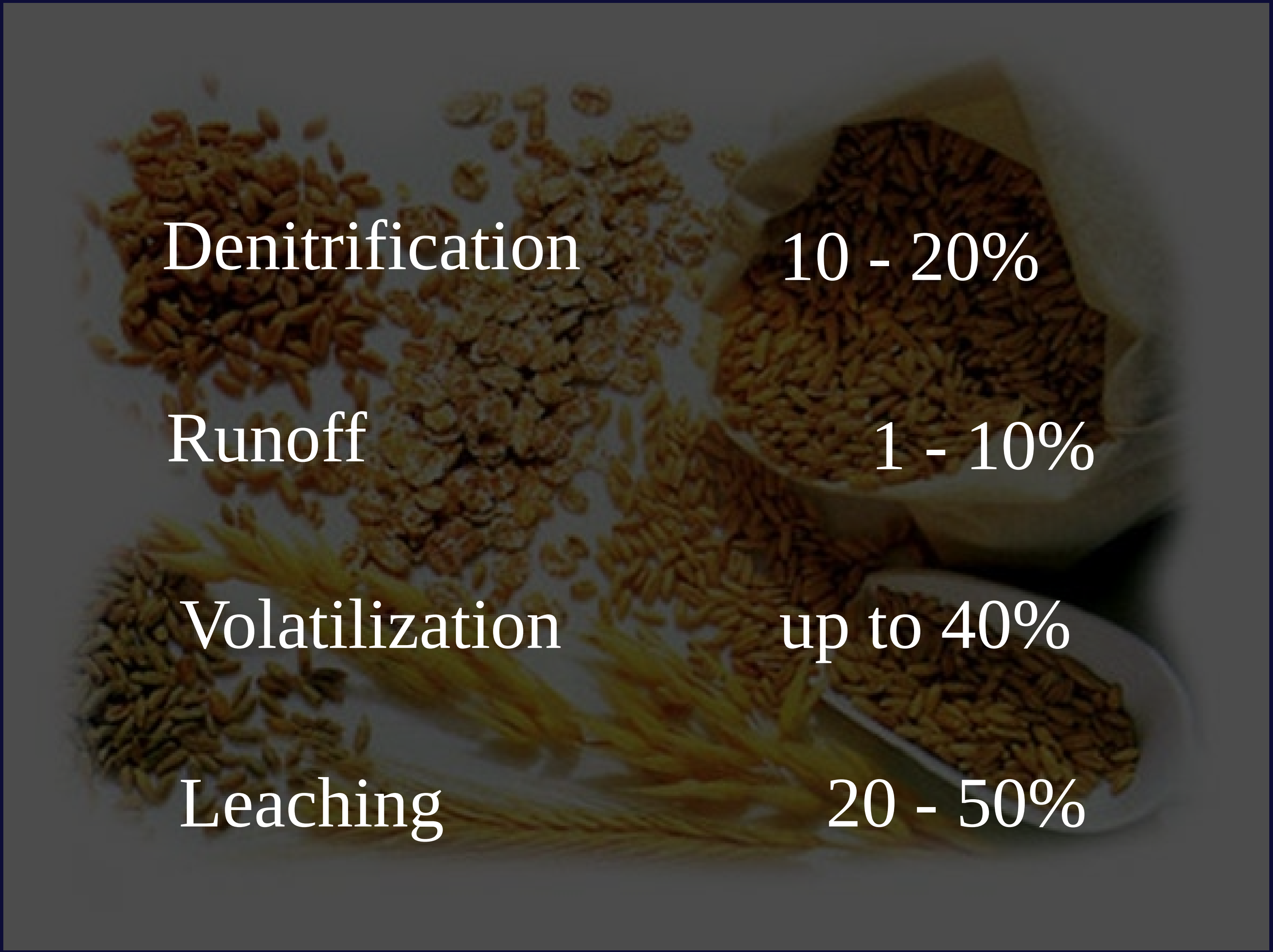


$$\text{N.U.E.} = \frac{(34 \text{ x } 10^6) - (17 \text{ x } 10^6)}{(49 \text{ x } 10^6)} \text{ x } 100$$

$$= 35\%$$

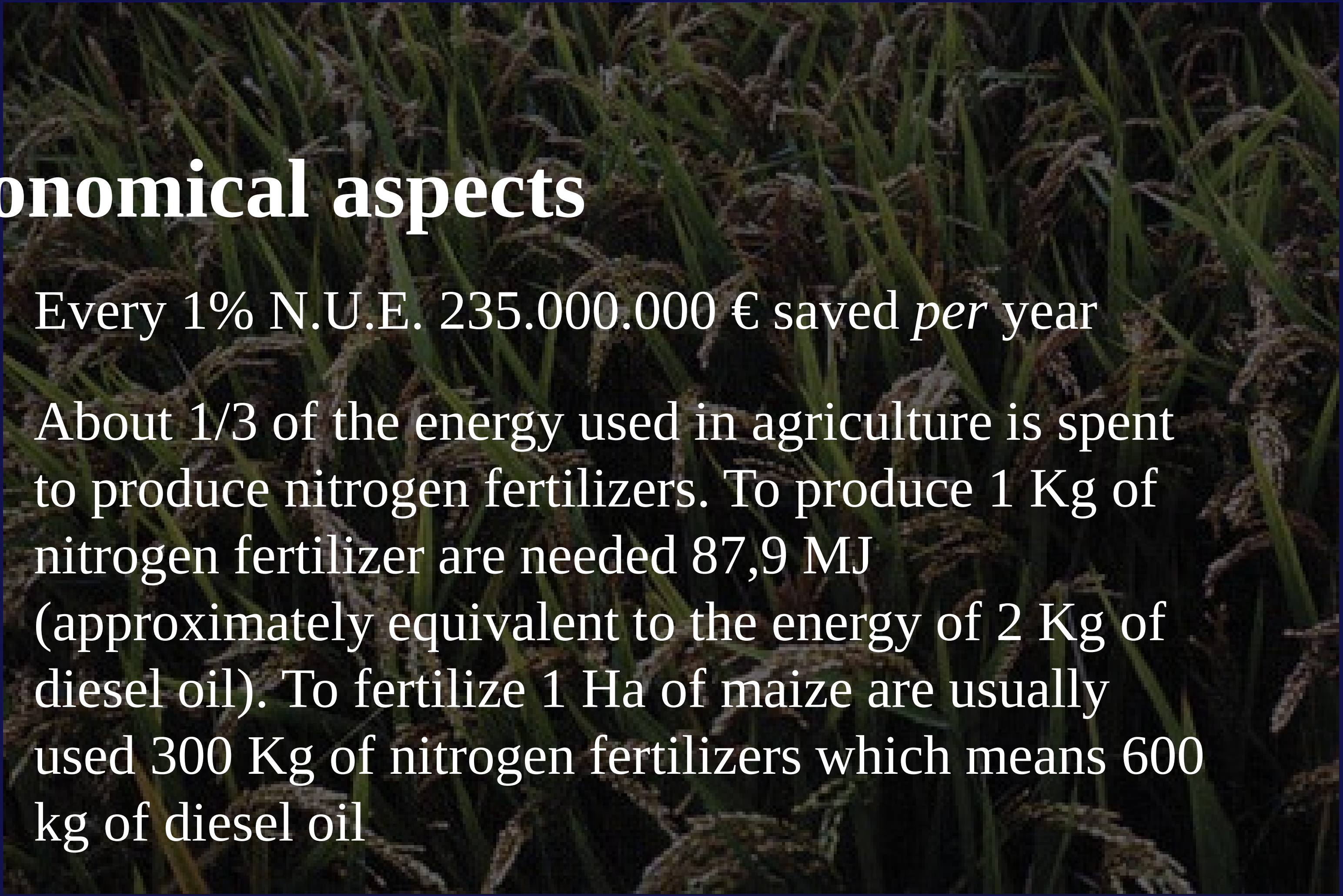
Raun and Johnson, 1999 Agron J 91; 357

Why N.U.E. in cereals is so low?



Denitrification	10 - 20%
Runoff	1 - 10%
Volatilization	up to 40%
Leaching	20 - 50%

Why improve?



