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Ecological Farming Group

Research needs for organic agriculture

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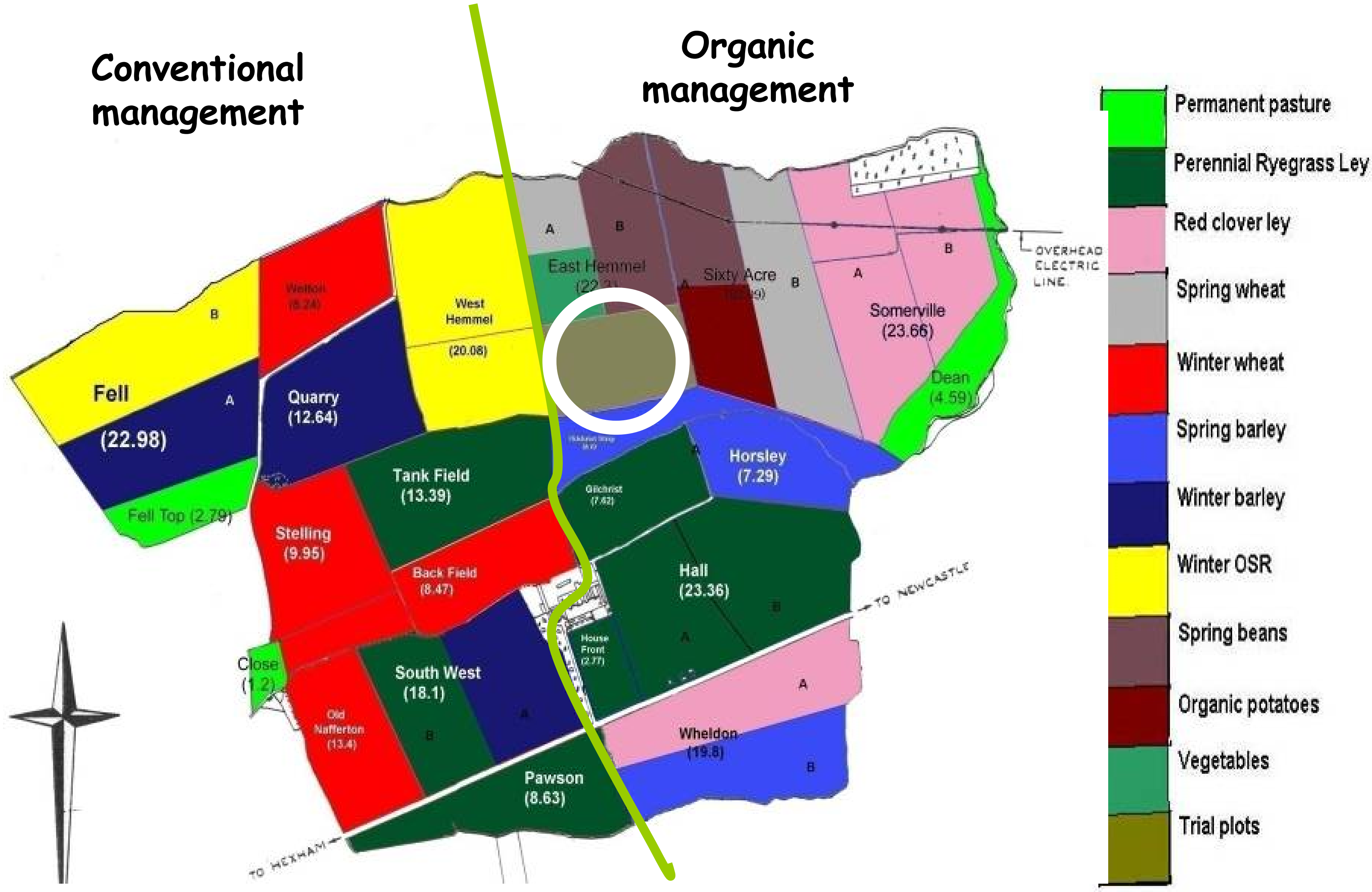
Why support organic farming?

- **Food quality**
- **Food security**
  1. **soil conservation**
  2. **environment/biodiversity protection**
  3. **self-sufficiency at farm level**
  4. **minimum use of non-renewable and scarce resources**
     - **Energy, minerals (NPK etc), water**
     - **Imported concentrate feed (soya, maize)**



Nafferton Factorial Systems Comparison experiments

Experimental Design

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

Food quality

Pesticide residues

- **The frequency of occurrence of pesticide residues is 3 times higher in conventional than organic crops** (Smith-Sprangler et al. 2012 Ann Inter Med **157**, 348-366)
- **Organic food consumption was shown to reduce exposure to organophosphorus pesticides in pre-school children** (Curl et al. 2003 Environ Health Perspect **111,** 377-382)
  - **78% of conventional fruit and 31% of conventional vegetables contain detectable pesticide residues**
  - **10% of organic fruit and vegetables also contain detectable pesticide residues**

Effect of fertilisation and crop protection on the Cadnium content in potato (average of 4 seasons)

(Cooper et al. 2013 *J Agric. Food Chem.* **59**, 4715-4724)

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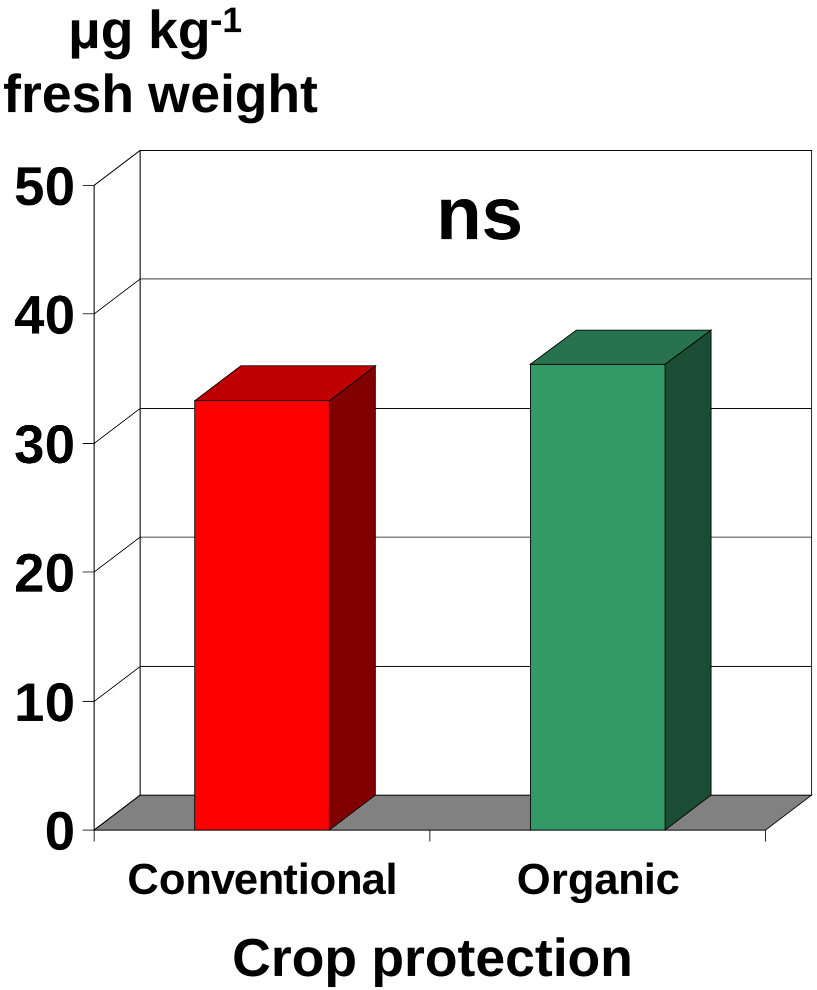

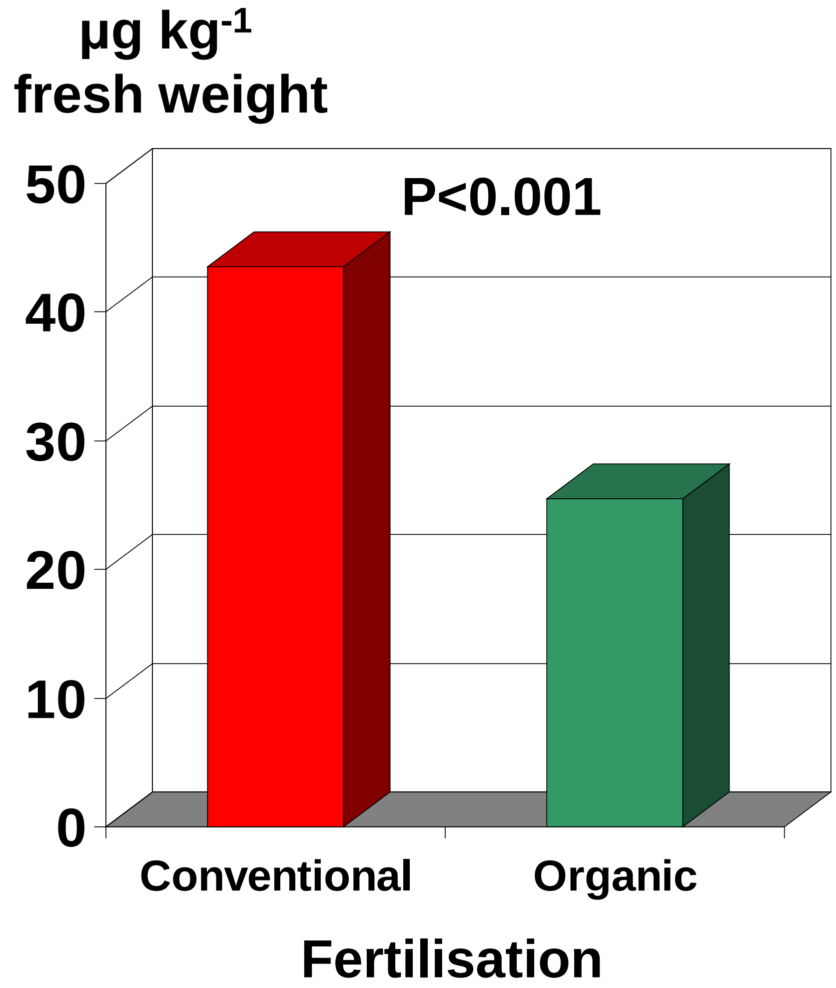

Relative levels of nutritionally desirable antioxidants in fruit and vegetables; a meta-analysis

(Brandt et al. 2011 *CRC Crit. Rev Plant Sci.* **30**, 177-197)

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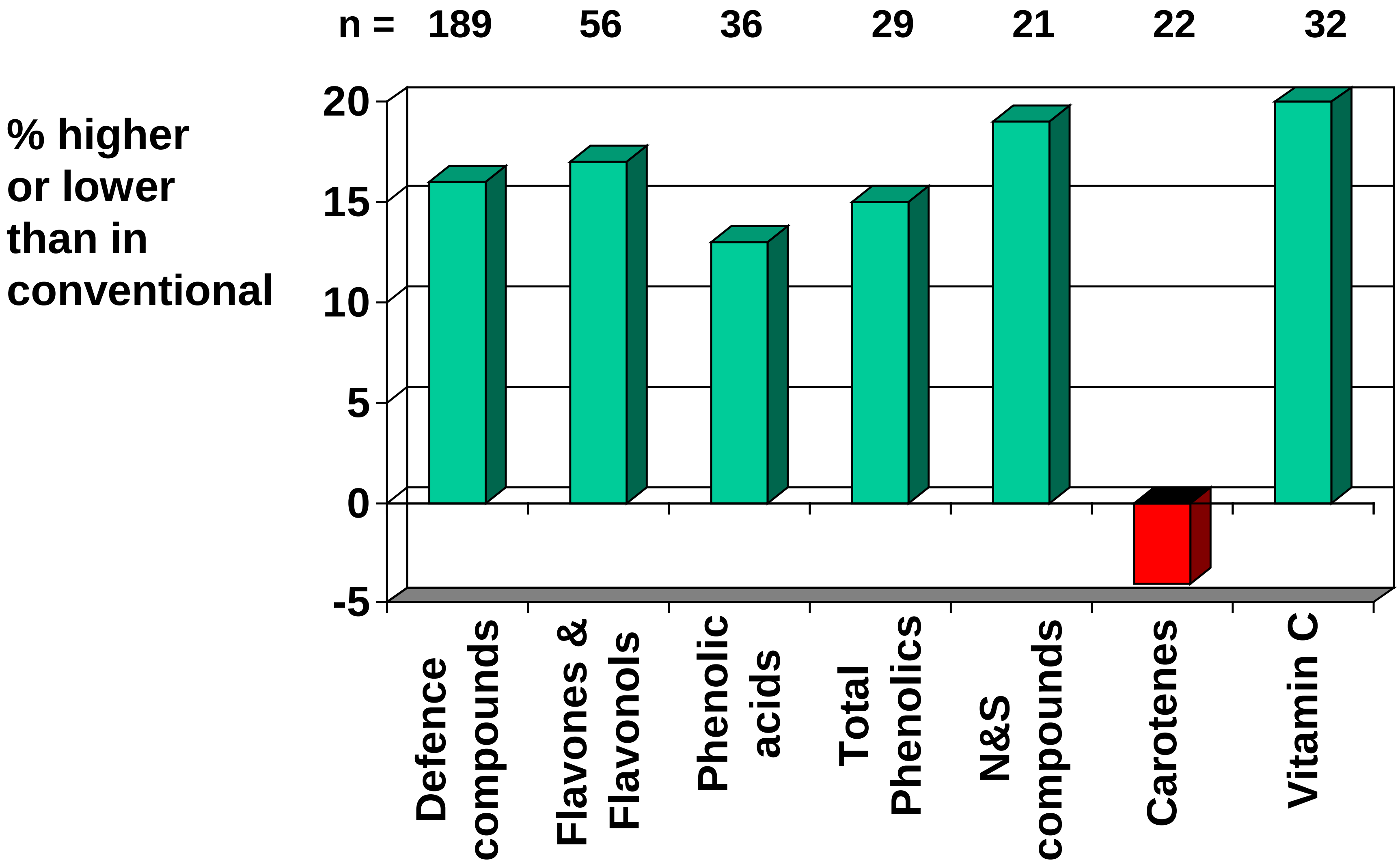

