

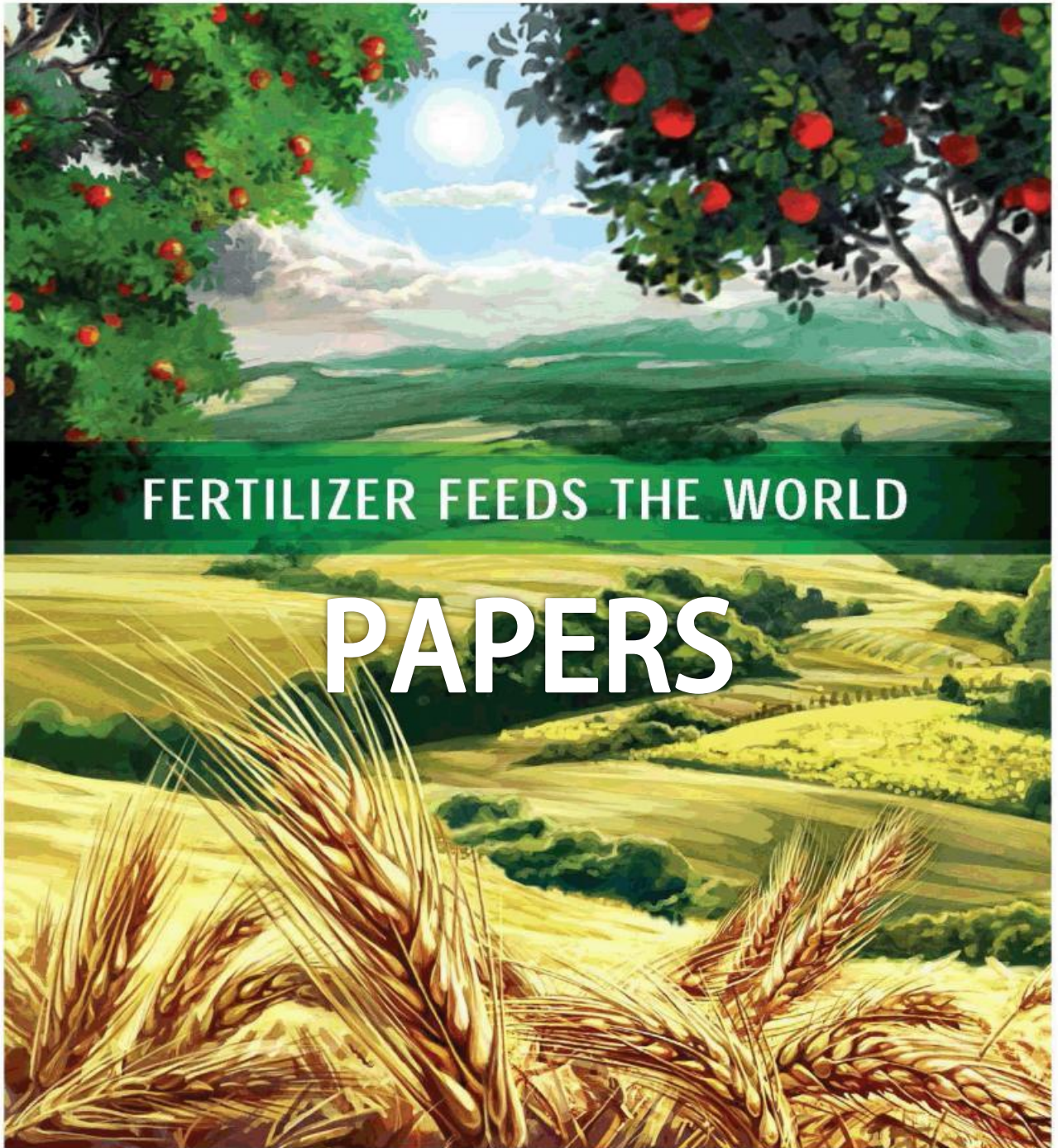


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Arab Int'l. Organization  
Arab Fertilizer Association  
Since 1975



19<sup>th</sup> Annual AFA  
Fertilizer Forum

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FERTILIZER FEEDS THE WORLD

PAPERS

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel

A calendar event of AFA





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# Program

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel







**FERTILIZER FEEDS THE WORLD**

**Under The Patronage of  
H.E. Eng. Osama Kamal  
Minister Of Petroleum & Mineral Resources, Egypt  
Feb., 26-28, 2013: Sharm El-Sheikh, Egypt**

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**Stamicarbon B.V.**

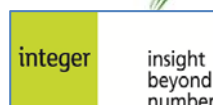


**Misr Phosphate**



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**FERTILIZER FEEDS THE WORLD**

**Program**

**Monday: Feb 25<sup>th</sup>, 2013**

09hr: 00 – 18hr: 00     Registration

**DAY 1: Tuesday: Feb 26<sup>th</sup>, 2013**

10hr: 00 – 16hr: 00     Registration

14hr: 30     Networking Lunch

16hr: 30

**I- Forum Opening**

**- Welcome speech:**

- AFA Secretary General

**- Opening speech:**

- AFA Chairman

**- Patronage address**

- H.E. Eng. Osama Kamal  
Minister of Petroleum & Mineral Resources, Egypt

**II- Keynote Speakers:**

**- *Ramping Up Fertilizer Use in Sub Saharan Africa***

- Mrs. Charlotte Hebebrand, Director General, IFA - France

**- *Energy Saving - a Major Issue in Ammonia Revamps***

- Mr. Jim Gosnell, Vice President- Fertilizer & Syngas  
Technologies, KBR Technology - USA

**III- Recognition & Appreciation: Former Board Members**

- Eng. Mohamed El-Mouzi, Egypt
- Eng. Mohamed S. Baderkhan, Jordan
- Eng. Jihad N. Hajji, Kuwait

**IV- Exhibition Opening**

14hr: 30

Networking Lunch







**DAY 2: Wednesday: Feb 27<sup>th</sup>, 2013**

**Session I- II: Global Fertilizer Policies & Supply/ Demand Balance**

**10hr: 00 – 12hr: 00**

**Chairperson:** **Eng. Fahad Alsheaibi**  
**AFA Chairman**  
**& Executive Vice President, fertilizers, SABIC, Saudi Arabia**

- 1- ***EU Trends in Fertilizer Regulation & Consumption***  
Mr. Jacob B Hansen, Director General, Fertilizer Europe (EFMA), Belgium
- 2- ***Urea: A Great Way to Monetize Natural Gas***  
Mr. Steven Zwart – Stamicarbon
- 3- ***Prospects for the Potassium Chloride Market***  
Mr. Paul Burnside, Manager: Fertilizer Analysis Products, CRU, UK
- 4- ***Shipping Cost and Challenge Facing Dry Bulk Exporters***  
Mr. Hazza Al-Qahtani, Amad Shipping, Saudi Arabia

**12hr: 00** **Coffee Break Networking**

**12hr: 30 – 14hr: 30**

**Chairperson:** **Mr. Abdallah A. AL-SWAILEM**  
**Deputy Managing Director, Fertilizers**  
**Petrochemical Industries Co. – PIC**

- 5- ***The Year Ahead: World Fertilizer Supply & Demand in 2013***  
Mr. Michel Prud'homme, Director, Production & International Trade Services, IFA - France
- 6- ***Challenges and Opportunities for Maize Production Intensification in Sub-Saharan Africa Security***  
Dr. Terry L. Roberts, President, IPNI, USA
- 7- ***From Projects to end-consumer: Sustainable Development of Fertilizer Industry in Russia***  
Mr. Danil Safonov, NIIK – Russia
- 8- ***Developments and Prospects in the Phosphate Fertilizer Business***  
Mrs. Monica Baker, Research Manager, Integer Research, UK

**14hr: 30** **Networking Lunch**

**20hr: 00** **Gala Dinner**



**aifa**



**DAY 3: Thursday: Feb 28th, 2013**

**Session III- IV: Fertilizer & Human Health: Feed, Food and Fiber**

**10hr: 00 – 11hr: 30**

**Chairperson:** **Dr. M. Mustafa El-Fouly**  
**Professor, National Research Centre – Egypt**

- 1- ***Fertilizing Crops to Improve Human Health: a Scientific Review***  
Dr. Tom Bruuslema, Director, IPNI –Canada
- 2- ***Meeting Animals Nutritional Mineral Demands through Fertilizer Fortified Fodder Plants***  
Prof. Dr. Ewald Schnug, inst. Plant Production - Germany
- 3- ***Importance of Micro-Nutrients in Agriculture in Africa and their Impact on Human Health***  
Prof. Dr. Victor Chude, National Programme for Food Security, Federal Ministry of Agriculture, Abuja – Nigeria
- 4- ***Food, Feed and Plant Nutrition: an Intricate Relationship***  
Dr. Ghassan Hamdallah, Ex. Senior FAO Soils & Fertilizers Regional Officer

**11hr: 30** **Coffee Break Networking**

**12hr: 00 – 13hr: 15**

**Chairperson:** **Dr. Terry L. Roberts**  
**President, IPNI- USA**

- 5- ***Nutrient Management with Wastewater Irrigation and Feed Quality***  
Dr. Munir Rusan, Middle East Consulting Director, IPNI
- 6- ***India's Struggle for Food Security and Efforts for Sustainable Fertilizer Usage***  
Dr. MP Sukumaran Nair, Director, Center for Green Technology & Management (CGTM) – India
- 7- ***Increasing Salinity Tolerance of Crops through Appropriate Fertilizer Use Technologies***  
Dr. M. El-Fouly & Dr. El-Zanaty Abu El-Nour, Fertilization Technology Dept., National Research Centre – Egypt

**13hr: 15** **Closing Remarks**

**13hr: 30** **Networking Lunch**



**afa**





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# OPENING SESSION

Feb. 26 – 28, 2013

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## *Ramping Up Fertilizer Use in Sub Saharan Africa*

Mrs. Charlotte Hebebrand,  
 Director General, IFA - France

**Feb. 26 – 28, 2013**

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International  
Fertilizer Industry  
Association

## Fertilizer: “the world’s most important humanitarian product”

Charlotte Hebebrand  
Director General , IFA



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Cairo, Egypt,  
26-28 February 2013



**ANDREW YOUN**  
FOUNDER, One Acre Fund



[www.oneacrefund.org](http://www.oneacrefund.org)

www.oneacrefund.org

## Most of the world's hungry people actually *grow food as a profession*

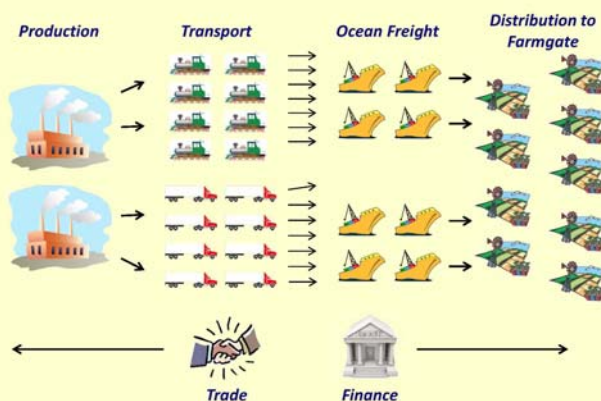
- Most of the world's hungry people are farmers, and their profession is to grow food
- They have land, abundant sunshine, rainfall, and equatorial climates
- But they are missing nutrients. Modern fertilizer and training double their farm income per acre

*Fertilizer is the world's most important humanitarian product*



www.oneacrefund.org

## What would the world's most important humanitarian army look like?



- ▶ The people in this room have already built the world's most important humanitarian army



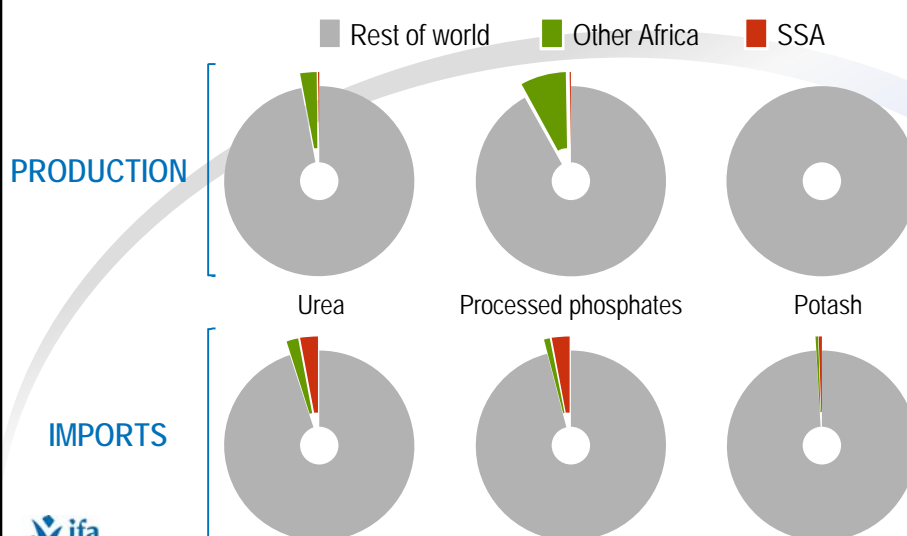


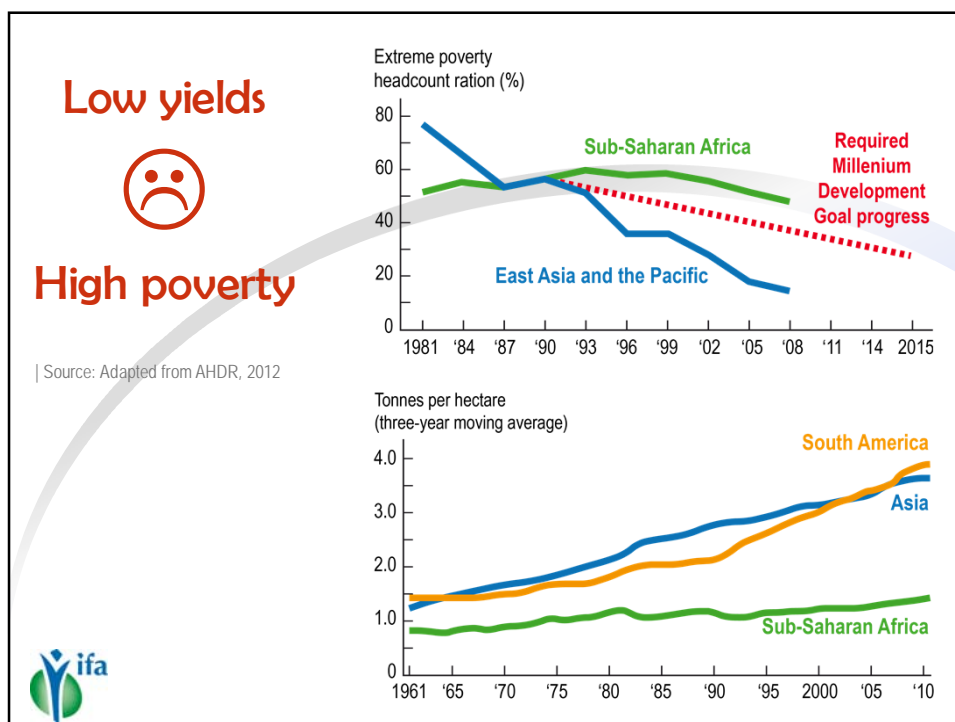
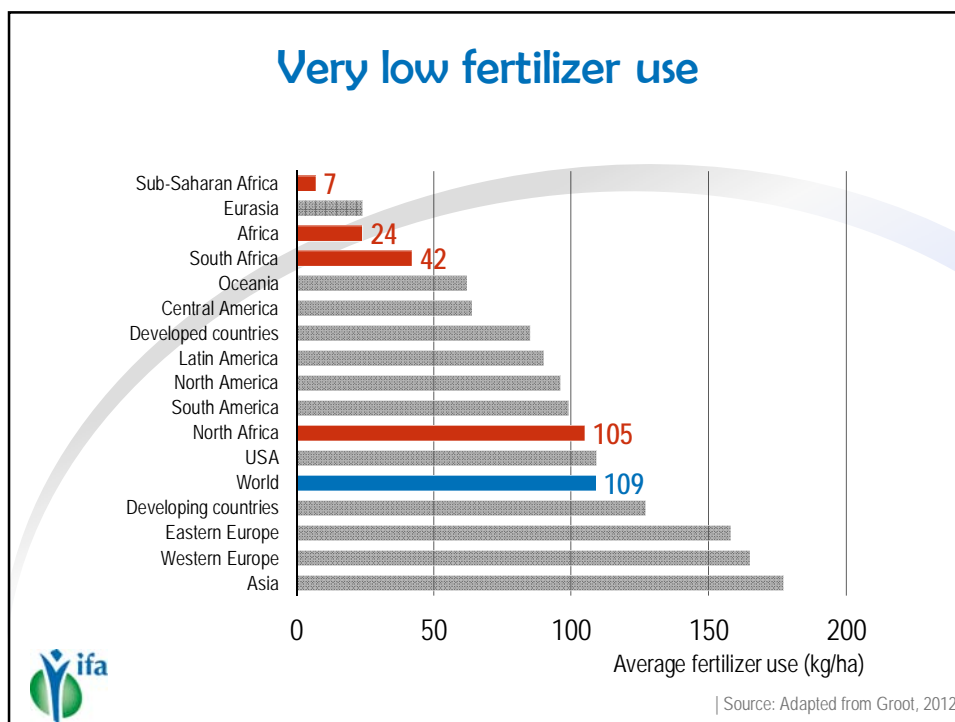
[www.oneacrefund.org](http://www.oneacrefund.org)

We just need to “micro-size” your army

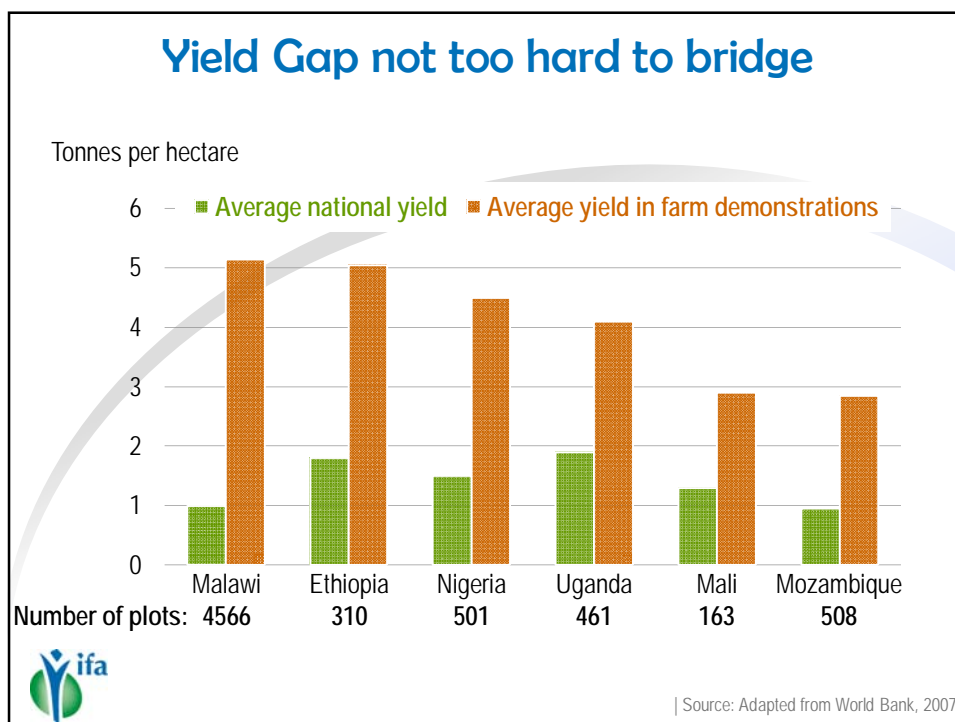
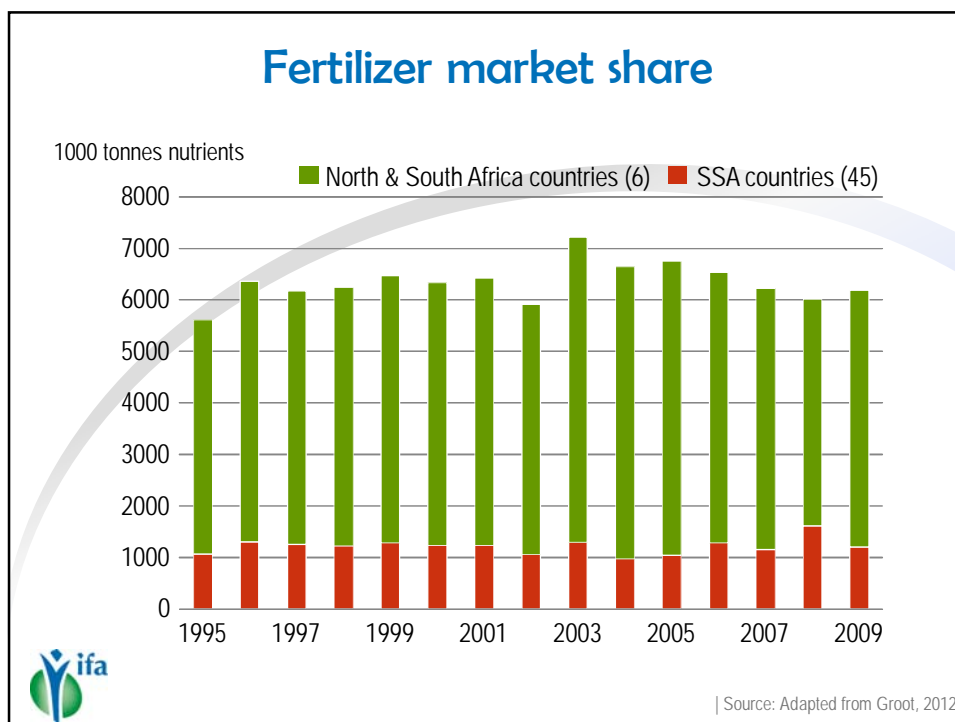


## World fertilizer production and imports contribution of Sub-Saharan Africa









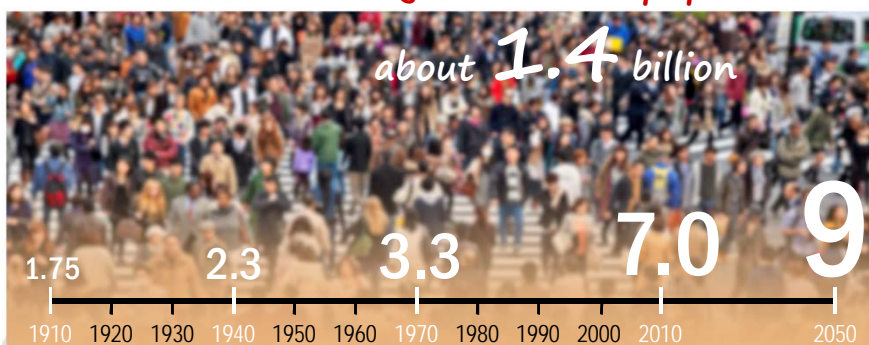
## The 2006 Abuja Declaration

To accelerate the timely access of farmers to fertilizers



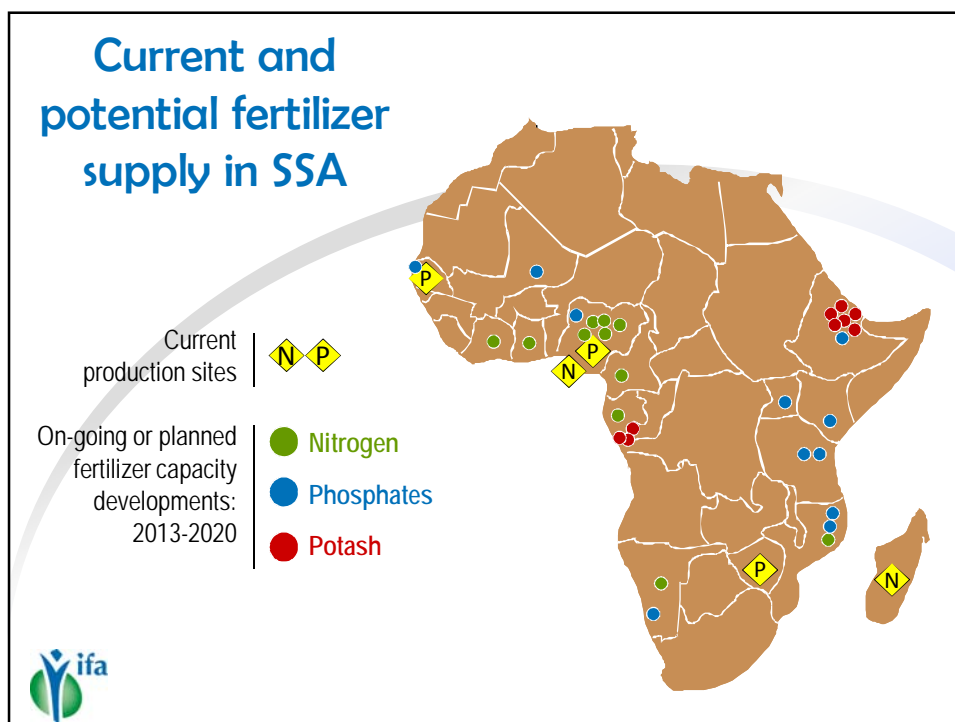
## What's different ? By 2025 SSA population

about 1.4 billion

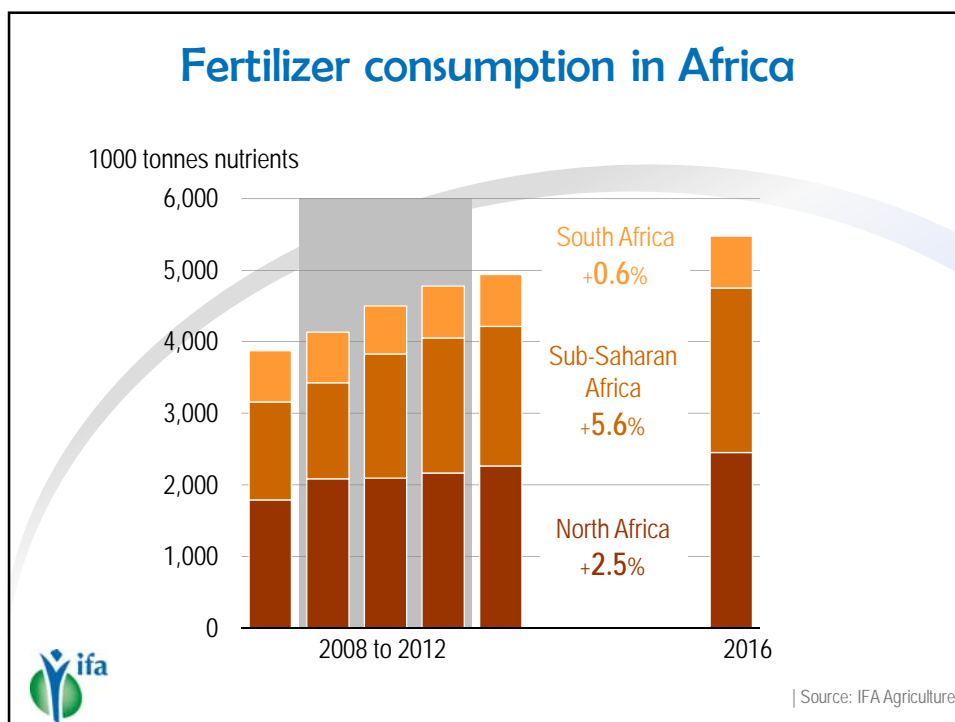
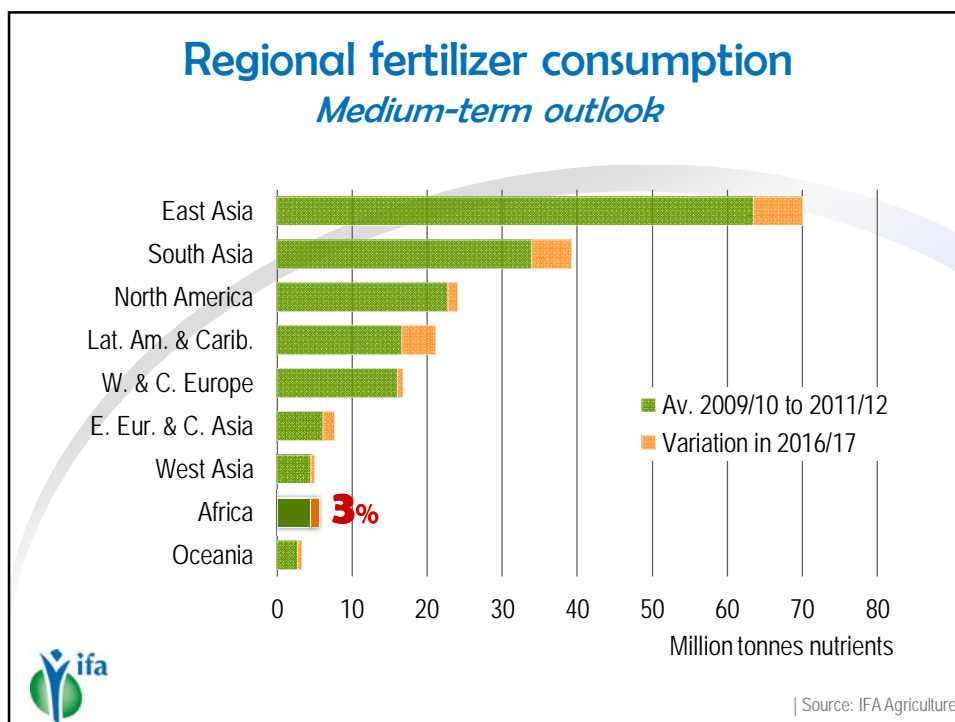


Global population explosion









## IFA's Africa strategy



✓ Market analysis

✓ Issue management

✓ Network facilitation

✓ Expertise sharing



| Photos: IFDC



## Feb. 26 – 28, 2013

## Savoy Sharm El Sheikh Hotel





## *Energy Saving is a Major Issue in Ammonia Revamps*

Mr. Jim Gosnell,  
 Vice President- Fertilizer & Syngas Technologies  
 KBR Technology - USA

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**



## ***Energy Savings in Ammonia Plants A Major Issue***

***Presented To: 19th AFA Annual Forum***

***Date: 26 February 2013***

***Location: Sharm El-Sheikh, Egypt***

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### ***Topics***

- » **A few Words about KBR**
- » **Brief History of Ammonia Business**
- » **Current Situation – Imminent Glut?**
- » **Options for Staying in Business**
- » **Summary Comments**

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## About KBR



- Revenue 2012 ~ \$8 Billion
- Backlog 31 Dec 2012 ~ \$15 Billion
- Headquartered in Houston, Texas
- Publicly traded on NYSE (“KBR”)
- 100+ years of operating history
- ~25,000 employees
- Operate in 45+ countries
- Extensive service capabilities:
  - Hydrocarbon Industry
  - Infrastructure & Government

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## Four Business Groups

**KBR**



### Four Business Units in Hydrocarbon Group

- Each BU has own Sales Force
- Each BU has own P & L responsibility

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## *Technology Business Unit Scope*

Technology Licensing

Basic Engineering Design

Support to Detailed Engineering

Proprietary Equipment & Catalyst

Plant Operations Management Systems

Training, Commissioning and Start-Up Services

Tech Services, Studies and Revamping



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## *Technology Sales and Operations*



**Sales & Representative Offices**

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# Technology Sales and Operations



# Technology Product Lines



Refining	Olefins	Chemicals	SynGas	Coal Gasification	Advanced Chem Eng	Proprietary Equipment
<ul style="list-style-type: none"> <li>• ROSE</li> <li>• HDS</li> <li>• FCC</li> <li>• VCC</li> </ul>	<ul style="list-style-type: none"> <li>• SUPERFLEX</li> <li>• SCORE</li> <li>• ACO</li> </ul>	<ul style="list-style-type: none"> <li>• Phenol</li> <li>• Aniline</li> <li>• SK-KBR JV</li> </ul>	<ul style="list-style-type: none"> <li>• Purifier</li> <li>• KRES</li> <li>• Reforming Exchanger</li> </ul>	<ul style="list-style-type: none"> <li>• TRIG</li> <li>Transport Gasifier</li> </ul>	<ul style="list-style-type: none"> <li>• OTS</li> <li>• OMS</li> <li>• Technical Services</li> <li>• APC</li> </ul>	<ul style="list-style-type: none"> <li>• Reactors</li> <li>• Furnaces</li> <li>• Custom Heat Exchangers</li> <li>• Vessel Internals</li> </ul>

**Seven Technology Business Lines  
Over 15 Technologies Licensed**

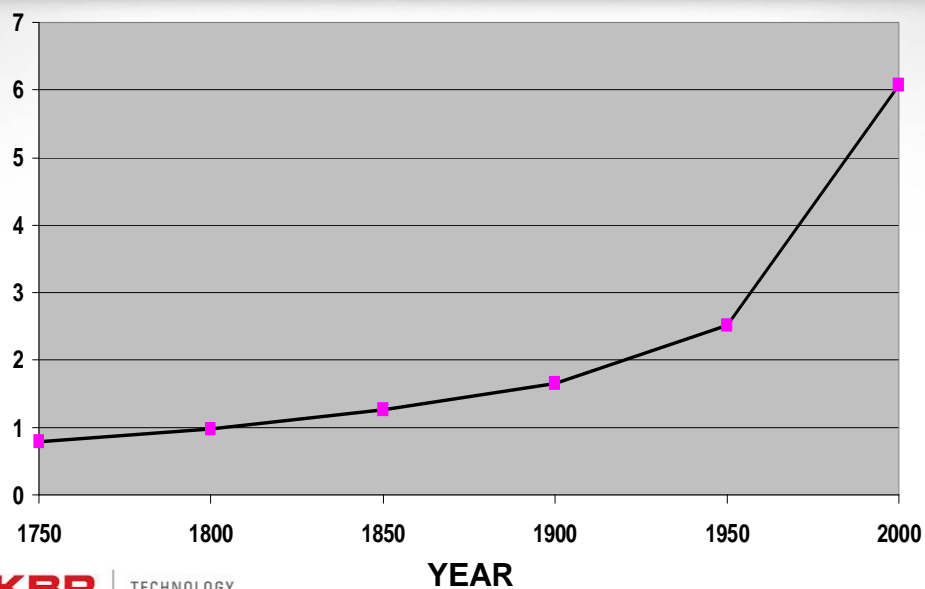
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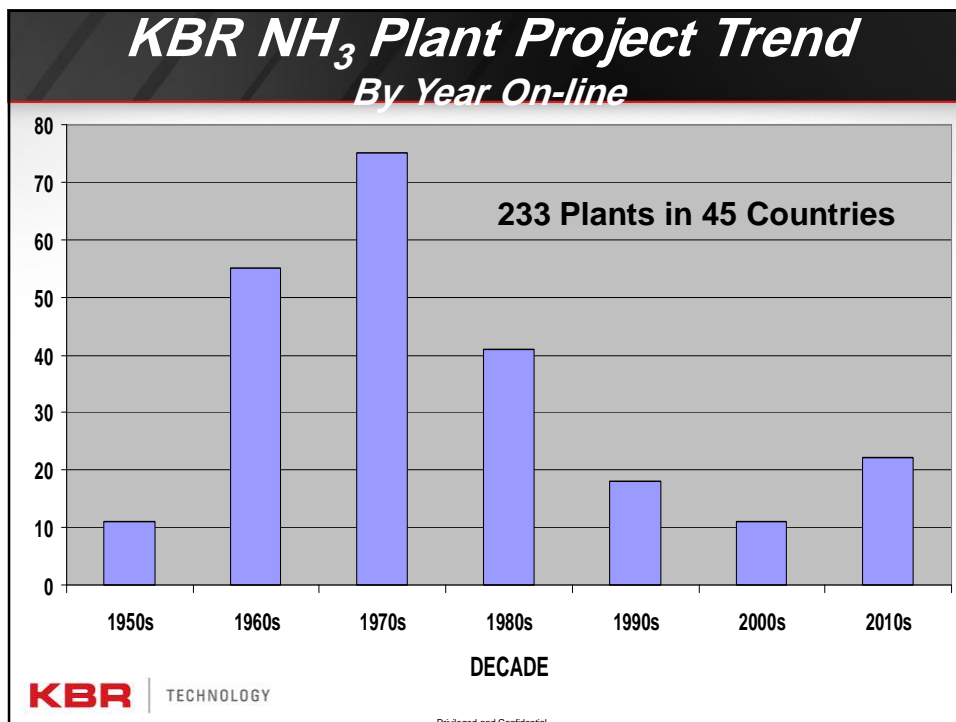
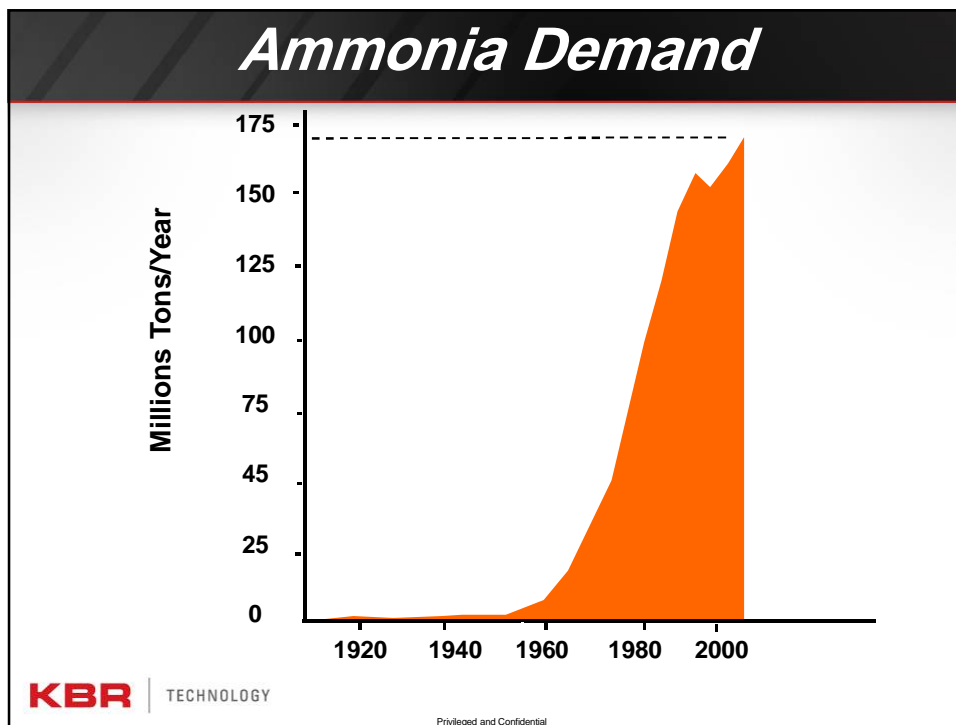
## Topics

- » A few Words about KBR
- » **Brief History of Ammonia Business**
- » Current Situation – Imminent Glut?
- » Options for Staying in Business
- » Summary Comments

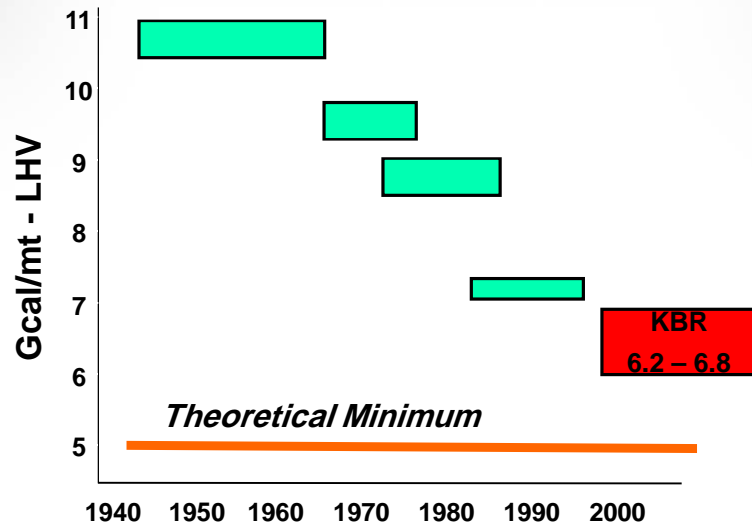
## World Population - Billions







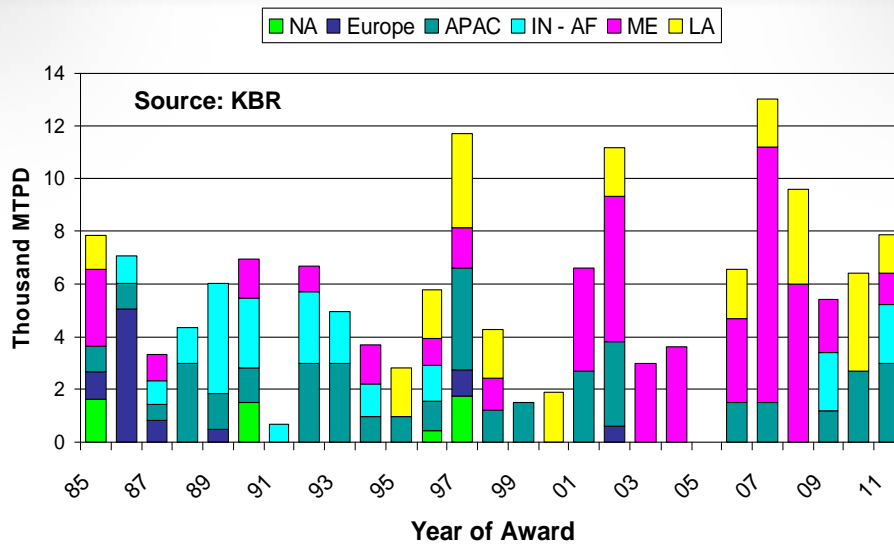
## Trend in New NH<sub>3</sub> Plant Energy Use