Economical aspects

Every 1% N.U.E. 235.000.000 € saved *per* year

About 1/3 of the energy used in agriculture is spent to produce nitrogen fertilizers. To produce 1 Kg of nitrogen fertilizer are needed 87,9 MJ (approximately equivalent to the energy of 2 Kg of diesel oil). To fertilize 1 Ha of maize are usually used 300 Kg of nitrogen fertilizers which means 600 kg of diesel oil

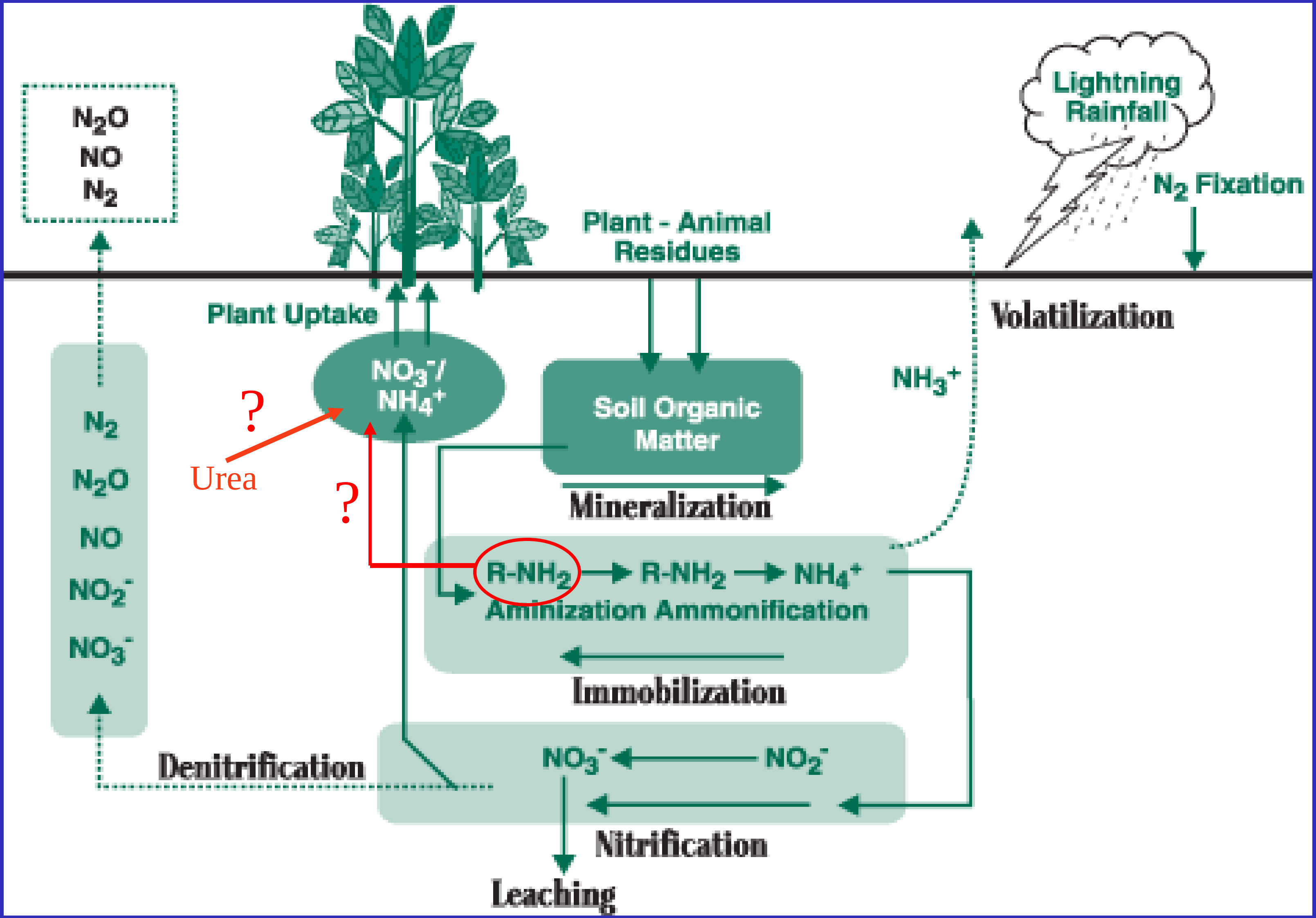
Why improve?

Environmental aspects

Reduction of water bed pollution

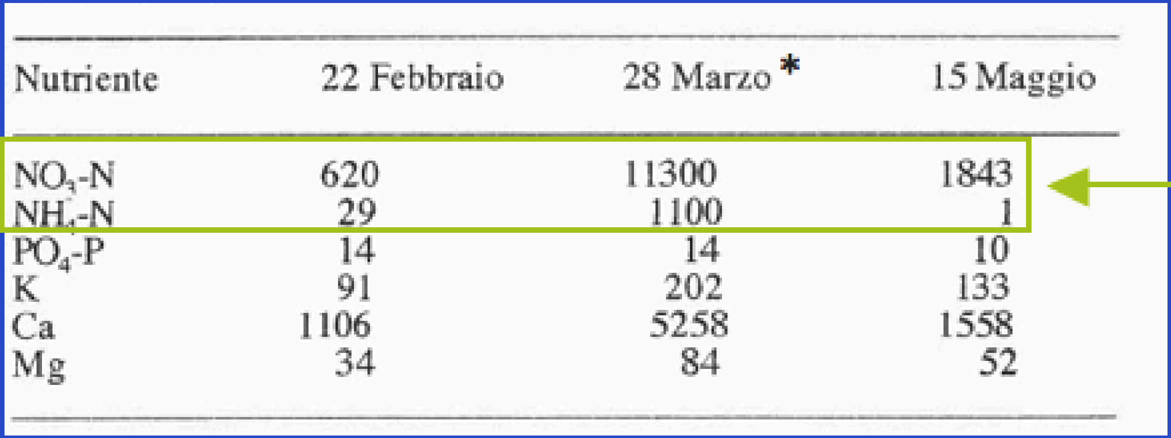
An urgent problem in Italy the application of "Direttiva nitrati"

Nitrogen in soil



Nitrate and ammonium in soil

- Nitrate and ammonium are the main form of nitrogen absorbed by plants in soils of our latitudes
- [NO_3^-] in agricultural soils ranges from 0,5 to10 mM
- [NH_4^+] from 10 to1000 times lower than nitrate
- Highly fluctuating concentration in soil solution



Nutriente	22 Febbraio	28 Marzo *	15 Maggio
NO_3-N	620	11300	1843
NH_4-N	29	1100	1
PO_4-P	14	14	10
K	91	202	133
Ca	1106	5258	1558
Mg	34	84	52

μM

*Application of 265 kg N ha^{-1} (as calcium-ammonium-nitrate) the 25th february and 25th march. From Barraclough, 1989.