Effect of fertilisation and crop protection on the vitamin C content in potato (average of 4 seasons)

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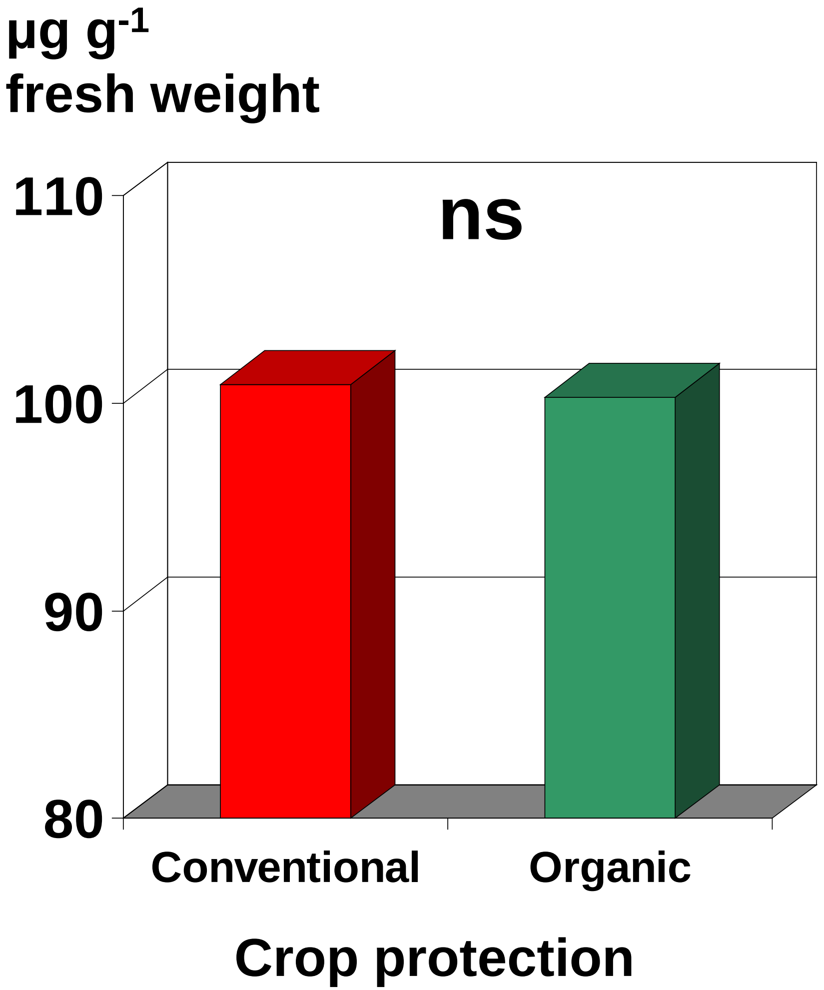

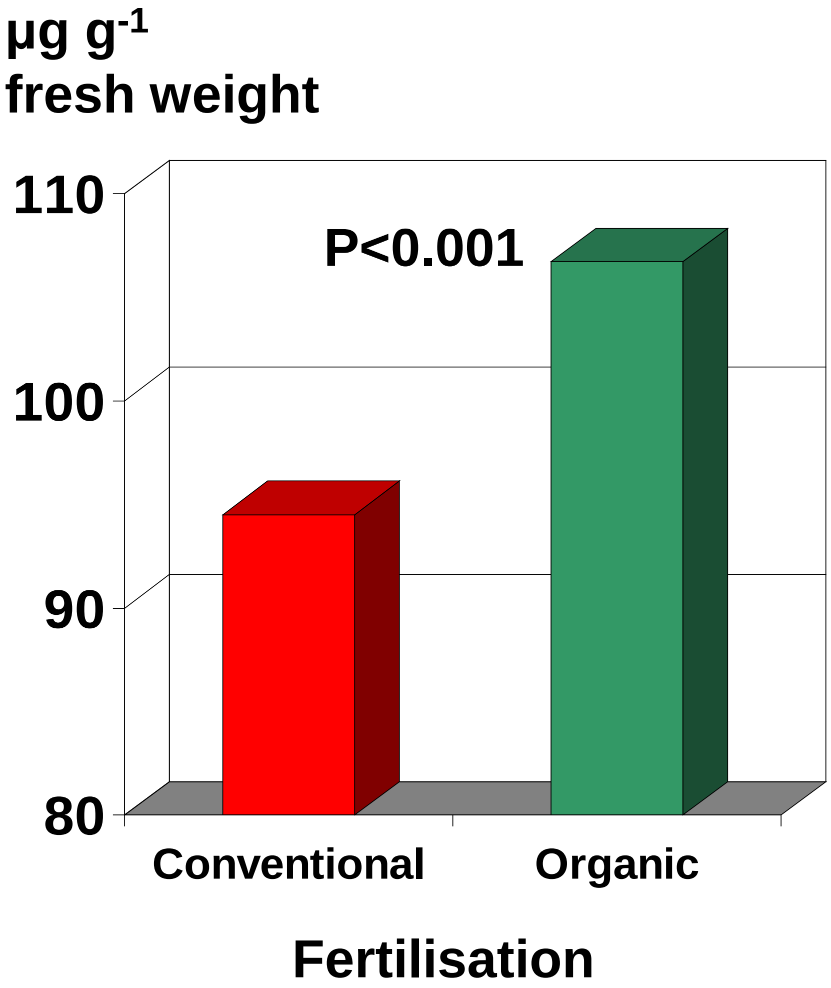

Effect of fertilisation and crop protection on the glycosinolate content in cabbage (average of 2 seasons)

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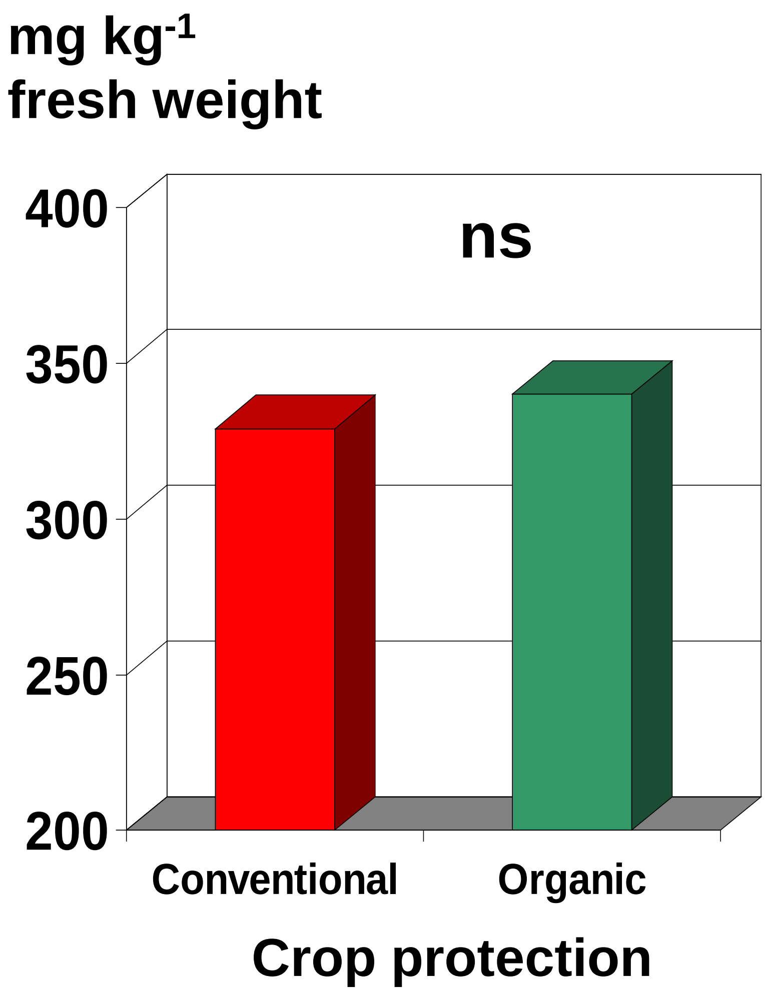