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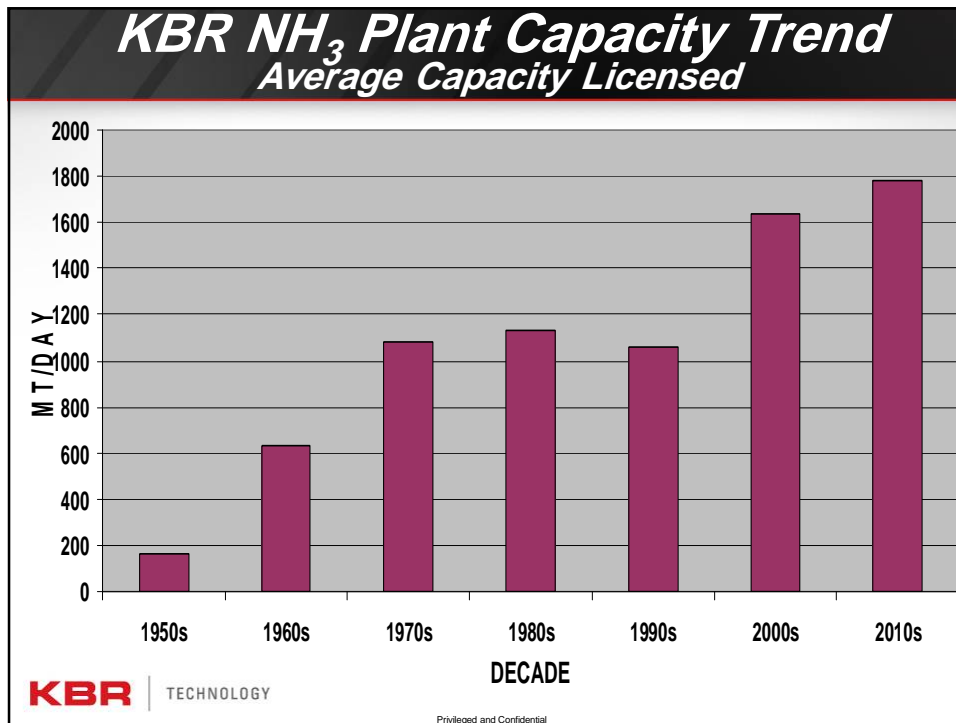
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## Ammonia Plant Capacity Addition by Region (Natural Gas Based Plants Only)



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### ***Summary of Business History***

- » 1960s & 1970s – build up in global capacity
- » 1980s – began an era of improving efficiency
- » 1990s – capacity added in low gas cost regions
- » 2000s – larger single train capacities

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## *Topics*

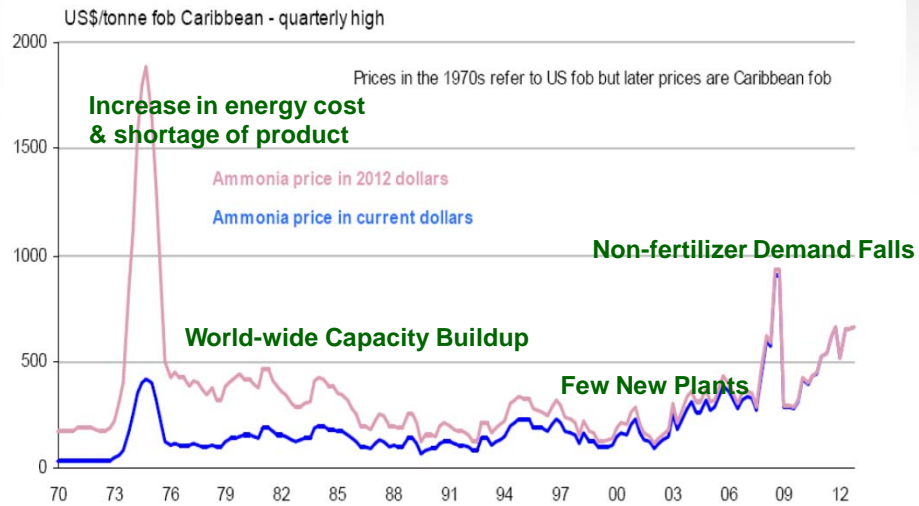
- » A few Words about KBR
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## *Implications of NH<sub>3</sub> Business History*

- » There are about 200 ammonia plants built prior to 1985 that are still operating
- » They compete with newer plants which:
  - Are more efficient
  - Have better economy of scale
  - Are built in regions with low-cost natural gas
- » These older plants are:
  - Technologically obsolete, but...
  - Financially viable due to current high fertilizer prices



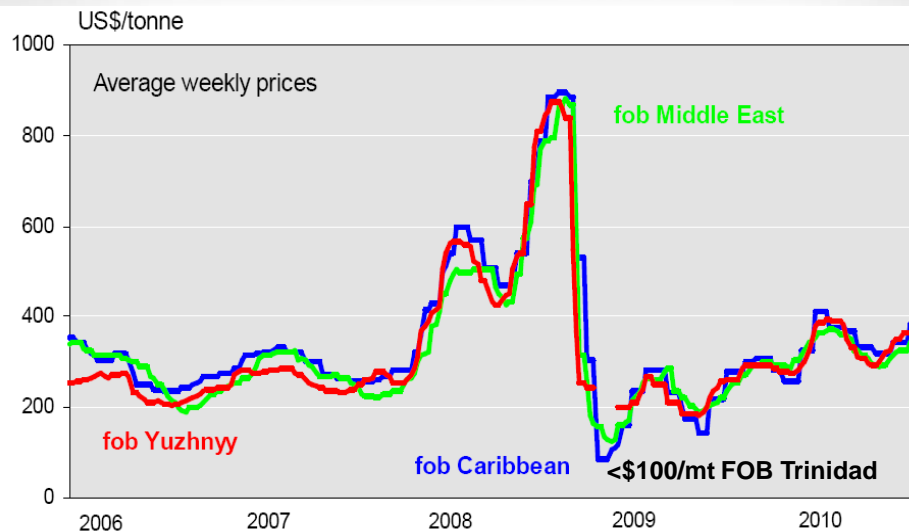
## Historical Ammonia Price (Fertecon – 3Q12)



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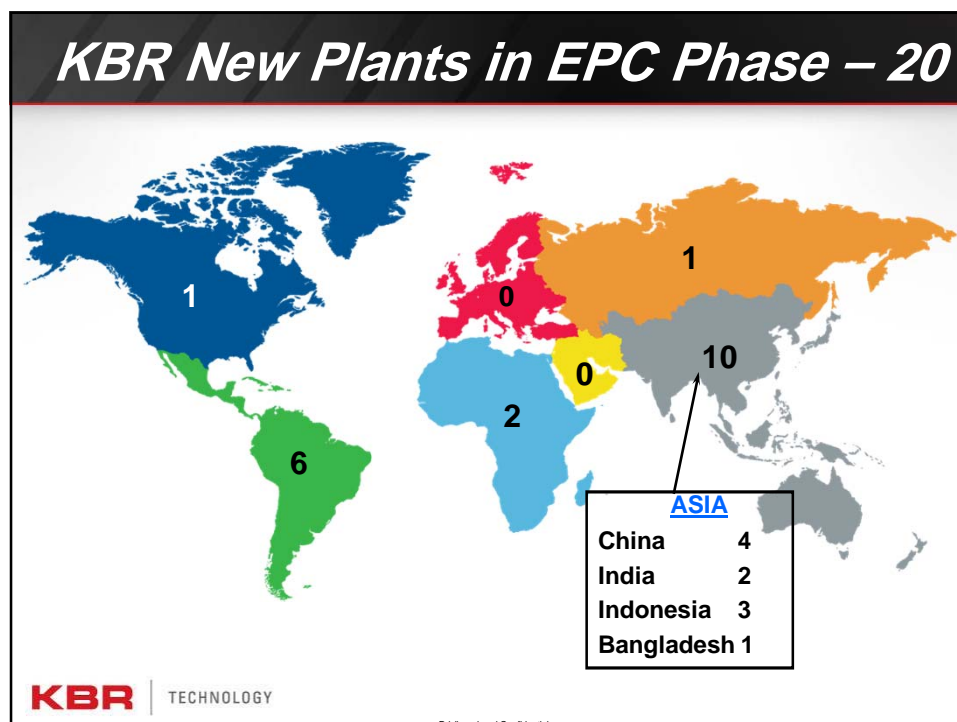
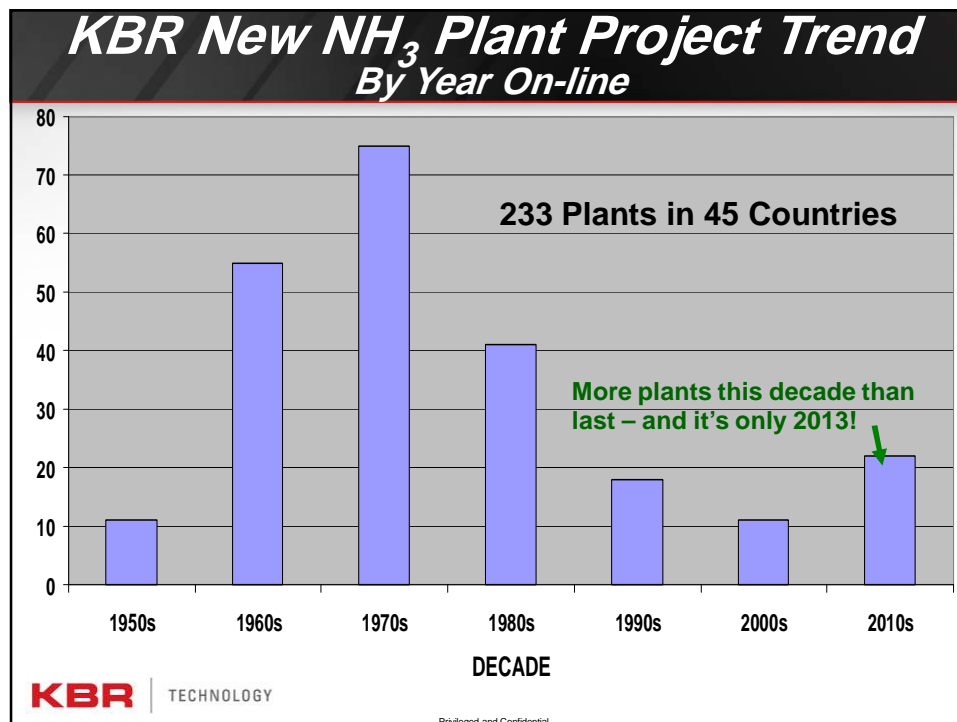
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## Recent History of Ammonia Prices (Fertecon)

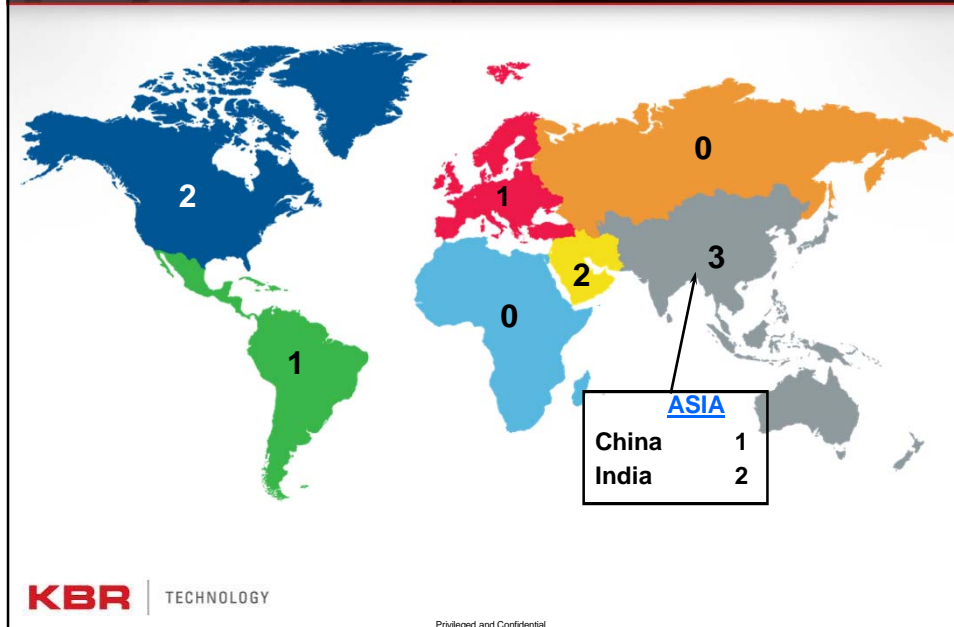


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## KBR Revamp Projects in EPC Phase – 9



## Summary of Current Situation

- » **A lot of capacity is scheduled to be added**
  - KBR currently has ~14 million t/a in EPC
  - Average annual demand increase is ~ 4 million t/a
- » **Shale gas in USA is a “game changer”**
  - More than 25 announced projects in N America
  - N America imports ~6.4 million t/a of  $\text{NH}_3$  which is about 1/3 the world trade & most of any region
  - N America imports ~6.2 million t/a of urea which is about 1/6 of world trade & 3<sup>rd</sup> most of any region
  - Where will this trade go when plants in NA start up?

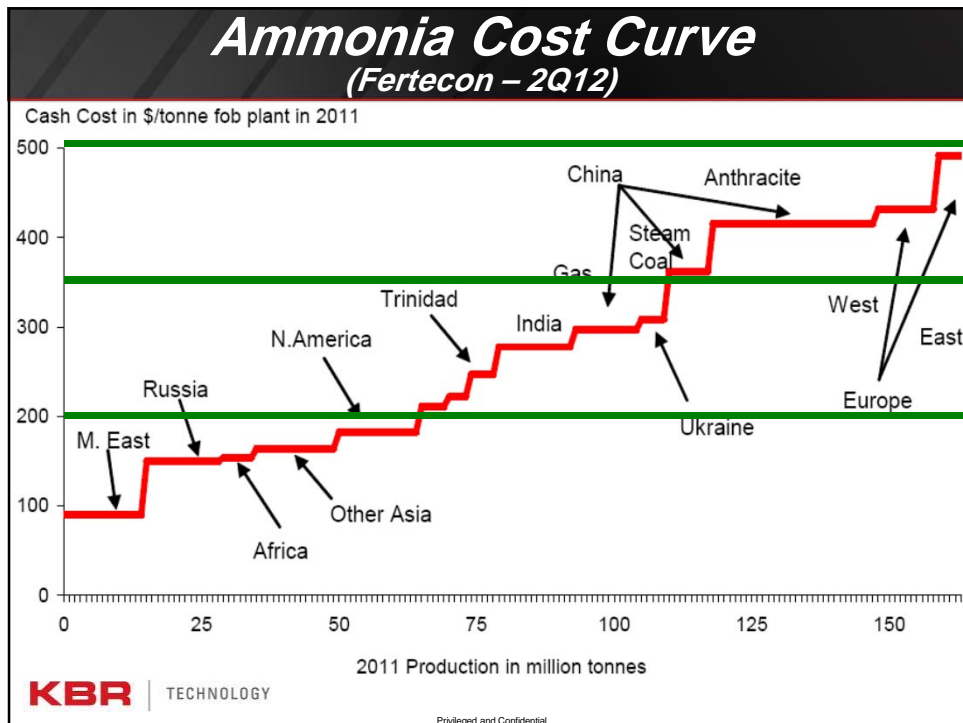
## *Summary of Current Situation (Cont'd)*

- » **Where will excess ammonia trade go?**
  - Ammonia price will fall
  - Financial pressure on high-cost producers
- » **What is the life expectancy of an NH<sub>3</sub> plant?**
  - Plants rarely shut down because of old age
  - With proper maintenance they last indefinitely
  - Plants close mainly because they become uneconomic
  - Are you prepared for the coming crunch?

## *Topics*

- » A few Words about KBR
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- » Summary Comments





## Only Two Ways to Cut Production Cost

- » **Reduce Fixed Operating Cost**
  - Increase capacity & spread cost over more tons/day
- » **Reduce Variable Operating Cost**
  - Decrease energy consumption
- » **Let's Look Briefly at Each**

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## *Fixed Operating Cost*

### » Consists of

- Operating labor
- Supervisory staff
- Overheads
- Insurance
- Maintenance



### » Typical Fixed Operating Costs

- \$20 to \$50/mt depending on capacity
- Can be reduced by capacity debottleneck
- Not a big component in total cost of production

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## *Variable Operating Cost*

### » Consists of

- Natural Gas
- Catalyst
- Chemicals
- Cooling Water
- Electric, Steam



### » Typical Variable Operating Costs

- Natural gas accounts for 75-90% of total
- Depends on gas price & plant efficiency

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## What Variable Opex Can I Afford?

### » From FOB Sales Price Deduct

- Net Profit (5%)
- Sales/marketing costs (5%)
- Fixed operating costs (\$35/mt)
- Taxes (5%)
- Depreciation if applicable



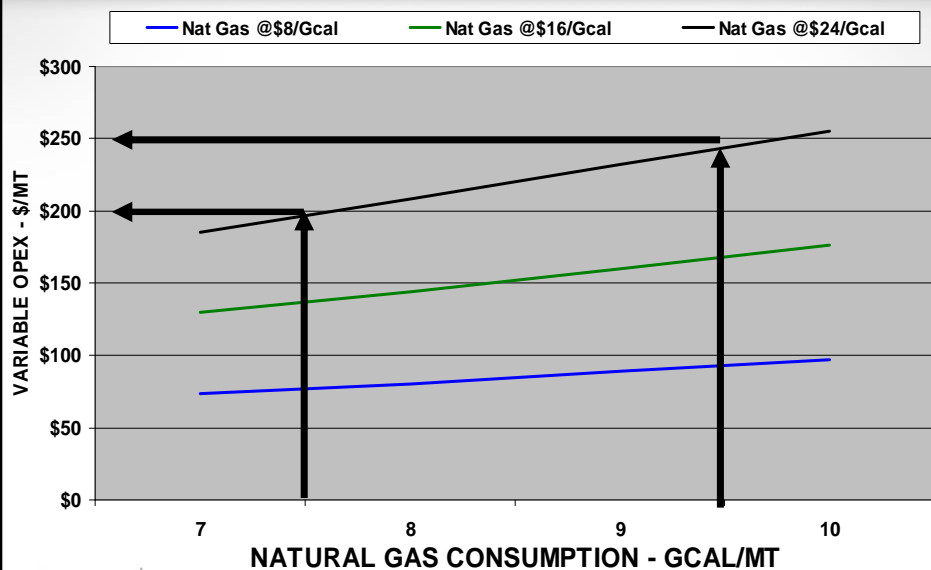
### » Example Calculation

- If sales price of ammonia is \$300/mt
- Assume a fully depreciated plant
- Then max affordable variable opex is ~\$220/mt

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## Variable Opex vs. Gas Usage



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## ***KBR Revamp Project Examples***

### » **Project #1**

- Yara Unit C, Sluiskil, The Netherlands
- Reduce energy & increase capacity

### » **Project #2**

- Liaohe, Panjin, China
- Reduce natural gas use by substituting coal for fuel

### » **Project #3**

- Nitrogenmuvek, Petfurdo, Hungary
- Reduce energy & increase capacity

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## ***Yara Revamp Project***

**Yara Site**



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## ***Yara Revamp Targets***

- » **Original capacity = 908 mt/d**
- » **Plant came on-line in 1971**
- » **Energy consumption = 8.43 Gcal/mt**
- » **Increase capacity to 1100 mt/d**
- » **Reduce energy use to 7.48 Gcal/mt**

## ***Yara Results***

	<u>Base</u>	<u>Target</u>	<u>Actual</u>
<b>Energy, Gcal/t (LHV)</b>	<b>8.43</b>	<b>7.48</b>	<b>7.43</b>
<b>Capacity, mt/d</b>	<b>908</b>	<b>1100</b>	<b>&gt;1100</b>

## ***Liaohe Revamp Project***



## ***Liaohe Revamp Targets***

- » Came on-line in 1976 at 1000 mt/d
- » Operating at ~1100 mt/d
- » Reduce natural gas usage at same mt/d
- » Replace expensive (& often unavailable) natural gas fuel with coal fuel
- » Solution – throw away primary & secondary reformers and install KRES

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## Liaohe Revamp Results

### GCal/Metric Ton - LHV

	Before Revamp	After Revamp
Feed Natural Gas	5.4	6.2
Fuel Natural Gas	3.8	0.3
<b>Total Natural Gas</b>	<b>9.2</b>	<b>6.5</b>
Coal-Fired boiler & other credits	0.0	2.1
<b>Total (excl. ASU)</b>	<b>9.2</b>	<b>8.6</b>

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## Nitrogenmuvek Revamp Project

Nitrogenmuvek  
Site



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## ***Nitrogenmuvek Revamp Targets***

- » Original capacity = 1000 mt/d
- » Came on-line in 1976
- » Operating at 1200 mt/d & 8.45 Gcal/mt
- » Increase capacity to 1650 mt/d
- » Reduce energy use to 7.70 Gcal/mt

## ***Nitrogenmuvek Results***

	<u>Base</u>	<u>Target</u>	<u>Actual <sup>(1)</sup></u>
Energy, Gcal/t (LHV)	8.45	7.70	TBD
Capacity, mt/d	1200	1650	TBD

(1) Project in EPC with expected startup in 2016



## Topics

- » A few Words about KBR
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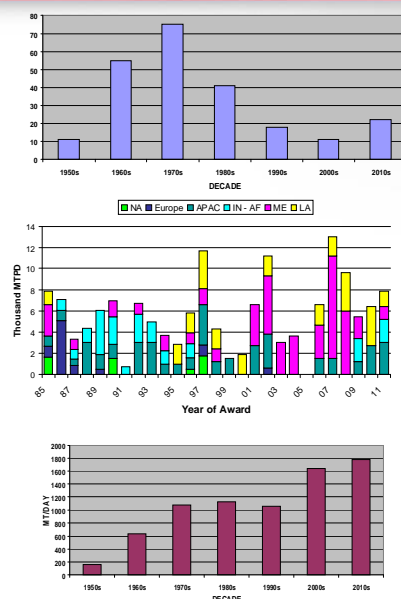
## History of Ammonia Business

**1970s - Big Build Up of Capacity**

**1980s – Plants become more efficient**

**1990s - Shift to low gas cost areas**

**2000s – Average capacity increases**



## Current Situation

Current NH<sub>3</sub> prices are high  
History shows that prices can crash when supply > demand



A lot of capacity will come on line in the next few years

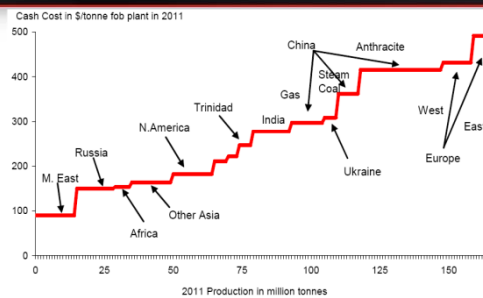


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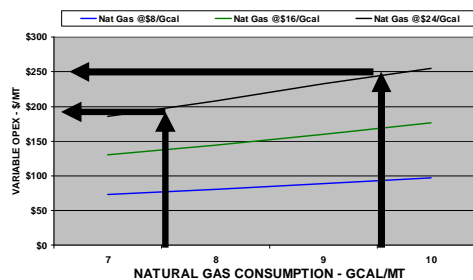
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## The Coming Price Squeeze

Where does your plant fall on the global production cost curve?



Can you get your variable Opex down to where your plant will survive?



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## ***KBR NH<sub>3</sub> Revamp Experience***

- » **KBR has completed several hundred revamp studies & projects**
- » **KBR has unique technology available to enable energy savings in ammonia plants**
- » **KBR has successfully reduced ammonia plant energy use down to the 7.5 Gcal/t range**

**KBR** | TECHNOLOGY

Privileged and Confidential





# *EU Trends in Fertilizer Regulation & Consumption*

Mr. Jacob B Hansen  
 Director General  
 Fertilizer Europe (EFMA), Belgium

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**




## EU Trends in Fertilizer Regulation & Consumption

Jacob B. Hansen  
19th AFA Annual Fertilizer Forum & Exhibition  
26-28 February 2013  
Cairo, Egypt



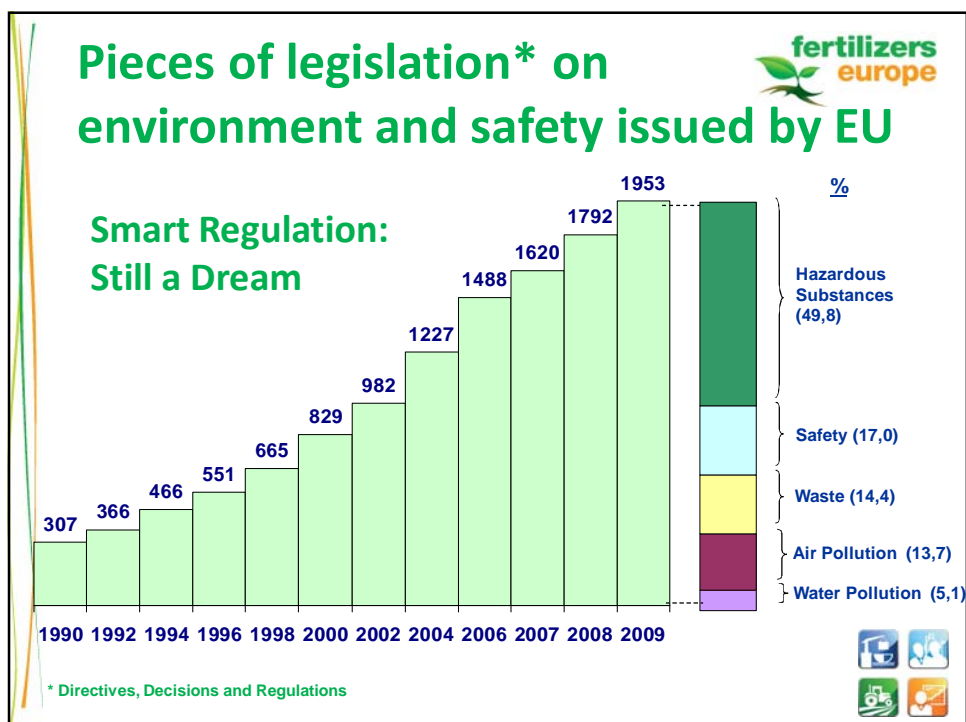
**Partnership  
for growth**  
Sustainable agriculture in Europe



## Contents

- ✦ Introduction
- ✦ EU Policy and Legislative Arena
  - Environmental and Safety Regulations
  - Fertilizer Regulation
  - Fertilizer security
  - EU Farm support
  - Emission Trading Scheme
- ✦ DAN fertilizers
- ✦ Fertilizers Europe Consumption Forecast 2012-2022
- ✦ Conslusions







## New Fertilizer Regulation



- There will be a full EU harmonization and no more national fertilizer legislations
- The new regulation will cover, for the first time, all product types contributing to crop nutrition whatever the origin (mineral or organic), fertilizers, soil improvers, growing media and bio-stimulants
- Organic fertilizer will grow in importance
- Re-cycling especially of phosphates will grow in importance
- Heavy metals, like Cd, will become an issue
- It will apply on imports



## Fertilizer security



- ✿ In general, EU rules are strict but the fertilizer industry can work with them. The industry itself has introduced a Product Stewardship Program which contains sensible security measures
- ✿ Accidents and terrorist acts can lead to new rules



## Fertilizers Europe Product Stewardship Programme



**Security measures related to the production, transport & distribution, storage, and trading of fertilizers**

- ✦ We recognize that nitrogenous fertilizers can be misused as precursors for making improvised explosive devices
- ✦ Our Stewardship Programme operates throughout the whole chain, from production to the farm
  - Production and warehouses including storage
  - Transport and distribution
  - Trading and sales
  - Farm
- ✦ Our Stewardship Programme has an analytical security plan which has to be respected by the Fertilizers Europe's members and provides advice on security to distributors and farmers



## EU farm support



- ✦ EU Farm Support is decoupled
- ✦ EU Farm Support under discussion; budget reduction of 3% decided plus redistribution from old to new member states
- ✦ The new proposal emphasizes the need for more “greening”:
  - 30% of direct aid to be contingent on performing environmentally friendly farming practices
- ✦ Attempts to support a “bringing science to the field”



## Emission Trading Scheme



- ✿ Goal for EU as a whole
  - emission reduction by 14% compared to 2005
- ✿ ETS – cap and trade system
  - power stations, oil refineries, iron and steel plants, cement, petrochemicals, ammonia and nitric acid sectors are covered by ETS
  - free emissions up to a benchmark, i.e. 10% best for each industry
  - above the benchmark the allowances need to be bought on the market
  - ETS sectors must reduce emissions by 21% compared to 2005 (50% more burden)
- ✿ Current state of affairs
  - Discussion on how to increase the low price of emission allowances



## Direct Available Nitrogen DAN fertilizers

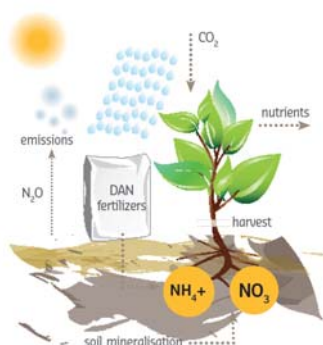


European society requires solutions:

- ✿ Higher productivity in European agriculture
- ✿ Better environmental protection
- ✿ Sustainable use of natural resources in agriculture



## Direct Available Nitrogen DAN fertilizers

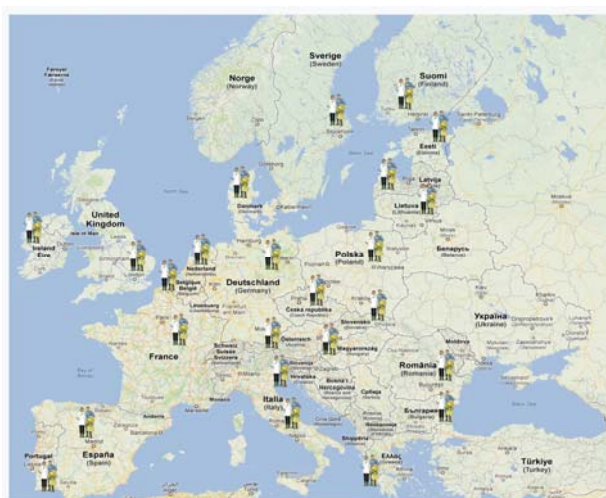


- Plants have to eat.
- We have to eat.
- Fertilizers feed half the global population.

NO<sub>3</sub> Nitrate  
NH<sub>4</sub><sup>+</sup> Ammonium

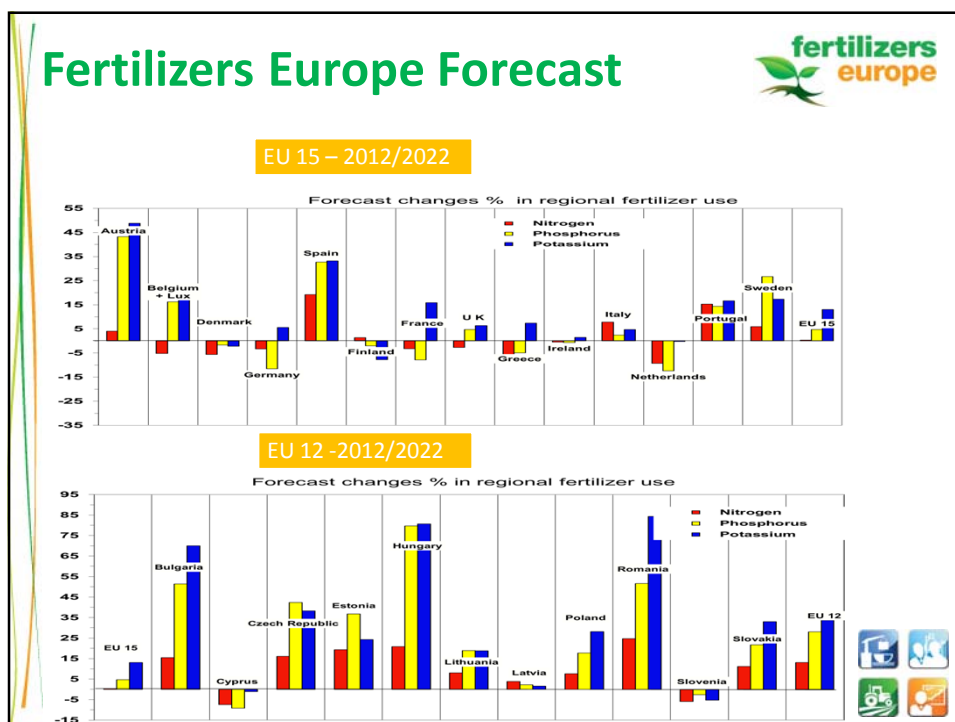
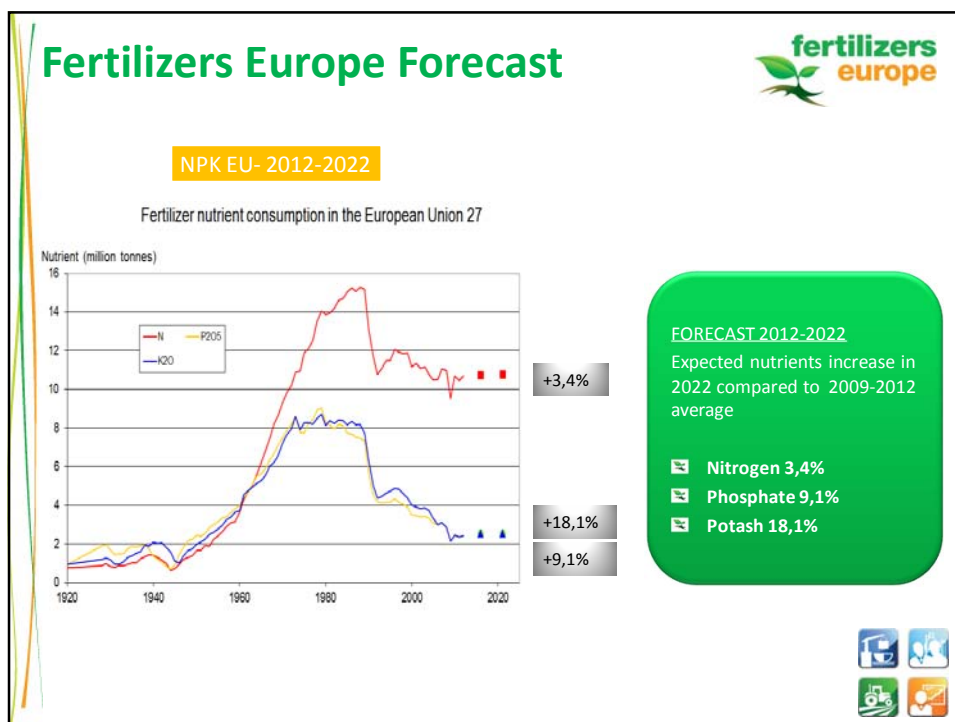


## DAN campaign in the EU

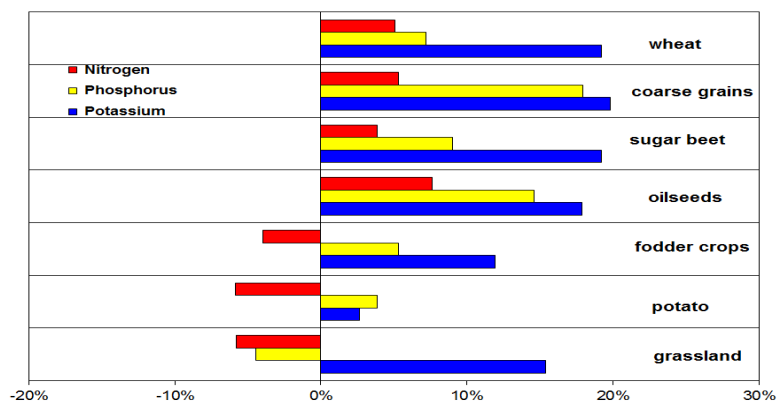


- Full roll-out across member states 4-8 March 2013.





