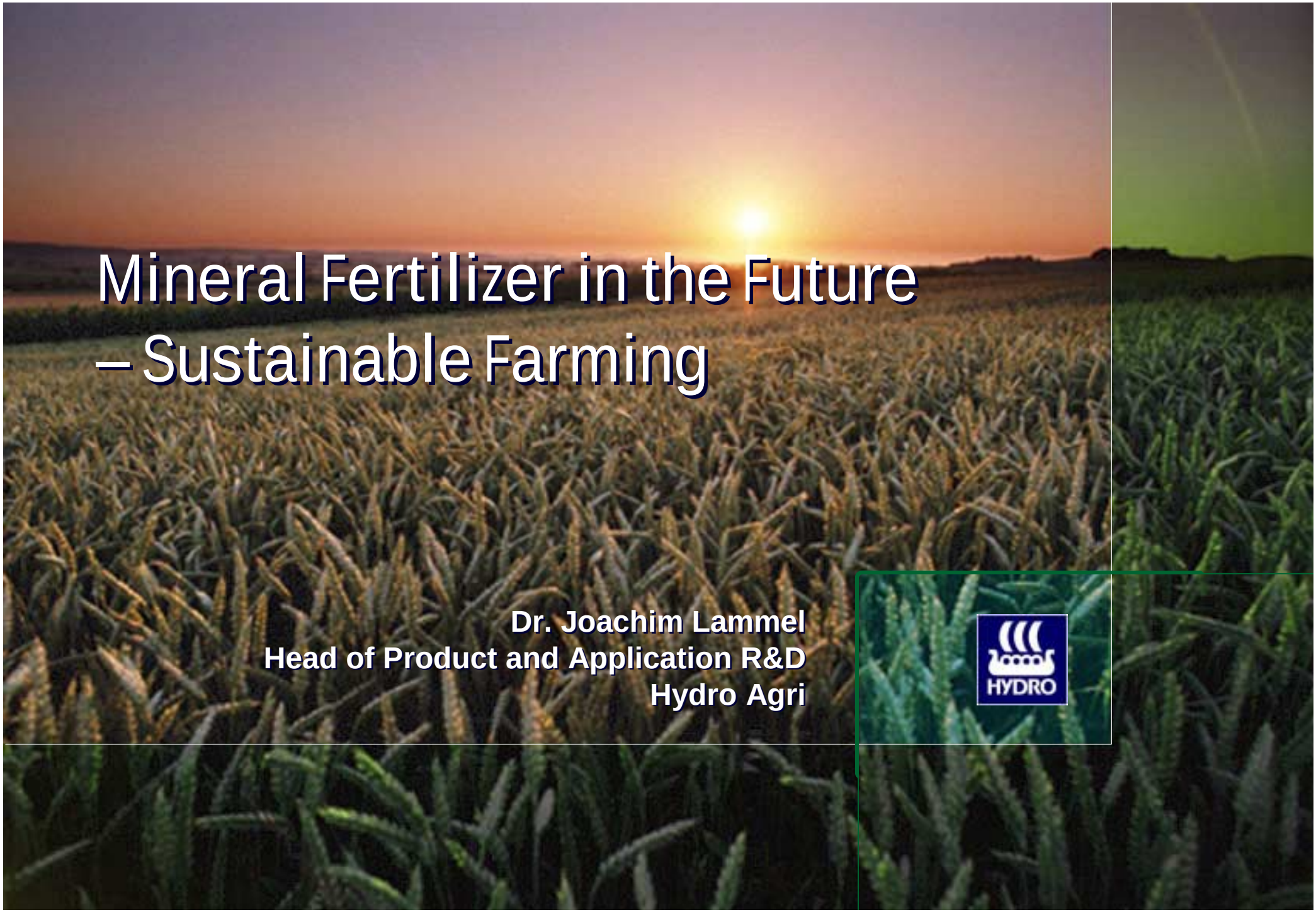


Mineral Fertilizer in the Future – Sustainable Farming

Dr. Joachim Lammel
Head of Product and Application R&D
Hydro Agri

Definition of Sustainability

"Sustainable development is any development which meets the needs of the present without compromising the ability of future generations to meet their needs“ (according to. Brundtland, 1987):

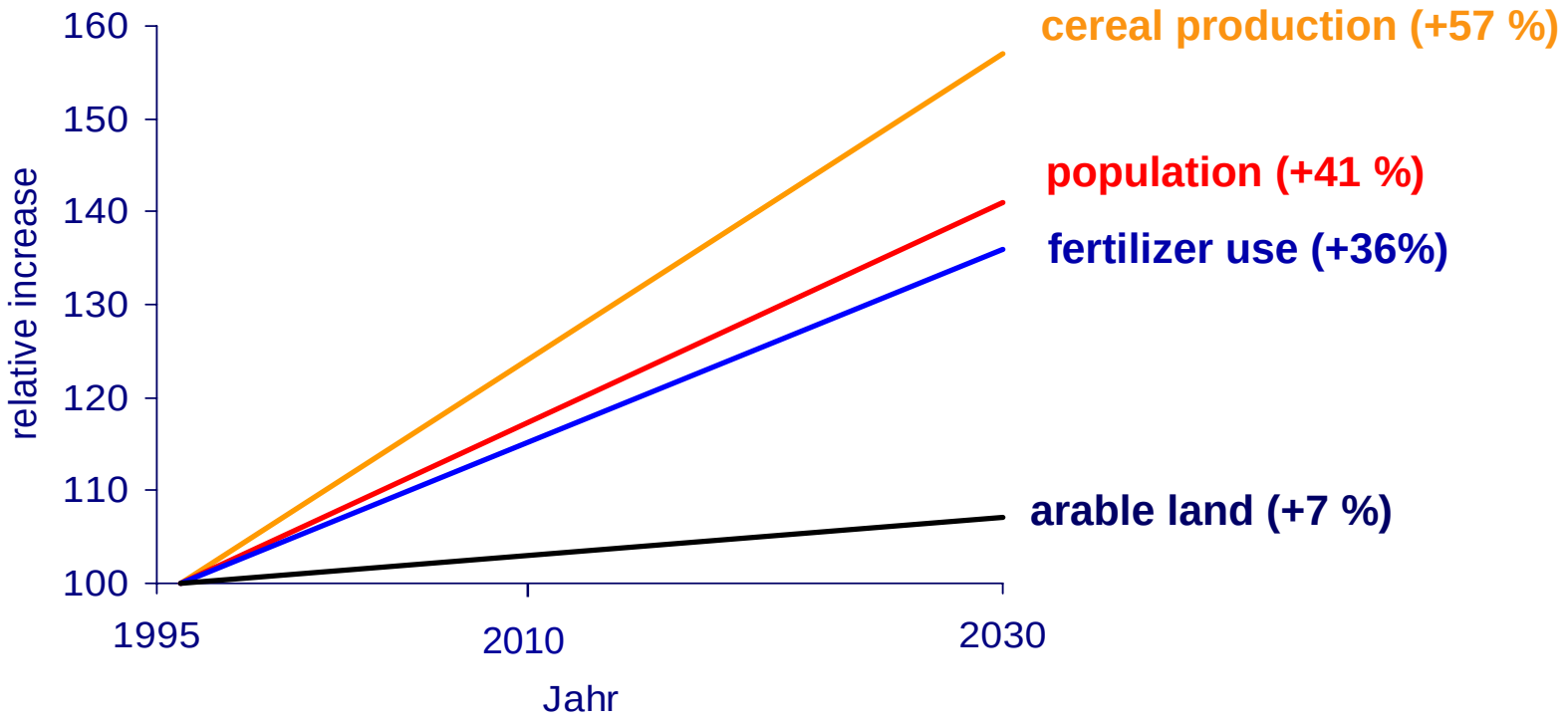
Sustainability comprises three main elements which have to be balanced

- **Social aspects**
- **Economic targets**
- **Environmental impact**

Sustainability in agriculture has to balance

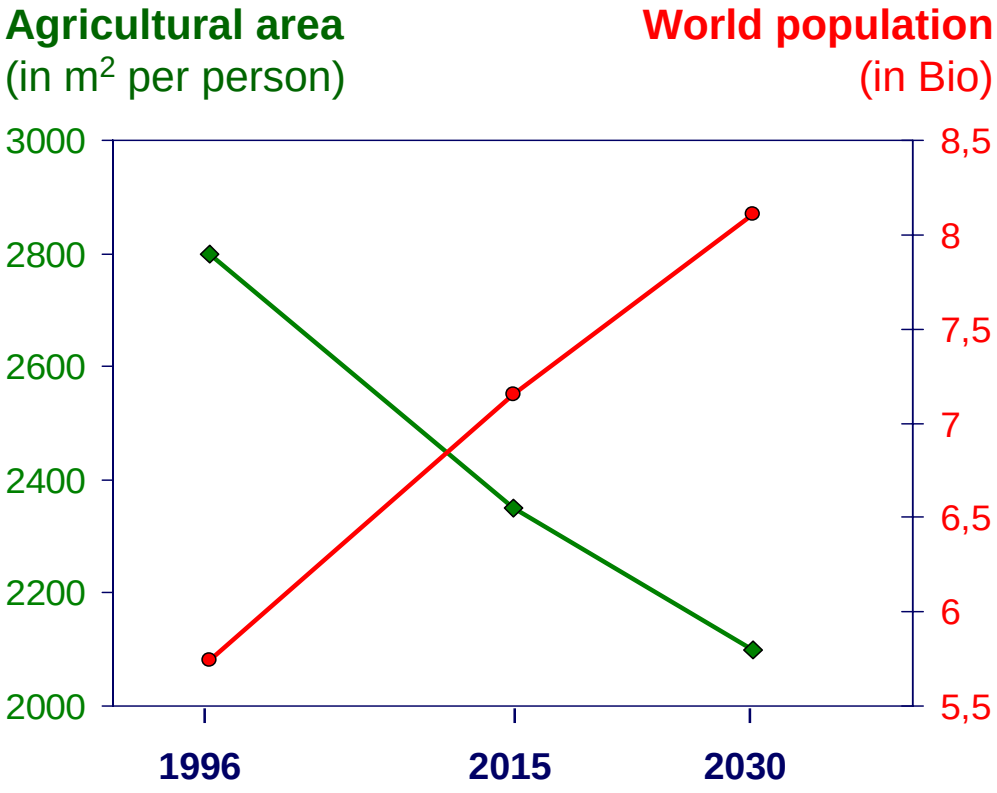
- **the need for food in good quality**
- **at affordable prices for the consumer and acceptable farm income level**
- **produced with minimum adverse effects on the environment**

Global trends: Development of cereal production, world population, fertilizer use and arable land



Source: FAO; Towards 2015/30; Technical interim report 4/2000

The intensity of arable production has to increase



- World population increases up to 8.3 Billion people in 2030.
- In the same time the agricultural area can only be extended by about 7%.
- Thus, the agricultural area per person decreases rapidly.