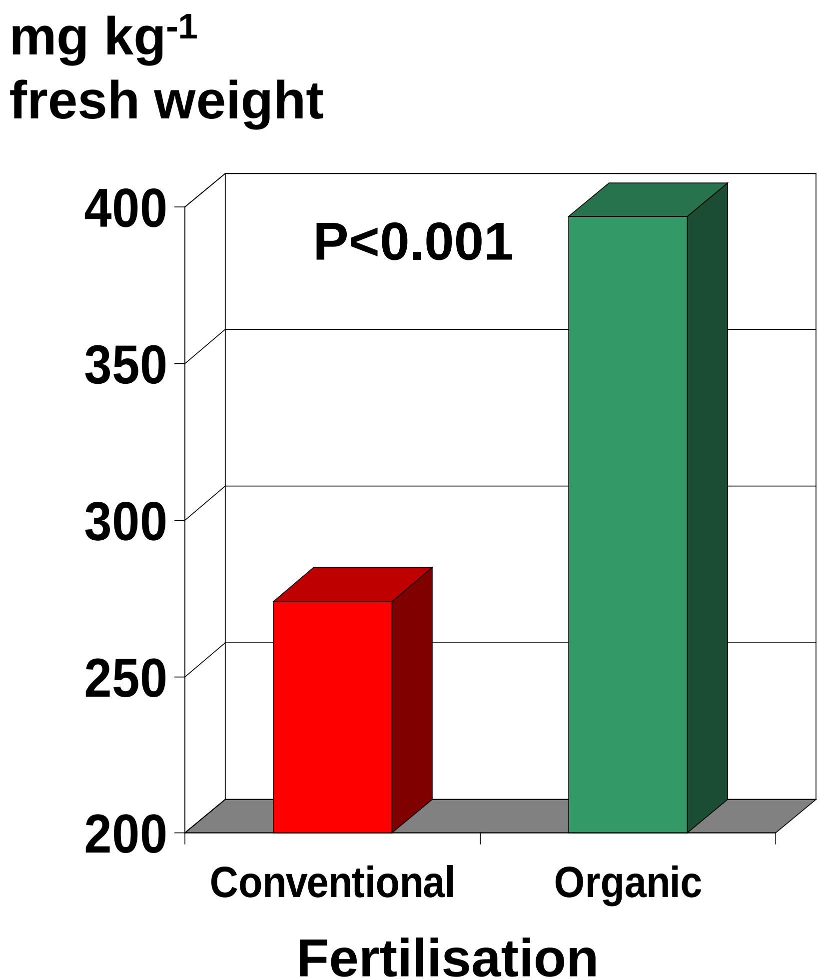

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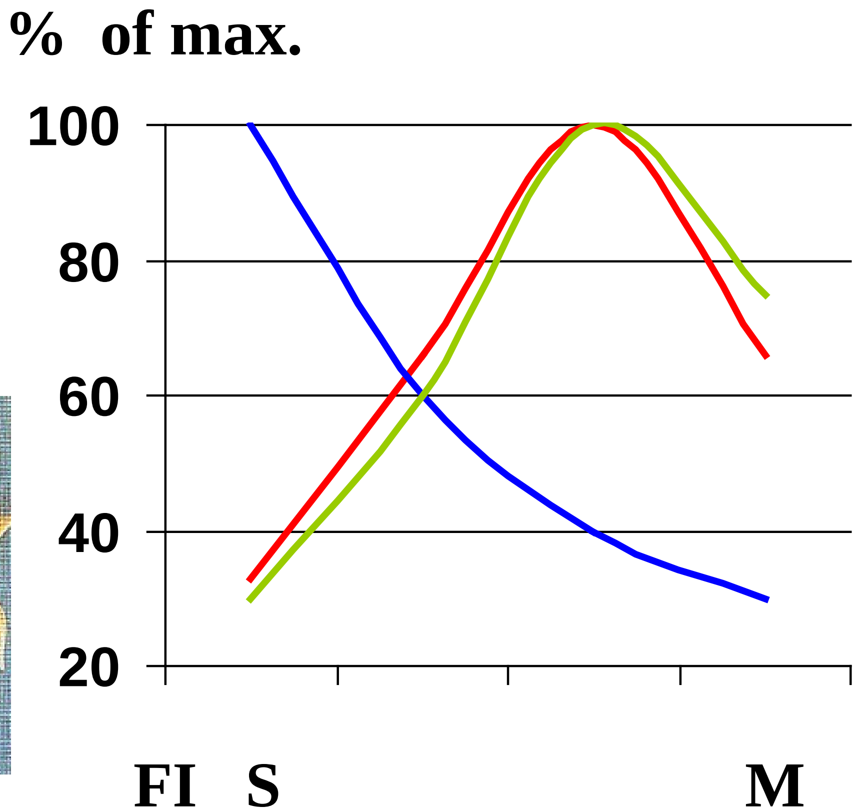
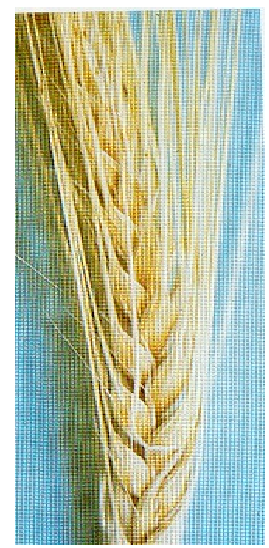
Main cause of lodging – Physiological weakness and fungal infections of the stem base caused by <u>imbalanced N-supply</u>





S = sowing M= maturity FI= Fertility input

Effect of fertilisation and crop protection on the total carotenoid content in lettuce (average of 4 seasons)

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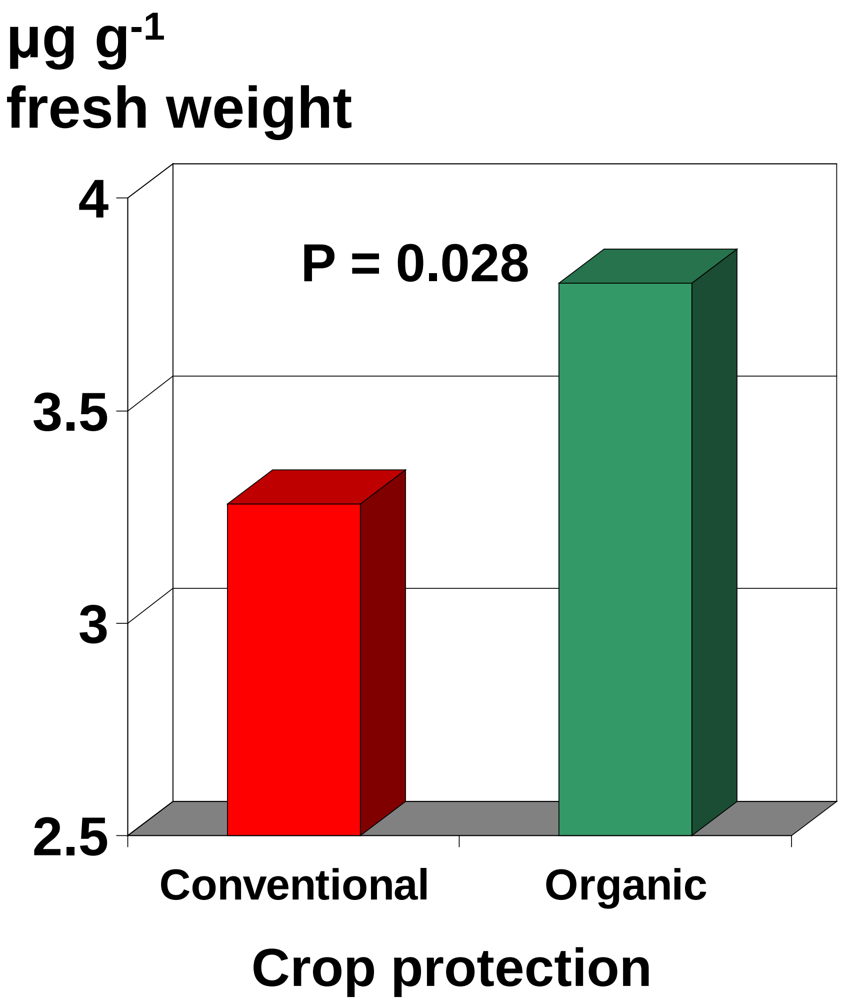

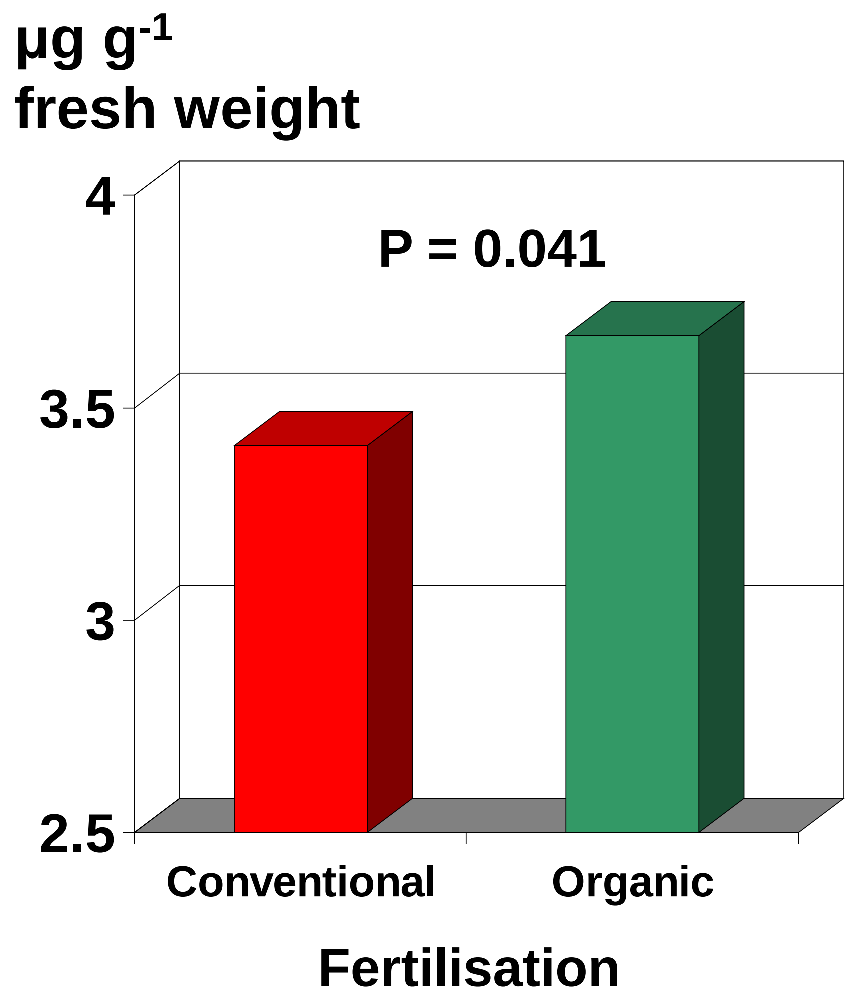

Composition differences between organic and conventional milk during the outdoor grazing and winter indoor period

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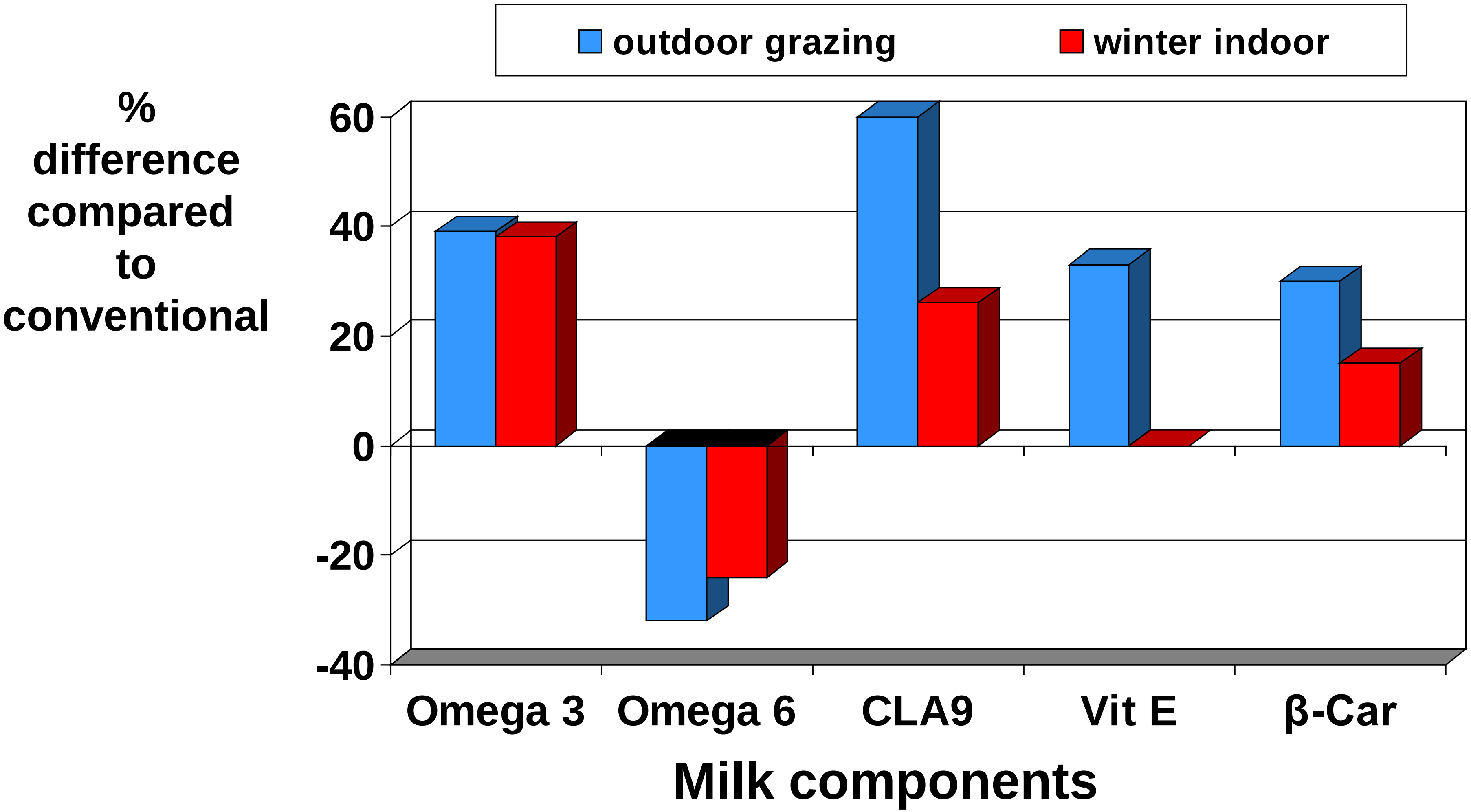
Butler et al. 2009 *J Sci Agric Food* **88,** 1431-1441.

