Knowledge grows

Yara Fertilizer Industry Handbook

January 2017

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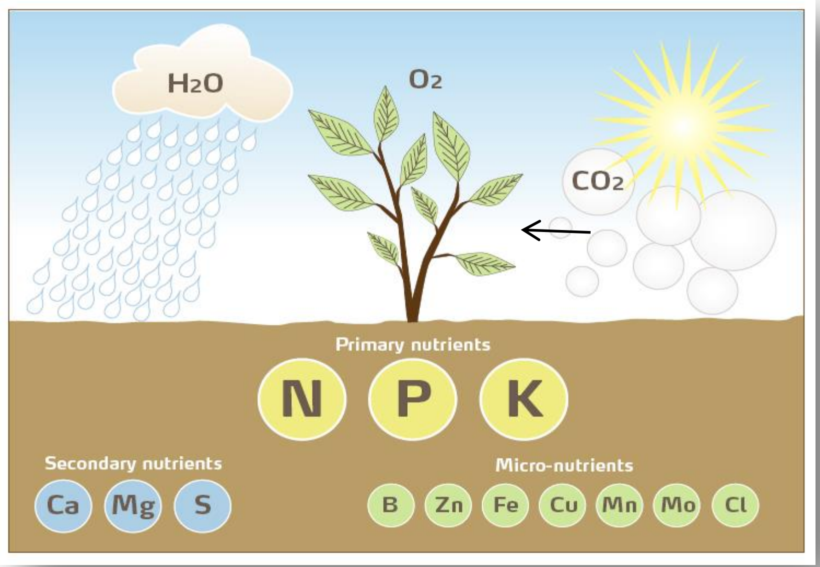
What is fertilizer?

Fertilizers are plant nutrients, required for crops to grow

- Crops need energy (light) CO_2, water and minerals to grow
- The carbon in crops originates from CO_2 absorbed through the leaves
- Crops absorb water and plant nutrients from the soil
- Plant nutrients are building blocks of crop material. Without nutrients the crops can not grow
- Mineral fertilizers provide plant nutrients for crops
- Three main nutrients: Nitrogen, Phosphorus and Potassium are primary nutrients



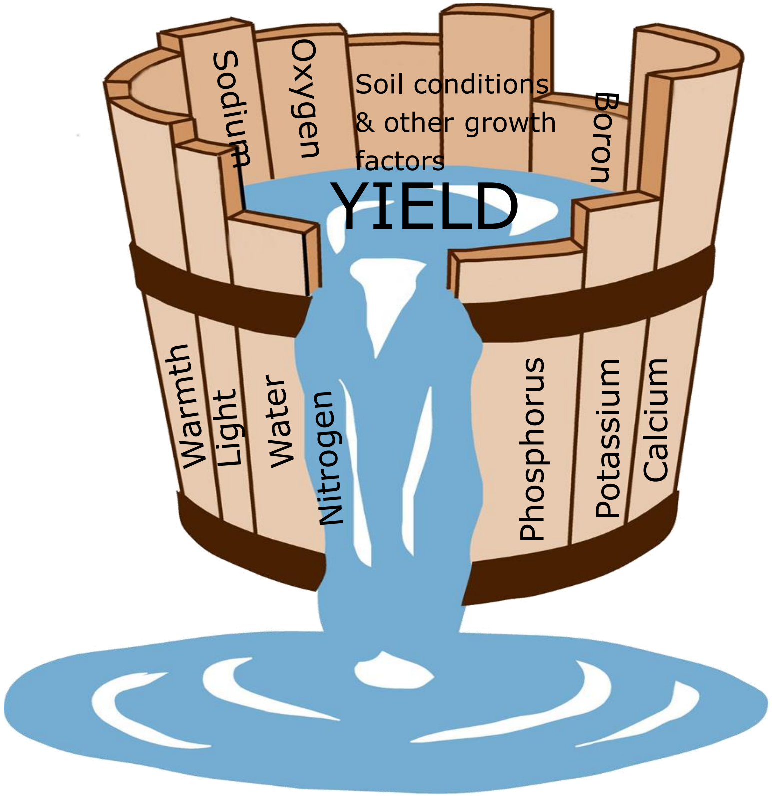
Principle of crop nutrition: crop growth is limited by the most deficient nutrient

- Law of the Minimum" (Liebig, 1843): "Crop yields are proportional to the amount of the most limiting nutrient."

- Plant nutrients have specific and essential functions in crop metabolisms

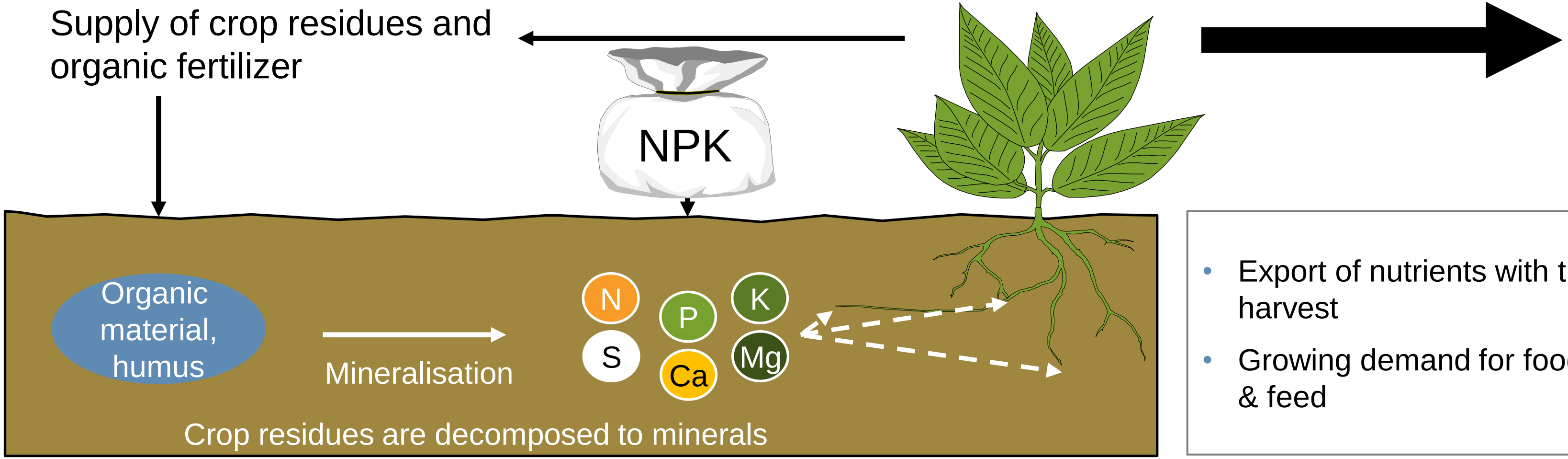
- They cannot replace each other, and lack of any one nutrient limits crop growth

- It is therefore essential to focus on a balanced nutrition of all plant nutrients



Why mineral fertilizer?

Mineral fertilizer replace nutrients removed with the harvest



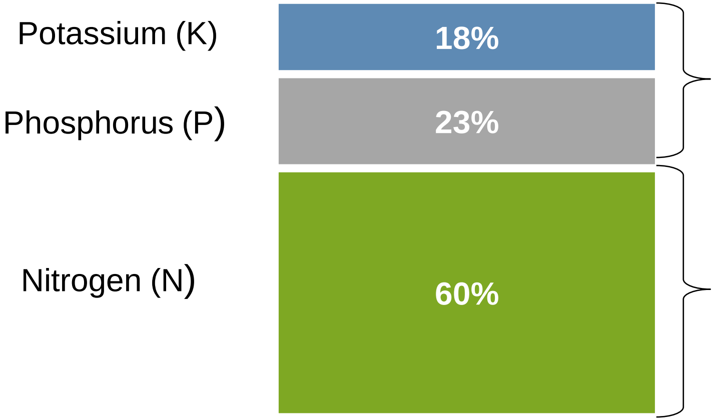
- Export of nutrients with the harvest
- Growing demand for food & feed

Mineral fertilizers are necessary to replace those nutrients that have been removed from the field

Mineral fertilizer characteristics compared to organic fertilizer

Characteristics	Mineral fertilizer	Organic fertilizer
Nutrient source	Nitrogen from the air, Phosphate and Potassium from deposits / mines	Crop residues and animal manures
Nutrient concentration	High nutrient concentration Low logistical cost	Low nutrient concentration Large volumes to transport and store
Nutrient availability	Immediately available for the crop	Variable, organic material needs to be decomposed to release nutrients
Quality	Traceable and consistent	Often inconsistent Dependent on source

Nitrogen – the most important nutrient



Total 181 million
tons nutrients

Nutrient characteristics

Primary benefit	Application	Industry structure
• Improve crop quality	• Application can be varied	• Fewer suppliers, production discipline
• Increase crop size • Most important and commonly lacking nutrient	• Annual application critical	• Fragmented Industry, under consolidation • More dynamic prices, but stable volume

Source: IFA 2015/2016 season (June 2016 estimates)

Environmental impact of fertilizer

Fertilizer reduces the carbon footprint of farming

Fertilizer - an efficient solar energy catalyst

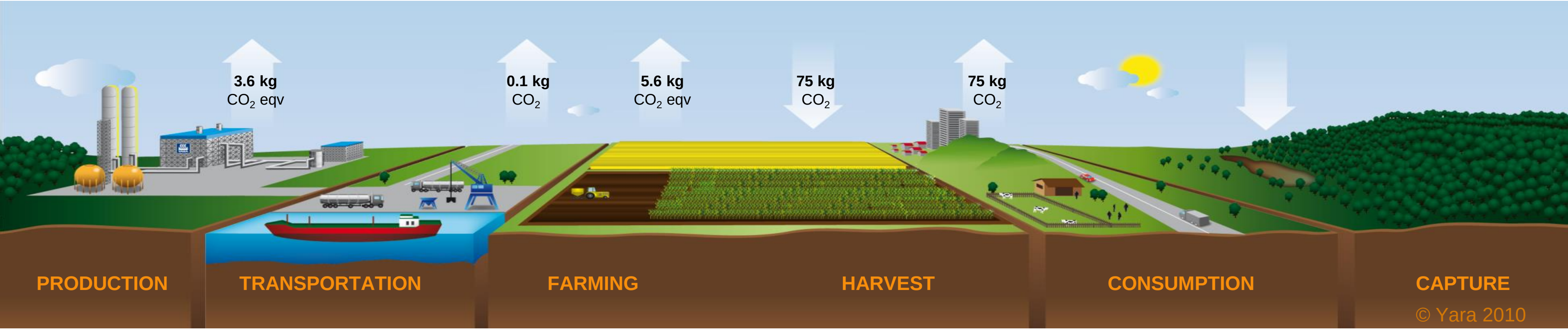
- Production is a marginal part of the carbon footprint; efficient application is more important
- Huge positive effects of fertilizer use, since higher yields enable lower land area use

Production

- Yara's production is more energy-efficient than competitor average

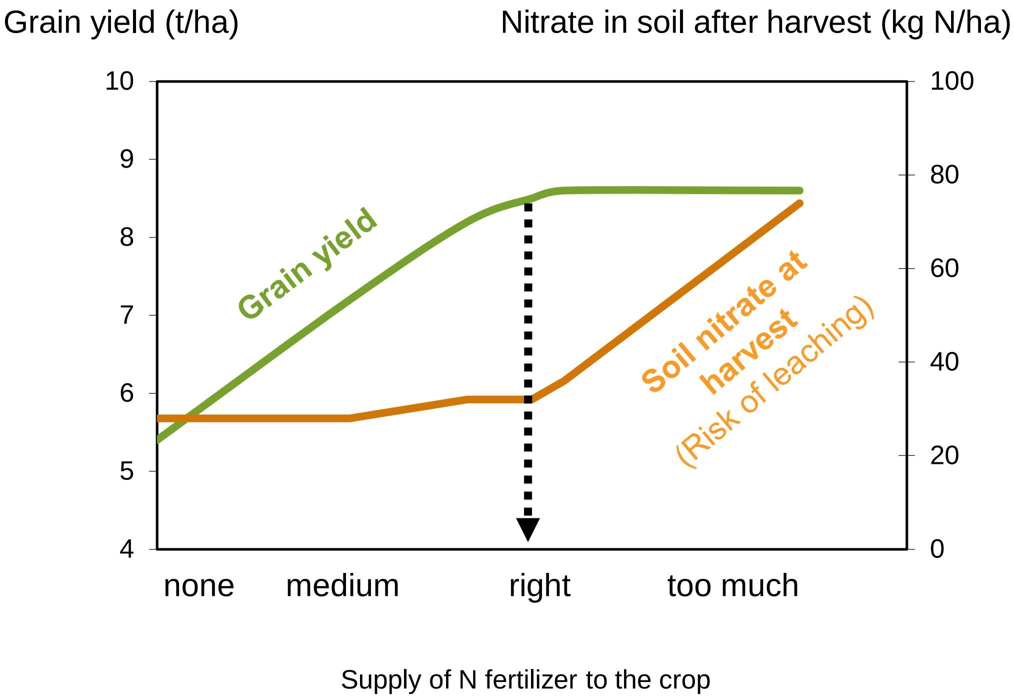
Application

- Higher efficiency with nitrates
- Precision farming tools



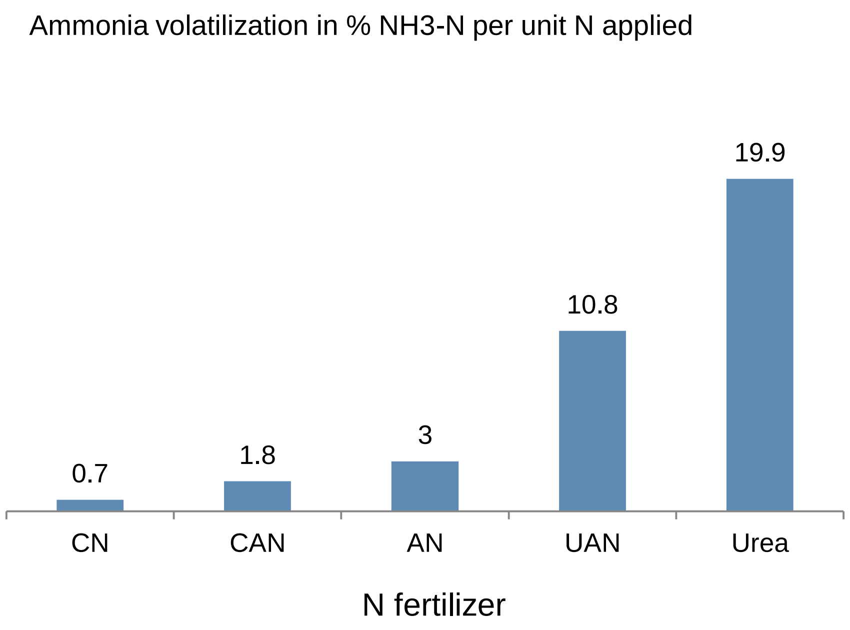
The right nitrogen fertilizer rate is key to avoid nitrate leaching

- Leaching of nitrate into groundwater affects water quality and contributes to eutrophication
- Oversupply of organic and mineral nitrogen fertilizer represents the main driver for nitrate leaching
- Nitrogen fertilizer application according to crop demand does not increase nitrate leaching



Choosing the right nitrogen fertilizer to avoid ammonia volatilization losses

- Volatilization of ammonia gas contributes to pollution, affects air quality and induces soil acidification
- The use of organic or urea-based nitrogen fertilizer represents the main driver for ammonia losses
- Nitrate-based N fertilizer or immediate incorporation of urea into the soil avoids volatilization losses



Reference: EMEP/EEA emission inventory guidebook 2013

Water availability is the main constraint on agricultural production in many important growing areas

Water scarcity is a clear issue

Rio Grande
failed to reach
Gulf of Mexico in 2001
for first time

Lake Aral
Only ~25% of
original size

Yellow River
Dry on last 100km:
1972: 15 days
1997: 226 days

Source: World Bank, 2008

Agricultural water use has to become more ”intelligent”

17% of cropland is irrigated, it is twice as productive as other land and contributes 40% of world food production…

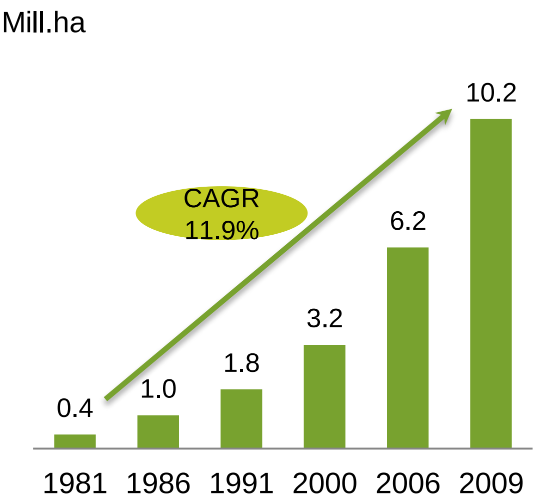
…but it uses 70% of all freshwater…

…thus, productivity growth from irrigation has to come from better use of water

Source: Center Pivot: carrot production in Brazil

The segment has seen strong growth historically

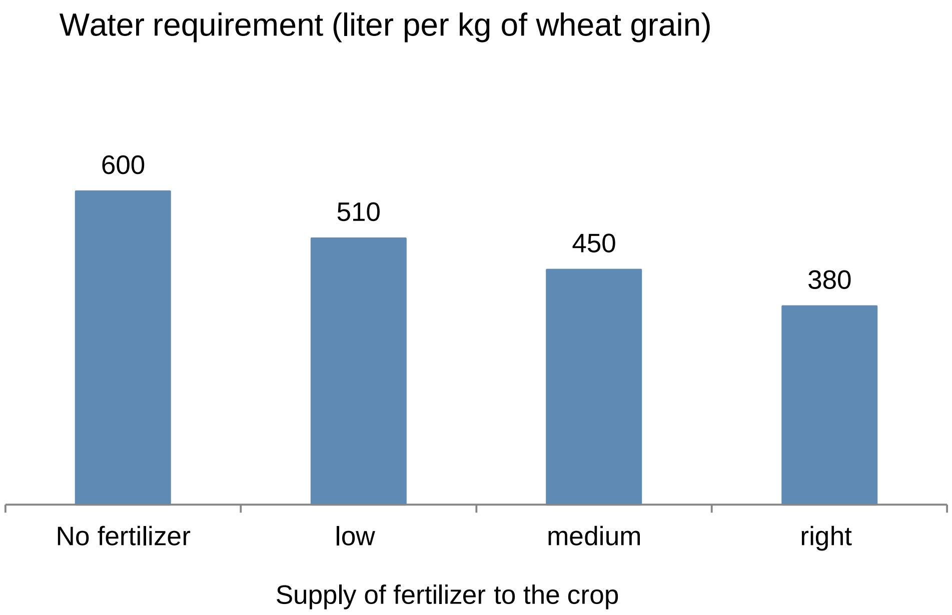
Expansion of Micro-irrigation



Source: Kulakarni et.al., 2006; Gopalakrishnan, 2008; USDA, 2008; MOI, 2009

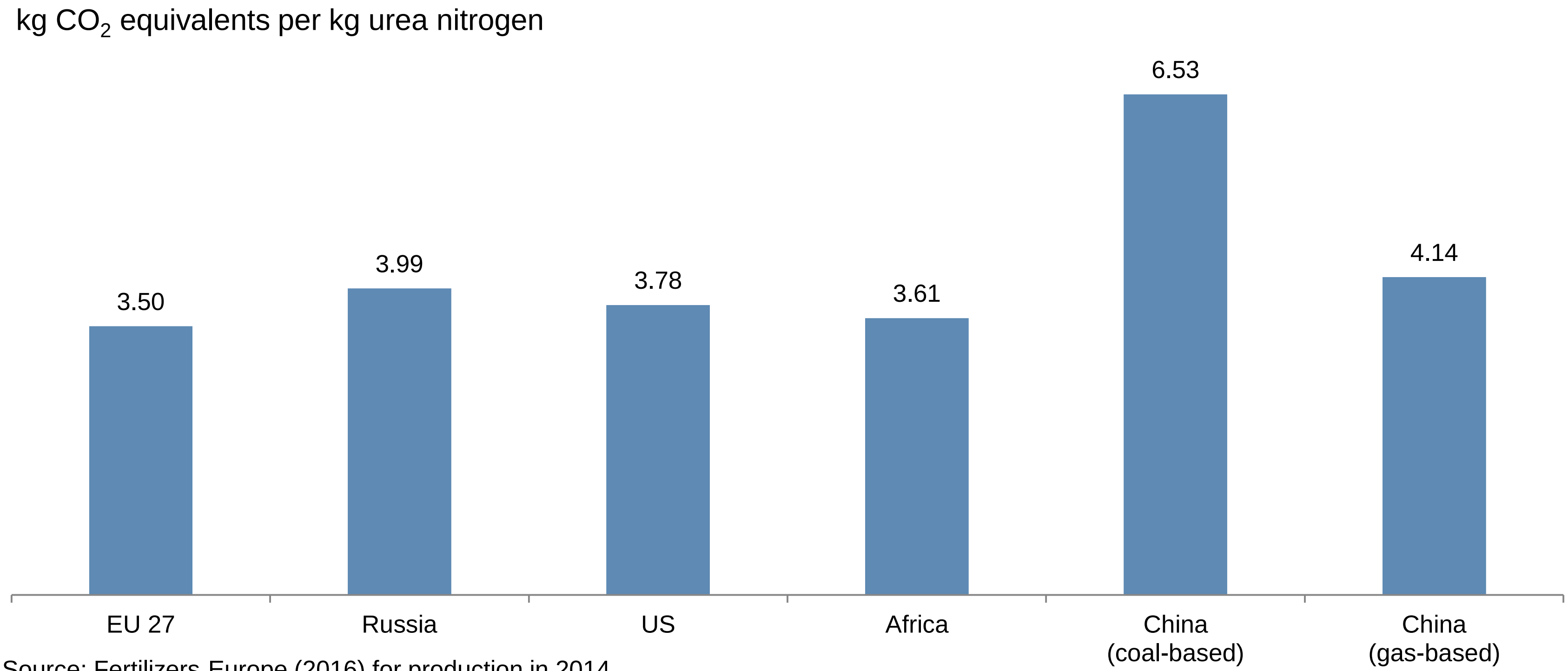
Good crop nutrition enables increased water efficiency: "more crop per drop"

- Water is a key input for crop growth
- About 70 % of global water consumption is for agriculture
- Sub-optimal crop nutrition tends to drive over-consumption of water
- Optimized crop nutrition improves water use efficiency



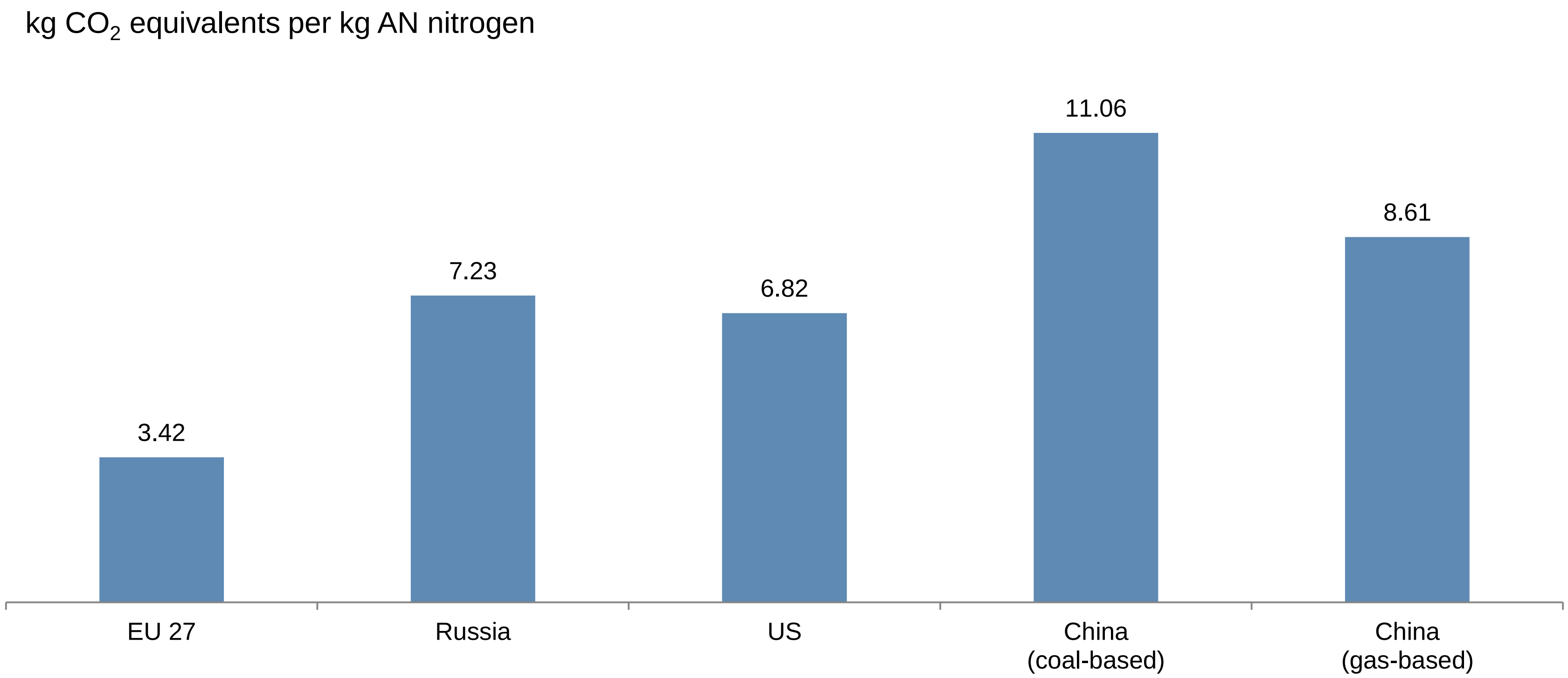
Source: Yara research

Carbon footprint of urea production differs by region



Source: Fertilizers Europe (2016) for production in 2014

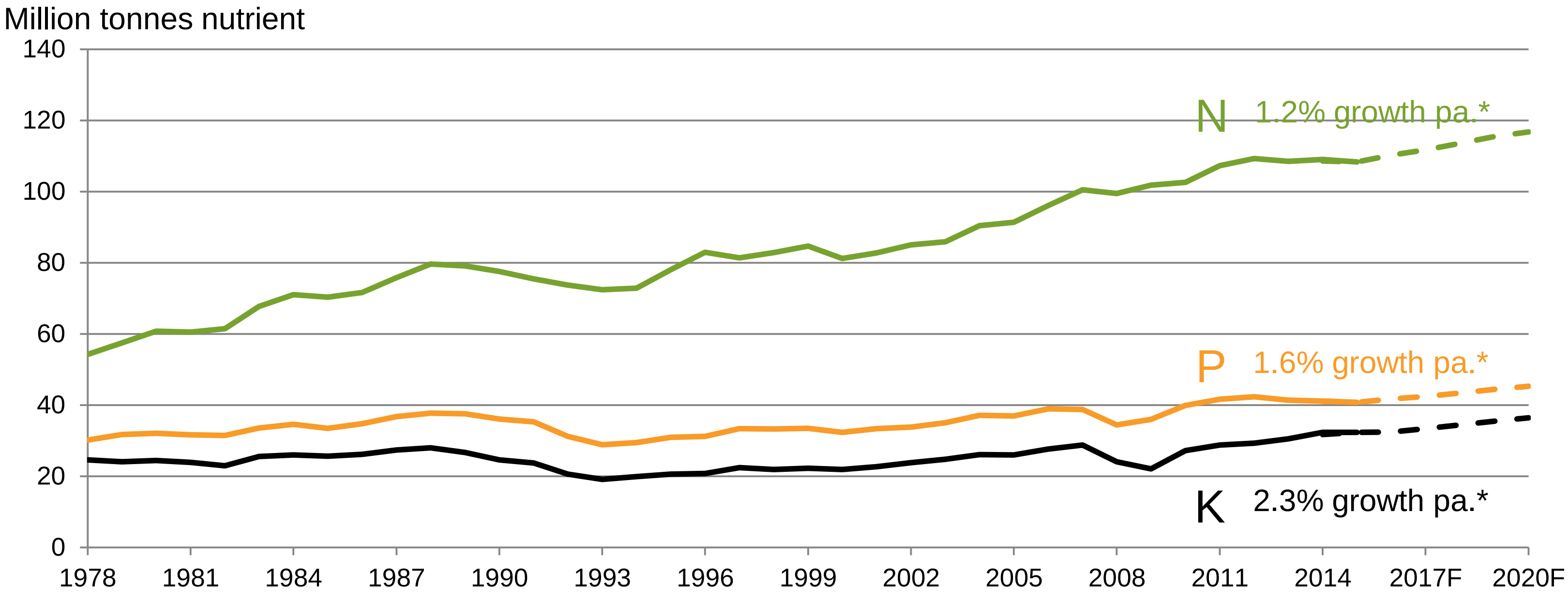
Carbon footprint of ammonium nitrate production by region