## Forecast changes in fertilizer use by crop 2012-2022



## Conclusions



- ✿ EU has a clear orientation towards environmental protection
- ✿ The new EU fertilizer regulation will hopefully clarify the different functions of the various product categories (fertilizers, soil improvers, growing media, bio-stimulants) and maintain the quality of fertilizer products
- ✿ The EU farm support will be greener but hopefully there will be room for higher productivity
- ✿ Fertilizers Europe is responding with DAN campaign
- ✿ In our 10 years' forecast we see a positive trend in consumption of fertilizers – slow for nitrogen, decent for phosphate and good increase for potash







**Thank you!**  
[Jacob.hansen@fertilizerseurope.com](mailto:Jacob.hansen@fertilizerseurope.com)

 [www.facebook.com/fertilizerseuropepage](http://www.facebook.com/fertilizerseuropepage)

 [www.twitter.com/FertilizersEuro](http://www.twitter.com/FertilizersEuro)

 <http://www.youtube.com/user/FertilizersEurope>

 [Group Fertilizers Europe](#)

 [www.fertilizerseurope.com](http://www.fertilizerseurope.com)  
[www.productstewardship.eu](http://www.productstewardship.eu)  
[www.memberslounge.eu](http://www.memberslounge.eu)  
[www.danfertilizers.com](http://www.danfertilizers.com)

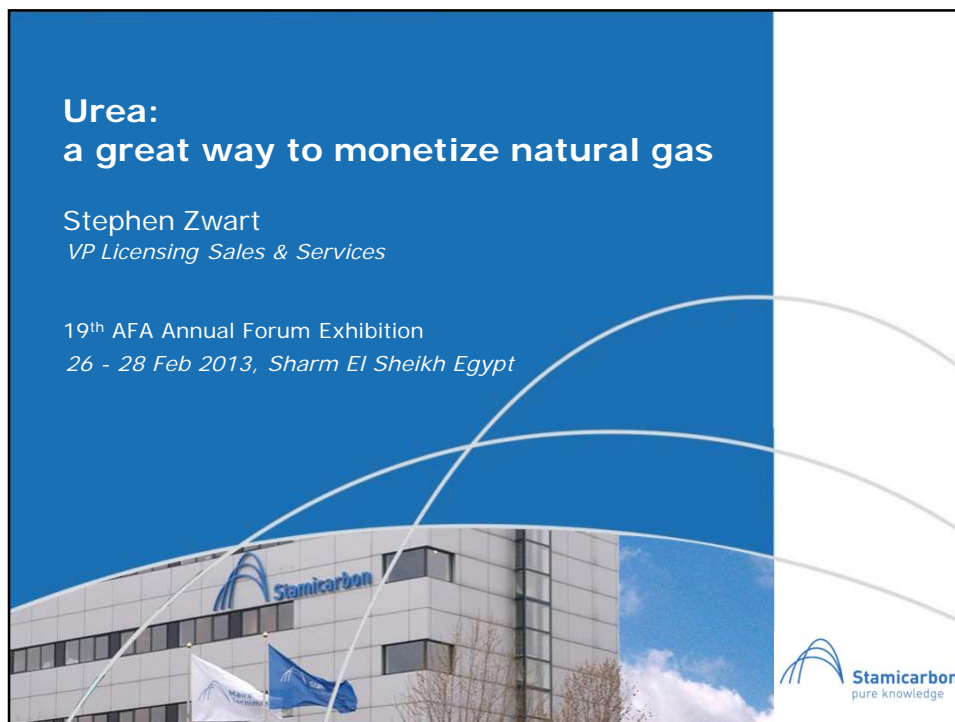
**Partnership  
for growth**  
Sustainable agriculture in Europe


# *Urea: a great way to monetize natural gas*

Mr. Steven Zwart  
 Stamicarbon , Netherland

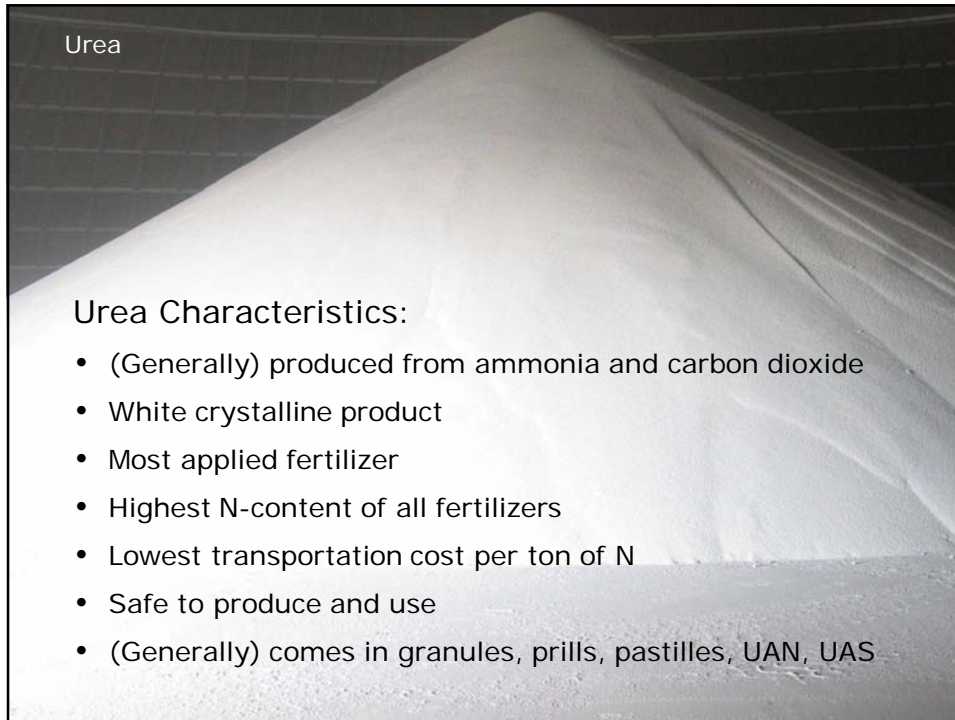
**Feb. 26 – 28, 2013**

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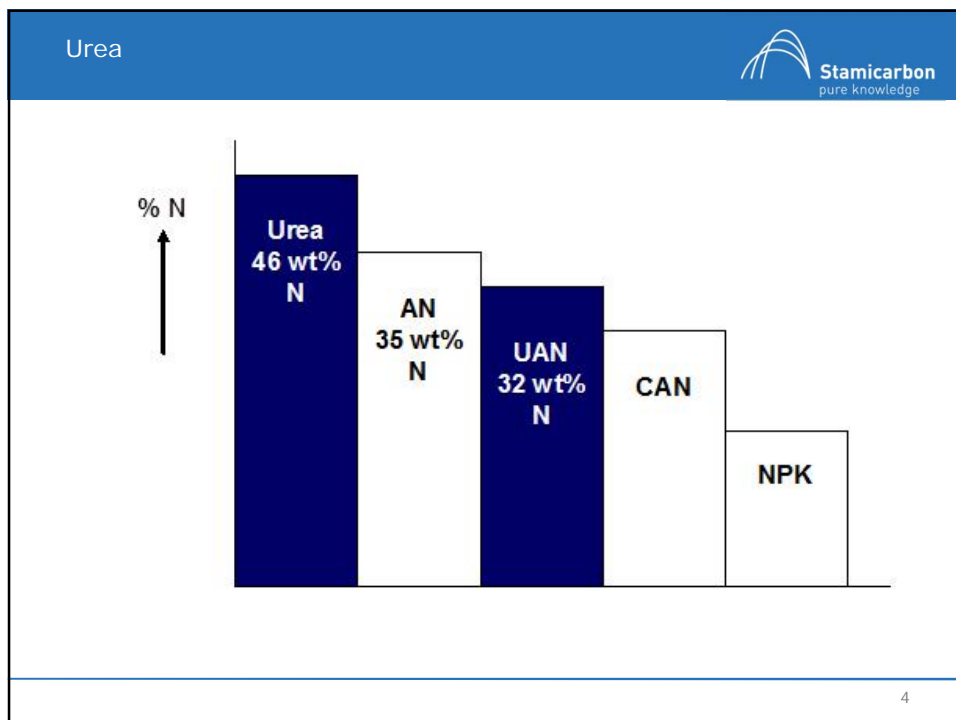
Agenda		
1.	Urea	
2.	The Urea Market	
3.	Operational Cost and Cost Break-down Urea Plants	
4.	Feedstock: Gas-to-coal parity pricing	
5.	Unconventional (Shale) Gas: a new Bonanza?	
6.	Where to Produce Urea	
7.	Stamicarbon's contribution to low cost of ownership	
8.	Carrying out a urea project	
9.	Conclusions	
		2

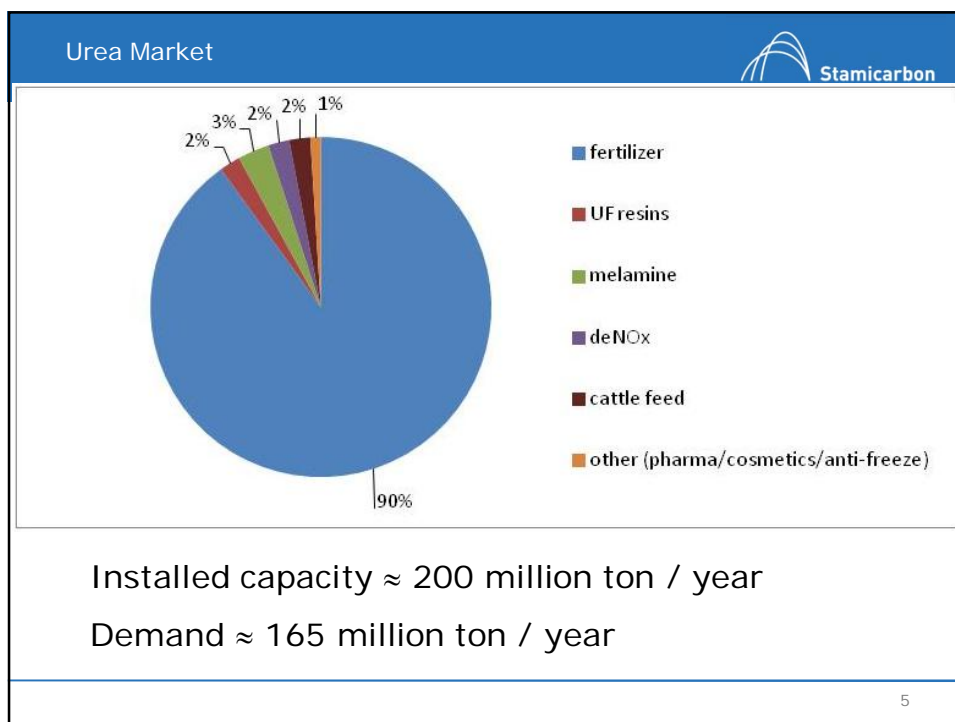
Urea

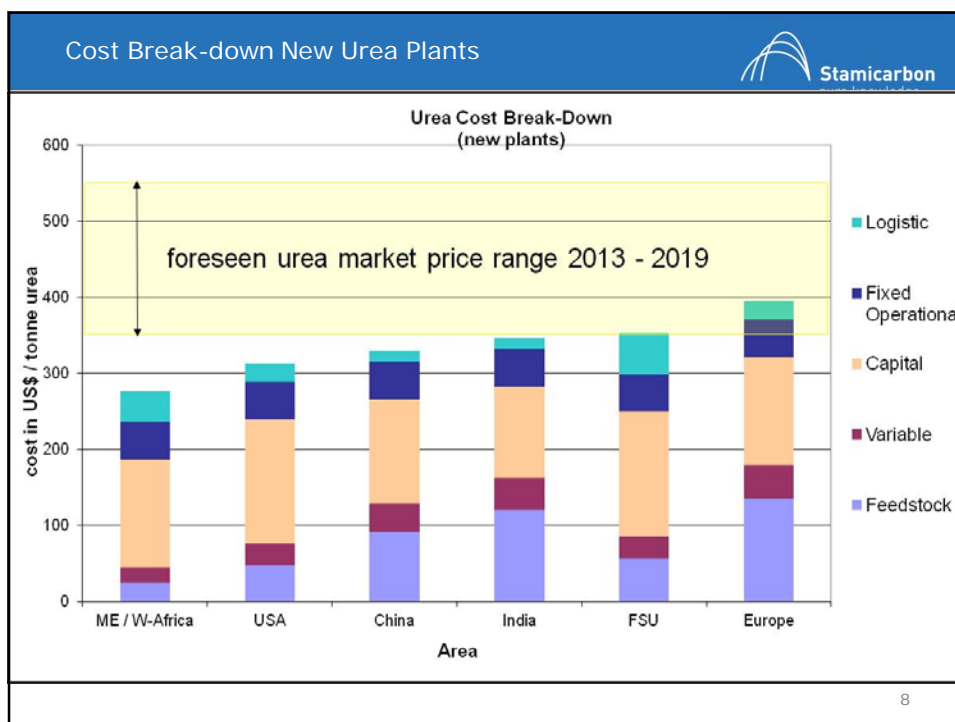
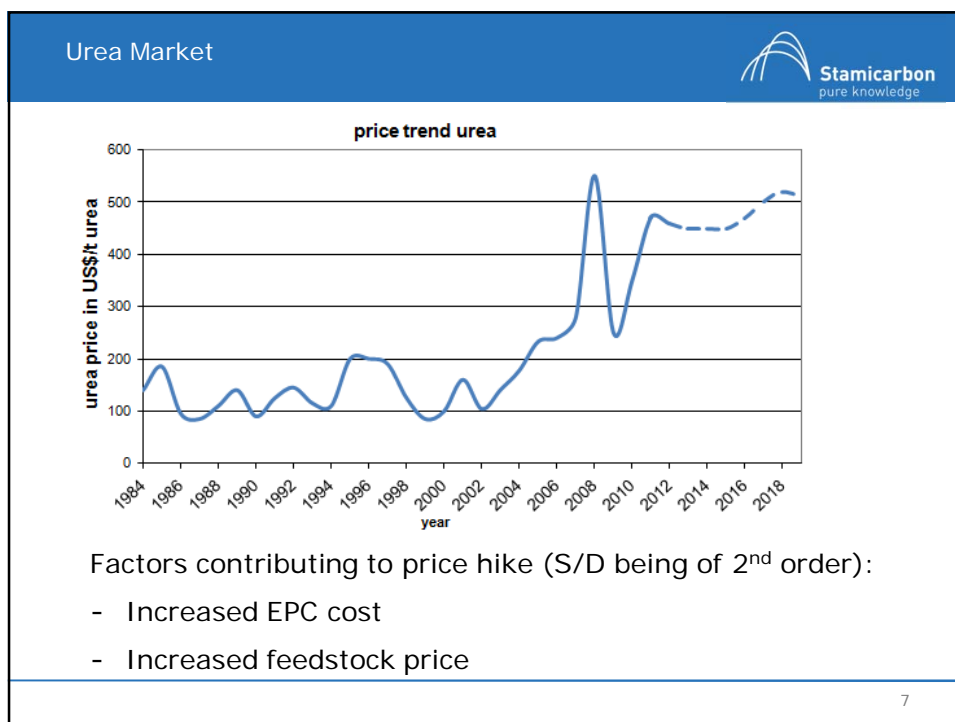


**Urea Characteristics:**

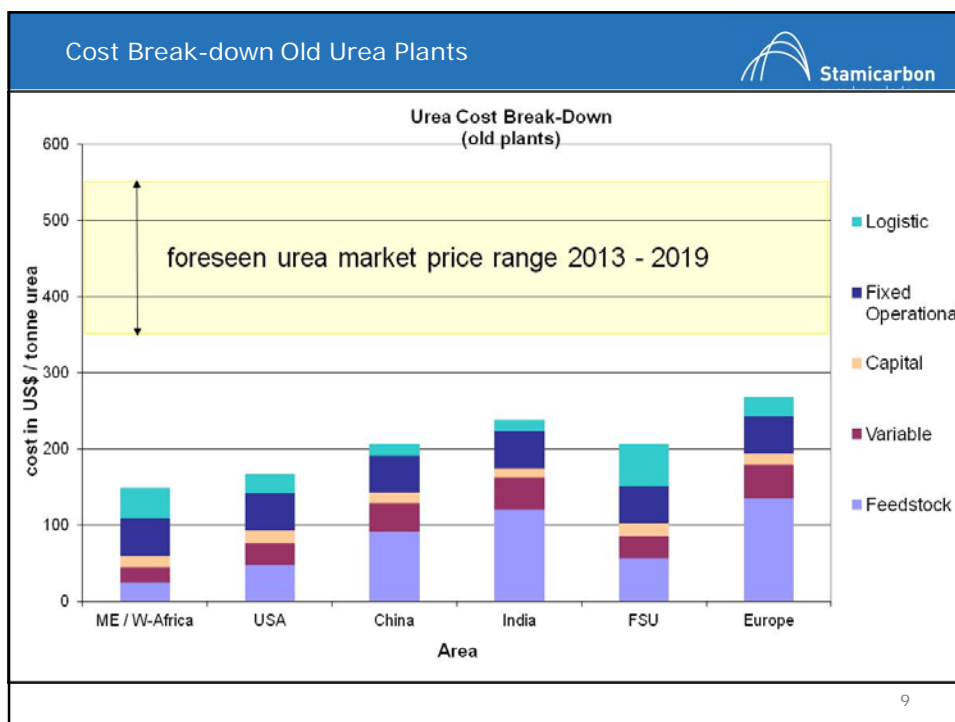
- (Generally) produced from ammonia and carbon dioxide
- White crystalline product
- Most applied fertilizer
- Highest N-content of all fertilizers
- Lowest transportation cost per ton of N
- Safe to produce and use
- (Generally) comes in granules, prills, pastilles, UAN, UAS











Operational Cost Urea Plants

Effect of natural gas price on urea plants:

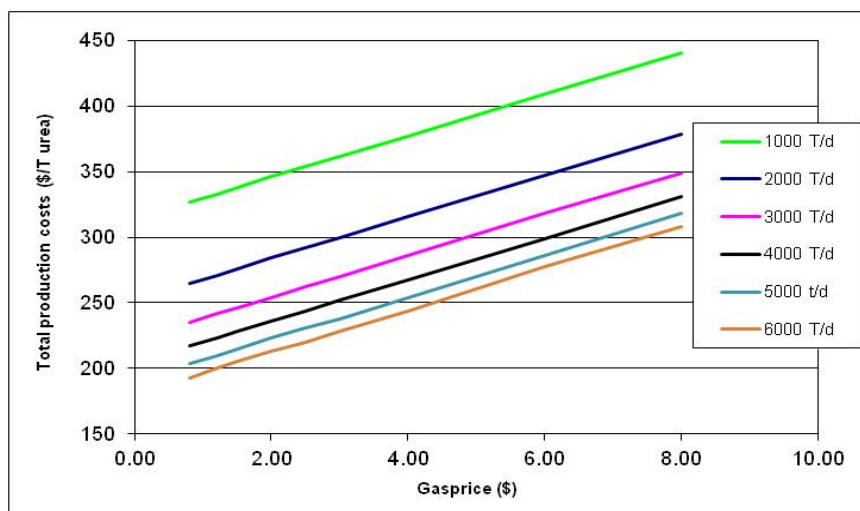
Cost factor	Example 1: gas cost = 1.5 US\$ / MMBTU		Example 2: gas cost = 7US\$ / MMBTU	
	Per ton amm.	Per ton urea	Per ton amm.	Per ton urea
Natural gas	42	24	196	111
Other variable ammonia	7	4	7	4
Fixed operational ammonia	52	29	52	29
Capital fixed assets ammonia	147	83	147	83
<b>- Sub total ammonia</b>	<b>248</b>		<b>402</b>	
Variable urea		17		35
Fixed operation urea		20		20
Capital fixed assets		59		59
<b>- Sub total ammonia/urea</b>		<b>236</b>		<b>341</b>
Working capital		3		3
<b>- Total urea ammonia/urea</b>		<b>US\$ 239</b>		<b>US\$ 344</b>

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## Operational Cost Urea Plants



## Economy of scale: production versus gas price

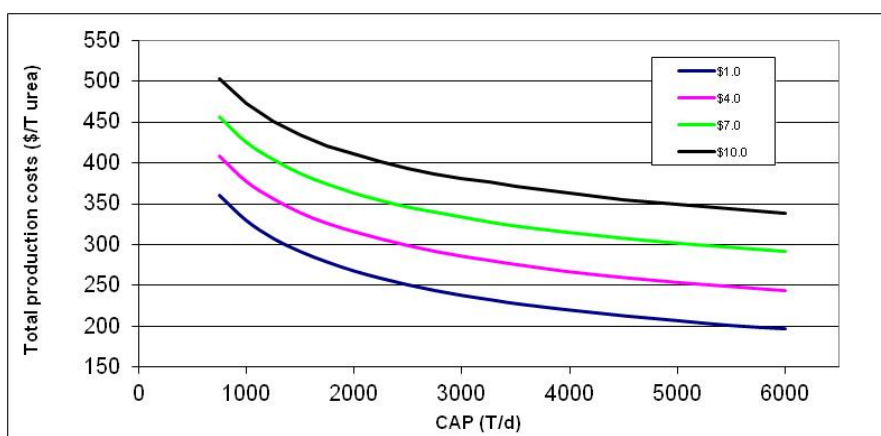


11

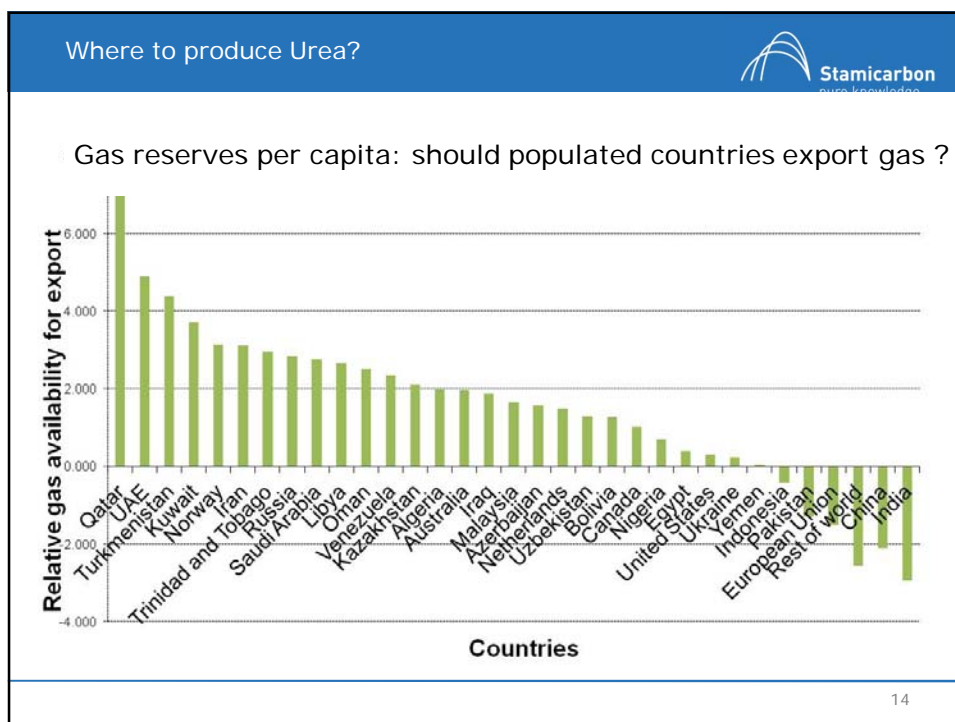
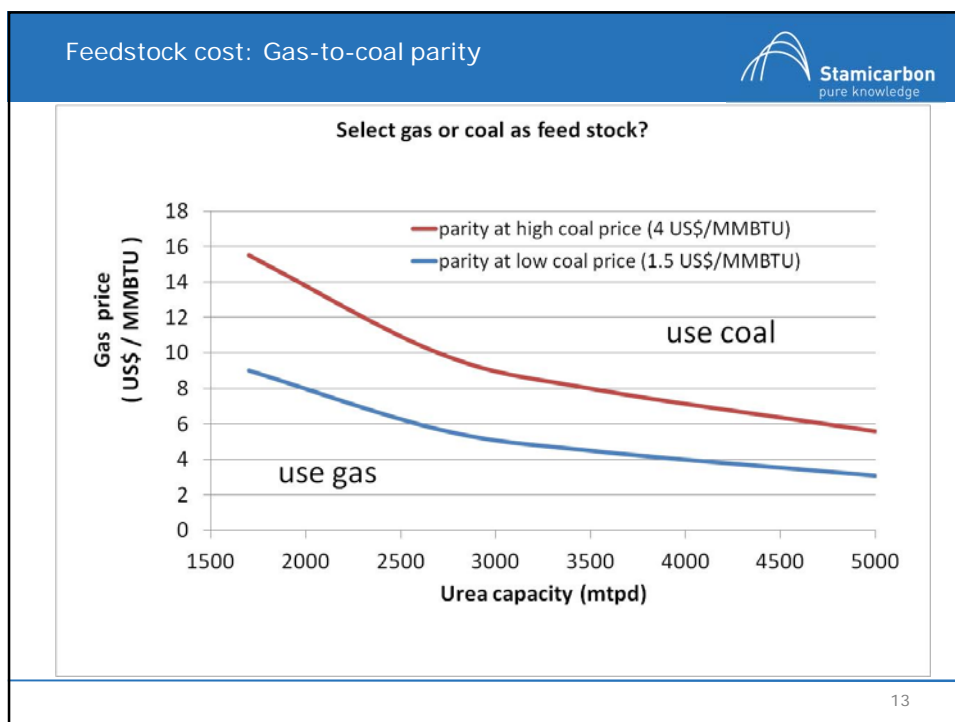
## Operational Cost Urea Plants



## Economy of scale: production versus capacity



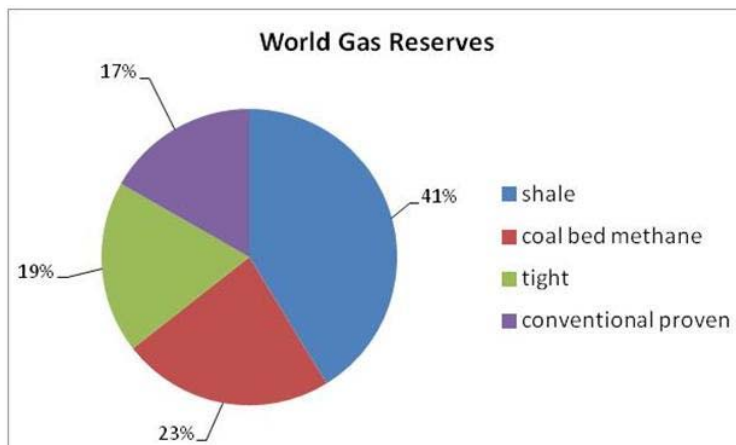
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## Where to produce Urea?



## Unconventional gas reserves: a safeguard for the future?

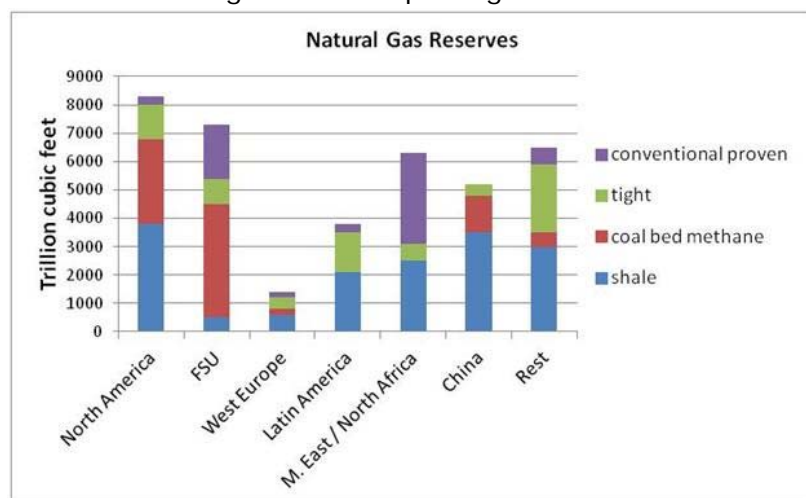


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## Where to produce Urea?



## Unconventional gas reserves per region

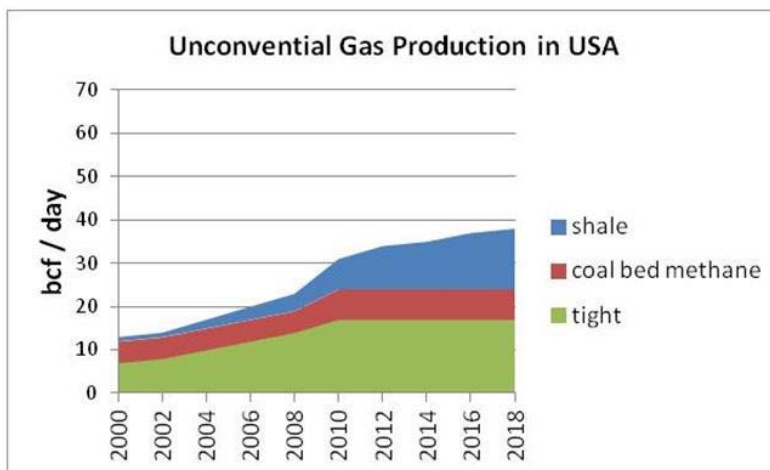


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## Where to produce Urea?



Example: USA: tripled use of unconventional gas in a decade

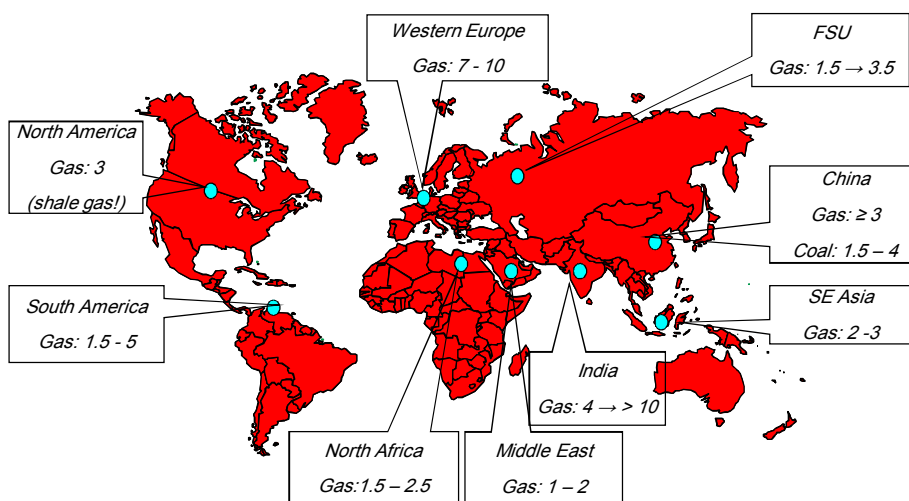


17

## Where to produce Urea?



Feed stock price (in US\$/MMBTU) in different parts of the world



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### Where to produce Urea?



Urea should be produced where;

- Feedstock (preferably gas) comes at a fair price
- Feedstock reserves per capita are large
- Unconventional gas reserves are developed
- In landlocked areas (advantage of logistic factor)
- Initial investments have been paid off (e.g. in old plants)
- Where urea monetizes better than other gas derivatives (e.g. LNG, GTL, Power, Methanol, Gas export through piping)

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### Stamicarbon's contribution to low cost



Technology is not a mere qualifier;

It's a cost competitive differentiator

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Stamicarbon's contribution to low cost of ownership



Urea2000<sup>plus</sup>™ technology: low skyline plants

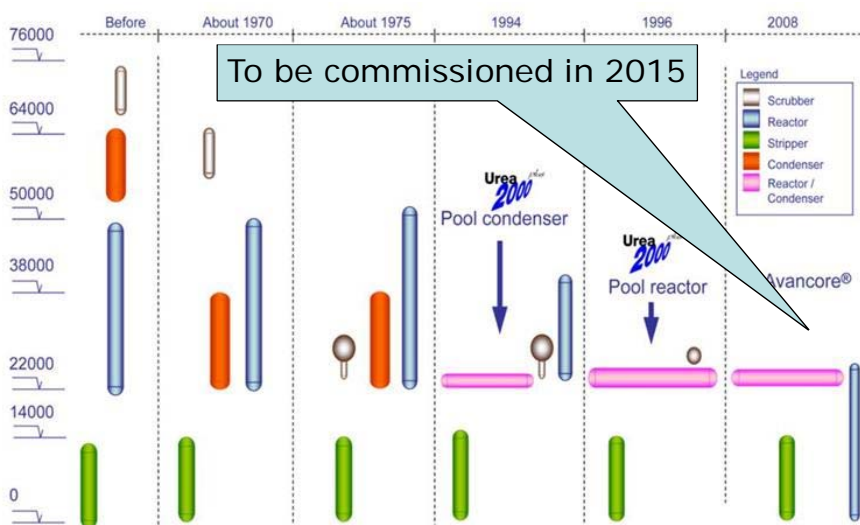


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Stamicarbon's contribution to low cost



Avancore® technology: lowest elevation plant



22

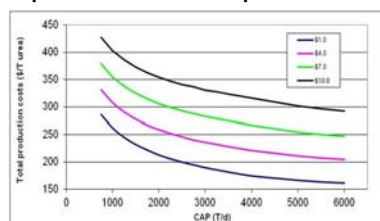
## Stamicarbon's contribution to low cost of ownership



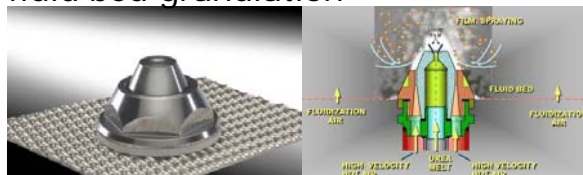
## Safurex® stainless steel



Economy of scale:  
up to 6000 mtpd urea



Film spraying  
fluid bed granulation



23

## Carrying out a urea project



- Allocation of gas (or other feed stock) to urea
- Feasibility study
- Start arranging permits
- Engage with lenders, equity suppliers, off takers, gas supplier and authorities
- Develop tender documentation or ask "what's on the shelves"
- Develop financing package
- Bidding
- Negotiation and contracting
- Financial closure, contract effectuation

Time: 33 months is possible; many projects need more!

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## Conclusions (1)



- Urea Market grows steadily with  $> 3\% \approx 6$  mtpa, main drivers being population growth, improving diet and niche applications
- Capex has more than doubled in the past decade; together with the increased gas prices this has been factored in the urea price.
- Urea price expected to float in 350 – 550 US\$ range in coming years
- Coal can be economical in large plants if gas price  $> 5$  US\$/MMBTU
- Shale gas has caused a shift in balance of power for USA producers
- Urea can be a great way to monetize natural (un)conventional gas if:
  - available at fair cost
  - gas reserves per capita are large
  - in land locked areas with logistic benefits
  - initial investments have been paid off (e.g. in old plants)

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## Conclusions (2)



- Economy of scale pays off, all the way to 6000 mtpd urea
- Stamicarbon has distinct urea technologies that contribute to low cost of ownership.

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www.stamicarbon.ru

info@stamicarbon.com – www.stamicarbon.com

# *Prospects for the Potassium Chloride Market*

Mr. Paul Burnside  
 Manager: Fertilizer Analysis Products  
 CRU, UK

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**



THE INDEPENDENT AUTHORITY  
MINING | METALS | FERTILIZERS

# Prospects for the Potassium Chloride Market

Paul Burnside

Manager, Fertilizer Analysis Products  
Principal Consultant, Potash

Arab Fertilizer Association Conference, Sharm el-Sheikh, February 2013

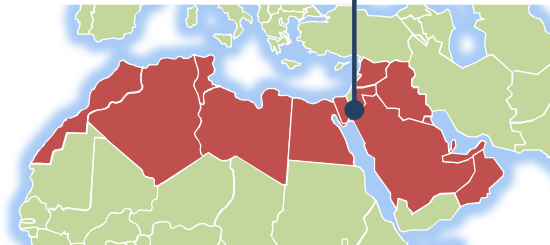
## Outline



- ❖ Potash in the Middle East & North Africa (MENA)
  - ❖ Demand prospects in India & China
  - ❖ Global potash outlook



Dead Sea: source of 10% of the world's KCl



AFA Member Countries

- Expansion constrained by available pond area
- Opportunities to improve recovery or prevent mill bottlenecks



Arab Potash, Jordan



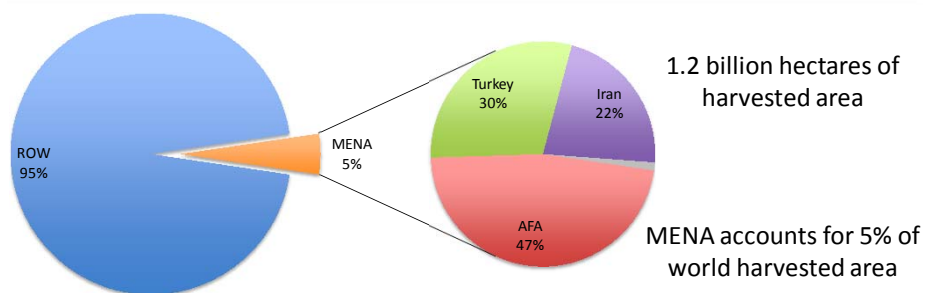
ICL Group, Israel

- New 450,000t/y plant completed in 2011
- Total capacity now 2.45Mt
- Exports via Red Sea (Aqaba)
- Capacity estimated at now 4.1Mt
- Exports via Red Sea (Eilat) and Mediterranean (Ashdod)

CRU THE INDEPENDENT AUTHORITY  
MINING / METALS / FERTILISERS

## Regional agriculture and potash demand

CRU



MENA 14% of world MOP demand in 2012

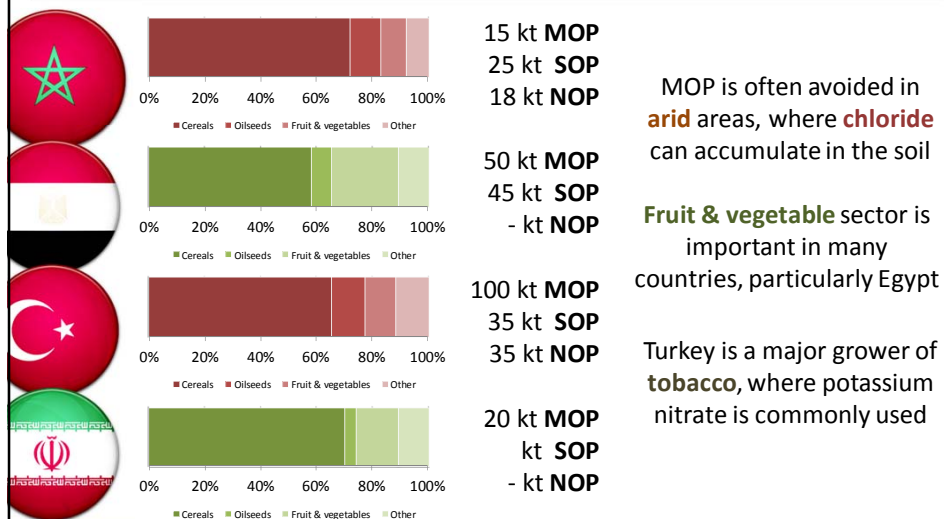
Jordan & Israel → 68% of regional demand

North Africa → 7% of regional demand

The regions also consumes other forms, esp. potassium sulphate and NPKs

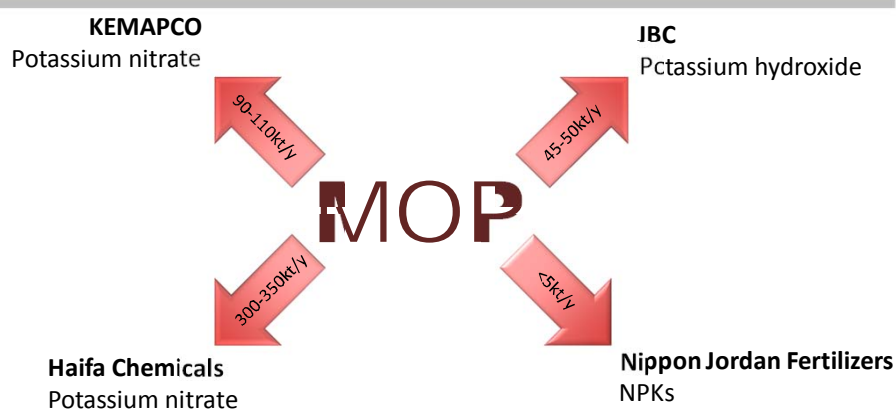
## Regional agriculture and potash demand

CRU



## Production of potash derivatives

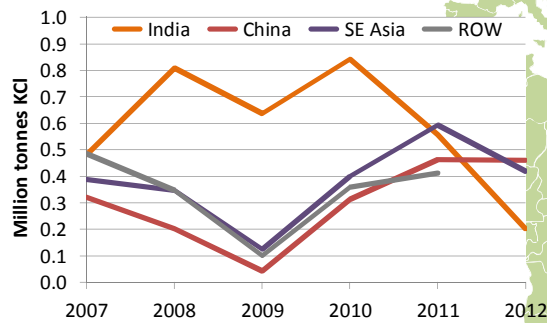
CRU



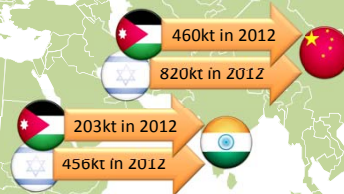
- Also minor production of potassium sulphate in Egypt, Jordan and Saudi Arabia
- Demand from oil & gas industry for drilling mud additives

## Jordan's export markets

Jordan has become less dependent on India...  
...more sales to China and Indonesia



250-350,000t contracted with China for H1 2013



## India subsidy system

CRU

Back in **April 2010**, India changed its subsidy system

The new **Nutrient-Based Subsidy** made payments according to N, P, K content instead of being set for each product...  
...but it also removed **MRP for P&K**

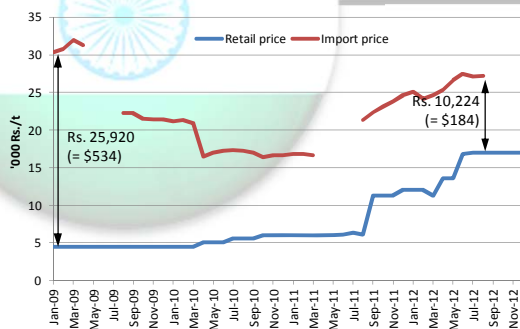
*i.e. subsidy is now fixed, with prices floating...  
...this is OK if subsidy is enough to protect retail prices*

Govt cut subsidy for 2011/12 by **\$20/t**...  
...then new contract saw import price rise by **\$100/t**  
...bad news for consumption

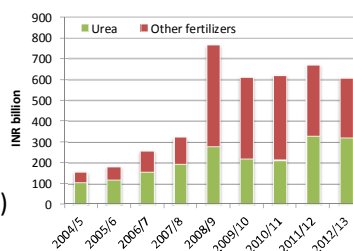


## India prospects

CRU



Retail prices have quadrupled...  
...consumption has slumped...  
...urea still \$100/t



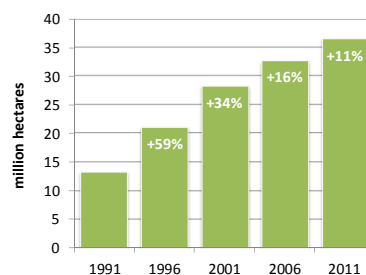
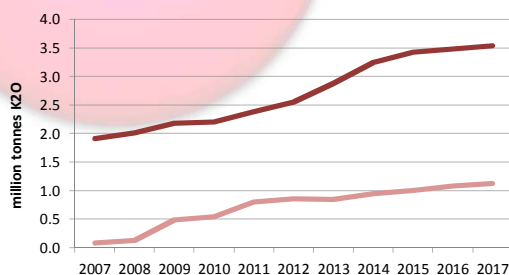
- Rupee is up in 2013, but still low  
...hit 57/\$ in June, now 53/\$
- Import price has been cut to **\$427/t CFR**
- Will this be passed on to retail prices (-Rs. 3,340)  
...or will govt try to cut subsidy?

