Presentation for the

"Scientific Seminar on Organic Food "

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European Organic Farming Research; the need focus on "*Eco-functional Intensification*"

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EU Organic farming R&D

FP5 Environmental impact (e.g. Blight-MOP)

FP6 Food Quality (e.g. QualityLowInputFood)

Standard development (Organic Revision)

FP7 Breeding and management innovations to improve robustness/resource use efficiency

- QualityLowInputBreeds
- NUE-crops

EU Horizon 2020 Food Security

IFOAM *Ecofunctional intensification*

Food security

"The ability to provide enough food of high quality for humans through sustainable methods of production, processing, storage, transport, distribution, trading and retailing"

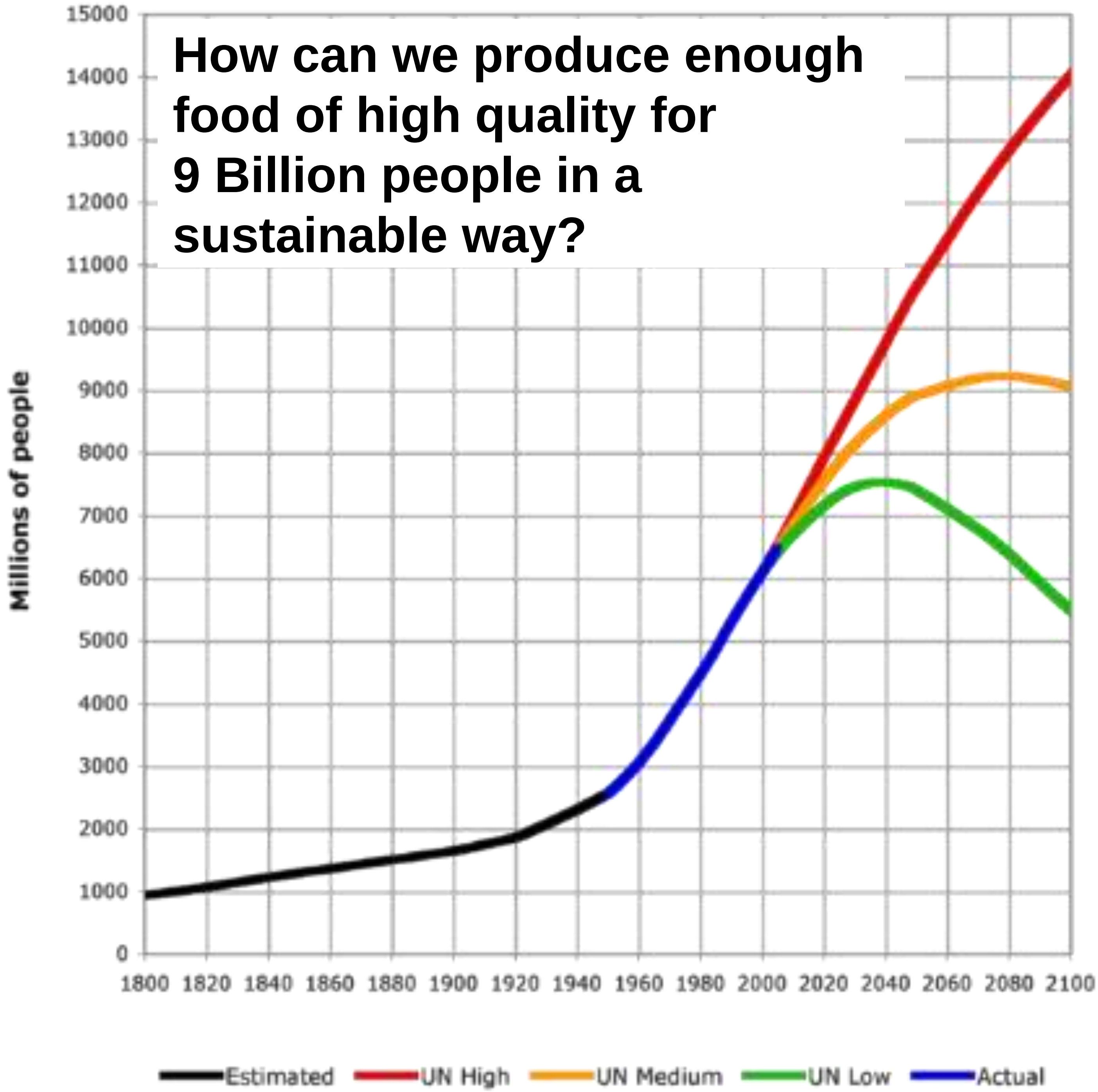
Sustainability in this context means without

- **negative impacts on the environment,**
- **reliance on non-renewable resources,**
- **an erosion of current ethical standards**

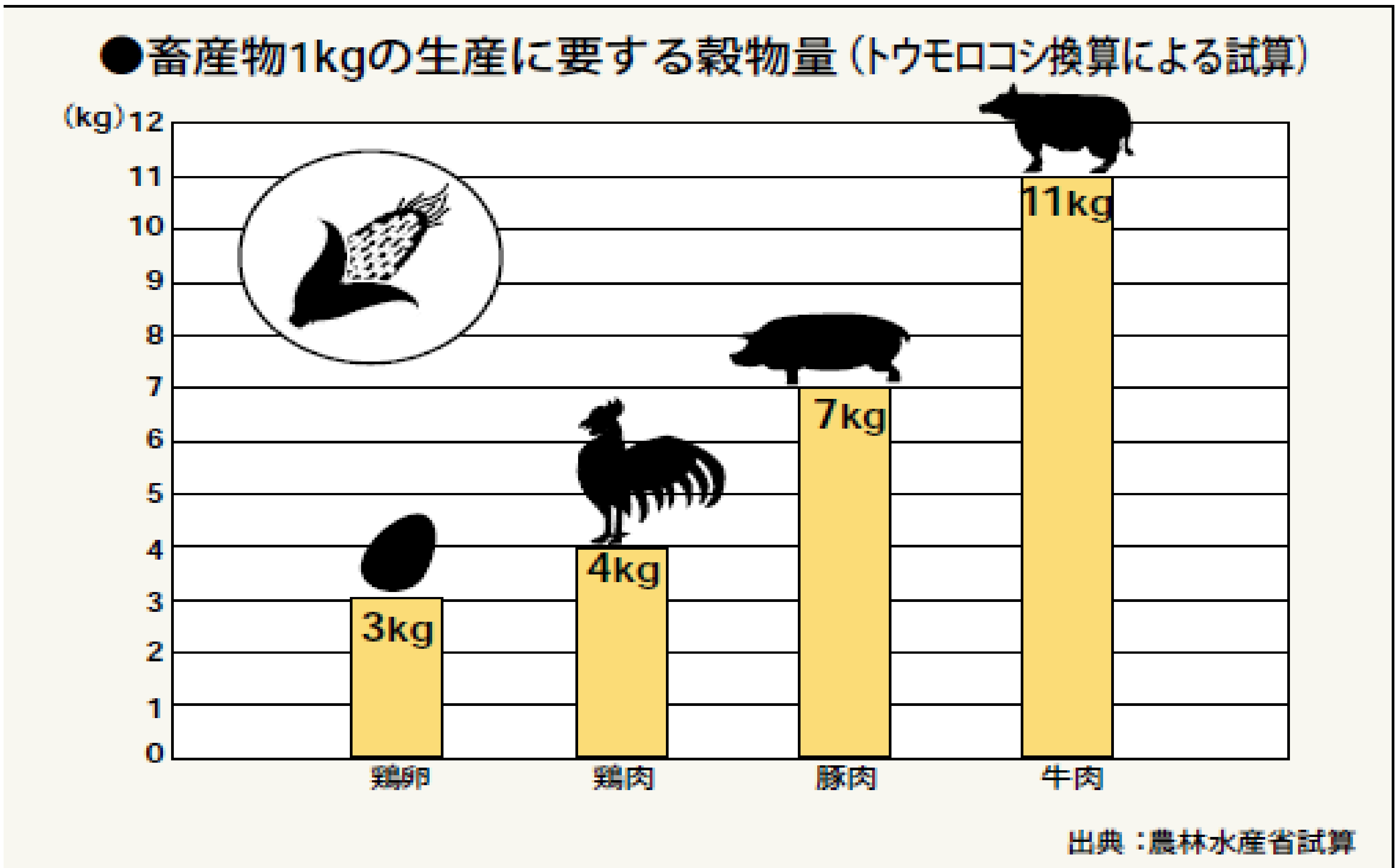
while ensuring

- **fair economic returns to all food chain stakeholders**
- **flexibility to meet the challenges of global change**

How can we produce enough food of high quality for 9 Billion people in a sustainable way?



Amount (kg) of cereal (corn-equivalents) necessary to produce 1 kg of livestock products



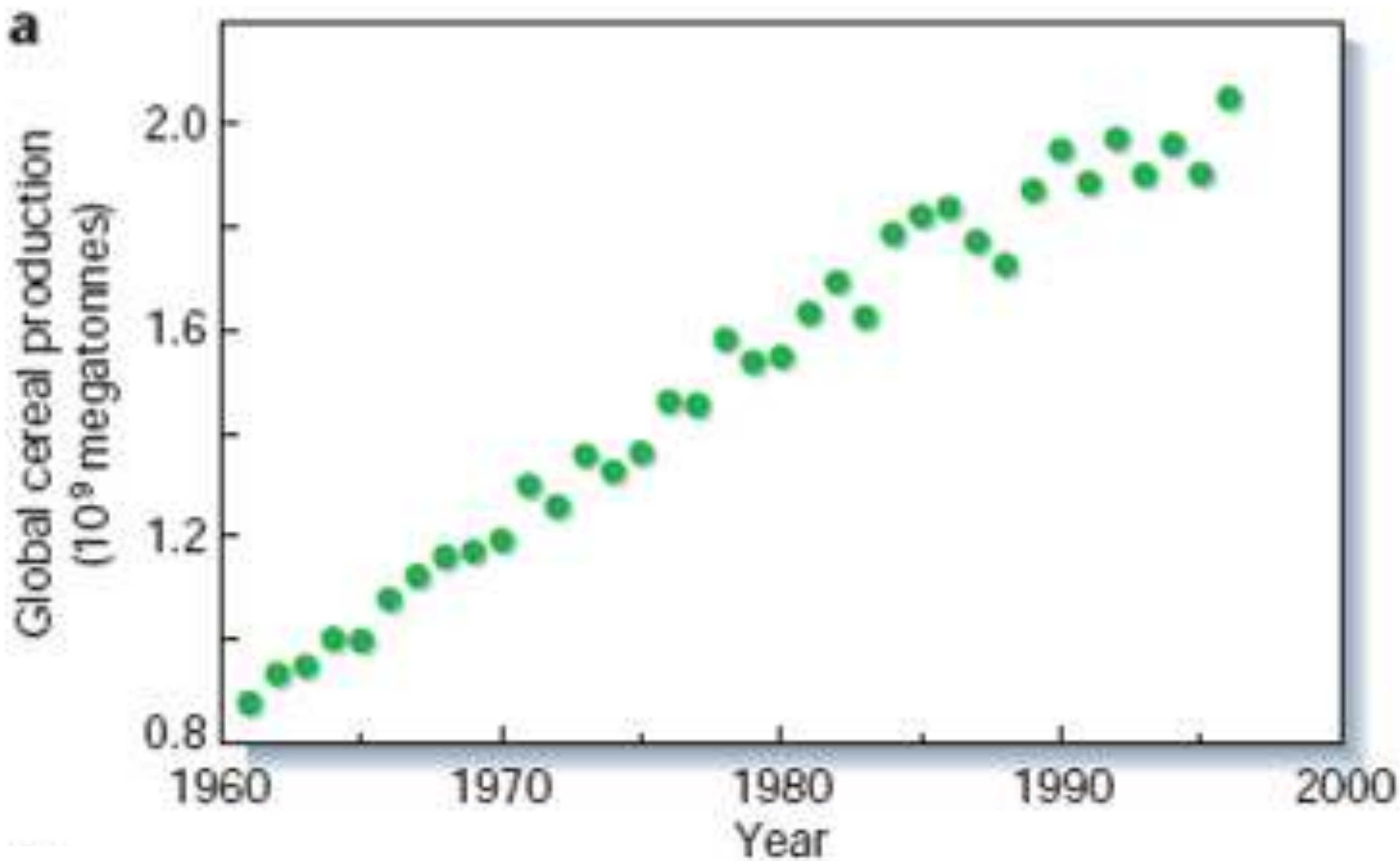
Jeremy Grantham* (2012)
Welcome to Dystopia! Entering a longterm and politically dangerous food crisis. *GMO Quarterly letter July 2012*

*** Co-founder and Chief Investment Strategist of Grantham Mayo Van Otterloo (GMO), a Boston-based asset management firm**

"Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist"