Source: Fertilizers Europe (2016) for production of granulated AN in 2014

The fertilizer industry

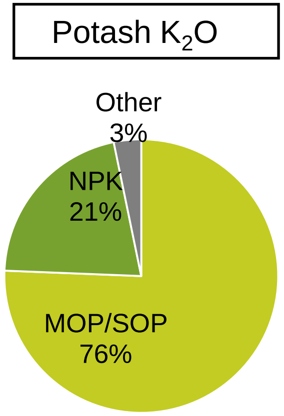
Consumption trend per nutrient



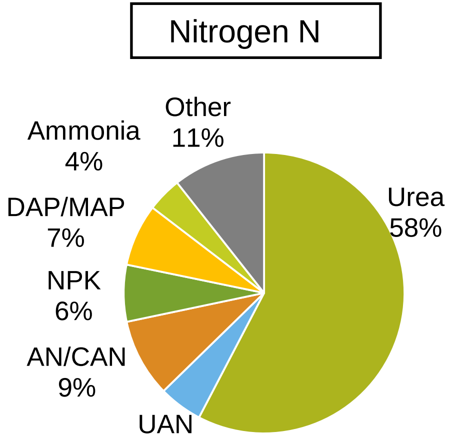
Source: IFA, June 2016

* CAGR avg. 2013-2015 to 2020

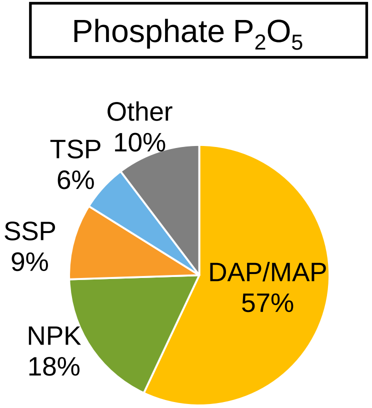
Key global fertilizer products



32 million tonnes



108 million tonnes*

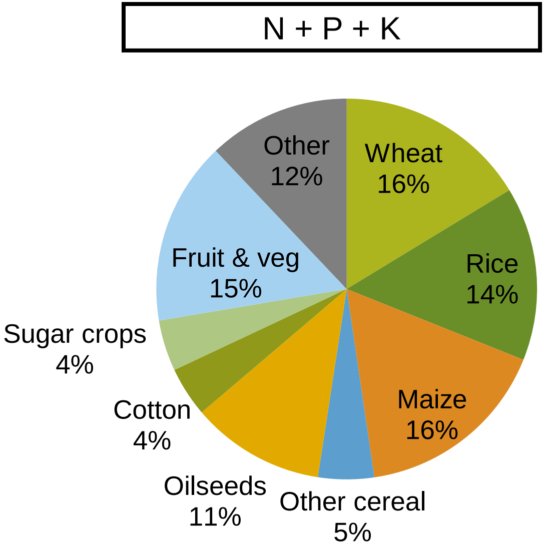


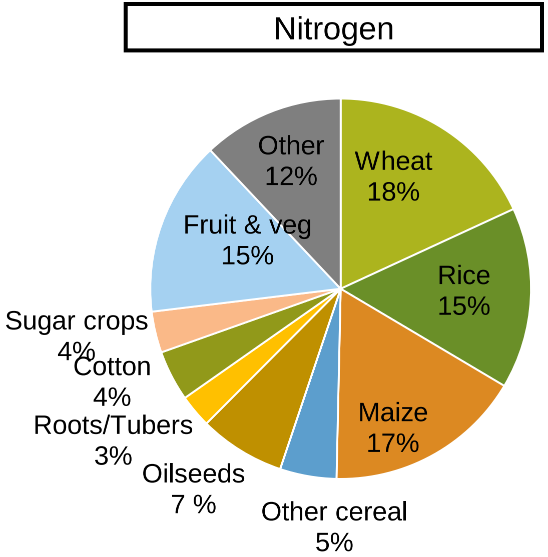
41 million tonnes

Source: IFA 2015 (nutrient totals) and 2014 (product split) * Does not include industrial nitrogen applications

Nutrient application by crop

By tonnes nutrient

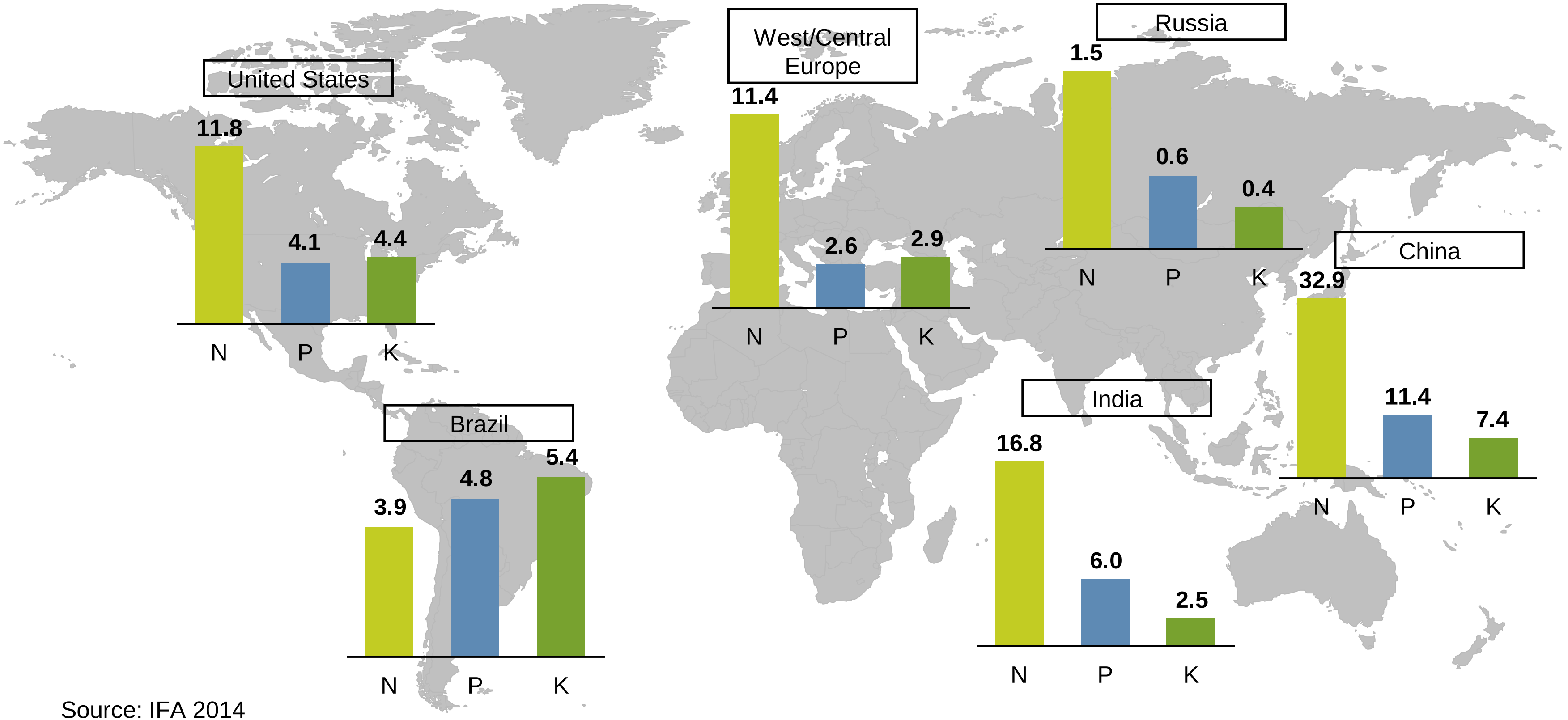




Source: IFA (2010/11)

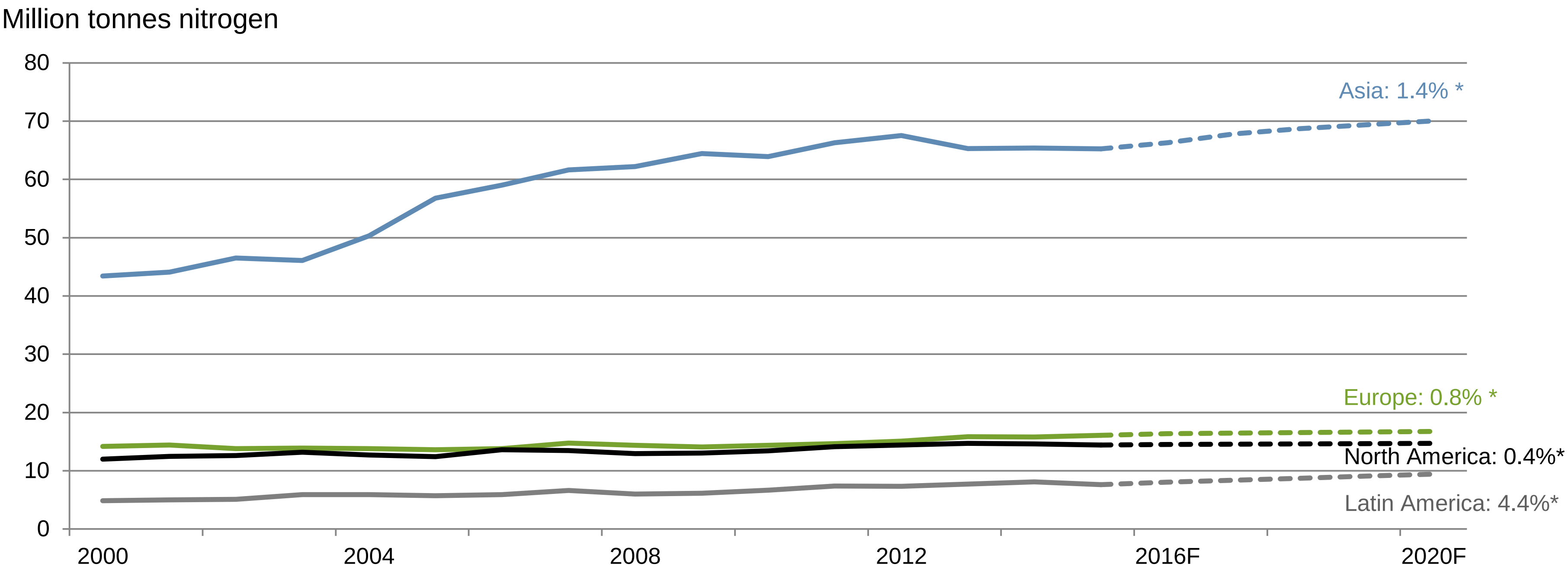
Fertilizer consumption by region – 5 key markets

Million tons nutrient consumption



Source: IFA 2014

Nitrogen consumption in key regions



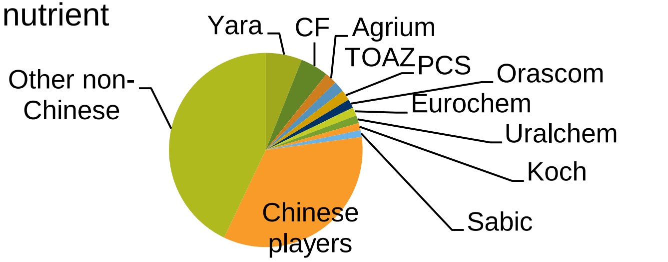
Source: IFA, June 2015

* CAGR 2015-2020

The N industry is fragmented, while the P and K industries are more concentrated

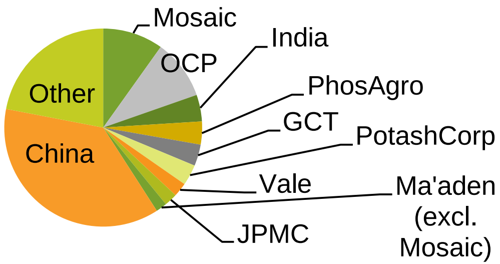
2015 figures[1], million tonnes nutrient

Nitrogen[1] (N)



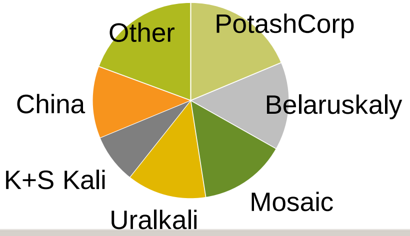
- Despite a consolidation trend, the industry is still higher fragmented
- Top 3 producers account for only ~15% of world capacity

Phosphate (P)



- More concentrated than N-industry
- Top 3 producers account for ~24% of capacity

Potash (K)

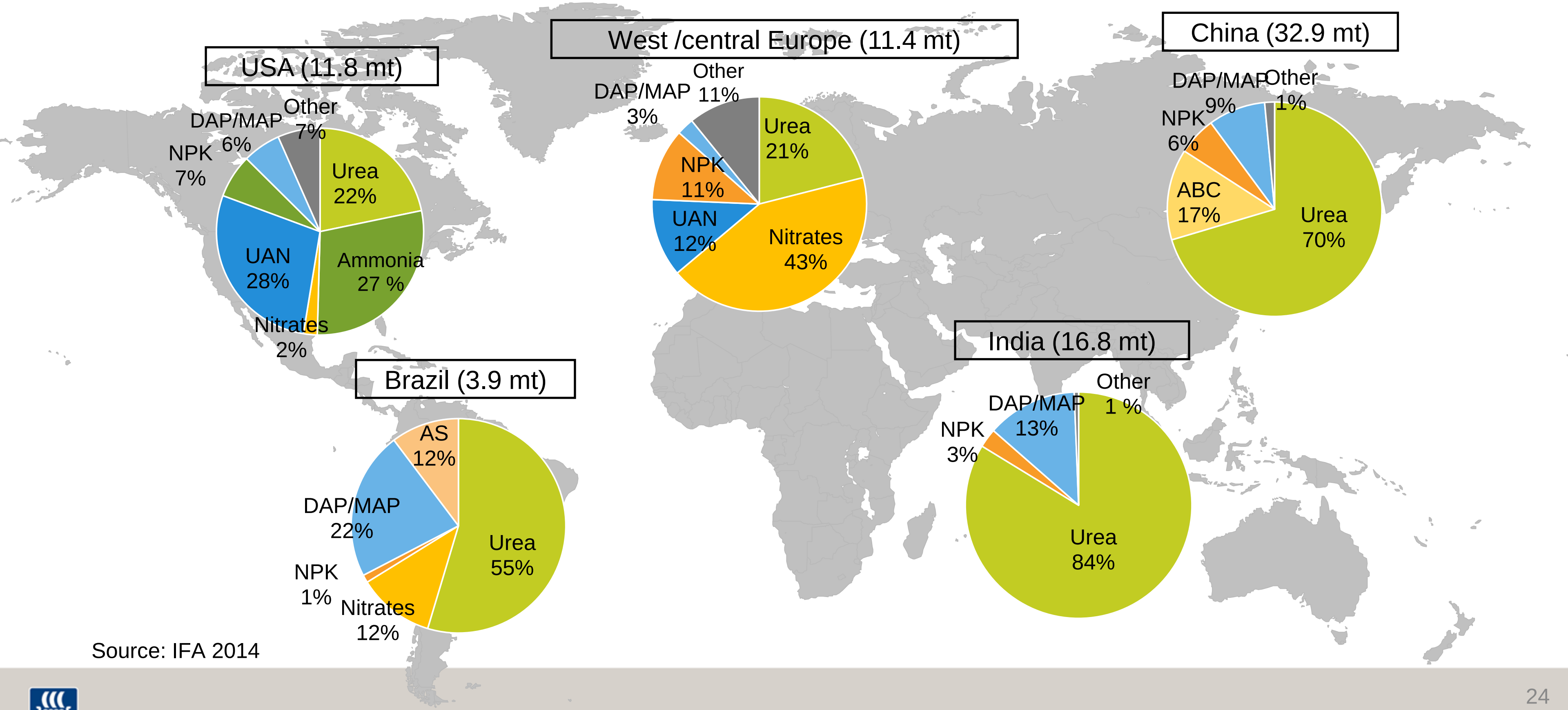


- Highly concentrated industry
- Top 3 producers account for ~48% of capacity

1) Nitrogen: 2013 figures

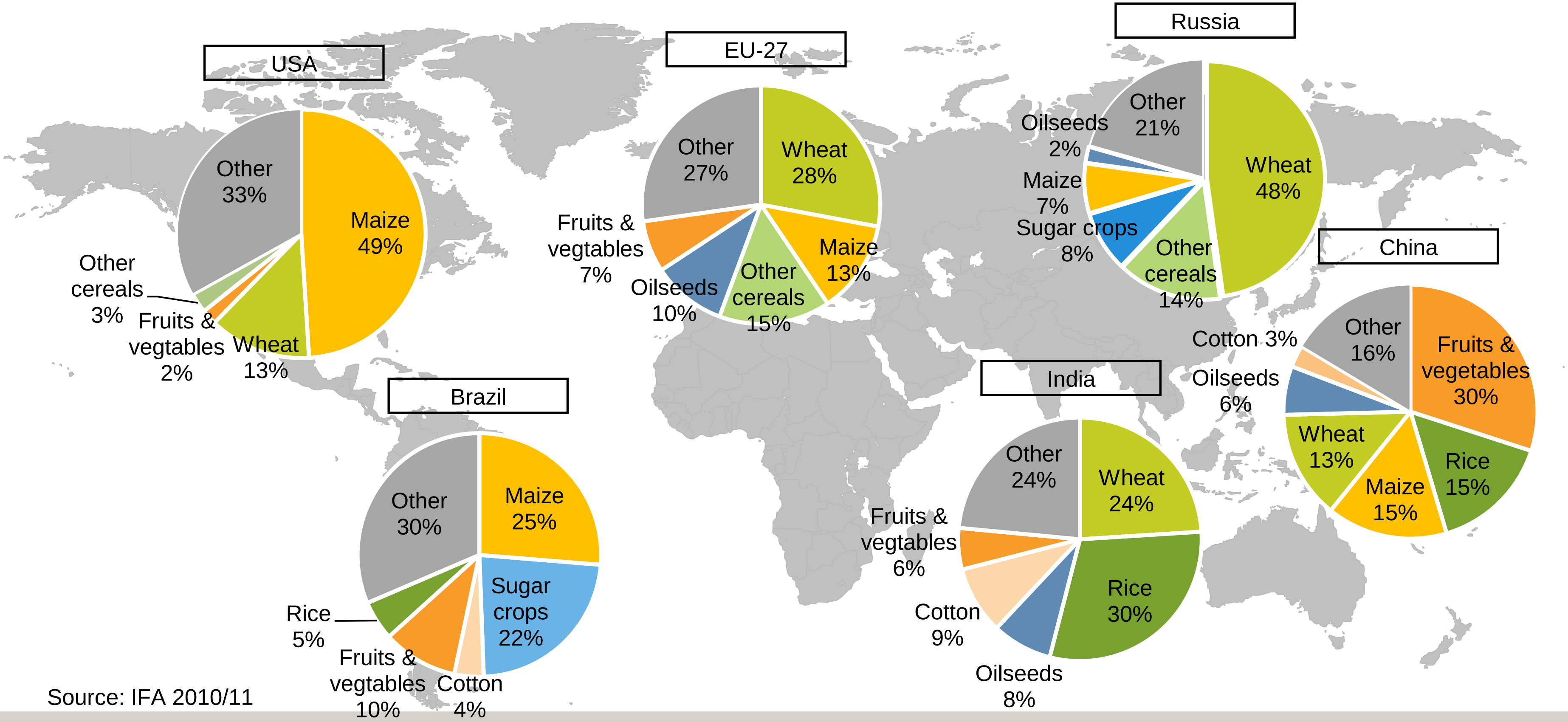
Source: IFA

Nitrogen fertilizer application by region and product



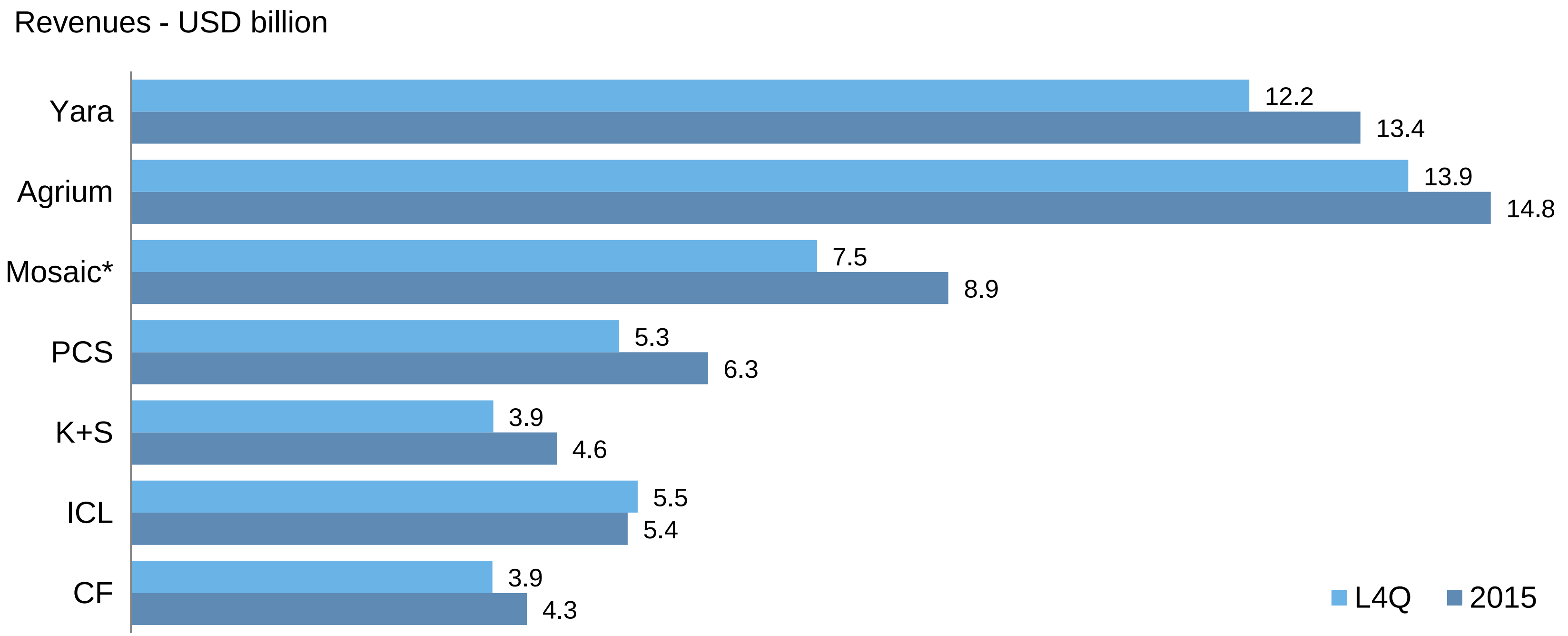
Source: IFA 2014

Nitrogen fertilizer application by region and crop



Source: IFA 2010/11

Fertilizer company comparison

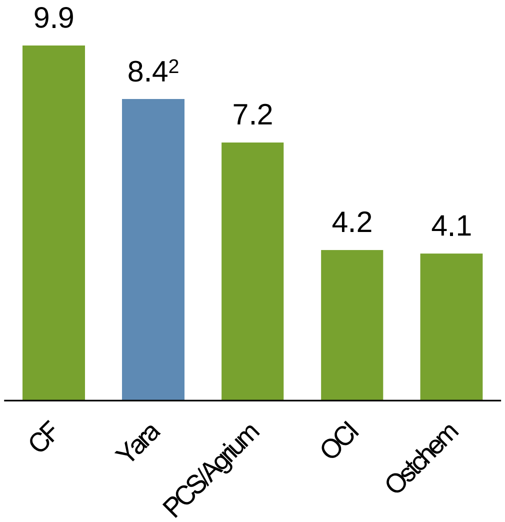


Source: Thomson Worldscope

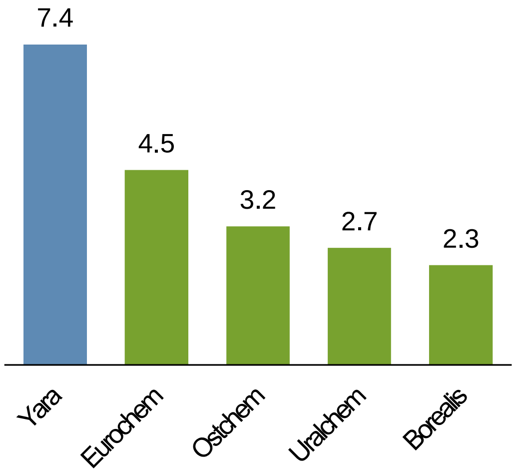
Yara – the leading nitrogen fertilizer company

2016 production capacity, excl. Chinese producers[1] (mill. tonnes)