## China prospects

CRU

- Higher domestic MOP production
- Competition from other potash fertilizers

- Switch to fruit & veg crops slowing



Coupled with higher prices...  
...demand growth constrained  
...and imports far below 2007 record

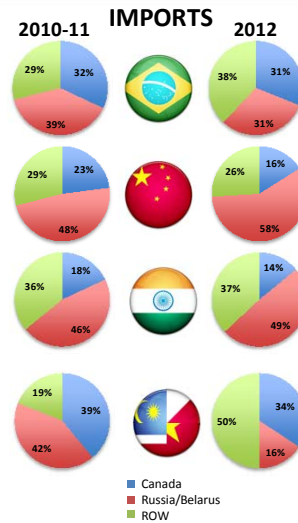
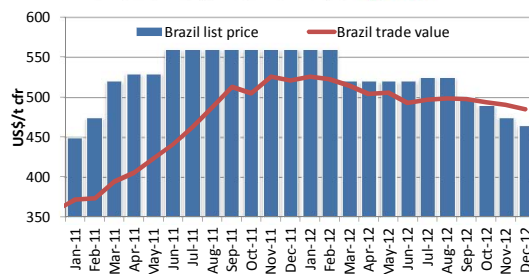
Data: CRU, FAO

## 2012 in review

CRU

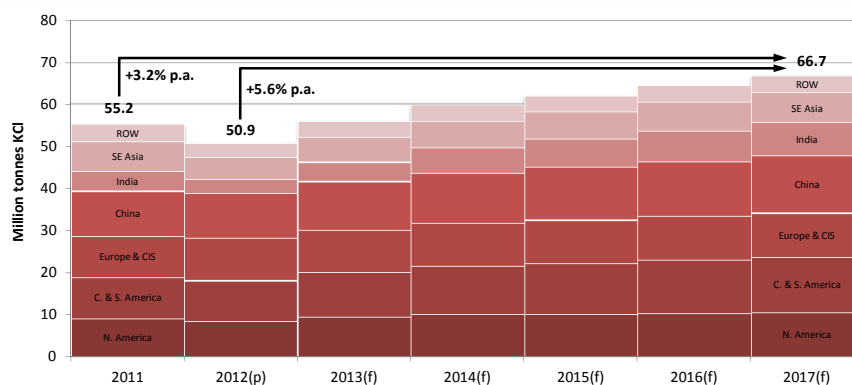
- Bad start to the year as US drought takes hold
- India & China largely absent in H2 2012...  
...spot markets cautious about buying large volumes
- Increased competition in spot markets...  
...BPC lost out, but Canpotex competed with 2<sup>nd</sup> tiers

KCl deliveries 50.8Mt ↓8%  
Vancouver price \$449/t ↑14%



## Demand in the medium-term

CRU



- How much of a rebound will we see in India?
- South America will continue to be key driver of growth
- Risk that pricing policy will continue to choke demand...  
...but less likely with operating rates <75%

Data – CRU

## Capacity forecast

CRU

17 million tonnes of **brownfield**

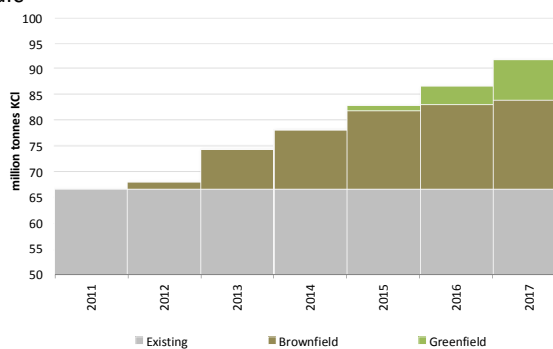
- 69% at PCS, Uralkali & Mosaic

**Greenfield** includes:

- EuroChem Volgskiy I+II
- EuroChem Usolsky Potash I
- K+S Legacy
- Acron Talitsky
- Turkmenhimiya Garlyk

...but not:

- Vale Rio Colorado
- BHP Billiton Jansen
- any juniors

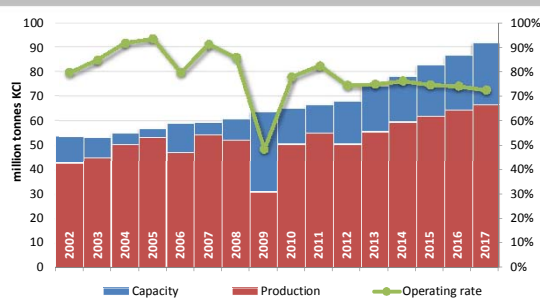
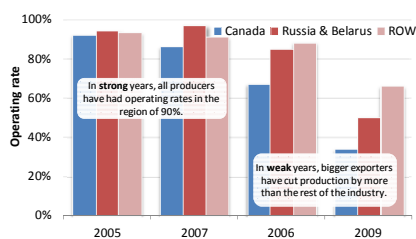


Data – CRU

## Market balance

CRU

- After 20 years of oversupply, the potash market tightened sharply in 2002-2005
- Prices started to impact demand and volumes became erratic
- Underlying trend has seen operating rates fall back



- Despite demand bounce in 2013, new capacity will hold O.R. at 2012 level
- More brownfield expansions to come
- Greenfield capacity beyond 2017 expected to further lower O.R.

Data – CRU



## The short-term outlook

CRU

China contract settled at **\$400/t**  
...India followed at **\$427/t**

⇒ Spot prices should take hold at \$430-440/t standard, \$450-460/t granular

Demand outlook for H1 is positive, particularly given India deal

- 3Mt contracted with China
- 1-2Mt likely for India
- US rebound after last year's drought
- Brazil and SE Asia will return in light of new China/India contracts

**BUT:**

Capacity growing too: major additions at PCS Allan, PCS Cory, Uralkali Berezniki-4

Volumes agreed with China (and India) suggest we could see another H2 hiatus  
⇒ spot prices would drift down in H2 2013

## The medium-term outlook

CRU

**LOTS** of new capacity!

⇒ Even with delays, O.R. won't get much above 2012 level

Potential investors love the potash oligopoly...

- Can this survive persistently low operating rates and market fragmentation?
- Already seeing more competition...has Canpotex shifted its strategy?

We take the view that:

- Prices will ease in 2013-14, leading to above-trend demand growth
- India is a problem – how can it be fixed?
- Even so, capacity growth will match demand growth
- From 2015, greenfield capacity hits the market...more pressure on prices

*How low could we go? SRMC of export capacity is \$234/t...*



## Fertilizers: Global leaders in fertilizer analysis

### Analysis: Our Products

#### MARKET OUTLOOKS

Ammonia Market Outlook –

published every 3 months

Urea Market Outlook –

published every 3 months

Sulphur Market Outlook –

published every 3 months

Sulphuric Acid Market Outlook

– published every 3 months

Phosphate Fertilizer Market

Outlook – published every 3

months

Potassium Chloride Market

Outlook – published every 6

months

Phosphate Rock Market

Outlook – published every 6

months

#### COST SERVICES

Phosphate Rock Cost Report

Nitrogen Cost Report

Phosphate Fertilizer Cost

Report

Potash Cost Report

#### SPECIALIST REPORTS

UAN Market Outlook

Explosive Grade Ammonium

Nitrate Market Outlook

Ammonium Nitrates Market

Outlook

Ammonium Sulphates

Market Outlook

Potassium Sulphates &

Potassium Nitrate Market

Outlook

China Fertilizer Market

Outlook

Industrial and Food

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Market Outlook

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# *Shipping Cost and Challenge Facing Dry Bulk Exporters*

**Mr. Hazza Al-Qahtani**  
**Amad Shipping, Saudi Arabia**

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**

## Shipping Cost and Challenge Facing Dry Bulk Exporters



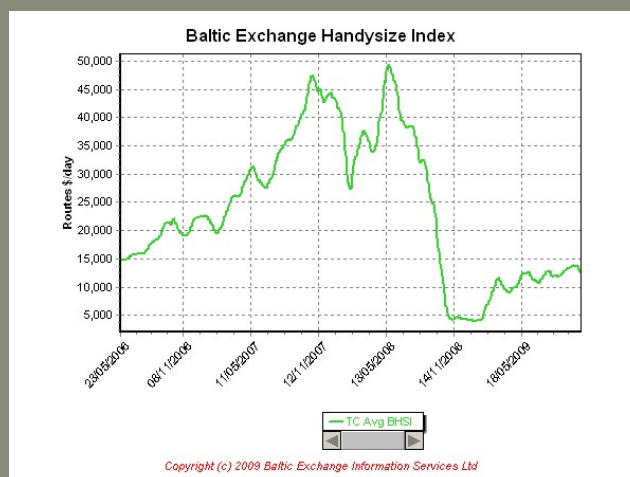
Presented By Amad Shipping

## Freight Rate

Sea Freight Rate consist of the following cost elements:

- Time Charter daily rate.
- Fuel cost
- Handling and port due charges.
- Destination.
- Size of Shipment.

## Time Charter daily rate



## Freight at different Time Charter daily rate Port A to B

Per Day T/C	12K	15K	20K	25K	30K	35K	40K	45K
T/C (000)	240	300	400	500	600	700	800	900
Operating Cost(000)	360	360	360	360	360	360	360	360
Total Cost (000)	600	660	760	860	960	1,060	1,160	1,260
\$ per ton @30k	20	22	25.3	28.7	32	35.4	38.7	42

## Freight rate at different Fuel cost Port A to B

Banker Cost	\$700 Per Ton	\$800 Per Ton	\$900 Per Ton	\$1,000 Per Ton
T/C (000)	240	240	240	240
Operating Cost(000)	360	380	400	420
Total Cost (000)	600	620	640	660
<b>\$ per ton @30k</b>	<b>20</b>	<b>20.67</b>	<b>21.34</b>	<b>22</b>

## Handling and port due charges from port A to B compare to C same destination

Port	B	C
T/C (000)	240	300
Operating Cost(000)	360	360
Total Cost (000)	600	660
<b>\$ Per Ton @30K</b>	<b>20</b>	<b>22</b>



## Impact of Destination to Freight rate from port A to B compare To D

Port	B	D
T/C (000)	240	480
Operating Cost(000)	360	772
Total Cost (000)	600	1,252
<b>\$ Per Ton @30K</b>	<b>20</b>	<b>41.70</b>

## Impact of Size of Shipment to Freight rate from port A to B

Size of Shipment	30K	40K
T/C (000)	240	300
Operating Cost(000)	360	410
Total Cost (000)	600	710
<b>\$ Per Ton</b>	<b>20</b>	<b>17.75</b>

## Market Outlook

- ◉ Ships prices and rates are at 10 years low which will lead to :
  - Reduction in tonnage by 2015, as a result of twenty of the world
  - ◉ fleet being more than fifteen years old and finding it difficult
  - ◉ to operate with lower than cost rate.
- Steel prices is five time the steel prices ten years which will
  - ◉ encourage more scrapping with the result that the demand /
  - ◉ supply imbalance should even out before 2014.
- The last quarter of 2013 will be the last hurdle before we see the
  - ◉ return of some stability and solid ground recovery.
- 36% of charters anticipate improved rates , compare to just 15%
  - ◉ last year (Moore Stephens)



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Arab Fertilizer Association  
Since 1975



19<sup>th</sup> Annual AFA  
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PLATFORM

# SESSION II

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel





# *The Year Ahead: World Fertilizer Supply & Demand in 2013*

Mr. Michel Prud'homme  
 IFA , France

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**



International  
Fertilizer Industry  
Association

# The Year Ahead : World Fertilizer Supply and Demand in 2013

Michel Prud'homme

International Fertilizer Industry Association

Paris, France

**19th Annual AFA Fertilizer Forum & Exhibition**  
**Egypt, February 2013**

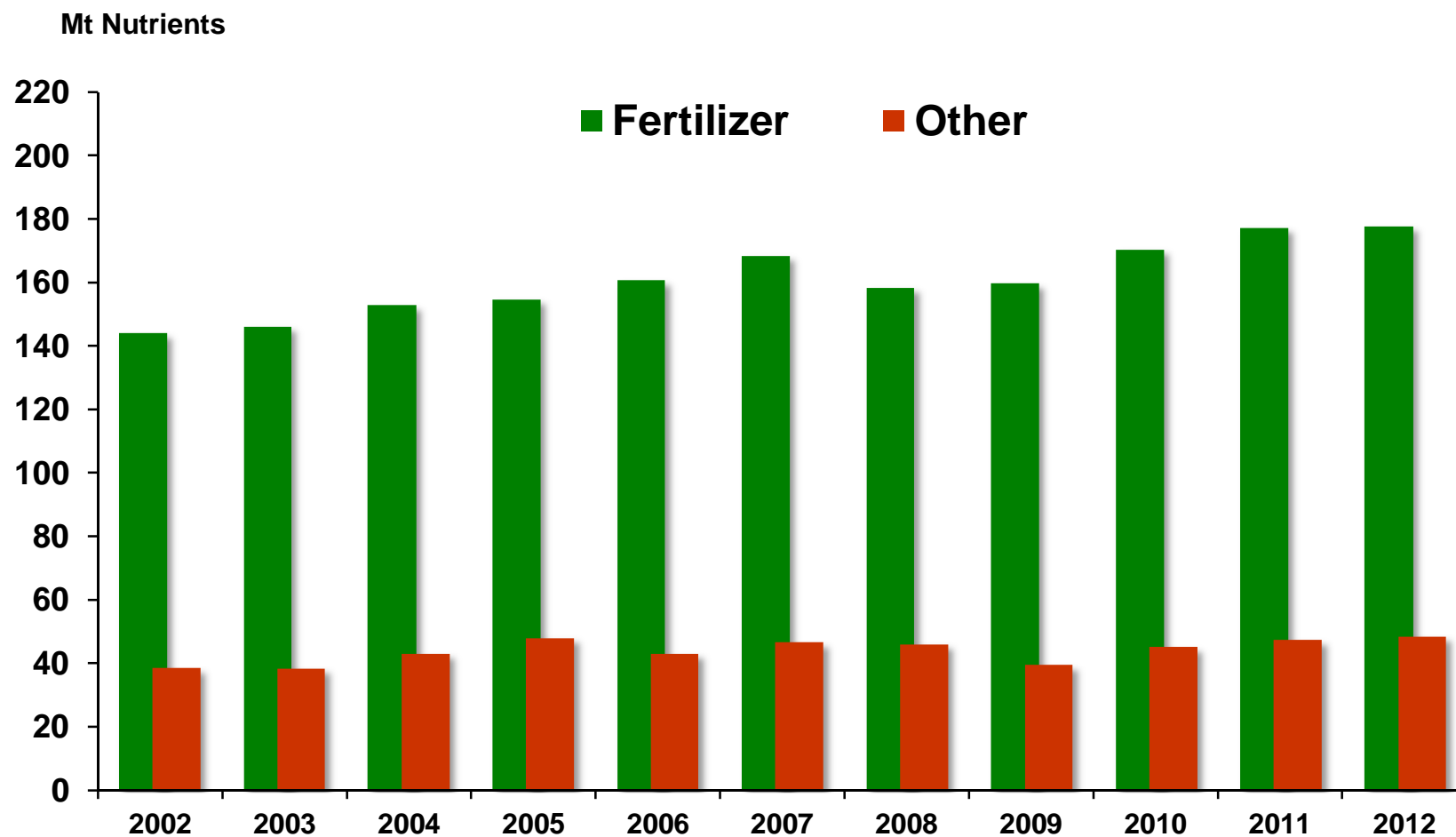


# Content

- ✓ Global Fertilizer Demand 2012 and 2013
- ✓ Global Supply Situation in 2012
- ✓ Short-Term Capacity Developments
- ✓ World Trade Prospects 2013



# Global Nutrient Deliveries

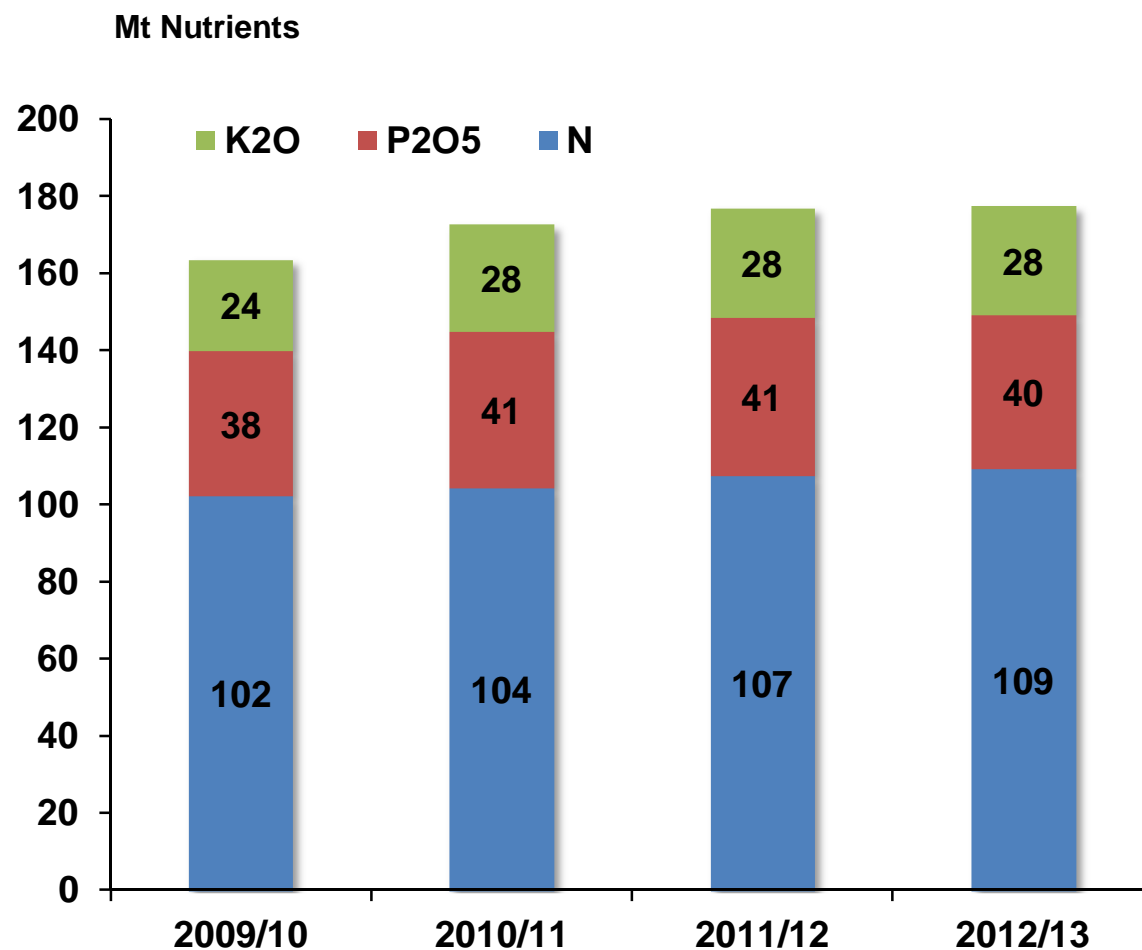


Source: IFA PIT Committee,

# Fertilizer Demand Drivers 2012-2013

<b>Agriculture</b>	<b>Fertilizer Demand</b>
<ul style="list-style-type: none"><li>• <b>firm agri-commodity prices</b></li><li>• <b>Firm demand for cash crops</b></li><li>• <b>Rising inventory for rice and wheat</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Emerging demand in low-use regions</b></li><li>• <b>Recovery of demand since 2009</b></li></ul>
<ul style="list-style-type: none"><li>• <b>Slowdown in global grain demand</b></li><li>• <b>Reduction in grain production</b></li><li>• <b>Drought conditions in the US</b></li><li>• <b>Low inventory for coarse grains</b></li></ul>	<ul style="list-style-type: none"><li>• <b>Nutrient subsidy</b></li><li>• <b>Currency devaluation</b></li><li>• <b>Unbalanced fertilization</b></li><li>• <b>Over-application in key countries</b></li></ul>

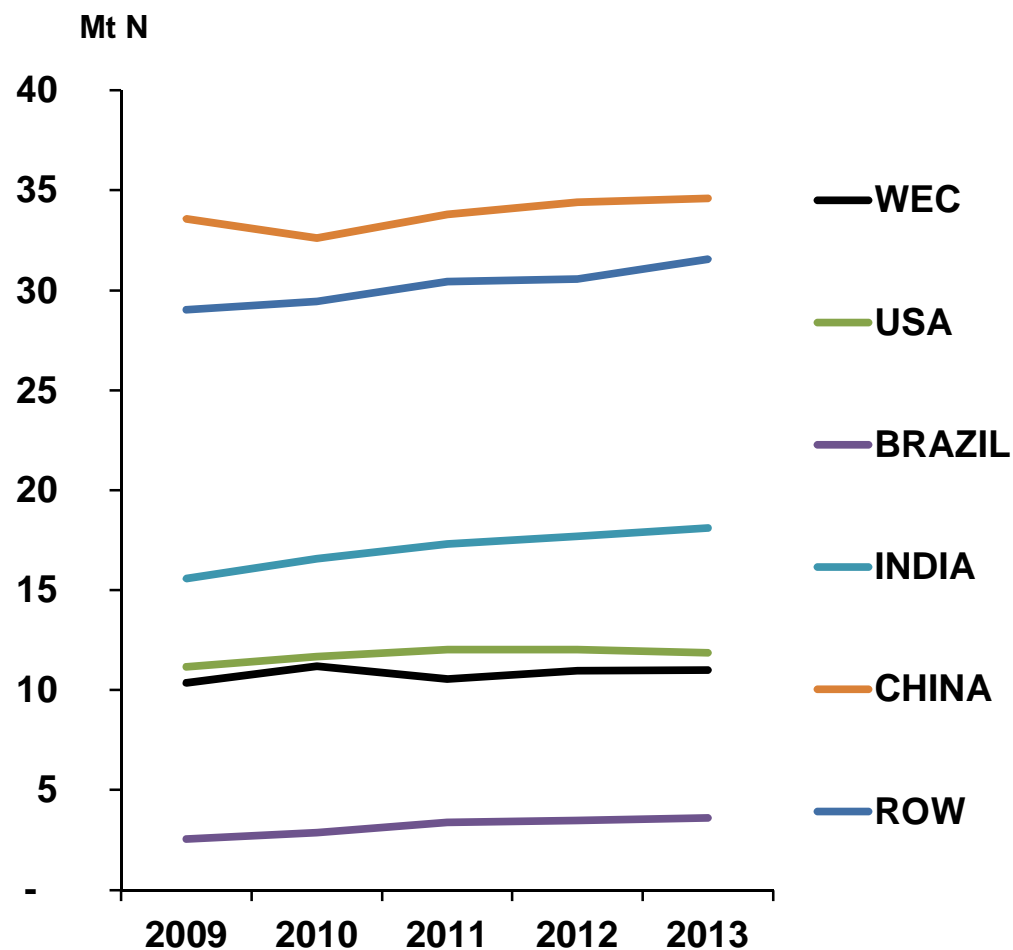
# World Fertilizer Short-Term Demand



Yearly Variations		
	2011/12	2012/13
N	+3.0%	+1.5%
P <sub>2</sub> O <sub>5</sub>	+1.2%	-2.7%
K <sub>2</sub> O	+2.1%	+0.1%
Total	+2.4%	+0.3%

Source: IFA Agriculture Committee,

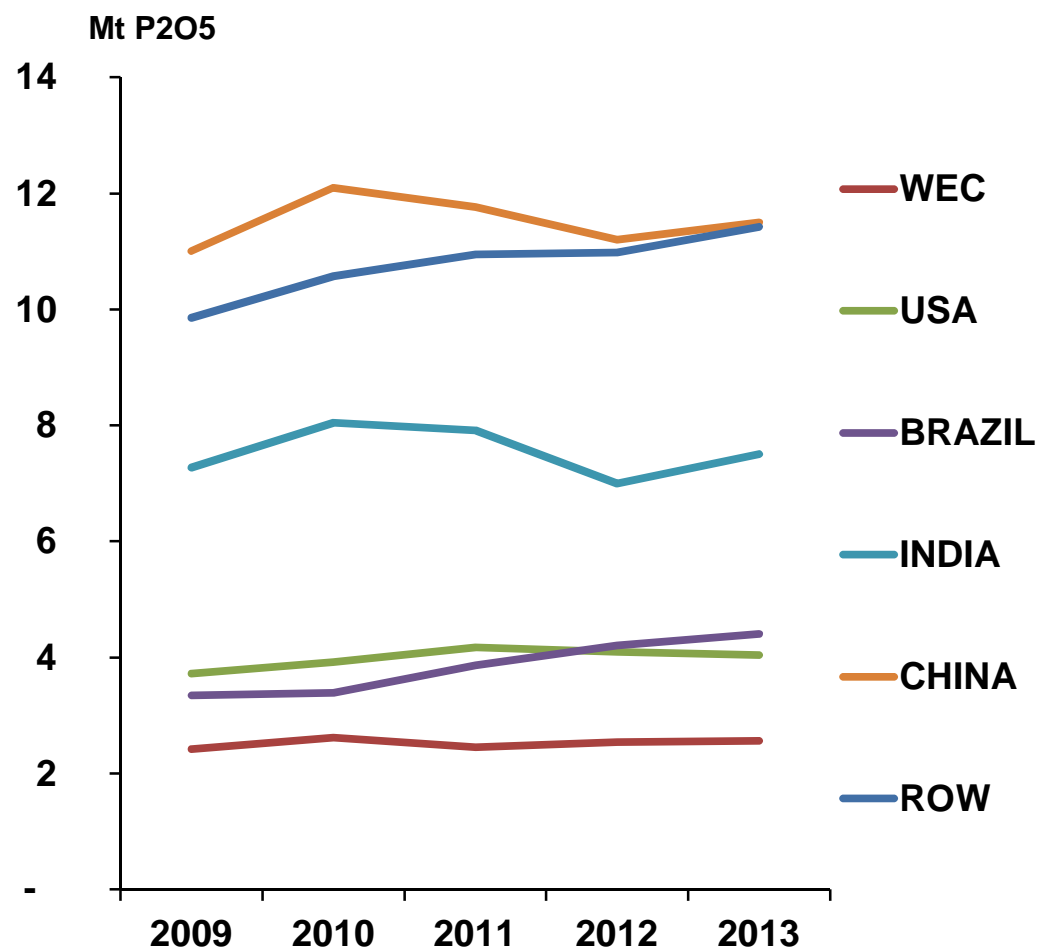
# N Fertilizers Short-Term Demand : Top-5



YoY %	2011/12	2012/13
CHINA	2%	1%
ROW	0%	3%
INDIA	2%	2%
USA	0%	-1%
WCE	4%	0%
BRAZIL	3%	4%

Source: IFA Agriculture Committee,

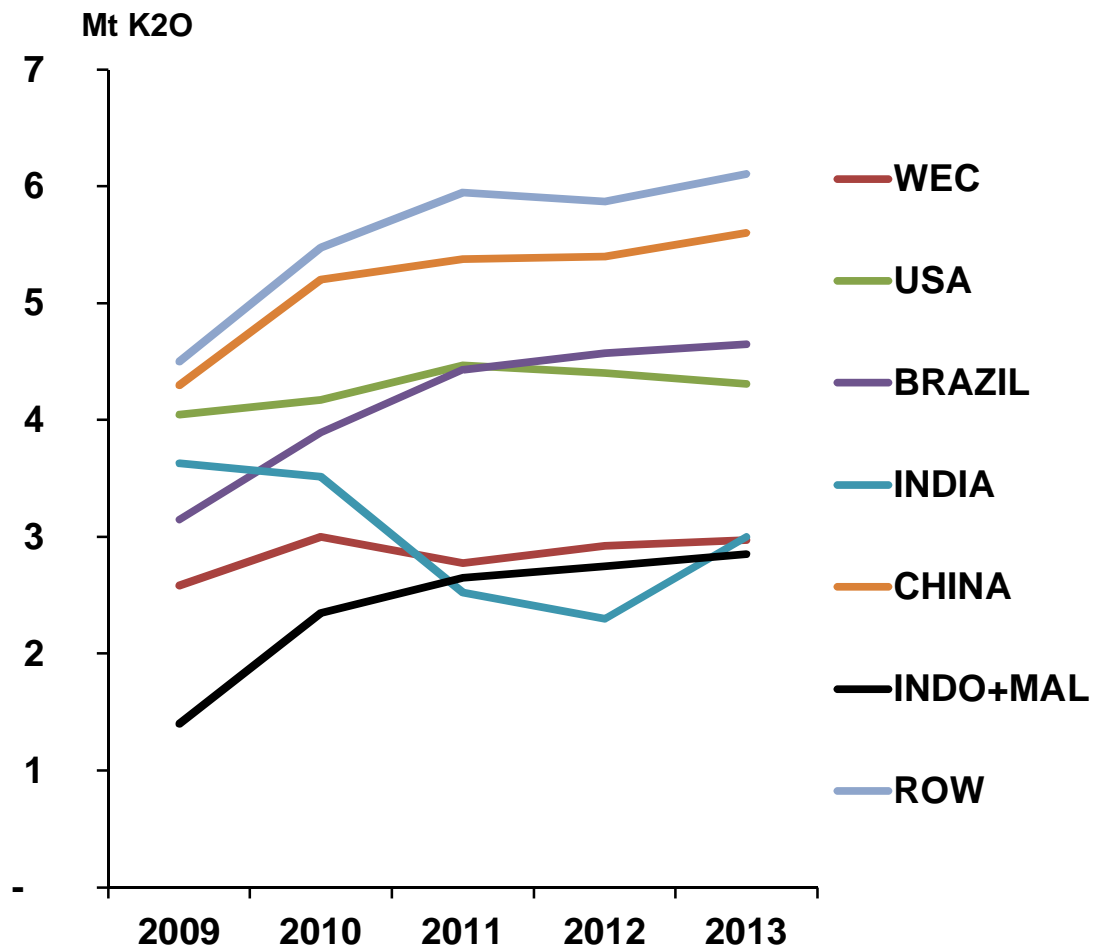
# P Fertilizers Short-Term Demand : Top-5



	YoY %	2011/12	2012/13
CHINA	-5%	3%	
INDIA	-12%	7%	
USA	-2%	-2%	
WCE	3%	1%	
BRAZIL	9%	5%	
ROW	0%	4%	

Source: IFA Agriculture Committee,

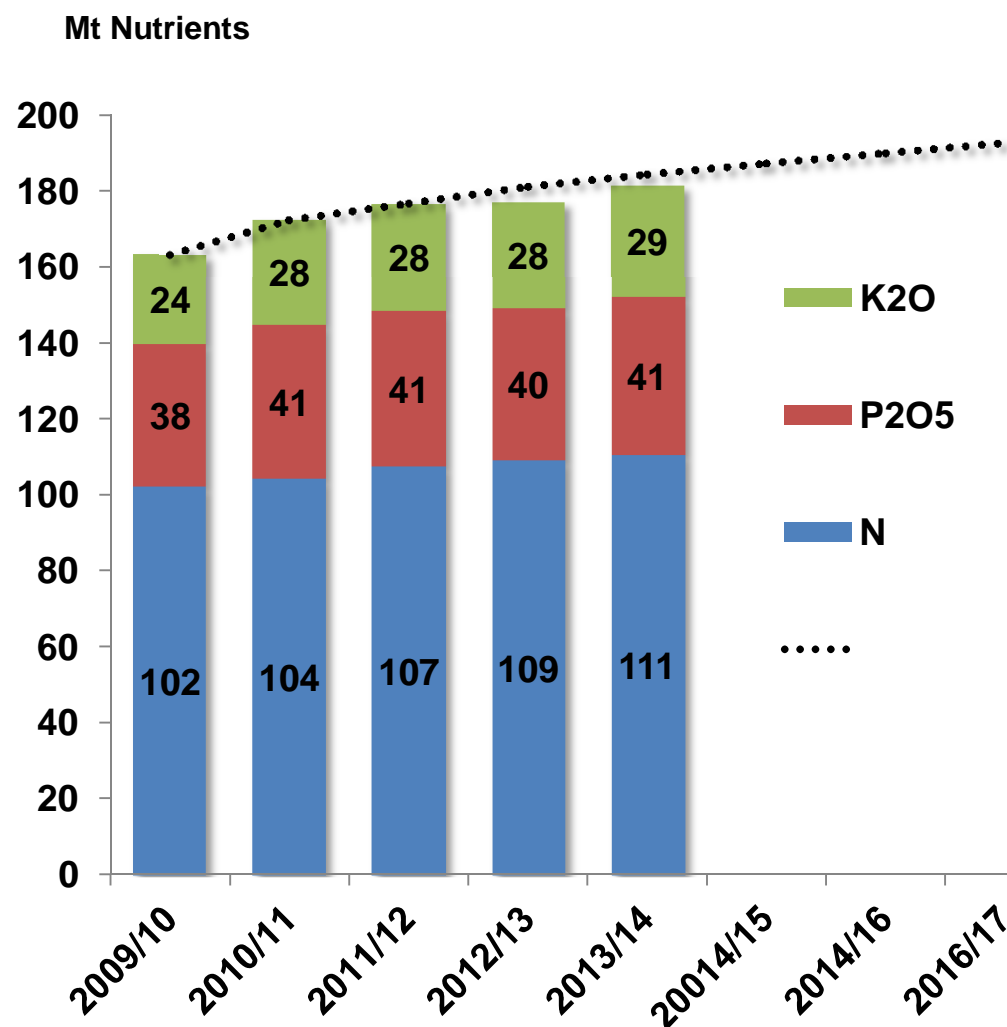
# K Fertilizers Short-Term Demand : Top-6



	YoY %	2011/12	2012/13
CHINA		0%	4%
INDIA		-9%	30%
USA		-2%	-2%
WCE		5%	2%
BRAZIL		3%	2%
INDO +MAL		4%	4%
ROW		-1%	4%

Source: IFA Agriculture Committee,

# World Fertilizer Demand Outlook



Yearly Variations			
	2011/12	2012/13	2013/14
N	+3.0%	+1.5%	+1.5%
P <sub>2</sub> O <sub>5</sub>	+1.2%	-2.7%	+3.5%
K <sub>2</sub> O	+2.1%	+0.1%	+4.5%
<b>Total</b>	<b>+2.4%</b>	<b>+0.3%</b>	<b>+2.4%</b>

Source: IFA Agriculture Committee,



# Market Factors 2012-2013

## Demand

- Fertilizer demand recovery
- Strong agri fundamentals
- Growth in fertilizer and industrial uses

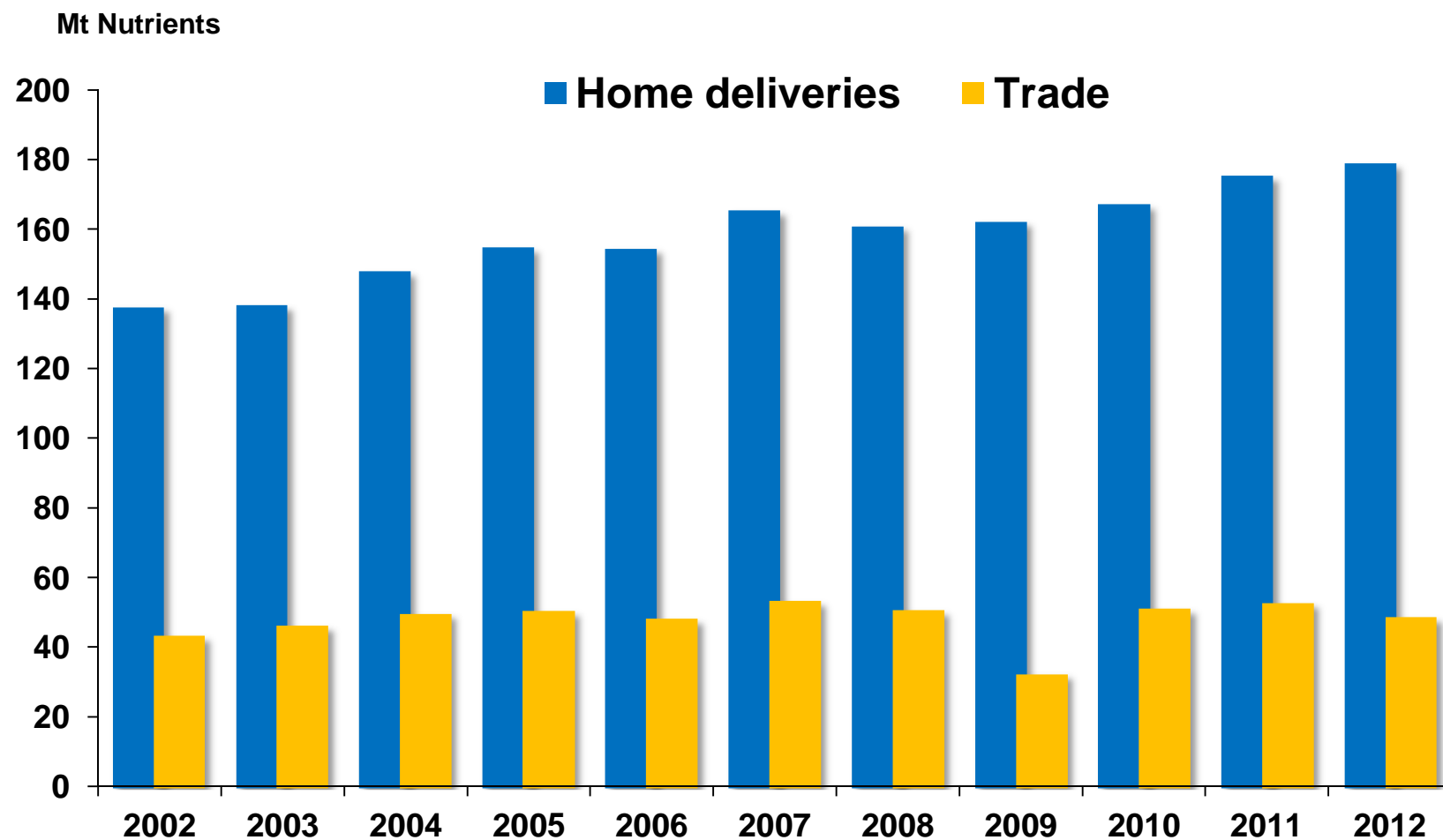
- Economic uncertainty
- Growth slowdown
- Nutrient subsidies
- Inventory carryovers

## Supply

- New capacity
- Capacity ramp-up
- Shale gas
- Junior mining projects
- Expanding resources