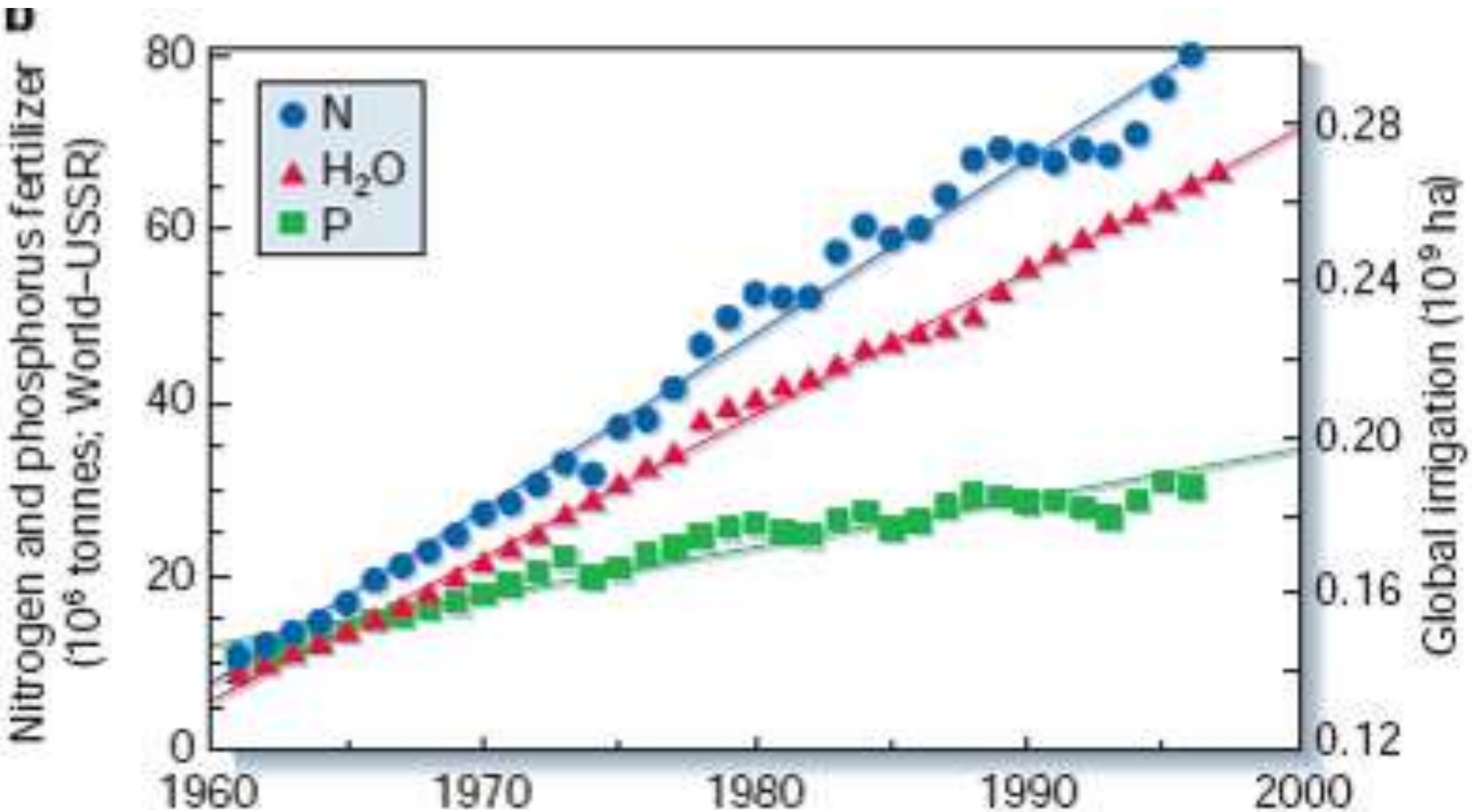
Kenneth Boulding, economist

Total global cereal production



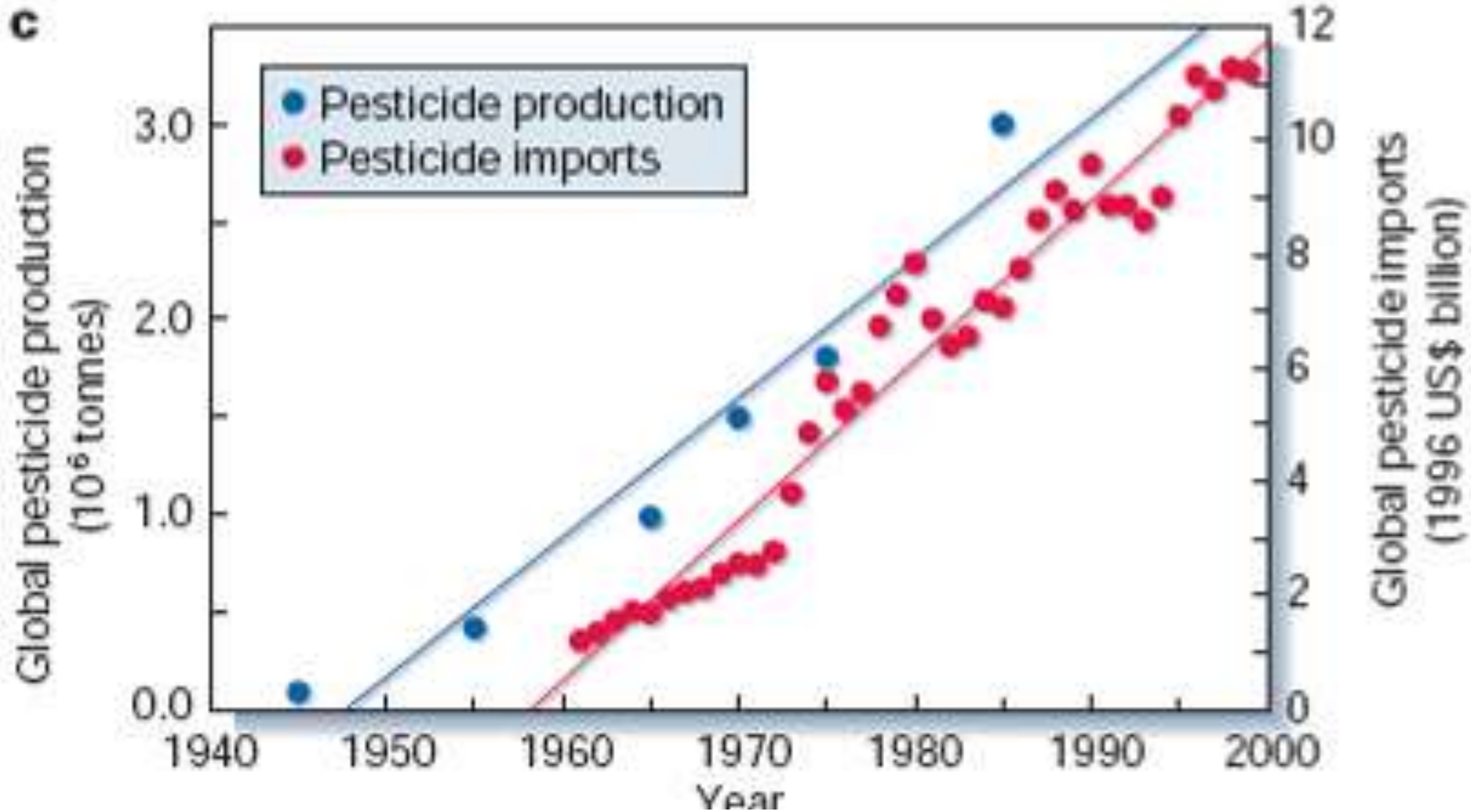
Tillman et al. (2002) ***Nature*** 418, 671-677

Total global use of nitrogen, phosphorus and area of irrigated land



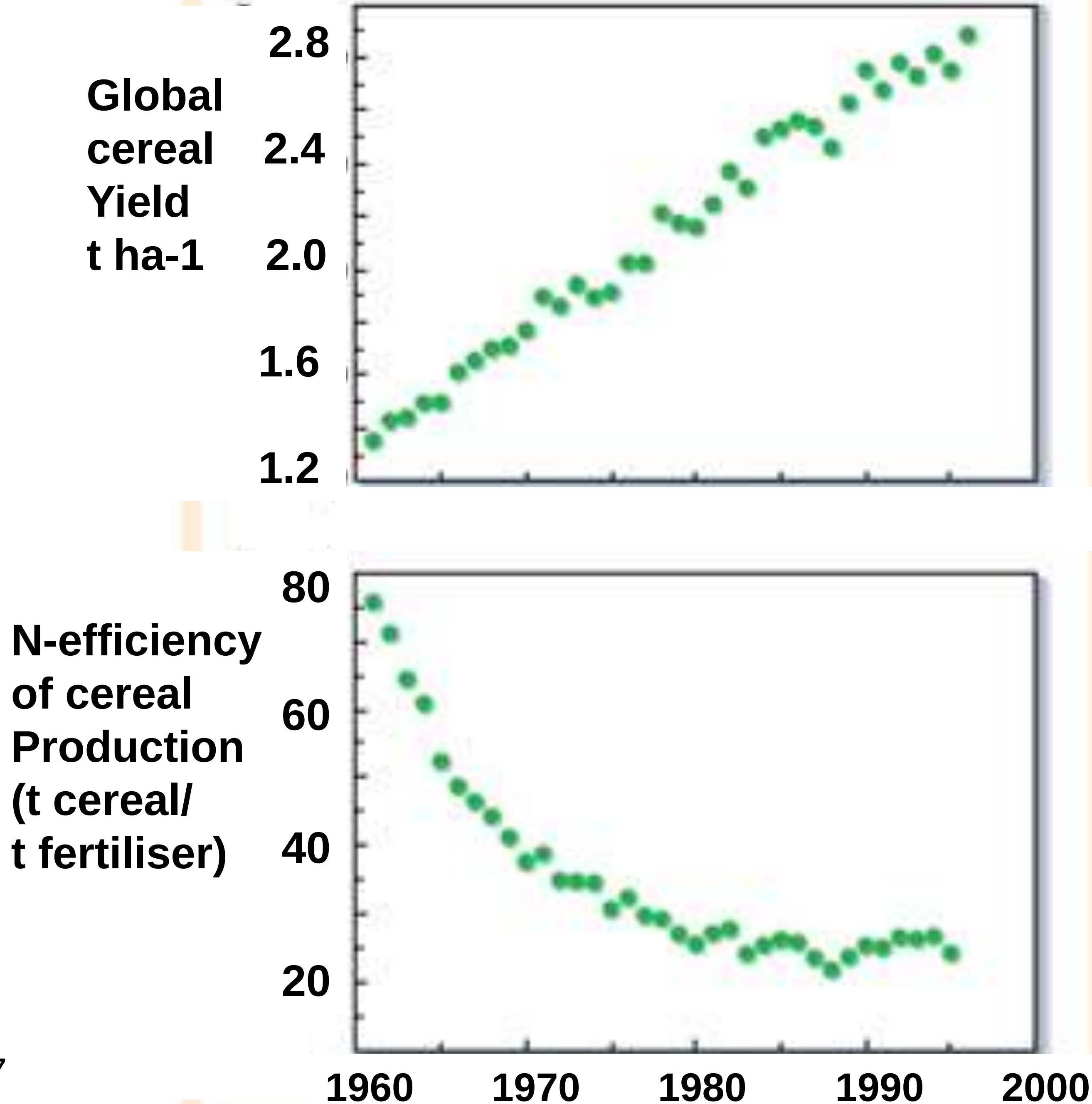
Tillman et al. (2002) ***Nature*** 418, 671-677

Total global pesticide production and imports



Tillman et al. (2002) ***Nature*** 418, 671-677

Diminishing returns of fertiliser applications



Tillman et al. (2002)
Nature 418, 671-677

Declining resource use efficiency

Agricultural intensification over the last 40 years is estimated to have resulted in:

- **a 2 fold increase in global food production[1]**
- **a 5-7 fold increase in mineral NPK use[1]**
- **resulting in a 2-3 fold reduction in <u>nutrient use efficiency</u> of crop production**
- **2-3 times as much NPK is needed to produce a kg of food than 40 years ago**

[1] Hirel et al. (2007) *Journal of Experimental Botany* **58:** 2369-2387

Why has nutrient use efficiency (NUE) decreased?

- **semi-dwarfing genes were introduced into wheat to reduce straw length and lodging risk**
- **semi-dwarfing genes also reduced root length/root system size and thereby nutrient uptake efficiency[1]**

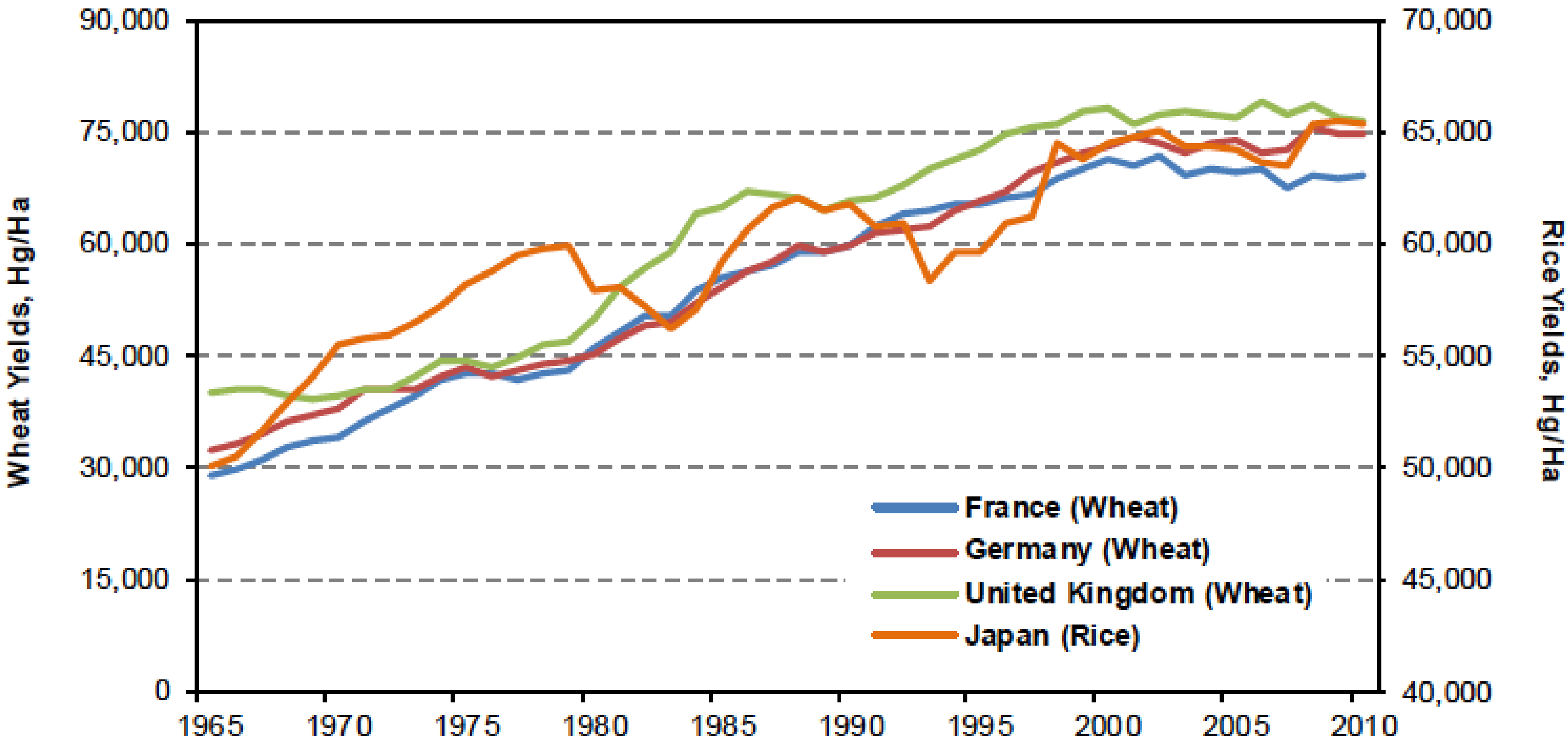
[1] Hawkesford 2014. J Cereal Sci. May 2014; 59(3): 276–283

Rothamsted Research, BBSRC Institute, UK

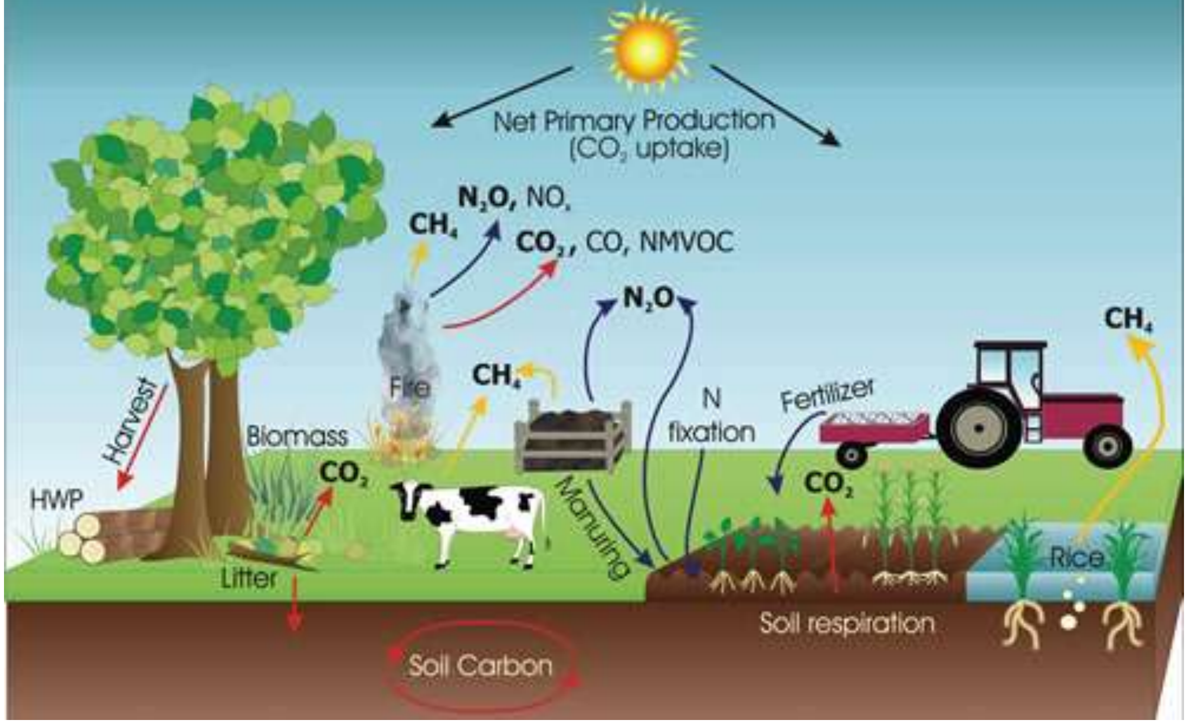
Target: 20 t ha^{-1} wheat by 2050

Method: GMO-technology + more inputs

Exhibit 1
Crop Yields (5-year moving average)
Wheat – France, Germany, United Kingdom; Rice – Japan



Source: UN Food and Agriculture Organization *As of 12/31/10*



What will limit crop yields in the future?