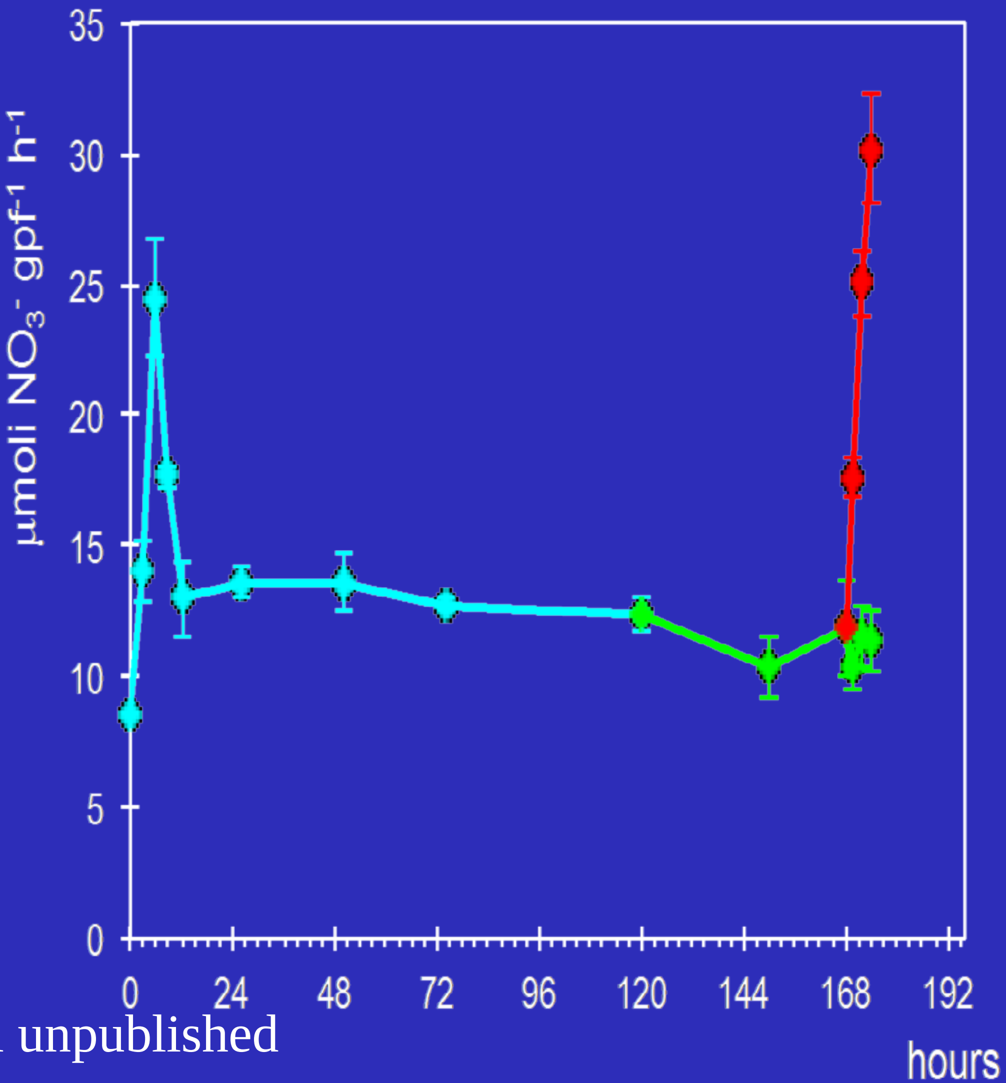
Dal lato del suolo…

Nella pratica si utilizza ancora quasi esclusivamente l’analisi dell’azoto totale.

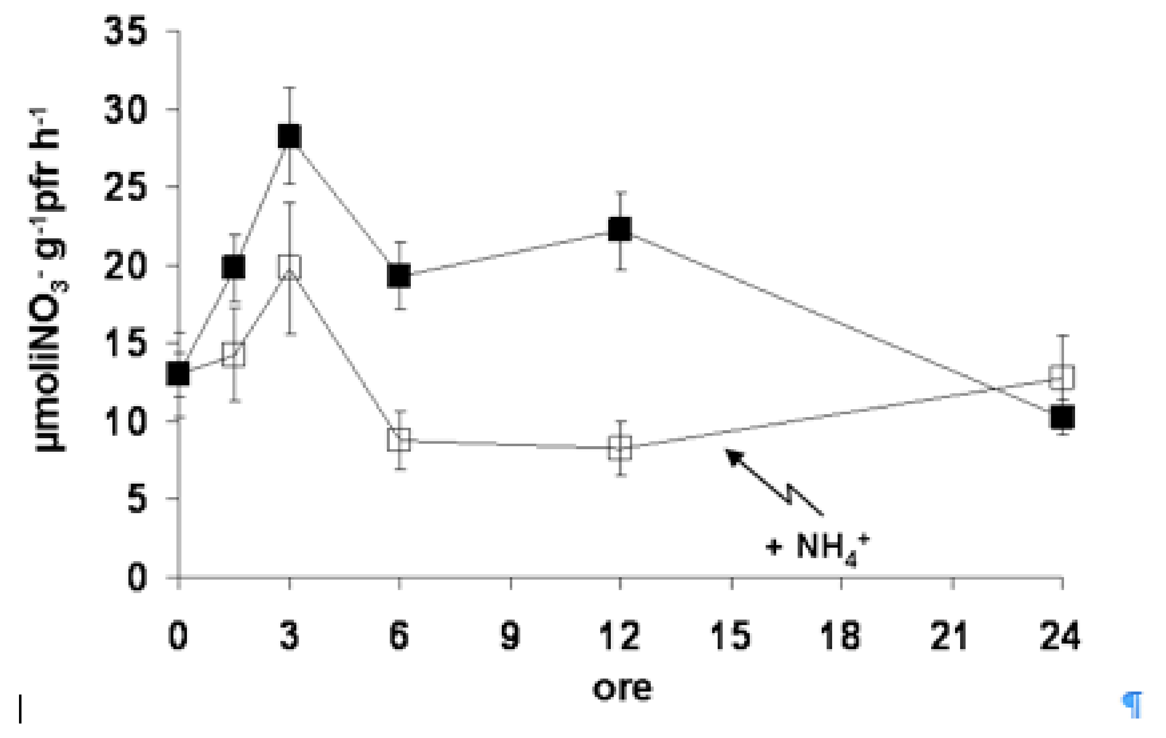
-Validazione di test diagnostici innovativi per la valutazione dello stato di fertilità del suolo in relazione alle performances delle colture (attività VIII).
-Utilizzazione di nuove tecnologie (es sensoristica) per la razionalizzazione dell’uso e la valorizzazione di effluenti (attività IX)
-Fondamentale la comprensione del ruolo della sostanza organica nel mantenimento della fertilità (attività X)
-(Ri)scoprire il potenziale biologico del suolo attraverso la conoscenza di popolazioni microbiche utili

Nitrate uptake mechanism

A dynamic system: inducible and down-regulated



Locci et al unpublished



La velocità di assorbimento del nitrato in presenza di ammonio è più bassa

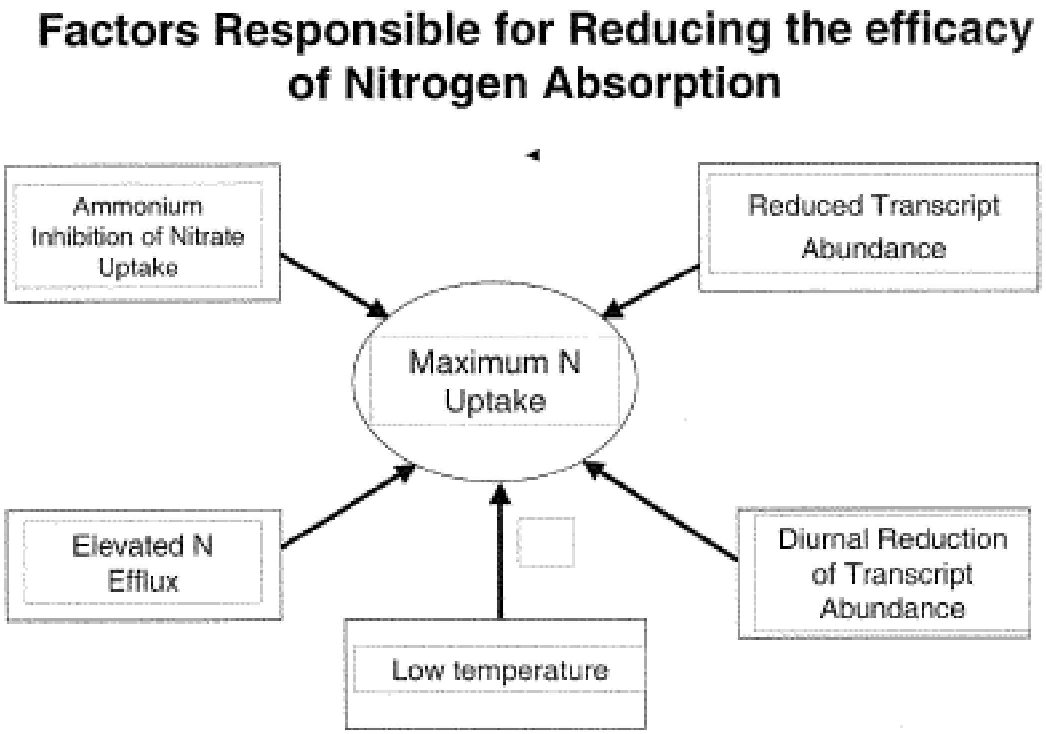
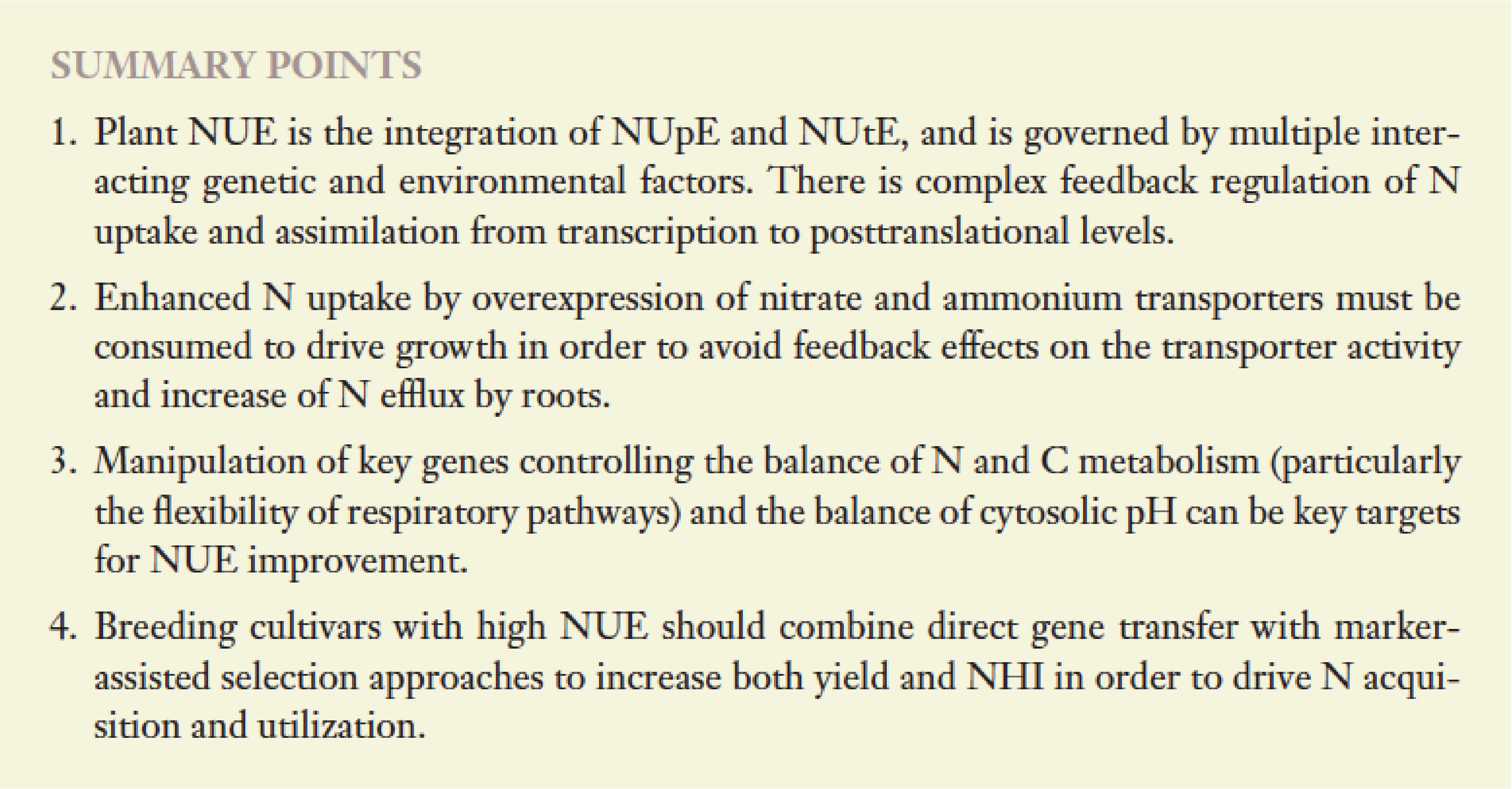