- Natural gas supply issues
- Country issues
- Permitting issues
- Export taxes

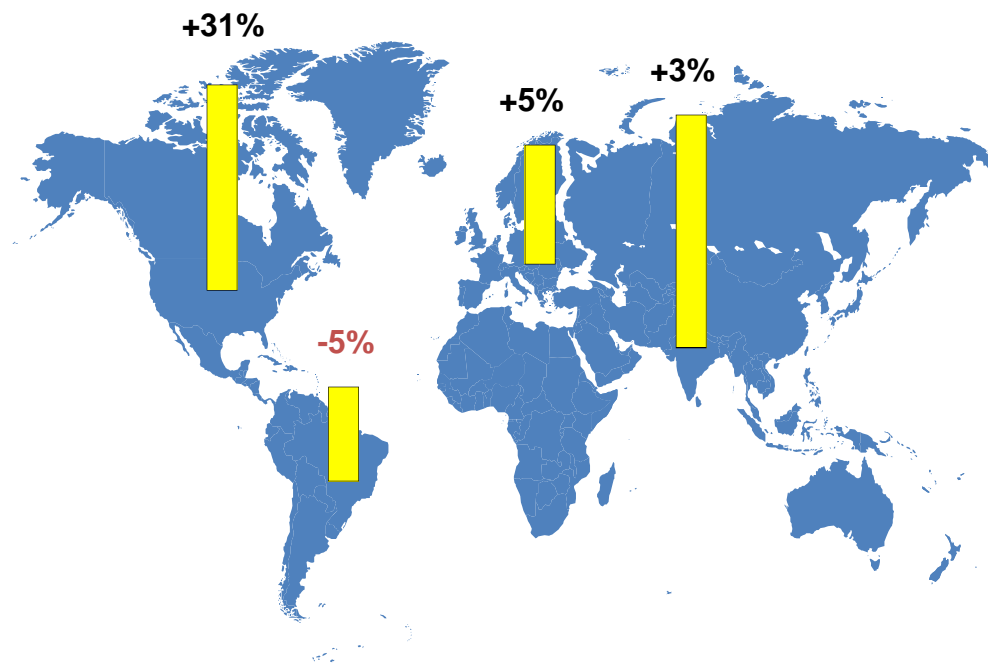
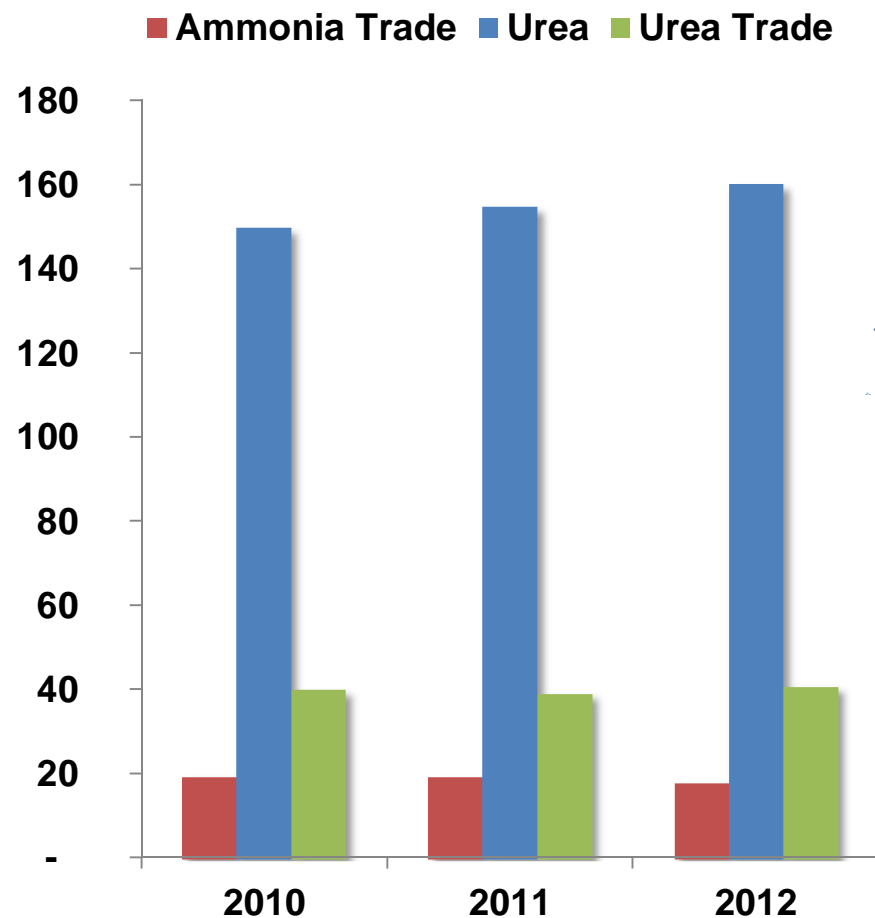
# Global Nutrient Deliveries



Source: IFA PIT Committee,

# Nitrogen Production and Trade : 2012

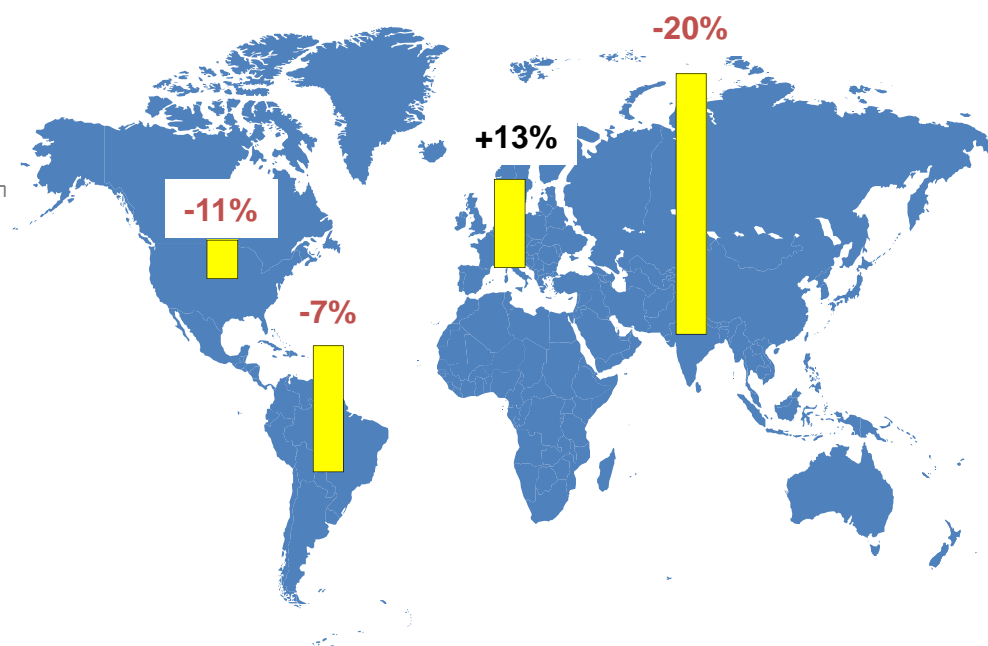
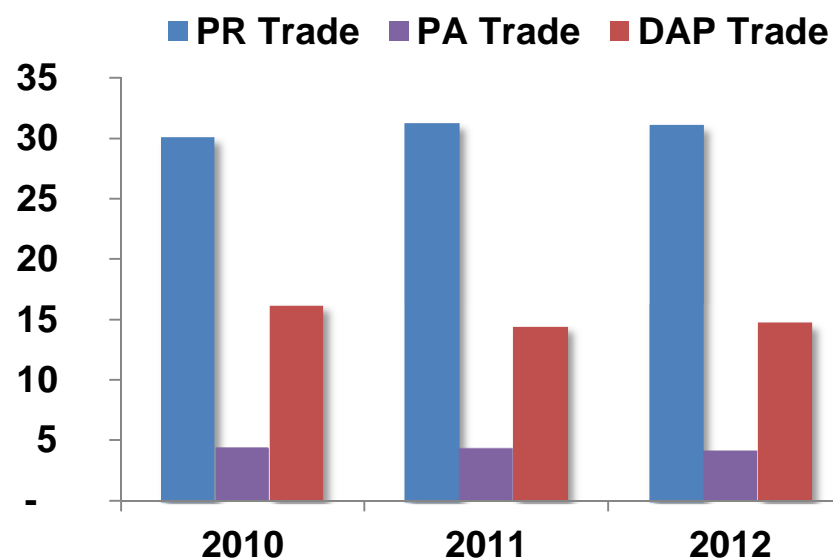
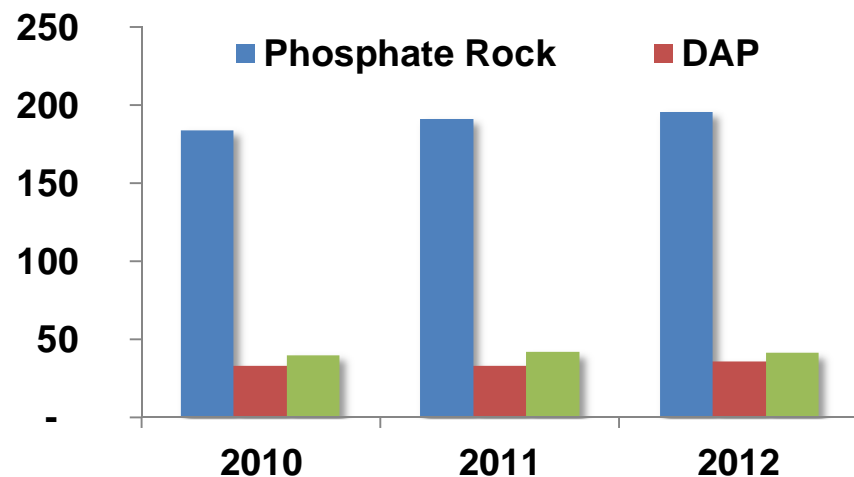
Mt Products



Source: IFA PIT Committee,

# Phosphates Production and Trade : 2012

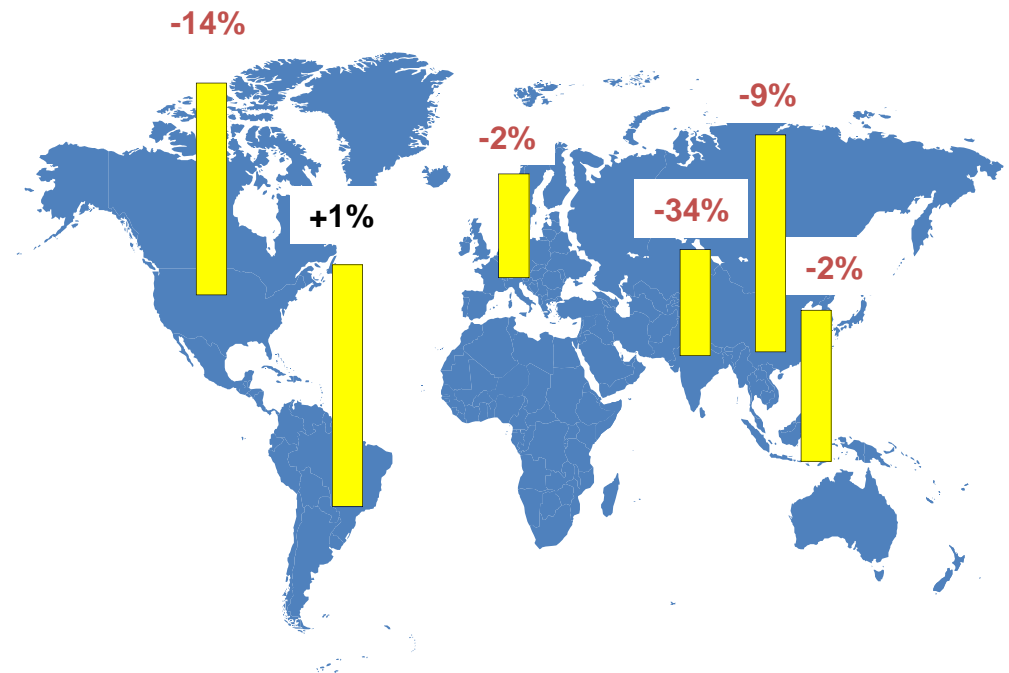
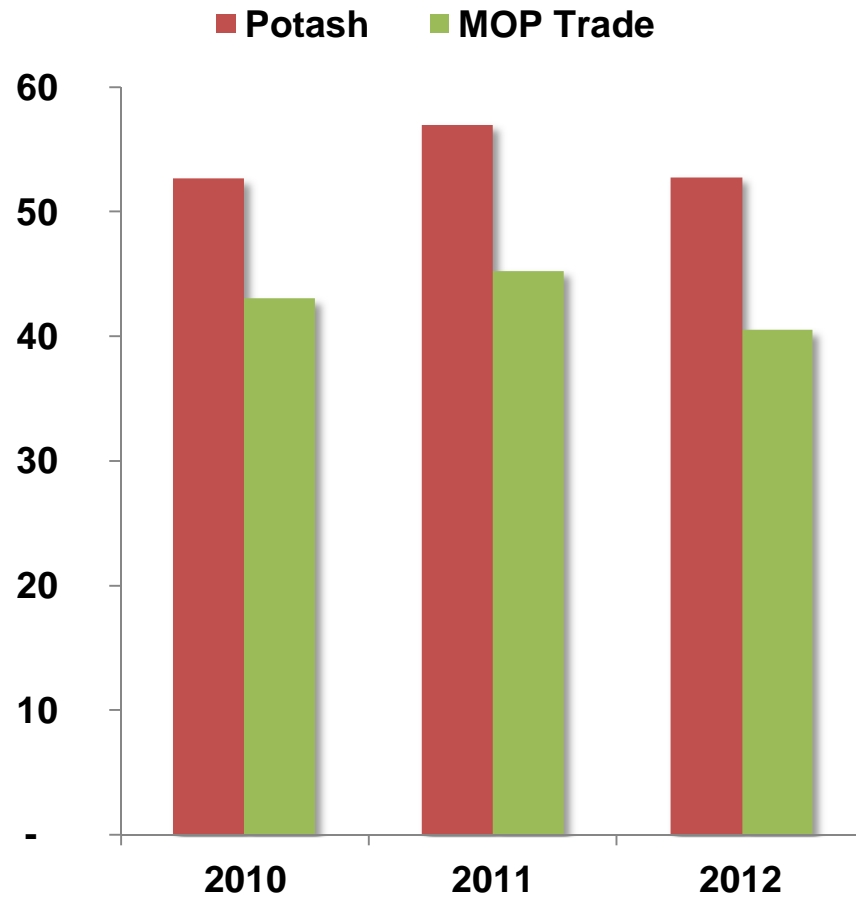
Mt Products



Source: IFA PIT Committee,

# Potash Production and Trade : 2012

Mt Products



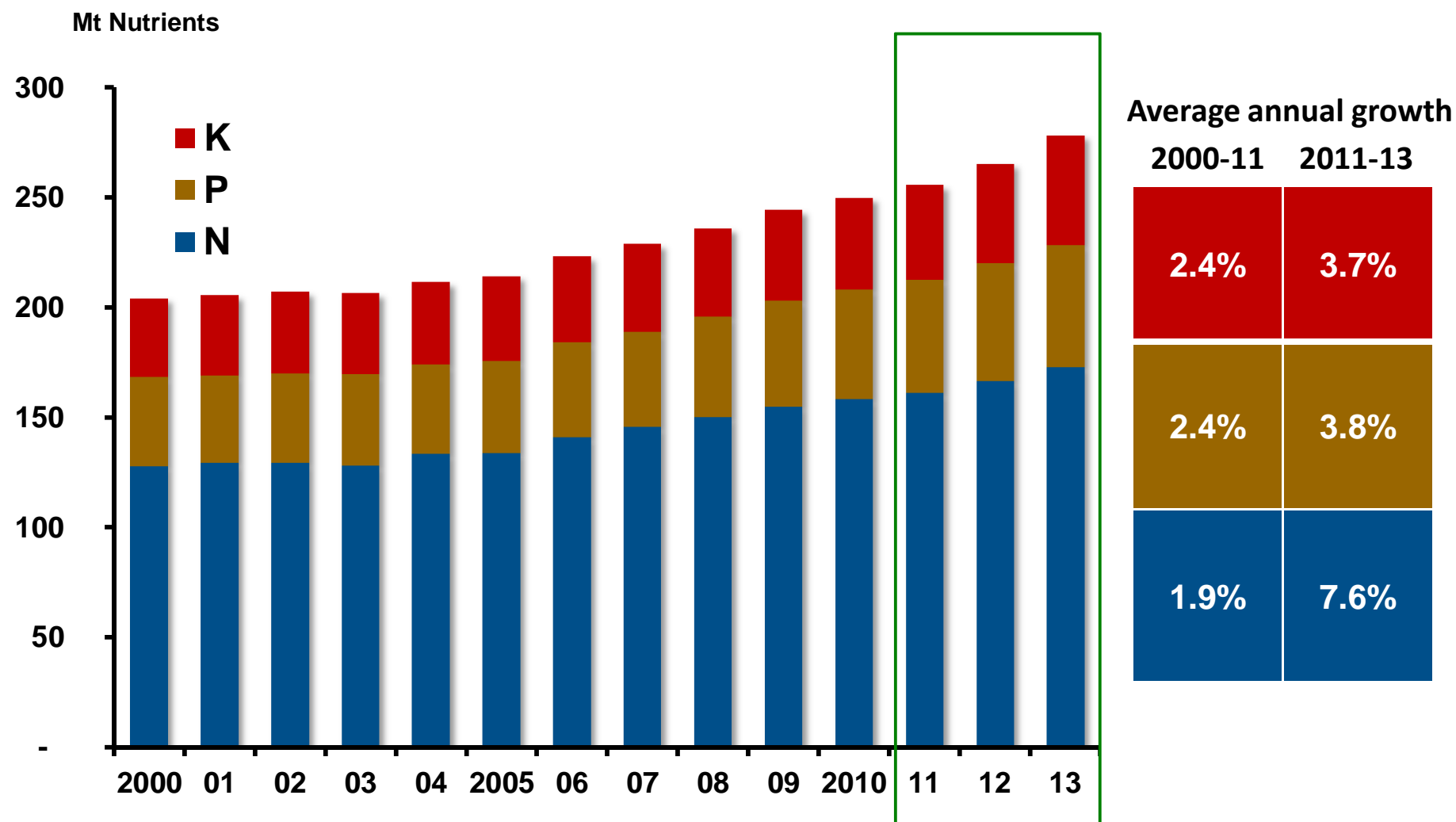
Source: IFA PIT Committee,

19th Annual AFA Fertilizer Forum & Exhibition - Egypt, February 2013



# Global Capacity Developments

## 2000/2011 & 2011/2013



Source: IFA PIT Committee,

# Nitrogen Capacity : Short-Term Developments

New Capacity		
Mt Products	2012	2013
<b>NH3</b>		
Algeria		800
Mexico		480
USA		800
<b>Urea</b>		
France	350	
Russia	830	
Qatar	2 540	
Viet Nam	1 370	
Algeria		3 500
Abu Dhabi		1 150
China	4 900	3 800
<b>Urea</b>	<b>10 000</b>	<b>9 200</b>

Source: IFA PIT Committee,



# Phosphates Capacity : Short-Term Developments

New Capacity		
Mt Products	2012	2013
<b>MGA</b>		
Tunisia	330	
Jordan		500
<b>PP</b>		
Venezuela	150	
Brazil	610	
Morocco		1 750
China	2 600	1 500
<b>PP</b>	<b>3 360</b>	<b>3 250</b>

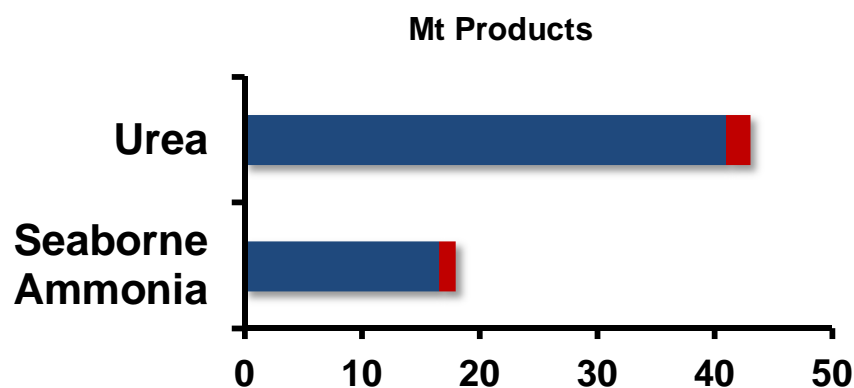
Source: IFA PIT Committee,

# Potash Capacity : Short-Term Developments

New Capacity		
Mt Products	2012	2013
<b>MOP</b>		
Belarus	750	750
Russia	880	1 000
Chile	500	
China	870	200
Canada		4 000
Laos		820
<b>MOP</b>	<b>3 000</b>	<b>6 770</b>

Source: IFA PIT Committee,

# 2013 Sales and Trade Prospects

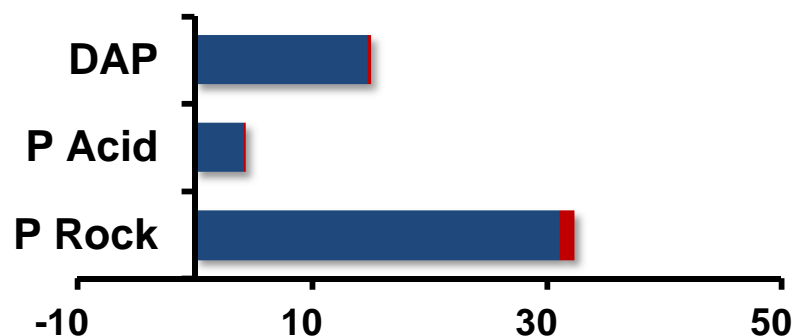


## Urea

- Large supply develops in West Asia and Africa.
- Potential deficits would expand in WE and SA.
- Stable import demand in NA and LA.
- Urea trade may expand by 5%, to 43 Mt in 2013.

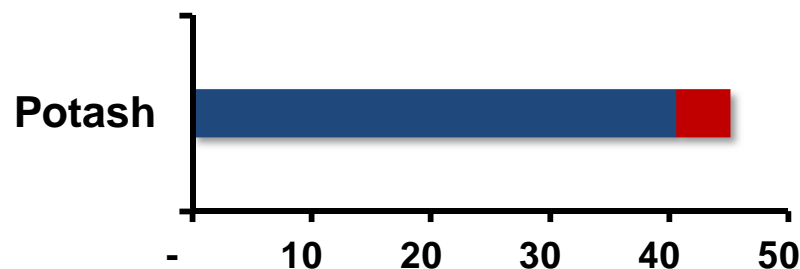
## Phosphates

- Large supply develops in China and Morocco.
- Potential  $P_2O_5$  deficits would expand in LA and CE.
- Stable DAP import demand in most regions.
- Rising imports in AF and LA.
- DAP trade may expand by 2-3%, to 16 Mt in 2013.



## Potassium

- Large supply develops in NA and EECA.
- New supply emerging in China and Laos.
- Potential larger imports in LA, SA and EECA.
- Potash trade may expand by 5-10%, to 42-45 Mt in 2013.



Source: IFA PIT Committee,



International  
Fertilizer Industry  
Association



[WWW.Fertilizer.org](http://WWW.Fertilizer.org)



# *Challenges and Opportunities for Maize Production Intensification in Sub-Saharan Africa Security*

Dr. Terry L. Roberts  
 President  
 IPNI, USA

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**

# Challenges and Opportunities for Maize Production Intensification in Sub-Saharan Africa

*Terry L. Roberts and Shamie Zingore*  
*International Plant Nutrition Institute*

19<sup>th</sup> Annual AFA Fertilizer Forum  
February 26-28  
Savoy Hotel & Resort, Sharm El-Sheikh  
Egypt



**Primary food staple in smallholder systems ...  
mostly rainfed, with low yields**



## Maize area harvested, production, and yield in SSA regions (2008-2010)

Region in SSA	Area, M ha	Production, Mt	Yield, t/ha
Western	8.04	14.61	1.81
Central	2.60	3.08	1.18
Eastern	8.00	12.28	1.54
Southern	7.43	9.16	1.23
<b>SSA</b>	<b>26.11</b>	<b>39.19</b>	<b>1.50</b>
So. Africa	2.93	12.74	4.35



## Great potential to increase maize yields and production in SSA

- Total area available for expansion almost equals the 161 M ha currently harvested globally
- Currently producing an estimated 20% of potential yield

Average yields (t/ha) from 2005 to 2008	
SSA	1.4
Brazil	3.8
Mexico	3.1
Philippines	2.5
Thailand	3.9





## Maize yield variability is extremely high

- CVs range from 41% in Zimbabwe to 33% in Malawi and 31% in Zambia to 11% in Kenya
- Most variability is due to climate, but soils heterogeneity also contributes

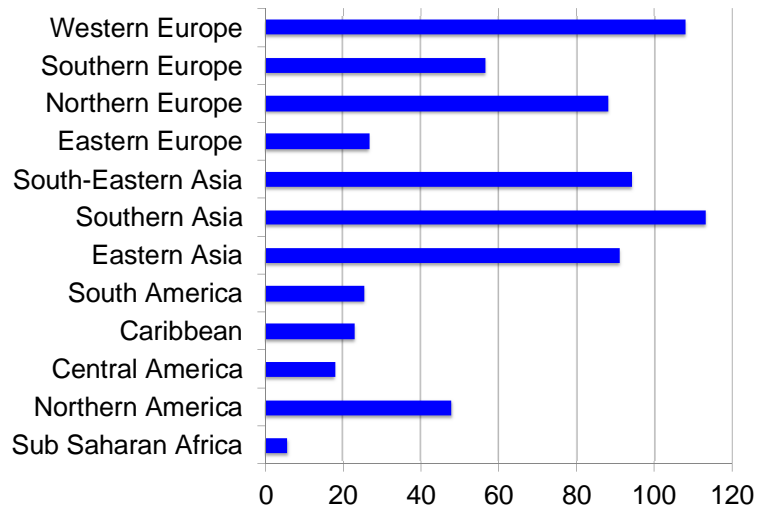


## Soil Fertility and Fertilization

- Soils have been farmed for decades with little or no additions of fertilizers
- Fertilizer use is the lowest in the world ...



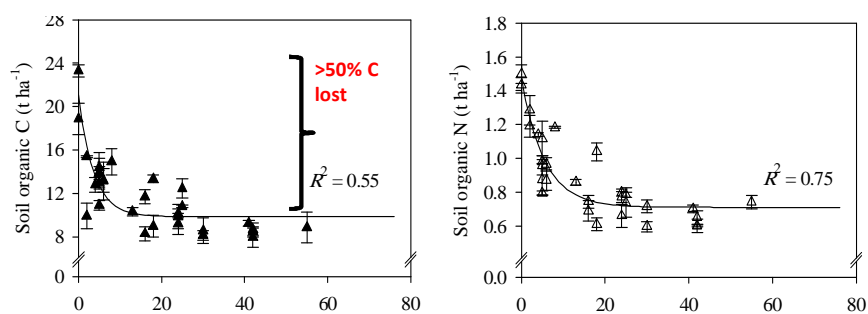
## Regional NPK application rates\*, kg/ha



\*Based on nutrient consumption per agricultural area (FAOSTAT)

## Consequences of low nutrient use

Rapid depletion of soil organic matter and nutrients



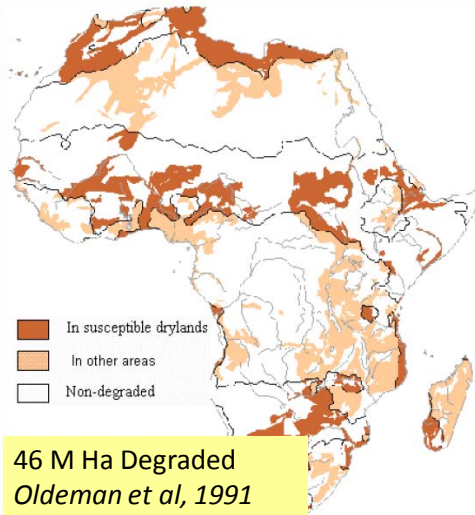
Zingore et al., 2005; Bostick et al., 2007

Negative  
nutrient  
balances

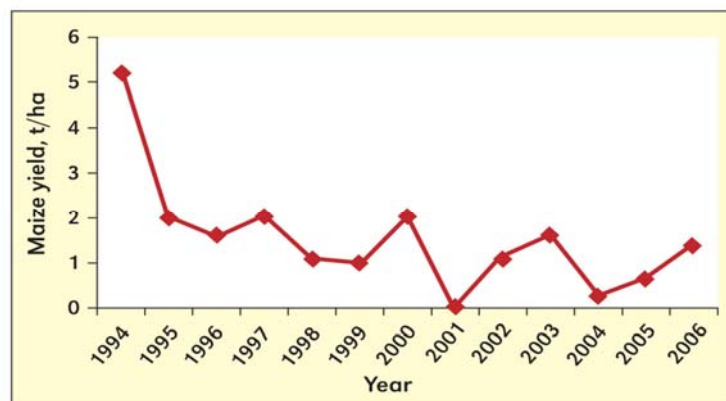
	N	P	K
Kenya	-46	-1	-36
Malawi	-67	-10	-48
Nigeria	-37	-4	-31



## Land degradation a major crisis



## Continual cultivation and low nutrient input ... low maize yields

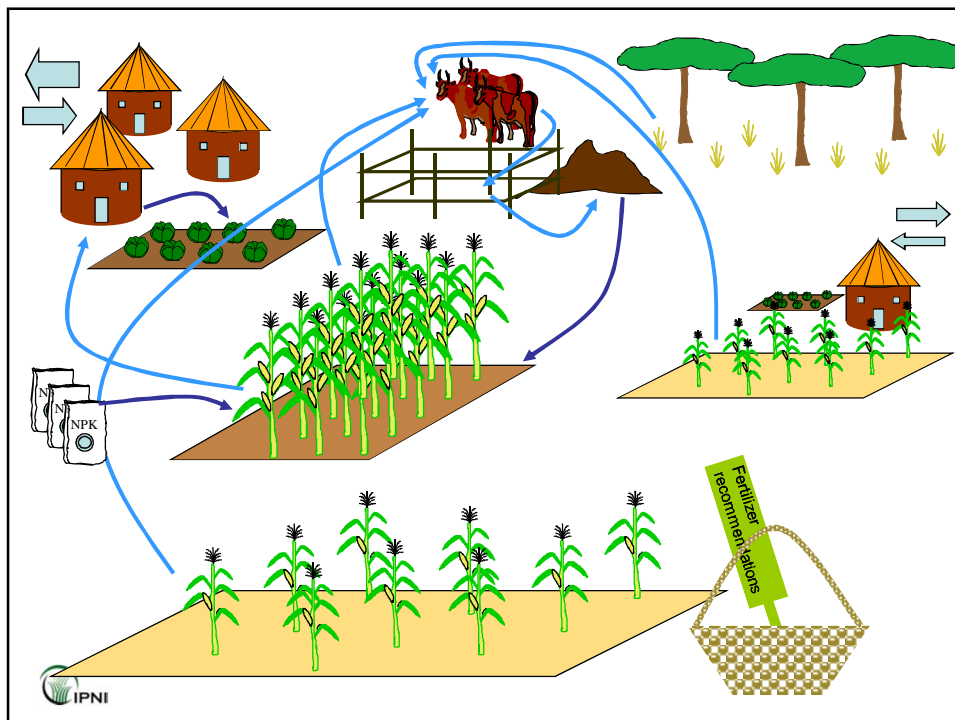
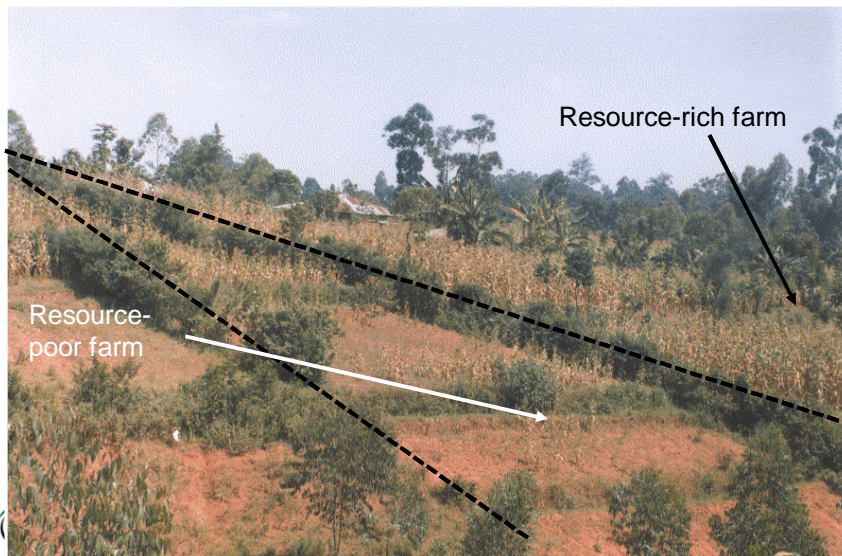


Average maize yields with no fertilizer application from long-term experiments in southern Africa



Waddington et al. 2007

## Variable soil fertility due to inherent infertility and poor management





**Zingore summarized studies conducted across SSA that showed baseline yields and yield response to fertilizer increases with soil fertility status**

**Fertility Categories:**

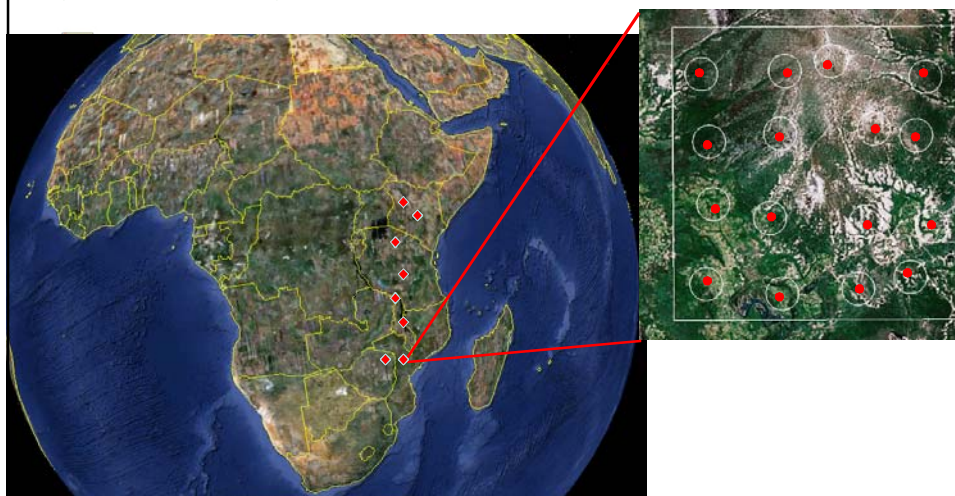
- Low soil fertility – SOC deficit (>70%)
- Medium soil fertility – SOC deficit (40 – 70%)
- High soil fertility – SOC deficit (<40%)



Zingore, 2011

**Study sites**

High maize yield gaps in the sub-humid zone



Zingore, 2011

## Modified Nutrient Omission Trial Design

- Control
- P+K
- N+P
- N+K
- N+P+K
- N+P+K+Ca+Mg+S+Zn+Mn
- N+P+K+Ca+Mg+S+Zn+Mn + manure
- Full fertilizer rate for 7 t/ha



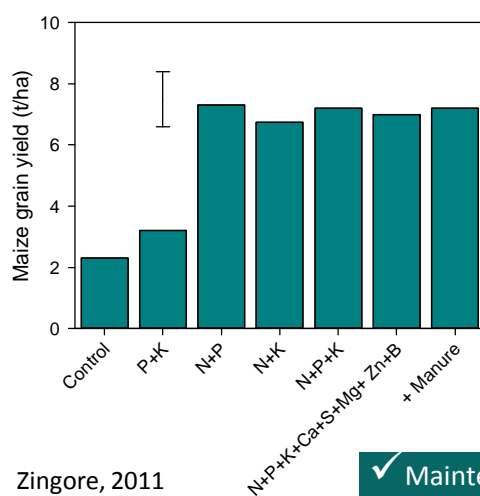
Zingore, 2011

- Measurements: Grain and residue yields, Soil properties, rainfall



## Maize yield response to fertilizer

High Fertility (SOC deficit , 40%)



Zingore, 2011

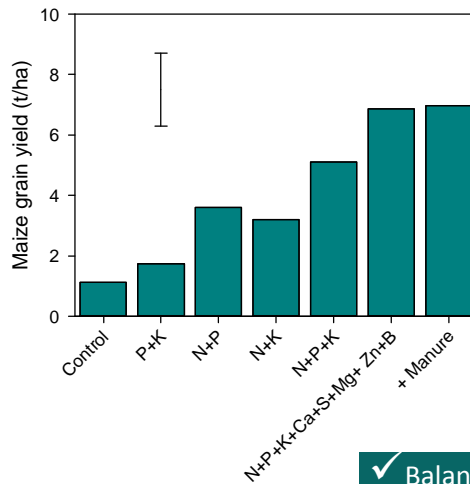
- Small areas with history of high manure application rates
- Baseline yields ~ 2 t/ha
- N most limiting



✓ Maintenance fertilization with judicious N management

## Maize yield response to fertilizer

Medium Soil Fertility (SOC deficit 40-70%)



- Baseline yields ~ 1.2 t/ha
- Multiple nutrient deficiencies

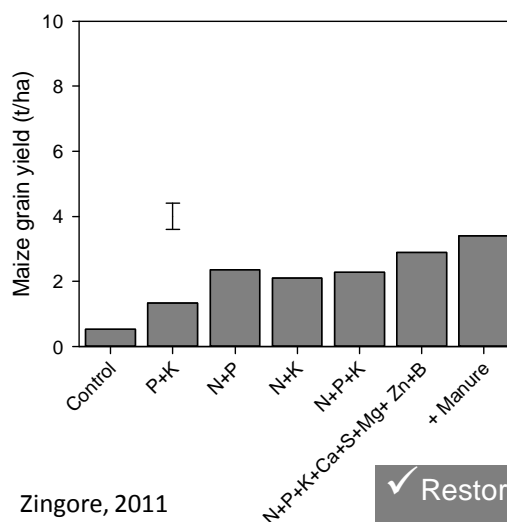


Zingore, 2011

✓ Balanced nutrient management to optimize yields

## Maize yield response to fertilizer

Low Soil Fertility (SOC deficit > 70%)



- Baseline yields < 1 t/ha
- Limited attainable yields with all nutrient sources

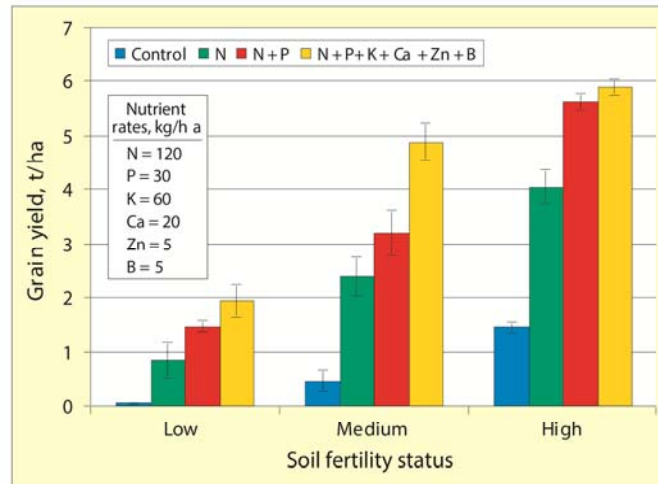


Zingore, 2011

✓ Restoration of degraded land



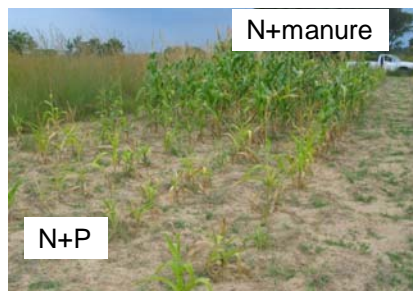
## Maize yield response to various nutrient combinations a influenced by soil fertility status



Zingore, 2011

## Restoring Productivity to Degraded Soils

- Can't be corrected by fertilizer alone ... incorporating both organic and inorganic nutrients along with improved seed is needed to increase yields in SSA



## Integrated Soil Fertility Management (ISFM)

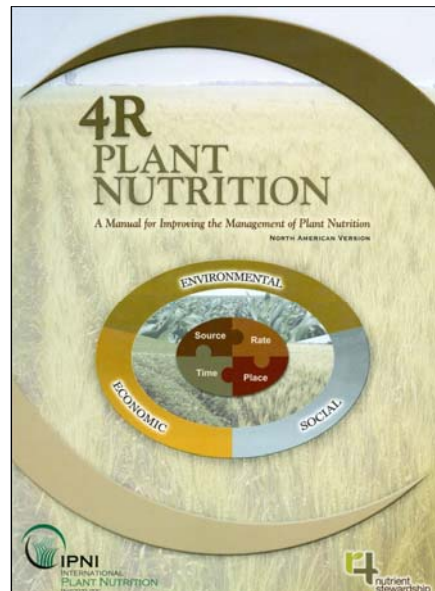
*“... the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm.”*

Alley and Vanlauwe, 2009



## ISFM fits within 4R Nutrient Stewardship ...

4R concept — apply the right source of plant nutrients, at the right rate, at the right time, and in the right place



Manual available from IPNI  
[www.ipni.net/4r](http://www.ipni.net/4r)



## Manure interacts positively with N fertilizer on degraded soils in SSA

Soil fertility status	Control	Manure	N fertilizer	Manure + N fertilizer
	Yield, t/ha			
Low	0.3	0.8	1.2	2.8
Medium	0.8	1.7	3.8	4.3

Zingore, 2011



## Fertilizer Recommendations Using Nutrient Expert (NE)

- Blanket recommendations based on agro-ecological zones are the basis for fertilizer application in SSA ... do not address temporal variability
- IPNI has developed a simple computer-based decision support tool to help advisers assist smallholders with site-specific fertilizer recommendations – Nutrient Expert (NE)
- NE utilizes omission plot techniques to estimate the nutrient supply from the soil



## Supply of nutrients from the soil can estimated using omission plot techniques.

- Omission plots are small plots where each of the nutrients being evaluated is omitted, while all the other nutrients are adequately supplied
- Use the agronomic efficiency ( $AE = (Y - Y_0)/F$ ) from omission plots to determine fertilizer rates in similar soils
  - basis for site-specific nutrient management (SSNM)



## Example: calculating fertilizer rates from omission plot data

Treatment	Yield, kg/ha
1. Ample rates of N, P, and K	5,556
2. N omitted; ample rates of P and K	1,667
N rate= 150 kg/ha	

$$AE = (5,556 - 1,667)/150 = 26 \text{ kg of grain/kg of N}$$

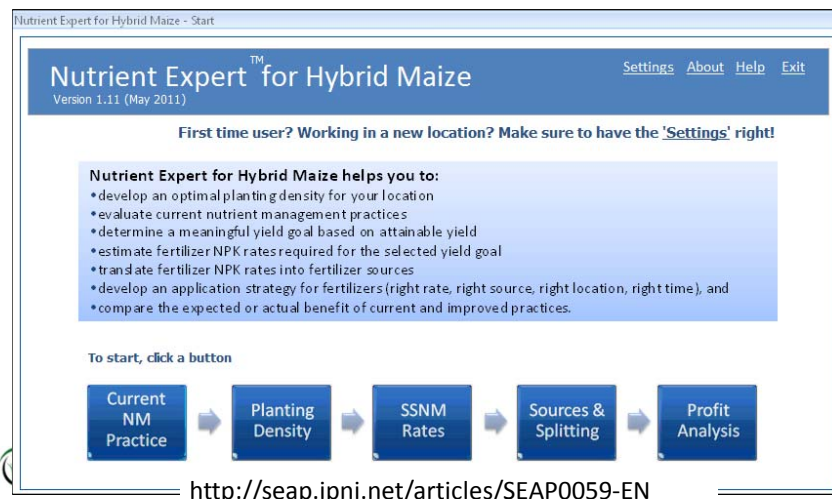
If the target yield was 4,500 kg/ha:

$$\text{Calculated N rate} = (4,500 - 1,667)/26 = 109 \text{ kg/ha}$$

IPNI unpublished data from wheat data, 2011



**Decision support tool developed to help local experts replace blanket fertilizer recommendations with site-specific recommendations based on SSNM principles.**



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## Nutrient Expert for Hybrid Maize

Current NM Practice
Planting Density
SSNM Rates
Sources and Splitting
Profit Analysis

**Name and/or location:**       **Field size:**  ha

Fertilizer N, P, and K requirements are based on yield goal (i.e. attainable yield) and expected yield responses to fertilizer application.