Butler et al. 2011 *J Dairy Sci* **94,** 24-36



Proportion of cows receiving antibiotic treatments for mastitis in conventional and organic dairy herds (annual average)

(Butler et al. unpublished)

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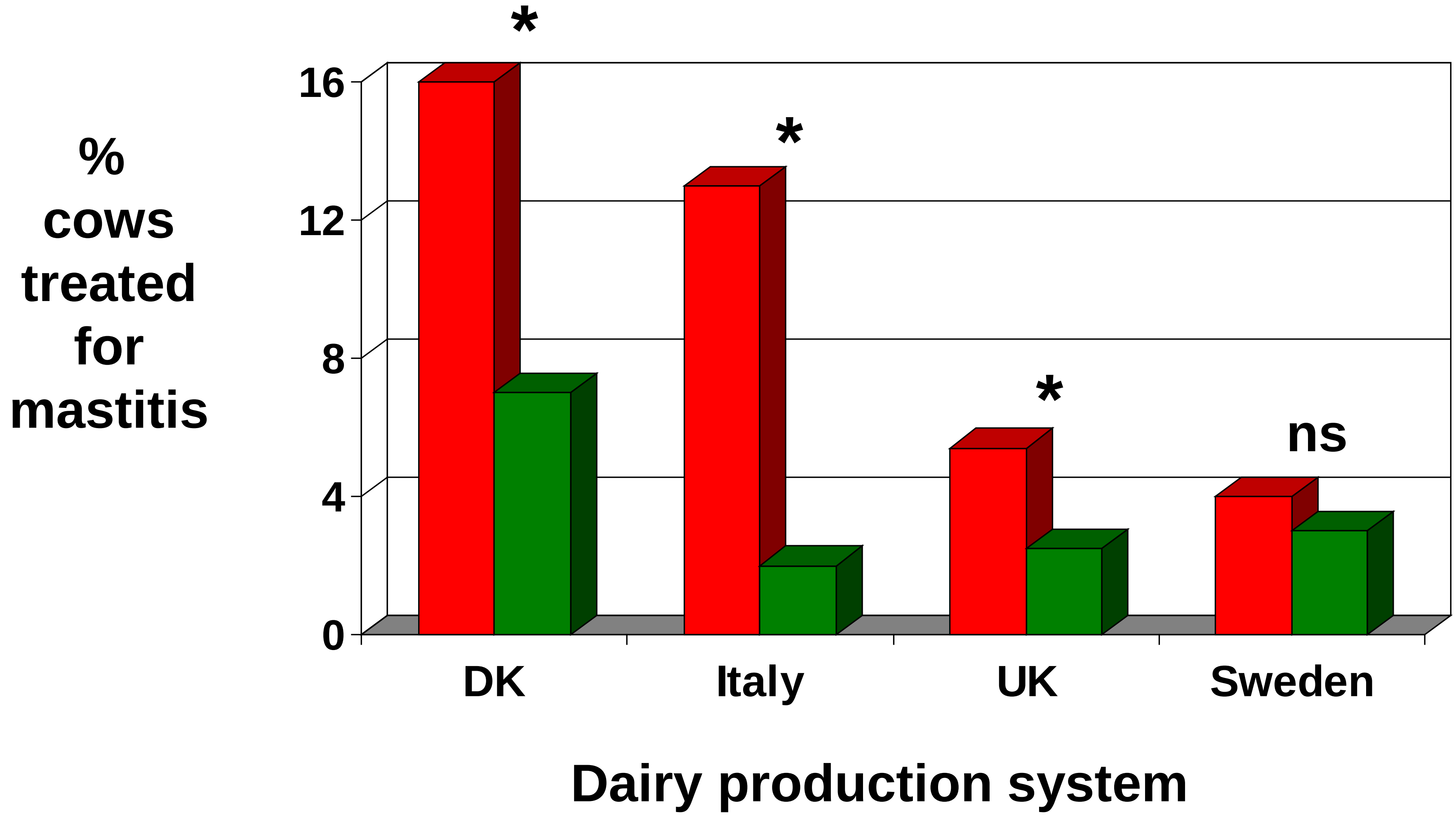

Research needs
Food quality

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- Breeding/genotype selection, management and supply-chain organisation based strategies to
  - optimise sensory quality, storability and shelf-life of organic fruit and vegetables (and dairy products?)

- Breeding/genotype selection and management based strategies to optimise
  - protein and phytochemical content and processing quality in organic cereal production
  - micro-nutrient supply to organic crops and livestock (Se, Zn, Cu and Iodine)

Food security

"The ability to provide access to enough food of high quality for humans through sustainable methods of production"

Sustainability in this context means without

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

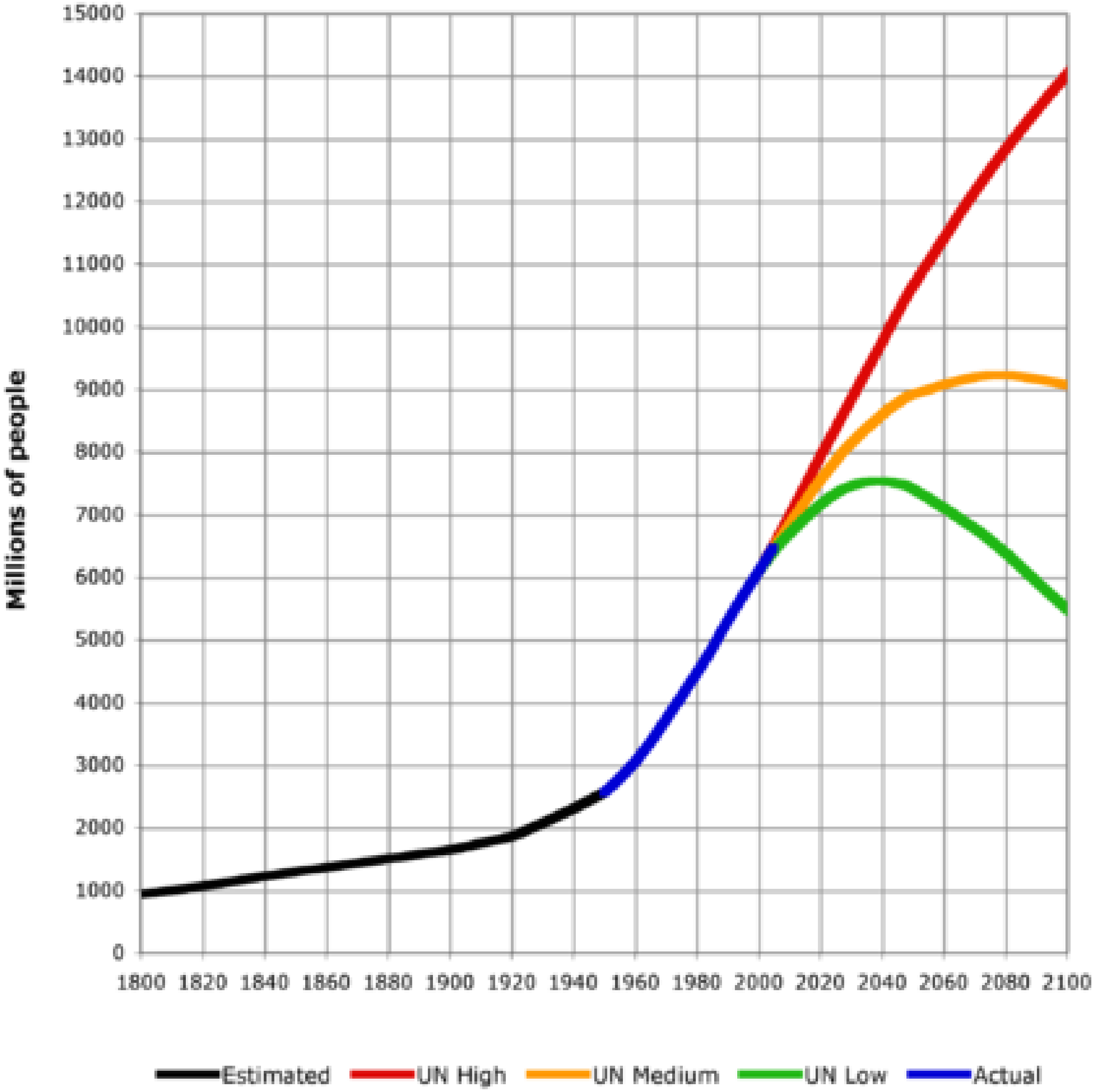
while ensuring

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

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

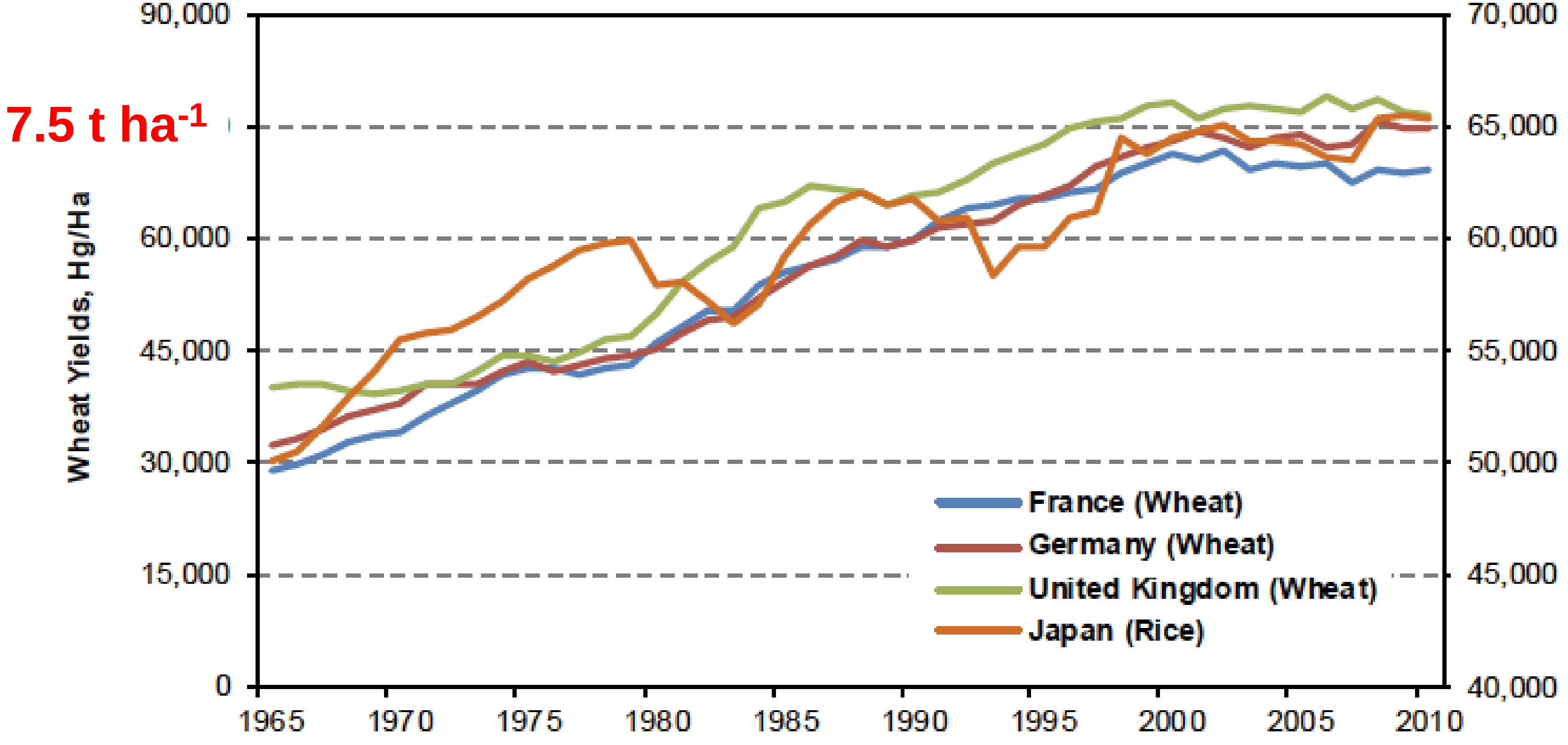
Kenneth Boulding, economist

How can we feed 9 Billion people in a sustainable way?