FIGURE 6. Various factors responsible for reducing the efficacy of N uptake by plant roots.

Glass A.D.M. (2003), *Critical Reviews in Plant Sciences*; 22(5): 453-470.

Approcci biotecnologici per incrementare la NUE

(Xu et al., Annu Rev Plant Biol 2012)



SUMMARY POINTS

1. Plant NUE is the integration of NUpE and NUtE, and is governed by multiple interacting genetic and environmental factors. There is complex feedback regulation of N uptake and assimilation from transcription to posttranslational levels.
2. Enhanced N uptake by overexpression of nitrate and ammonium transporters must be consumed to drive growth in order to avoid feedback effects on the transporter activity and increase of N efflux by roots.
3. Manipulation of key genes controlling the balance of N and C metabolism (particularly the flexibility of respiratory pathways) and the balance of cytosolic pH can be key targets for NUE improvement.
4. Breeding cultivars with high NUE should combine direct gene transfer with marker-assisted selection approaches to increase both yield and NHI in order to drive N acquisition and utilization.

Dal lato della pianta…

-Gli studi riguardano quasi esclusivamente piante modello. (BIOGESTECA: Mais, Riso, Frumento…)

-Esplorare la variabilità genetica rispetto a parametri dell’efficienza d’uso (Attività I,II,III,V)

Il caso del fosforo

In ¼ of arable land, phosphate is the limiting growth factor

THE DISAPPEARING NUTRIENT

Y. ARTHUS-BERTRAND/CORBIS

Phosphate-based fertilizers have helped spur agricultural gains in the past century, but the world may soon run out of them. **Natasha Gilbert** investigates the potential phosphate crisis.

Ten years ago, Don Mavinic was working on a way to get rid of a pesky precipitate that plugs up the works of waste-water treatment plants. Known as struvite, the solid crud forms in pipes and pumps when bacteria are used to clean up sewerage sludge.

Mavinic, a civil engineer at the University of British Columbia in Vancouver, Canada, realized that struvite was more than just rubbish. A combination of phosphate, magnesium and ammonium, struvite contains many of the essential nutrients that plants need. Mavinic has developed a way to remove the precipitate during the water-treatment process and he is now selling it as a 'green' fertilizer. His technology was first used commercially in 2007 in a treatment plant in Edmonton, Alberta, Canada. It has since been exported to a plant in Portland, Oregon, which began using it this year. A sewage works in Derby, UK, successfully tested the technology in September.

Aside from finding a use for a troublesome by-product, the recycling of struvite could also help solve a much bigger problem: the dwindling supply of phosphate rock. All life forms require phosphorus in the form of phosphate, which has an essential role in RNA and DNA and in cellular metabolism. Every year, China, the United States, Morocco and other countries mine millions of tonnes of phosphate from the ground (pictured above), the bulk of which is turned into fertilizer for food crops. But such deposits are a finite resource and could disappear within the century.

Experts disagree on how much phosphate is left and how quickly it will be exhausted. But many argue that a shortage is coming and that it will leave the world's future food supply hanging in the balance.

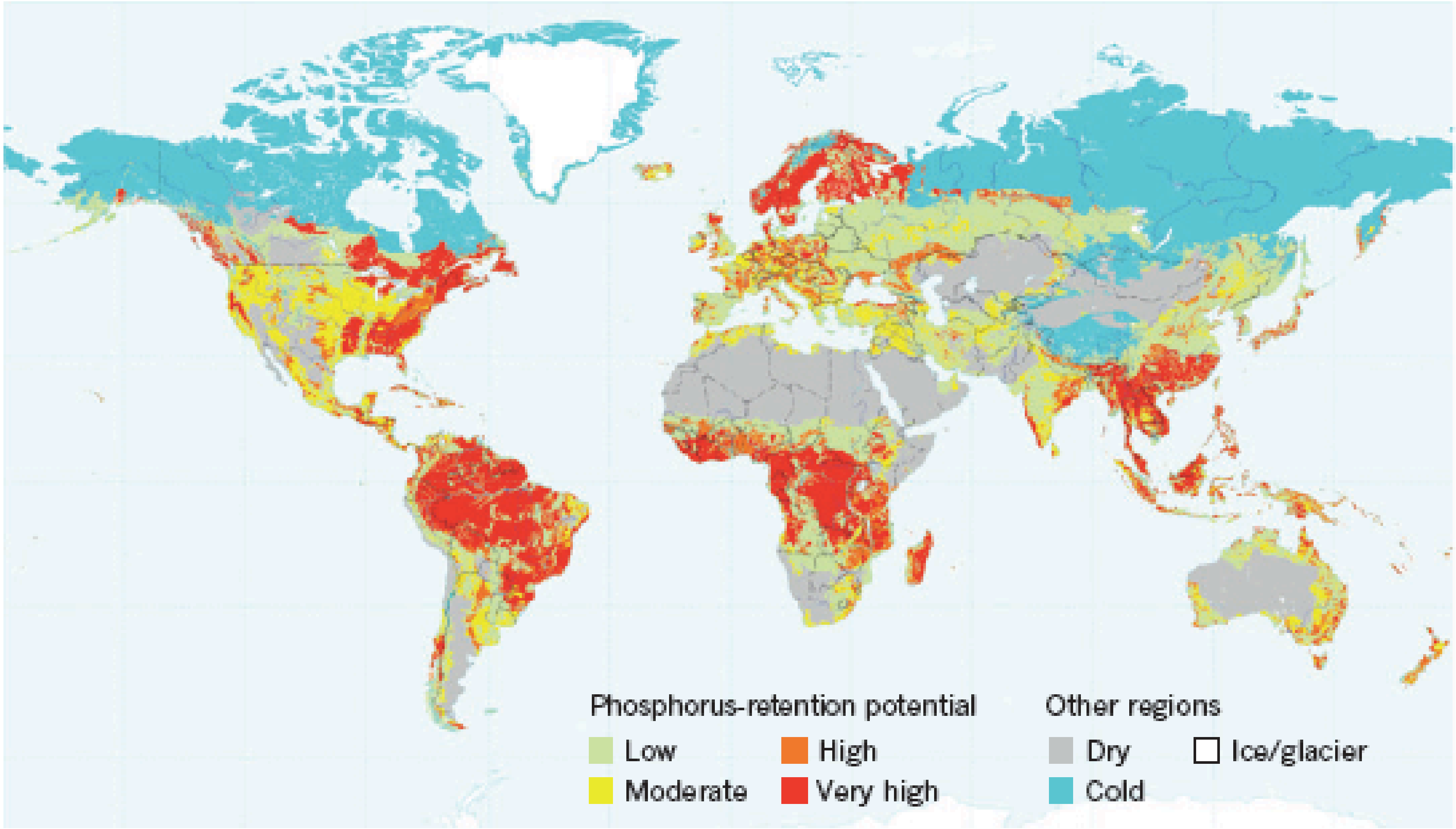
"I am starting to think phosphate rock is becoming a strategic material for many countries. In the future it's going to become more and more valuable," says Steven Van Kauwenbergh of the IFDC, an International Center for Soil Fertility & Agricultural Development based in Muscle Shoals, Alabama. Indeed, as political and social tensions build over the reserves of phosphate rock, the world could move from an oil-based to a phosphate-based economy, say some scientists and industry representatives.