1. What is the attainable yield for your location?  t/ha

2. What do you do with maize residues after harvest?

☐ Remove all the above ground residues from the field  
☐ Retain stover in the field and incorporate

☐ Retain stover in the field and burn  
☐ Compost stover for incorporation to next crop

3. Will you apply organic fertilizers (e.g. manure)? ☐ Yes ☒ No

4. Determine residual benefit from your previous crop? ☐ Yes ☒ No

5. Do you have results from omission plot trials conducted in a similar field in your municipality or district?  ☒ Yes ☐ No

N response:  t/ha

P response:  t/ha

K response:  t/ha

6. Will you apply Bio-N? ☐ Yes ☒ No

N response (t/ha)	Fertilizer N (kg/ha)
2	110
3	130
4	150
5	170
6	190
7	210
8	230

Yield (t/ha)	P response (t/ha)	Fertilizer P <sub>2</sub> O <sub>5</sub> (kg/ha)
0		
0.5		
1.0		
1.5		
2.0		
2.5		

Yield (t/ha)	K response (t/ha)	Fertilizer K <sub>2</sub> O (kg/ha)
0		
0.5		
1.0		
1.5		
2.0		
2.5		

N credits:  kg N/ha  
Final N rate:  kg N/ha

P credits:  kg P<sub>2</sub>O<sub>5</sub>/ha  
Final P rate:  kg P<sub>2</sub>O<sub>5</sub>/ha

K credits:  kg K<sub>2</sub>O/ha  
Final K rate:  kg K<sub>2</sub>O/ha

## Nutrient Expert for Hybrid Maize

- In the absence of data from nutrient omission plots, NE estimates attainable yield and yield responses to N, P, and K based on climate and soil properties, i.e. soil fertility indicators

**Estimate yield responses to fertilizer N, P, and K**

Name and/or location:  Attainable yield:  t/ha (15.5% MC)

Growing environment:

In the absence of omission plot results, we use general soil characteristics and nutrient balance to estimate yield responses.  
Please note that the estimated responses are subject to verification and fine tuning (e.g. through farmer participatory evaluation).

1. Soil type: ☒ clayey ☐ loamy ☐ sandy

2. Soil color and organic matter content: ☐ reddish or yellowish ☐ grayish or brownish ☐ very dark soil with high organic matter

3. Application of manure and/or compost: ☐ yes ☐ no

4. Has your soil been analyzed for P and K in the past 3-5 years? ☐ yes ☐ no

5. Is your soil known to be of volcanic origin and contain allophane? ☐ yes ☒ no



## Agronomic and economic performance of Nutrient Expert for Hybrid Maize (NE) vs. farmers' fertilizer practice (FFP) at five sites (3-5 farmers/site) in Indonesia

	FFP	NE	NE-FFP	Significance
Grain yield, t/ha	7.5	8.4	+0.9	***
Fertilizer N, kg/ha	173	160	-12	ns
Fertilizer P, kg/ha	19	14	-4	*
Fertilizer K, kg/ha	23	34	+11	**
Fertilizer cost, \$/ha	126	126	0	ns
Gross return <sup>†</sup> , \$/ha	1,761	2,032	=271	***



ns = not significant; \* p=0.05, \*\* p=0.01, \*\*\* p=0.001

<sup>†</sup> Gross return above seed and fertilizer costs in USD

**Agronomic and economic performance of Nutrient Expert for Hybrid Maize (NE) vs. farmers' fertilizer practice (FFP) at seven sites (2-7 farmers/site) in the Philippines**

	FFP	NE	NE-FFP	Significance
Grain yield, t/ha	7.5	9.1	+1.6	***
Fertilizer N, kg/ha	107	132	+25	**
Fertilizer P, kg/ha	12	15	+4	**
Fertilizer K, kg/ha	18	29	+11	**
Fertilizer cost, \$/ha	176	240	+64	***
Gross return, \$/ha	1,738	2,117	+379	***



ns = not significant; \* p=0.05, \*\* p=0.01, \*\*\* p=0.001  
† Gross return above seed and fertilizer costs in USD.

**Scenario analysis comparing Nutrient Expert for Hybrid Maize fertilizer recommendations with current farmers' fertilizer (FFP) practice in western Kenya.**

Moderate Soil Fertility				
	Yield, t/ha	NPK, kg/ha	Fertilizer Cost, \$/ha	Gross Return, \$/ha
FFP	1.8	32-7-0	48	488
	NE Recommendations			
Optimal	5.0	130-67-63	226	1,250
Low cost	2.5	60-25-23	106	630
Poor rain	3.0	79-40-40	154	735



Zingore, unpublished data



**Scenario analysis comparing Nutrient Expert for Hybrid Maize fertilizer recommendations with current farmers' fertilizer (FFP) practice in western Kenya.**

Low Soil Fertility				
	Yield, t/ha	NPK, kg/ha	Fert. Cost, \$/ha	Gross Return, \$/ha
FFP	0.7	0	0	198
NE Recommendations				
Optimal	2.0	40-20-15	73	511

Zingore, unpublished data



## Conclusions

- Declining soil fertility is widespread throughout sub-Saharan Africa, but there is great potential to increase maize yields, especially in high soil fertility areas
  - Erratic rainfall is a major limiting factor
- Rehabilitation of degraded soil is necessary to reduce yield gaps



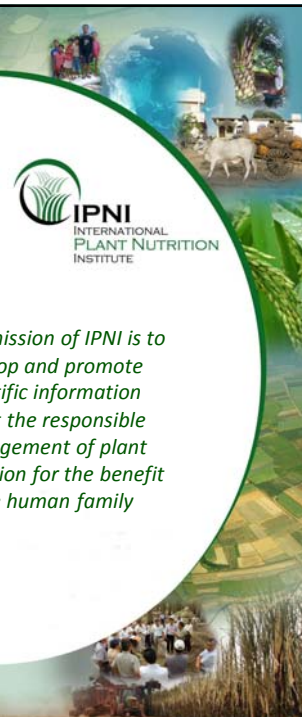
## Conclusions

- Fertilizer + organic nutrient sources, targeted towards variable soil fertility condition are essential to increasing yields
- Decision support tools, like Nutrient Expert, offer viable options to the blanket fertilizer recommendations currently used.



***Thank  
You***

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management of plant  
nutrition for the benefit  
of the human family*

# Challenges and Opportunities for Maize Production Intensification in Sub-Saharan Africa<sup>1</sup>

T.L. Roberts<sup>2</sup> and Shamie Zingore<sup>3</sup>  
International Plant Nutrition Institute

## Introduction

Maize is the primary food staple in Sub-Saharan Africa (SSA). It covers about 26.1 M ha or 32% of the total cereal acreage, mainly in smallholder systems (**Table 1**). Most of the maize is rainfed with the most important production areas in the sub-humid zone in East and southern Africa. Maize production is also expanding rapidly in west and central Africa, with an increase in acreage of 3-4% per year. Yields are low with averages ranging from 1.18 t/ha in central Africa to 1.81 t/ha in western Africa.

**Table 1.** Maize area, production, and yield in regions of Sub-Saharan Africa, 2008-2010. (FAOSTAT, 2012)

Region†	Area harvested, M ha	Production, M t	Yield, t/ha
Western Africa	8.04	14.61	1.81
Central Africa	2.60	3.08	1.18
Eastern Africa	8.00	12.28	1.54
Southern Africa	7.43	9.16	1.23
<b>Sub-Saharan Africa</b>	26.11	39.19	1.50
South Africa	2.93	12.74	4.35

† Western: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo  
Central: Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Gabon, Sao Tome and Principe  
Eastern: Burundi, Comoros, Eritrea, Ethiopia, Kenya, Mauritius, Réunion, Rwanda, Somalia, Uganda, United Republic of Tanzania  
Southern: Angola, Botswana, Lesotho, Madagascar, Malawi, Mozambique, Swaziland, Zambia, Zimbabwe

SSA has a great potential to increase yields and production of maize. It has large tracts of land suitable for maize production with a large proportion of smallholders with low productivity (Deininger and Byerlee, 2011). The total area available for maize expansion almost equals the 161 M ha currently harvested globally. SSA has an additional estimated 87 M ha of uncultivated land that could be planted to maize.

<sup>1</sup> 19<sup>th</sup> Annual AFA Fertilizer Forum. Feb. 26-28, 2013, Cairo Semiramis Intercontinental Hotel, Egypt

<sup>2</sup> Norcross, GA. USA

<sup>3</sup> Nairobi, Kenya

Most of these areas already produce some maize and all of them have the potential to significantly increase yields.

### **Maize Yield Potential**

It is estimated that only 20% of the potential maize yield is realized in SSA (Deininger and Byerlee, 2011; Smale et al., 2011). From 2005 to 2008, its maize yields averaged 1.4 t/ha. In contrast Brazil's maize yields averaged 3.8 t/ha, Mexico 3.1 t/ha, Philippines 2.5 t/ha, and Thailand 3.9 t/ha. Annual yield growth from 1961 through 2008 averaged 2.4%, 2.8%, and 1.6% respectively in Brazil, Philippines, and Thailand, while yields in Mexico have been rising at about 1.9% per annum since the 1970s, on average about double the 1% annual rise in SSA. Although total maize production has been increasing by about 4% in SSA in this period, this is largely due to expansion of the area under cultivation, rather than productivity increases.

Maize yield variability is extremely high in SSA. The highest variability occurs in southern Africa. Zimbabwe's coefficient of variation in maize production from 1991-2007 was 41% compared to 33% in Malawi, 31% in Zambia, and only 11% in Kenya (Smale et al., 2011). Most of the variability is attributed to climate, but soil fertility heterogeneity due to localized differences in parent materials, landscape position and agronomic management also contribute to yield variability (Zingore et al. 2011; 2013).

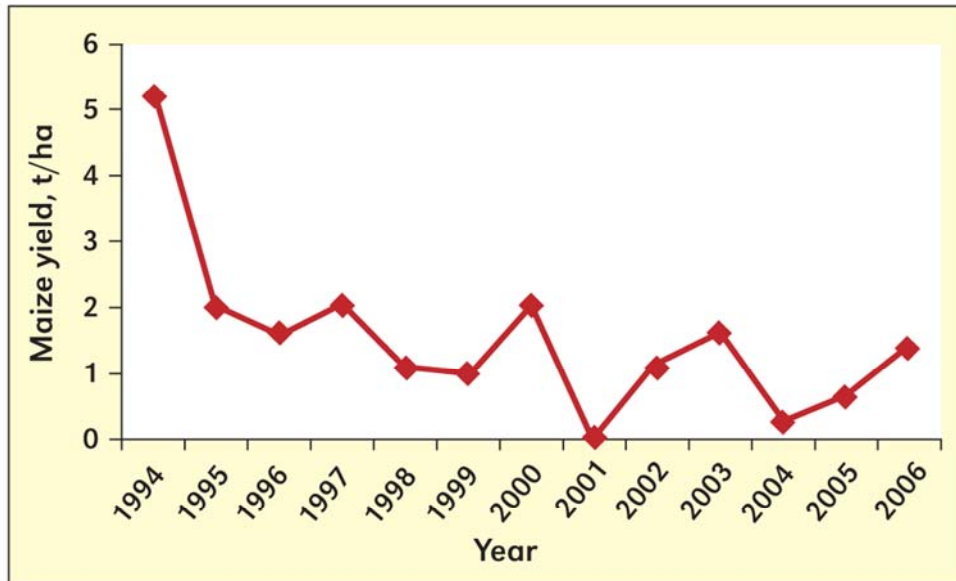
Farmers in the United States routinely grow five to seven times more maize per hectare than smallholder farmers in SSA. Closing this yield gap will be vitally important for world food security. Using high-yielding modern maize varieties and fertilizer is necessary to close this yield gap.

Plant breeding, biotechnology, and genetic advances are critical to increasing maize production and are believed by many to be the solution to increasing yields and closing yield gaps. Major seed companies have pledged to develop new varieties of maize that will yield twice as much using less N and water, but genetic developments alone will be insufficient (Roberts and Tasistro, 2012). Increasing maize yields will require a combination of improved genetics and agronomic advances (e.g. better planting densities, improved soil management, increased fertilizer efficiency). Such advance biotechnologies and mechanization to improve crop and nutrient management may not be possible or accessible for smallholders in SSA, but much can be done to increase yields with access to hybrid seeds, fertilizer, and better management.

### **Soil Fertility and Fertilization**

The soils in SSA have been farmed for decades with little or no addition of fertilizer nutrients exacerbating their inherent low fertility (Bationo et al., 1998; Bekunda et al., 1997). Fertilizer use in SSA is the lowest in the world. Fertilizer use has remained stagnant over the past three decades, despite a ten-fold increase in the use of improved seed varieties (World Bank, 2008). African farmers apply on average

less than 10 kg/ha of nutrients, although there are areas where application rates are higher. Continual cultivation of crops with such low levels of nutrient input mines nutrients from the soil causing declining soil fertility and degraded soil. Without the addition of fertilizers, NPK depletion rates can range between 22 and 72 kg/ha/yr. Low maize yields are the natural result of declining soil fertility. Long-term studies have shown how rapidly yields decline once native woodlands are cleared for cultivation (**Fig. 1**).



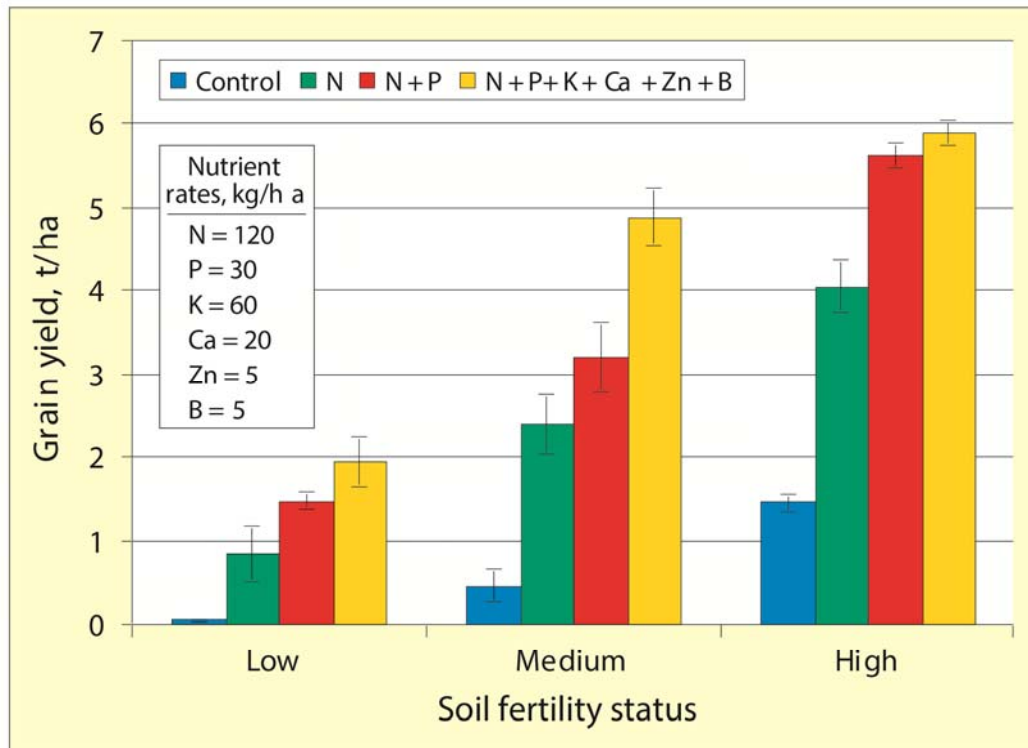
**Figure 1.** Average maize yields with no fertilizer application from long-term experiments in southern Africa (Waddington et al., 2007).

Variable soil fertility resulting from a combination of inherent infertility and poor management factors leads to variable and often large yield differences (Zingore et al., 2007; Zingore, 2011). Smallholders typically use their limited nutrient resources (e.g. manure) on fields closest to home resulting in gradients of decreasing soil fertility moving away from the homestead (Prudencio, 1993). Combined with the natural differences in soils (i.e. temporal variability) preferentially applying nutrients near the homestead leads to great differences in local variability between fields on the same farm and other farms in the area where everyone may not have access to the same nutrient sources.

Restoring agricultural productivity on these degraded soils is often challenging and cannot always be corrected by simply adding fertilizer nutrients. Blanket recommendations based on agro-ecological zones are the basis for fertilizer

application in SSA, but blanket recommendations do not adequately address the temporal variability in soil fertility that exists in these depleted soils.

Zingore (2011) summarized studies conducted across SSA that demonstrated baseline yields and yield response to fertilizer increases with the increasing status of soil fertility (**Fig. 2**). Results showed that N application gave the greatest yield response in maize regardless of soil fertility status, but response to applied P only occurred in soils with a high fertility status. In fields categorized with medium soil fertility status, the addition of base cations (K and Ca) and micronutrients (Zn and B) were required to increase yields above the N only treatment. Baseline maize yields were very low on the most depleted fields (i.e. low fertility) increasing to less than 1 t/ha with the addition of N and less than 2 t/ha with the addition of N and P. The lack of response may be attributed to low organic matter, which impacts general soil health, nutrient and water retention, and nutrient supplying capacity.



**Figure 2.** Maize yield response to various nutrient combinations as influenced by soil fertility status (Zingore, 2011)

Incorporating organic and inorganic inputs together with improved plant genetics is a necessary management strategy needed to increase yields in SSA. This practice,

known as “integrated soil fertility management” (ISFM) can be defined as “... *the application of soil fertility management practices, and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity. These practices necessarily include appropriate fertilizer and organic input management in combination with the utilization of improved germplasm.*” (Alley and Vanlauwe, 2009). ISFM strives to maximize the interactions that result from the combination of fertilizer, organic inputs, improved germplasm, and farmer knowledge.

**Table 2** shows how adding manure to N fertilizer to soils of low and medium fertility status increased yields greater than fertilizer alone, especially in the soils categorized with low soil fertility. Such a positive interaction between fertilizer and manure on fertility-degraded soils is common in SSA (Zingore et al., 2008; Mtambanengwe and Mapfumo, 2005). In situations of severe soil degradation, it has been shown that addition of large amounts of manure (> 10 t/ha) for at least three years is necessary to restore maize productivity to meaningful level and for fertilizer use to become economically viable (Zingore et al., 2007). The main challenge for using manure to improve crop productivity is the low amounts available due to limited livestock ownership rates. Inclusion of legumes in rotations or intercropping maize with legumes improves overall productivity of both crops and enhances soil fertility through biological N fixation (Giller et al., 1997).

**Table 2.** Maize yield as affected by manure and N fertilizer applications under low, medium, and high soil fertility conditions (Zingore, 2011).

Soil fertility status	Control	Manure	N fertilizer	Manure + N fertilizer
	Yield, t/ha			
Low	0.3	0.8	1.2	2.8
Medium	0.8	1.7	3.8	4.3
Standard error	0.12	0.23	0.19	0.24

### Fertilizer Recommendations Using Nutrient Expert

Targeting fertilizer use to variable soil fertility conditions rather than blanket recommendations is an ideal management strategy, but requires individualized or more local recommendations that are not readily available in SSA. The International Plant Nutrition Institute has developed a simple computer-based decision support tool — Nutrient Expert for Hybrid Maize (NE) —to help advisers assist smallholder systems with site-specific nutrient management recommendations tailored to a farmer’s field or growing environment. NE accounts for the most important factors affecting nutrient management recommendations, which enables crop advisers to provide farmers with recommendations suited to their farming conditions, thereby



reducing the uncertainty associated with highly variable conditions (e.g. site characteristics, climate, input prices, and crop produce prices).

NE has been successfully adopted in Indonesia, the Philippines, and India and is now being evaluated for adoption in SSA. Pampolina et al. (2012) outlined the conceptual framework for NE. This tool determines fertilizer need based on the relationship between the uptake of nutrients at harvest and grain yield (i.e. internal nutrient efficiency) which can be predicted using a model developed for the quantitative evaluation of the fertility tropical soils known as QUEFTS (Janssen et al., 1990). The fertilizer requirement for a field or location is estimated from the expected yield response to each fertilizer nutrient, which is the difference between the attainable yield and the nutrient-limited yield as determined by nutrient omission plots.

A nutrient omission plot is a field tool used to determine the amount of fertilizer needed for attaining a target crop yield. Omission plots can be used in place of soil tests to determine the soil nutrient supplying capacity. The yield from a small plot where a particular nutrient was omitted when all other nutrients are supplied at sufficiently high rates (e.g. minus N, but ample P and K) to ensure that yield is not limited provides an indirect estimation of the nutrient supplying capacity of the soil. The yield difference between a fully fertilized plot and an omission plot approximates the potential response to the addition of the nutrient of interest.

The fertilizer requirements in NE are determined from nutrient omission trials in farmers' fields, while attainable yield is the yield for a typical year at a location using best management practices without nutrient limitations. Nutrient-limited yield is that when only the nutrient of interest is omitted. The amount of nutrients taken up by a crop is directly related to its yield so that the attainable yield indicates the total nutrient requirement and the nutrient limited yield indicates the indigenous nutrient supply. The yield response indicates the nutrient deficit, which must be supplied by fertilizers. In the absence of omission plot data; NE can estimate these parameters using proxy information.

NE asks a series of simple questions about current nutrient management practices, planting densities, attainable yields, residue management, use of fertilizers and/or manure, availability of local omission plot data, fertilizer sources, etc. Consistent with 4Rs (right source, right rate, right time, and right place) of nutrient stewardship (IPNI, 2012) NE specifies the amount and timing of fertilizer to apply, including split applications and it provides profit analysis.

Field evaluations of NE have demonstrated that NE can increase yield and profits for smallholder farmers in Indonesia and the Philippines (**Table 3**). Results from 22 farmers' fields showed that NE increased yields by 0.9 t/ha over the farmer's fertilizer practice (FFP) and gross returns by US\$ 270/ha. Recommendations generated by NE reduced fertilizer P by 4 kg/ha and increased K by 11 kg/ha, but did not significantly change fertilizer N compared to FFP. In the Philippines, across

31 fields, comparing NE to FFP; maize yield was increased by 1.6 t/ha and gross return by US\$ 379/ha. Compared to FFP, NE recommended higher rates for all three nutrients (+25 kg N/ha, + 4 kg/P/ha, and +11 kg K/ha), which increased fertilizer costs, but still increased profits by about six times the additional investment in fertilizer.

**Table 3.** Agronomic and economic performance of Nutrient Expert for Hybrid Maize (NE) compared to farmers' fertilizer<sup>†</sup> practice (FFP) at five sites (3-5 farmers/site) in Indonesia and seven sites (2-7 farmers/site) in the Philippines. (Pampolina et al., 2012)

	Grain yield, t/ha	Fertilizer N, kg/ha	Fertilizer P, kg/ha	Fertilizer K, kg/ha	Fertilizer Cost, US\$/ha	Gross return <sup>†</sup> , US\$/ha
Indonesia (n=22)						
FFP <sup>‡</sup>	7.5	173	19	23	126	1,761
NE	8.4	160	14	34	126	2,032
NE - FFP	+0.9	-12	-4	+11	0	+271
Significance	***	ns	*	**	ns	***
Philippines (n=31)						
FFP	7.5	107	12	18	176	1,738
NE	9.1	132	15	29	240	2,117
NE - FFP	+1.6	+25	+4	+11	+64	+379
Significance	***	**	**	**	***	***

ns = not significant; \* p=0.05, \*\* p=0.01, \*\*\* p=0.001

<sup>†</sup> Gross return above seed and fertilizer costs. <sup>‡</sup> Farmers' fertilizer practice

Preliminary results in Kenya, show NE has the potential to be just as successful. A scenario analysis of fertilizer recommendations generated by NE is shown in **Table 4**. Under moderate soil fertility status, maize yields have the potential to reach 5 t/ha under optimal conditions and 3 t/ha under poor rainfall using the NE recommended fertilizer rates generating a gross return of US\$ 735-1,250/ha compared to current farmer yields of 1.8 t/ha and returns of US \$488/ha. Using a low cost recommendation, NE recommendations would be expected to double farmer yields and increase returns by about 30%. Under low soil fertility conditions, NE estimates that farmers can only achieve 0.7 t/ha without addition of fertilizer. However, yields can be tripled and income increased by US \$ 511 on such soils with balanced application of fertilizer at low rates, and application of lime under acidic soil condition.

**Table 4.** Scenario analysis comparing Nutrient Expert for Hybrid Maize fertilizer recommendations with current farmers' fertilizer (FFP) practice in western Kenya. (Zingore, unpublished data)

	Yield, t/ha	N-P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O, kg/ha	Fertilizer cost, US\$/ha	Gross return, US\$/ha
FFP – moderate soil fertility	1.8	32-7-0	48	488
NE Recommendations for Moderate Soil Fertility				
Optimal	5.0	130-67-63	226	1,250
Low Cost	2.5	60-25-23	106	630
Poor rainfall	3.0	79-40-40	154	735
FFP – low soil fertility	0.7	0	0	198
NE Recommendations for Low Soil Fertility				
Optimal	2.0	40-20-15	73	511

## Conclusions

Although declining soil fertility is widespread throughout SSA, it has great potential to increase maize yields using improved seed and fertilizers. Judicious use of fertilizers, complimented by organic nutrient sources, and targeted towards variable soil fertility conditions is an essential component of achieving food security. Decision support tools for site-specific nutrient management, such as NE, offer viable options to the current blanket fertilizer recommendations based on agro-ecological zones.

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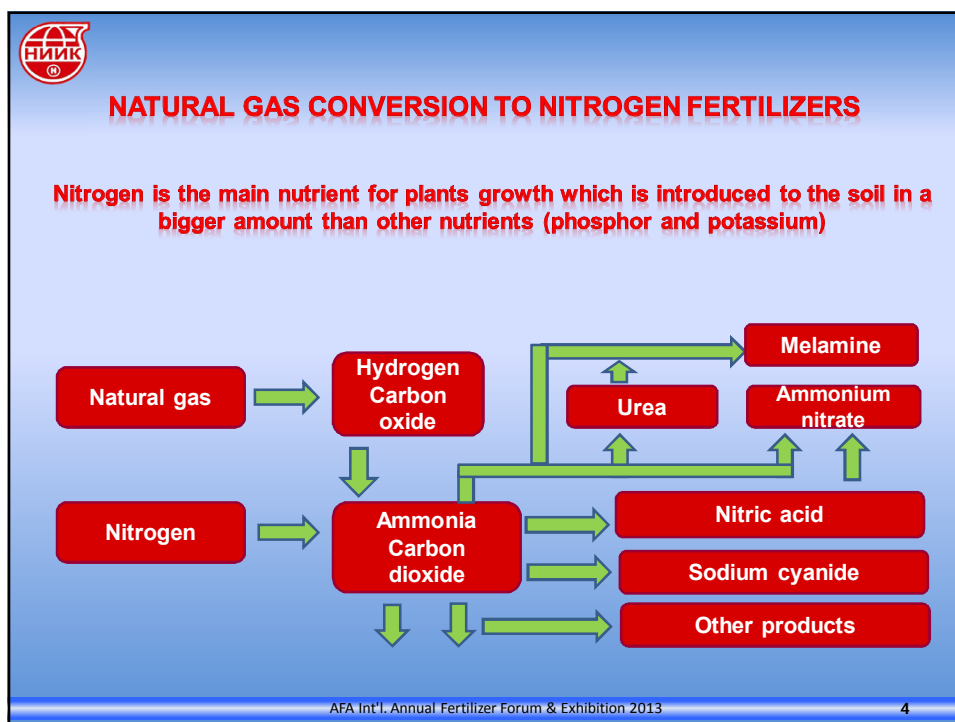
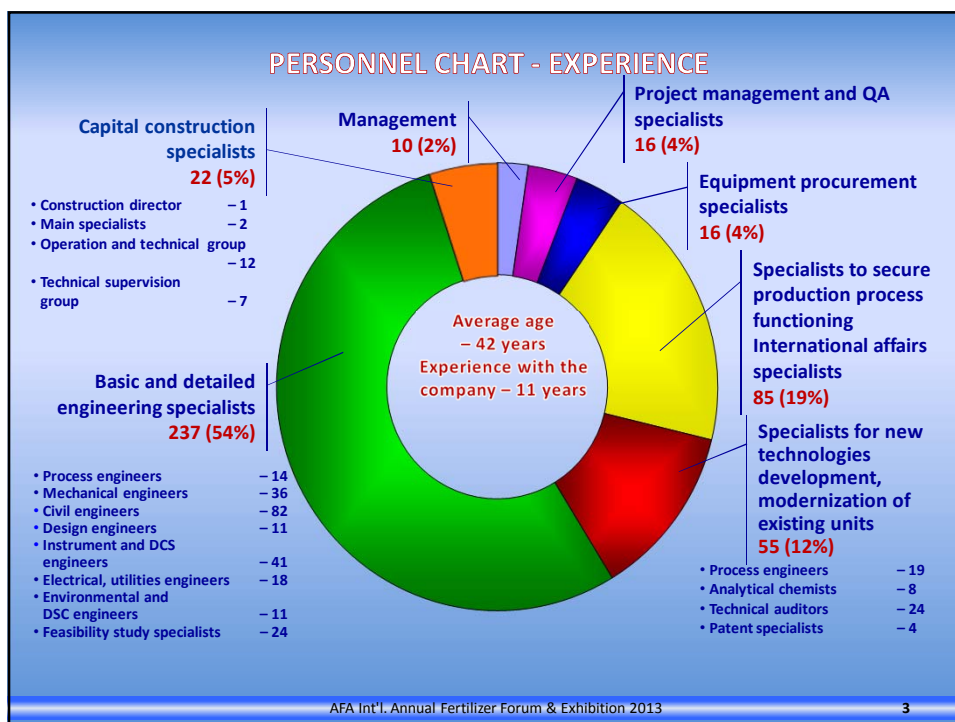
- 1952 г.** founded as a branch of State Nitrogen Industry Institute (GIAP)
- 1990 г.** separated into an independent company
- 1993 г.** reformed into a private company
- 1999 г.** renamed into «NIIK» (R&D Institute of Urea)

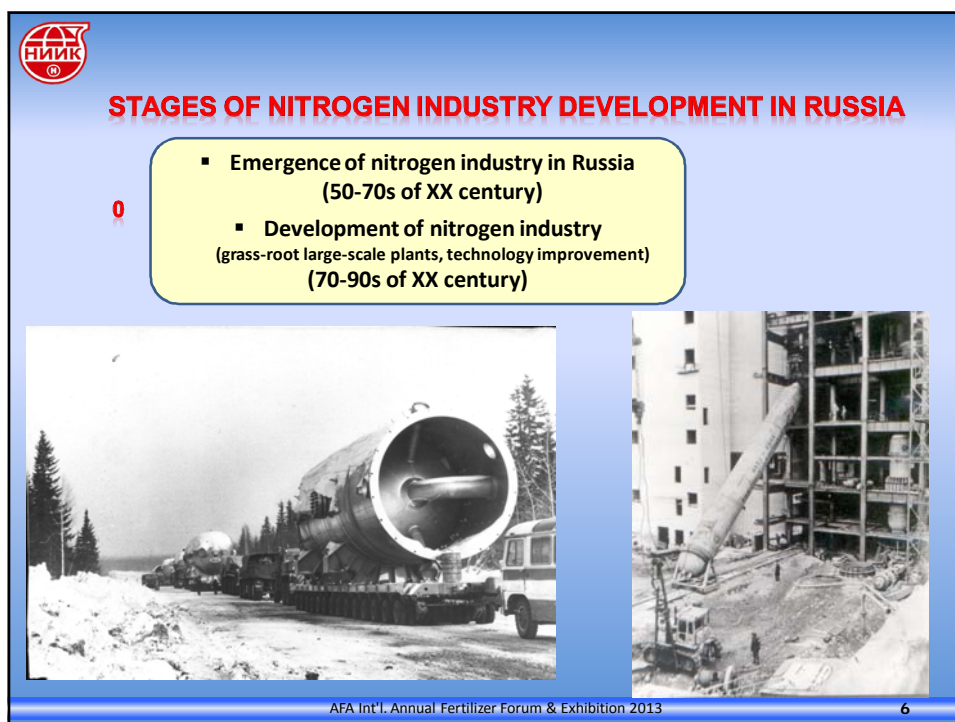
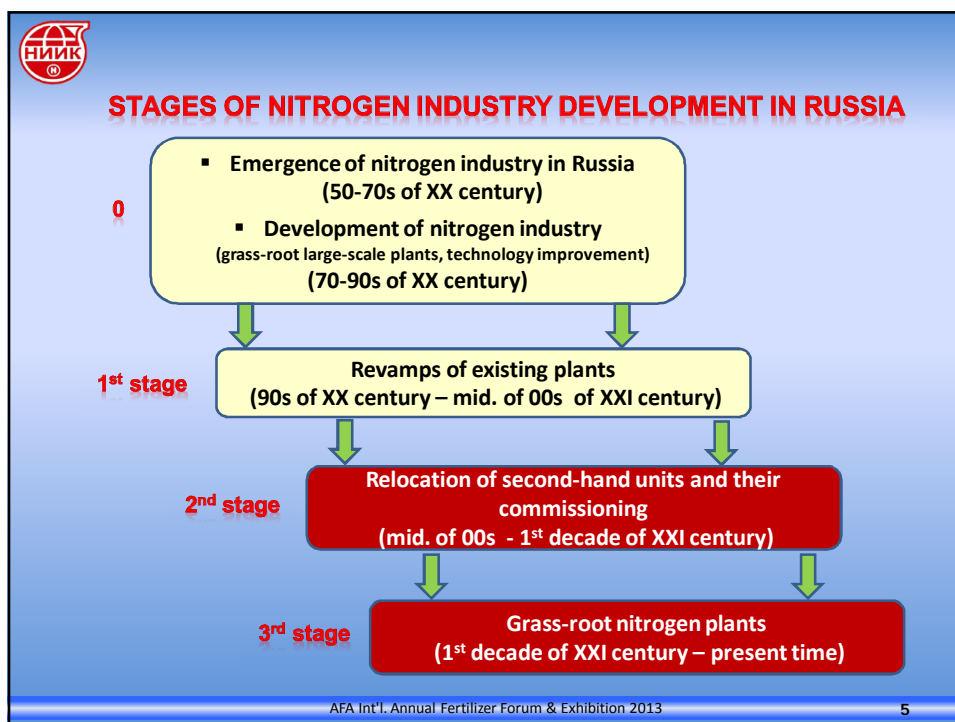
Total number of employees ~ 440 people

**Leading Russian engineering company providing full range of services**

- Urea technologies proprietary urea process technologies and equipment for efficient production, environmental friendliness and industrial safety
- Engineering, design and project management project documentation development
- Procurement and turn-key projects







**НИИХ**

## STAGES OF NITROGEN INDUSTRY DEVELOPMENT IN RUSSIA

0

- Emergence of nitrogen industry in Russia (50-70s of XX century)
- Development of nitrogen industry (grass-root large-scale plants, technology improvement) (70-90s of XX century)




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**НИИХ**

## STAGES OF NITROGEN INDUSTRY DEVELOPMENT IN RUSSIA

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## DEVELOPMENT OF NITROGEN INDUSTRY IN RUSSIA

### 1<sup>st</sup> STAGE. REVAMPS OF EXISTING PLANTS

(90s of XX century – mid. 00s of XXI century)

- ✓ During the period of urea units revamps, the urea capacity of modernized units increased from 5 mil up TPA to 6.5 mil TPA



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## DEVELOPMENT OF NITROGEN INDUSTRY IN RUSSIA

### 2<sup>nd</sup> STAGE. RELOCATION OF SECOND-HAND UNITS AND THEIR COMMISSIONING


(mid. 00s – 1<sup>st</sup> decade of XXI century)




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 **PECULIARITIES OF THE PROJECTS ON RELOCATION OF SECOND-HAND NITROGEN UNITS AND THEIR COMMISSIONING**

**ADVANTAGES OF SECOND-HAND UNITS RELOCATION**




Cost cutout (relatively low equipment cost)




Reduction of commissioning period

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 **PECULIARITIES OF THE PROJECTS ON RELOCATION OF SECOND-HAND NITROGEN UNITS AND THEIR COMMISSIONING**

**PECULIARITIES OF THE PROJECTS IMPLEMENTATION ON SECOND-HAND UNITS RELOCATION AND THEIR COMMISSIONING**



- availability of nameplates and certificates for second-hand equipment, fittings, control valves, safety devices etc.
- technical equipment inspection


- revamps of several sections to achieve required capacity and optimal operation mode of the unit

- installation of second-hand equipment, not designed for severe climatic conditions, in heated rooms. If it is impossible – its replacement with new equipment fit for the climatic zone.