Source: FAO; Towards 2015/30; Technical interim report 4/2000

Continuous cropping without nutrient replacement is mining the soil

Effects of ‚soil mining‘:

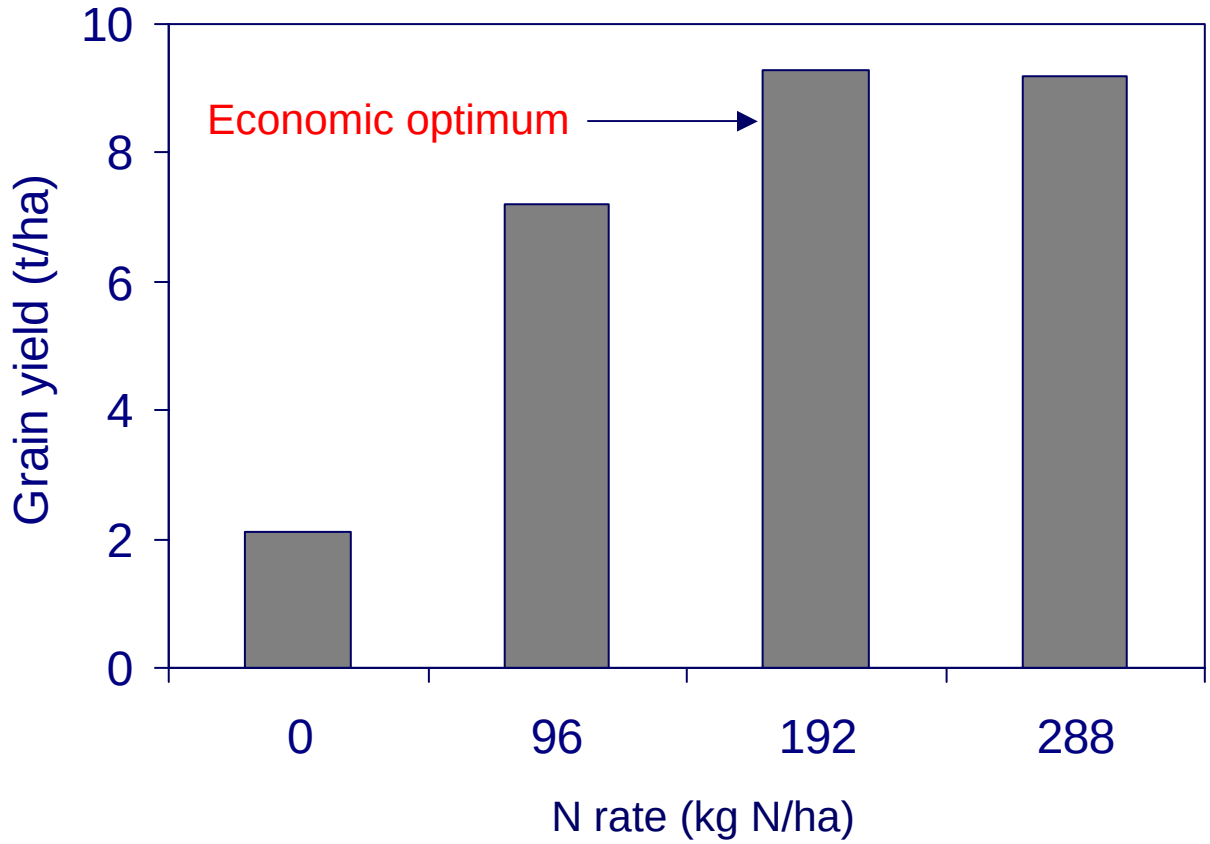
- reduced soil fertility
- soil compaction
- reduced humus content
- increased erosion risk
- reduced yields

zero fertilizer Fertilizer + Compost

Photo: Dr. Paul Seward, maize in Kenya

The effect of mineral N fertilizer application can best be studied in long-term trials

Data from a long-term field trial with winter wheat, Rothamsted (UK)
-> without mineral nitrogen the grain yield is only at 2 t/ha;



P = 80kg P_2O_5; K = 108 kg K_2O

Optimum N application produces high yields at low production costs per unit

	N rate		
	zero	opt – 50%	optimum
grain yield t/ha	2,1	7,1	9,3
production cost €/ha	558	727	853
production cost €/t grain	269	102	92

Grain market price: 112 EUR/ton
Source: Yield data; long term trial, Broadbalk, Rothamsted (since 1856)
Economic data: KTBL Germany

The environmental impact of wheat production - seen from a Life Cycle Assessment perspective

Raw materials
- Fossil fuels
- Minerals

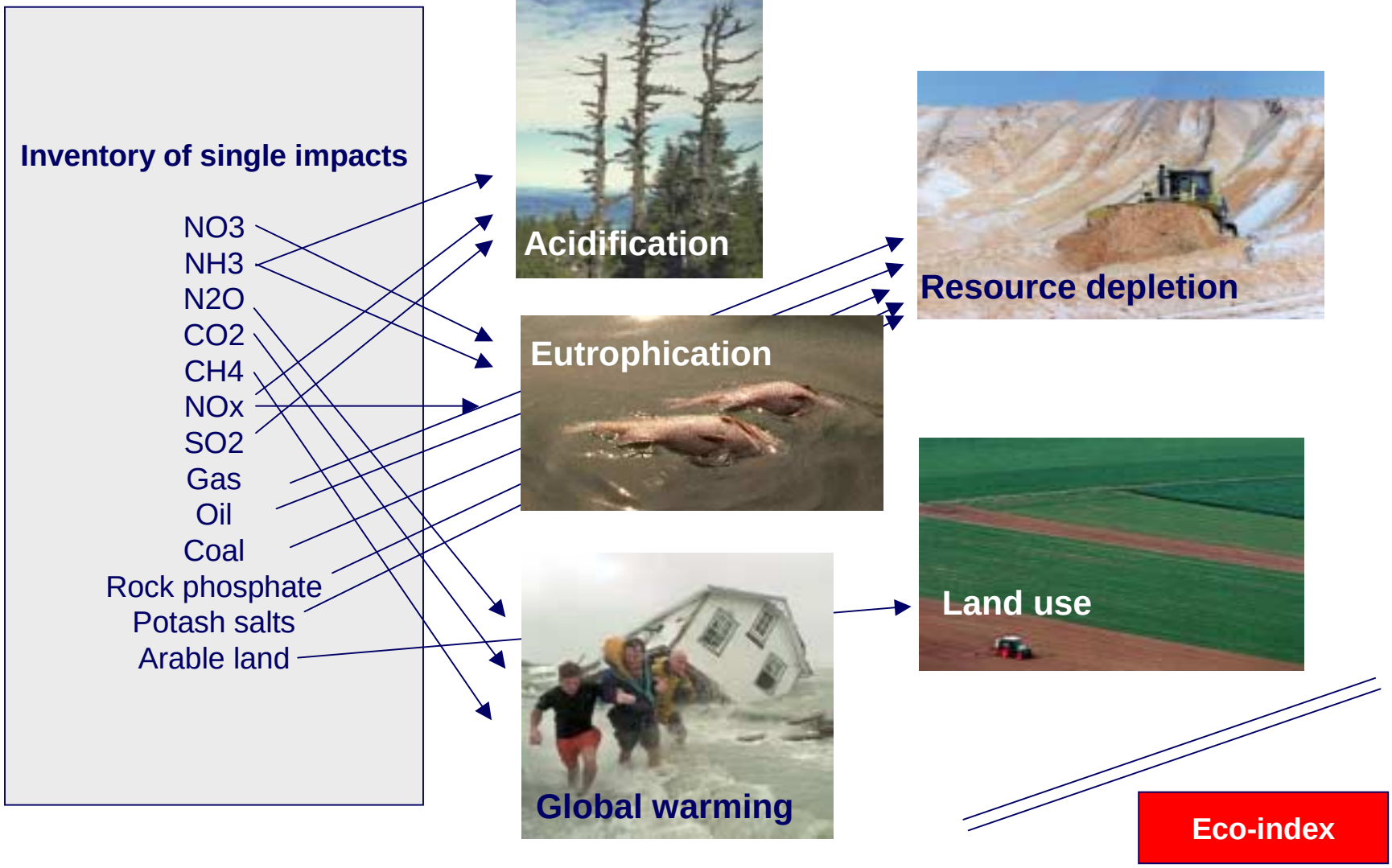
Production & transportation
- Fertilizer
- Pesticides
- Machines
- Seeds