Availability and costs of:

Nitrogen (N) = energy

Phosphorus (P)

Potassium (K)?, other minerals and **WATER**

Energy use – CO_2 emissions

Mineral N-Fertiliser

- **1 kg Nitrogen-fertiliser = 36,000kJ = 1 L fuel**
- **1 kg nitrogen fertiliser (NH_3NO_3) results in = 2.38 kg CO_2 (equivalents of CO_2, CH_4 and N_2O)**
- **UK Farm level = 100 ha cereals x 200 kg N/ha/annum**

  = 20,000 Litre fuel used

  = 47,600 kg CO_2 into the atmosphere

- **European level = 11 Million t N/annum***

  = 11,000 Million Litre fuel used

*** Fertiliser Europe (2009) Annual Forecast 2009. www.fertilizereurope.com**

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(Gellings and Parmenter 2004)

Energy requirement in agricultural system (world average) in KJ/kg			
	Nitrogen	Phosphate	Potash
Production	69,530	7,700	6,400
Packaging	2,600	2,600	1,800
Transportation	4,500	5,700	4,600
Application	1,600	1,500	1,000
Total	78,230	17,500	13,800

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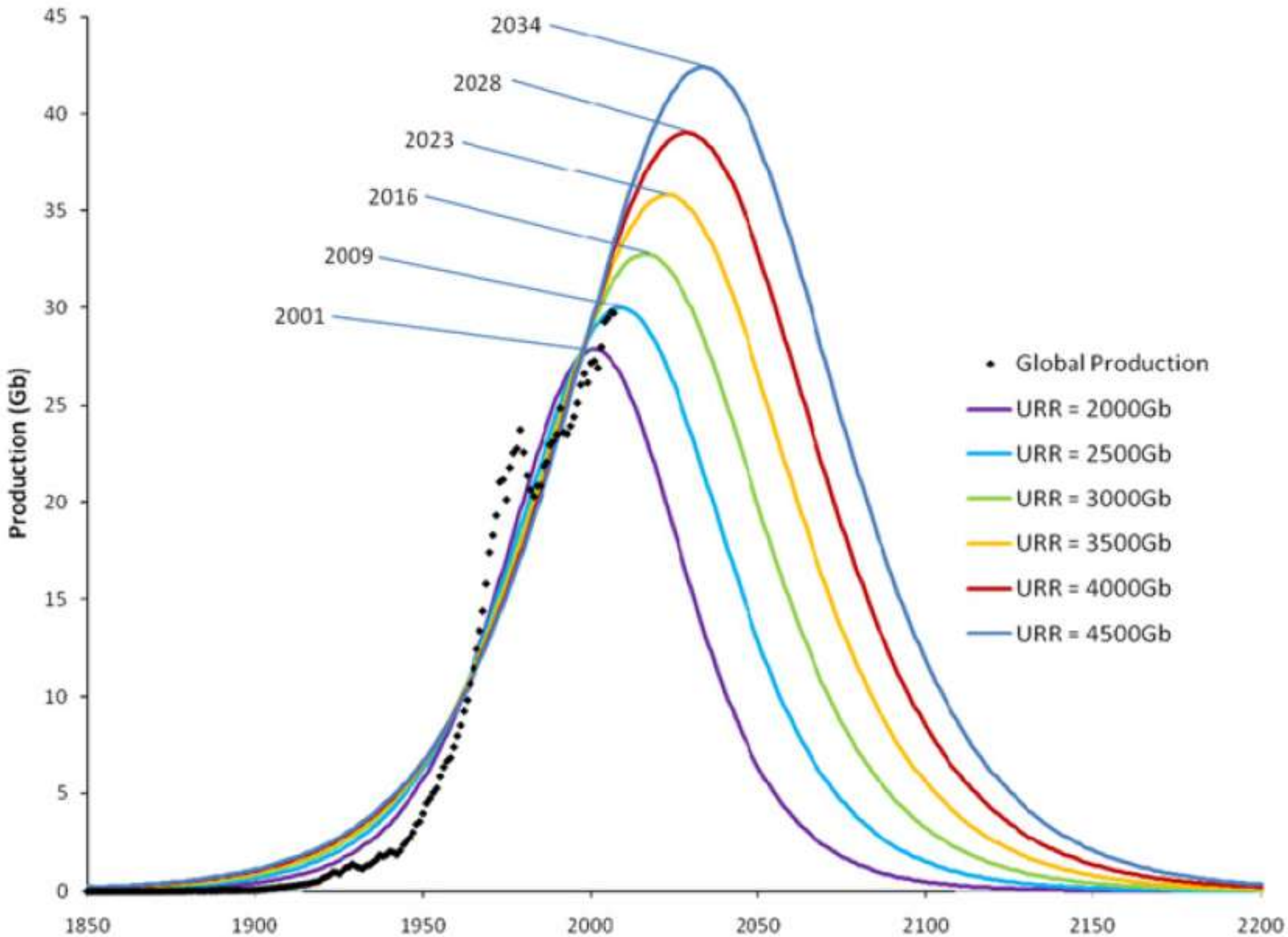
Peak of Oil Production



URR= Ultimate Recoverable Resource (Proven + Provable)

(Sorrell et al.,2010)

<u>Proven</u> global reserve: **1,333Gb:**
45.7 years-consumption of 2009
(BP, 2010)

Nitrogen, population growth and emissions

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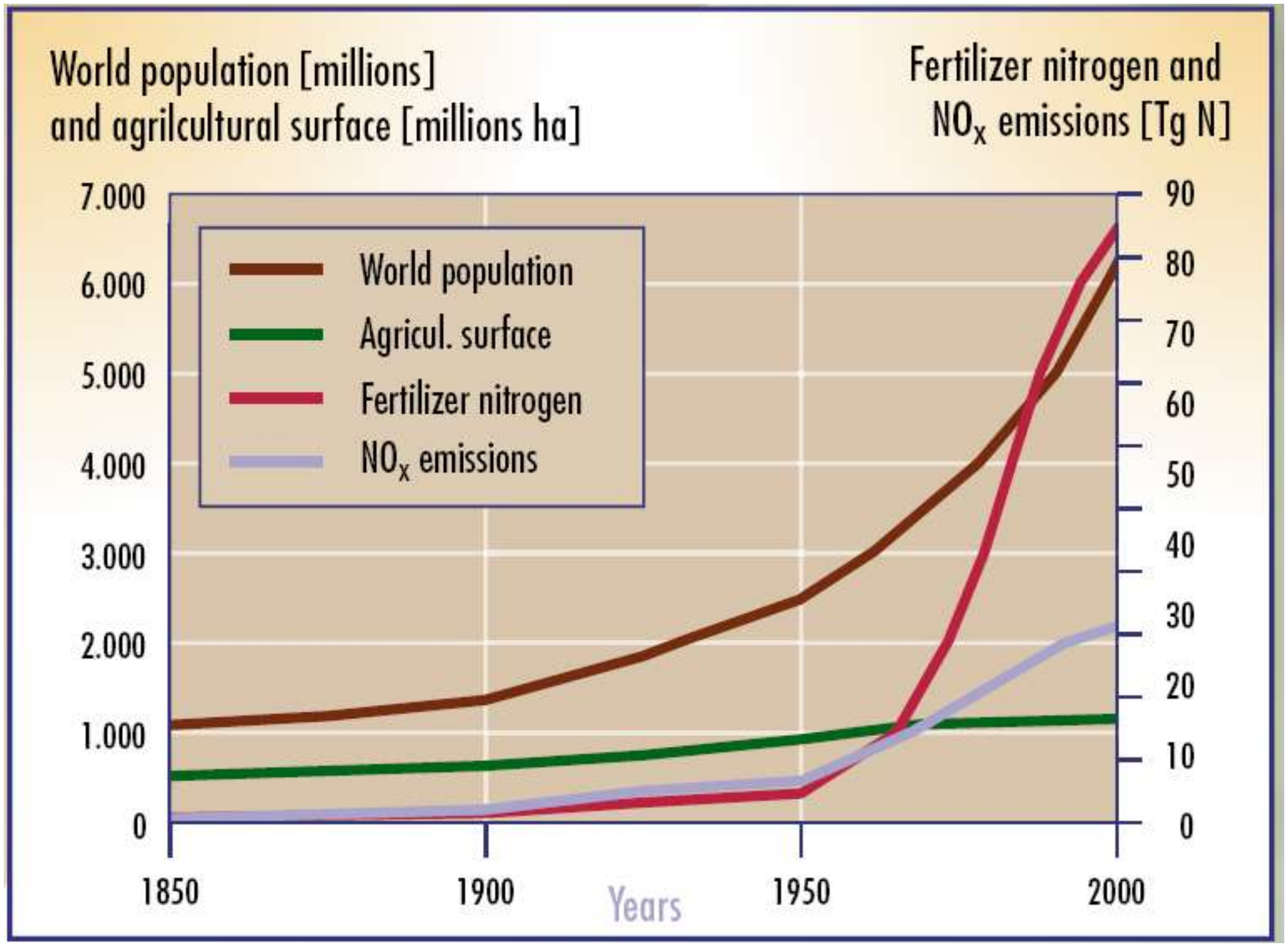
World population and agricultural surface vs Fertilizer Nitrogen and NO_x emission (UNESCO-SCOPE, 2007)



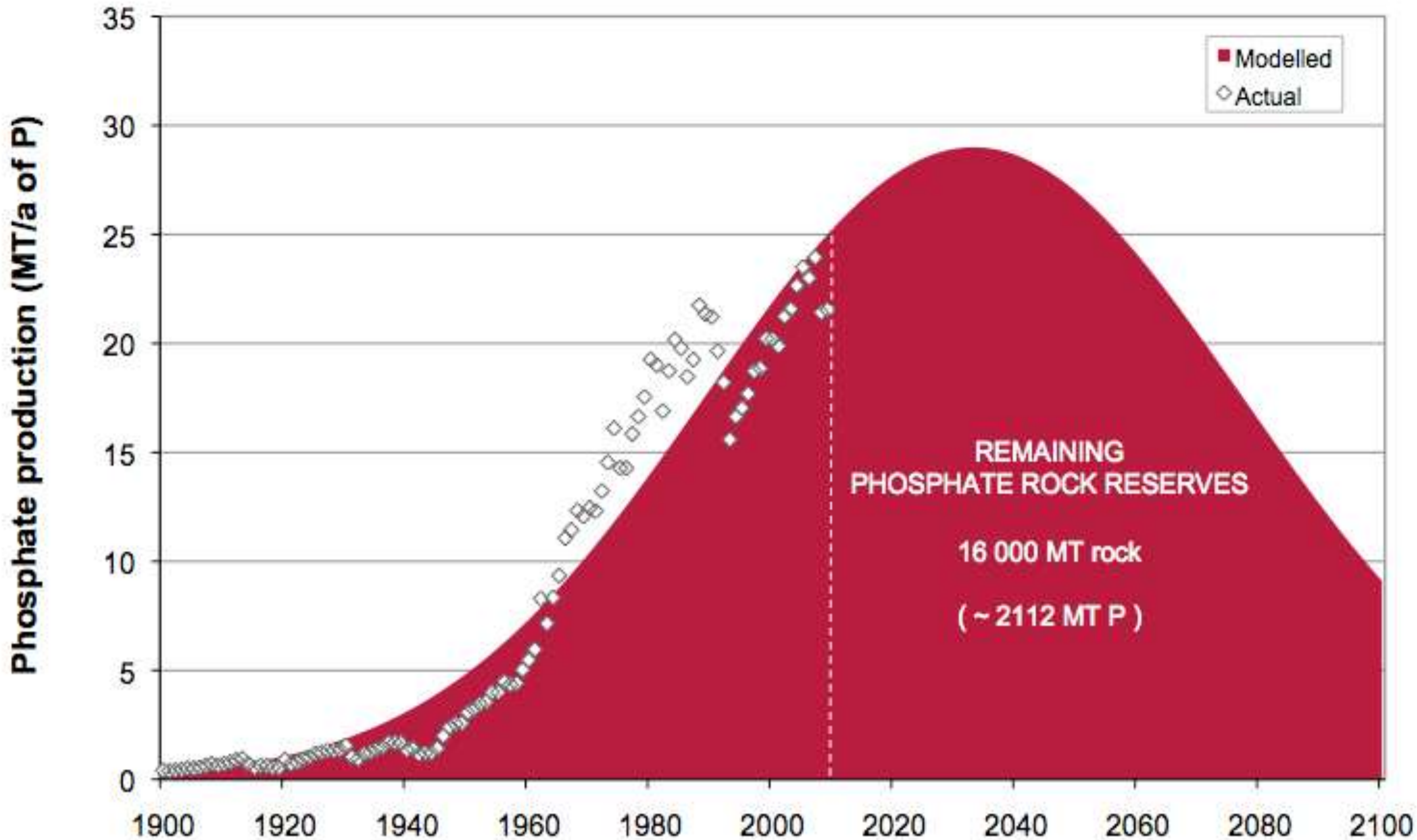
Why will Phosphorus become a <u>bottleneck</u> for productivity?