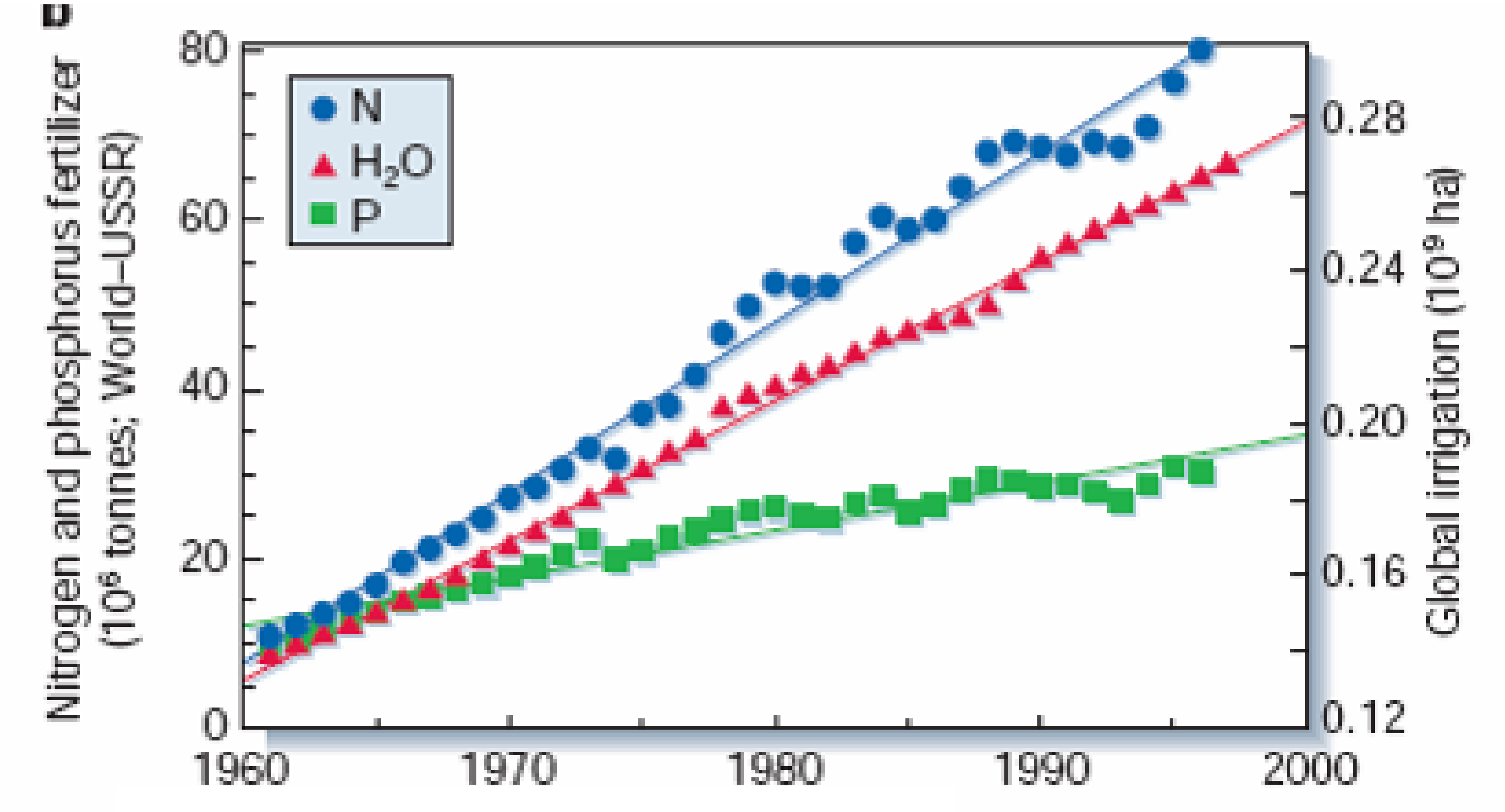
Can yields be further increased?

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



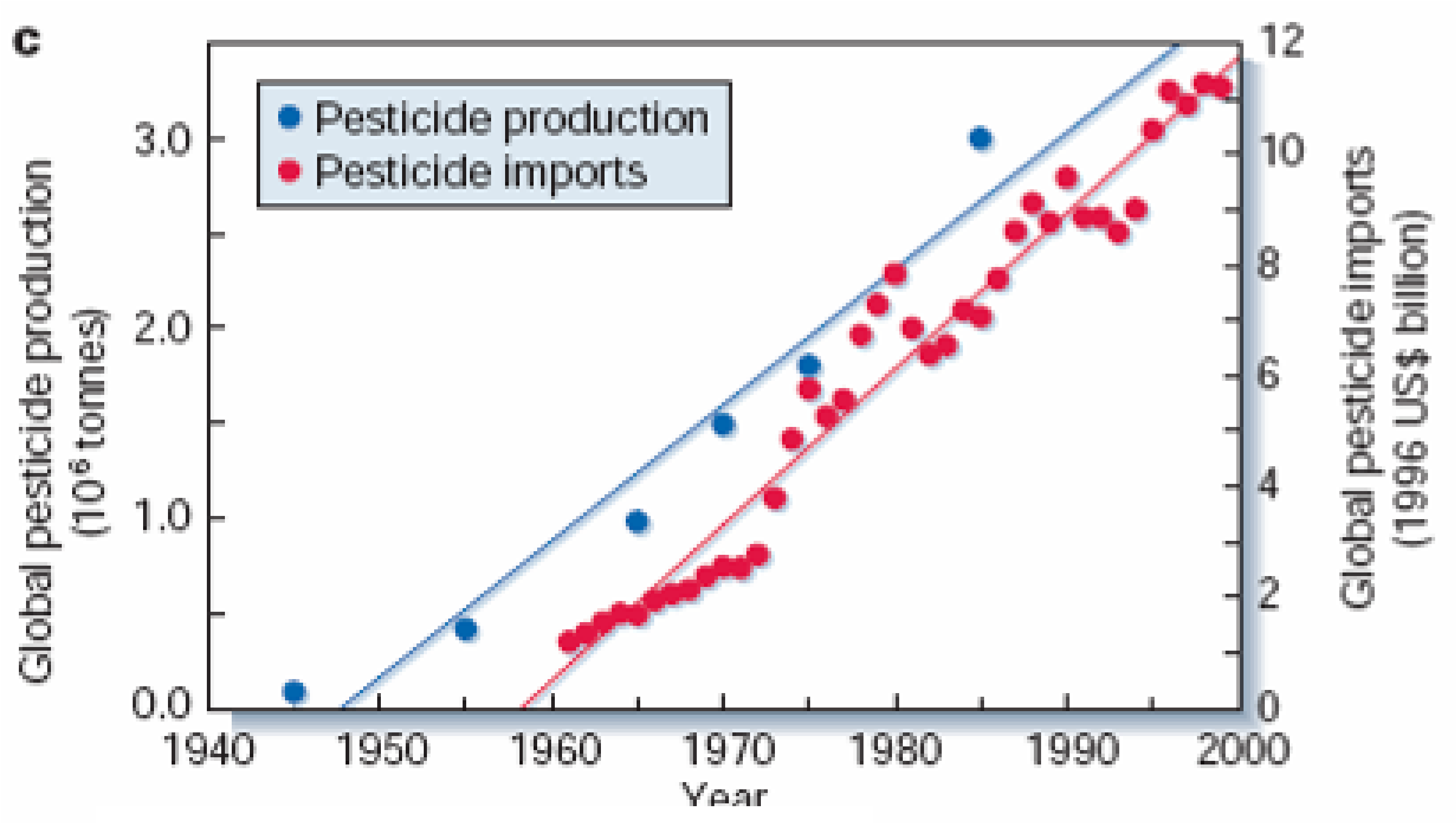
Source: UN Food and Agriculture Organization As of 12/31/10