Arable farming
- Tillage
- Sowing
- Plant nutrition
- Plant protection
- Harvest

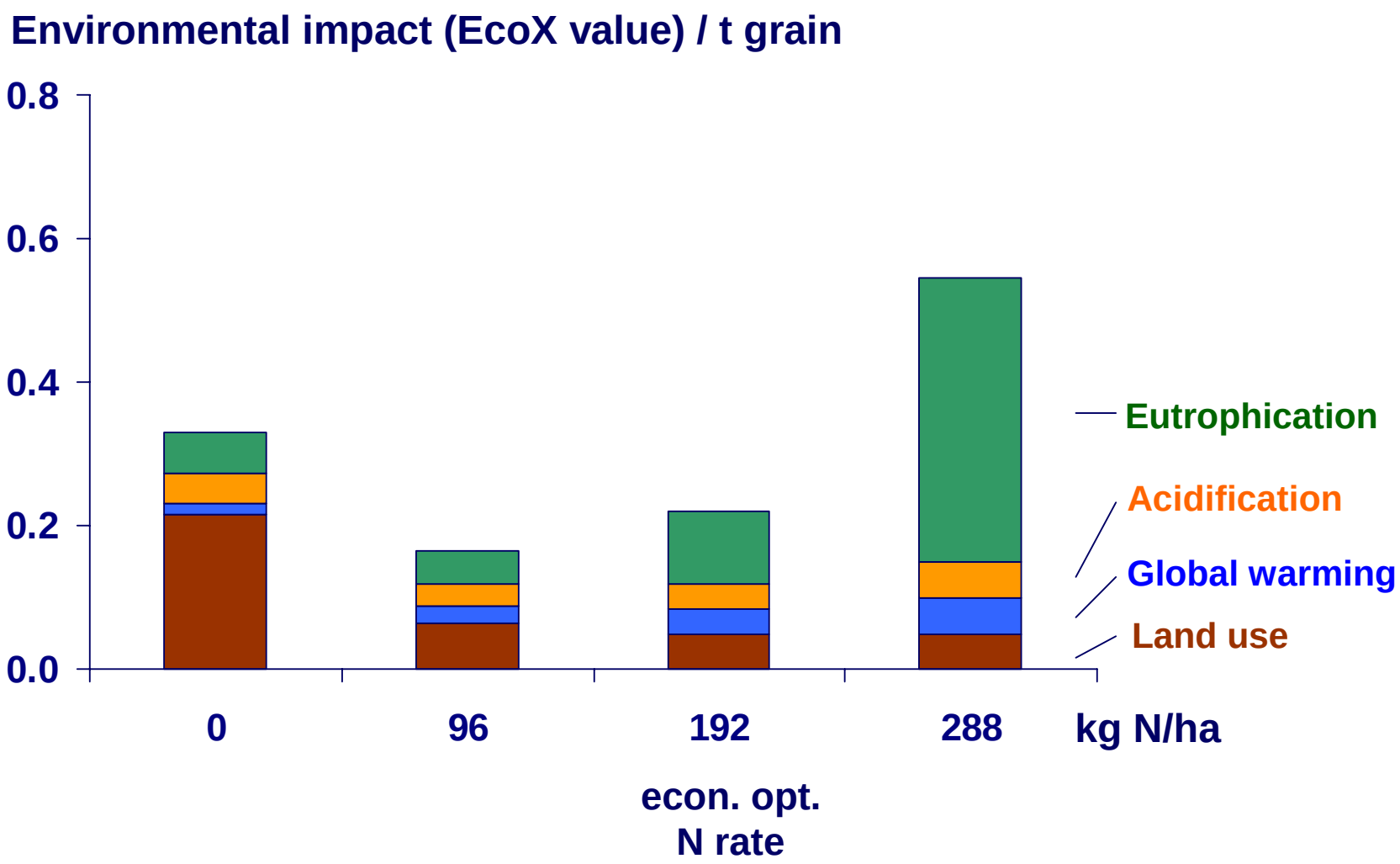
Inventory of single impacts

NO_3
NH_3
N_2O
CO_2
NOx
SO_2
VOC
Cd
Gas
Oil
Coal
Rock phosphate
Potash salts
Arable land

LCA: To summarize the inventory data of single impacts into environmental effects and a Eco-index



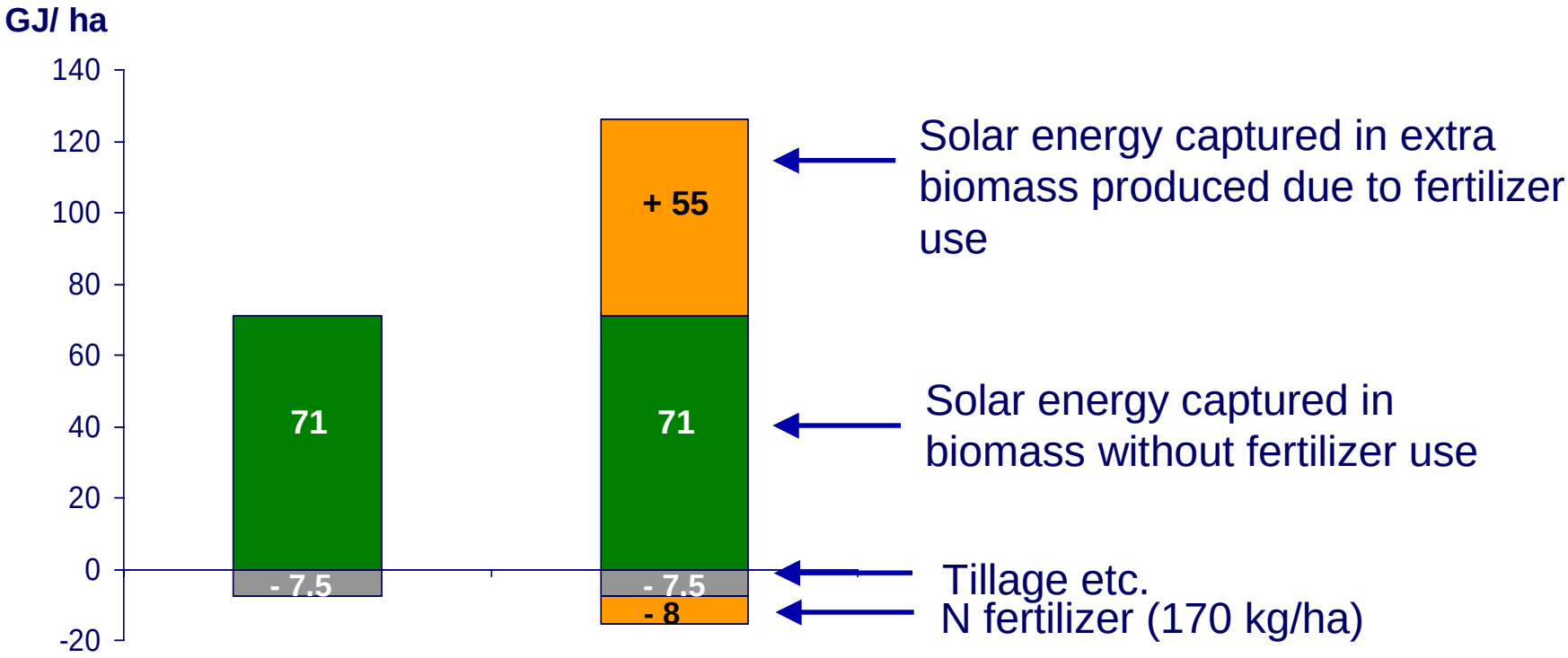
Aggregated environmental impact of wheat production at different N rates



Sustainability of wheat production at optimum and reduced N fertilization

	reduced	optimum
Environmental impact	+/-	
Economic targets (profit for farmer,food prices)	-	+
Social aspects (food quality, food security)	-	+

Fertilizer use enables the crop to grow more biomass which fixes additional energy

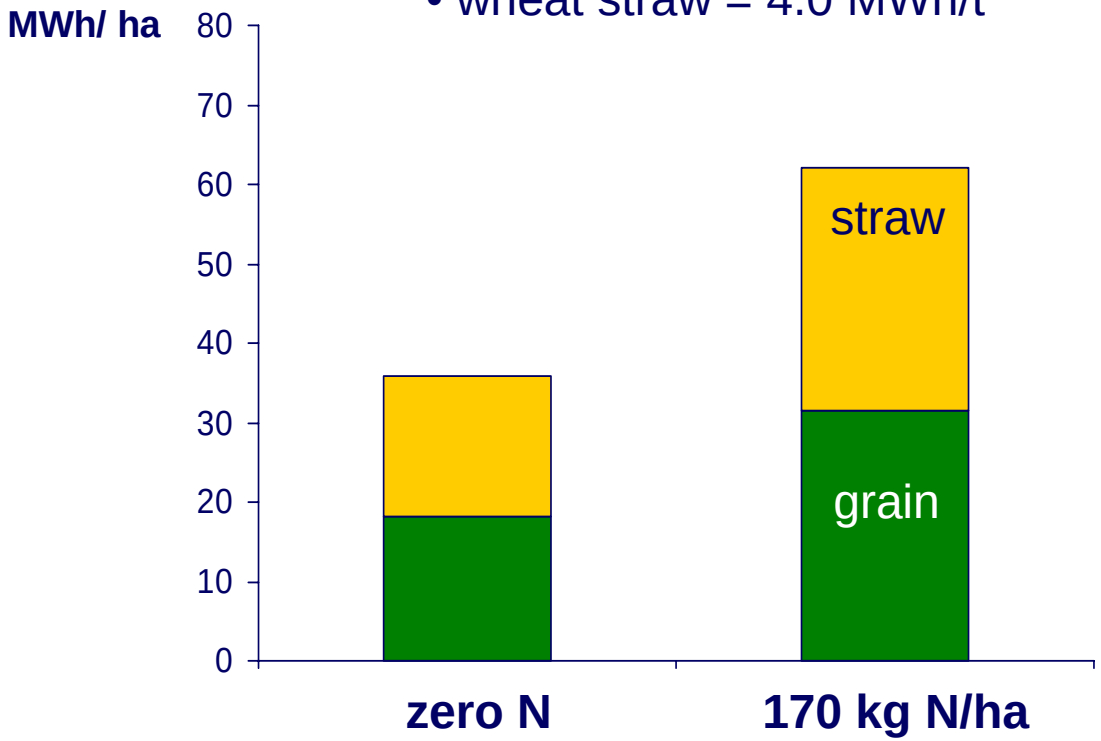


zero N	170 kg N/ha	
4.7	8.2	Grain yield (t/ha)
71	126	Energy yield (GJ/ha)
7.5	15.5	Energy consumption (GJ/ha)
63.5	110.5	Net energy yield (GJ/ha)