Phosphorus (P) fertiliser is a mined mineral

- **Numerous scientific studies conclude that phosphorus (phosphate rock) reserves-resources will be depleted in the 21st century**
  - **Pessimistic: in 30-40 years**
  - **More optimistic: in 70-80 years**

- **IFDC (International Fertilizer Development Centre) prediction: 300-400 years**
  - **Based on current consumption**
  - **Does the fertiliser industry and its lobbying bodies just want business as usual (avoid rationing)?**

Global Phosphorus use and reserves



Source: Cordell, D, Drangert, J-O & White, S (2009) *The Story of Phosphorus: Global food security and food for thought*. Global Environmental Change, 19 (2), p292-305

World Phosphate Rock Reserves by Country

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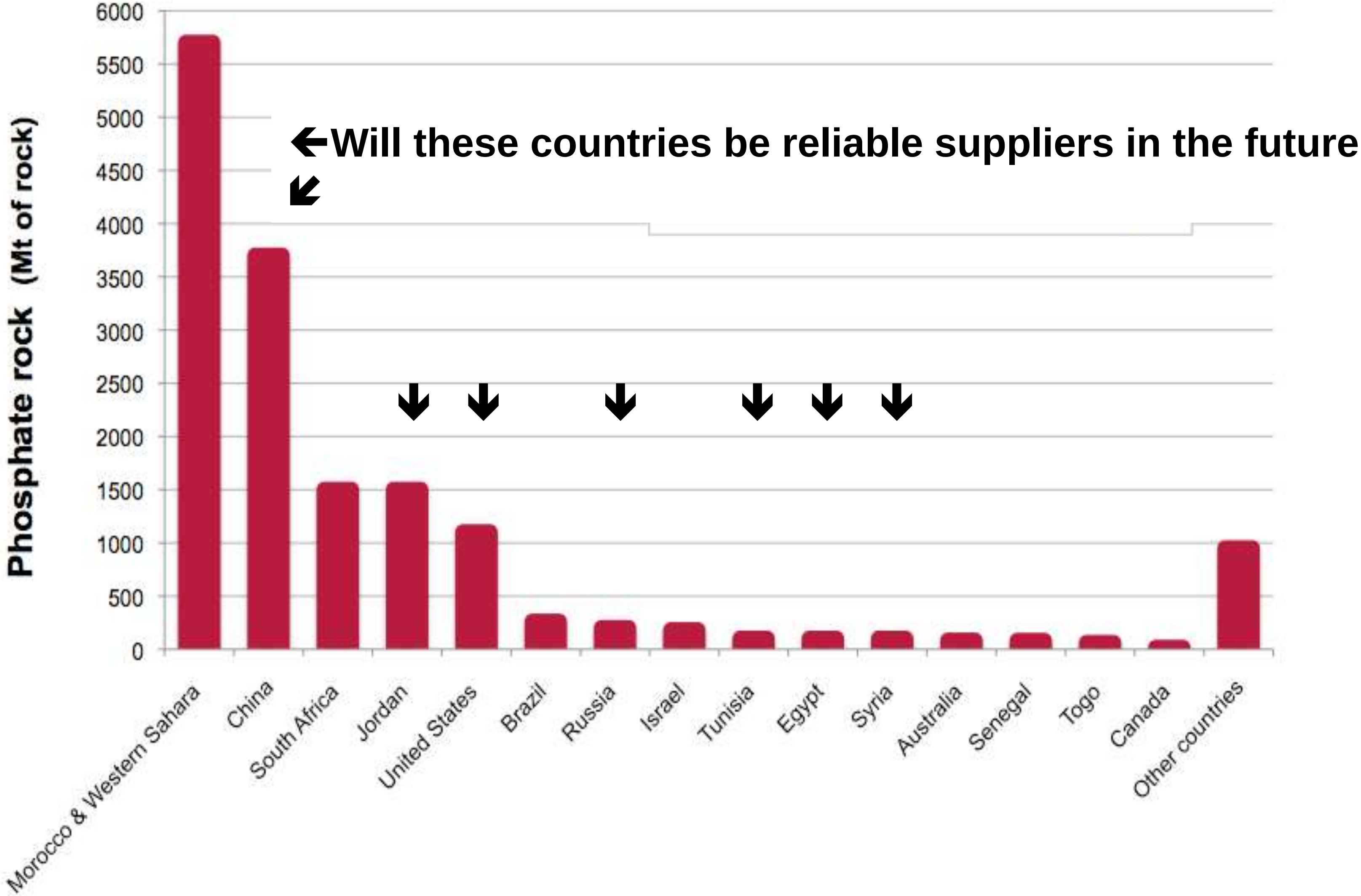

Data: Jasinski, S (2010) *Phosphate Rock, Mineral Commodity Summaries*, US Geological Survey.

Relative energy, fertiliser, mineral and agricultural commodity costs (2000-2008)

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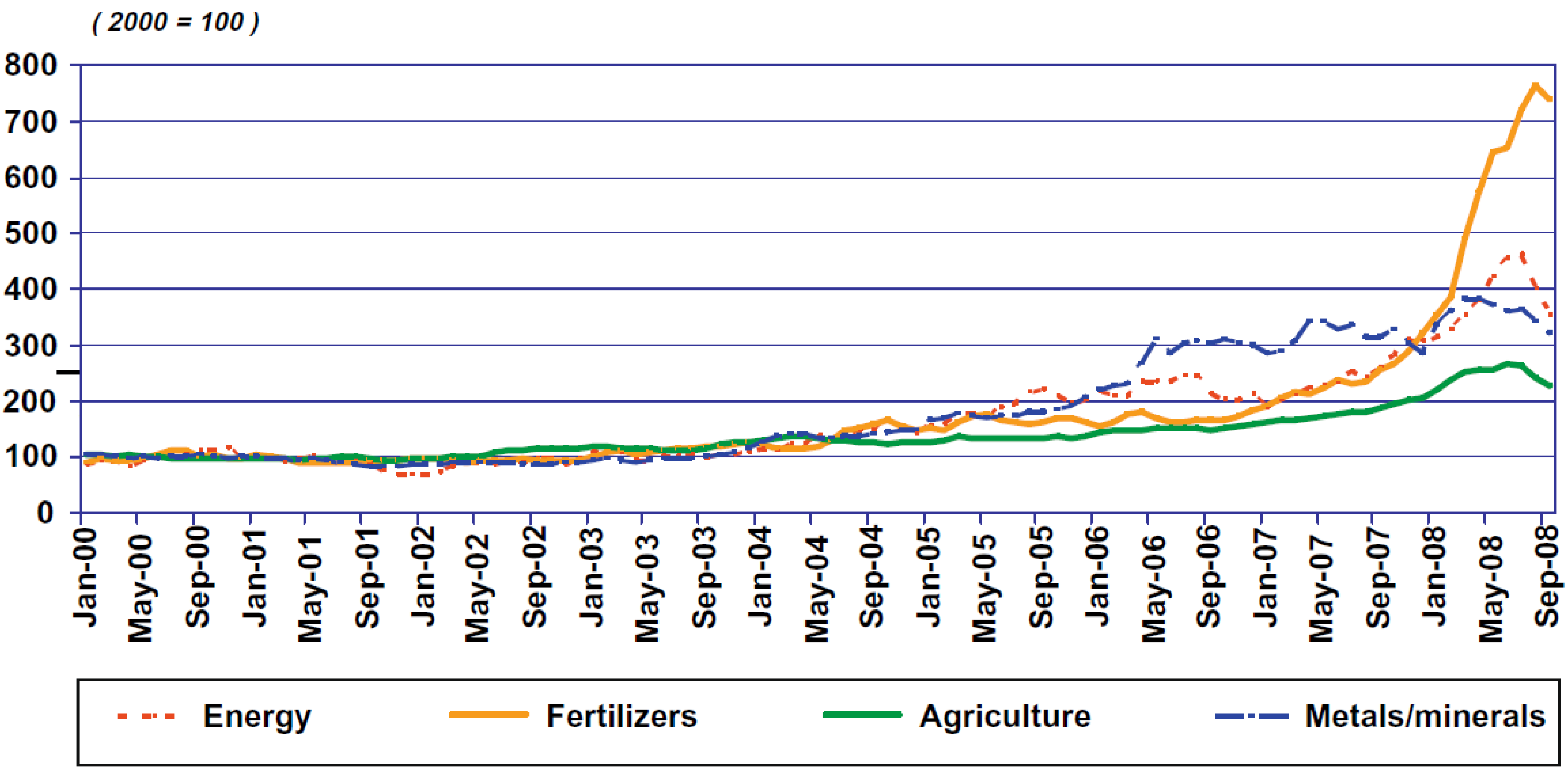

(Source: Piesse and Thirtle, 2009)

What is the effect of running out of mineral P-fertiliser
(example: UK wheat production)

Wheat yield Nafferton Farm - 2004

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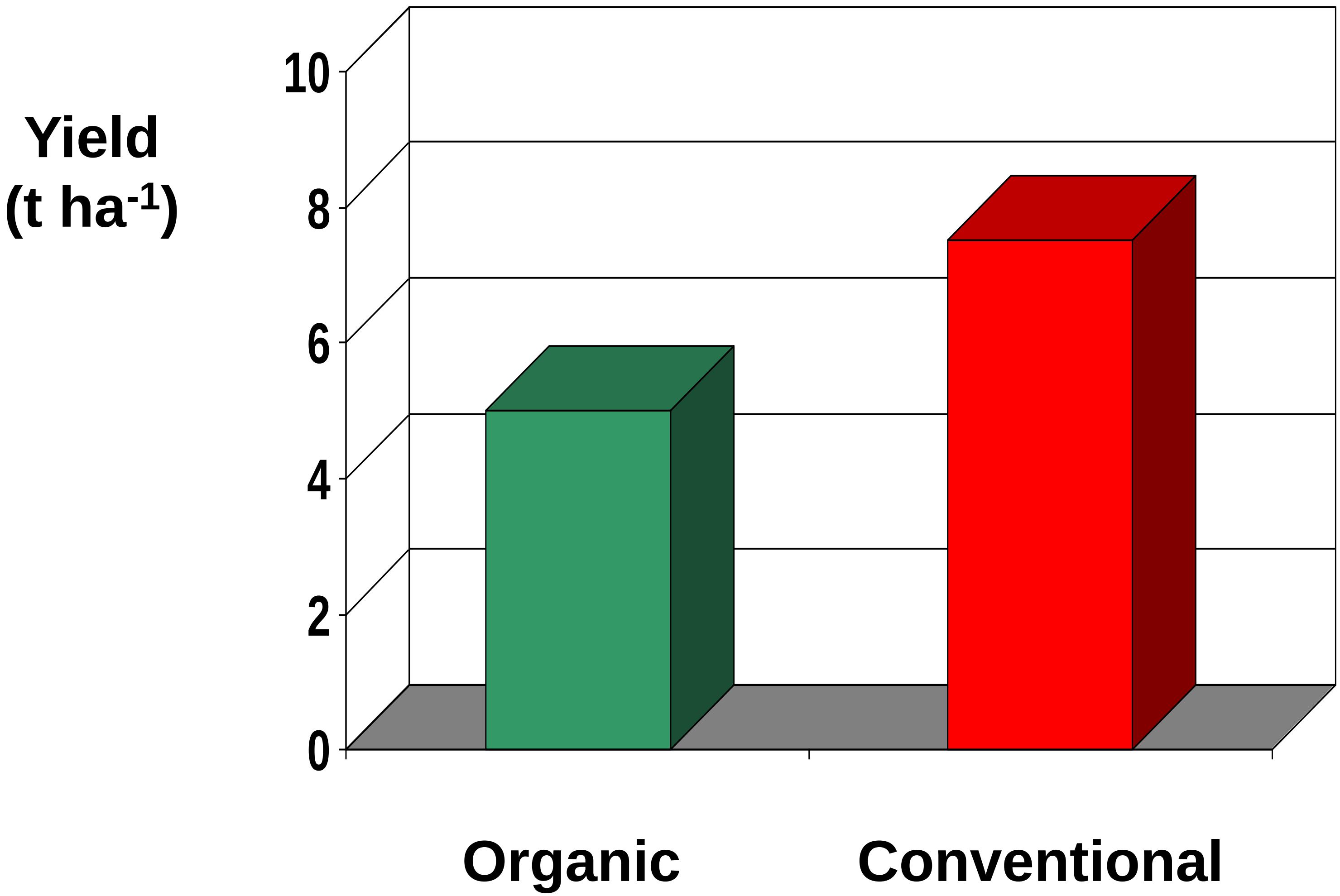
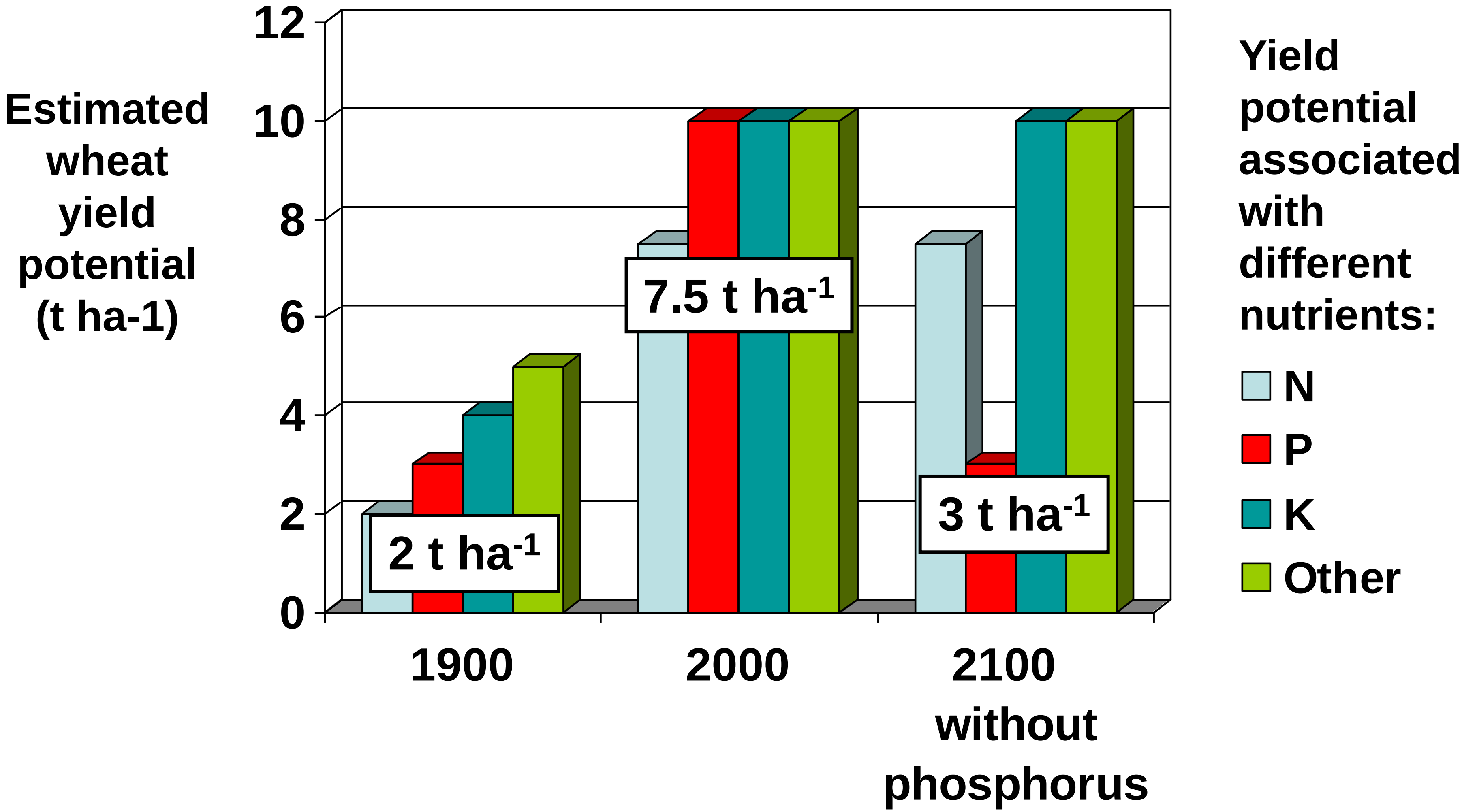


Nutrients limiting wheat yield in 1900 and 2000 and predicted 2100 yields without P-fertilisation