"It is a very curious thing that something so important is so poorly understood and so little talked about in the larger political arena," says Arno Rosemarin, a water-resources specialist at the Stockholm Environment Institute who has researched global phosphate use. Although international leaders have not tended to focus on the potential for phosphate shortages, the issue has been proposed for discussion next month at a United Nations meeting on global food security — an indication that it is starting to attract the attention of the international community.

Just decades left?

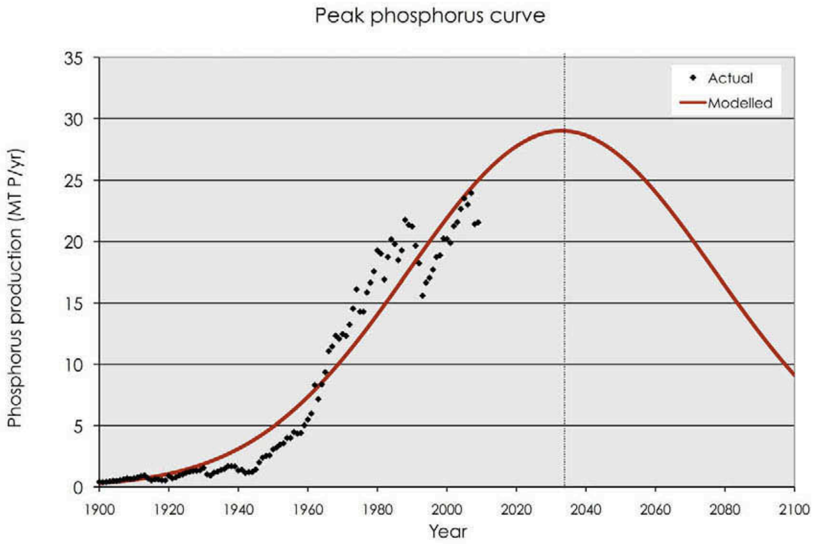
In many countries, phosphorus is a limiting plant nutrient in short supply in the soil. So farmers add phosphate-based fertilizers to increase agricultural yields. That has spawned a global phosphate-mining industry with sales totalling in the tens of billions of dollars.

The US Geological Survey (USGS) in Reston, Virginia, estimates that around 62 billion tonnes of phosphate remain in the ground (see graphic). This includes 15 billion tonnes of deposits that are mineable at present and others



US DEPARTMENT OF AGRICULTURE

Figure 1 | The problem of phosphorus. Many of the world's agricultural soils are in regions of high or very high phosphorus-retention potential, which means that the phosphorus is tightly bound to soil particles or fixed in phosphorus-containing organic compounds. High phosphorus retention leads to low availability of phosphorus for plants in these regions. Gamuyao *et al.*[2] have identified a rice enzyme that enhances grain yield from plants grown on phosphorus-deficient soils.

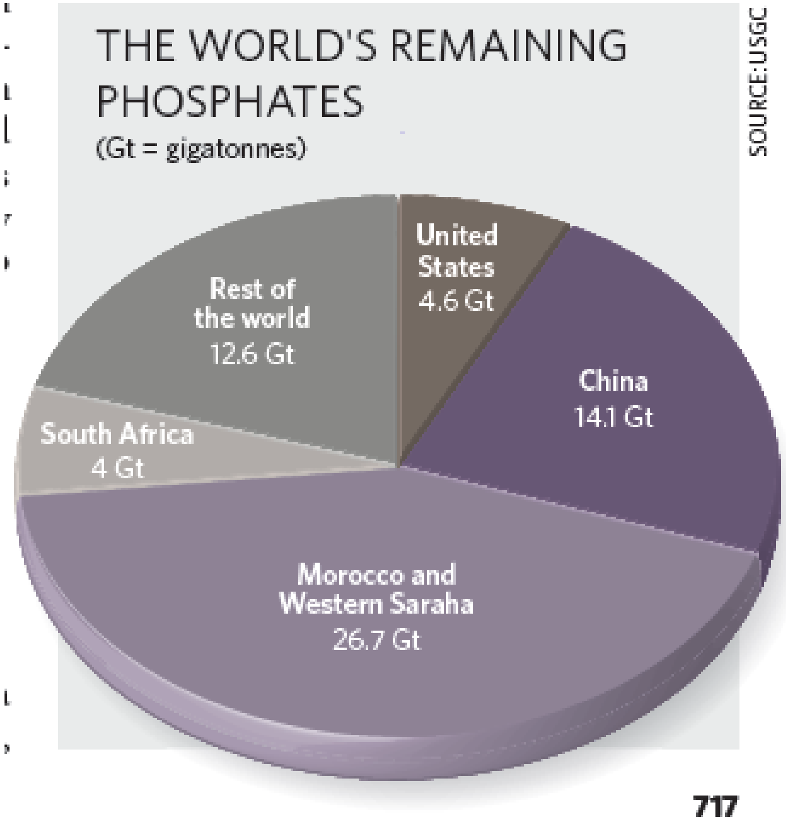


Cordell et al., 2009

At the present day rate of consumption and cost of extraction we estimate **stocks of rock phosphate for about 100 years**
(Vance, 2001 New Phytol. 157; 423)

The crops recover is less than 10% of phosphorous fertilizers added to the soil: **very low PUE**

The problem of redistribution: concentrated in the mines of rock phosphate and **diluted and mostly unavailable in the soil**