Example: field trials, Germany

Vision for the (near ?) future: Arable farming to produce energy

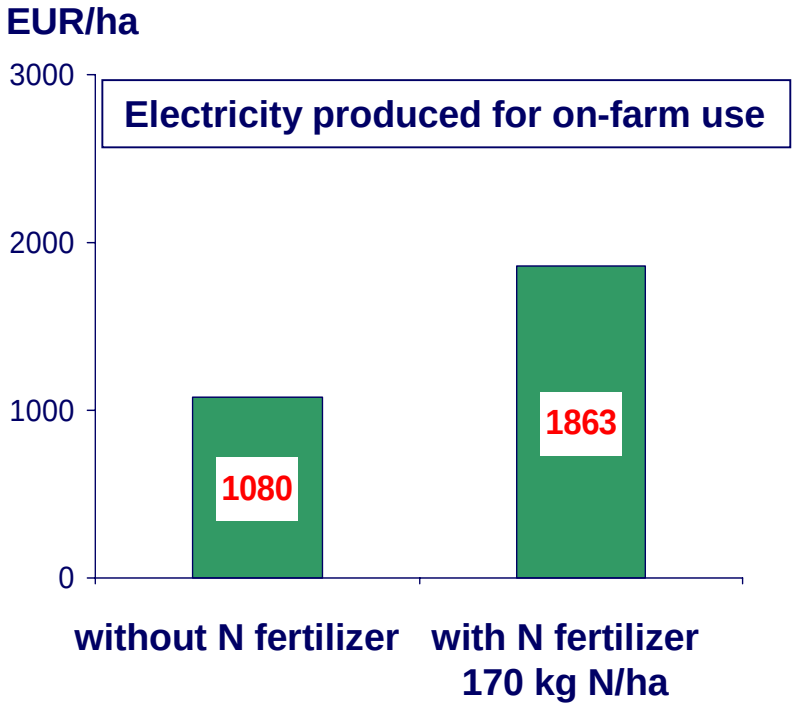
Heating value (85% DM; Hartmann, 1999):
- wheat grain = 4.1 MWh/t
- wheat straw = 4.0 MWh/t

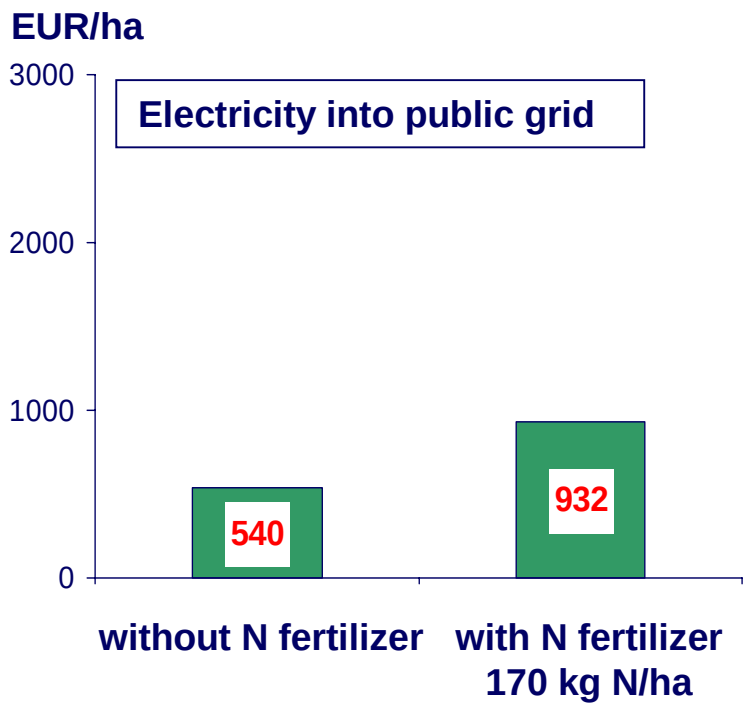


4.7	8.2	Grain yield (t/ha)
36.0	62.1	Net heating value (MWh/ha)

Straw and grain for electricity production - theoretical considerations

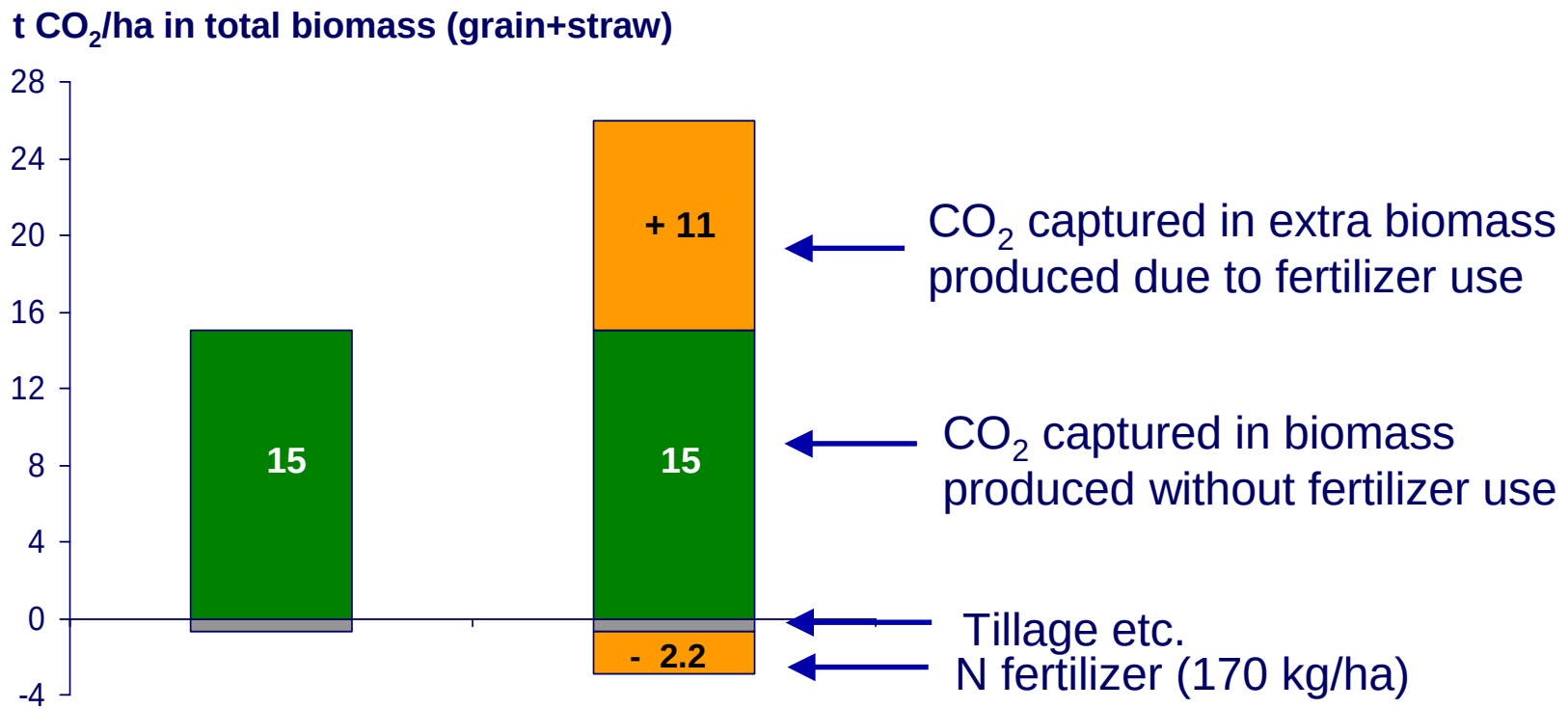
Assumptions:
- 30% efficiency of on-farm power generation
- 10 Cent/kWh by replacement of public electricity; 5 Cent/kWh electricity into the public grid





N fertilizer rate	0	170	kg/ha
Biomass (straw + grain)	9.4	16.4	t/ha
Net heating value	36.0	62.1	MWh/ha

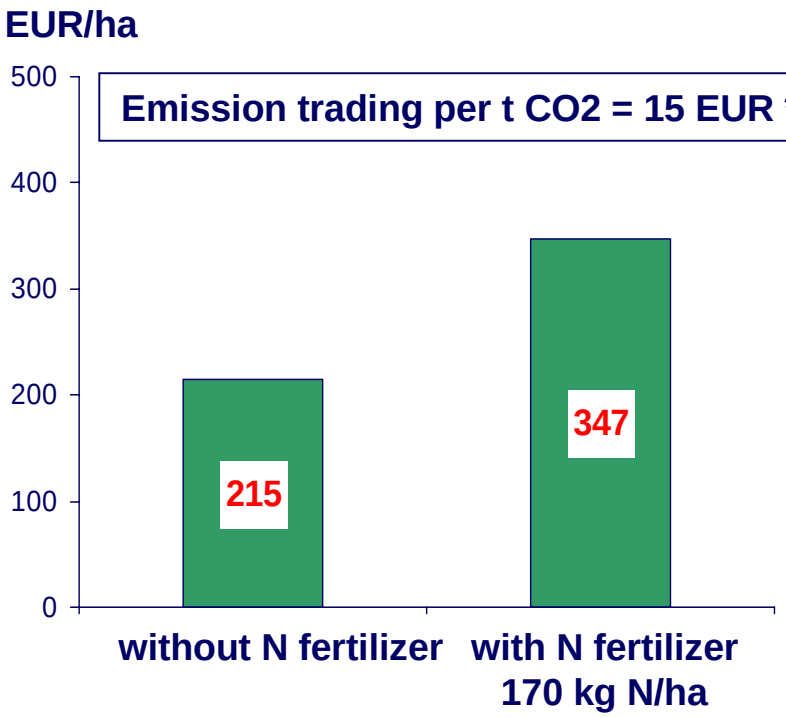
Fertilizer use helps to fix extra CO_2

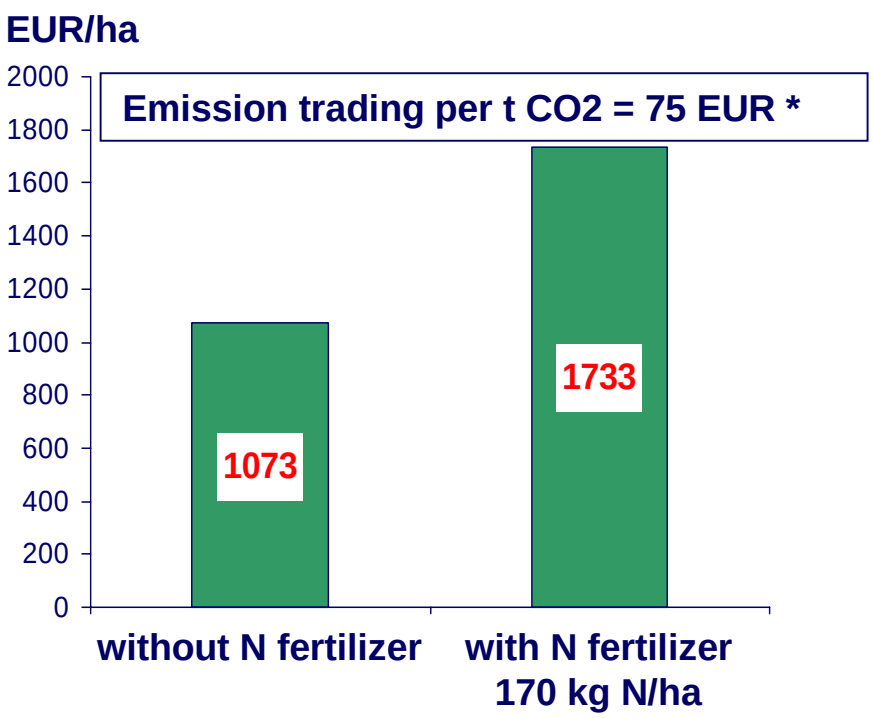


zero N	170 kg N/ha	
9.4	16.4	Biomass (grain+straw, t/ha)
0.7	2.9	CO_2 emission (t/ha)
15	26	CO_2 fixation (t/ha)

Example: field trials, Germany

Additional income through CO_2 trading if crops are used to produce energy?