Wheat yield Nafferton Farm 2100*

*** predicted**

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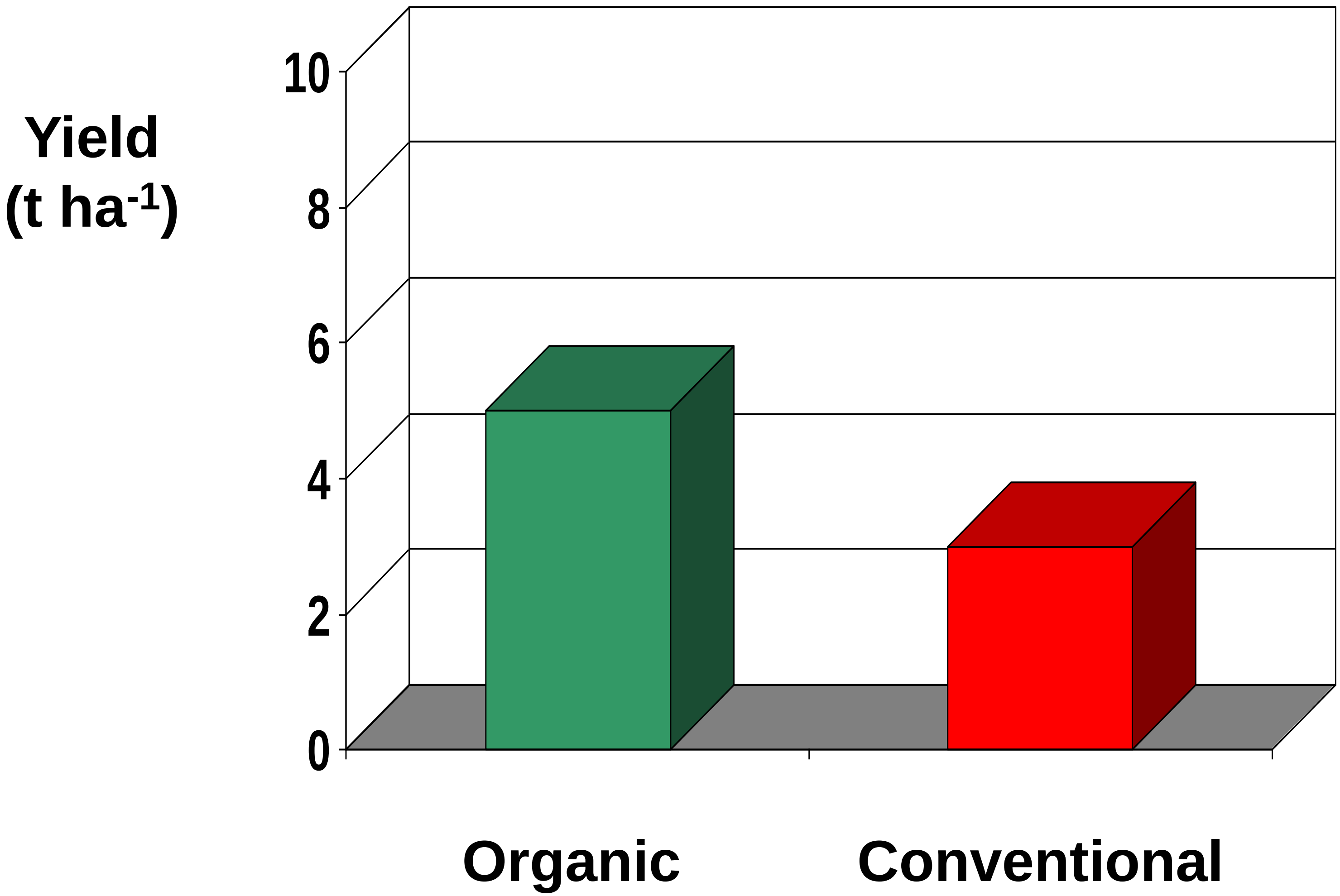
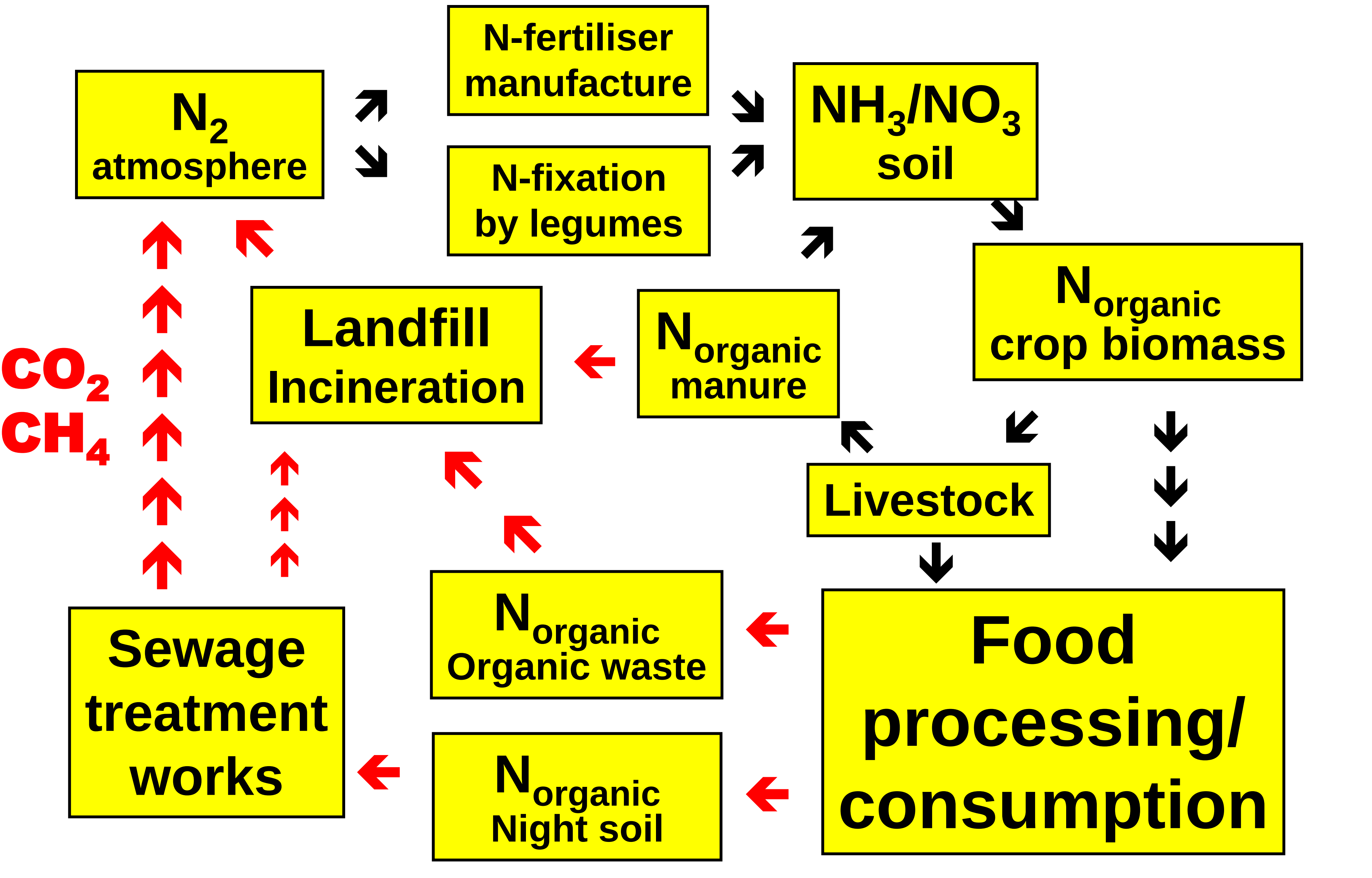


What are the solutions?

The main approaches available are:

1. **More efficient recycling** of NPK via
   - animal and green manures,
   - crop residues, food processing waste
   - communal and domestic organic waste
   - **human toilet waste/sewage**
2. **Reduction of losses** of fertiliser from soils
3. **Breeding/selection** of more nutrient (especially N and P) efficient crop varieties
4. **Diet change** (less meat, dairy products and eggs in the human diet)

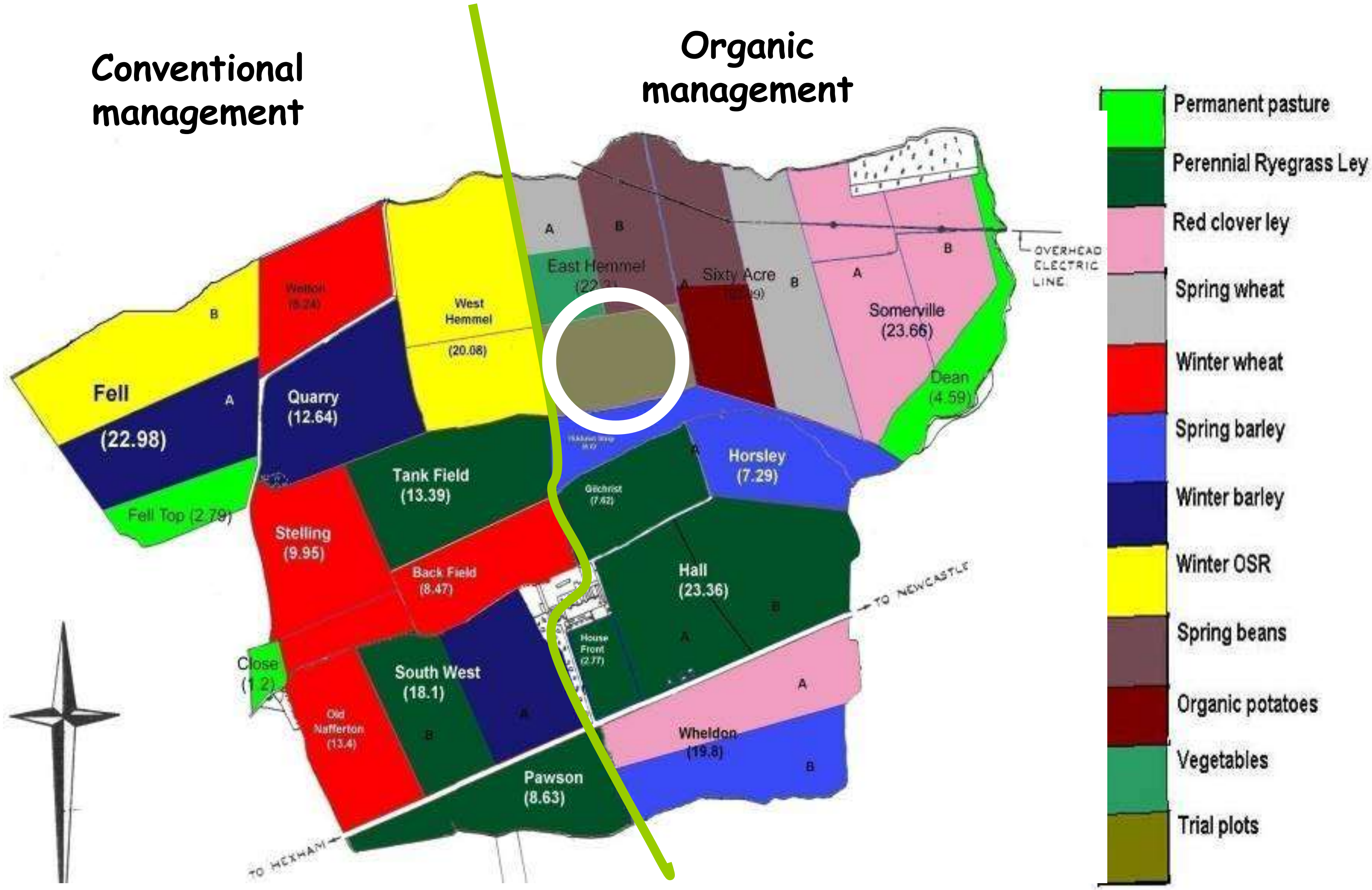
Closing the nitrogen (& other nutrient) cycles



Can conventional farming deliver food security?

- **High yields** in conventional systems rely on **mineral NPK fertiliser inputs** and **are not sustainable**
  - Mineral **N-fertiliser** manufacture is estimated to account for 10% of total greenhouse gas emissions from agriculture
  - Mineral **P-deposits** will be depleted in 30-100 (300?) years
- **Without mineral P-inputs yields in conventional farming will decline by more than 50%**
- **In the future** mineral fertilisers will need to be replaced by
  - **organic fertilisers** made from both **agricultural and domestic/communal organic waste (= recycling of NPK)**
  - the use of **legume crops** to increase **N-inputs** into soils
- **Currently mineral NPK fertilisers are still too cheap**
  - **BUT mineral fertiliser prices have increased more than 8-fold in the last 10 years**

Can organic farming deliver food security?



Nafferton Factorial Systems Comparison experiments

Experimental Design

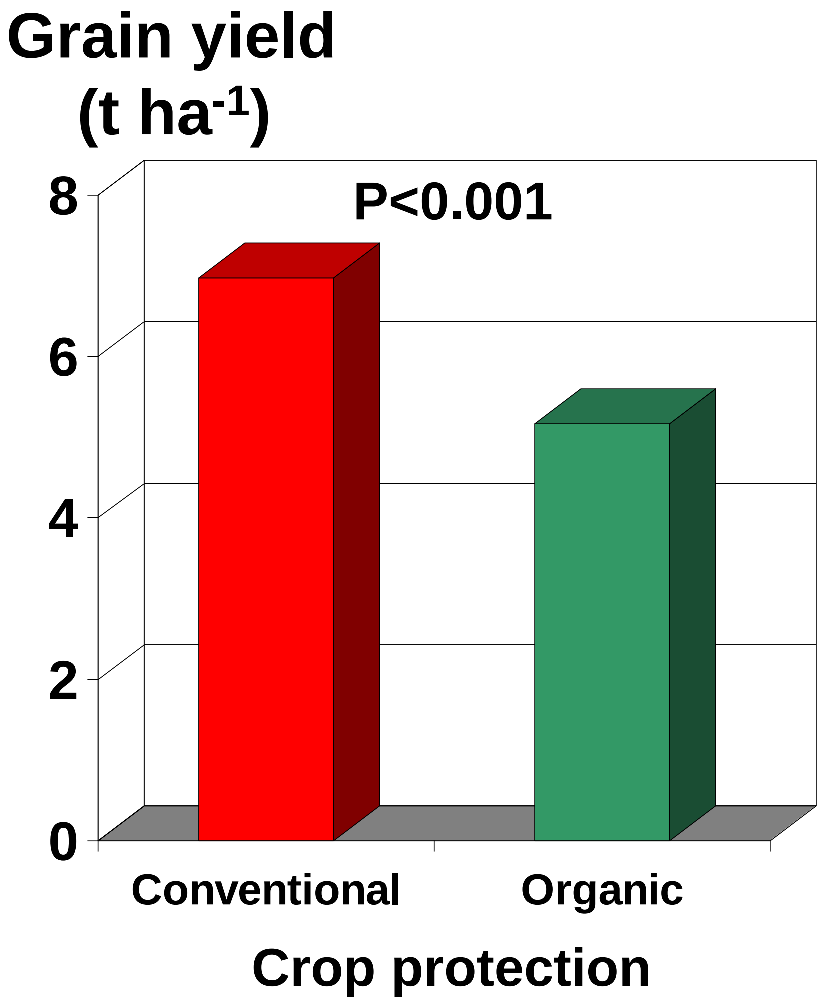
Nafferton **F**actorial **S**ystems **C**omparison **T**rial