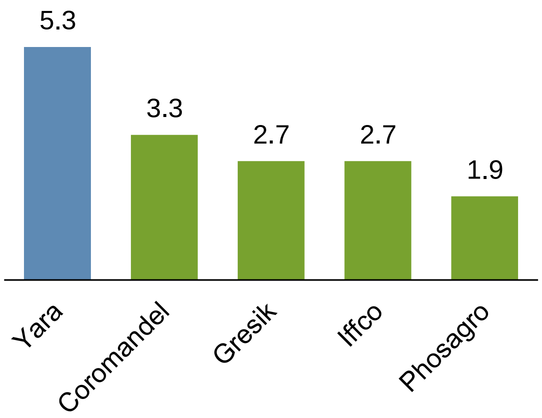
Global no 2 in ammonia



Global no 1 in nitrates



Global no 1 in NPK



1) Incl. companies' shares of JVs
2) As of end 2016

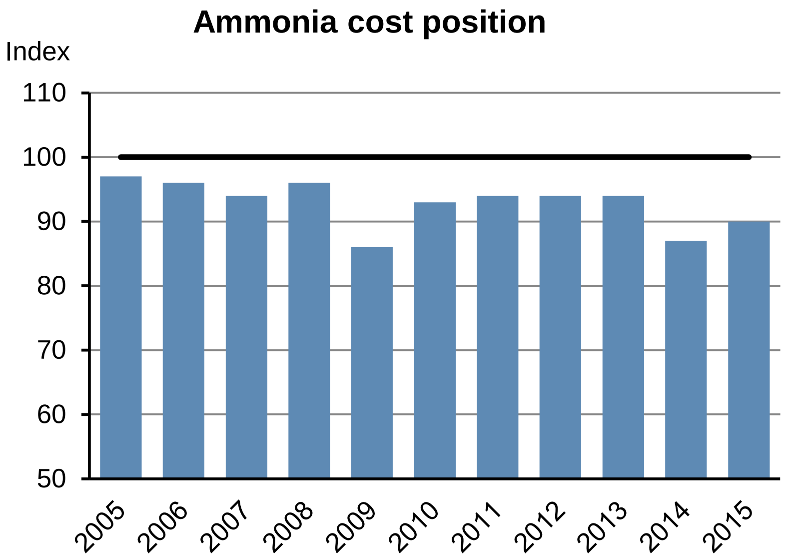
* Incl. TAN and CN

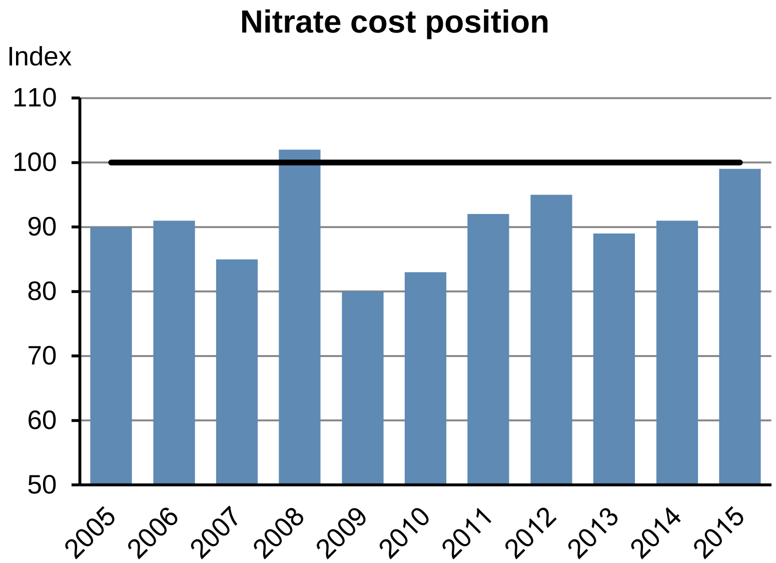
* Compound NPK, excl. blends

Source: Yara estimates, company info

Yara – the European cost leader

Production cost index: 100 = European industry average excl. Yara





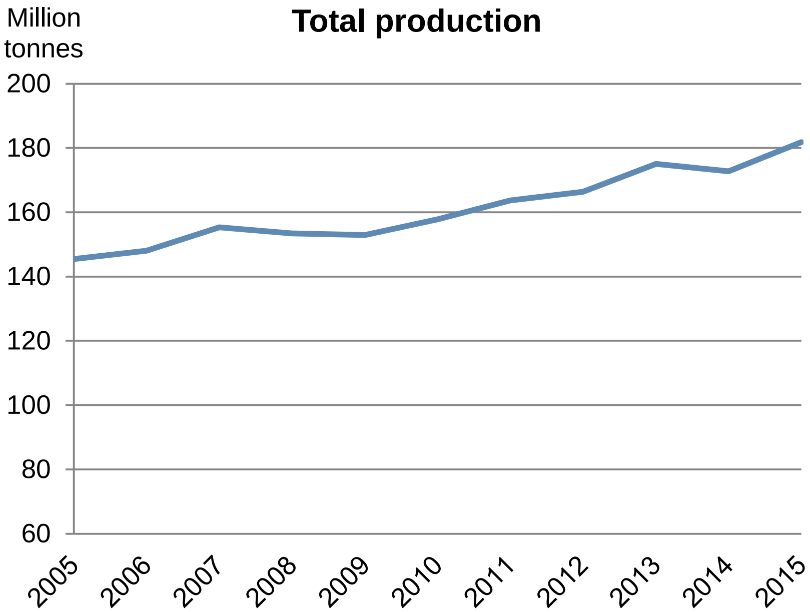
Average cost Yara's European plants

European average (excl. Yara)

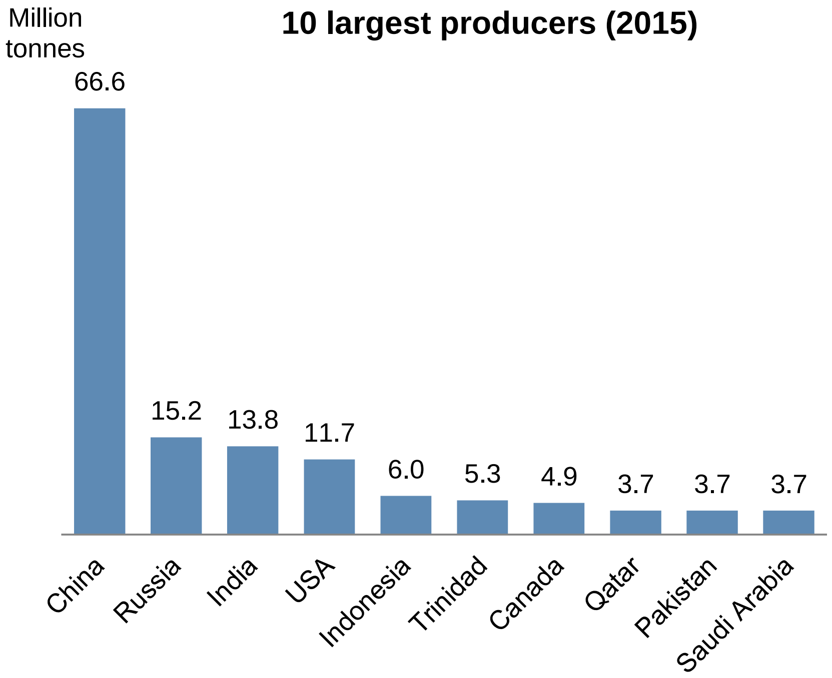
Source: Fertilizer Europe

Ammonia

Global ammonia production

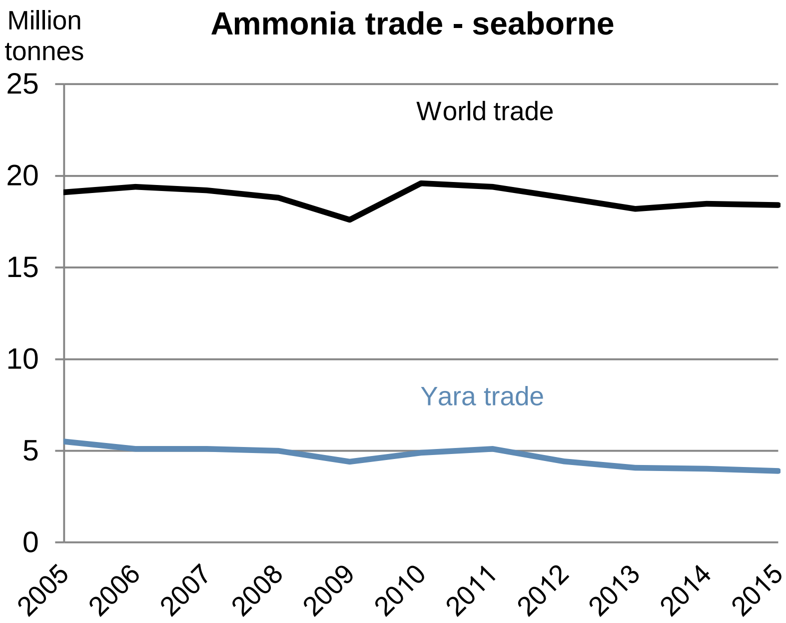


2005-2015 trend growth rate = 2.2%/year

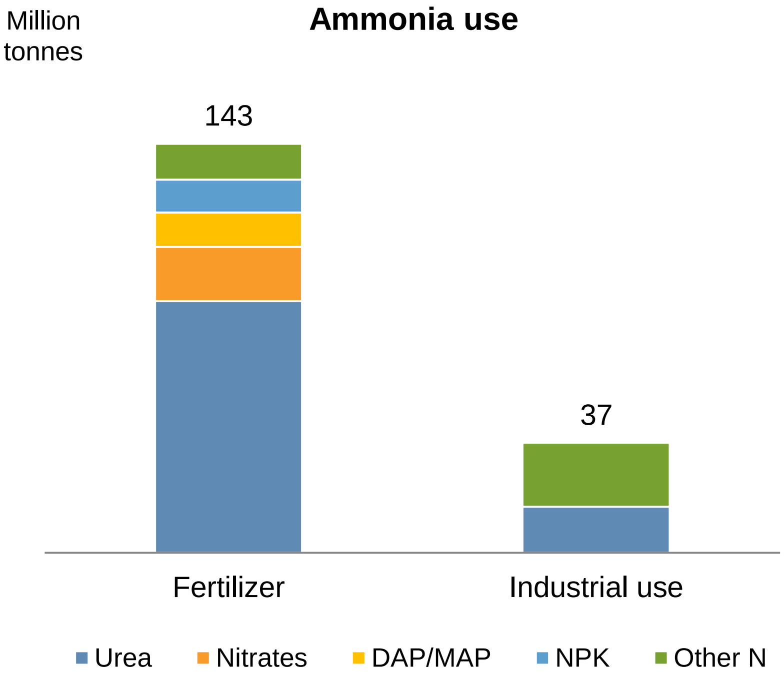


Source: IFA

Most of global ammonia production is upgraded to urea and other finished fertilizer

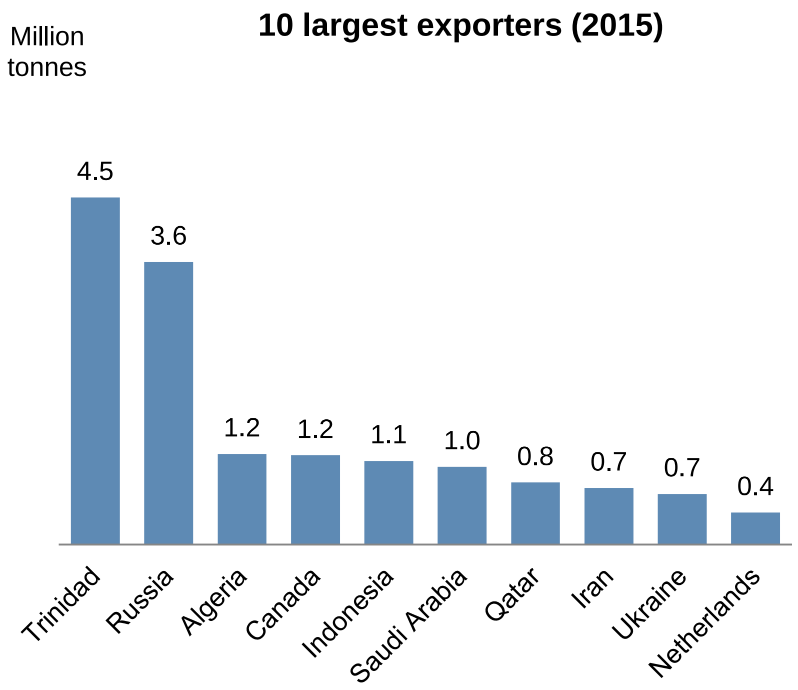


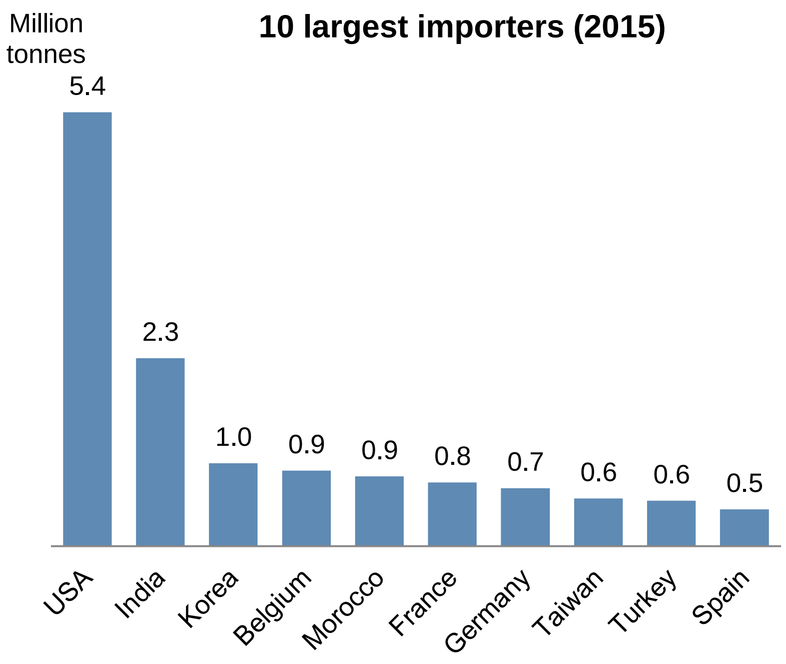
Source: Yara, IFA



Source: Fertecon

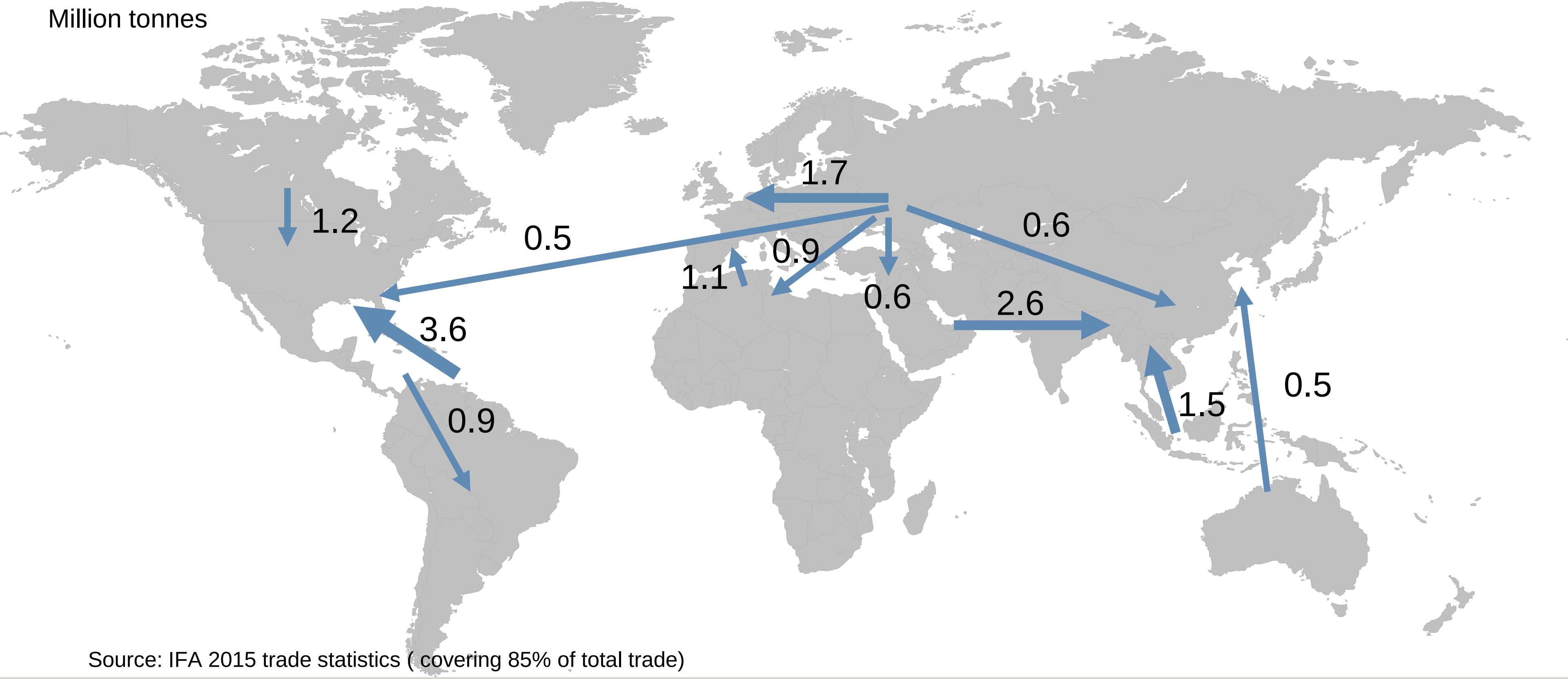
Global ammonia trade





Source: IFA

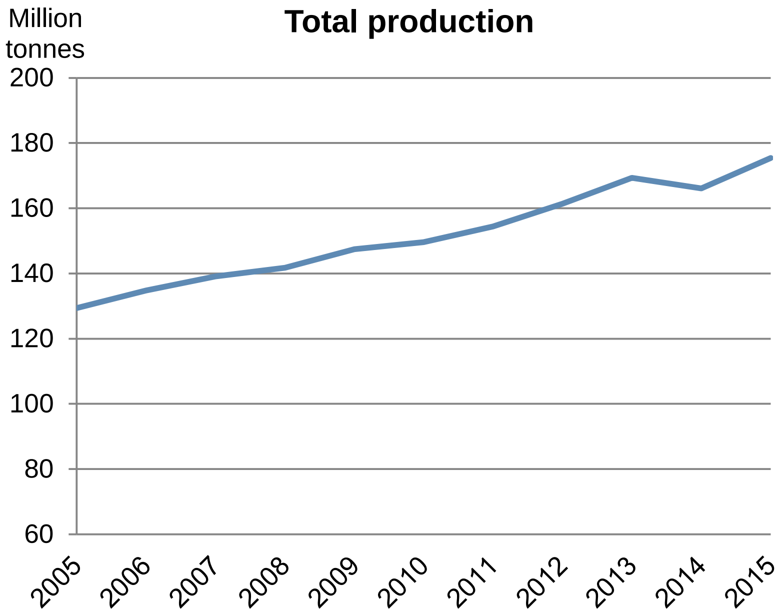
Main ammonia trade flows (2015)



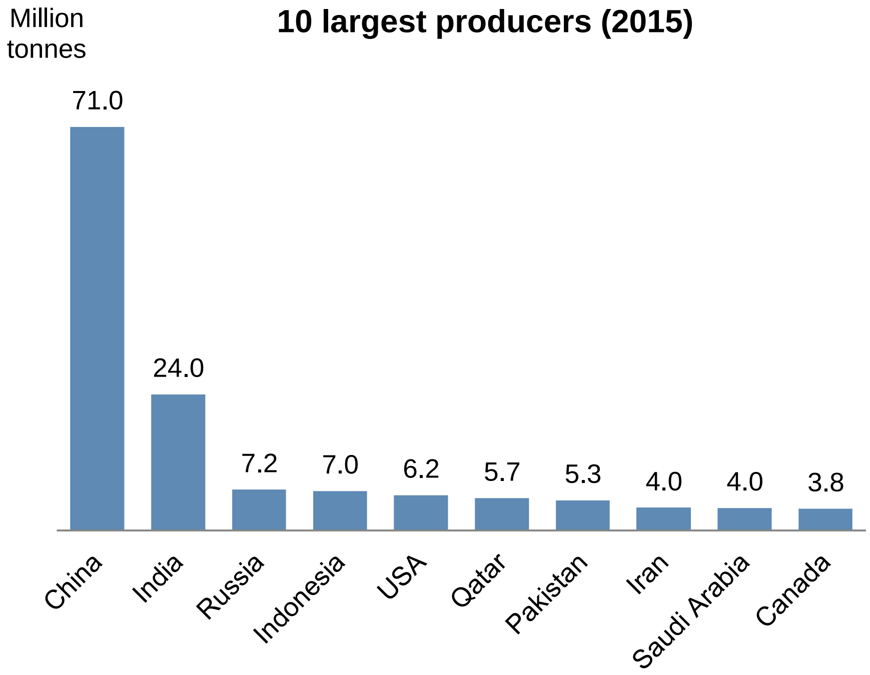
Source: IFA 2015 trade statistics (covering 85% of total trade)

Urea

Global urea production

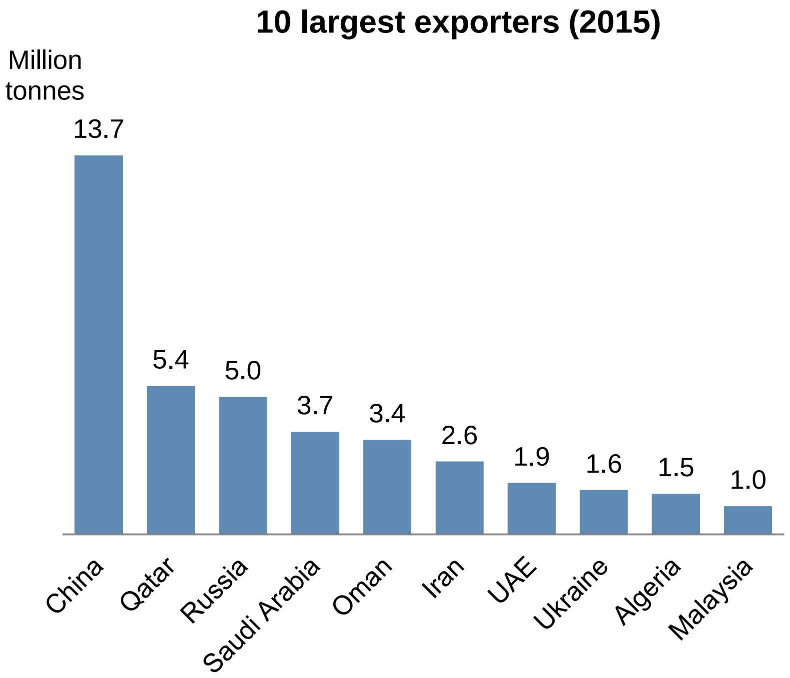


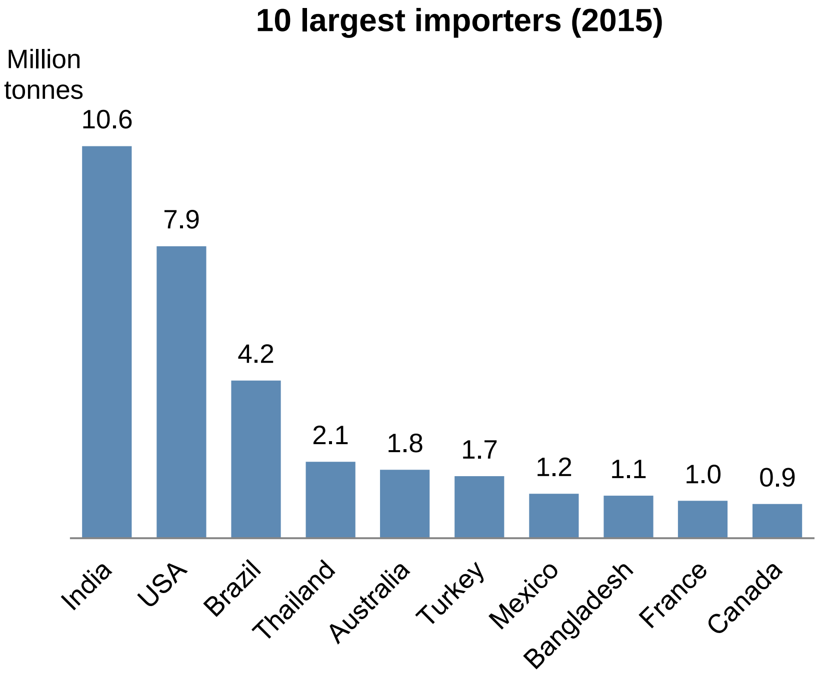
2005-2015 trend growth rate = 3.1% p.a.