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



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

Total global pesticide production and global pesticide imports

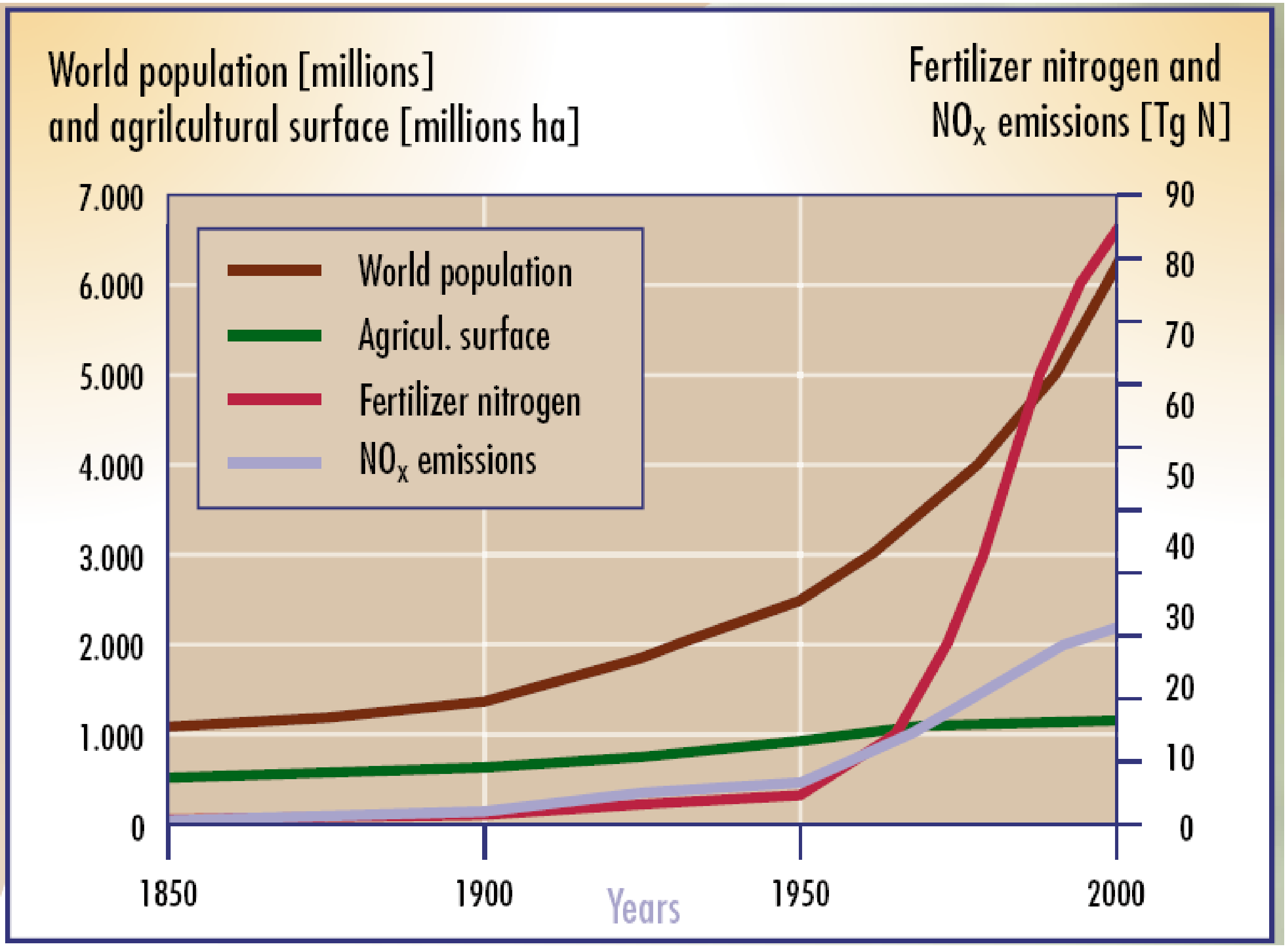


Tillman et al. (2002) ***Nature*** 418, 671-677

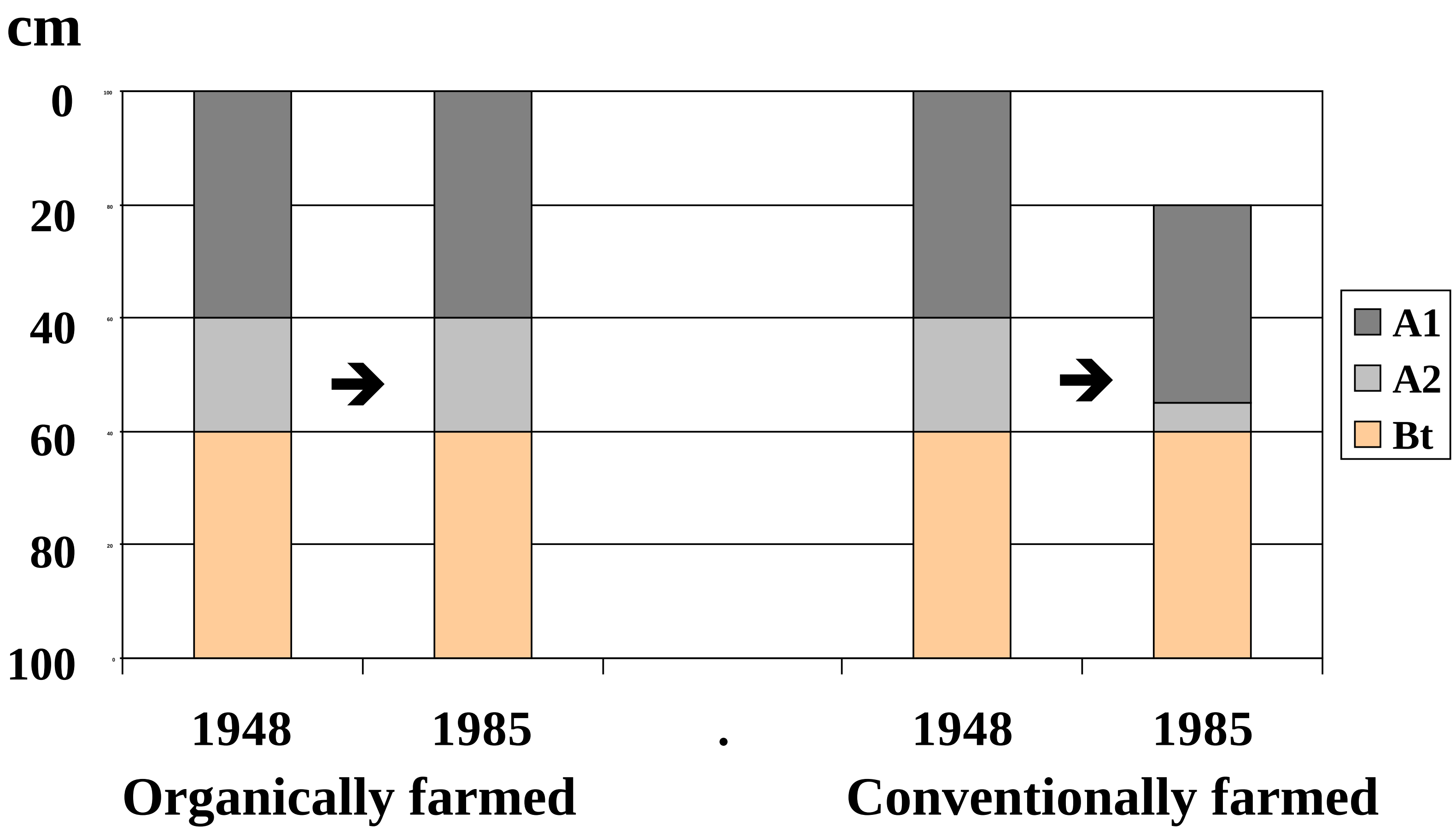
Nitrogen, population growth and emissions

- Manufacture of N-fertiliser accounts for 10% of agricultural GHG emissions

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

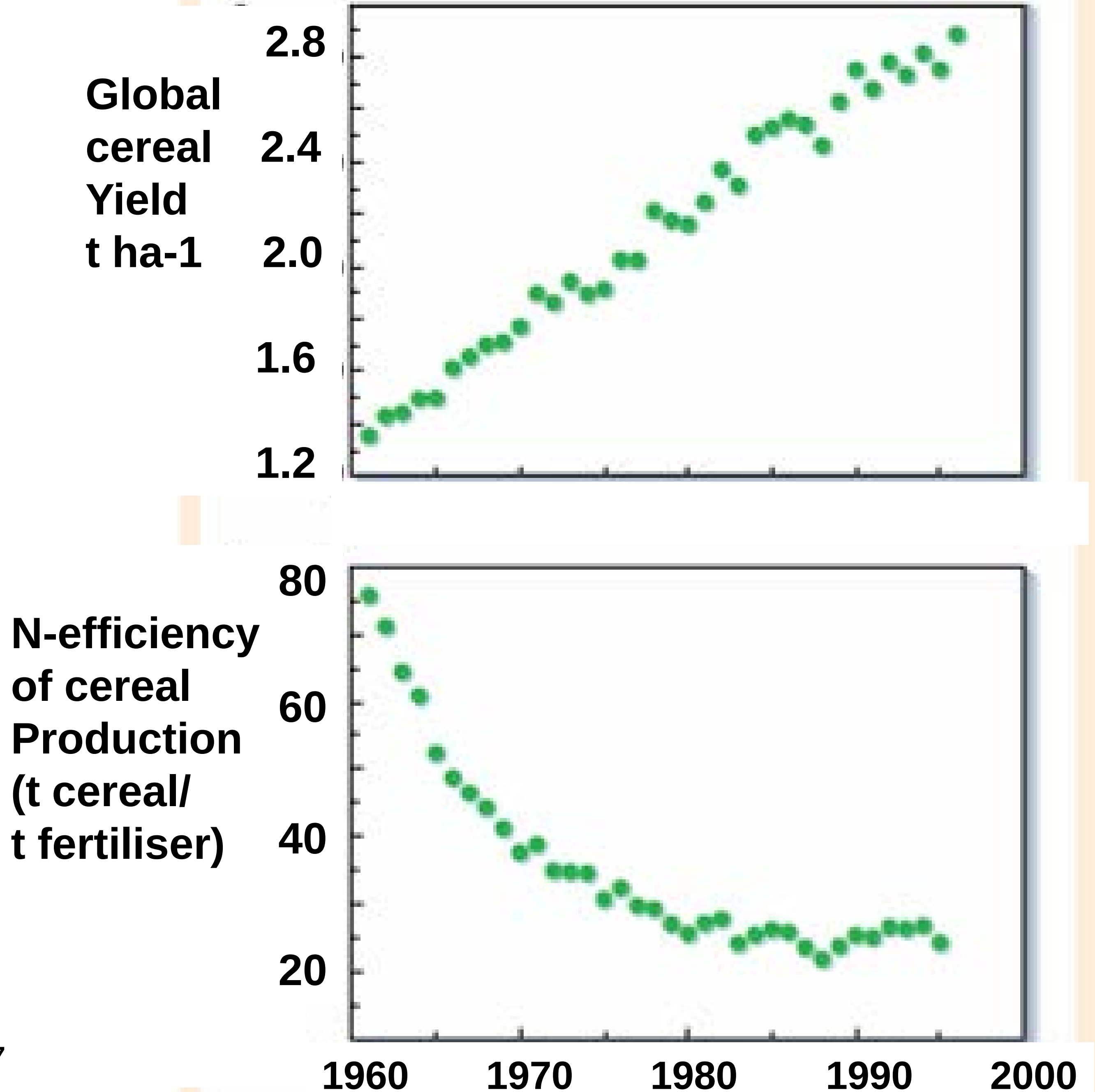


Organically and conventionally farmed soil (Naff silt loam) losses due to water erosion 1948 to 1985



(Reganold *et al.* 1987 Nature 330; 370-372)

Diminishing returns of fertiliser applications



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

Fertiliser 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 nutrient use efficiency of crop production**
- **2-3 times as much NPK is needed to produce a kg of food than 40 years ago**
- **can we get around the "*law of diminishing returns*"**

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

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

Peak of Oil Production

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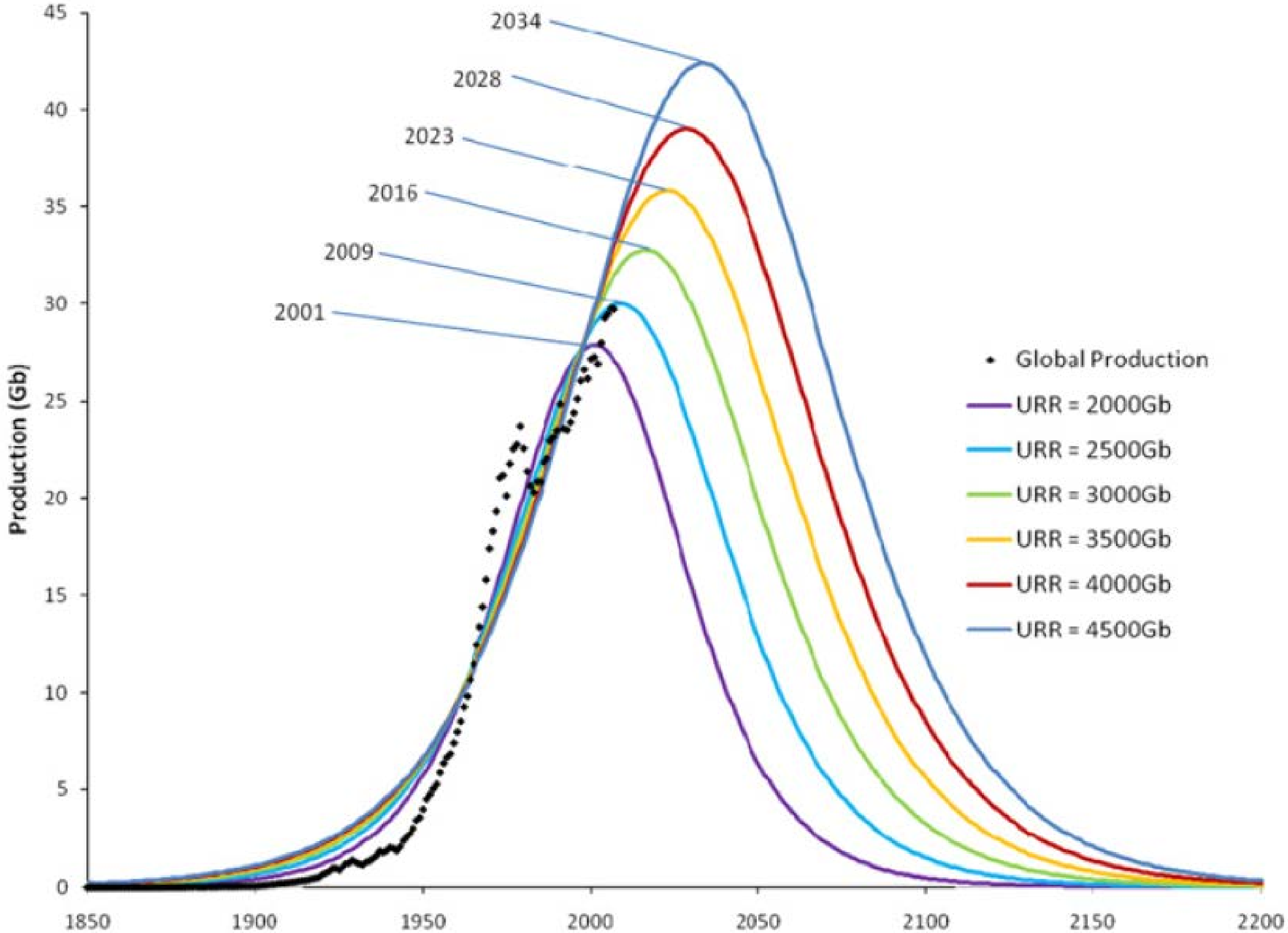

URR= Ultimate Recoverable Resource (Proven + Provable)

(Sorrell et al.,2010)

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

Why will Phosphorus become a bottleneck 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**
  - **P-consumption is likely to increase by >2 fold**

Peak Phosphorus Curve

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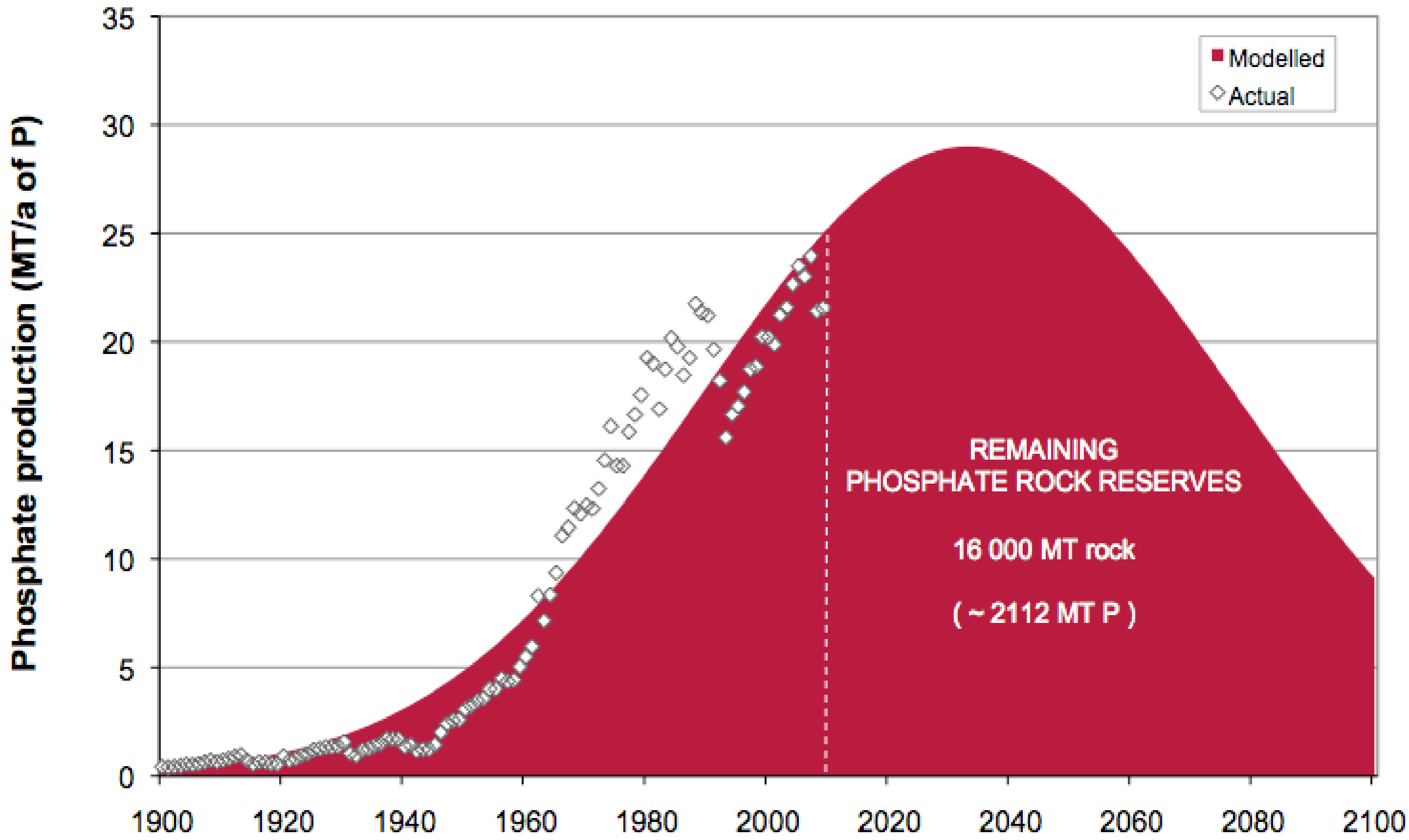