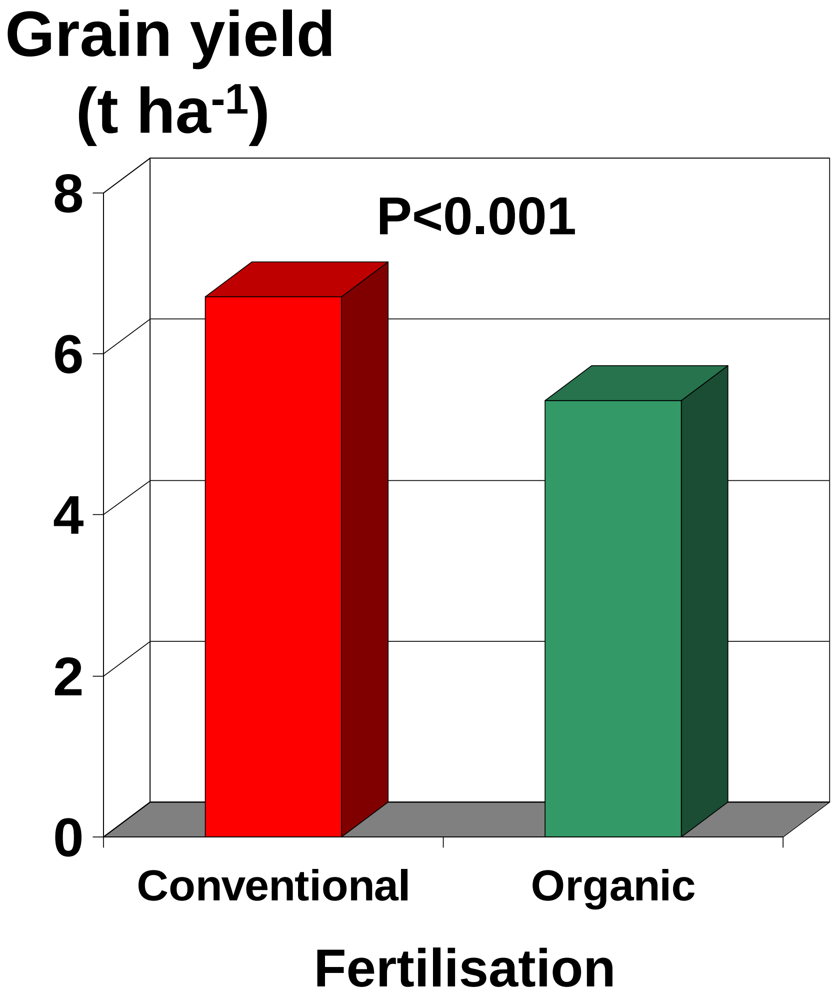
Nafferton factorial production systems comparison trial – experimental design

- Rotation design (4)
  - Non-diverse (2): 2 years grass/clover 6 years cereals, 1 year potato/ vegetables
  - Diversified (2): 3 years grass/clover, 2 years cereals 2 years potato/vegetables, 1 year faba beans)
- Crop protection (2)
  - Conventional (pesticides used to farm assured standards)
  - Organic (according to soil association standards)
- Fertilisation (2)
  - Conventional (pesticides used to farm assured standards)
  - Organic (composted manure inputs only)
- Replicate blocks (4)
- Replicate experiments (4)

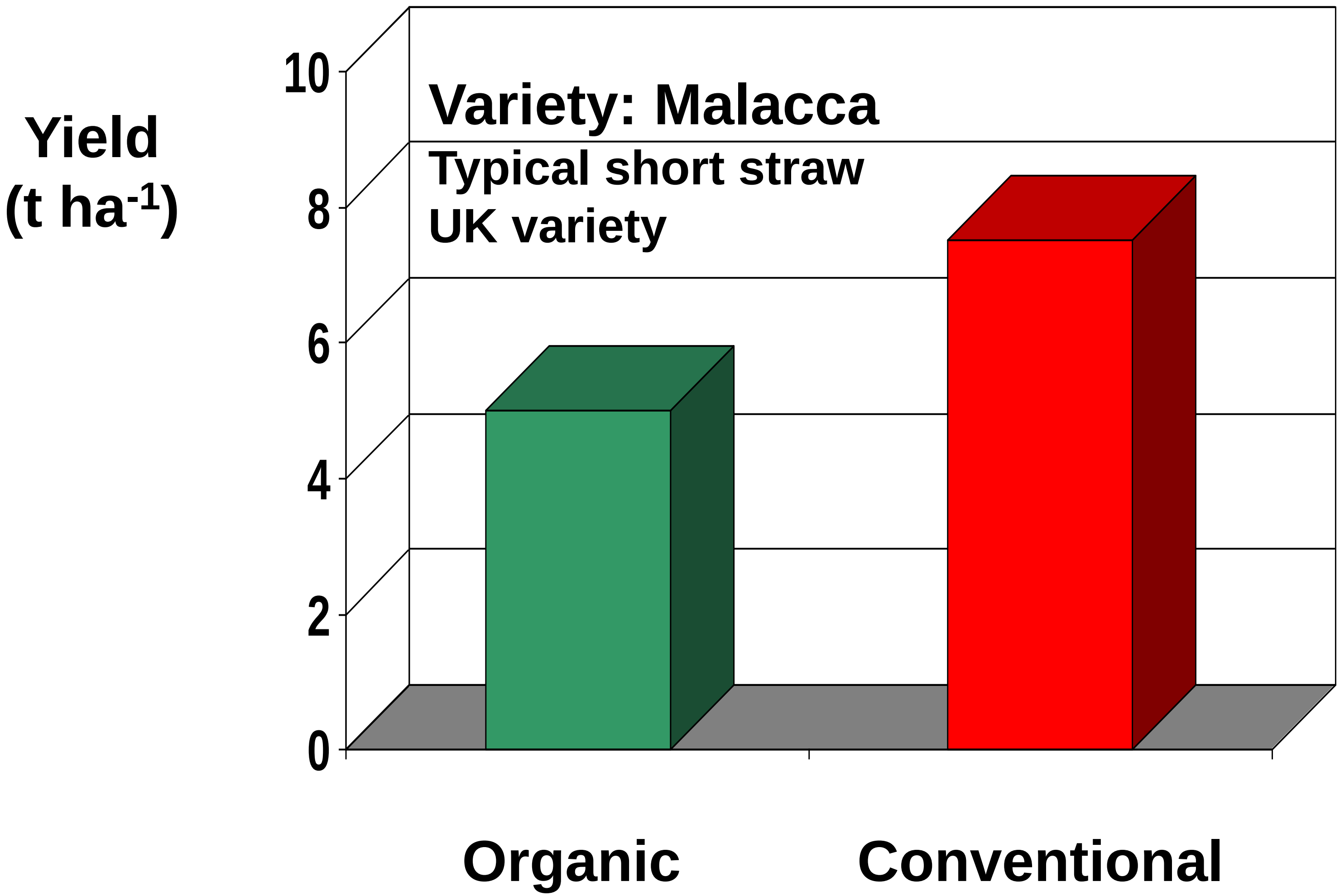
Total area: 6 ha

Effect of fertilisation and crop protection on the wheat yield (average of 4 seasons)

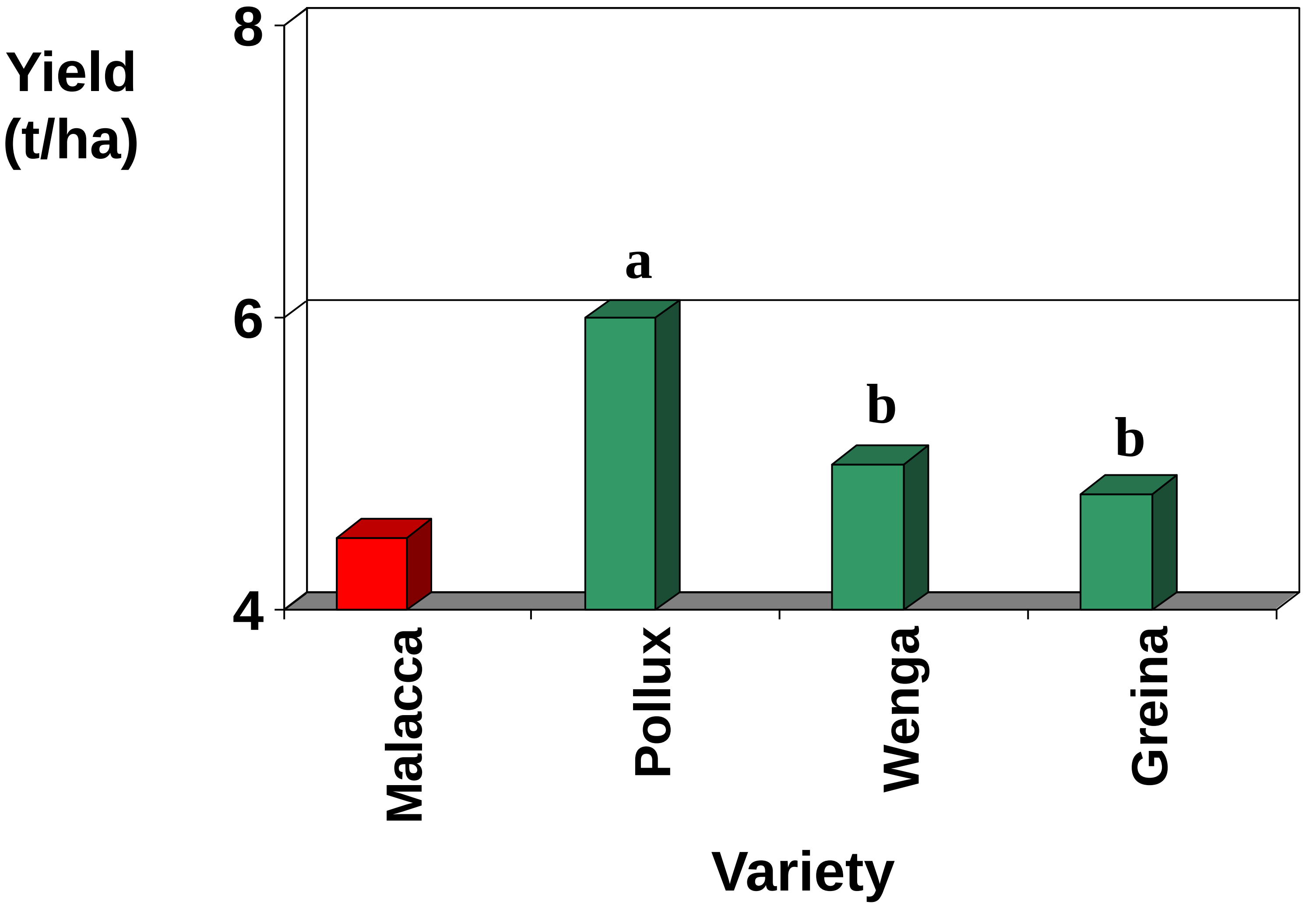




Wheat yield Nafferton Farm - 2004

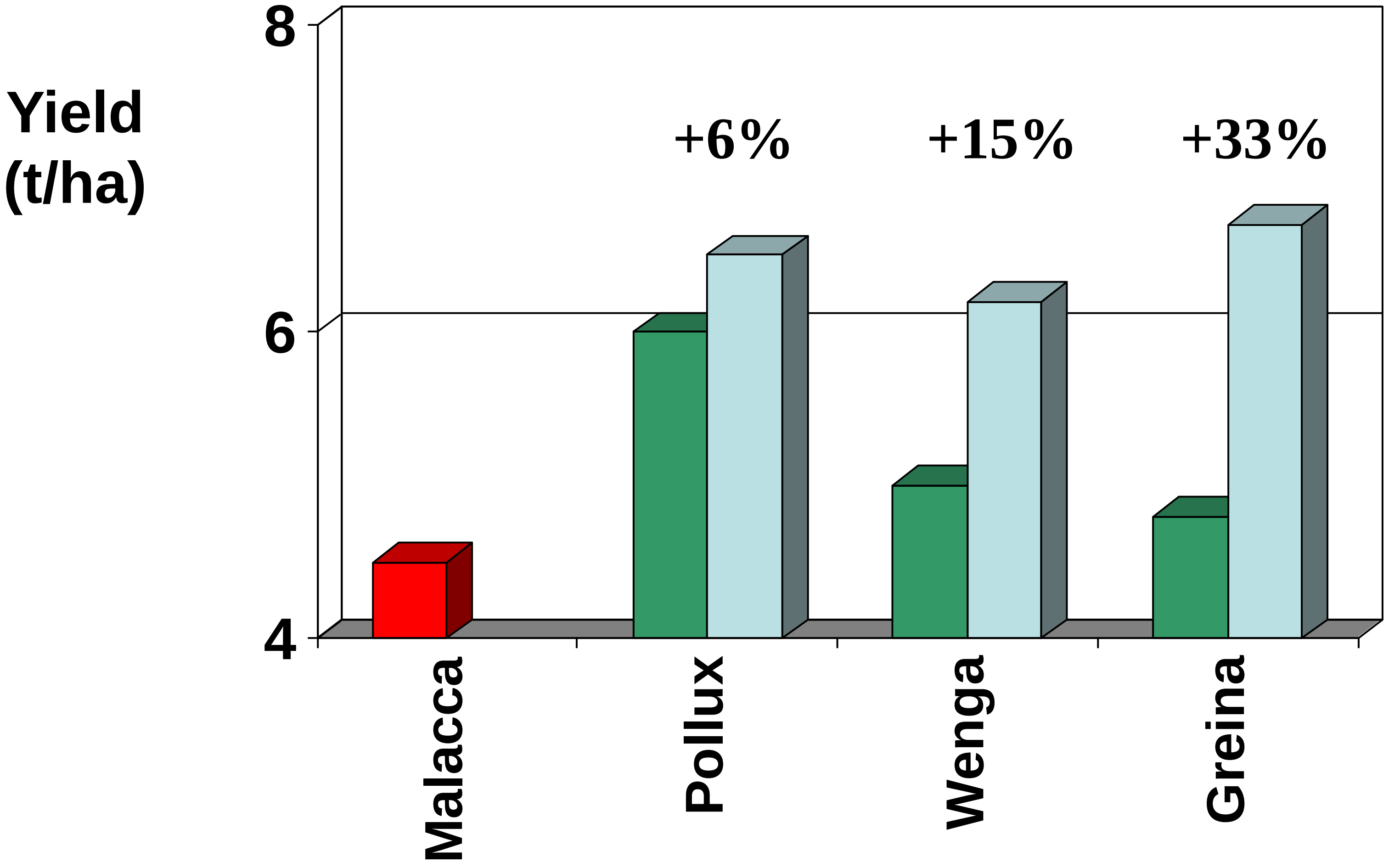


Wheat - Yield (2005)
Effect of using varieties adapted to organic systems



Wheat - Yield (2005)