Source: IFA

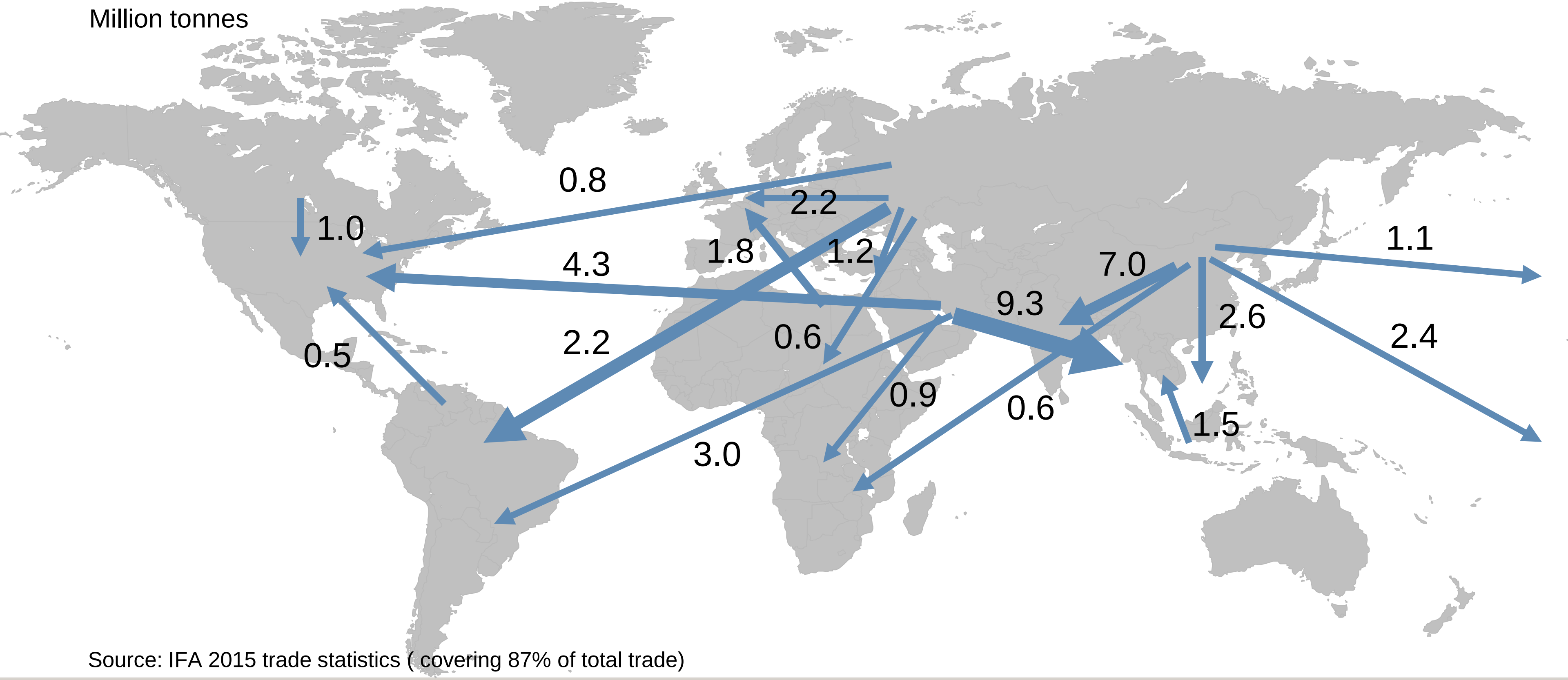
Global urea trade





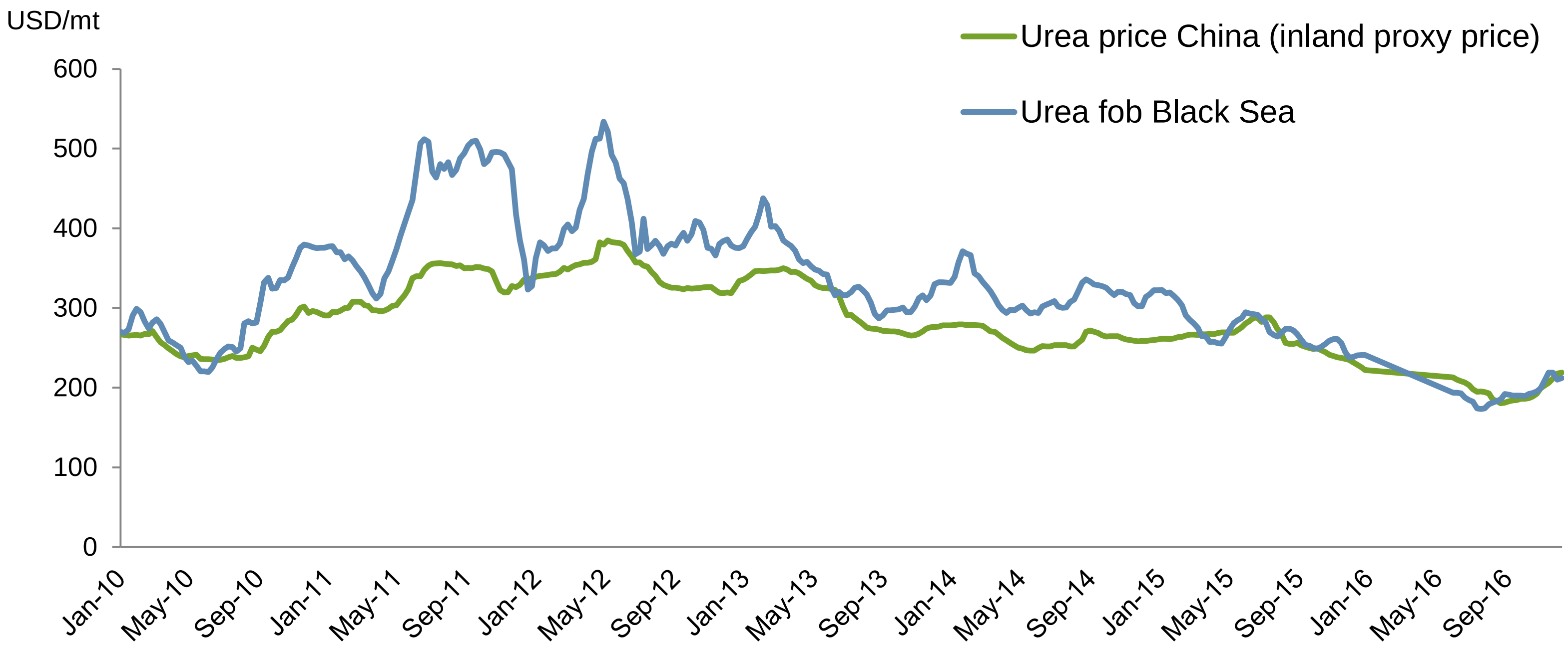
Source: IFA

Main urea trade flows (2015)



Source: IFA 2015 trade statistics (covering 87% of total trade)

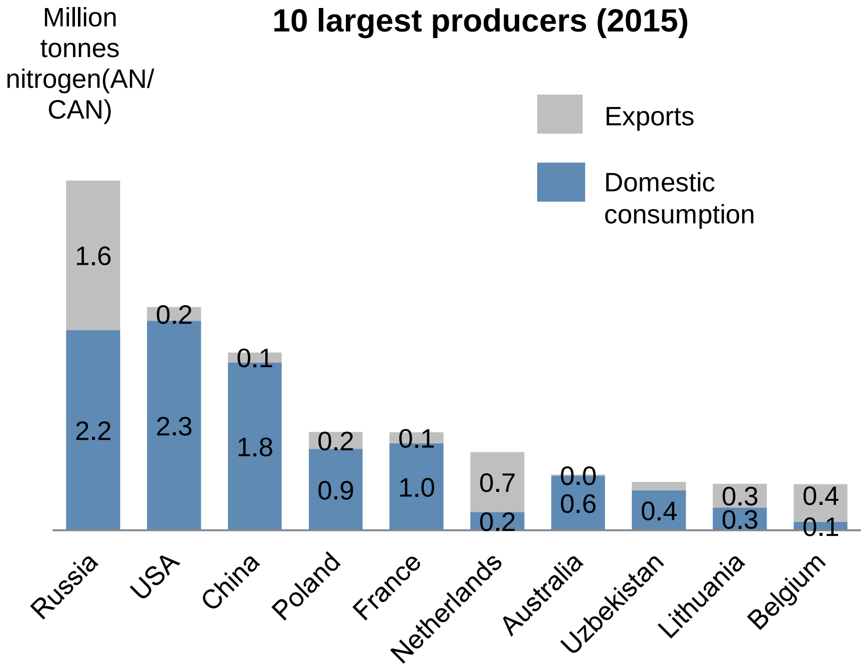
Chinese domestic urea price and export tax set the global floor price



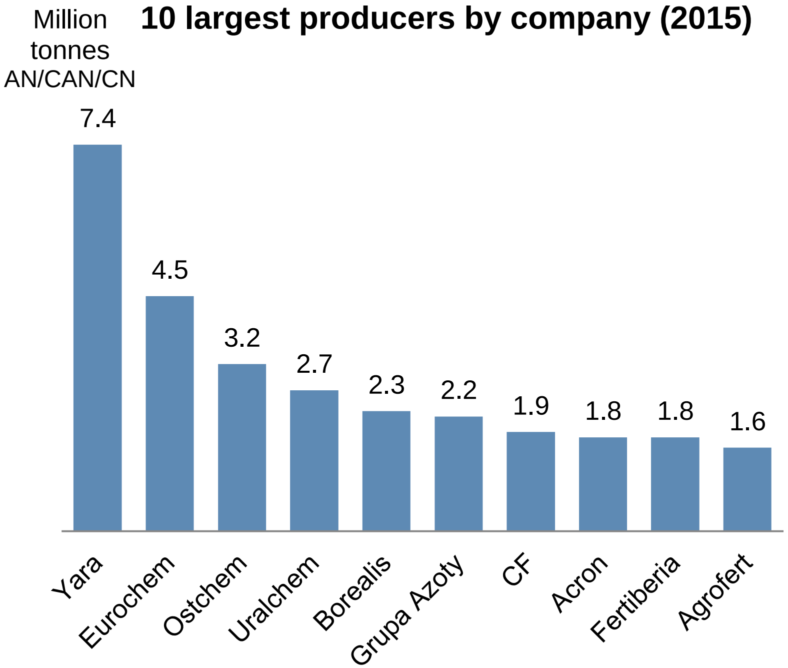
Source: China Fertilizer Market Week, International publications

Nitrates

Nitrate production



Source: IFA, AN/CAN including nitrate part of UAN, as are industrial grades



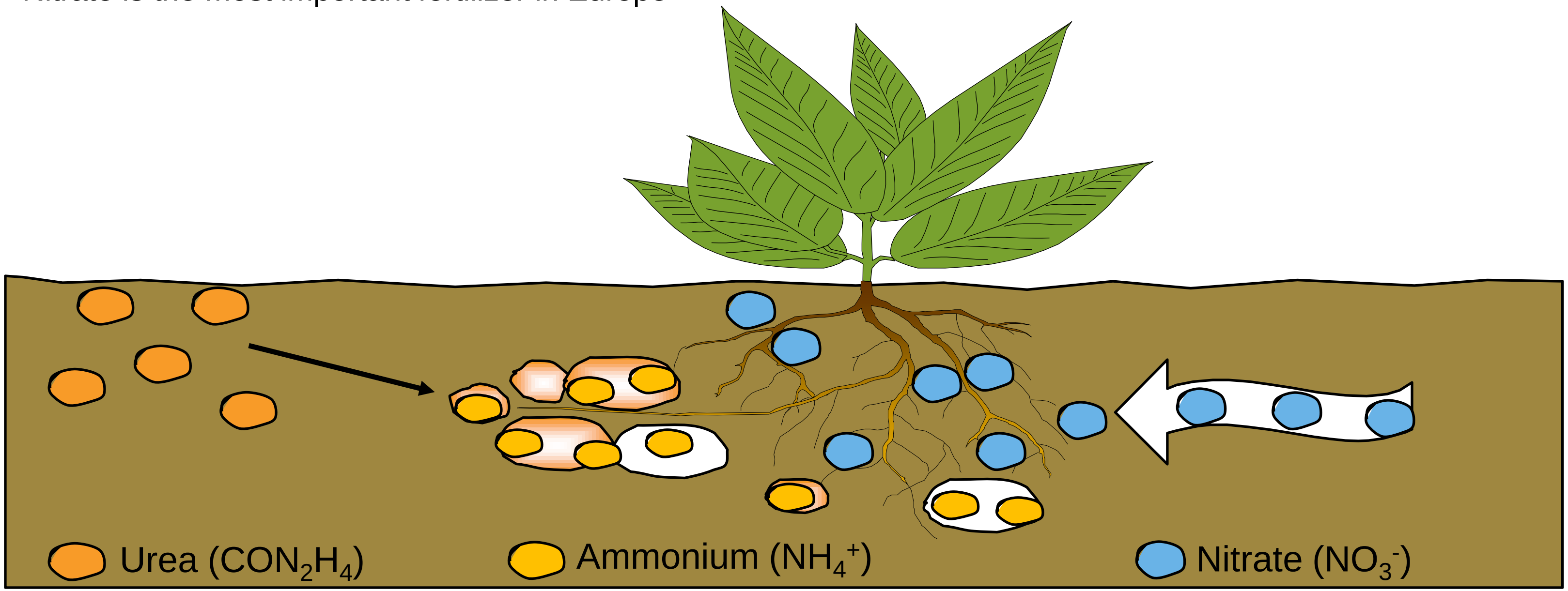
Source: Yara estimates, company info

Nitrates are products with a nitrate content of 50 % or more

N fertilizer	N content	Nitrate (% of total N)	Other nutrients
CAN (calcium ammonium nitrate)	27%	50%	4% MgO
AN (ammonium nitrate)	34%	50%	
NPK	various	about 50%	P & K
CN (calcium nitrate)	15.5%	93%	19% Ca
Urea	46%	0%	
UAN (liquid urea ammonium nitrate)	28%	25%	
ASN (ammonium sulfate nitrate)	26%	25%	13% S
AS (ammonium sulfate)	21%	0%	24% S

Nitrates vs. urea

Nitrate is the most important fertilizer in Europe



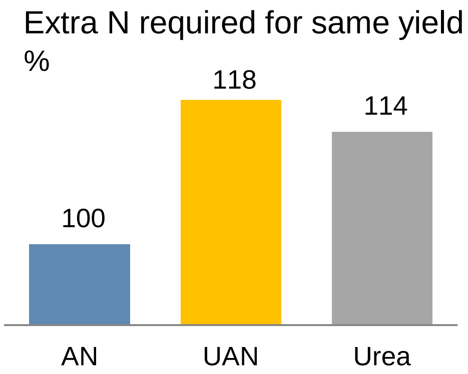
Urea-N needs to be converted into ammonium-N before it is plant available.

Ammonium-N is fixed onto clay minerals in the soil and therefore immobile. The plant roots have to grow actively towards the nutrient.

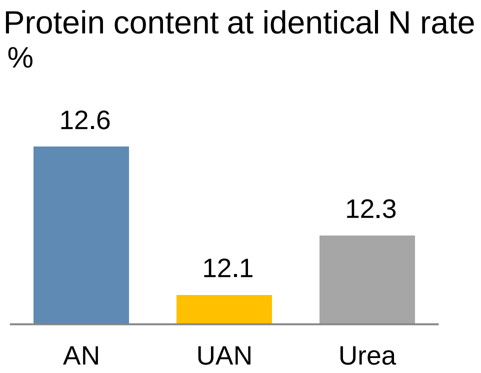
Nitrate-N is always dissolved in the soil water and is transported passively together with the water into the plant root. Thus, nitrate is rapidly effective.

Urea and UAN underperformance compared with ammonium nitrate

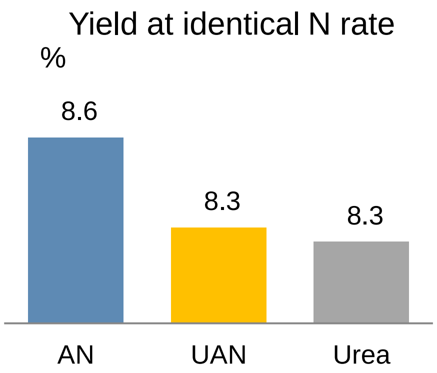
Trial results for arable crops (cereals, UK**)**



To maintain the same yield, significantly more nitrogen was needed from urea and UAN than from ammonium nitrate



Protein content was significantly lower on fields fertilized with urea or UAN than with ammonium nitrate



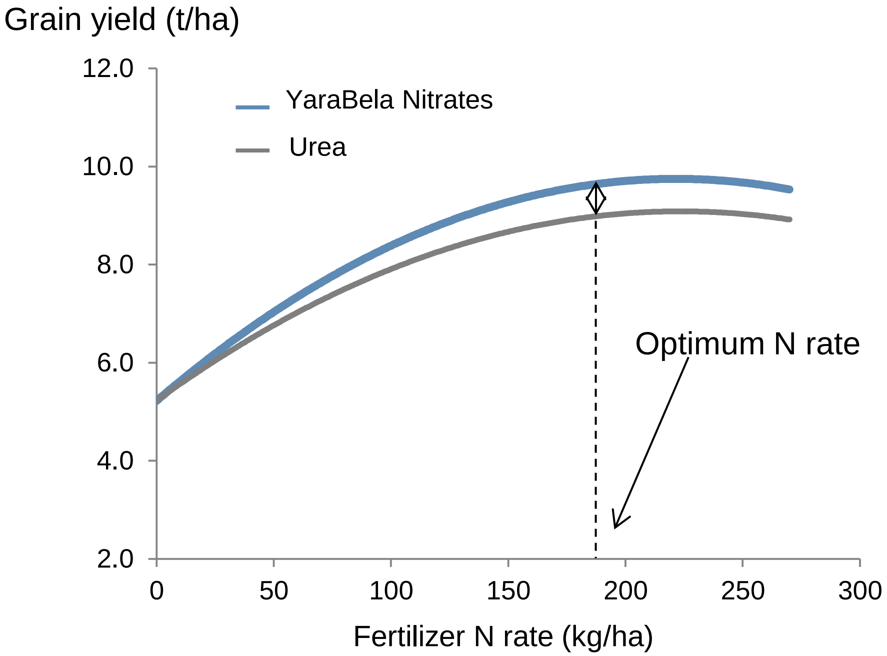
Yield was also significantly lower with urea and UAN than with ammonium nitrate

Source: DEFRA

Yield advantage of nitrates in tropical climate

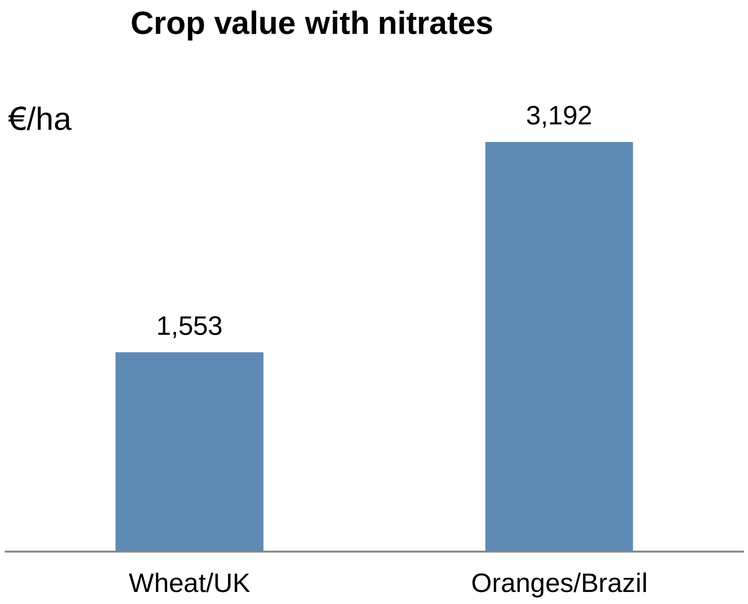
Brazil, main season corn

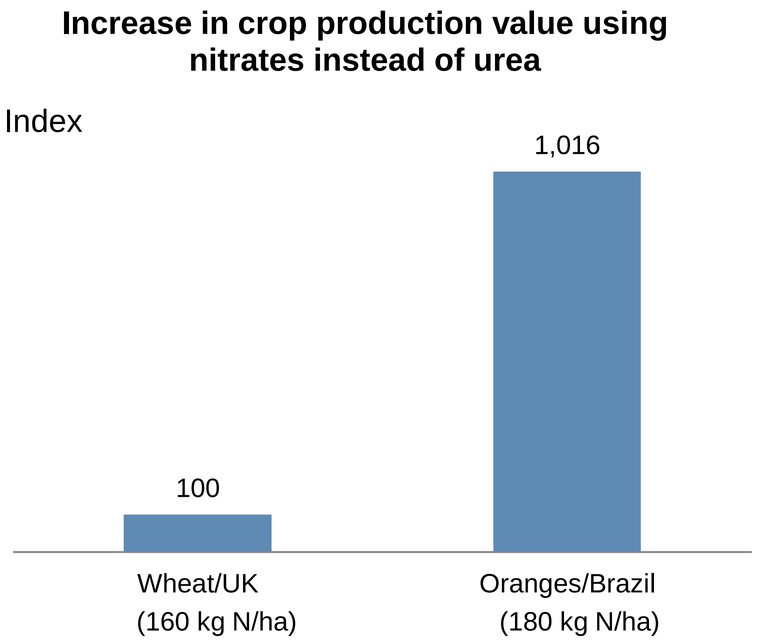
- Research shows that the benefits of nitrates are even more pronounced in the tropics than in colder climates
- YaraBela nitrate provides direct and efficient uptake of nitrate-N
- Consistently lower NH_3 volatilization losses
- Reduced acidification in the root zone, supporting root growth and nutrient uptake



Source: Fundation Bahia (2013)

Nitrates' agronomic advantage has higher value for cash crops than for commodity crops





NPKs

Compound NPKs contain all nutrients in one particle

Compound NPKs

All nutrients in each and every particle

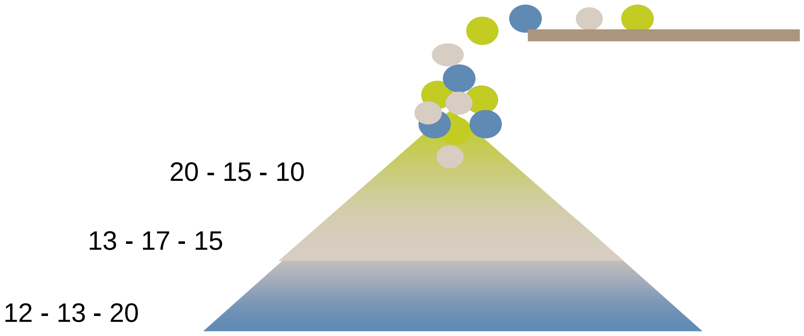
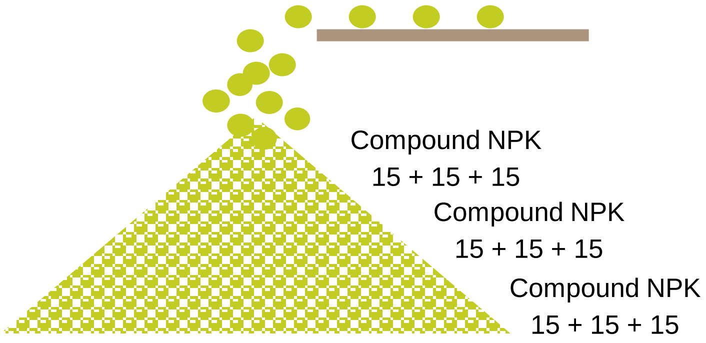
Even spreading of all nutrients

NPK bulk blends

A mix of products with different spreading properties

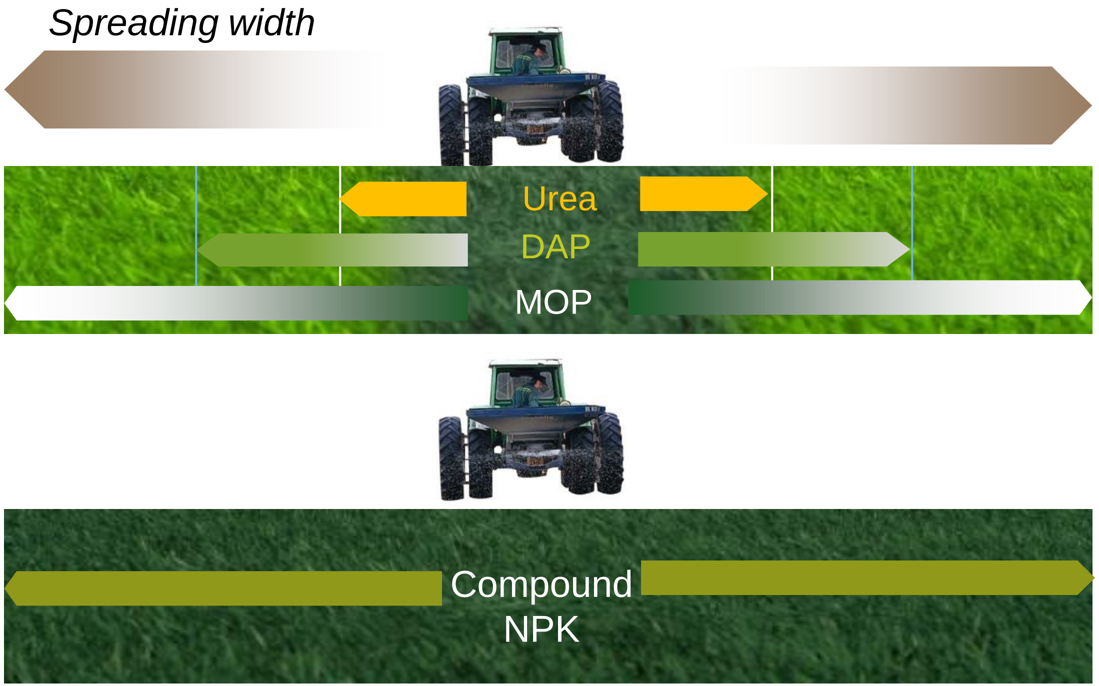
Risk of segregation and uneven spreading

Bulk blend segregation during loading and unloading

Urea + DAP + MOP **15-15-15**	**Compound NPK** **15-15-15**
 N – P_2O_5 – K_2O analysis in a pile of poor quality blend	 N – P_2O_5 – K_2O analysis in a pile of compound NPK 15-15-15

Segregation due to differences in specific weight and granule size

Better spreading with compound NPKs



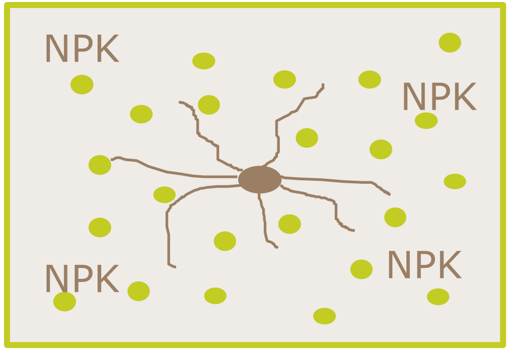
- Spreading width of light particles like Urea is less than those of heavier particles like DAP and MOP

Poor spreading patterns cause striped fields and significant yield losses

Compound NPKs give and excellent spatial distribution of nutrients and as a result higher crop yields

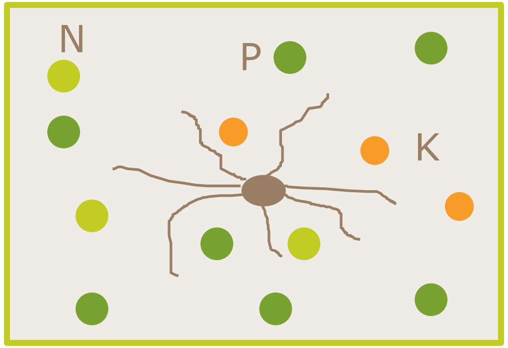
Compound NPKs
16+16+16

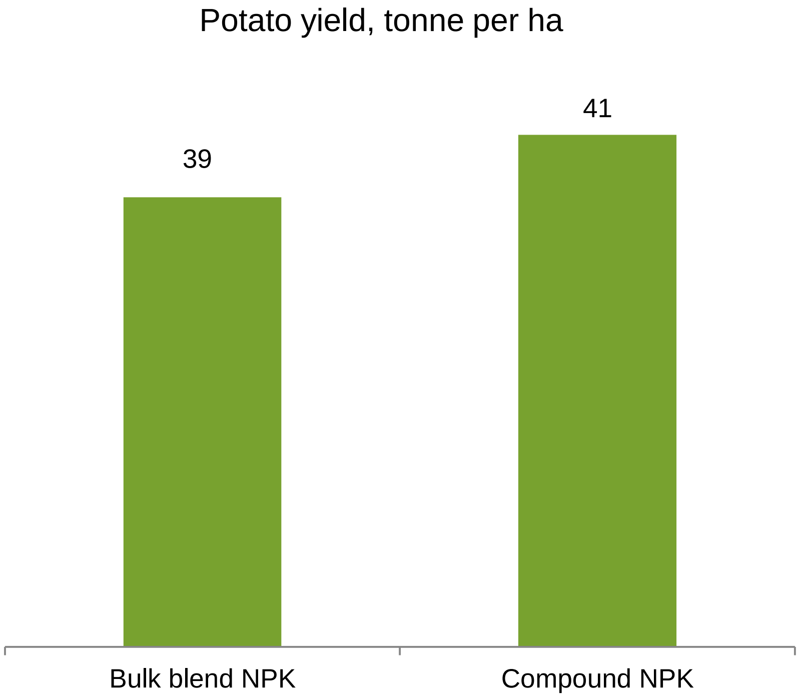
more particles and better distribution



Bulk blend
Urea-DAP-MOP

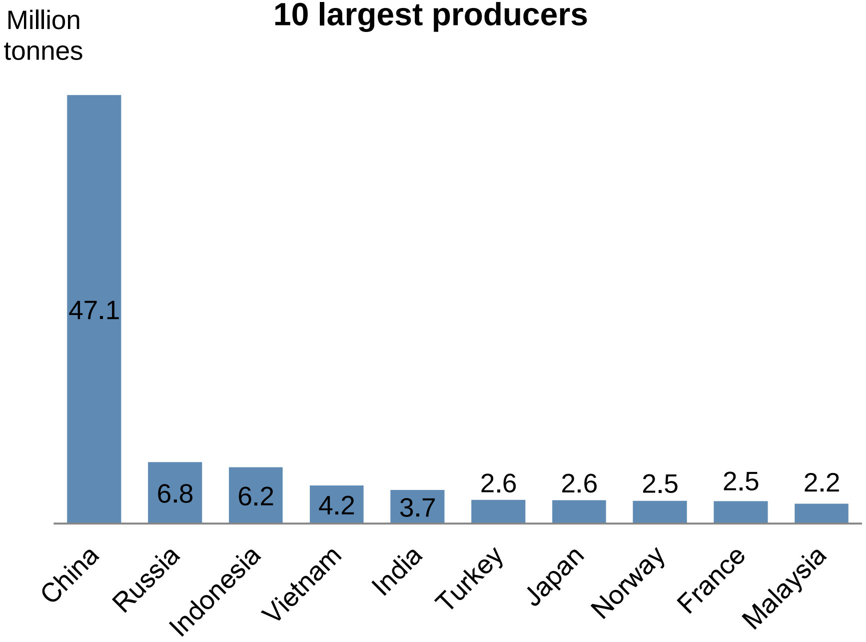
fewer particles, longer distance to roots