- compliance with the existing norms and regulations when the unit is relocated to Russia

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 **PECULIARITIES OF THE PROJECTS ON RELOCATION OF SECOND-HAND NITROGEN UNITS AND THEIR COMMISSIONING**

**PECULIARITIES OF THE PROJECTS IMPLEMENTATION ON SECOND-HAND UNITS RELOCATION AND THEIR COMMISSIONING**

- complete replacement of obsolete and deteriorated instrumentation
- industrial safety certification of the equipment inclusive of the one manufactured abroad under Russian Federation regulations
- reports on rolled metal products inspection in order to include relocated metal structures in design documentation

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 **НИИХ'S PROJECTS ON RELOCATION OF USED NITROGEN UNITS AND THEIR COMMISSIONING**



New urea plant based on second-hand equipment at ACHEMA (Jonava, Lithuania)

Capacity=500 TPD – based on second-hand unit relocated from Angarsk, 2006-2007

Capacity=1000 TPD – based on second-hand unit relocated from Manfredonia, 2008-2010

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## **NIIK'S PROJECTS ON RELOCATION OF USED NITROGEN UNITS AND THEIR COMMISSIONING**

**NAK Azot**

New urea unit based on second-hand  
equipment relocated from Pancevo (Serbia),  
2007-2010



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## **PROJECT ON NEW UREA UNIT BASED ON SECOND-HAND EQUIPMENT AT NAK AZOT**

### **BACKGROUND**

- Unit capacity (enhanced) - 1150 TPD
- Urea technology - Stamicarbon

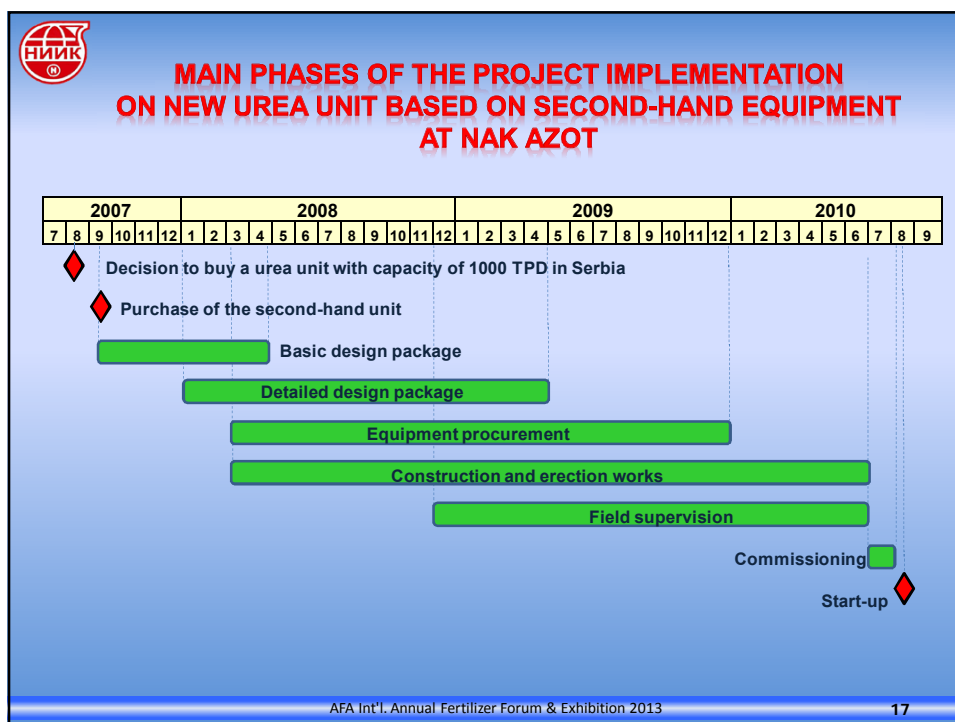
### **NIIK'S SCOPE OF WORKS**

- Basic and detailed design documentation
- Operating instructions
- Process adaptation to comply with the environmental safety requirements
- Capacity enhancement (from 1000 TPD up to 1150 TPD)
- DCS development
- Field supervision
- Process simulator development

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## CURRENT AND PROSPECTIVE PROJECTS ON NEW NITROGEN UNITS BASED ON SECOND-HAND EQUIPMENT

ACRON (Russia)

- Ammonia Unit 4 based on second-hand equipment (partially)

Kuibyshev Azot (Russia)

- Nitric acid unit based on second-hand equipment

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## DEVELOPMENT OF NITROGEN INDUSTRY IN RUSSIA

### 3<sup>rd</sup> STAGE. GRASS-ROOT NITROGEN PLANTS


(1<sup>st</sup> decade of XXI century – present time)






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## PROJECTS ON GRASS-ROOT NITROGEN PLANTS



Cherepovetsky Azot  
Grass-root urea plant,  
2008-2012



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## GRASS-ROOT UREA PLANT AT CHEREPOVETSKY AZOT

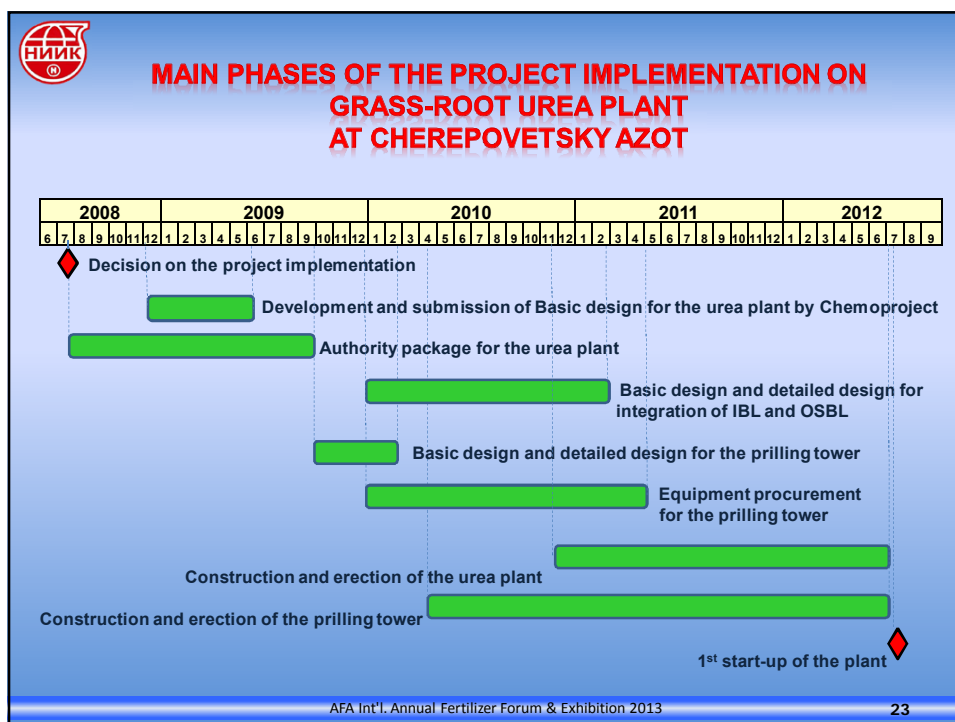
### BACKGROUND

<ul style="list-style-type: none"> <li>• Plant capacity</li> <li>• Urea technology</li> <li>• Finished product technology</li> <li>• EP-contractor</li> <li>• Construction contractor</li> </ul>	<ul style="list-style-type: none"> <li>- 1500 TPD</li> <li>- Stamicarbon</li> <li>- prilling tower designed by NIIK</li> <li>- Chemoproject</li> <li>- Koksohimmontazh</li> </ul>
--	---

### NIIK'S SCOPE OF WORKS

- Authority package for urea plant based on Chemproject's basic design package and authority approval
- Basic design and detailed design for the prilling tower (proprietary design of NIIK)
- Basic design, authority package and its approval and detailed design for integration of the urea unit (ISBL) with OSBL objects
- Equipment procurement for the prilling tower
- Field supervision for the prilling tower construction and OSBL objects

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**НИИК**

## PROJECT ON GRASS-ROOT COMPLEX NIIK IS INVOLVED IN NITROGEN COMPLEX IN TATARSTAN

### COMPLEX STRUCTURE AND PERFORMANCES

- ✓ Ammonia unit, capacity - 522 200 TPA
- ✓ Methanol unit, capacity - 233 800 TPA
- ✓ Urea unit - 717 500 TPA
- ✓ Urea formaldehyde concentrate unit, capacity - 5 950 TPA
- ✓ Methanol storage;
- ✓ Acids and alkali storage;
- ✓ Urea stock with handling;
- ✓ Isothermal ammonia storage;
- ✓ OSBL, infrastructure and utilities

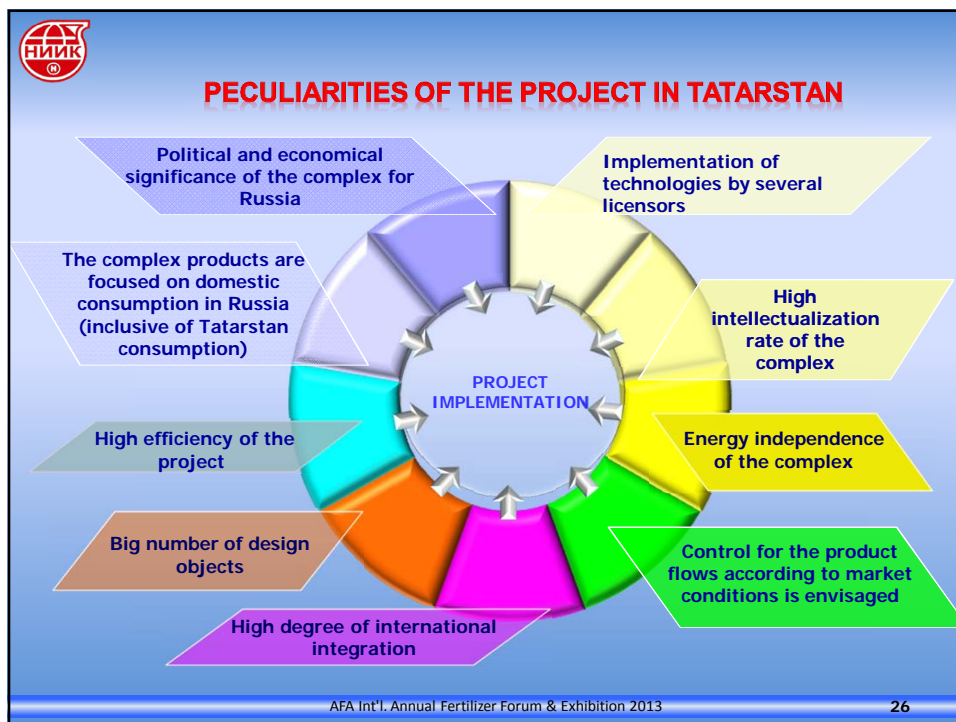
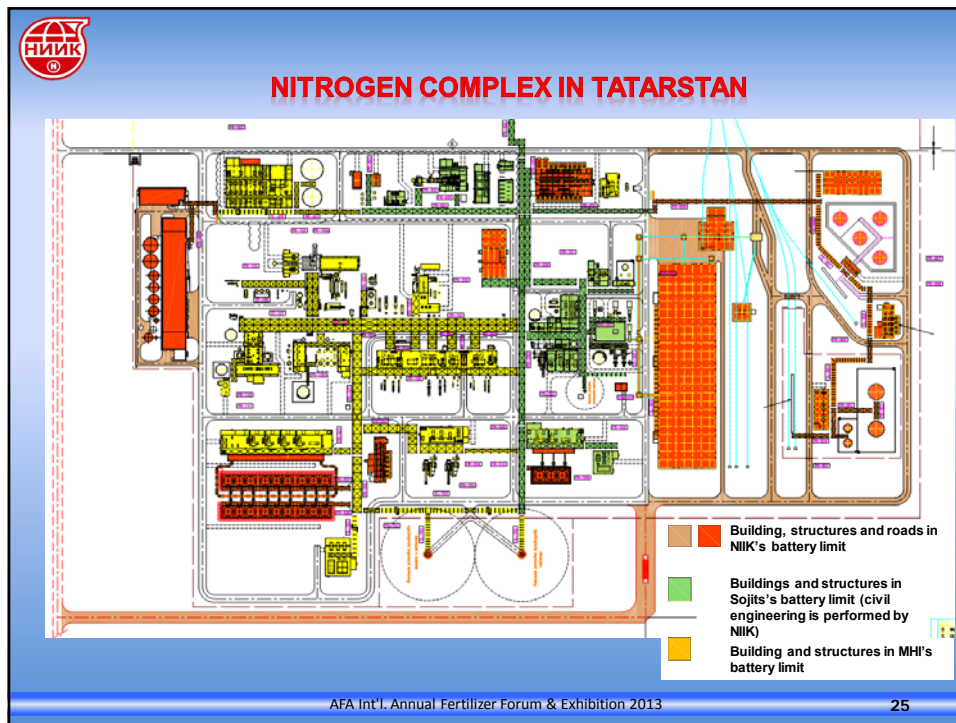
  

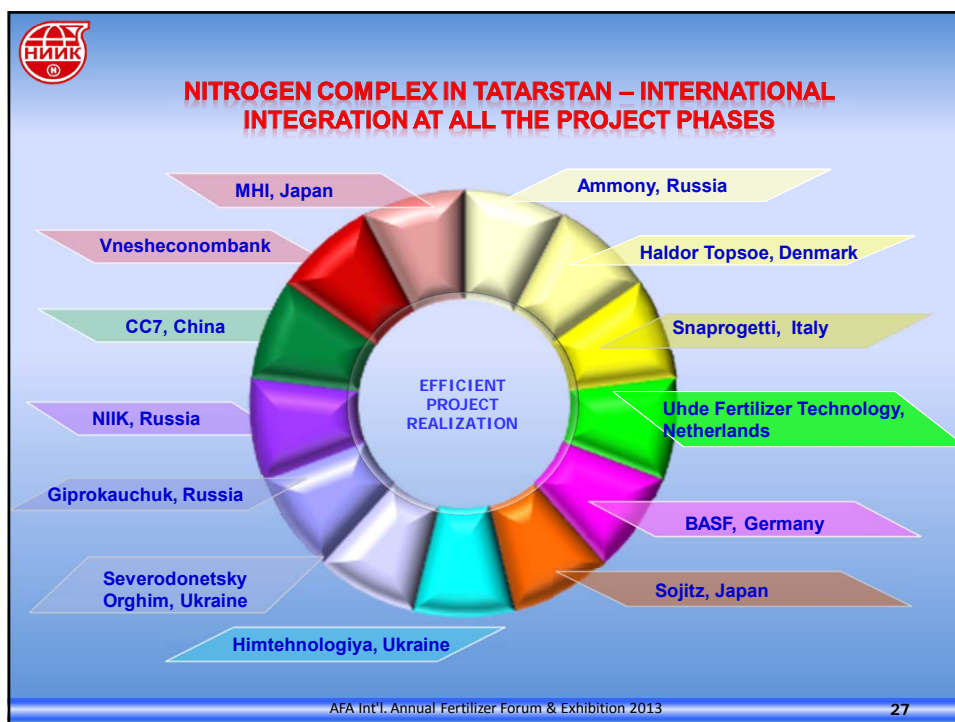
- ✓ Complex area ~37 ha
- ✓ Staff ~ 580 employees
- ✓ Gas consumption ~89 000 nm<sup>3</sup>/h
- ✓ Power consumption ~ 26-28 Mwh
- ✓ Cooling water consumption~ 50 000 m<sup>3</sup>/h

Foundation stone ceremony on the site of future ammonia/urea/methanol complex in Mendeleevsk

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**НИИХ**

### НИИХ'S SCOPE OF WORKS

**Design, procurement and construction of the objects at Methanol-Ammonia-Urea Complex in Tatarstan**

- ✓ Adaptation of the foreign documentation to Russian regulation and norms
- ✓ Certification of all the equipment items, inclusive of foreign contractors' equipment
- ✓ Quality control of foreign contractor's works
- ✓ OSBL turn-key contract including:
  - Design,
  - Equipment procurement,
  - Construction and erection works,
  - Commissioning,
  - Operating instructions development etc.
- ✓ Civil engineering part of foreign contractor's ISBL contract

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## НИИХ AS EPC-CONTRACTOR FOR OSBL

**НИИХ is an EPC-contractor for OSBL: design, procurement and construction of the objects at Methanol-Ammonia-Urea Complex in Mendeleevsk, Tatarstan**

- Liquid ammonia isothermal storage 20 000 m3 with compression and pump-house
- Biological treatment and local treatment for plant and storm wastewater
- Raw water and mineral wastewater processing unit (with transforming substation)
- Control room for cooling water system and auxiliary boiler-house
- Central control room, service buildings
- Office building
- Central distribution transforming substation
- Flares (for ammonia, urea and methanol units)
- Urea stock with packaging unit for packing in bags and big-bags including integrated control room and transforming substation
- Urea handling section for urea shipment in bulk in road-tanks and railcars
- Methanol loading/unloading railway rack
- Methanol pump-house
- Methanol tank farm
- Acids and alkali storage with loading/unloading railway rack
- Methanol and chemical reagents storage control room
- Local treatment units
- Cooling towers (for ammonia, urea and methanol units)
- HV power line - 110 kW substation Elabuga
- etc.

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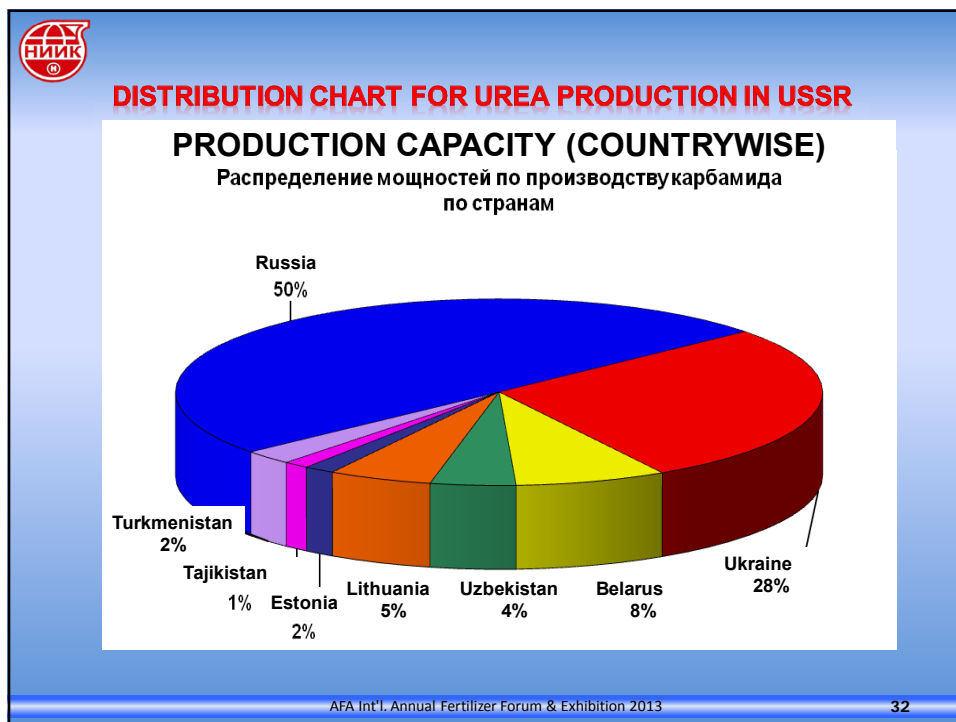
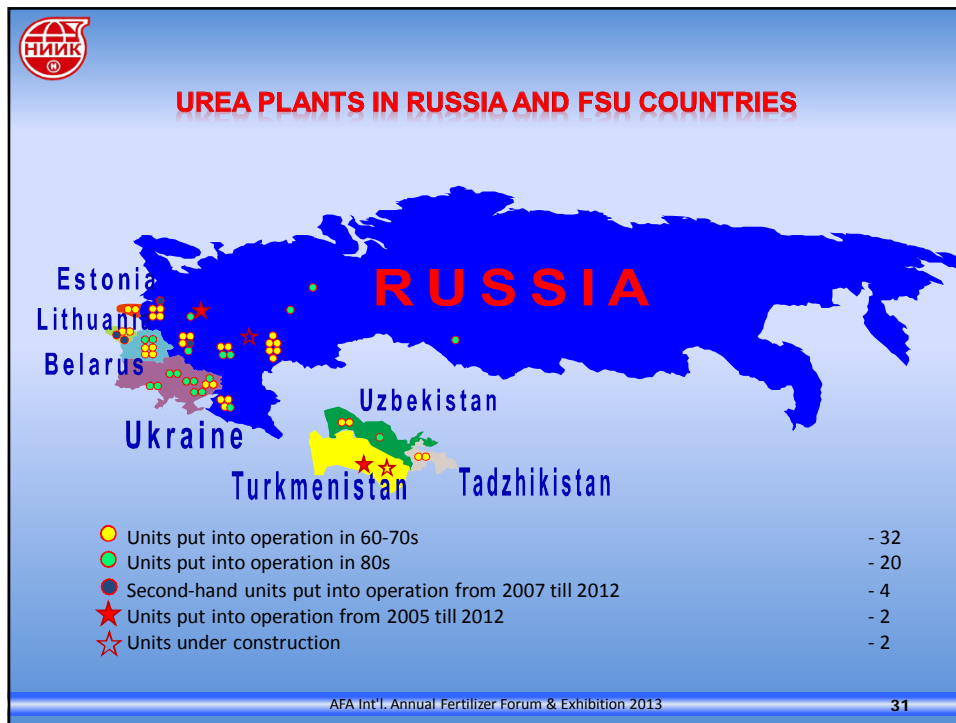


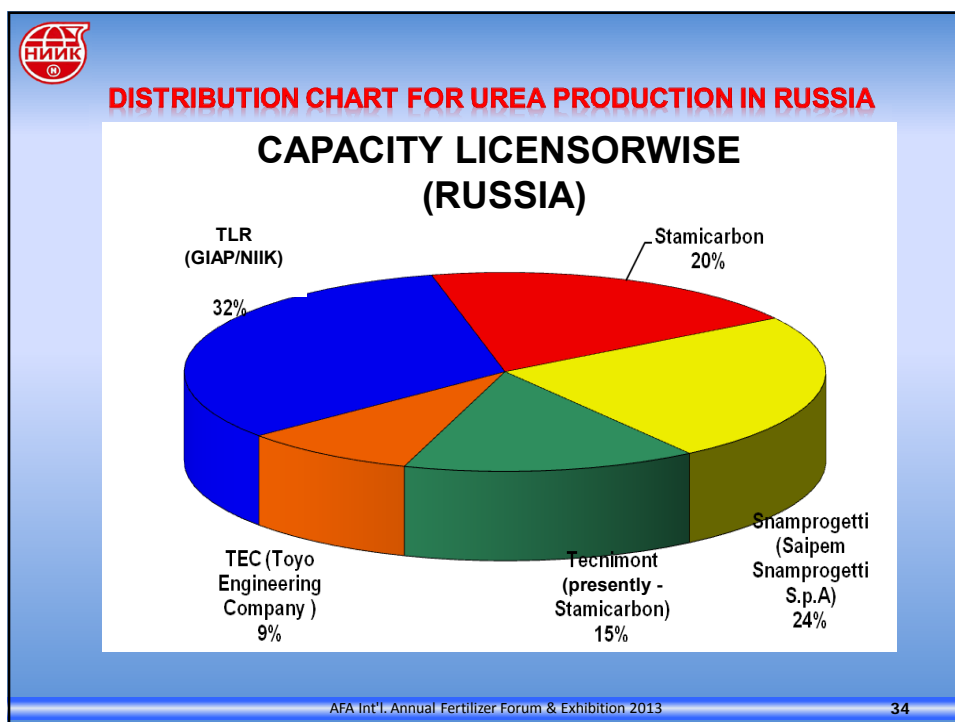
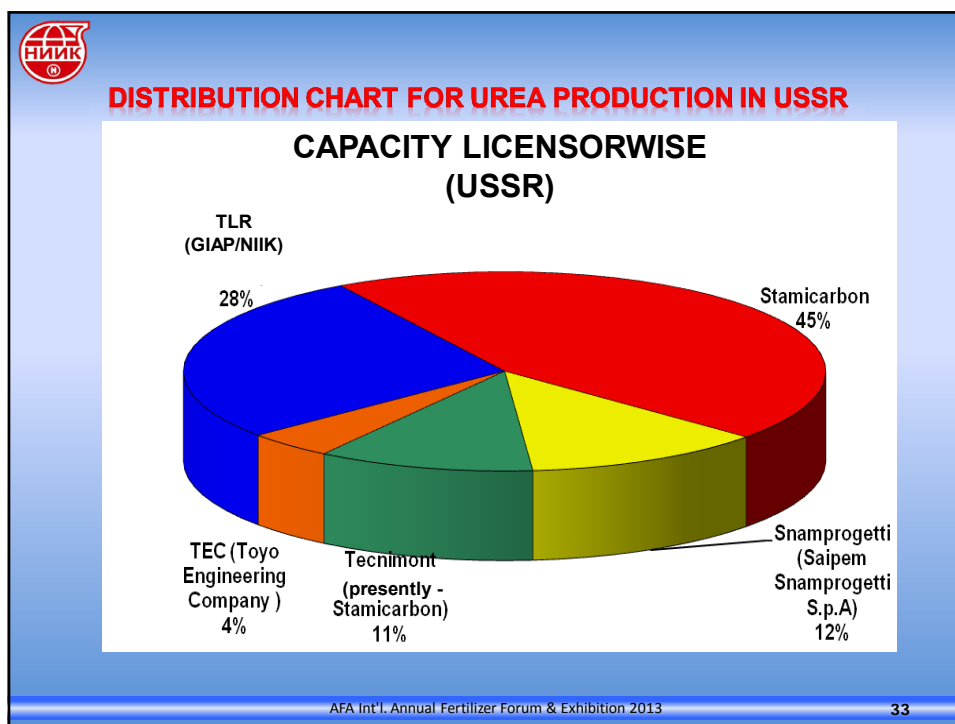
## OUTLOOK FOR AMMONIA AND UREA PLANTS DEVELOPMENT

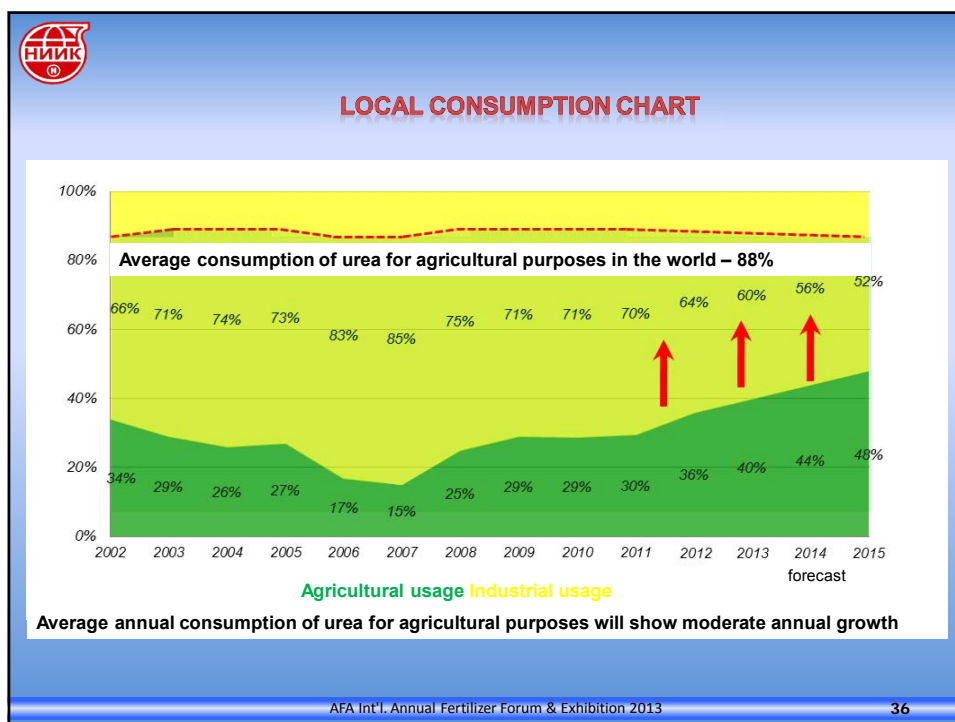
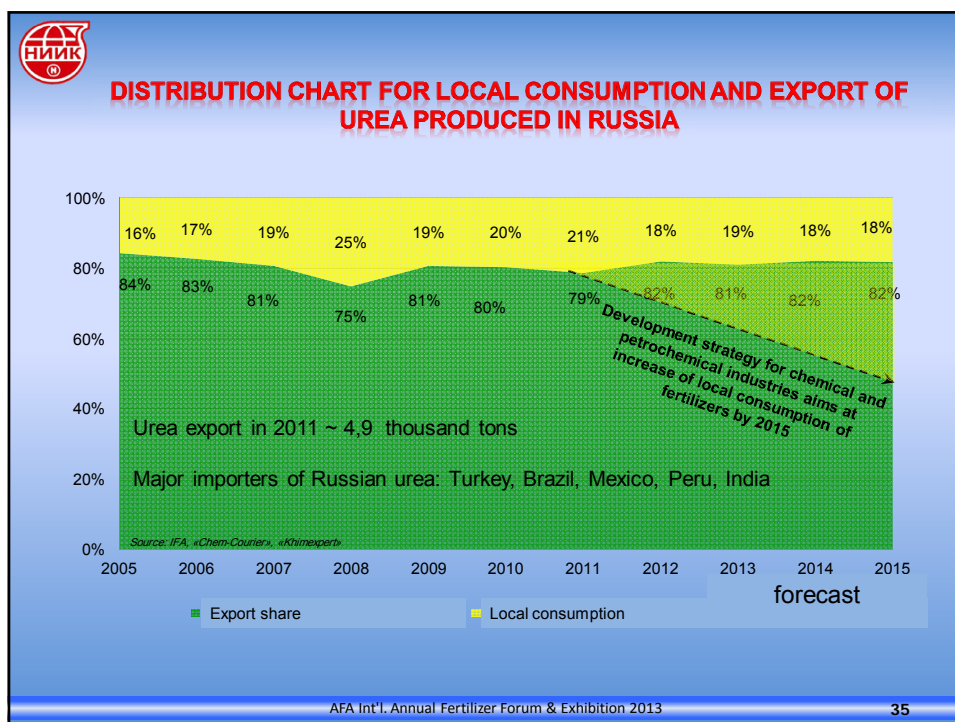


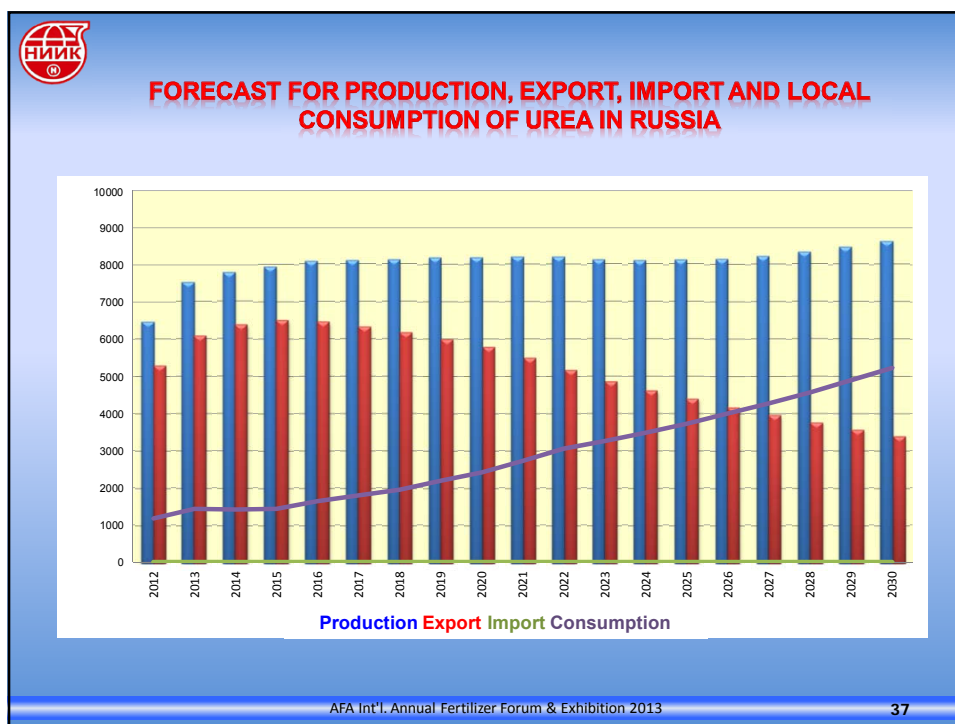
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**НИИК**

**Speaker:**  
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**Thank you for your attention!**

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 e/mail: [niik@niik.ru](mailto:niik@niik.ru)  
<http://www.niik.ru>

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# *Developments and Prospects in the Phosphate Fertilizer Business*

Mrs. Monica Baker  
 Research Manager  
 Integer Research, UK

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**

# **Developments and prospects for the phosphate fertilizer business**

**Prepared for AFA's 19<sup>th</sup> Annual Forum, Sharm-el-Sheikh**

**by Monica Baker, Research Manager, Integer Research**

**27 February, 2013**

---

## **Recent market developments**

- Industry profitability
- Phosphate and raw material pricing
- Production costs and profits: the benefits of integration

## **Investment**

- Outlook for new capacity: existing players and new entrants

## **Implications and conclusions**



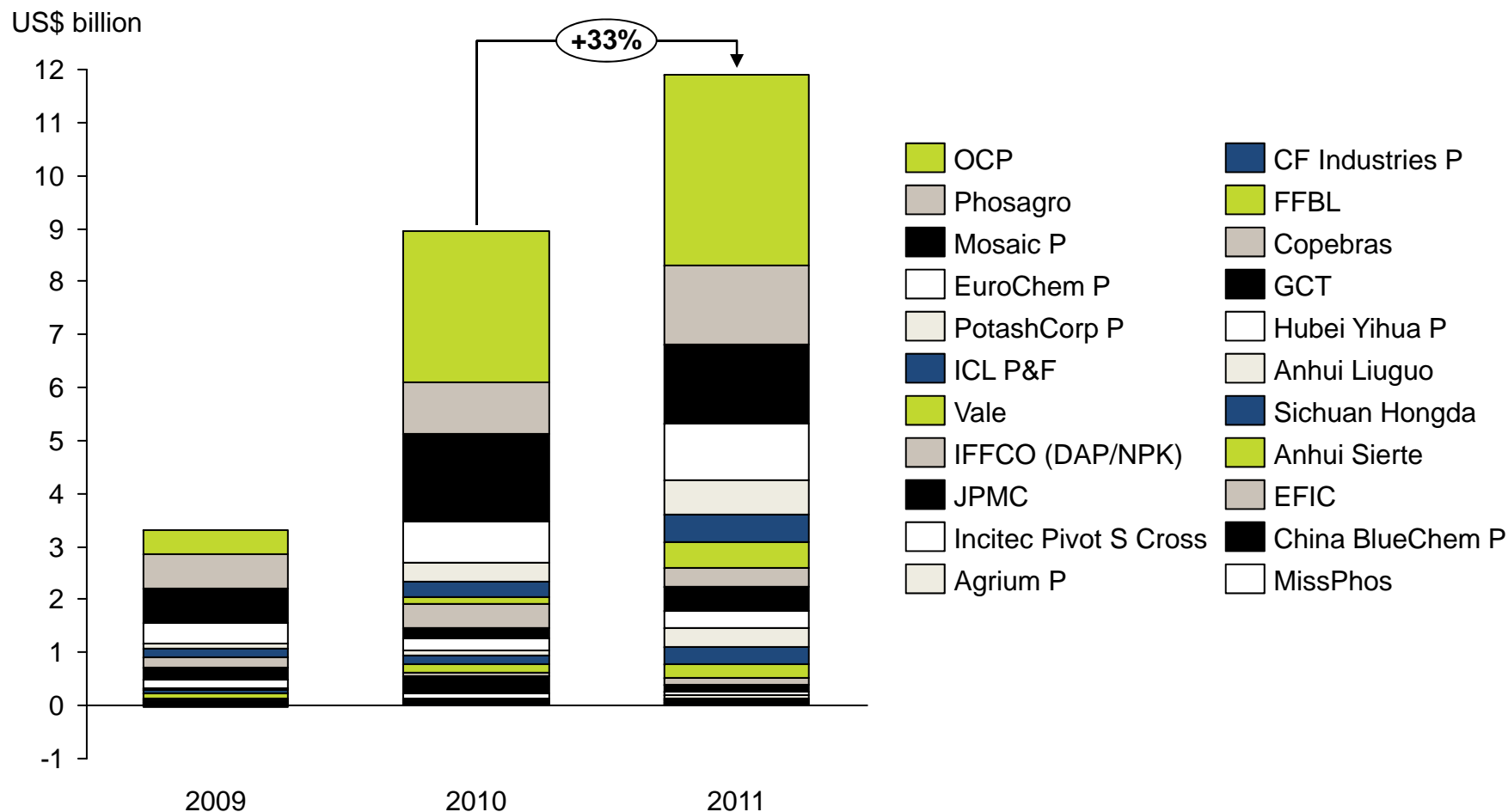
integer

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# Recent market developments

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## Phosphate company/segment stacked gross margins for the sample leapt up by over 30% in 2011 v 2012

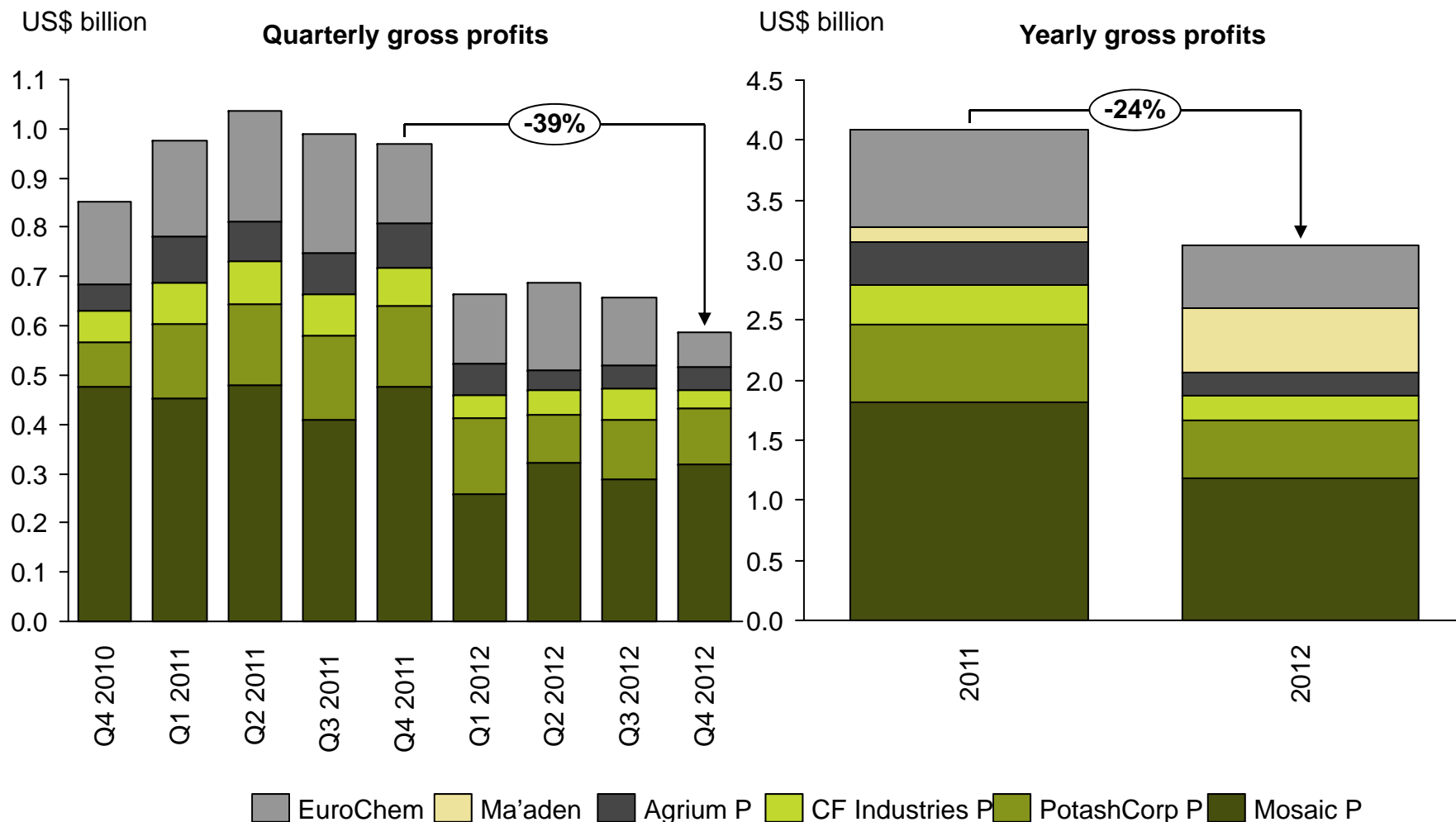


Source: Integer, company sources

Note: Mosaic data FY2012 - financial year ends 31 May, no data for Vale pre-acquisition

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**Cumulative phosphate gross profits decreased by 39% y-o-y in Q4 2012 for the sample analysed here, due to region-specific fluctuations in prices, higher COS and slowing demand**