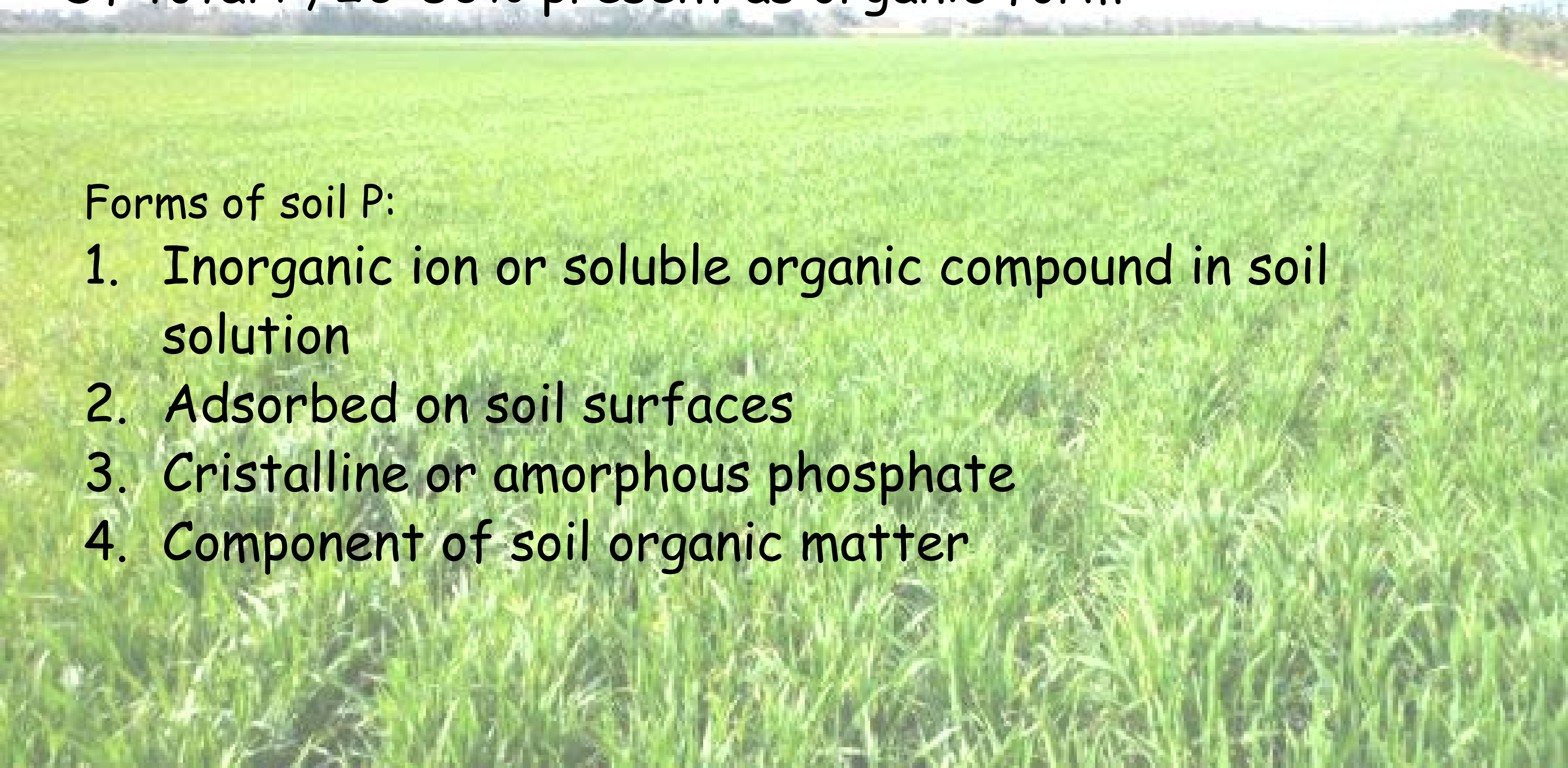


Gilbert 2009

Phosphorous in soil

Total P = 100 - 3000 mg Kg^{-1} (0.02 - 0.15%)
P in soil solution = 0.01 -3.0 mg L^{-1} (e.g. micromolar range)

Of total P, 20-80% present as organic form



Forms of soil P:

1. Inorganic ion or soluble organic compound in soil solution
2. Adsorbed on soil surfaces
3. Cristalline or amorphous phosphate
4. Component of soil organic matter

Risposte della pianta a condizioni di limitata disponibilità di P nel suolo

1 Modificazioni morfologiche
(architettura radicale e aumento peli radicali)

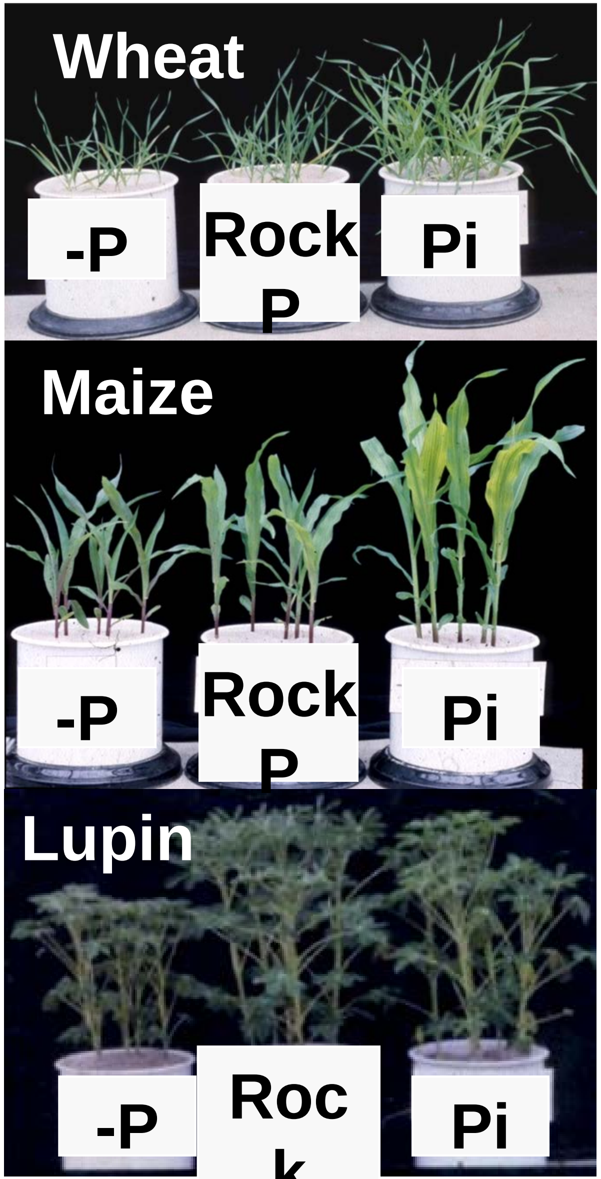
2 Modificazioni fisiologiche

Sintesi trasportatori del Pi
Rilascio enzimi P-idrolitici (fitasi, fosfatasi, RNAsi)

Diminuzione pH rizosferico
Rilascio acidi organici
Rilascio flavonoidi

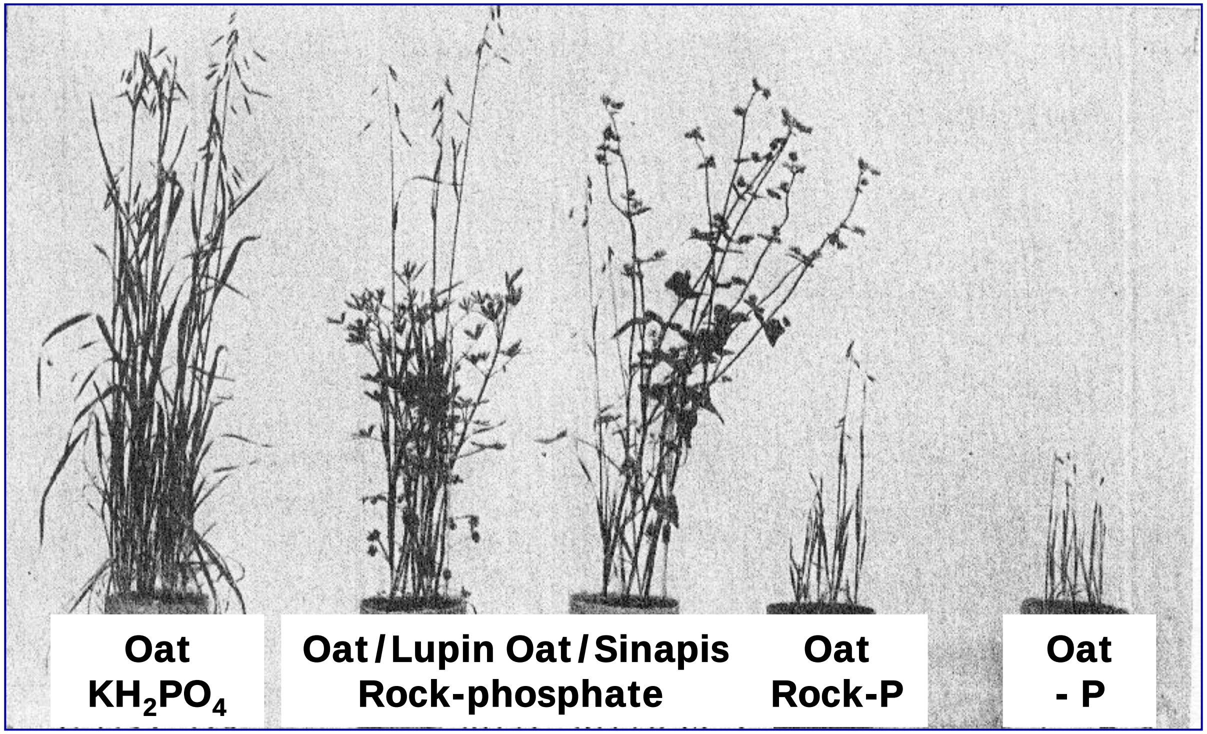
Risposte della pianta a condizioni di limitata disponibilità di P nel suolo