Source: Cordell, D, Drangert, J-O & White, S (2009) *The Story of Phosphorus: Global food security and food for thought.* Global Environmental Change, 19 (2), p292-305

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

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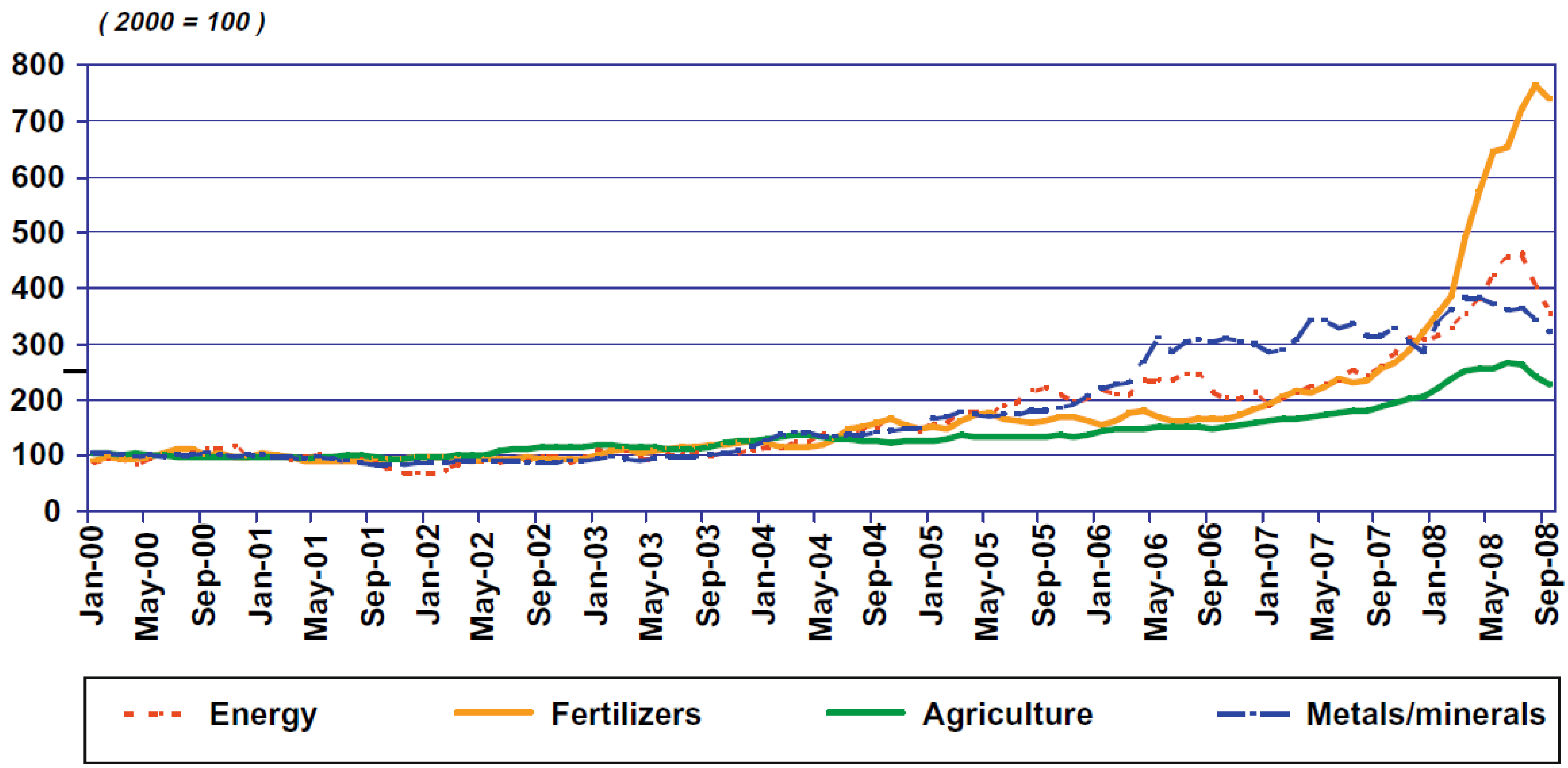


(Source: Piesse and Thirtle, 2009)

Can conventional farming deliver food security?

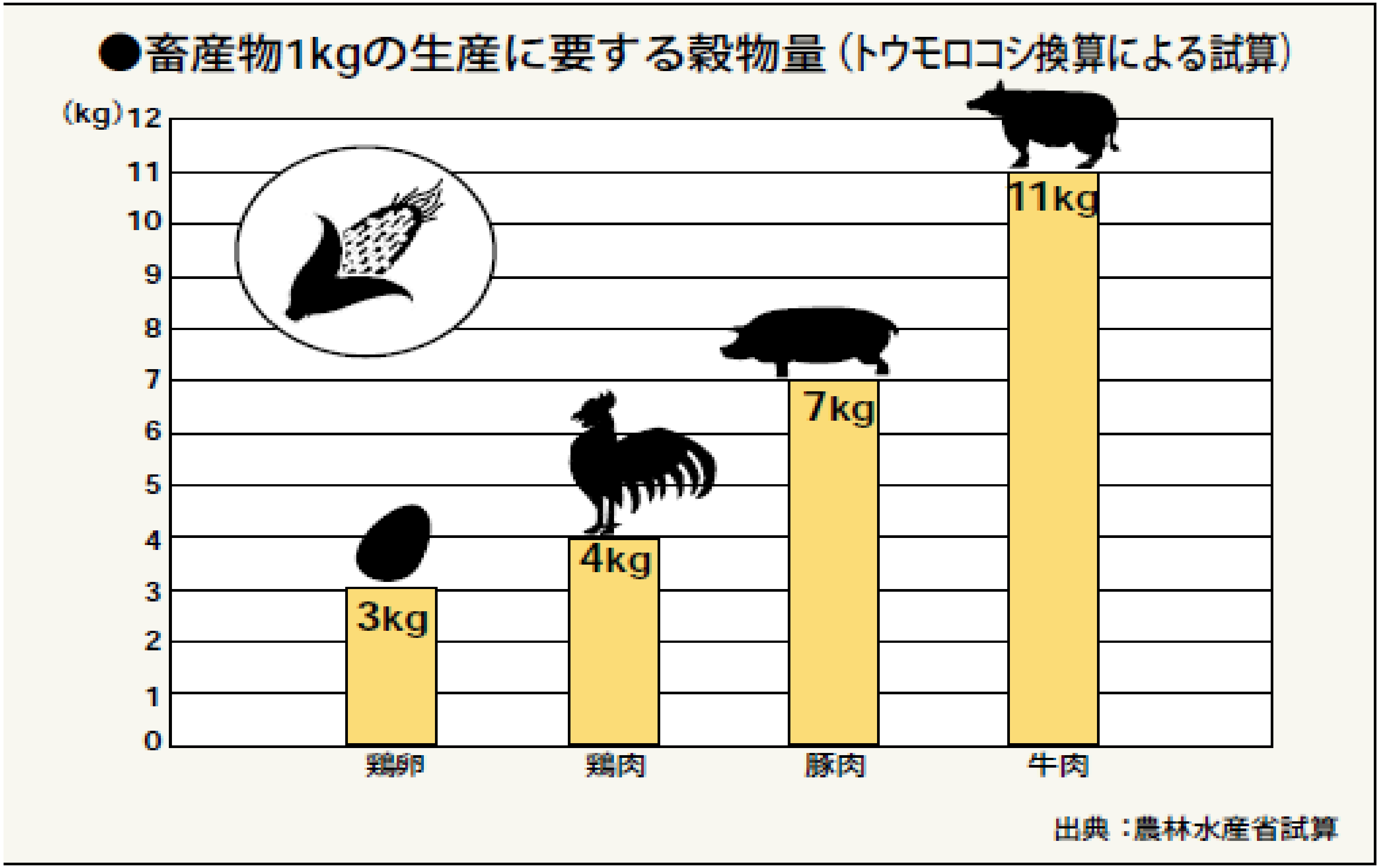
- **High yields** in conventional systems rely on **mineral NPK fertiliser inputs** and **are not sustainable**
  - Mineral **N-fertiliser** manufacture is estimated to account for 10% of total greenhouse gas emissions from agriculture
  - Mineral **P-deposits** will be depleted in 30-100 (300?) years
- **Without mineral P-inputs yields in conventional farming will decline by more than 50%**
- **Currently mineral NPK fertilisers are still too cheap**
  - **BUT mineral fertiliser prices have increased by more than 8-fold in the last 10 years**

What are the solutions?

The **main approaches** available are:

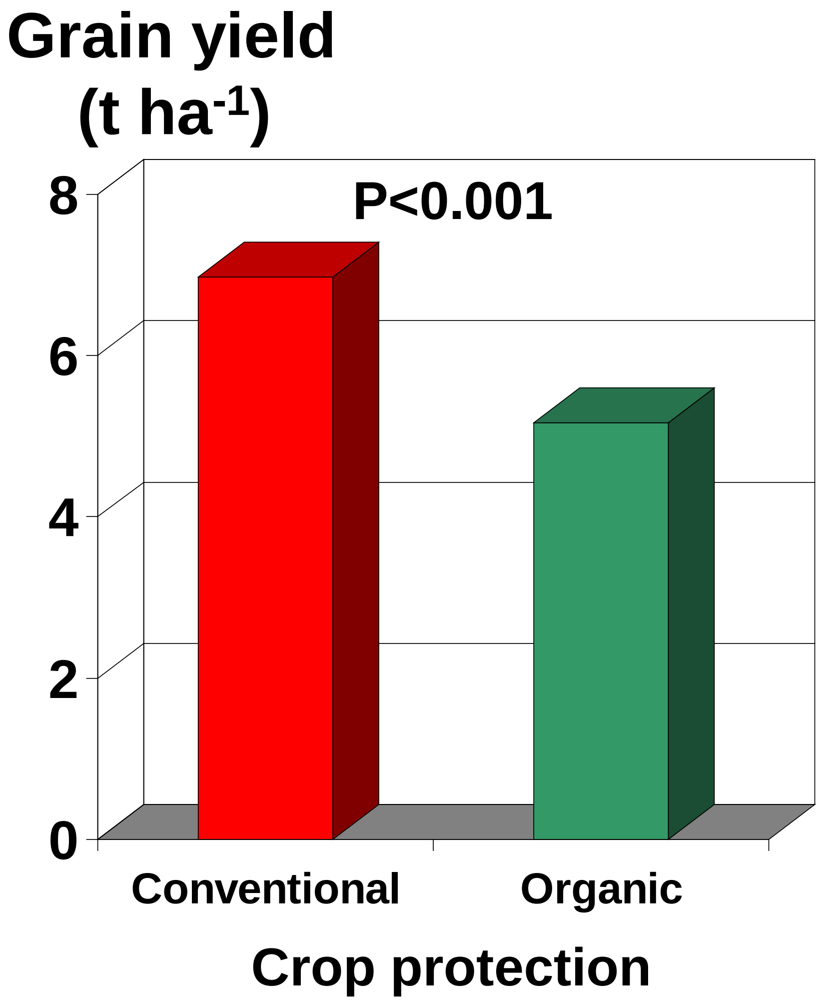
1. **More efficient recycling** of NPK via
   - animal and green manures,
   - crop residues, food processing waste
   - communal and domestic organic waste
   - **human toilet waste/sewage**
2. **Reduction of losses** of fertiliser from soils
3. **Breeding/selection** of more nutrient (especially N and P) efficient crop varieties (EU-NUE crops project)
4. **Reduce meat, egg and dairy production** and consumption