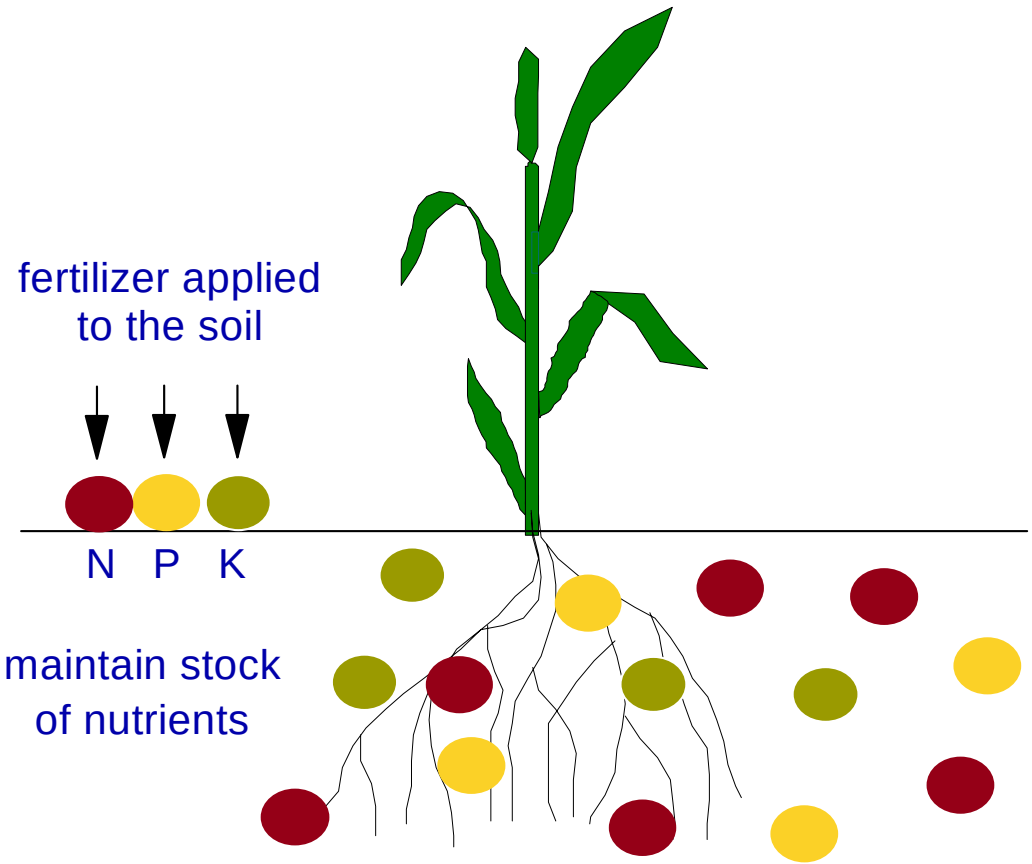


N fertilizer rate	0	170 kg/ha
Biomass (straw + grain)	9.4	16.4 t/ha
net CO2 fixation	14.3	23.1 t/ha

*** EU Green Paper on greenhouse gas emissions trading within the European Union - COM (2000)87:** 15 – 75 EUR per reduced tonne of CO2


Hydro Agri
Plant Nutrition Concept
" Just in time"
To increase the fertilizer use efficiency
HYDRO

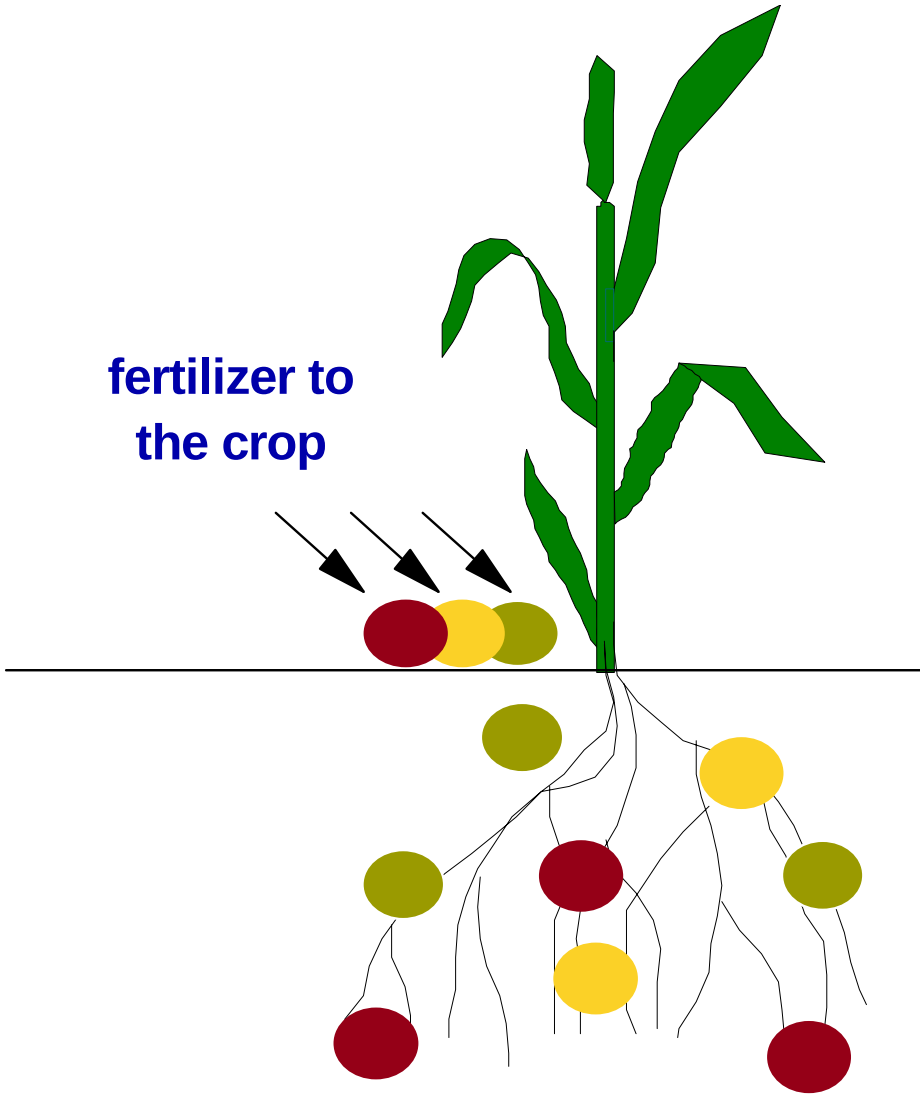
Today's Fertiliser Strategy: “stock-keeping”



Principle

- ✓ The crop takes up nutrients from the soil. A certain nutrient content of the soil is recommended and shall be maintained through fertilizer application.
- ✓ weak relation between the nutrient content in the soil and crop yield
- ✓ nutrients in the soil are not always plant available

Hydro Agri
"Just-in-time" nutrient management



Principle

- ✓ the nutritional status of the crop determines the application rate and timing

Benefits

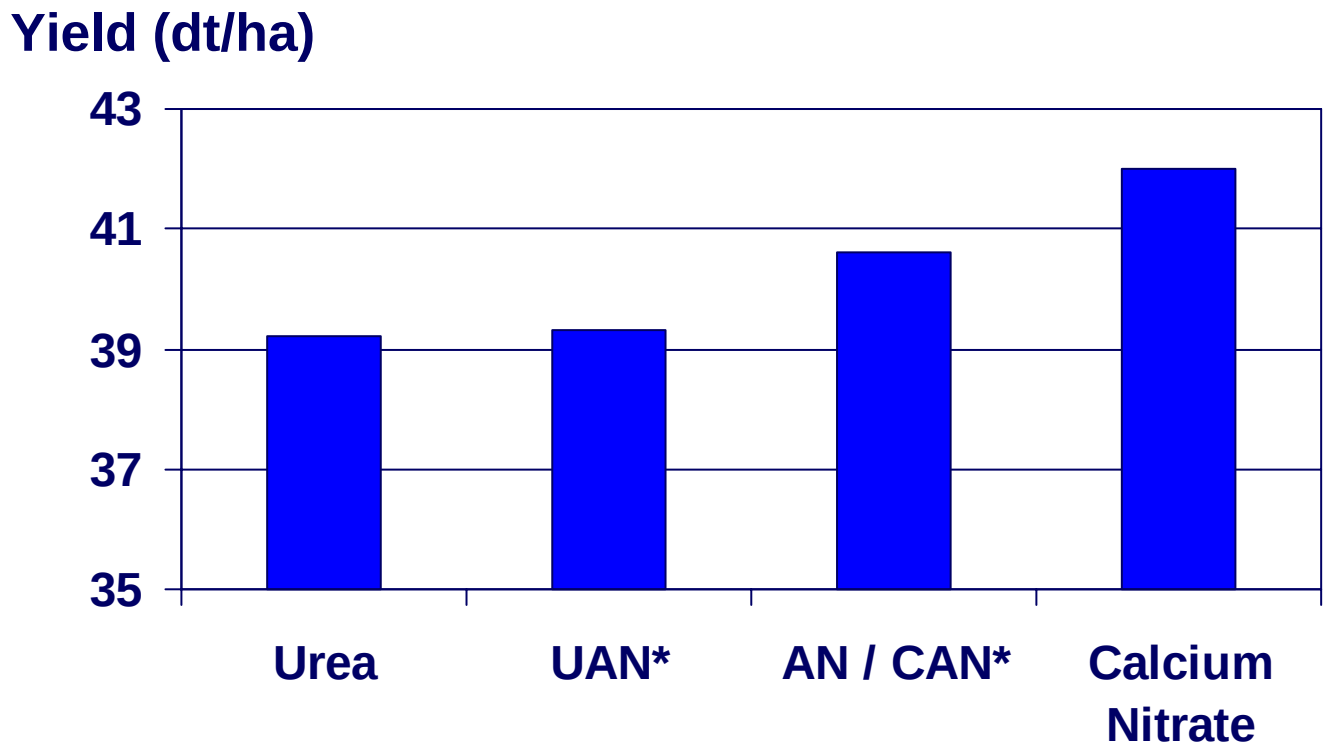
- ✓ higher nutrient use efficiency because nutrients applied when needed

Prerequisites ~ Research

- ✓ efficient fertilizers
- ✓ balanced nutrition
- ✓ advanced nutrient delivery systems
- ✓ diagnostic tools

Nitrate fertilizers are more efficient!