1. Modificazioni morfologiche



Neumann an d, 2002

White lupin solubilizes rock-bound P

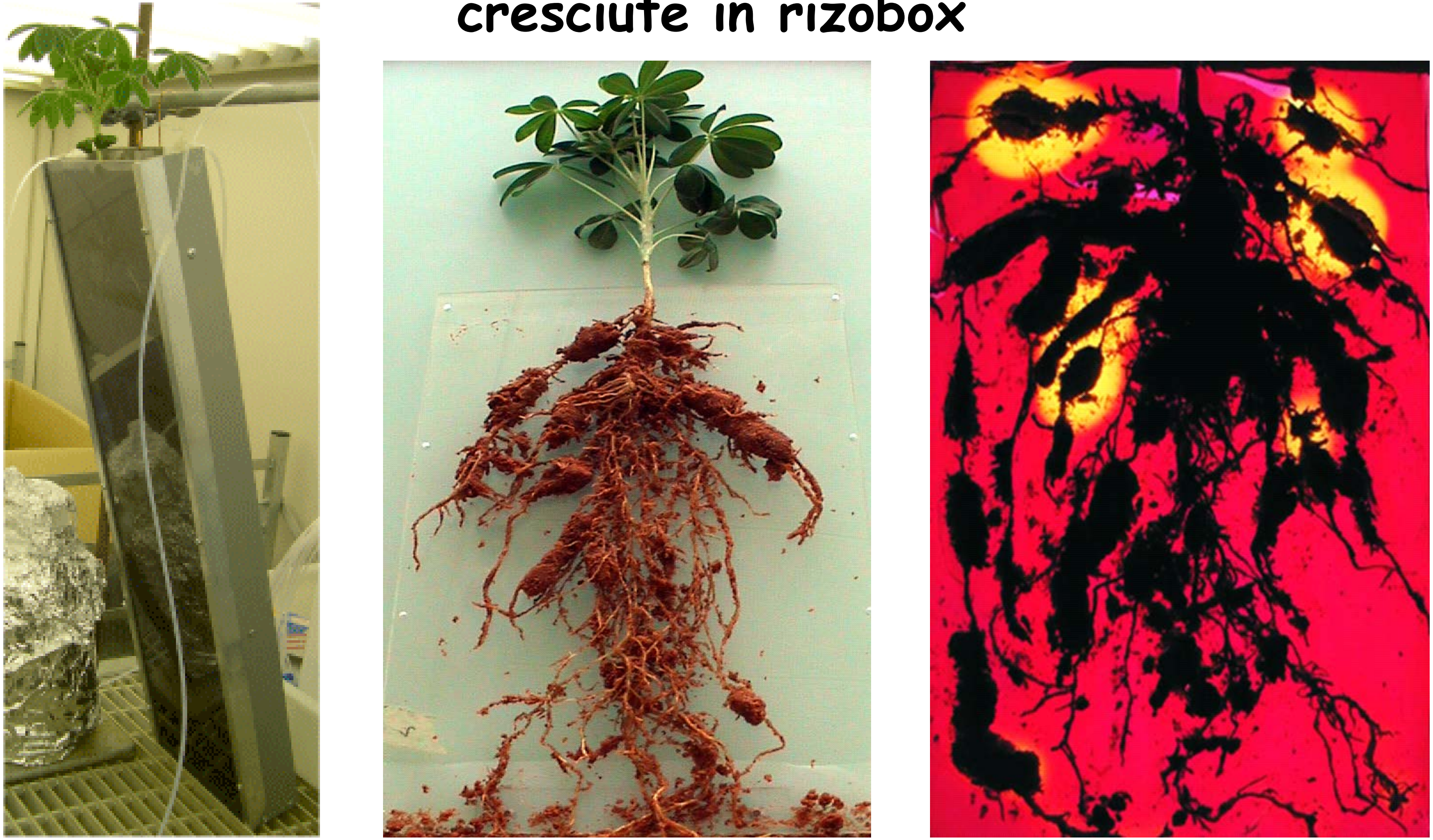


Prijanischnikov, 1934

Risposte della pianta a condizioni di limitata disponibilità di P nel suolo

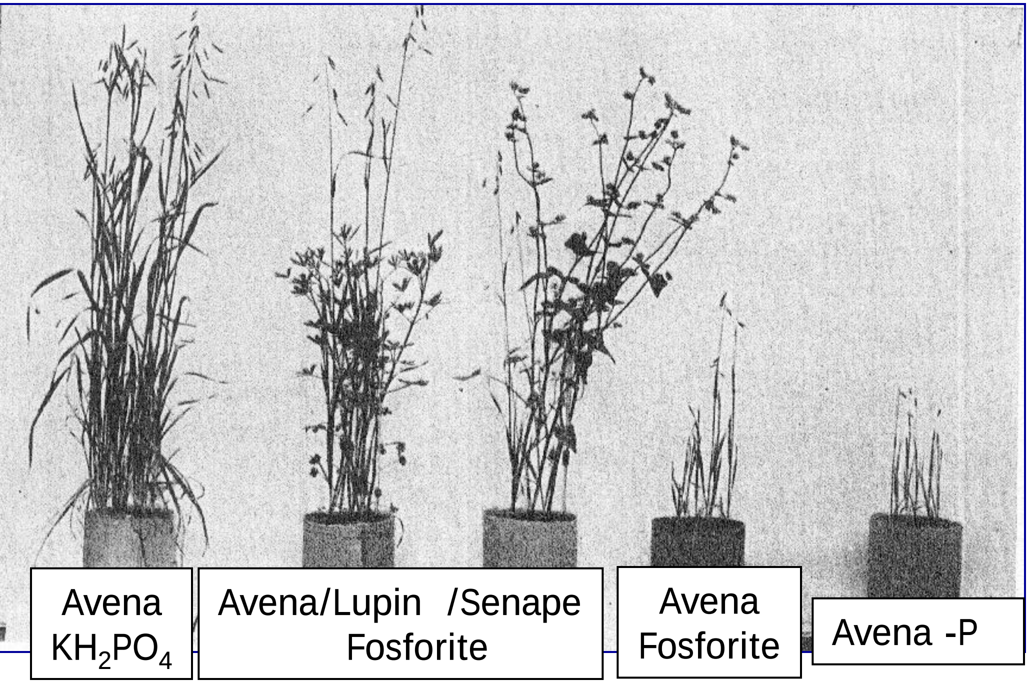
2. Modificazioni fisiologiche - Diminuzione pH rizosferico

Acidificazione da parte di radici di Lupino P-carente cresciute in rizobox



Uso efficiente delle disponibilità fosfatiche dei suoli

Effetto della consociazione sulla nutrizione fosfatica



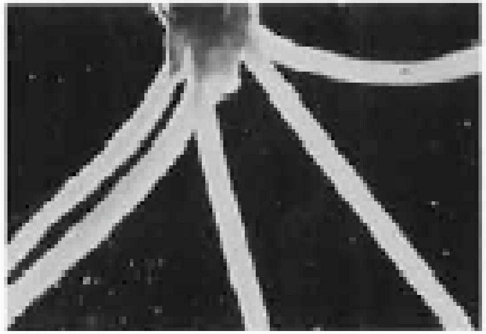
(Prijanischnikov, 1934; Gardener et al. 1983)

(Zhang et al. 2005)

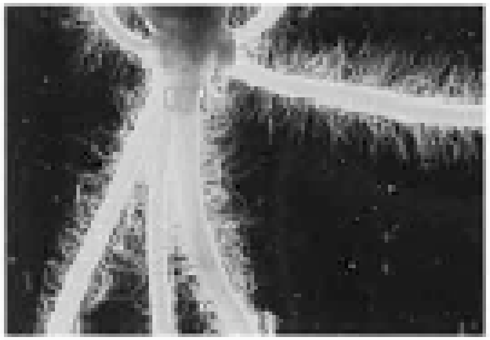
Risposte della pianta a condizioni di limitata disponibilità di P nel suolo