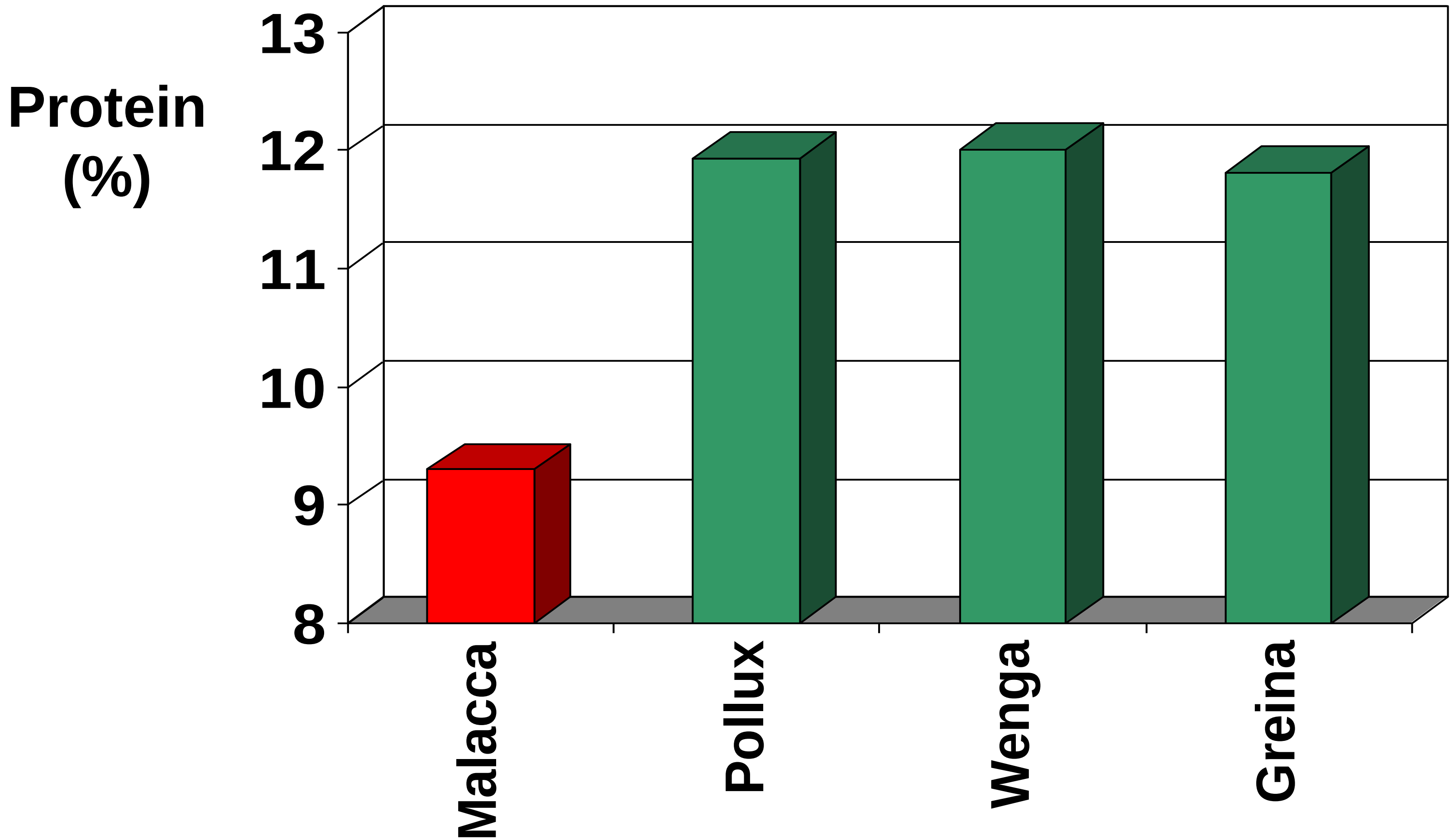
Effect of using varieties adapted to organic systems (longer straw!, higher NUE?)



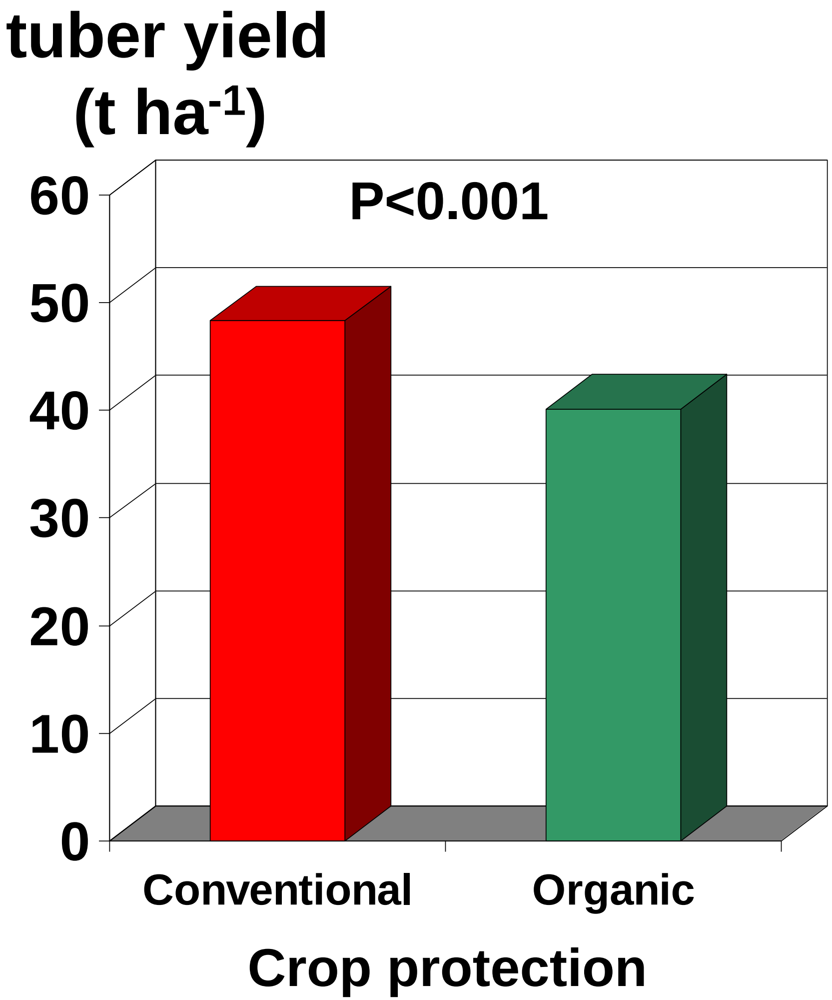
Dark Green colour: standard fertility management
Light Blue colour: improved fertility management

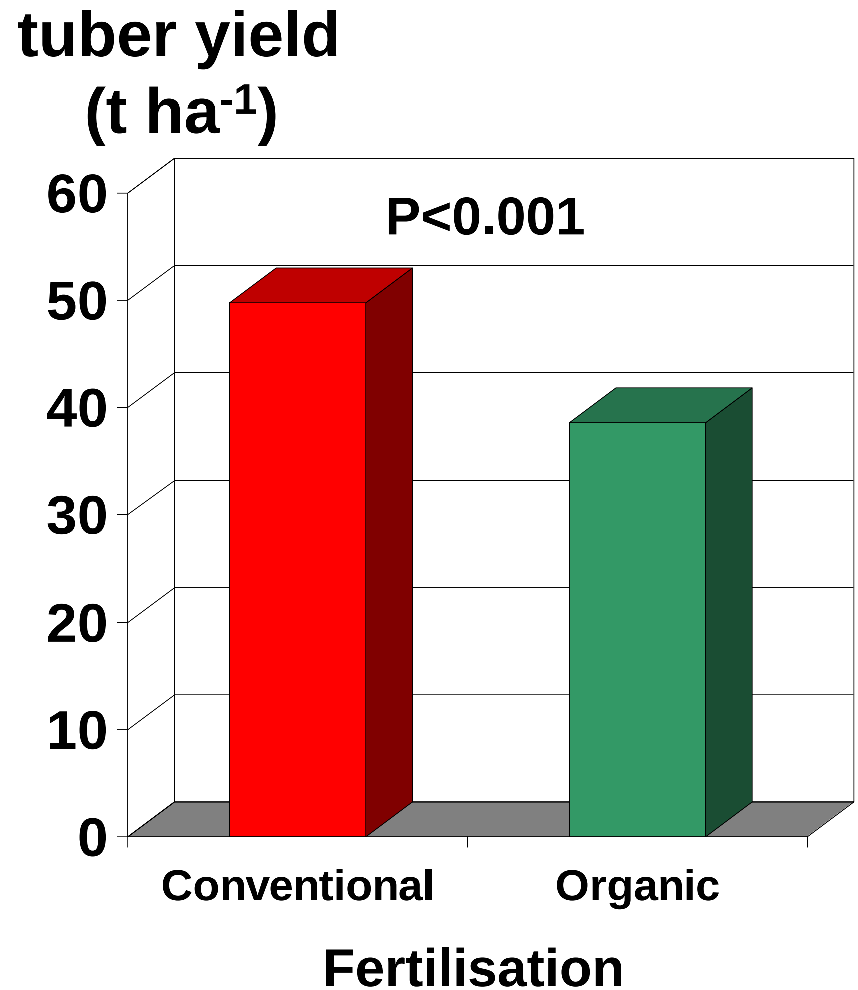
Wheat 2005 - Protein content

Effect of using varieties adapted to organic systems

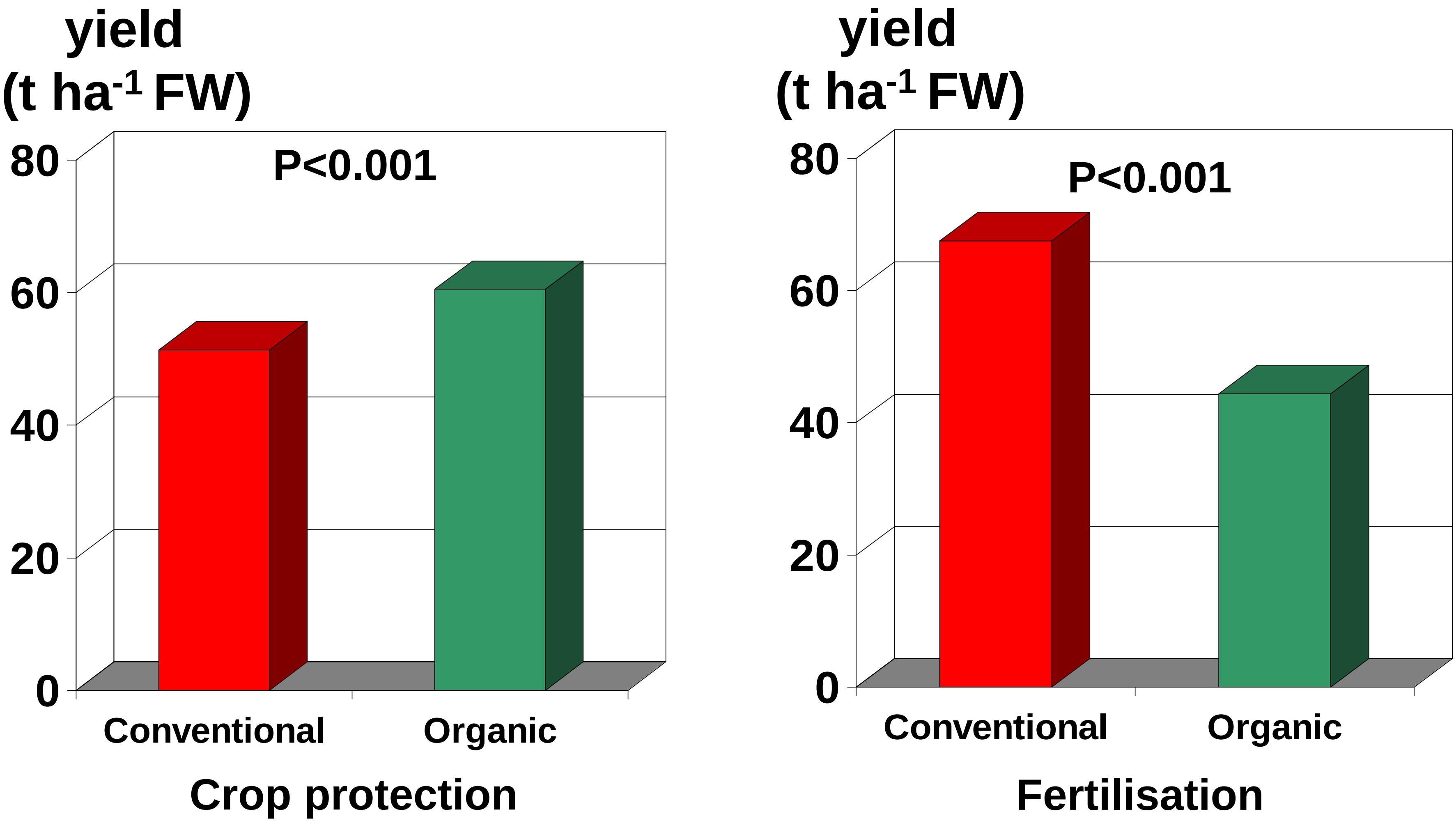


Effect of fertilisation and crop protection on the potato yield (average of 4 seasons)

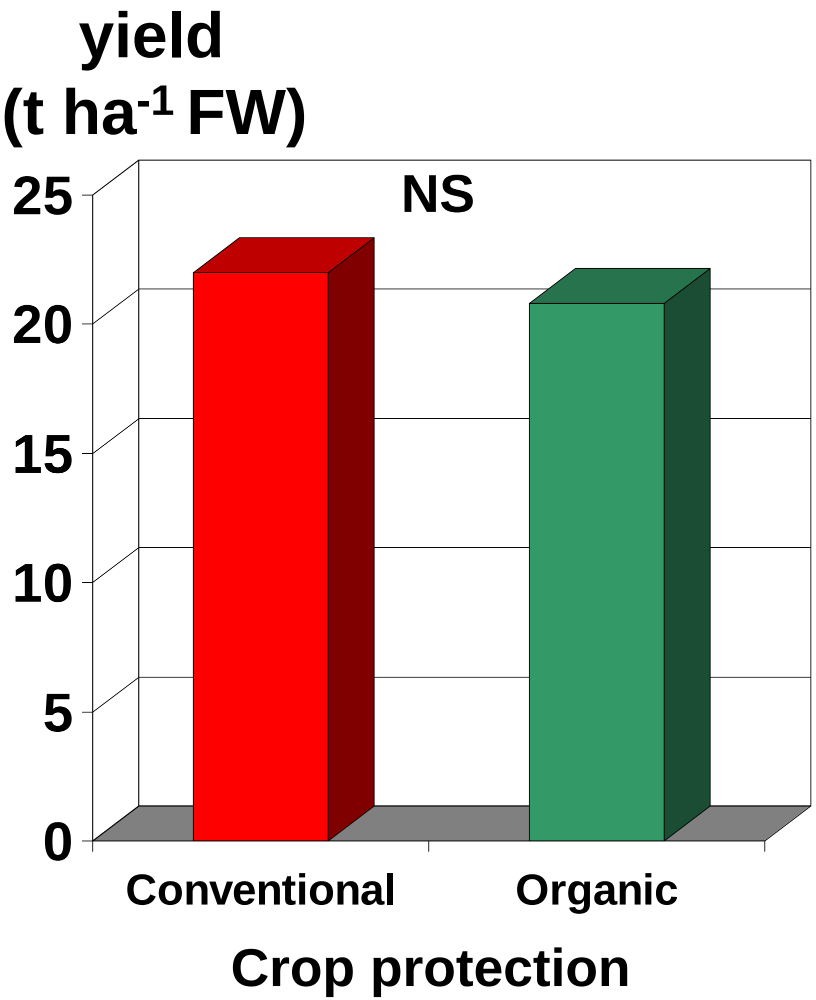


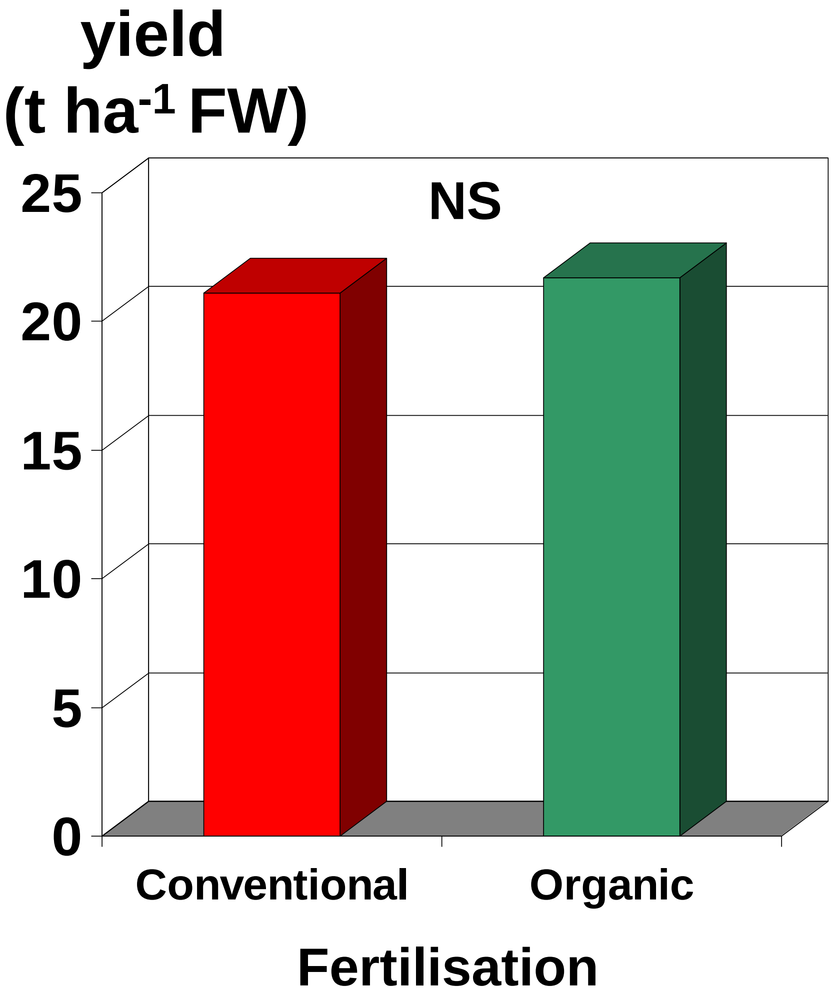


Effect of fertilisation and crop protection on the cabbage yield (average of 4 seasons)



Effect of fertilisation and crop protection on the onion yield (average of 4 seasons)





Can organic farming deliver food security?