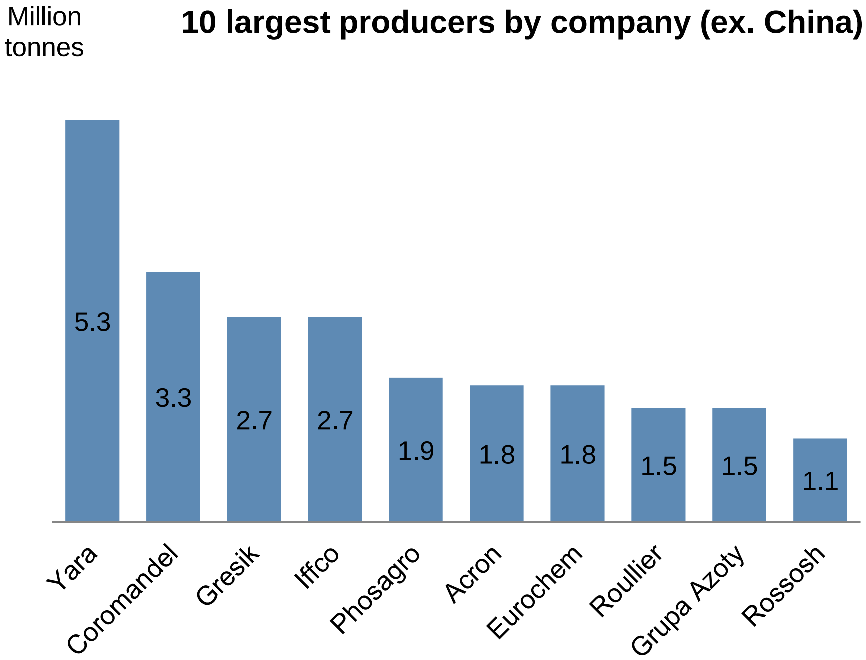


Source: Yara field trials

Compound NPK capacities



Source: IFA 2013/2014

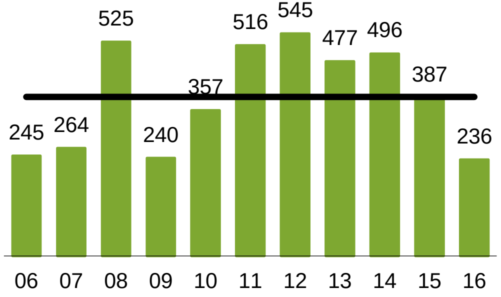


Source: Yara estimates, company info

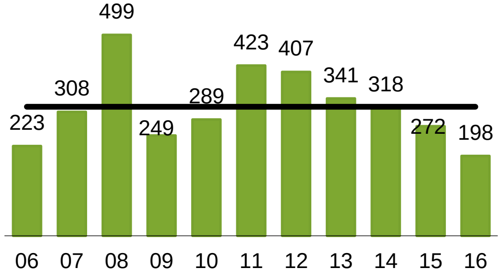
Industry value drivers

Key value drivers

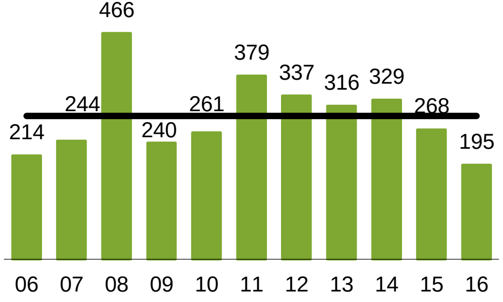
Ammonia fob Black Sea (USD/t)



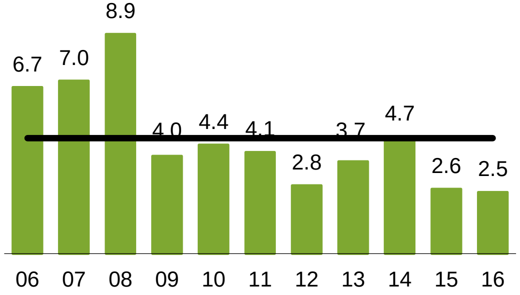
Urea prilled fob Black Sea (USD/t)



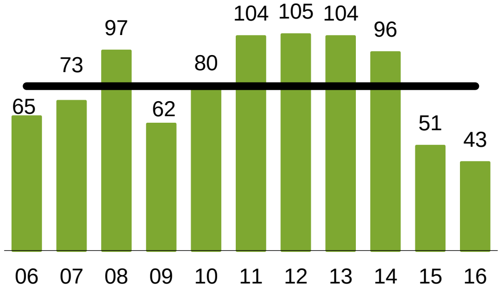
CAN cif Germany (USD/t)



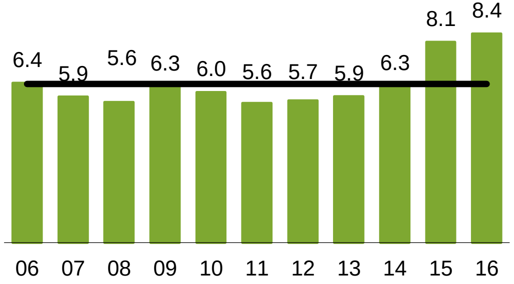
Henry Hub (USD/MMBtu)



Oil Brent blend spot (USD/bbl)



NOK/USD exchange rate



Source: The Market, Fertecon, CERA, World Bank, Norges Bank

Average 2006 – 2016

Nitrogen fertilizer value drivers

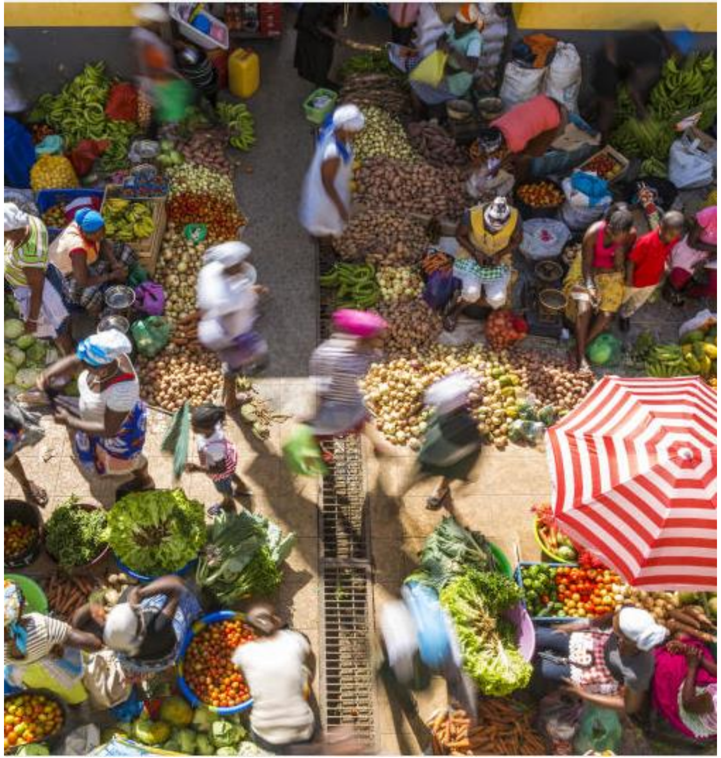
	Drivers		Effect on
Revenue drivers	Chinese coal prices	→	Supply-driven price for urea
	Grain inventories/prices	→	Urea demand
	New urea capacity vs. closures	→	Urea supply
	Global urea demand vs. supply	→	Urea price (above floor)
	Urea price	→	Most other nitrogen fertilizer prices
	Cash crop prices	→	Value-added fertilizer premiums
Cost drivers	Oil product prices and LNG capacity expansion	→	Gas cost in Europe
	Manning and maintenance	→	Fixed cost
	Productivity and economies of scale	→	Unit cost

Drivers of demand

Drivers of fertilizer consumption growth

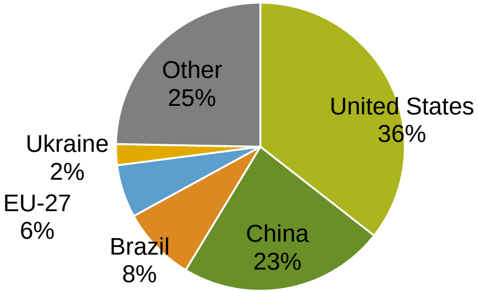
- Food demand drives fertilizer consumption
  - Population growth of about 80 million each year
  - Economic growth change diets
    - Higher meat consumption in developing countries
    - More protein-rich diets
    - More fruit and vegetables
    - Reduce hunger
  - Biofuels

- Industrial consumption
  - Economic growth
  - Environmental limits (e.g. reduction of NOx emissions)

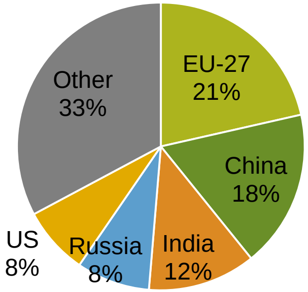


Key crops by producing by region

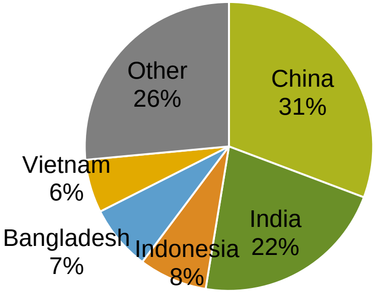
Maize-global production 975 mt



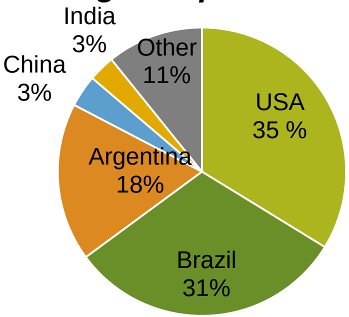
Wheat-global production 733 mt



Rice-global production 473 mt



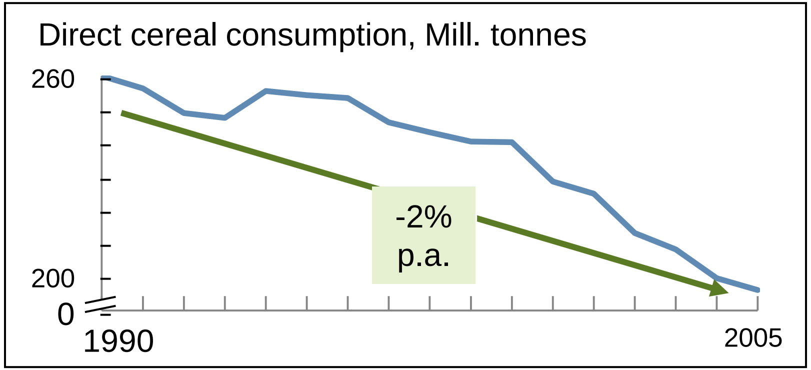
Soybeans-global production 321 mt

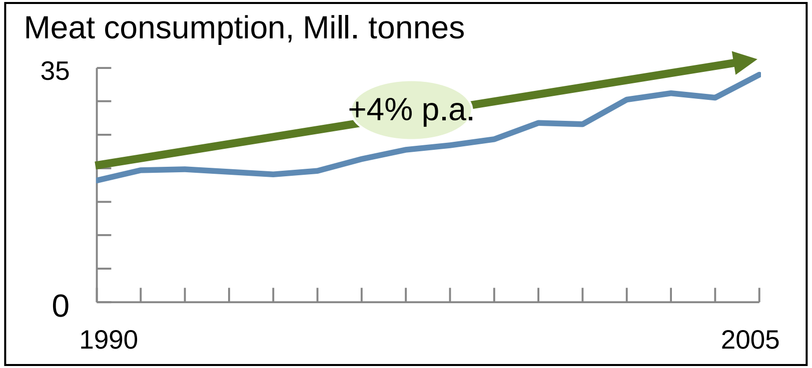


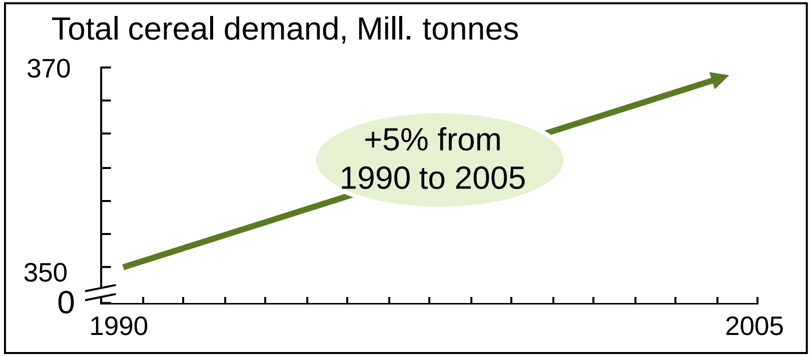
Source: USDA, 2015/16 season

Growing meat consumption increases demand for cereals

China example



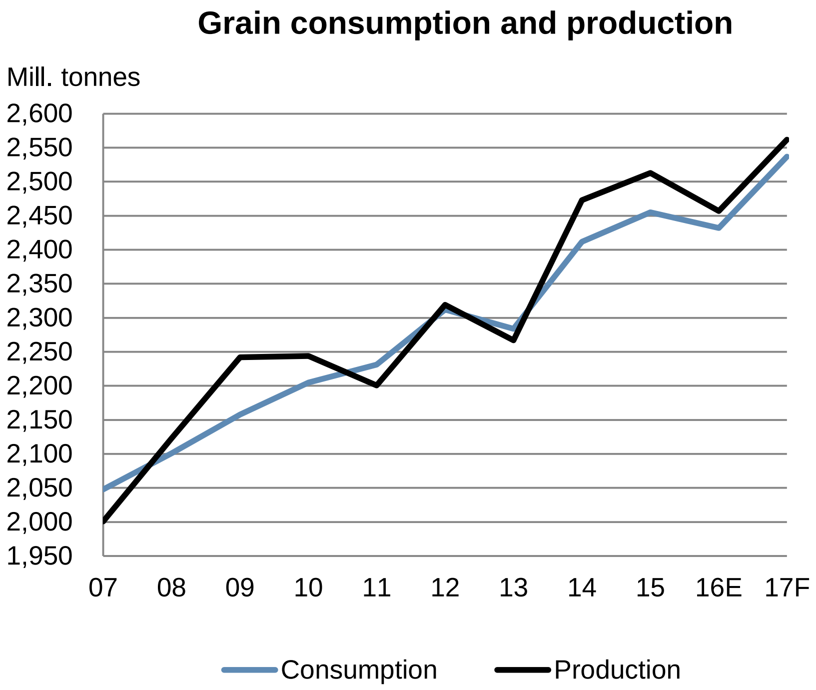


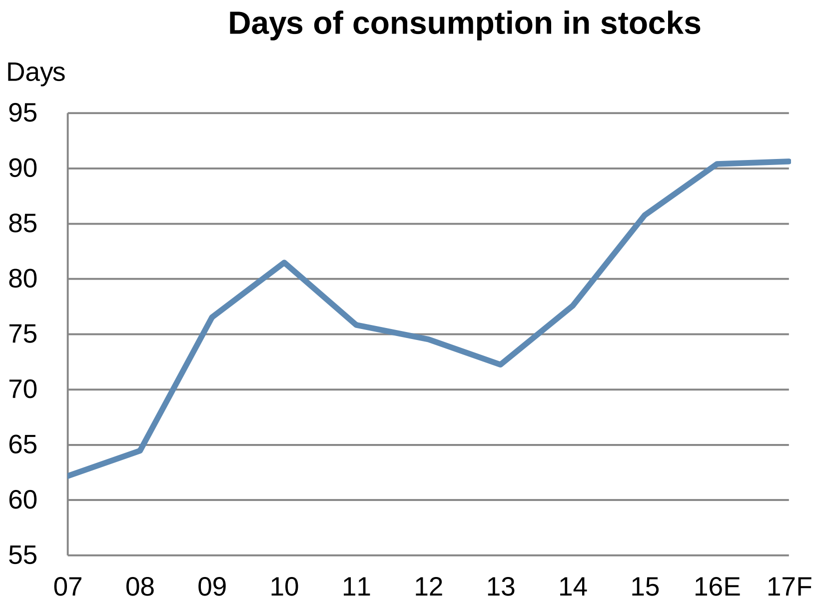


- The example of China illustrates that changing diets towards higher meat consumption increases overall demand for cereals
- Higher meat consumption requires more feed grain

Source: McKinsey

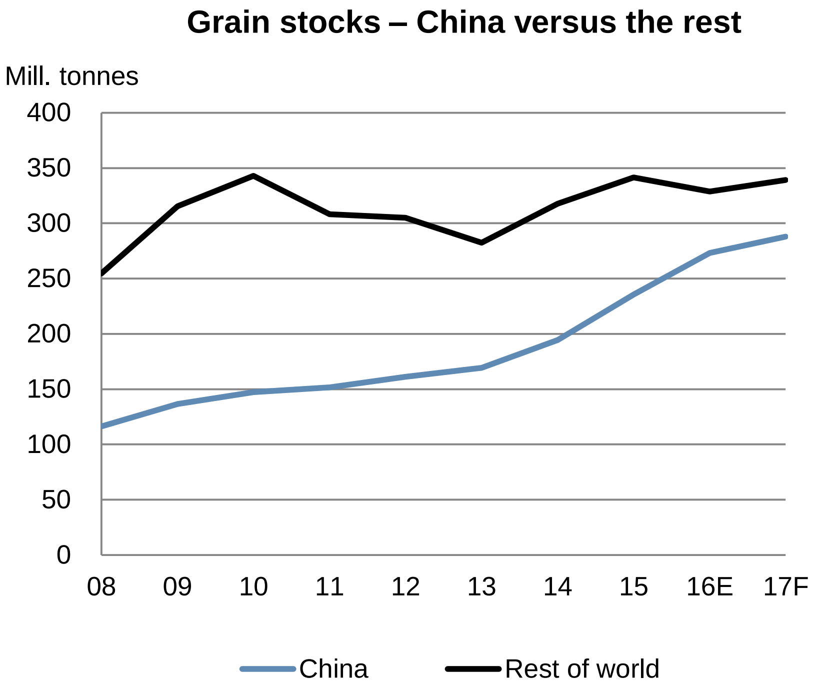
Steady growth in grain consumption, while production growth is more volatile due to weather variations

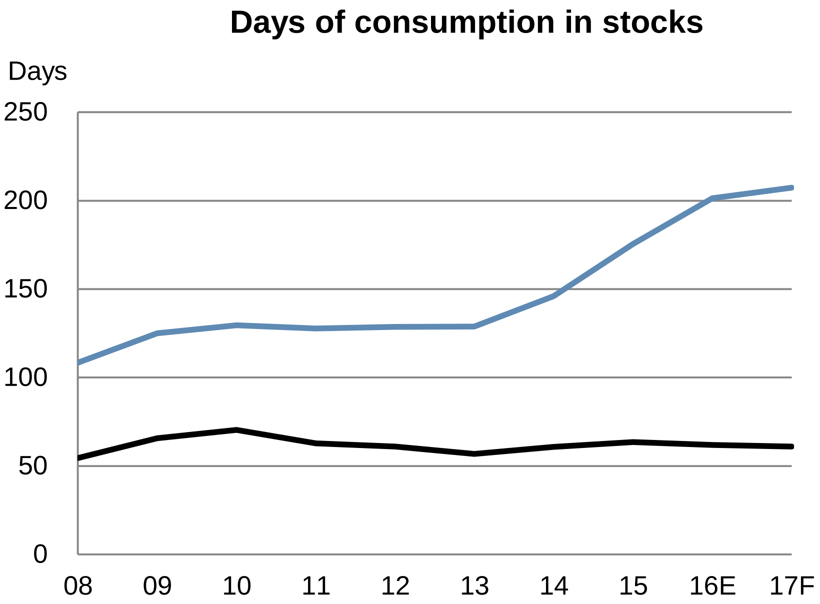




Source: USDA December 2016

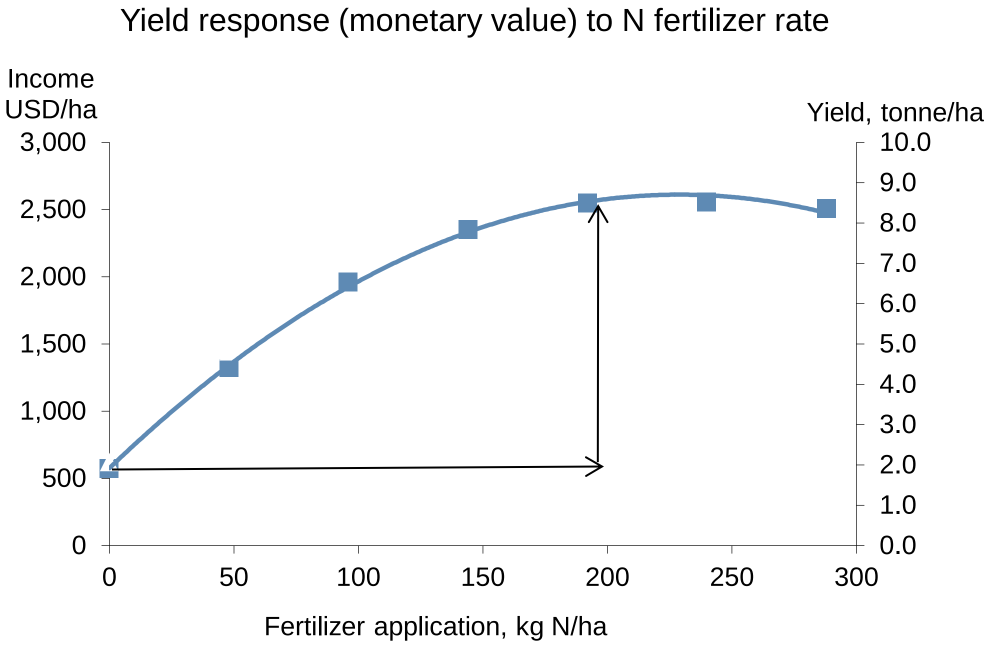
China drives recent years' increases in global grain stocks





Source: USDA December 2016

Profitability of investment in mineral fertilizers

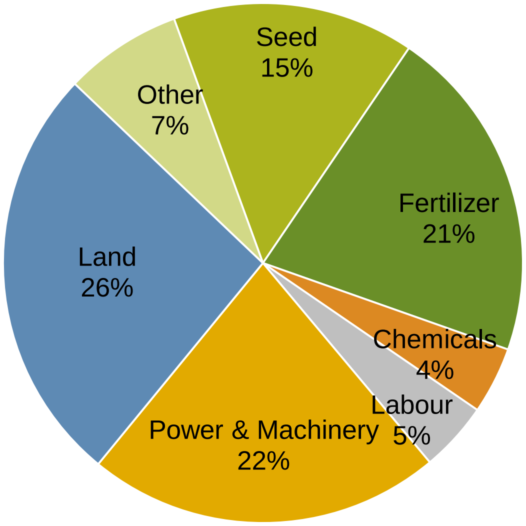


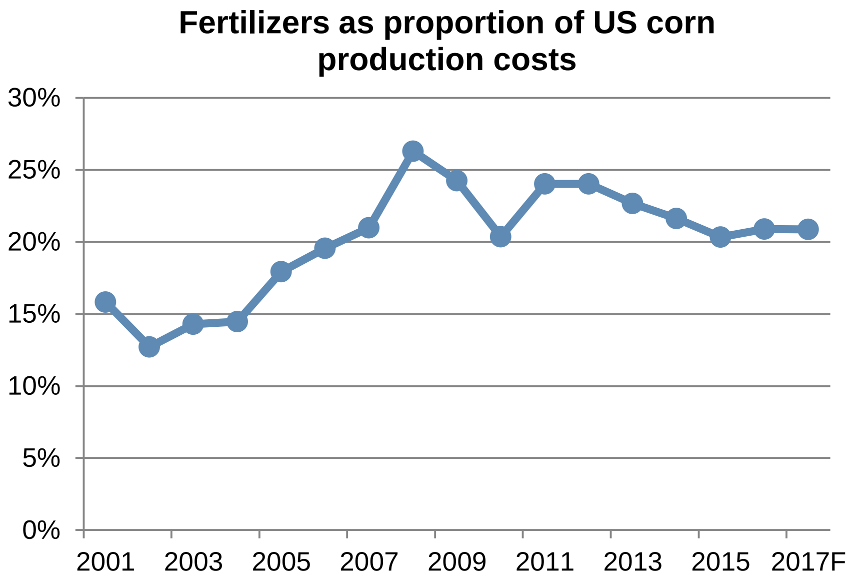
- The investment in nitrogen fertilizer is highly profitable for growers
- Fertilizer investment: 126 USD/ha
- Net return: 973 USD/ha
- **Net return > 8 x investment**

Source: Winter wheat yield data: Long term trial, Broadbalk, Rothamsted (since 1856).