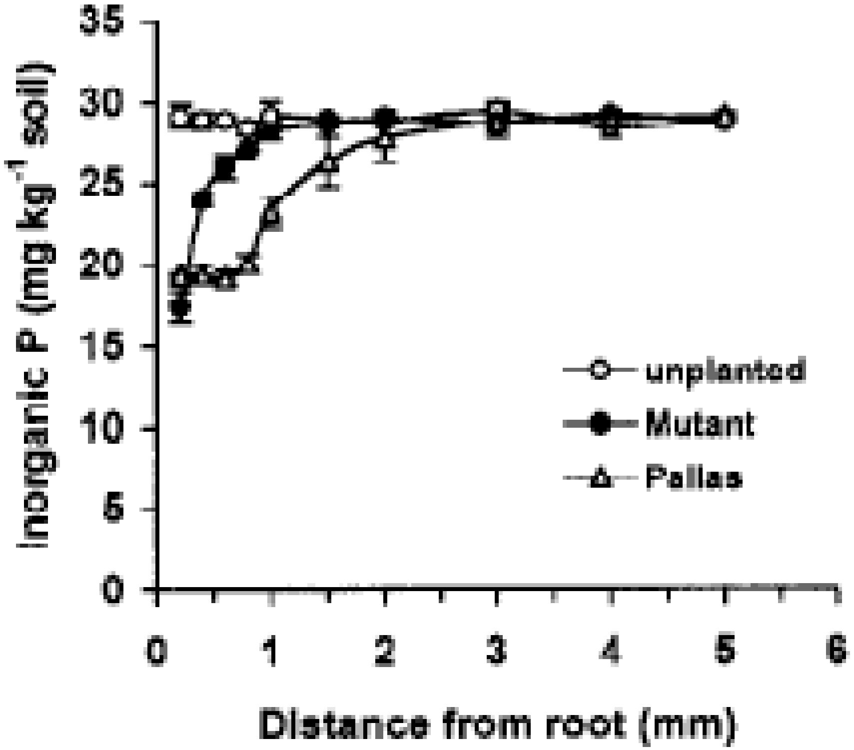
1. Modificazioni morfologiche

Mutant



Cv. Pallas





(*Gahoonia et al., 2001*)

Micorrize e acquisizione del P da parte delle piante

Benefici della simbiosi micorrizica:

a)Maggiore efficienza nell'assorbimento di P, N, Zn, K, Ca

b)Maggiore capacità di assorbimento dell'acqua

c)Maggiore tolleranza a stress abiotici

Giovannetti, 2001

Limitare gli apporti di P non utilizzabile nel suolo…

-Attività VI

Migliorare l’utilizzazione del fosforo presente attraverso attività delle piante…

-Attività VII

PLANT NUTRITION

Rooting for more phosphorus

The identification of an enzyme in rice that confers improved plant yields on phosphorus-deficient soils could open up new avenues for generating nutrient-efficient crops that can thrive on marginally fertile soils. See Letter p.535

LEON V. KOCHIAN

particles or is tied up (fixed) as organic phos-

However, subsequent efforts to identify the specific gene, or genes, responsible for phosphorus efficiency in the Kasalath strain were complicated by the fact that greater phosphorus efficiency can arise from several aspects of plant physiology. For example, more-active root growth that positions roots closer to where the soil phosphorus is located, or greater root-mediated biological and chemical activity to solubilize and absorb fixed phosphorus can both lead to more efficient acquisition. In addition, more-efficient cellular use of the mineral can contribute to enhanced phosphorus efficiency.

In the current paper[2], Gamuyao and colleagues further characterize this gene, which they have named *PSTOL1*, for phosphorus-starvation tolerance 1. The authors demonstrate that modern rice lines that are genetically engineered to overexpress *PSTOL1* show significant increases in grain and biomass production compared with wild-type plants when the plants are grown on phosphorus-deficient soils. They also show that the PSTOL1 protein belongs to the receptor-like cytoplasmic kinase sub-group of protein kinases. This is interesting, because receptor-like kinases have been implicated in plant responses to several types of abiotic stress, including drought[10].

By comparing the root architecture of rice plants overexpressing *PSTOL1* with that of the corresponding lines lacking the kinase, the authors found that *PSTOL1* expression resulted in increased early root growth and root proliferation, suggesting that the kinase enhances the plants' ability to 'mine' soil phosphorus. The proposal that PSTOL1 functions in root development and growth was supported by studies showing that *PSTOL1* expression is confined to specific tissue regions where crown roots, which make up a substantial portion of the mature rice root system, begin to emerge.

These findings have opened up new avenues for improving crop plant phosphorus efficiency — and possibly the efficiency of the uptake of other nutrients as well. Considerable work remains to be done to elucidate the molecular mechanisms and downstream targets of PSTOL1. But the researchers are already attempting to translate their discoveries into

The protein kinase Pstol1 from traditional rice confers tolerance of phosphorus deficiency

Rico Gamuyao[1], Joong Hyoun Chin[1], Juan Pariasca-Tanaka[2], Paolo Pesaresi[3], Sheryl Catausan[1], Cheryl Dalid[1], Inez Slamet-Loedin[1], Evelyn Mae Tecson-Mendoza[4], Matthias Wissuwa[2] & Sigrid Heuer[1]

As an essential macroelement for all living cells, phosphorus is indispensable in agricultural production systems. Natural phosphorus reserves are limited[1], and it is therefore important to develop phosphorus-efficient crops. A major quantitative trait locus for phosphorus-deficiency tolerance, *Pup1*, was identified in the traditional *aus*-type rice variety Kasalath about a decade ago[2,3]. However, its functional mechanism remained elusive[4,5] until the locus was sequenced, showing the presence of a *Pup1*-specific protein kinase gene[6], which we have named phosphorus-starvation tolerance 1 (*PSTOL1*). This gene is absent from the rice reference genome and other phosphorus-starvation-intolerant modern varieties[7,8]. Here we show that overexpression of *PSTOL1* in such varieties significantly enhances grain yield in phosphorus-deficient soil. Further analyses show that *PSTOL1* acts as an enhancer of early root growth, thereby enabling plants to acquire more phosphorus and other nutrients. The absence of *PSTOL1* and other genes—for example, the submergence-tolerance gene *SUB1A*—from modern rice varieties underlines the importance of conserving and exploring traditional germplasm. Introgression of this quantitative trait locus into locally adapted rice varieties in Asia and Africa is expected to considerably enhance productivity under low phosphorus conditions.

Phosphorus (P) is of unequivocal importance for the production of food crops, and the demand for P fertilizer is increasing worldwide. In Asia, where rice is the main and sometimes the only source of calories, 40% of the rice is produced in rain-fed systems, with little or no water control and frequent occurrence of floods, droughts and other calamities. In addition, 60% (29 Mha) of the rain-fed lowland rice is produced on poor and problem soils[9,10] (Fig. 1a) that are constrained by a multitude of abiotic stresses and are naturally low in phosphorus or P fixing. Rice yields are therefore low[11] and, not surprisingly, poverty in these regions is among the highest in the world (http://www.ruralpovertyportal.org/web/guest/region). A lack of resources or limited access to P fertilizer are some of the constraints for poor farmers. There is a high risk that the situation will be further aggravated given that phosphate rock, the source of P fertilizer, is a finite and non-renewable resource that is

Considerazioni finali

- Per razionalizzare le fertilizzazioni e aumentare l’efficienza d’uso dei nutrienti è necessaria una profonda conoscenza delle interazioni suolo-radice
- Va analizzato il potenziale inesplorato della variabilità su base genetica delle risposte delle radici che consentono migliori adattamenti e efficienza
- Utilizzando nuove tecnologie (sensoristica, bioindicatori, nanotecnologie …) dovrebbero essere possibili miglioramenti di efficienza e razionalizzazione in tempi relativamente brevi

La ricerca di oggi è la tecnologia di domani.

In tempi di crisi economica, è forte la tentazione di risparmiare tagliando i fondi della ricerca a lungo termine. Ma il danno può risultare immenso

(B. Ricther)

L’importanza delle sementi era nota in tutte le società agrarie primitive; anche nell’inverno più rigido, anche se incombeva la carestia, non andavano mangiate. Consumare le sementi significa sacrificare l’avvenire. La ricerca di base, senz’altro scopo che capire al natura, è la tecnologia di domani. Oggi ne stiamo forse mangiando le sementi, distruggendo le messi dei nostri figli?

(Samuel C.C. Ting)