Oil seed rape, UK: average of 15 trials (1994 – 98), N rate: 200 kg N/ha

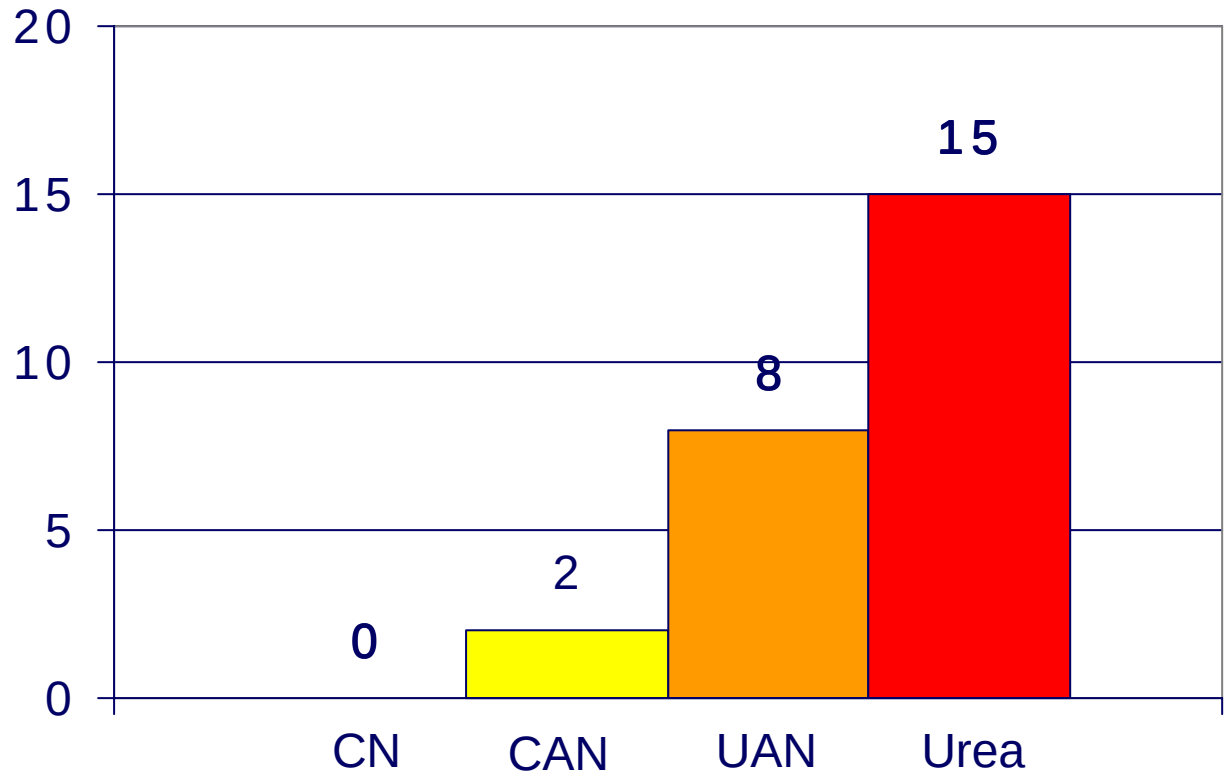


***UAN = Urea Ammonium Nitrate solution**
***AN = Ammonium Nitrate**
***CAN = Calcium Ammonium Nitrate**

Source: Levington Agriculture, UK (1999)

Average ammonia losses from mineral fertilizers Temperate climate

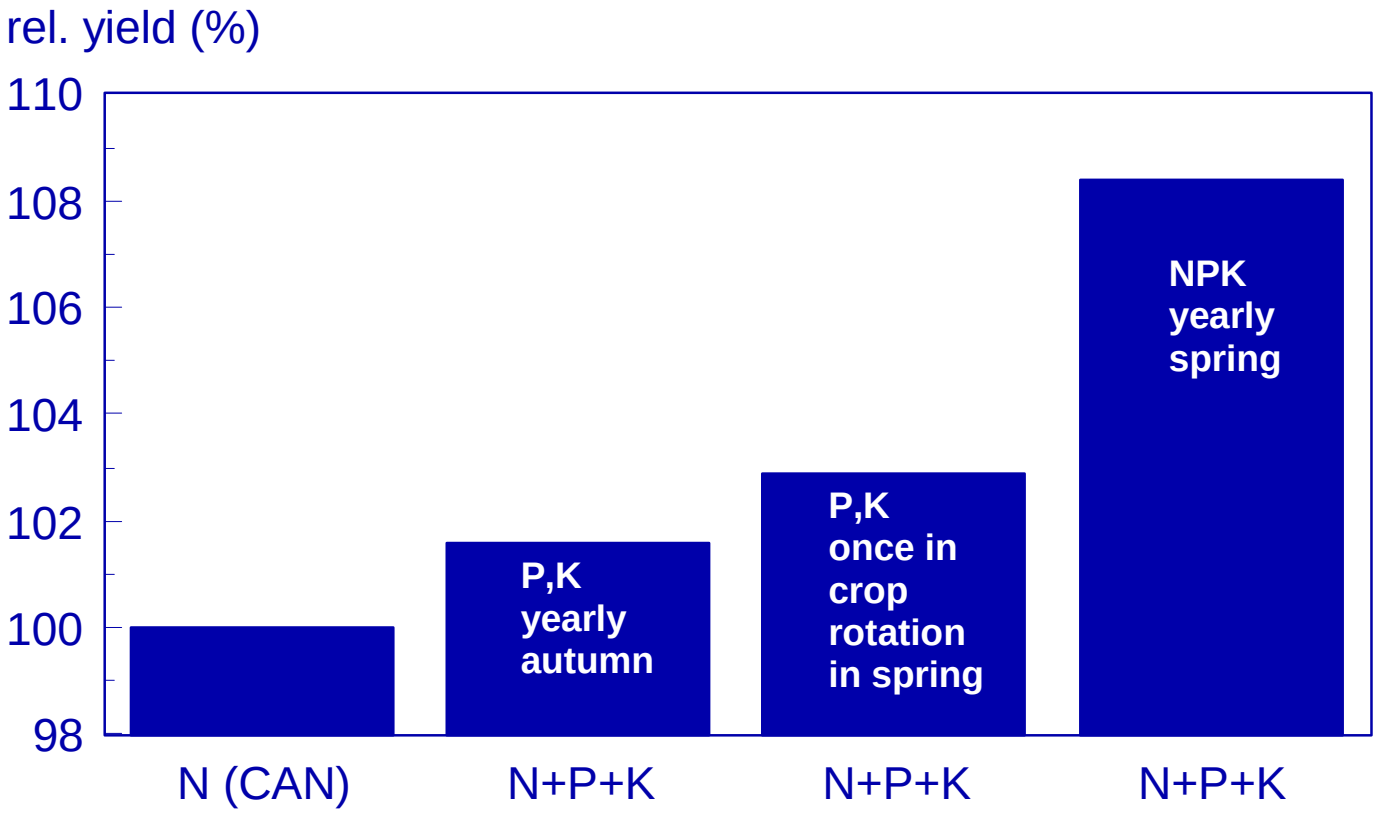
Ammonia losses (in % of the N application)



Source: ECETOC study

Balanced nutrition: The Starter Concept

Advantages of an annual application of NPK in spring compared to an application in autumn or once in the crop rotation

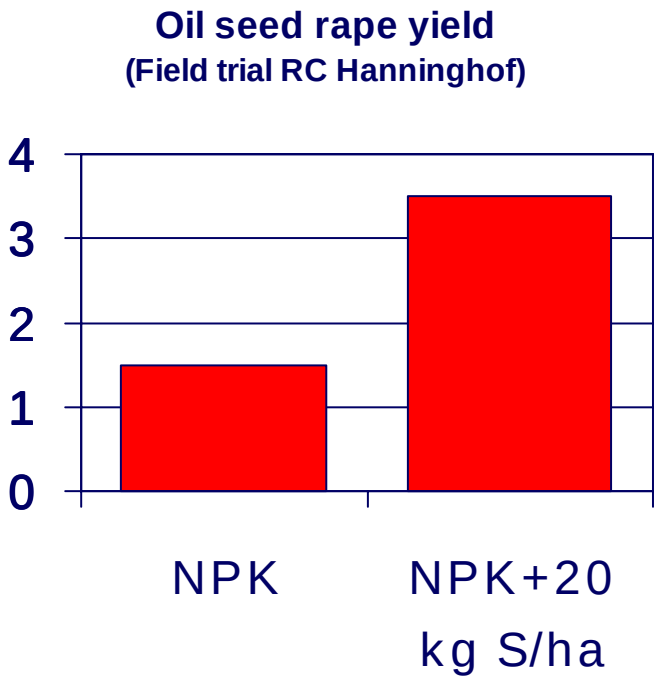


(CAN=100 %, average of 7 long-term trials, 6th year)