- **Crop yields** in organic farming systems are lower
  - by up to **40%** in arable crops such as cereals/potato
  - yields in many horticultural crops are only slightly lower

- There is **great potential to increase yields** in **organic farming** systems by **optimising/increasing organic fertiliser inputs regimes**
  - Evidence from **long term trials in China** suggest that when used **at the same mineral input level,** mineral and organic fertilisers (e.g. manure) will produce **similar yields**

- **There is increasing amount of organic waste !!!!!**

- **So what are the barriers for *“eco-functional intensification”* of organic crop production**

Barriers for “eco-functional intensification”

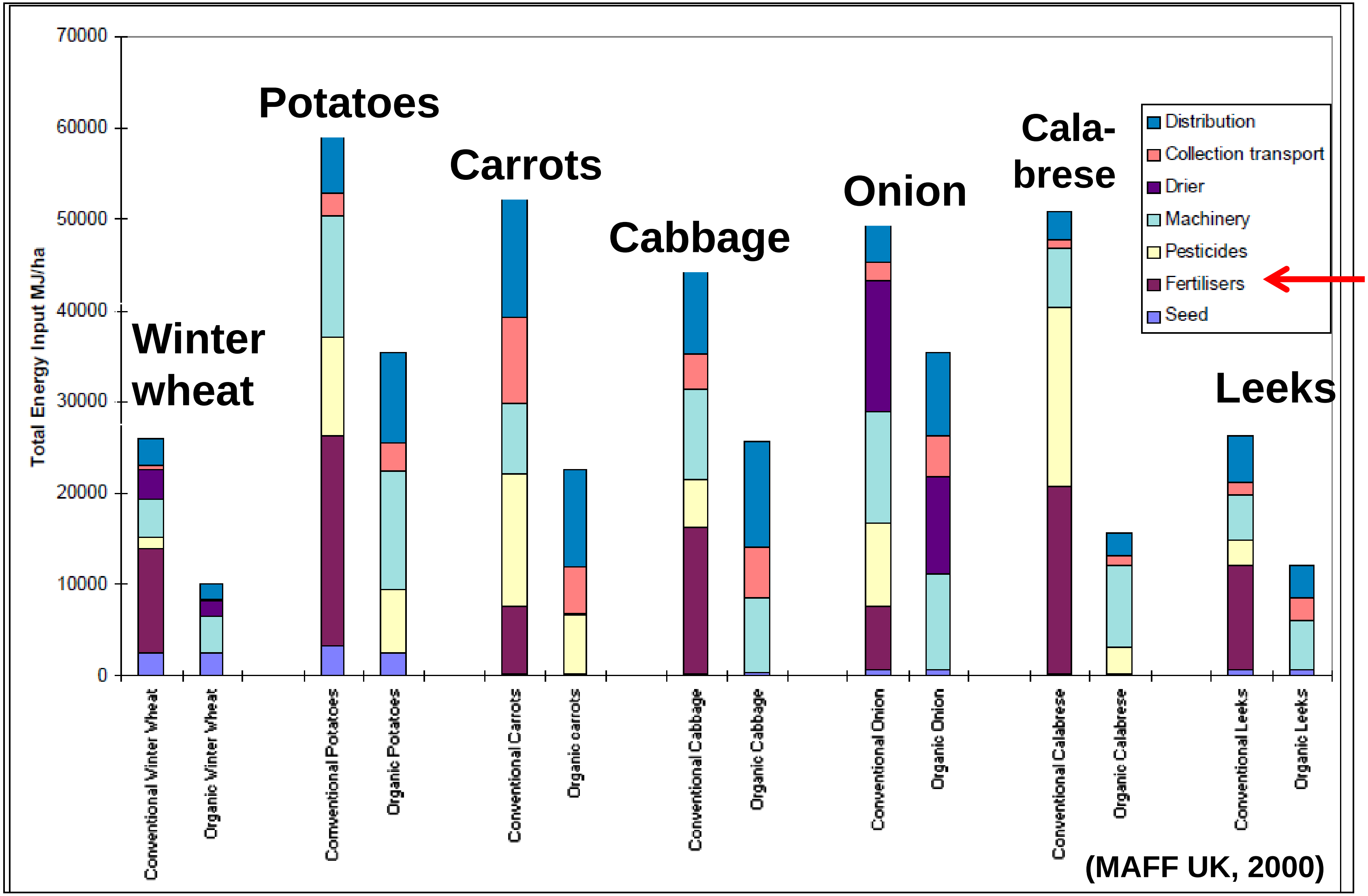
- **Organic standards/legislation** which
  - **restrict “imports” of fertility** (principle of on-farm sustainability)
  - **prohibit the use of certain organic wastes** (night soil, sewage, animal processing waste) as fertiliser

- **Environmental legislations** which
  - **restricts organic fertiliser inputs** to **170 kg N ha^{-1} $annum^{-1}$** although the **nitrate leaching and P-run-off risk** differ greatly between organic fertilisers
  - **requires farms to have waste management licences** to import urban organic waste onto farms

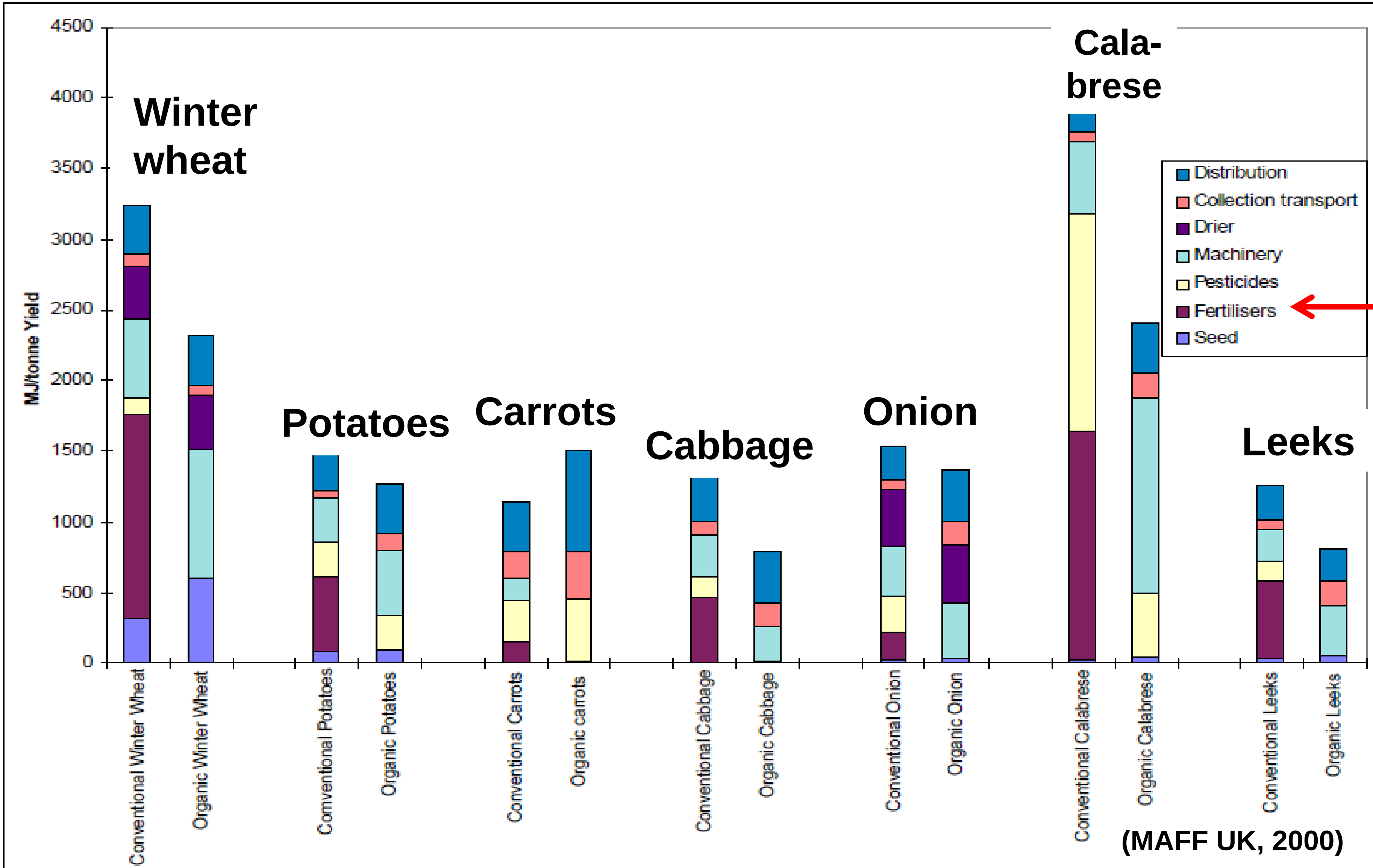
Issue associated with the “eco-functional intensification” of organic crop production

- **Food safety**
  - Is there an increased risk from food pathogen, heavy metals, other pollutants when using organic waste based fertilisers?
- **Consumer perceptions**
  - will organic consumers accept the use of night soil/sewage based fertilisers?
- **Crop health and nutritional quality**
  - will pest, disease and weed pressure increase?
  - will the nutritional value of crops decrease?
- **Environmental impact**
  - Will nitrate leaching and P-run off increase?
  - Will greenhouse gas emissions from fertiliser increase?
  - Will **energy use** increase further?

Energy consumption in conventional vs organic crops (per unit area)



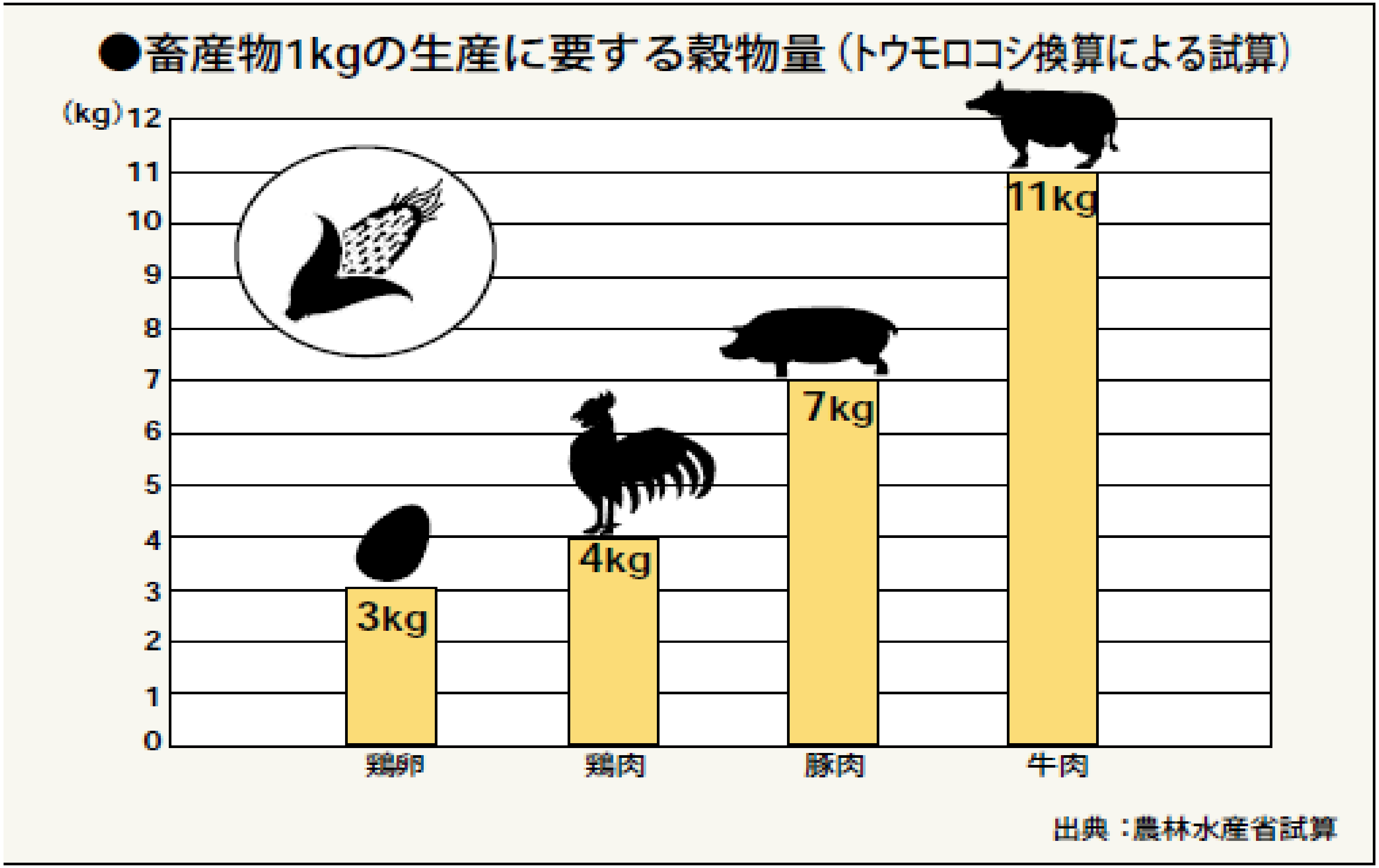
Energy consumption in conventional vs organic crops (per unit product)



We need to extensify organic animal production!!!!!

Amount of cereal (corn-equivalents)

necessary to produce 1 kg of livestock products




Thank you