Breakdown of grain production costs

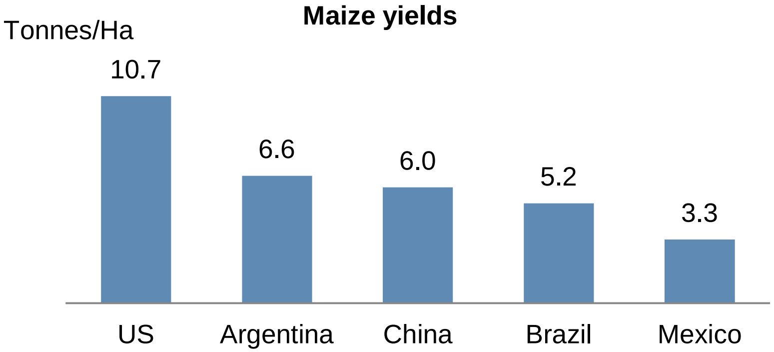
Example: 2016F average US corn production costs

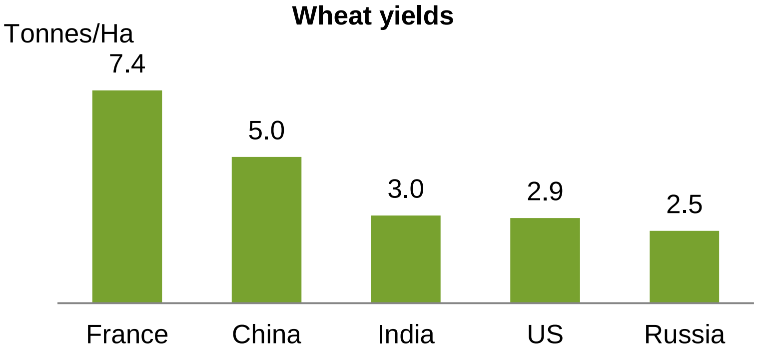


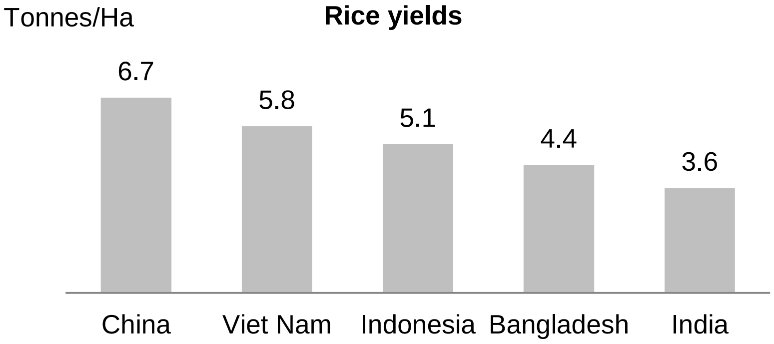


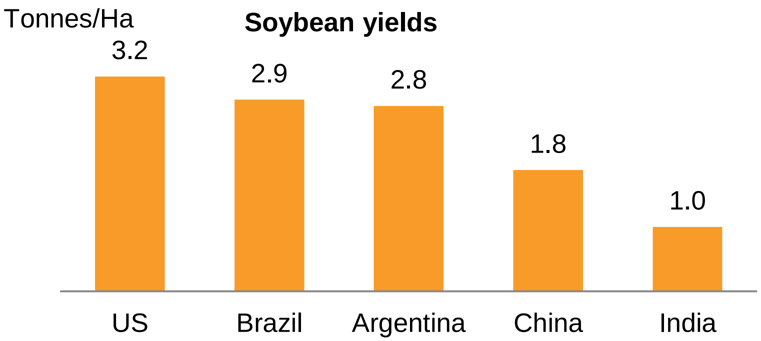
Source: USDA (Cost-of-production forecasts March 2016)

Large variations in yields across regions



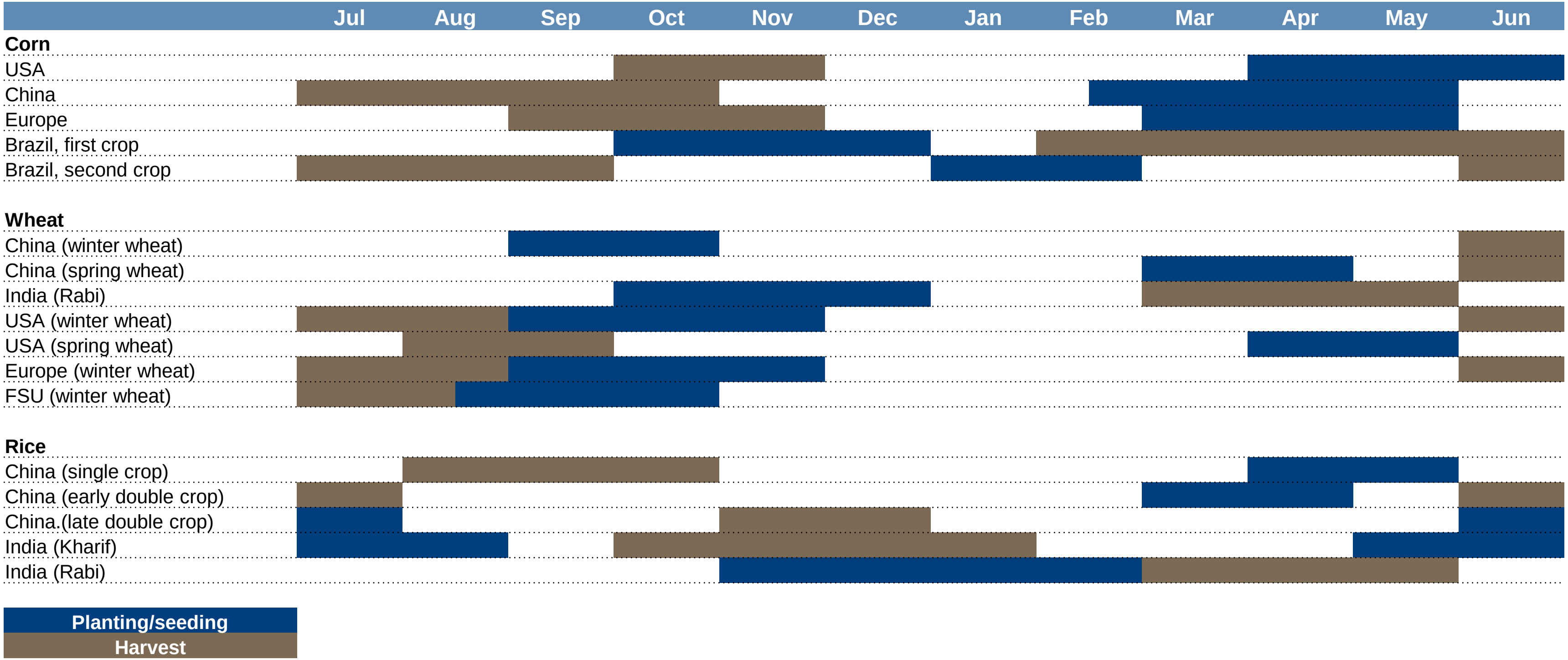






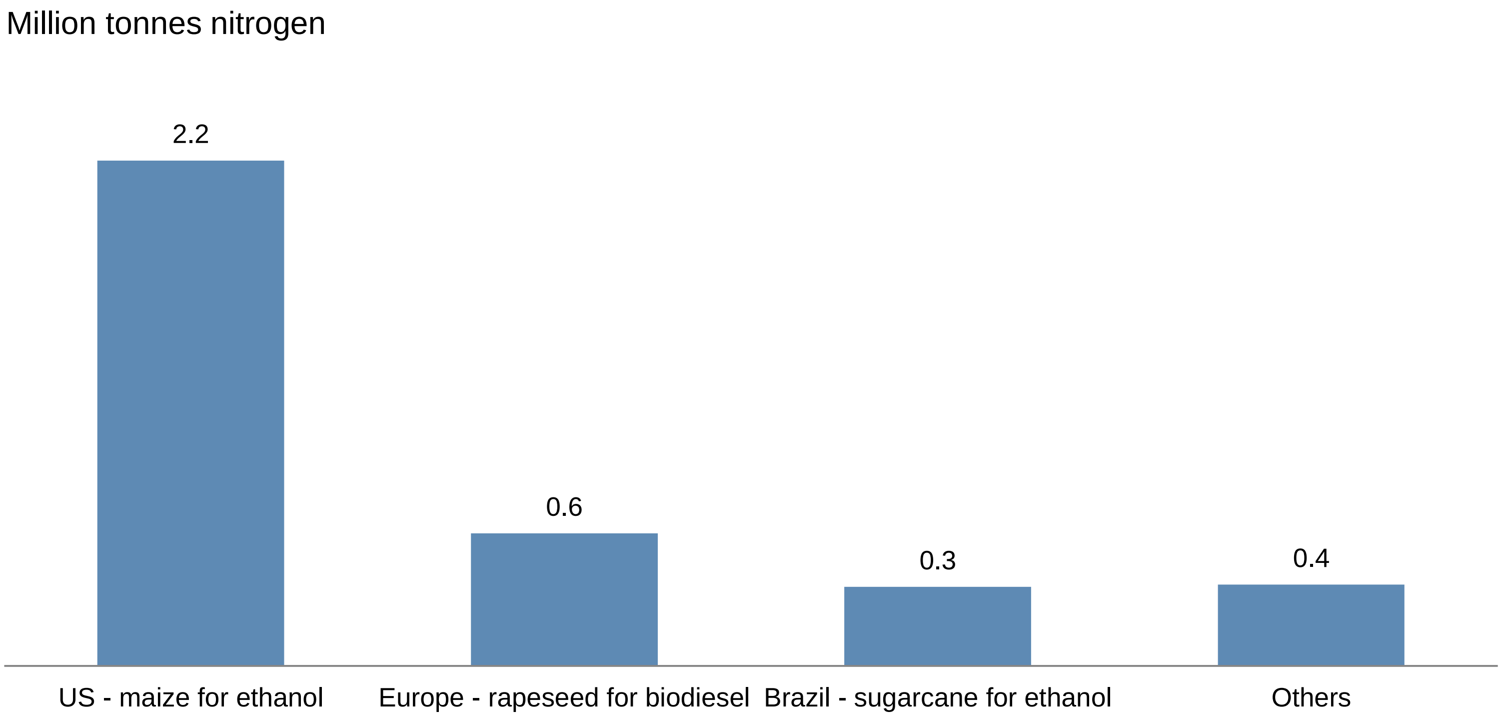
Source: FAOSTAT 2014

Seasonality in fertilizer consumption



Source: USDA

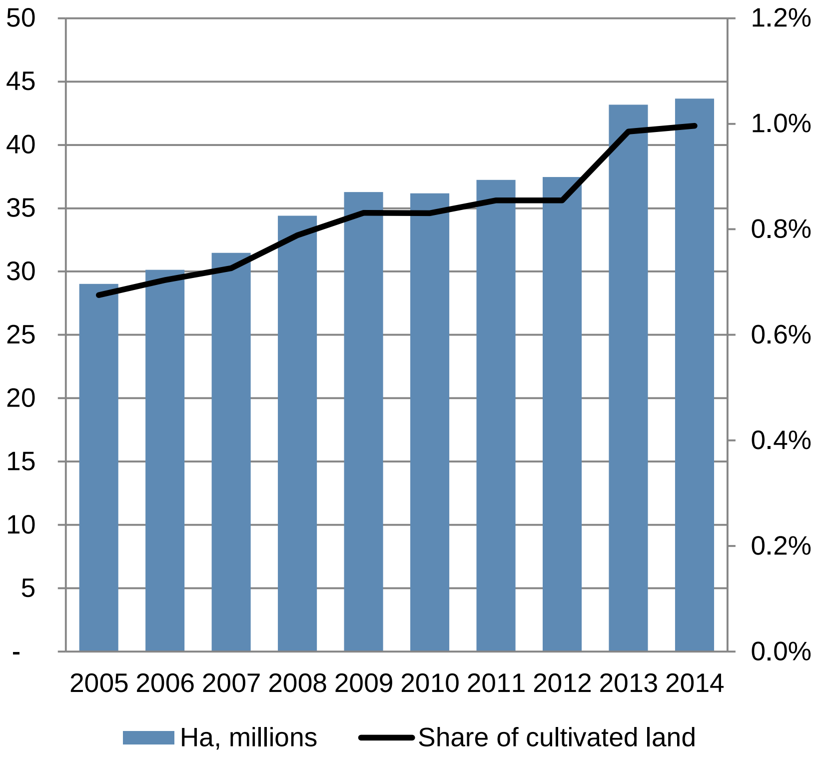
N-fertilizer consumption from biofuels production



Source: IFA 2013/2014

Organic farming represents a marginal share of total cultivated land

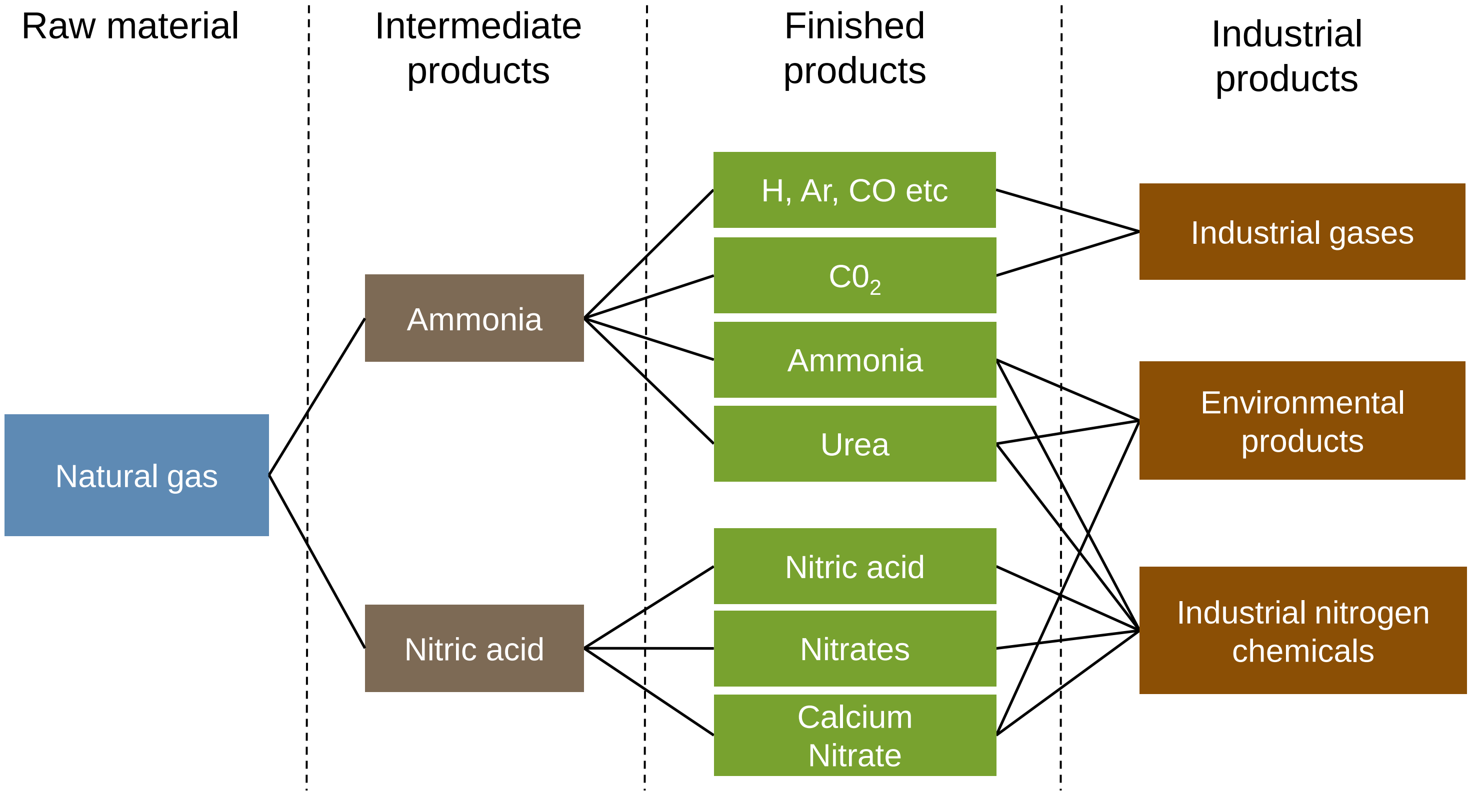
- The principles of crop nutrition are also valid for organic farms
- Organic farms use manure and crop residues to deliver minerals to their crops
- Organic farming is a niche market, mainly for consumers in the developed world