Crops require more than NPK:

"balanced" fertilisation with respect to all macro and micro nutrients

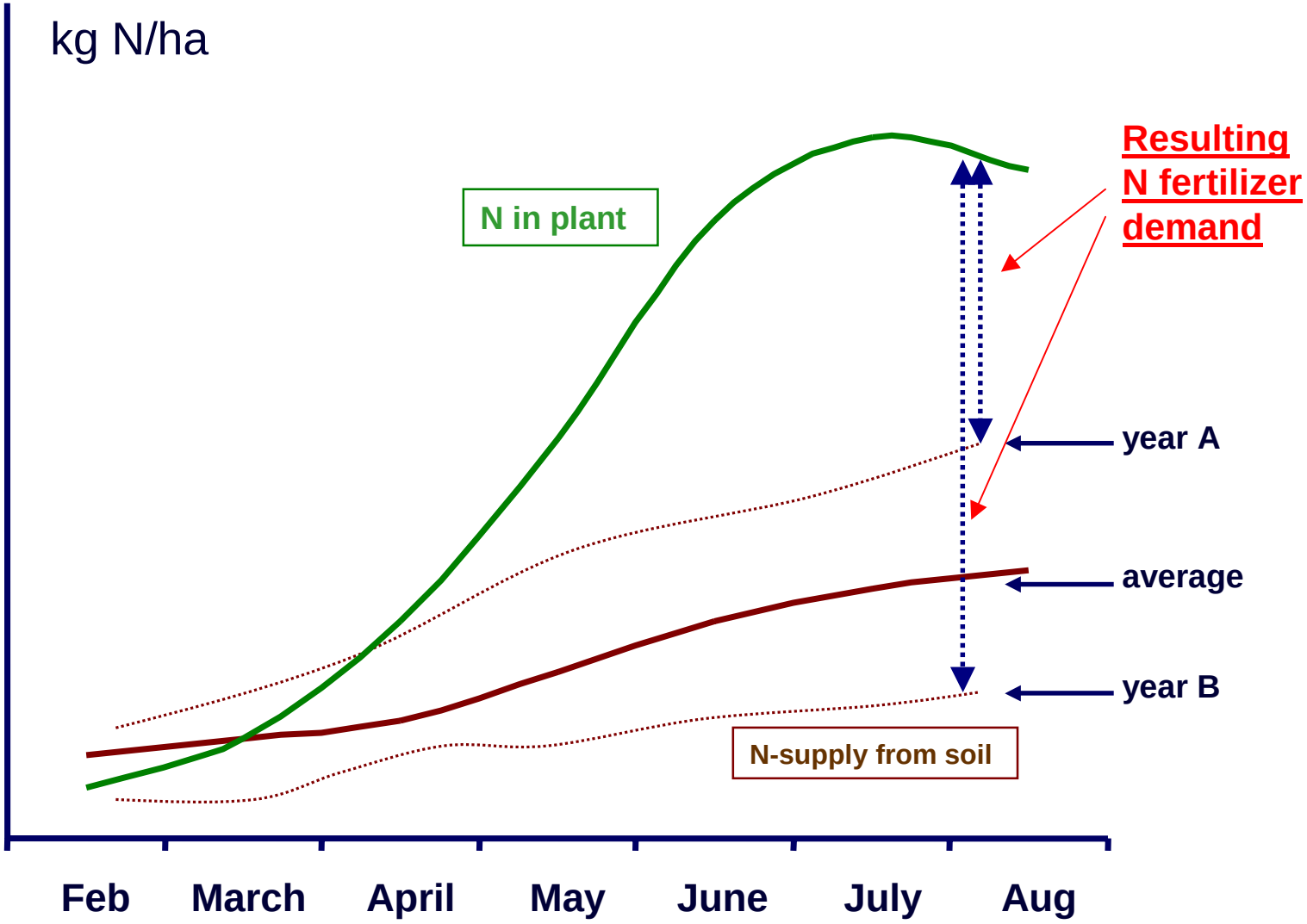
Fertilizer application (kg/ha)		no S Fertilization Yield 1.5 t/ha Nutrient uptake (kg/ha)	20 kg S/ha Yield 3.5 t/ha Nutrient uptake (kg/ha)	increased uptake due to 20 kg S/ha (kg/ha)
N	200	100	220	+ 120 N
P	50	20	45	+ 25 P
K	220	110	240	+ 130 K
Mg	50	15	40	+ 25 Mg



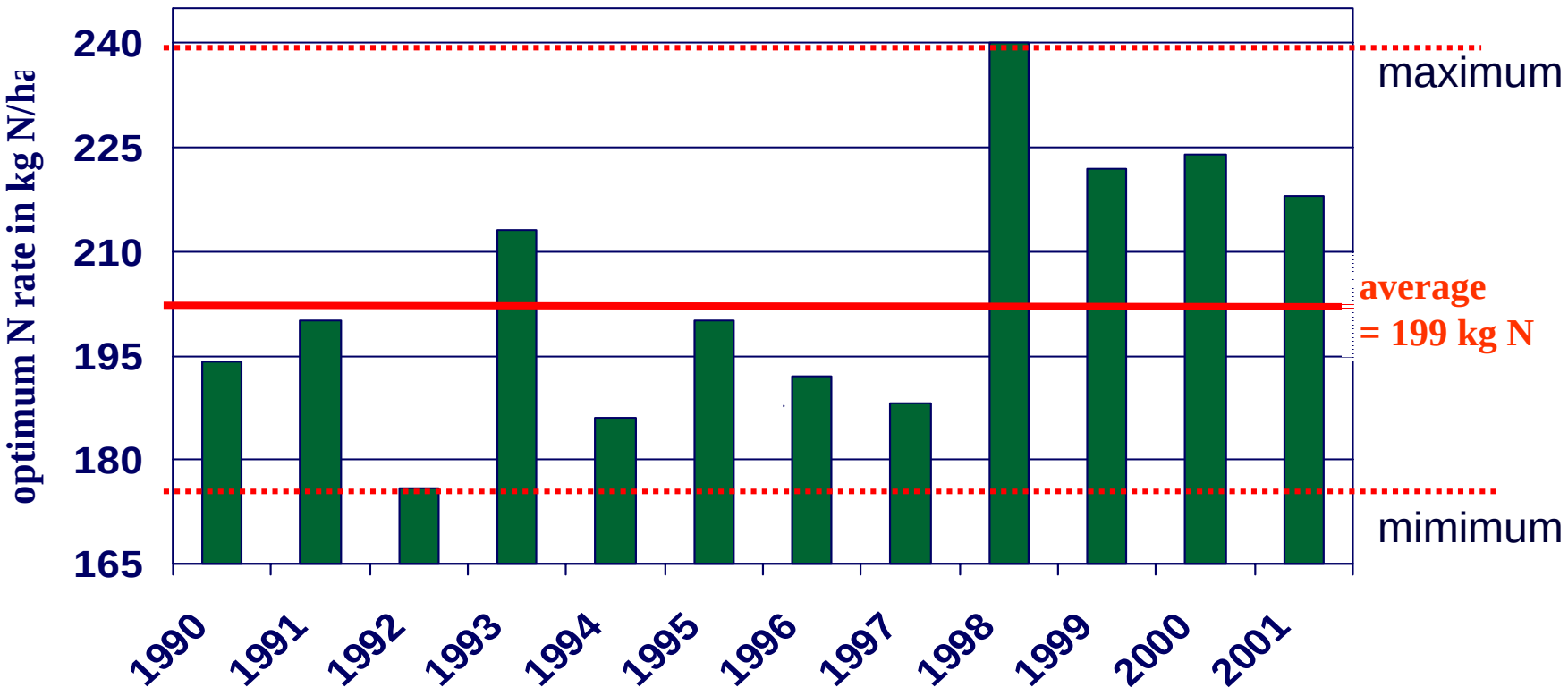
Fertiliser rate both treatments:
200 kg N/ha
50 kg P/ha
220 kg K/ha

- ✓increased revenues for the grower
- ✓Improved fertilizer use efficiency

Evaluation of the N fertilizer demand (schematic)



Variation of the economic optimum N rate at one single site in a winter wheat trial during 11 years



Rothamsted, UK

Tools to diagnose the nutritional status of crops

- **lab analysis of plant nutrient content**
- **on-farm chemical tests (e.g. tissue nitrate concentration)**
- **in-field equipment for plant testing (e.g. Hydro-N-Tester)**
- **remote sensing (Hydro N-Sensor)**

Hydro N-Tester

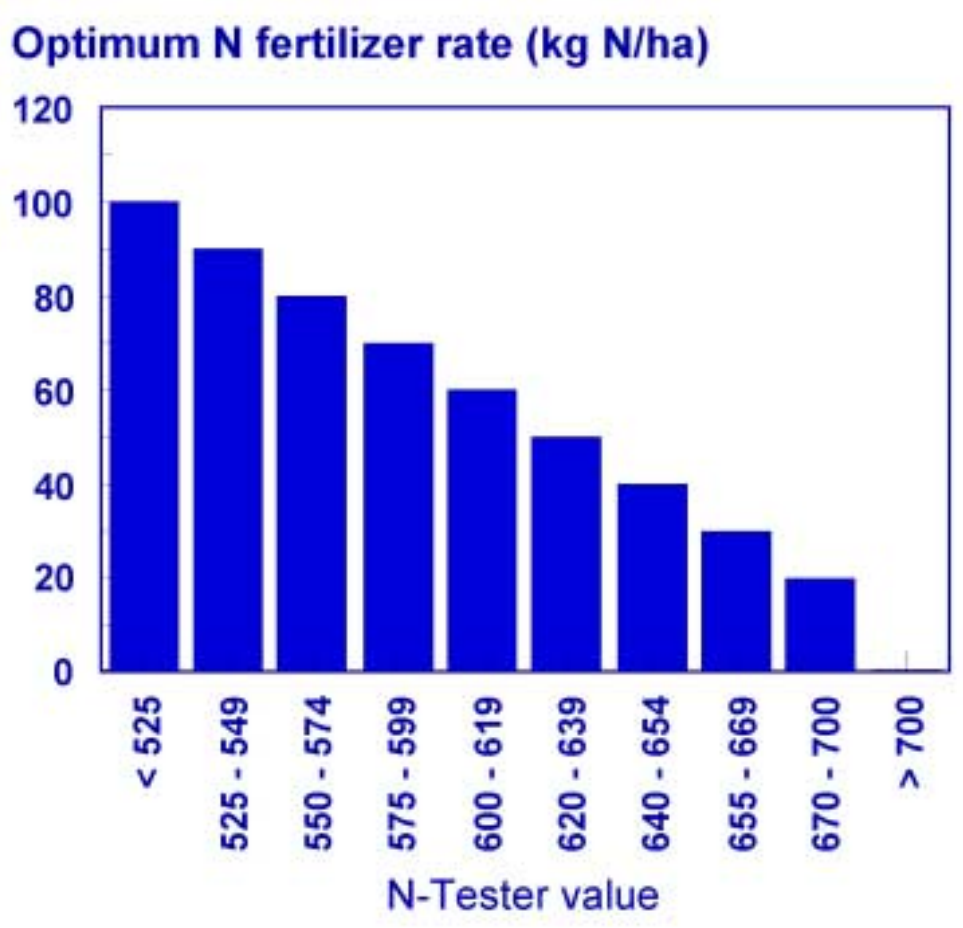
An accurate and convenient tool for nitrogen fertilizer management