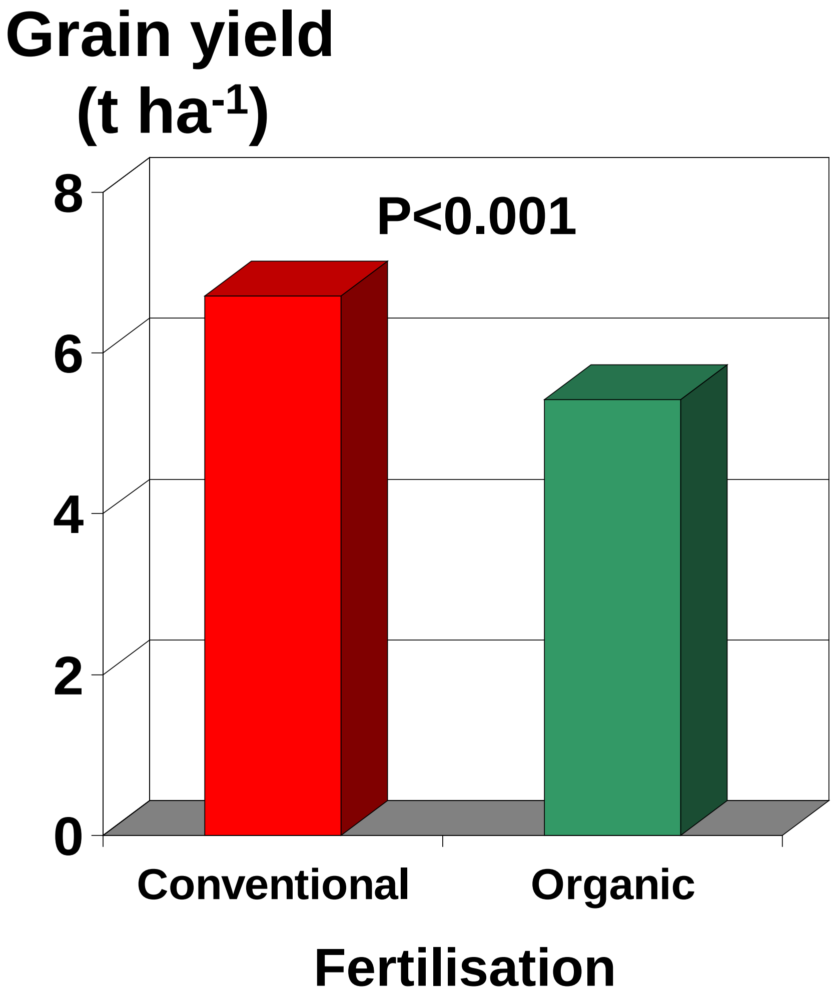
Amount of cereal (corn-equivalents) necessary to produce 1 kg of livestock products



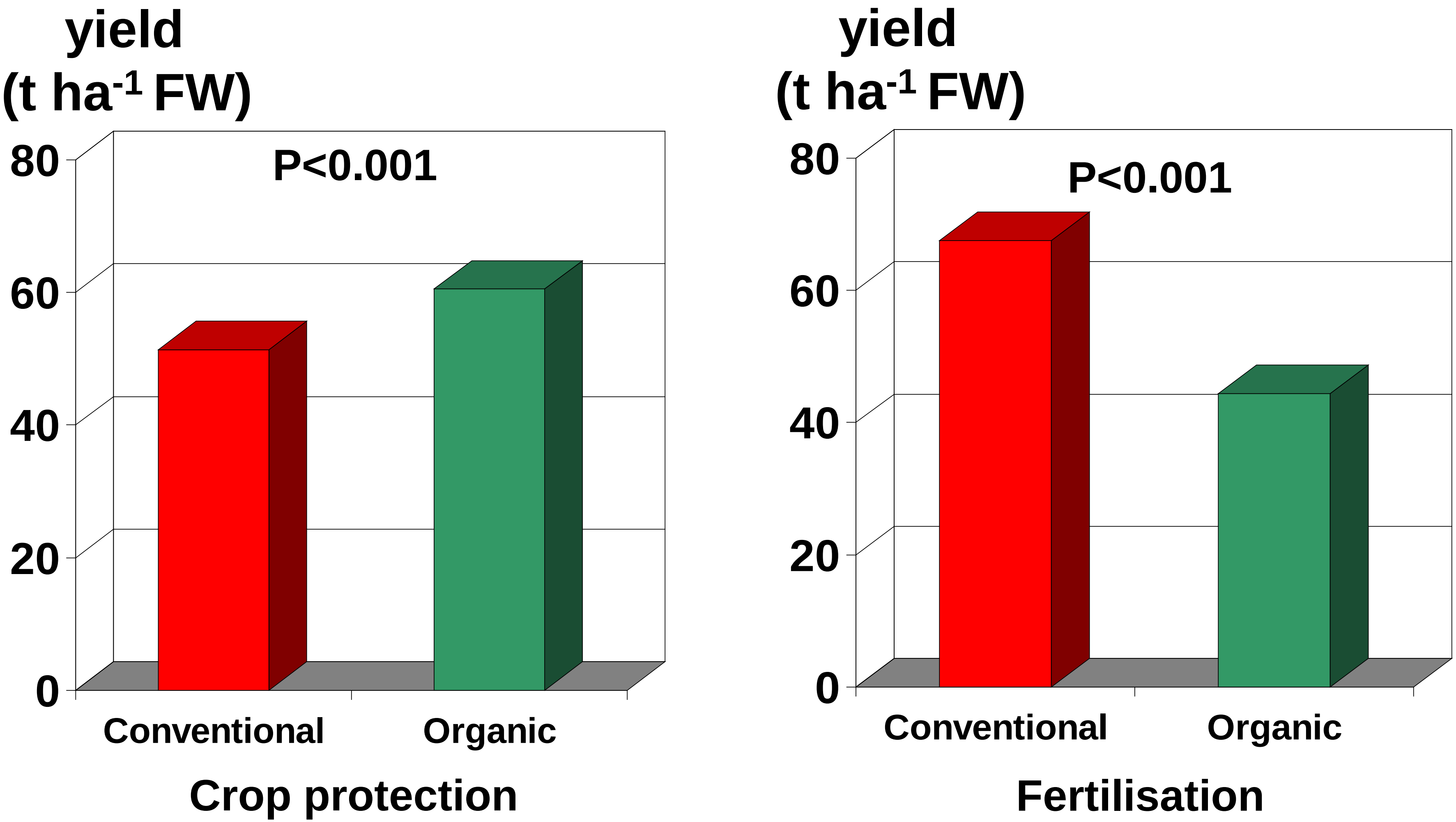
Effect of fertilisation and crop protection on wheat yield (average of 4 seasons)

(Bilsborrow et al. 2013 *Eur J Agron* **51**, 71-80)

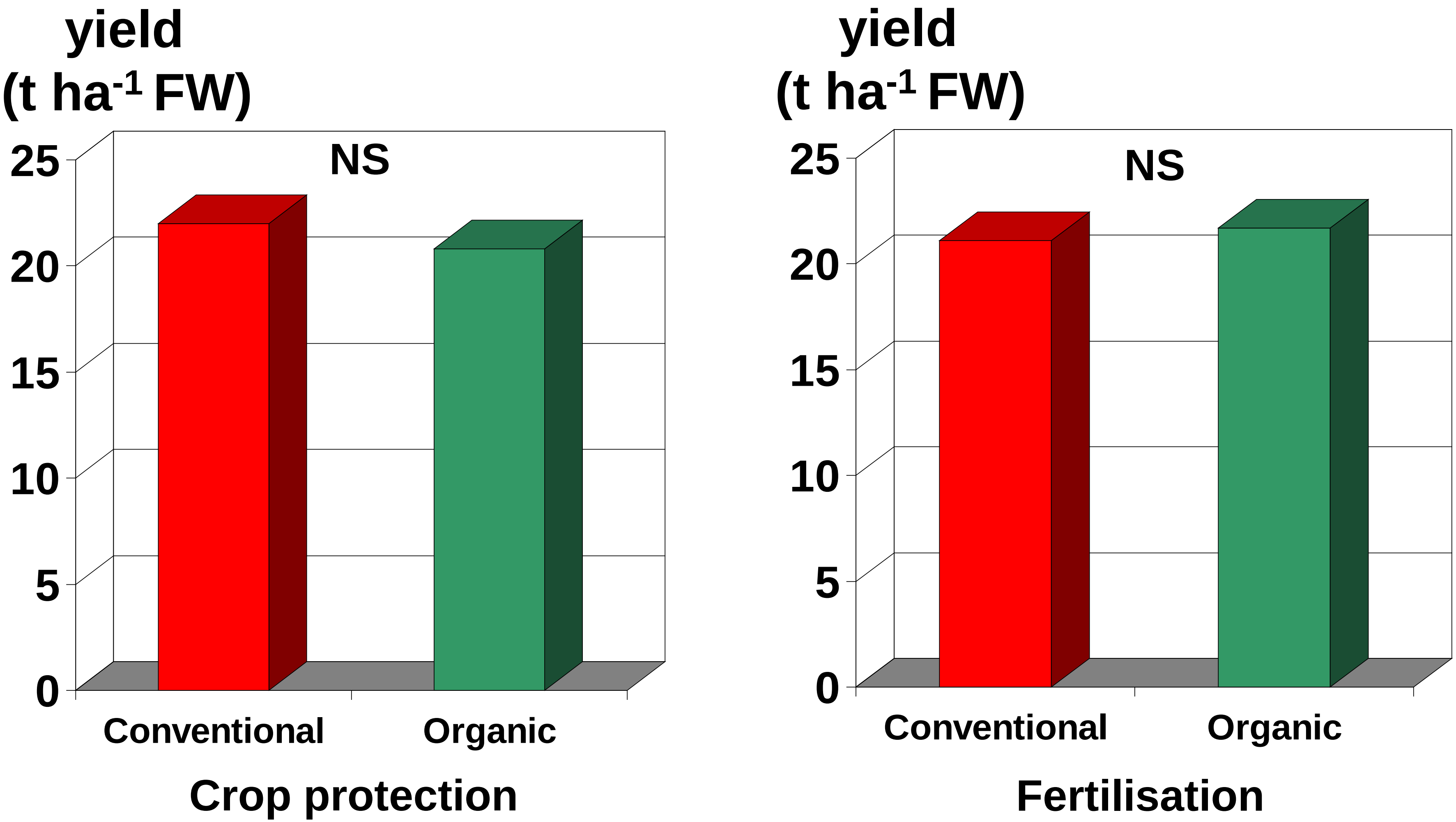




Effect of fertilisation and crop protection on the cabbage yield (average of 4 seasons)



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 !!!!!**
- **Need to integrate better soil management with innovations in other areas (e.g. breeding, crop protection, tillage)**

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Research needs
Food security (=profitability?)

- Development of "precision" organic waste based fertiliser products and fertilisation regimes
  - N:P:K ratios; micronutrient (e.g. Se, Zn, Cu, Iodine) supply
  - Predictable and optimised N&P availability/release pattern
  - Suppressiveness to soil-borne diseases
- Improved protocols for legume cover-,inter- or companion crops;

  - N-retention/fixation, weed control, soil structure
- Improved (a) protocols and genotypes for home grown grain legumes and (b) supply chains for soya

  - Protein feeds for pigs/poultry
- Crop breeding/variety selection for nutrient use efficiency (especially from organic fertiliser inputs)

Research needs
Food security (=profitability?)

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- **Crop breeding/selection for robustness and product quality**
  - Competitiveness against weeds
  - Disease resistances for crop pathogens that are also a problem in organic farming (late blight in potato, *Septoria* in cereals, soil soil borne diseases and nematodes in greenhouse crops)
  - Pest resistance/tolerance in crops
- **Development of crop protection products that are acceptable under organic farming standards**
- **Livestock breeding/selection for robustness, product quality and low environmental impact**
  - Disease (e.g. mastitis) and parasite (GIN) resistance
  - Meat/milk/egg quality/low GHG emissions in outdoor/grazing-based systems


Thank you

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Blight-MOP

QualityLowInputFood

NUE-crops, LowInputBreeds, N-Toolbox,

HealthyMinorCereals