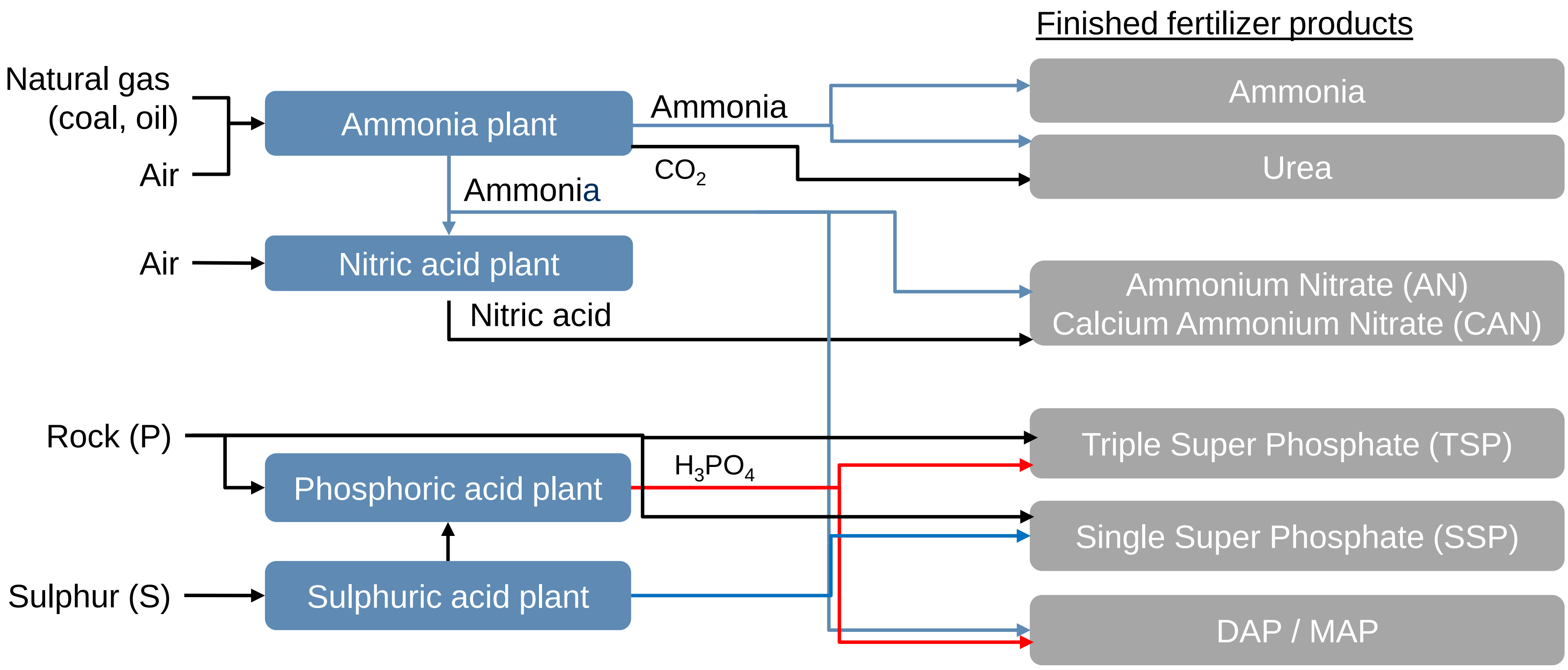
Source: Organic-world.net

Drivers of supply

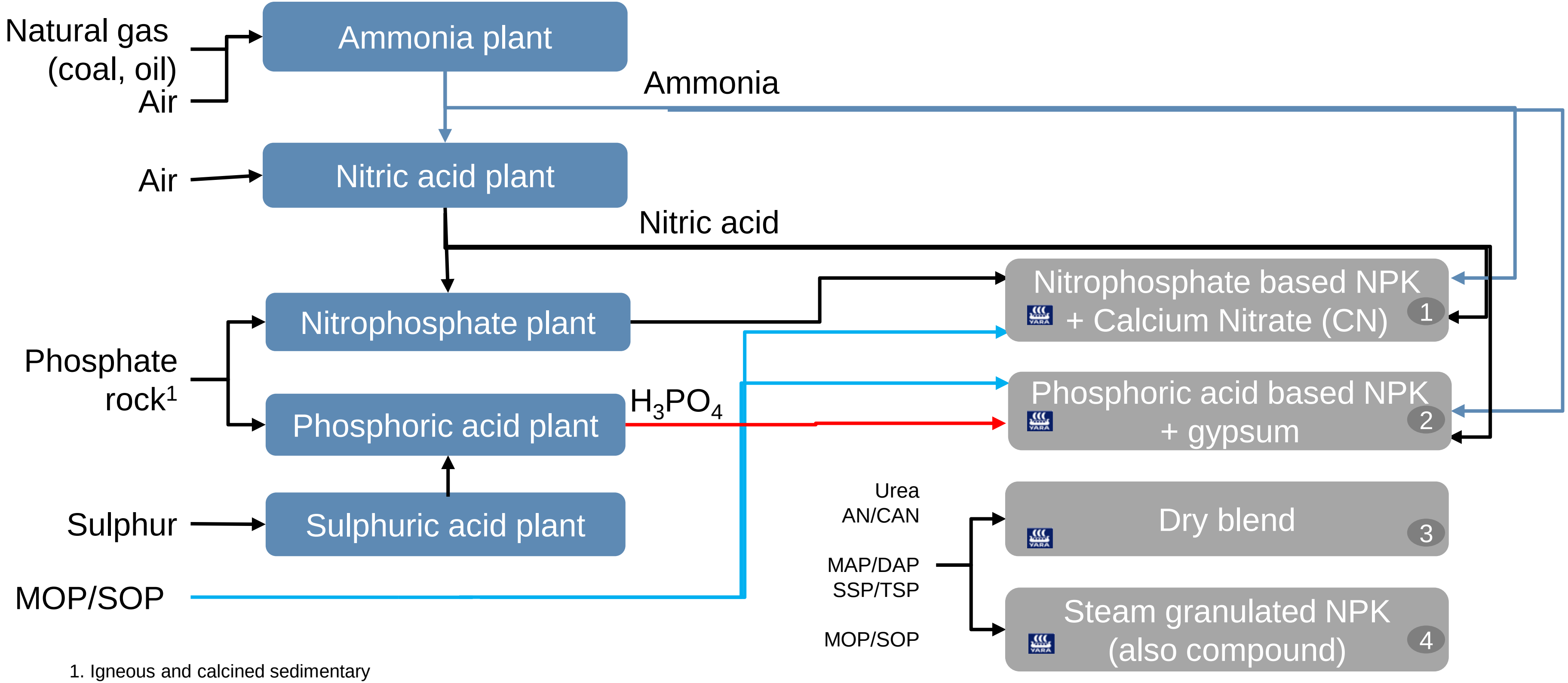
Nitrogen value chain



Fertilizer production routes

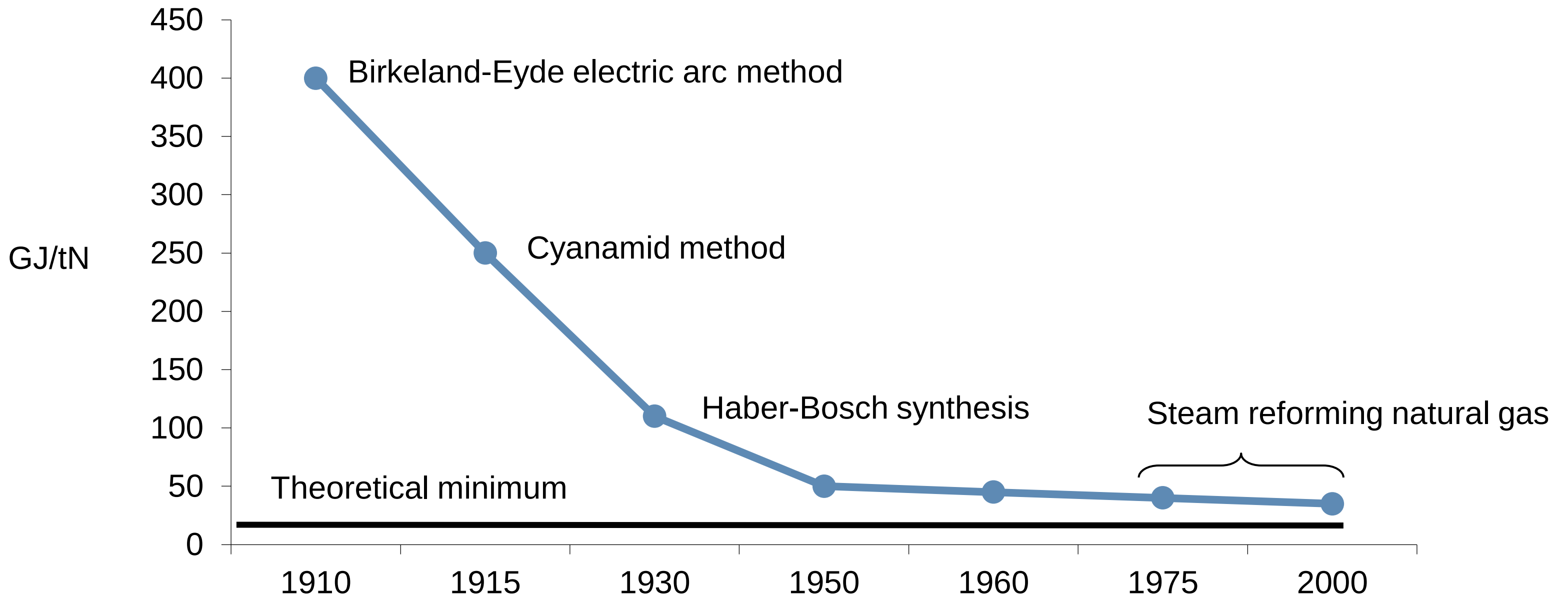


NPK production routes

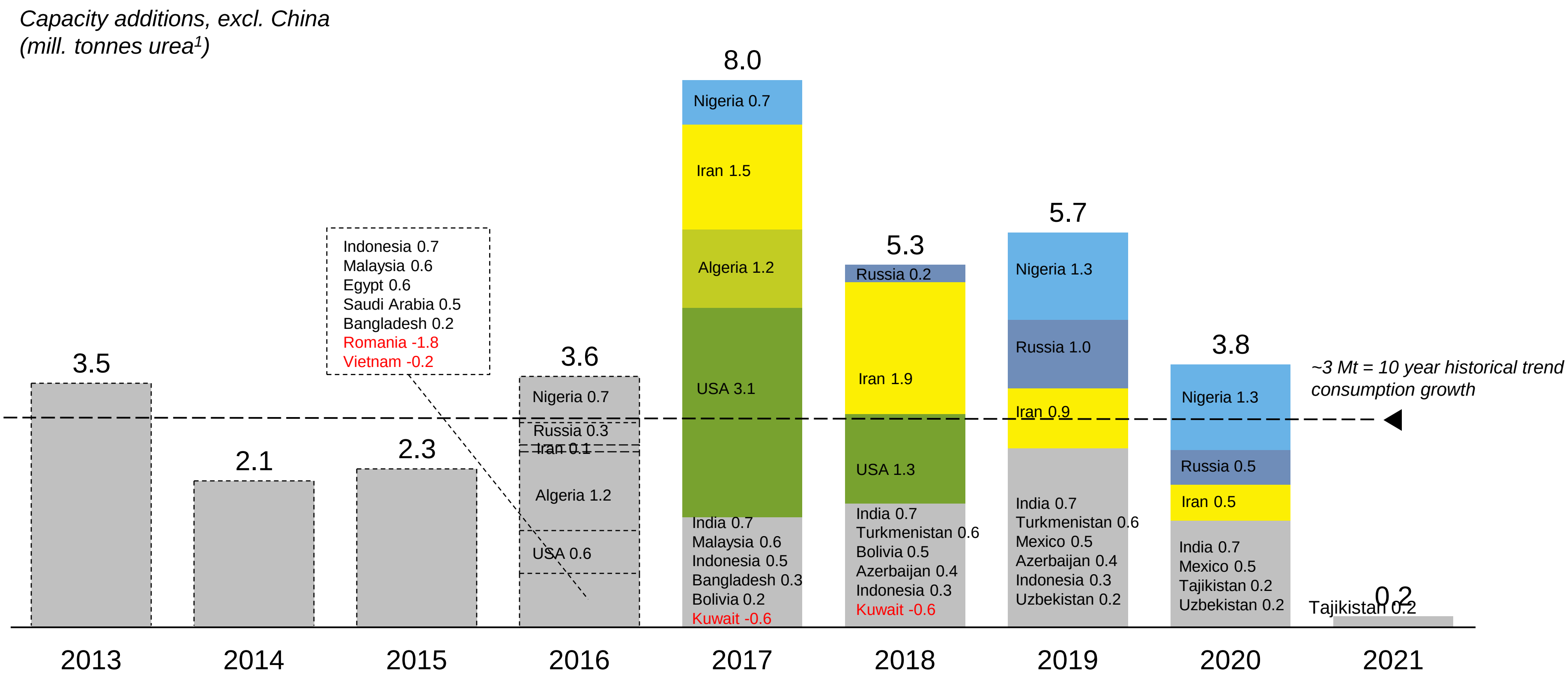


1. Igneous and calcined sedimentary

Nitrogen technology evolution



Projected nitrogen capacity additions outside China

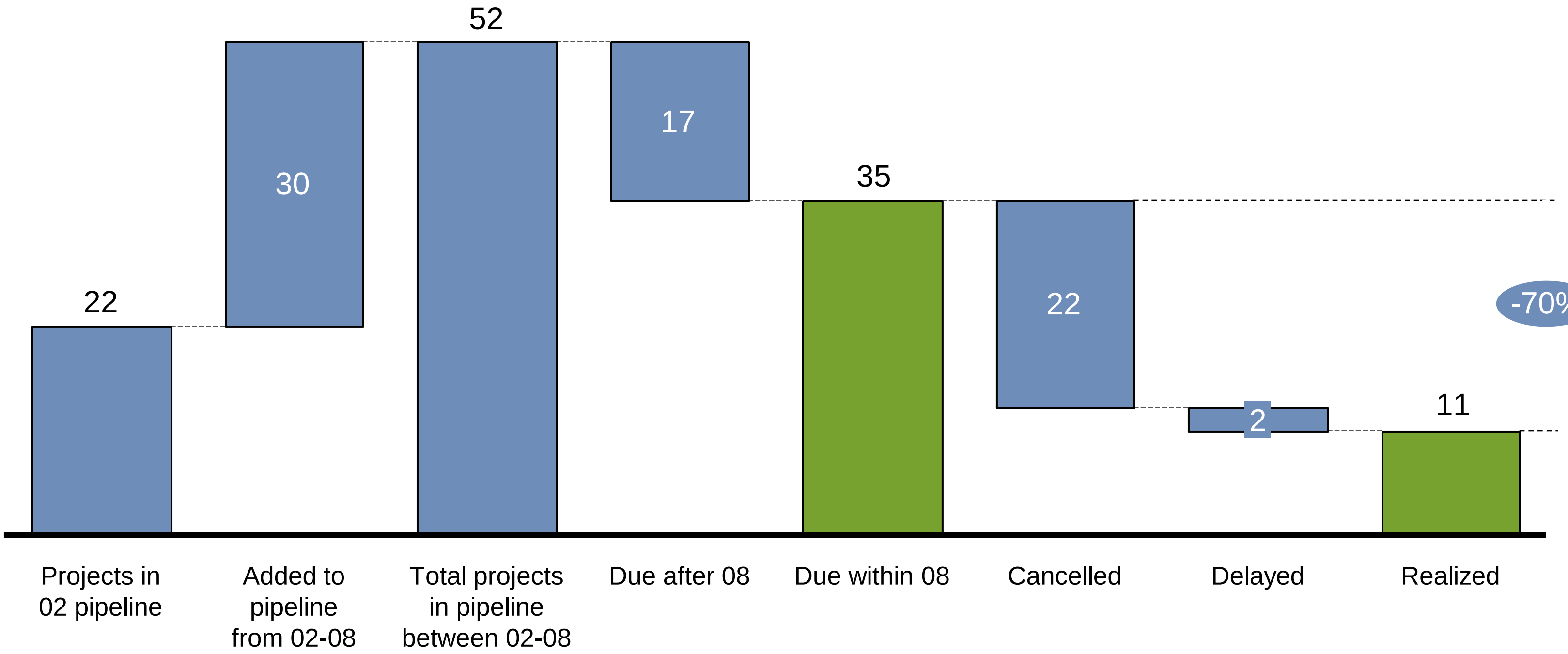


Source: CRU, December 2016. Numbers include both additions and closures of capacity.

1) Using 50% operating rate in new plants' first year of production.

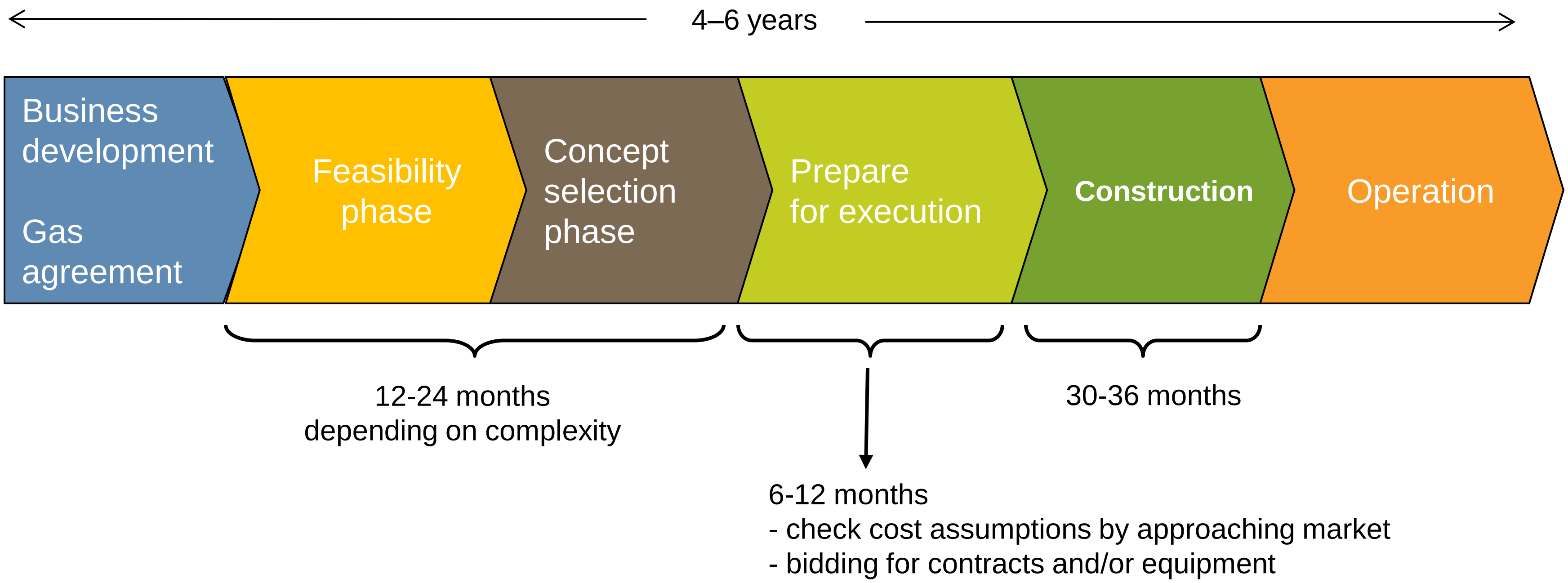
30% of announced nitrogen projects realized on time

Likely and probable ammonia projects in pipeline 2002-2008; Million tons



Note: Chinese projects are excluded from pipeline
Source: 2002, 2004, 2006, 2007, 2008 Fertecon Ammonia Outlook Reports

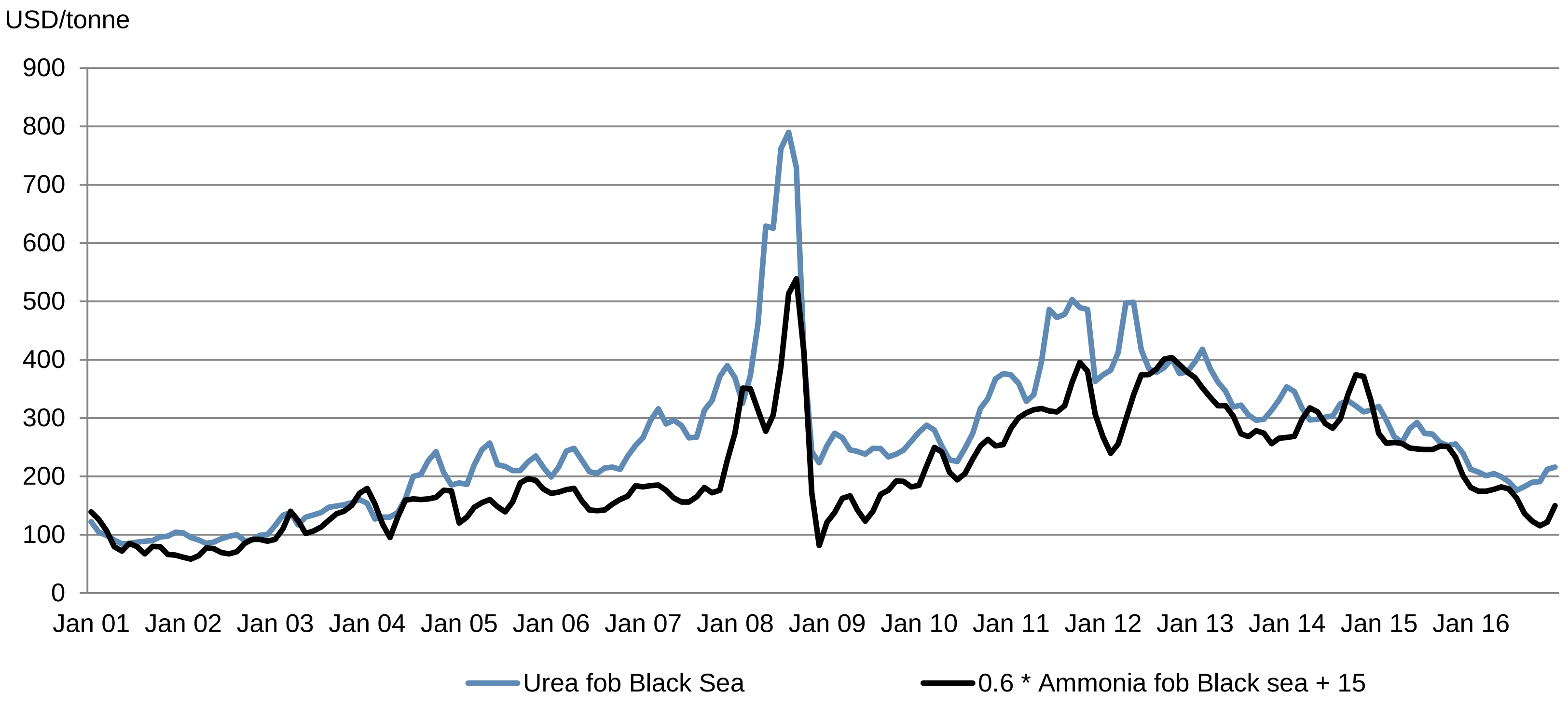
5 year typical construction time for nitrogen fertilizer projects*



* Ammonia and urea plant example

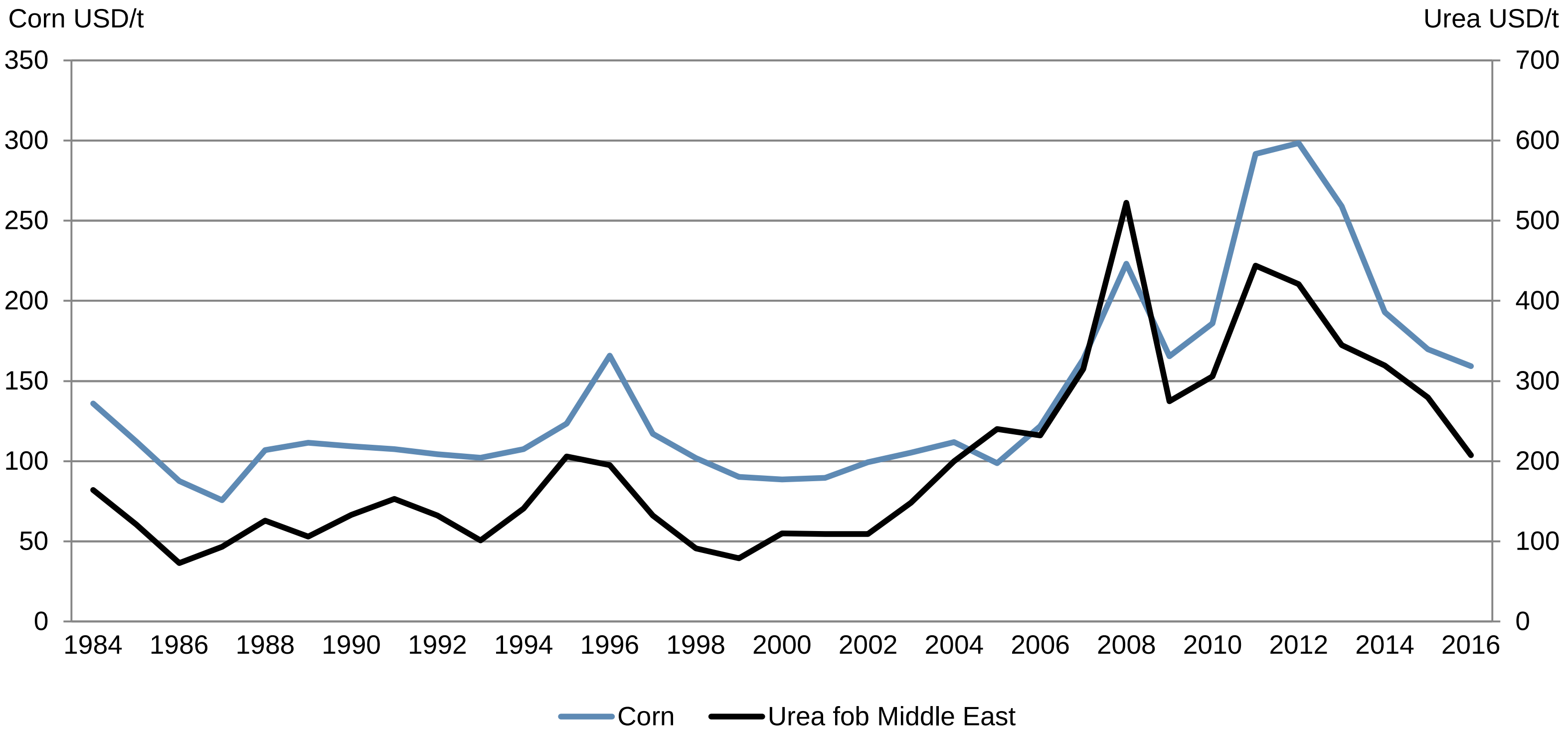
Price relations

Upgrading margins from ammonia to urea



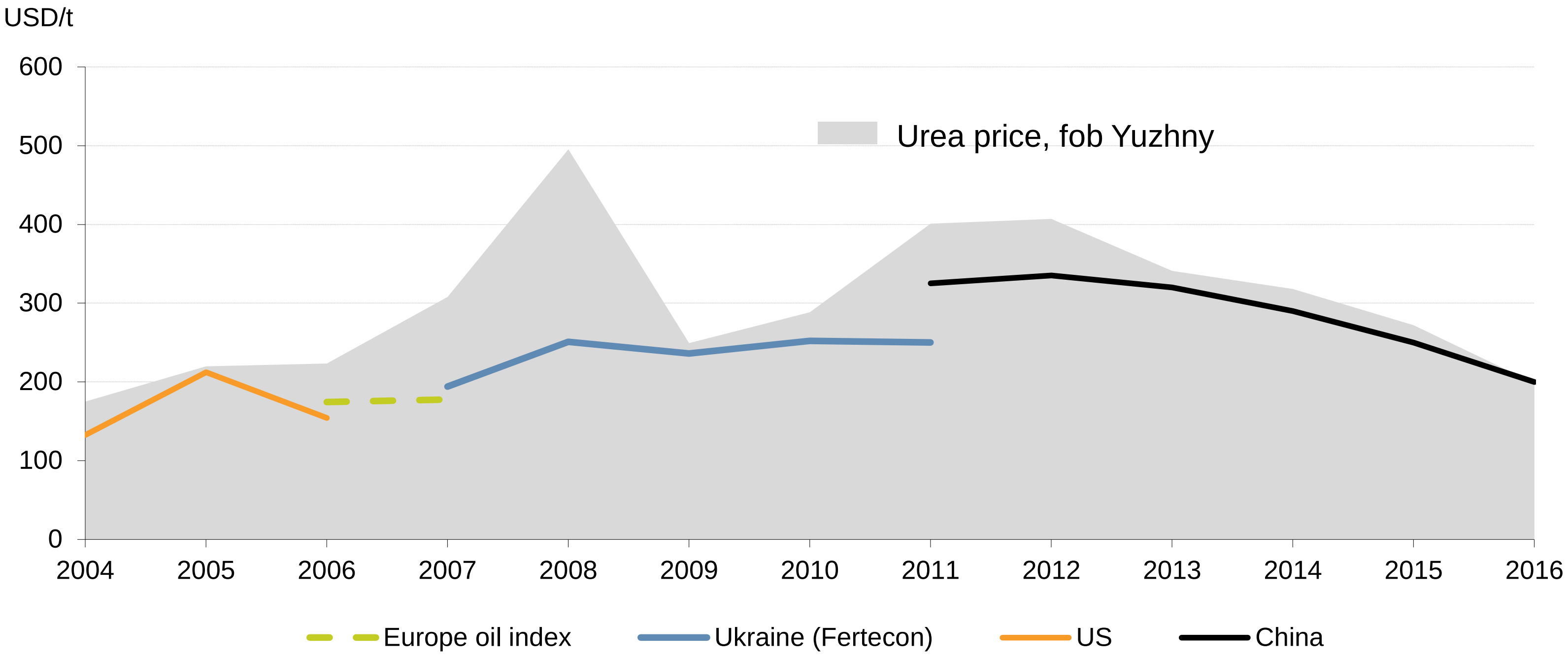
Source: Average of international publications

Grain prices important for fertilizer demand



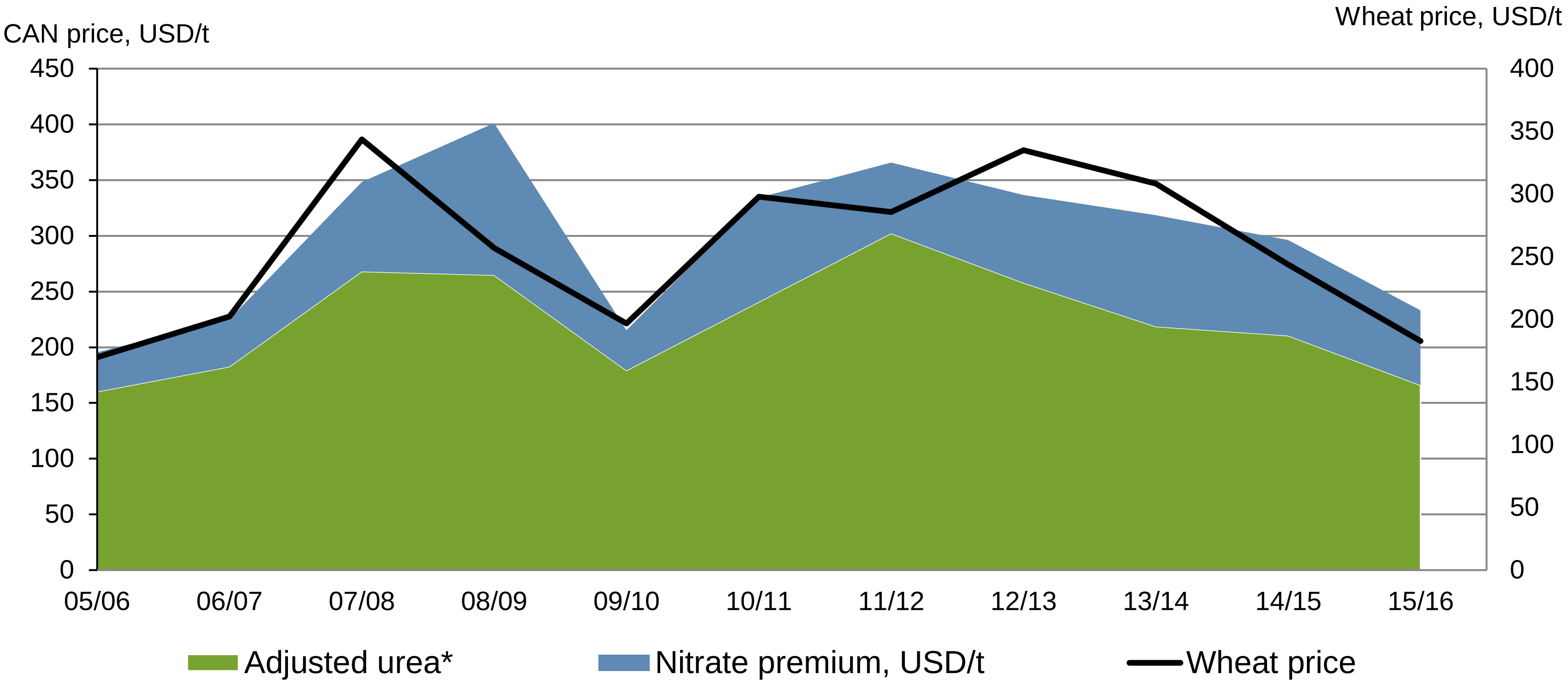
Source: World Bank, Fertilizer publications

The urea market has been supply-driven since 2014



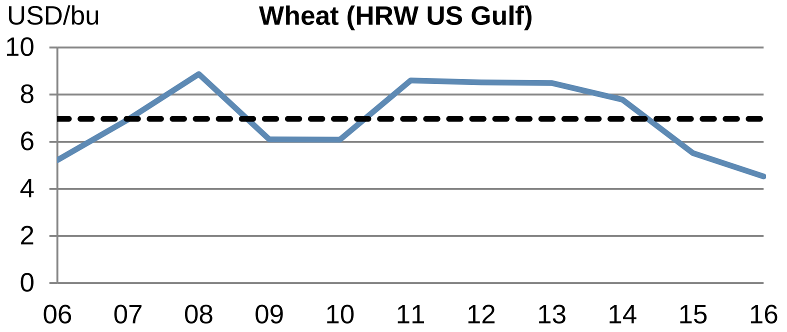
Source: Fertecon (Ukraine), Yara estimates

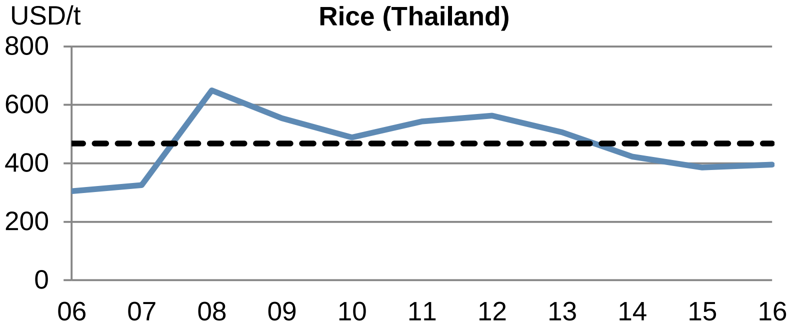
Nitrate premium is mainly a function of crop prices and marketing

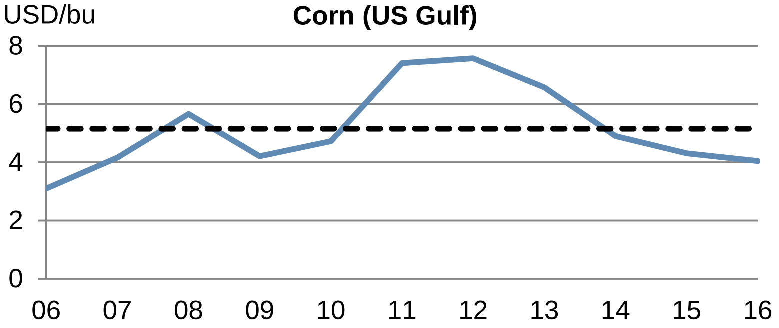


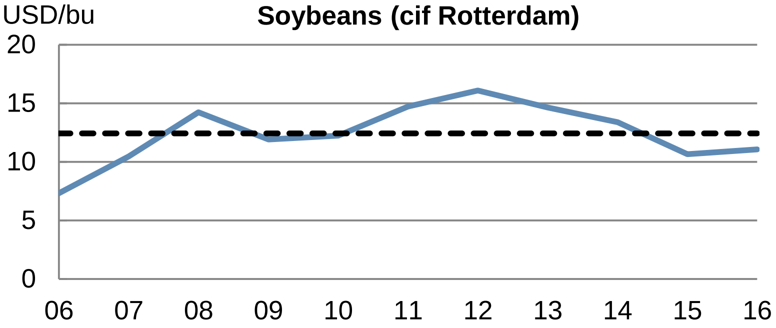
* Urea fob Black sea adjusted for import costs into Europe and nitrogen content similar to CAN