- ✓the N-status is deduced from the chlorophyll content of the leaves
- ✓the N fertilizer rate is adjusted to the N status
- ✓the Hydro N-Tester has been well accepted by farmers in several countries
- ✓the Hydro N-Tester is approved by authorities in several countries

Hydro N-Tester

Nitrogen fertilizer management - Example

To conclude from the Hydro N-Tester reading on the nitrogen fertilizer demand (kg N/ha), cereals, Example Germany



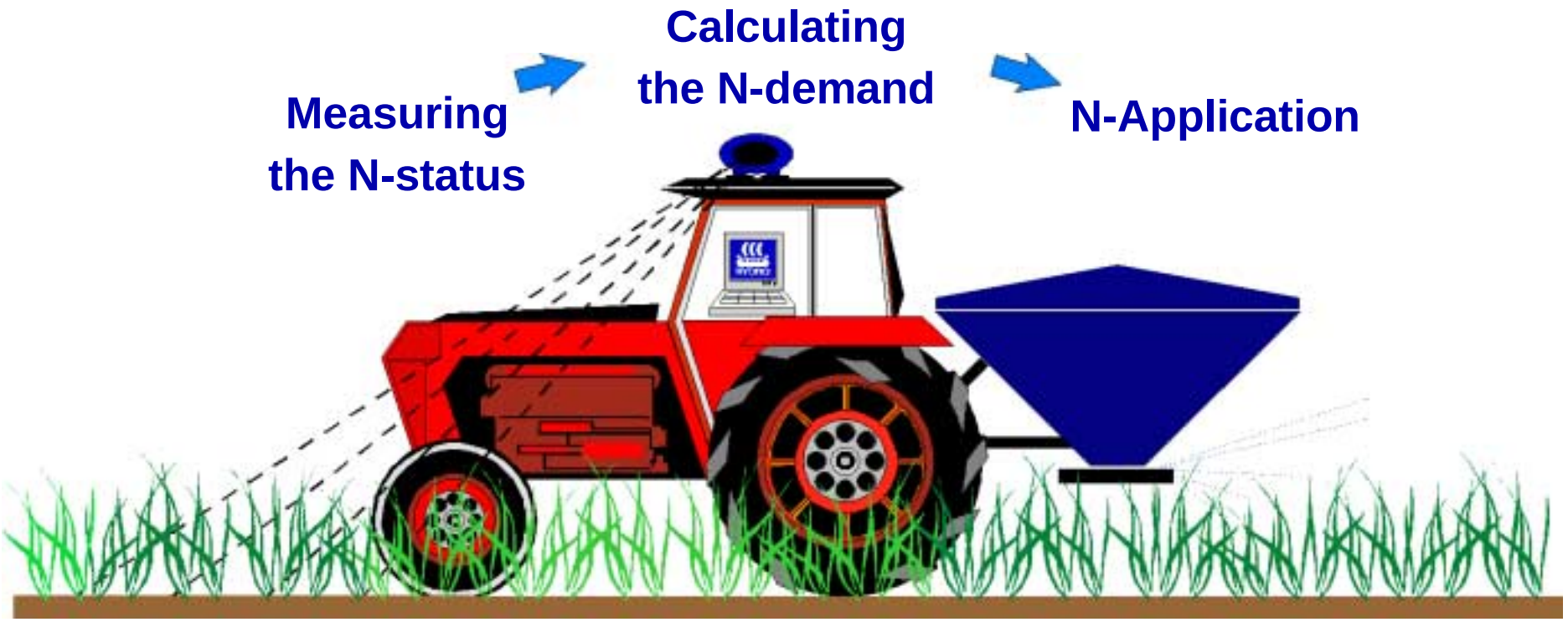
Winter wheat, 2nd N dressing at stem elongation, Germany, 2001

Hydro N-Sensor

The Challenge for the Grower is to respond to variation within a field

Hydro N-Sensor

A unique system to measure the N-status, to calculate the N-demand and to apply the right amount of N on every spot of the field



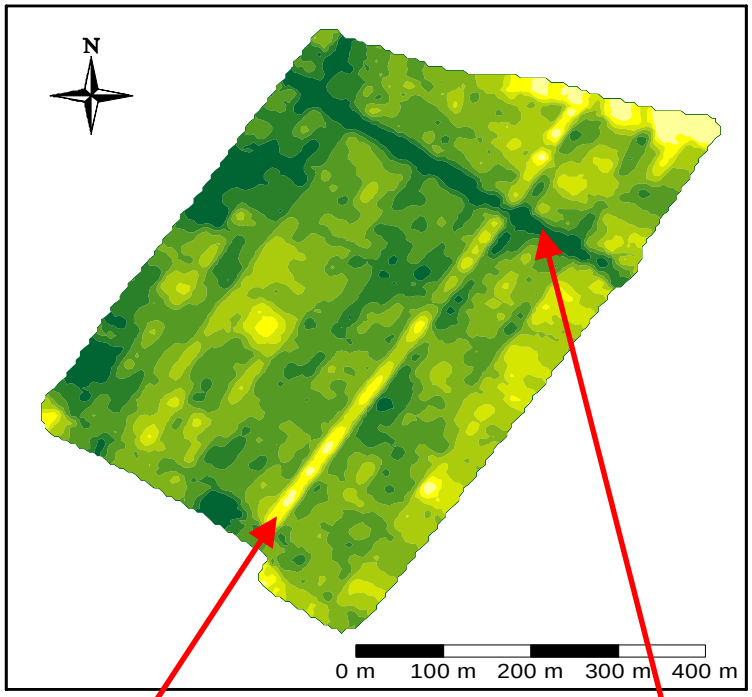
Hydro N-Sensor

Higher yield and quality ➔ More profit for the grower

- ✓ **Mountable on every tractor and truck**
- ✓ **Compatible with all spreader manufacturers**
- ✓ **Data-logging on data card**
- ✓ **Farmers can generate N-application maps on Hydro Agri's internet software *Sensor Office***

The Hydro N-Sensor detects areas of different N supply

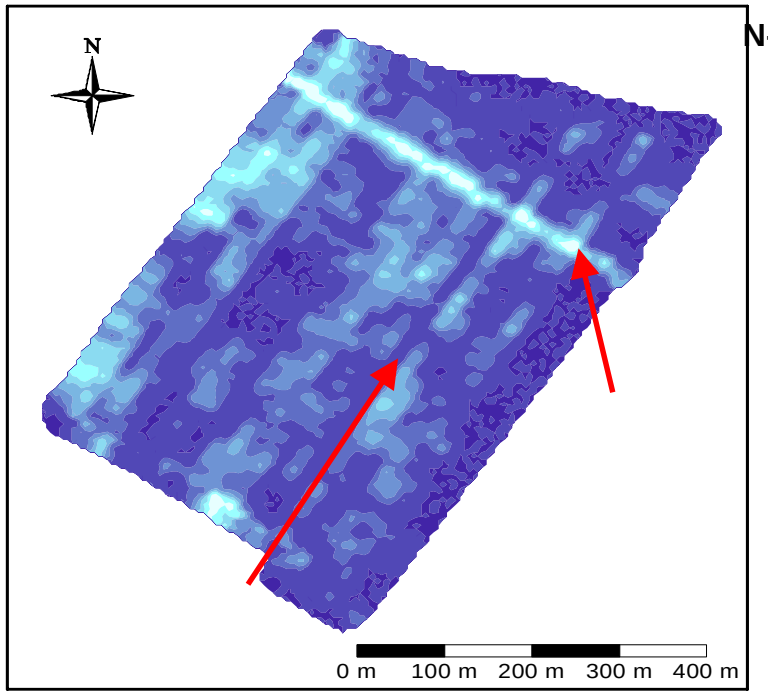
Sensor Map



Sensor value
High

Low

N-Application Map



N-Application kg N/ha

65
60
55
50
45
40
35
30
20

reduced N-Application (-35 kg N/ha), at 1st N Rate

Additional N-Application (+35 kg N/ha) at 1st N Rate

Winter Wheat Field
N-Sensor Measurement and N Application 30. 04.02
Source: Leading Farmers, Czech Republic

Agronomic use of the Hydro N-Sensor

- ✓ **Commercial use on farms**
  - Cereals (Europe)
  - Oil seed rape (Europe)
  - Maize (Europe)
  - Rice (Japan)

- ✓ **Testing and adaptation**
  - Wheat, Maize (Canada)
  - Cotton (North America)
  - Wheat, Corn (South America)
  - Sugar cane (South America)
  - Potatoes (Europe)

➔ More than **270** Hydro N-Sensors are in use on practical farms

Summary

- Plant nutrients will continue to be the most important input into agricultural production
- Mineral fertilizers are a necessity for sustainable agriculture
- The additional energy yield from nitrogen fertilizer use is seven times the energy input
- Arable farmer in Europe may explore the potential to produce renewable energy and to reduce CO_2 emissions
- To further increase the fertilizer use efficiency, Hydro is currently developing tools and products for a “just-in-time” plant nutrition management