Grain/oilseed prices – yearly averages





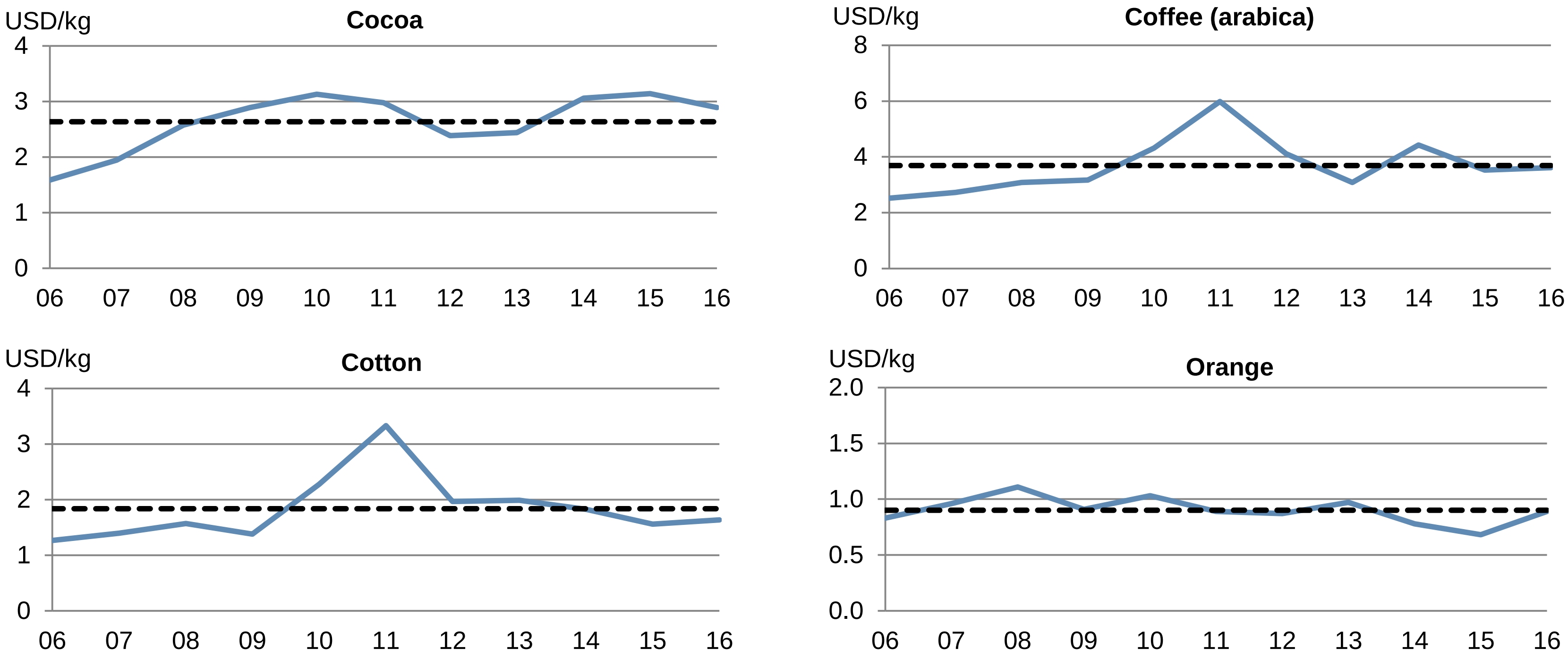




Source: World Bank, December 2016

---- Average prices 2006 - 2016

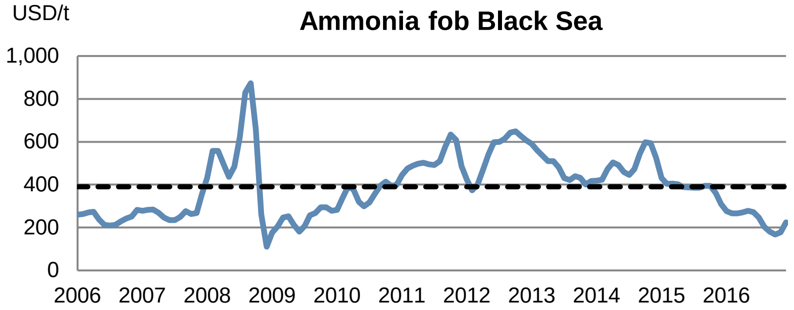
Cash crop prices – yearly averages

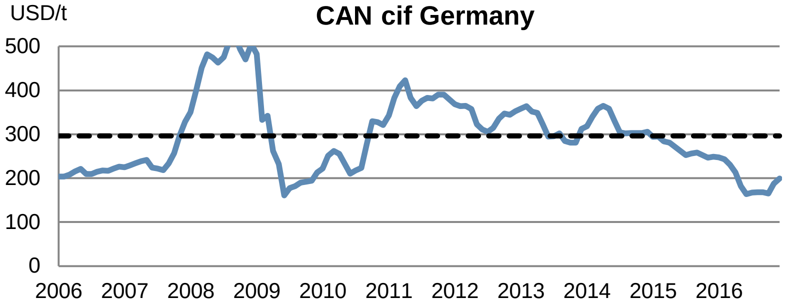


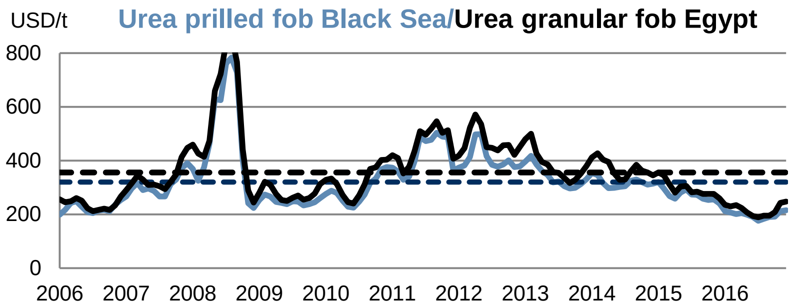
Source: World Bank, December 2016

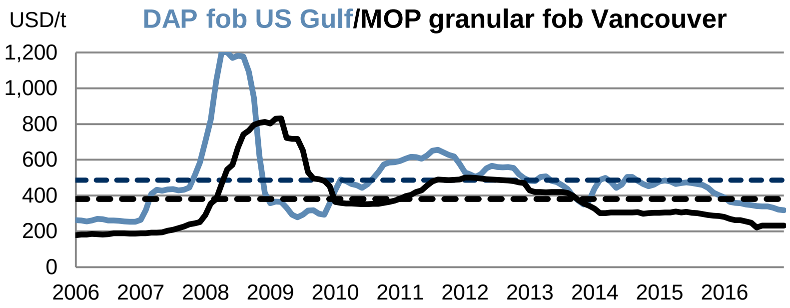
Average prices 2006 - 2016

10-year fertilizer prices – monthly averages







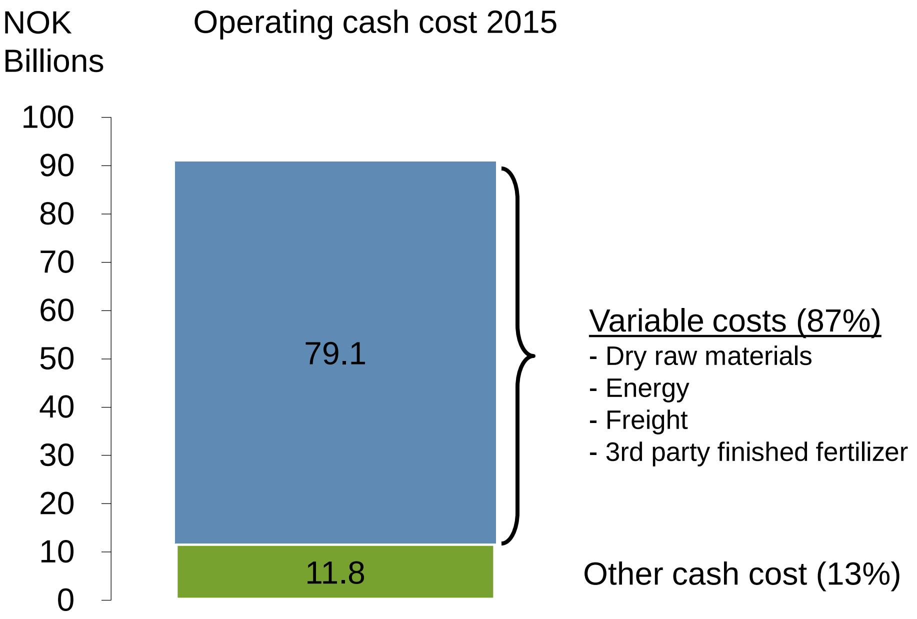


Source: Average of international publications

Average prices 2006 - 2016

Production economics

Yara's operating cash costs are mainly variable



- Temporary plant closures can be carrie out with limited stop/start costs
- Example for ammonia/urea plants:
  - Typically half a week to stop and a week to start
  - Cost of stopping is 2 days energy consumption
  - Cost of starting is 3 days energy consumption

Ammonia cash cost build-up – example

	Gas price:	4	USD/MMBtu
x	Gas consumption:	36	MMBtu/mt NH_3
=	Gas cost:	144	USD/mt NH_3
+	Other prod. cost:	29	USD/mt NH_3
=	Total cash cost	173	USD/mt NH_3

36 MMBtu natural gas/tonne ammonia

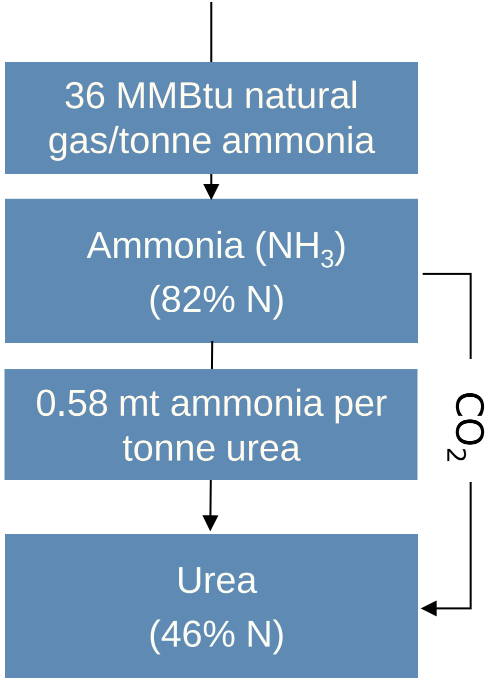
Ammonia (NH_3)
(82% N)

Typical natural gas consumption for ammonia production

Source: Blue Johnson & Associates.

Urea cash cost build-up – example

	Ammonia price:	173	USD/mt NH_3
x	Ammonia use:	0.58	NH_3/mt urea
=	Ammonia cost	100	USD/mt urea
+	Process gas cost*	21	USD/mt urea
+	Other prod. cost**:	25	USD/mt urea
=	Total cash cost	146	USD/mt urea

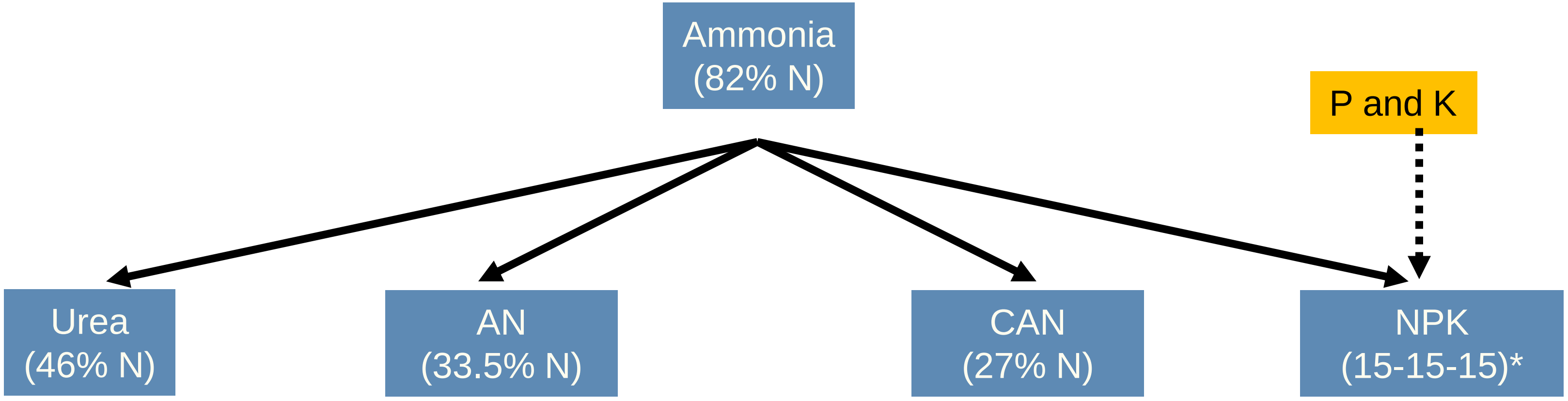


* Process gas cost is linked to natural gas price

** Including load-out

Source: Blue Johnson & Associates.

Theoretical consumption factors

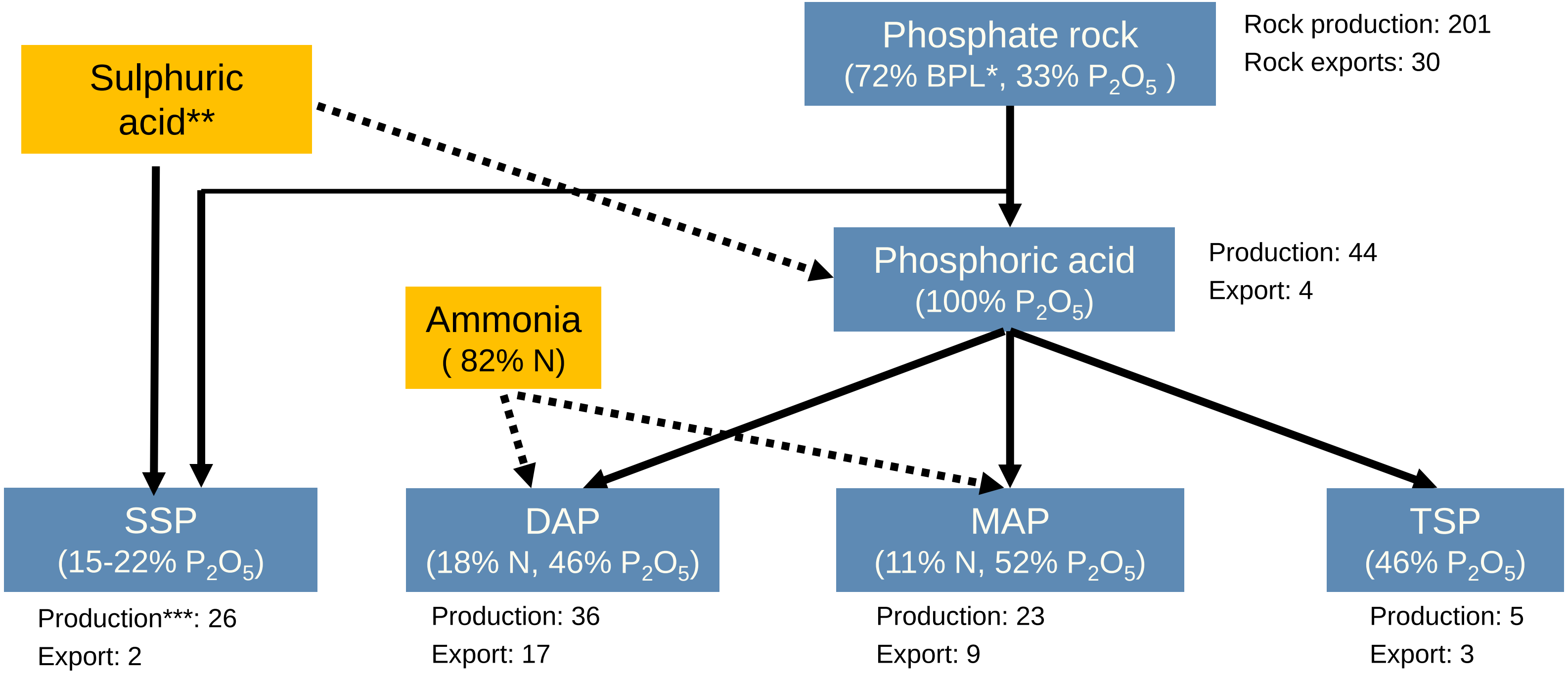


- Price comparisons should always be based on nutrient tons, not product tons

* There are many NPK formulas; 15-15-15 is one example

Main phosphate processing routes

2015 production and exports, million tons product



Source: IFA

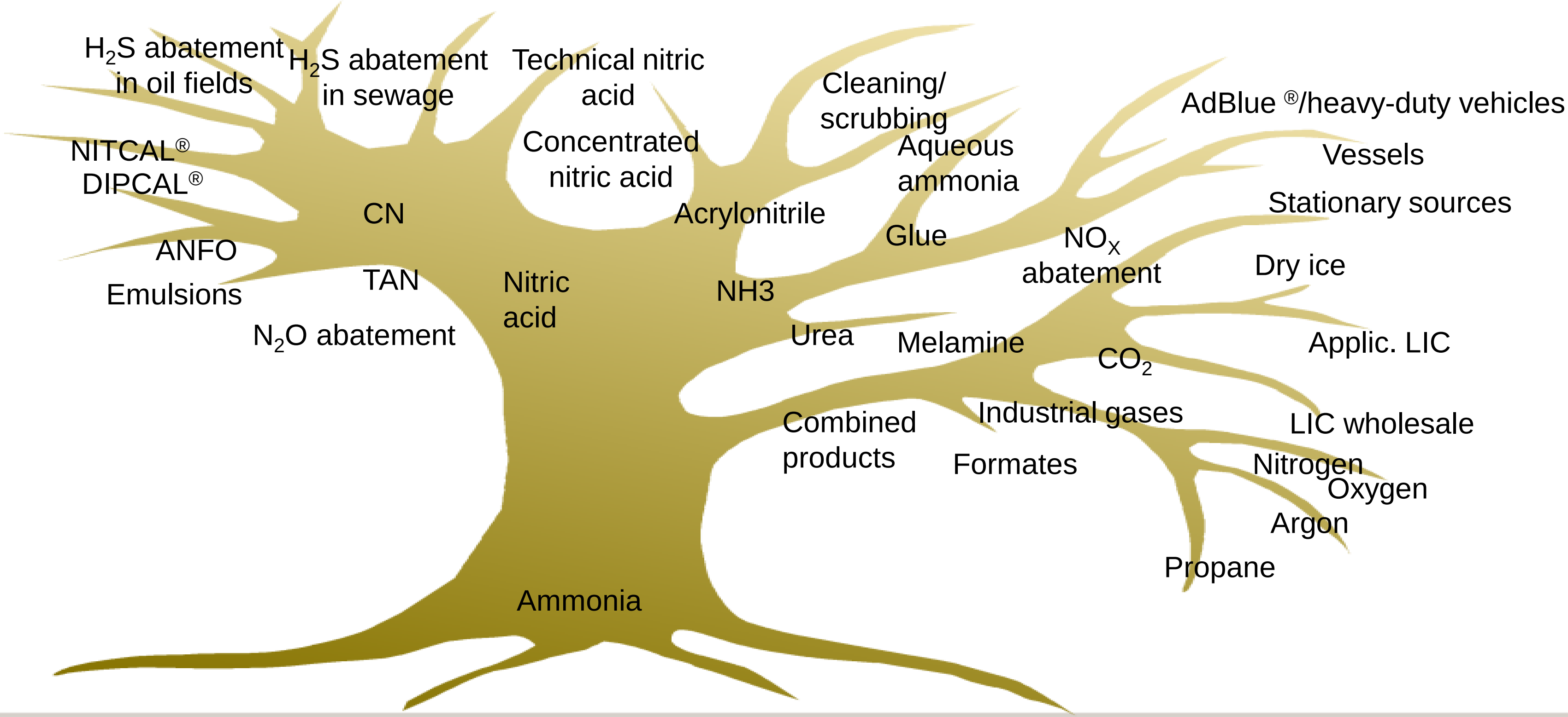
* P2O5 content of phosphate rock varies. This is an example.

** 1 ton of phosphoric acid requires 1 ton of sulphur.

***2013 figures

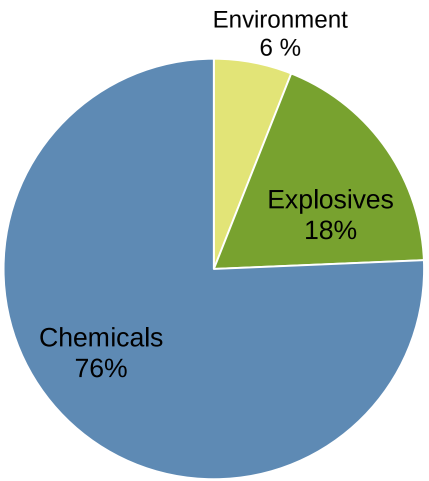
Industrial applications

Nitrogen has many industrial applications



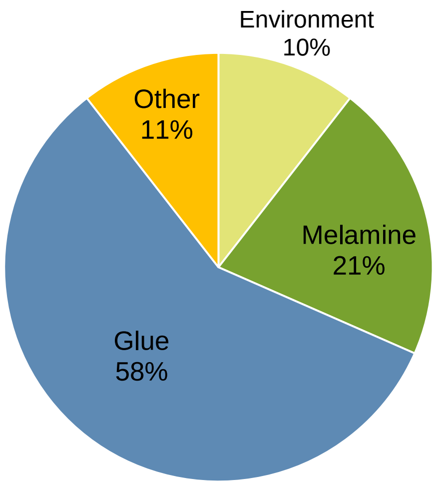
Industrial use accounts for 21% of global nitrogen consumption

~30 million tonnes N



~21% of total nitrogen consumption

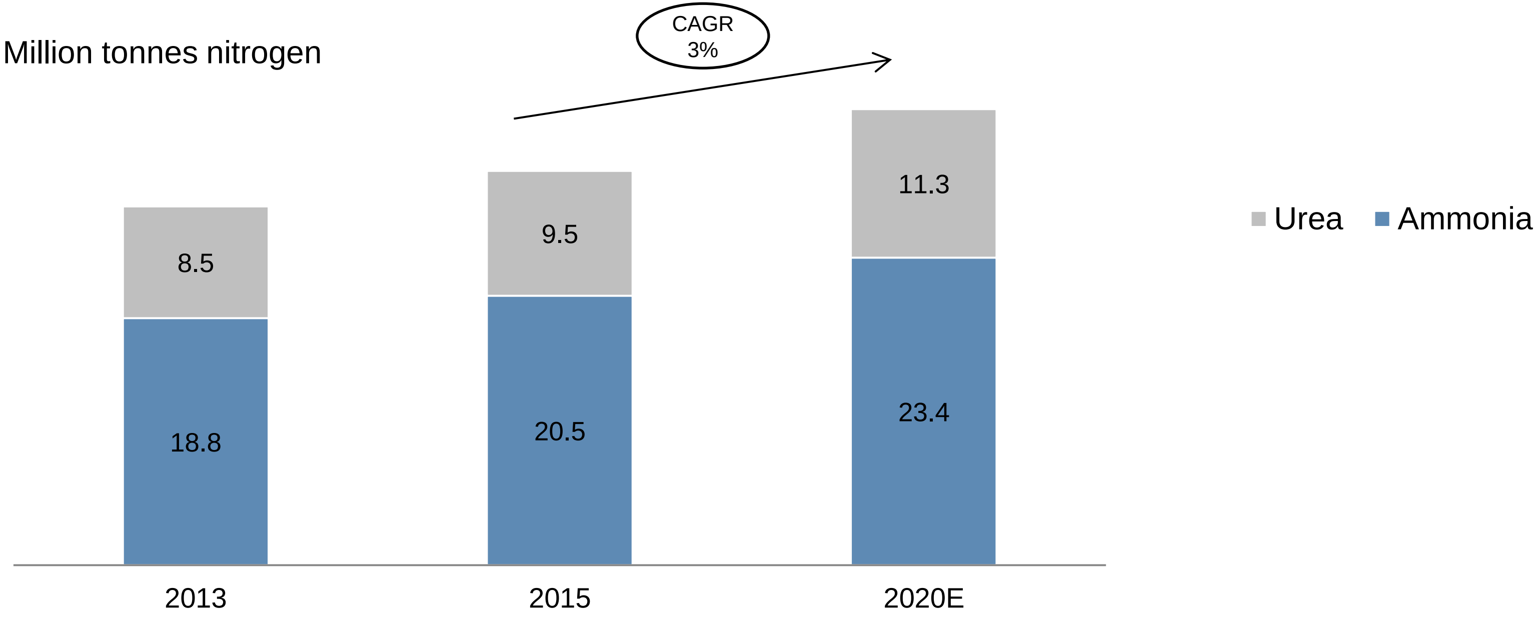
~9.5 million tonnes N as urea



~12-13% of total urea consumption

Source: Yara estimates 2015, IFA, Fertecon, CRU

Global demand development of nitrogen chemicals for industrial applications is strong



Demand growth for Industrial applications
is estimated to ~3 % annually

Source: Yara estimates 2015, IFA, Fertecon, CRU

Reagents, technology and services to improve air quality

Nitrogen oxides (NOx) are a major air quality issue causing serious problems mostly in urban centers related to both the environment and human health. Legislation around the world drives the business growth.

- **Air 1™   AdBlue/DEF** is a generic name for urea-based solution (32.5% liquid urea) Air 1 is Yaras brand name for AdBlue that is used with the selective catalytic reduction system (SCR) to reduce emissions of oxides of nitrogen from the exhaust of diesel vehicles such as trucks, passenger cars and off-road vehicles

- **NOxcare™** As a world leader in reagents like urea and ammonia in combination with our experience in abatement systems like SNCR and SCR technology Yara offers its clients one of the most comprehensive and effective solutions to reduce NO_x emissions in industrial power plants and utilities.

- In the maritime segment Yara offers SCR and scrubber technologies to abate NOx and SOx (sulphuric oxide) emissions.

Calcium Nitrate applications in wastewater treatment, concrete manufacturing, oil fields and latex industries

- **Nutriox™** provides H2S prevention for Corrosion, Odor and Toxicity control of municipal and industrial waste water systems
- **Nitcal™** is a multifunctional concrete admixture serving concrete admixtures companies around the world
- **PetroCare™** prevents well souring and supports drilling in oilfields around the world, for both the oil majors and the service companies that serve them
- **Dipcal™** is the premier dipping coagulant for the latex industry
- Other important applications are in the ceramics, bio-gas and solar CSP industries

Technical Nitrates for Civil Explosives

- Various grades of Ammonium Nitrate and Calcium Nitrate for use in the civil explosives and mining industries
- Largest customer segment are civil explosives companies and open-pit coal and iron mining sectors

Animal Feed industry with several nutritional products based on core chemicals

- **Feed Phosphates**
  - Macro-minerals such as phosphorus and calcium are essential elements to sustain healthy and productive animal growth
- **Feed Acidifiers**
  - Antimicrobial effect and lowering pH, replace AGP (antibiotic growth promoter) and effective against salmonella and moulds
- **Feed Urea**
  - Source of NPN (non-protein nitrogen) used by rumen micro-organisms forming proteins, replacing part of vegetable protein
- **Ammonia for fermentation**
  - Amino acids like lysine, methionine, threonine are essential to add to lower total use of protein

Sources of market information

- **Fertilizer market information**
  - FMB — www.fmb-group.co.uk
  - Fertecon — www.fertecon.com
  - Fertilizer Week — www.cruonline.crugroup.com
  - Profercy — www.profercy.com
  - The Market — www.icispricing.com
  - Green Markets (USA) — www.greenmarkets.pf.com
  - Beijing Orient Business (China) — www.boabc.com
  - China Fertilizer Market Week — www.fertmarket.com

- **Fertilizer industry associations**
  - International Fertilizer Industry Association (IFA) — www.fertilizer.org
  - Fertilizers Europe (EFMA) — www.efma.org

- **Food and grain market information**
  - Food and Agriculture Organization of the UN — www.fao.org
  - International Grain Council — www.igc.org.uk
  - Chicago Board of Trade — www.cbot.com
  - World Bank commodity prices — www.worldbank.org
  - US Department of Agriculture (USDA) — www.usda.gov


YARA
Knowledge grows