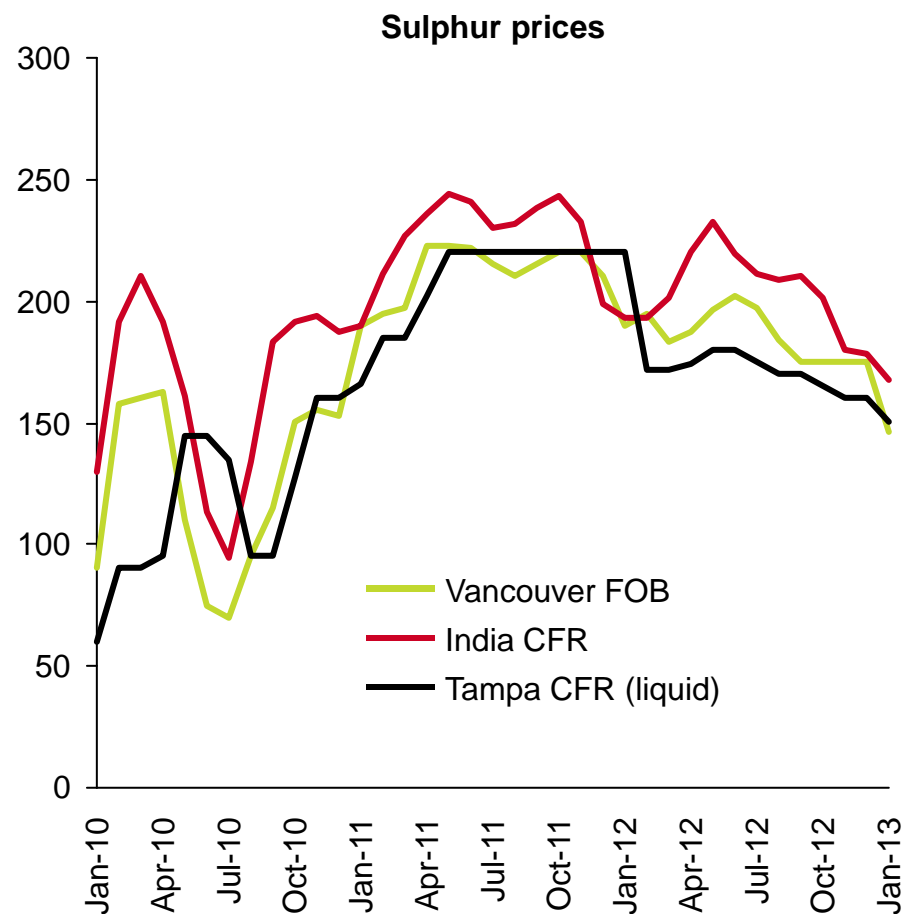
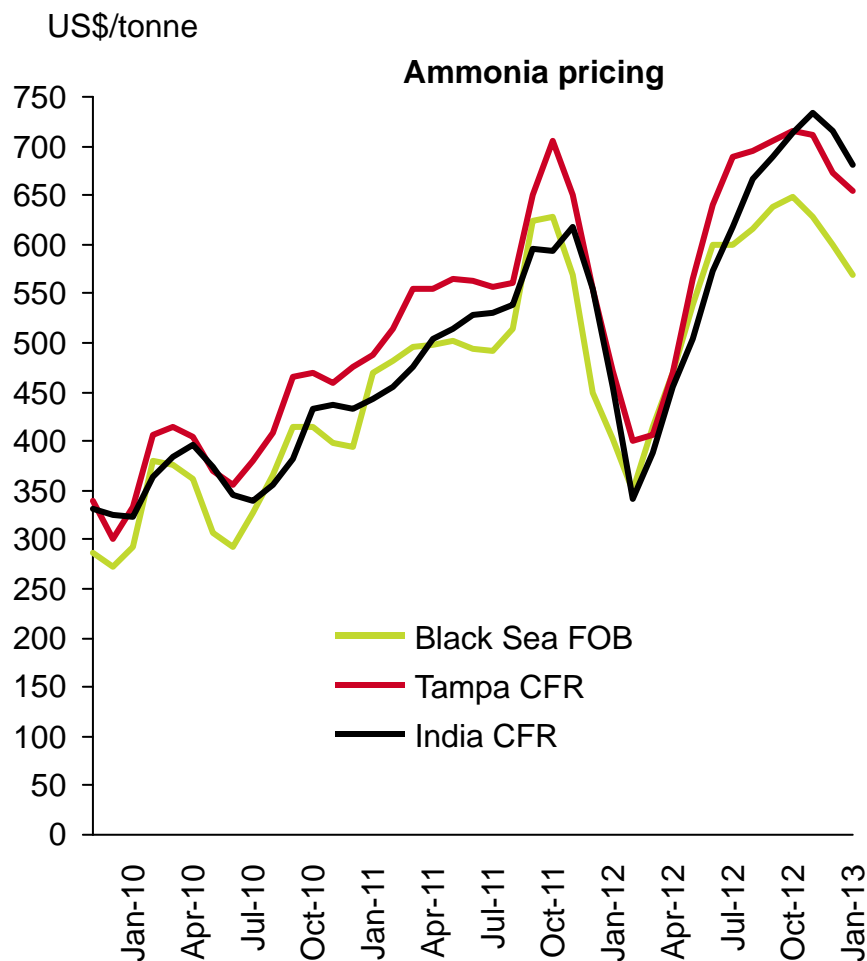


Source: Company data

Note: EBITDA for EuroChem; Mosaic financial quarter is one month prior to calendar quarter end

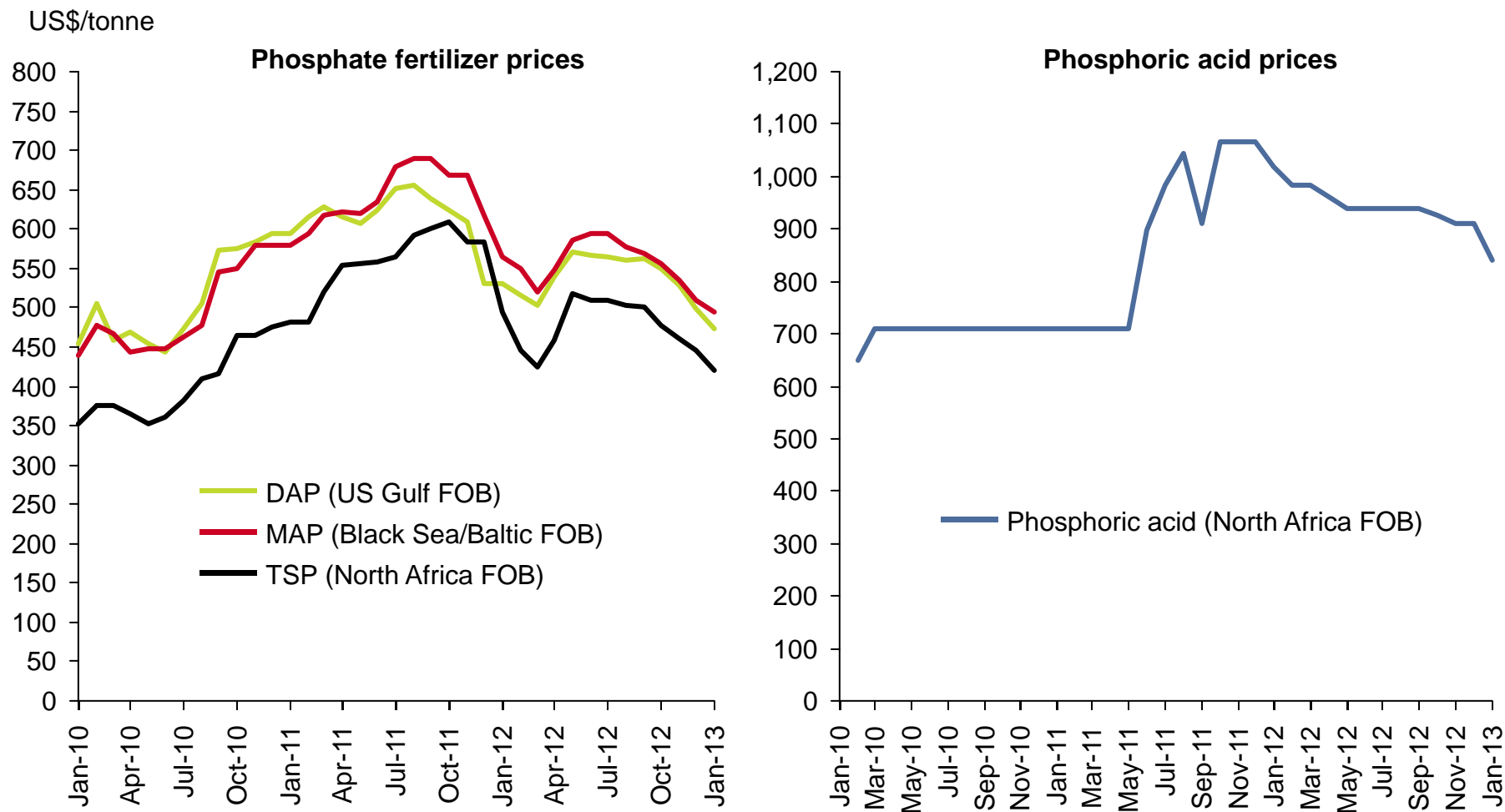
[Index](#)

## Ammonia pricing was up strongly in H2 2012, while sulphur values slipped throughout the year



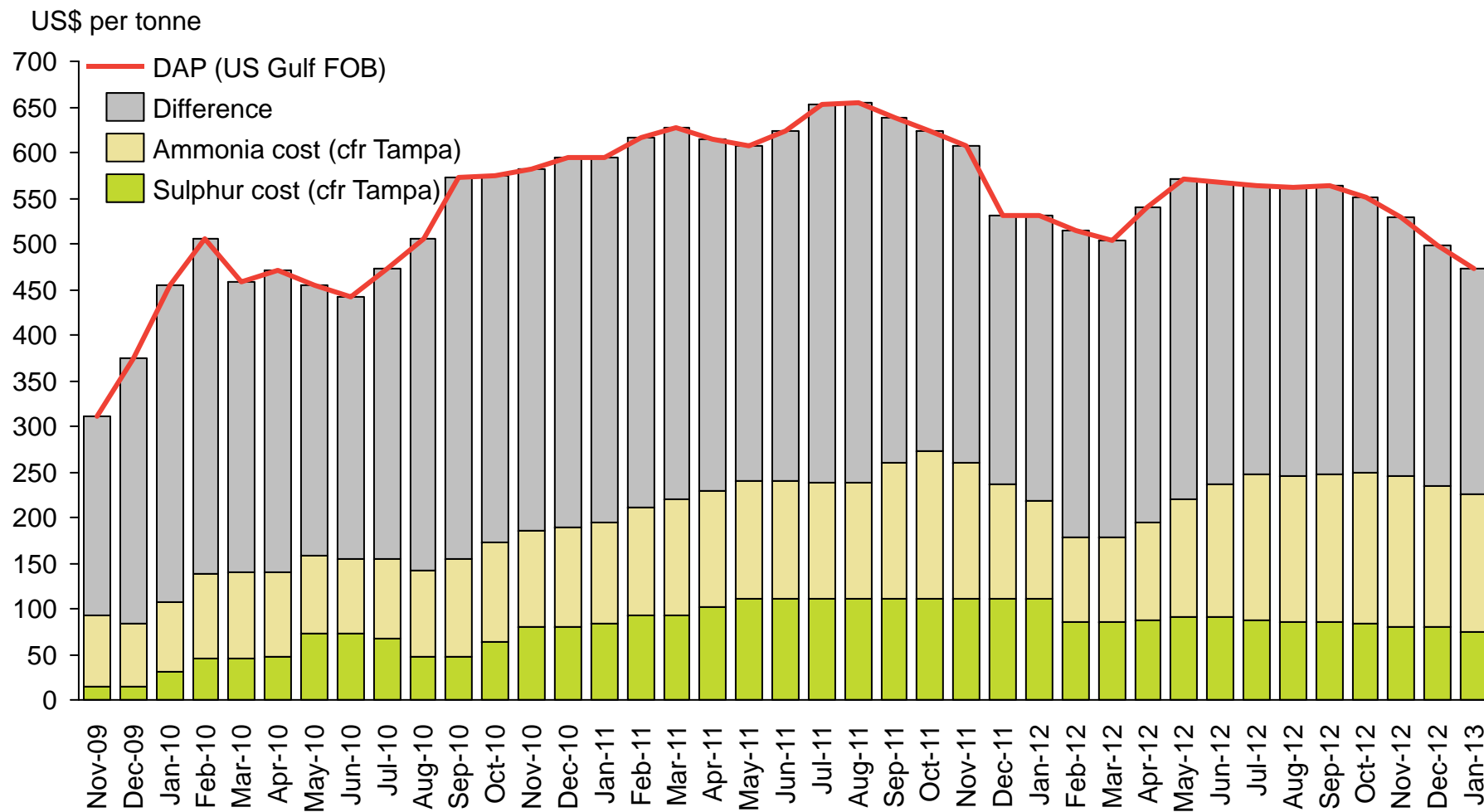
Source: Integer, ICIS

## Meanwhile, phosphoric acid and finished phosphate prices have eased over the course of 2012



Source: Integer, ICIS

## Lower DAP prices and higher ammonia costs impacted margins during H2 2012



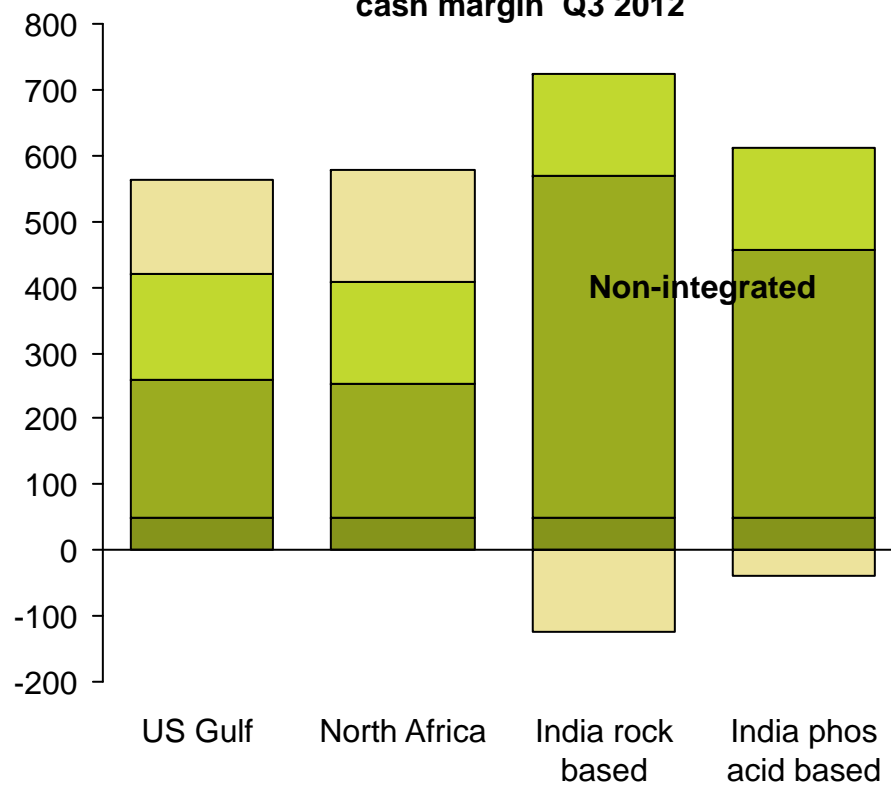
Source: Integer estimate

Note: Difference is what is available for rock and other costs and profit margin

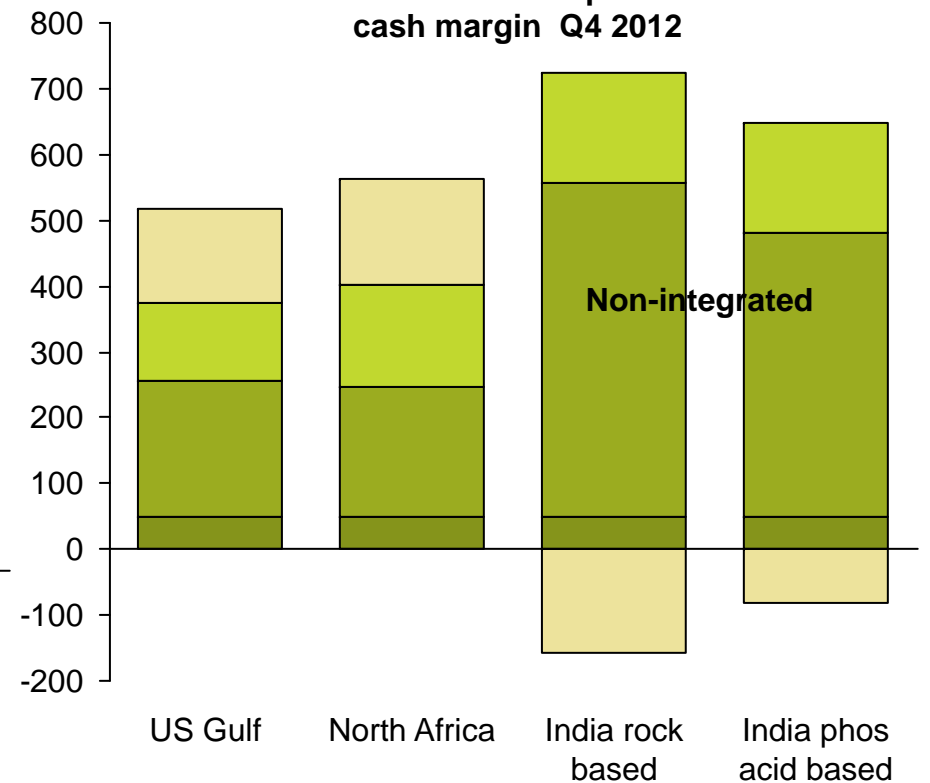
## A crude estimate of DAP production costs reveals worsening cash margins for non-integrated producers in H2 2012

US\$ per tonne

Estimated DAP costs of production and cash margin Q3 2012



Estimated DAP costs of production and cash margin Q4 2012



Margin Ammonia Phosacid Other

Margin Ammonia Phosacid Other

Source: Integer estimates

Note: Combined stack equates to the price or, in the case of India, the estimated delivered cost of DAP



## What differentiates most and least profitable phosphate producers?

- Integrated versus non-integrated?
  - Profits in the phosphates business primarily stem from access to low-cost phosphate rock
- But the cost of other raw materials is also influential
- Proximity to customers can make a significant difference to prices achieved

Location	Rock (DEL)	Sulphur	Ammonia
China	✓	-	-
Florida	✓	-	-
Russia	-	✓	✓
North Africa	✓	-	-
India	x	x	x
Saudi Arabia	-	✓	✓

Source: Integer

integer

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# Investment

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## The industry's supply/demand balance has tightened over the past 10 years

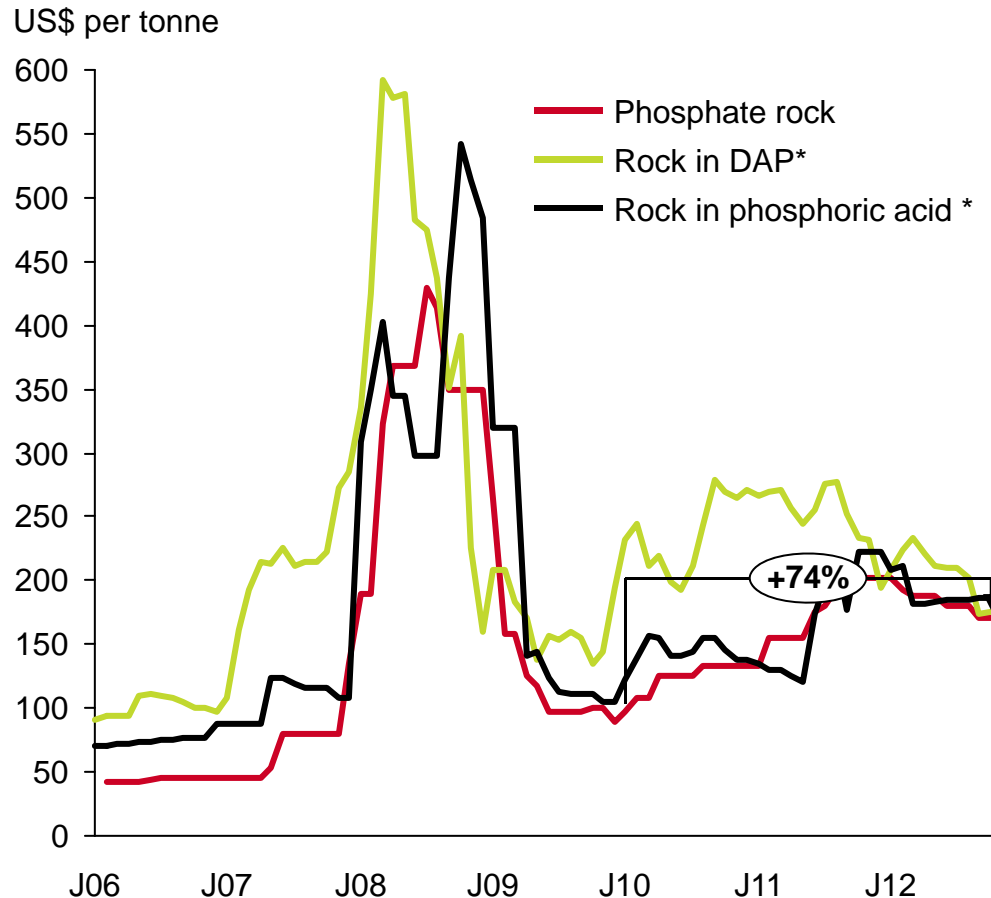
Phosphoric acid y-on-y production change (million tonnes)

Capacity utilization rate %



Source: IFA, Integer

## New investment activity raises an interesting point



- The cost of phosphate rock has increased relative to finished phosphates, squeezing non-integrated producers
- Rock sellers have been keen on moving downstream
- But, strong rock prices have also proved attractive for junior mining companies

Source: Integer

\*DAP formula is :  $(\text{DAP fob US Gulf} - (\text{del'd sulphur Tampa} \times 0.5 + \text{del'd ammonia Tampa} \times 0.23)) / 1.5$

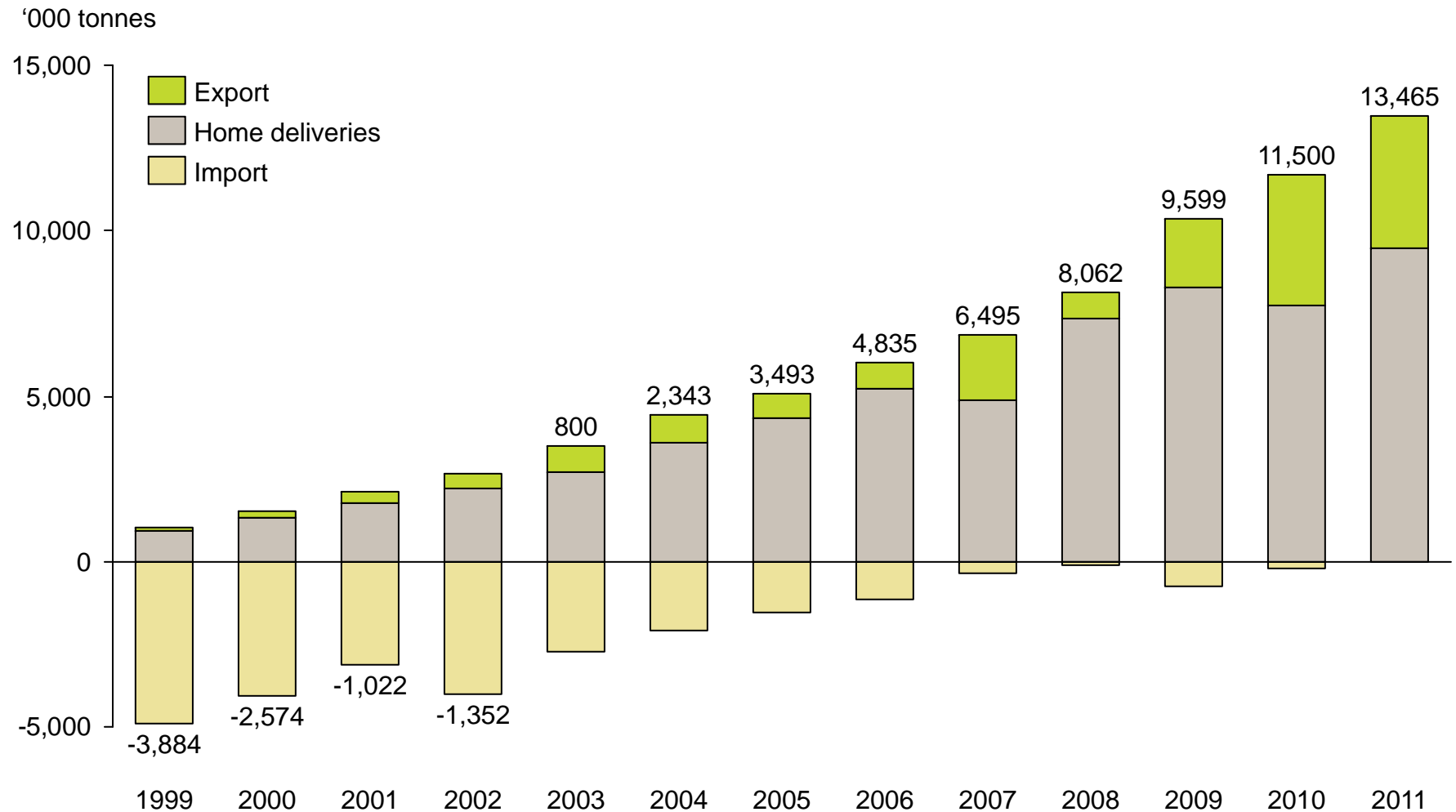
Phos acid formula is:  $((\text{Phos acid} - 1 \text{ tonne del'd sulphur}) / 3.5)$

## Where will new processing capacity be located?

**There are signs that future growth will be more geographically widespread:**

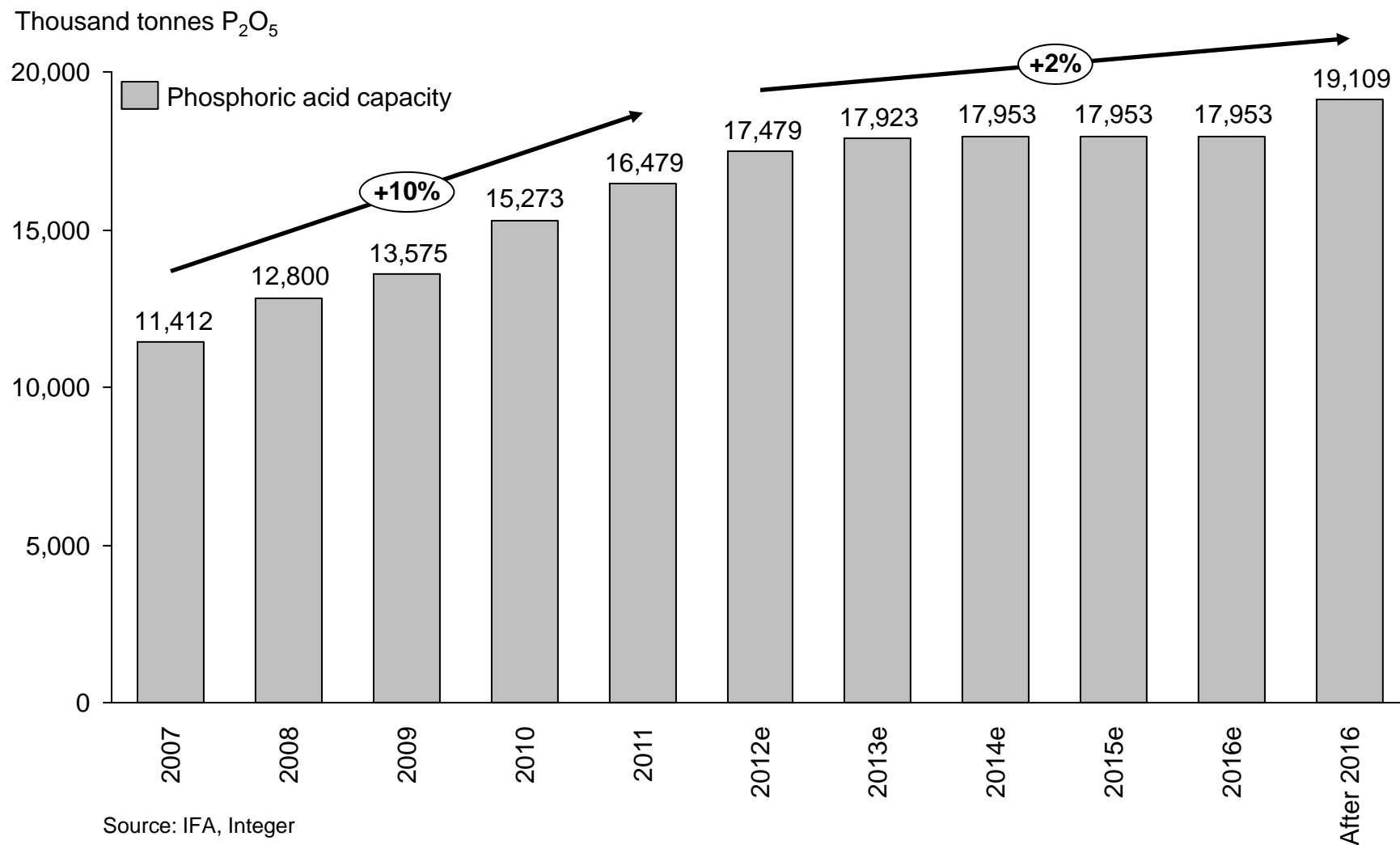
- Chinese expansion to decline
- US processing slowly declining
- Morocco to become a major processing hub
- Saudi Arabia planning a second phase of development in 2016
- Jordan and Tunisia expansions under construction and ramping up
- Brazil looking to build integrated capacity

## DAP production expansion eliminates China's import dependency and generates export surplus



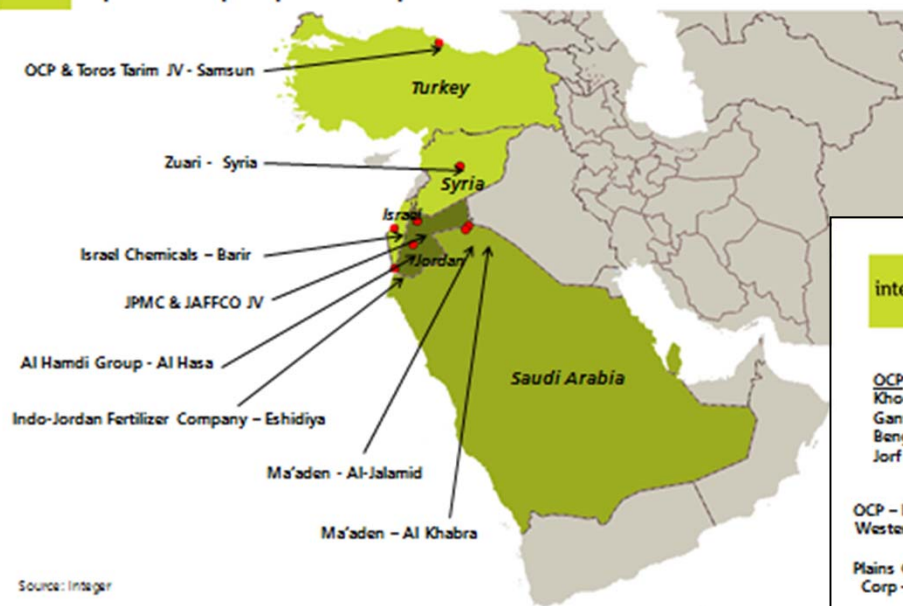
Source: IFA, Integer

## Having more than achieved self sufficiency, Chinese phosphate capacity investment is to slow down



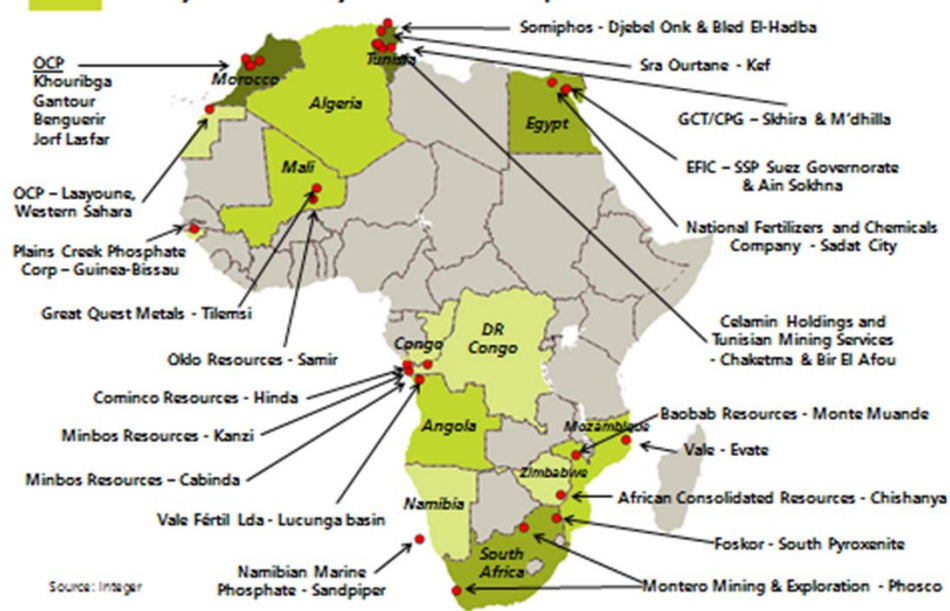
## Most junior miners' projects involve phosphate rock only and the key attraction is low capital cost for start up

Saudi Arabia and Jordan lead the way to expand rock and processed phosphates output in the Middle East



- We have been tracking over 100 projects in our research, including the Middle East and Africa region

Established producers will expand processed phosphates capacity and junior miners join the race to explore Africa's rock resources

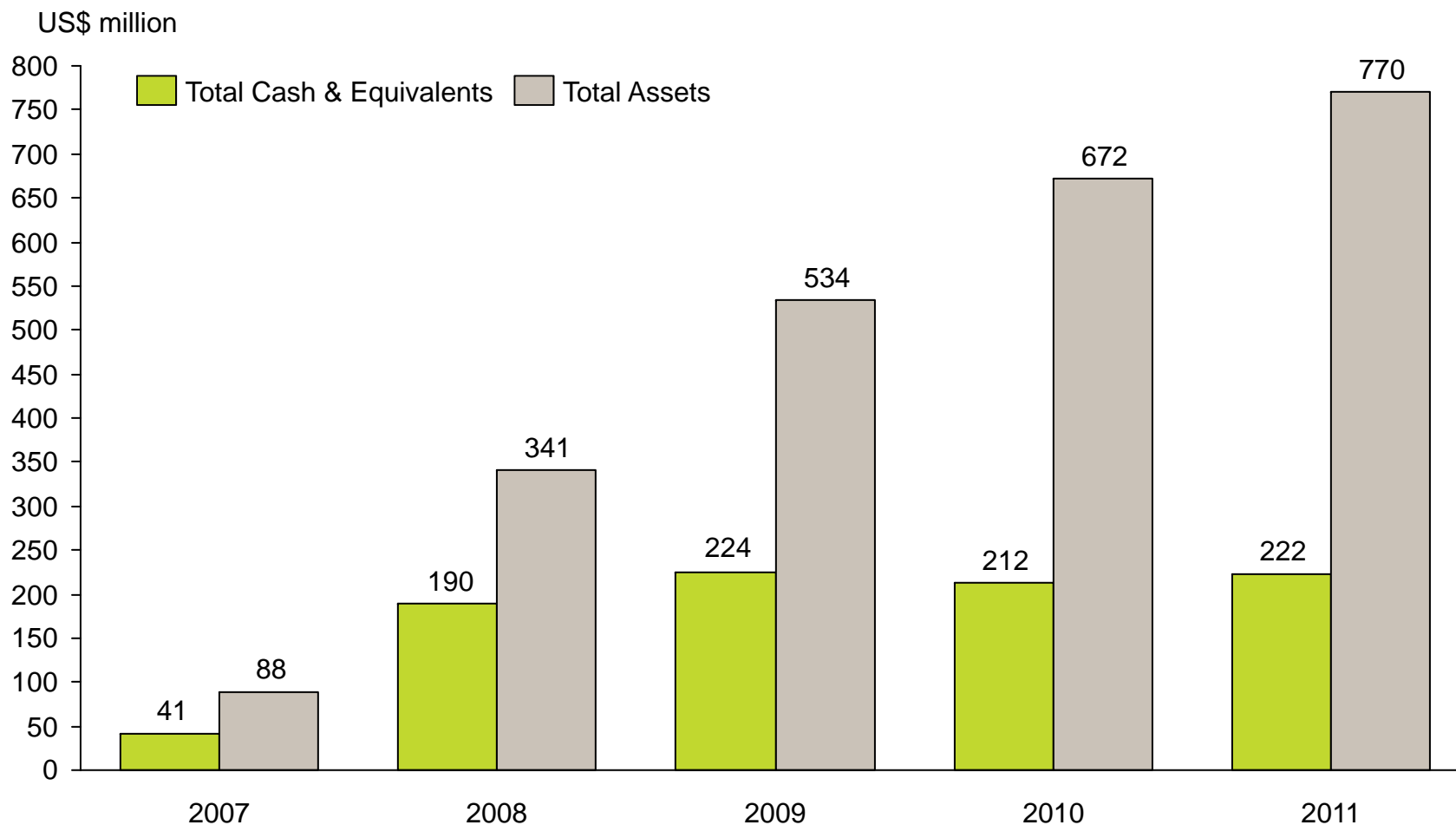


- Obtaining financing remains a significant hurdle for project development

Source: Integer



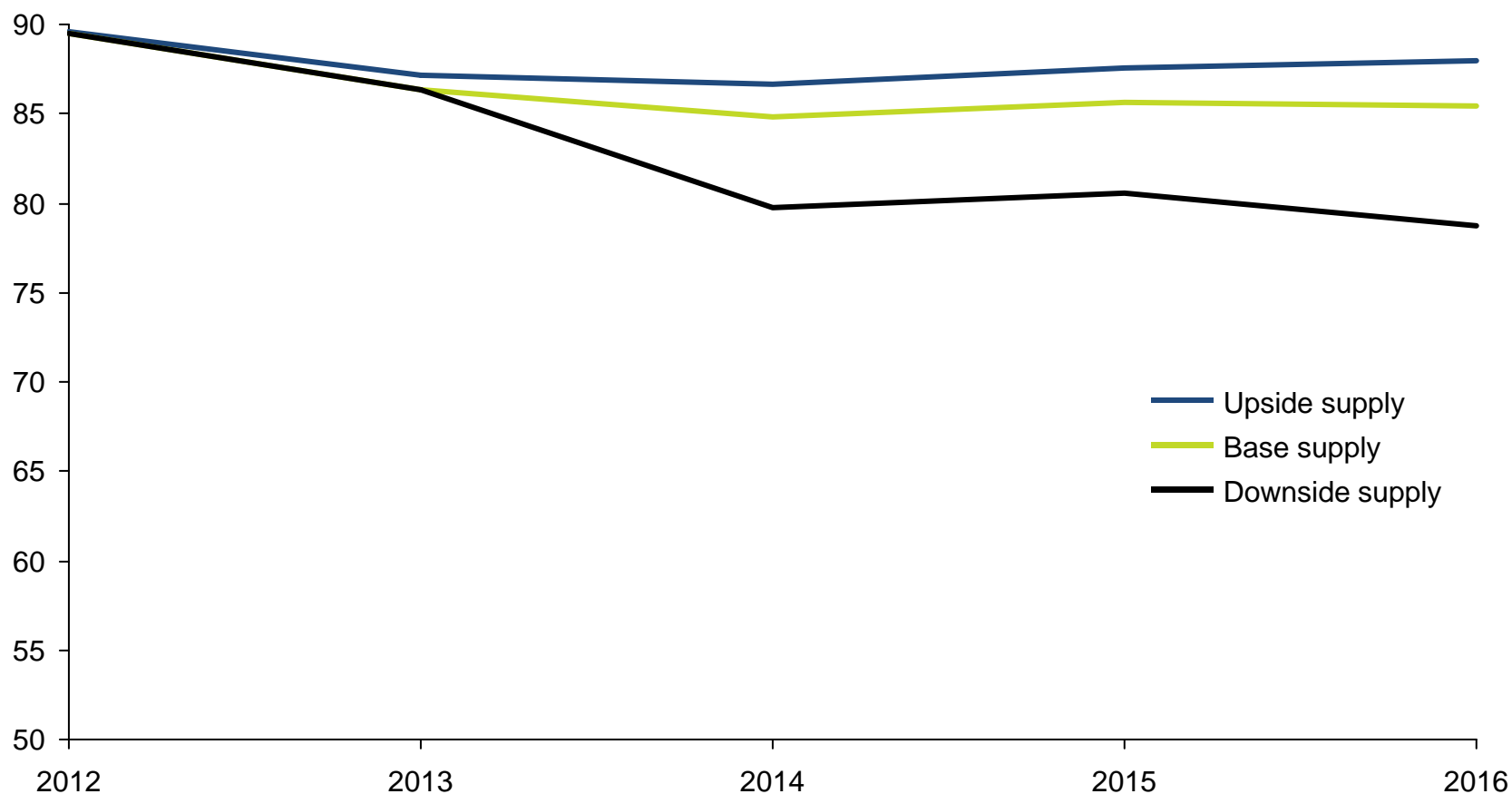
## Junior mining companies' financial positions have been improving over the past few years



Source: Bloomberg, Integer

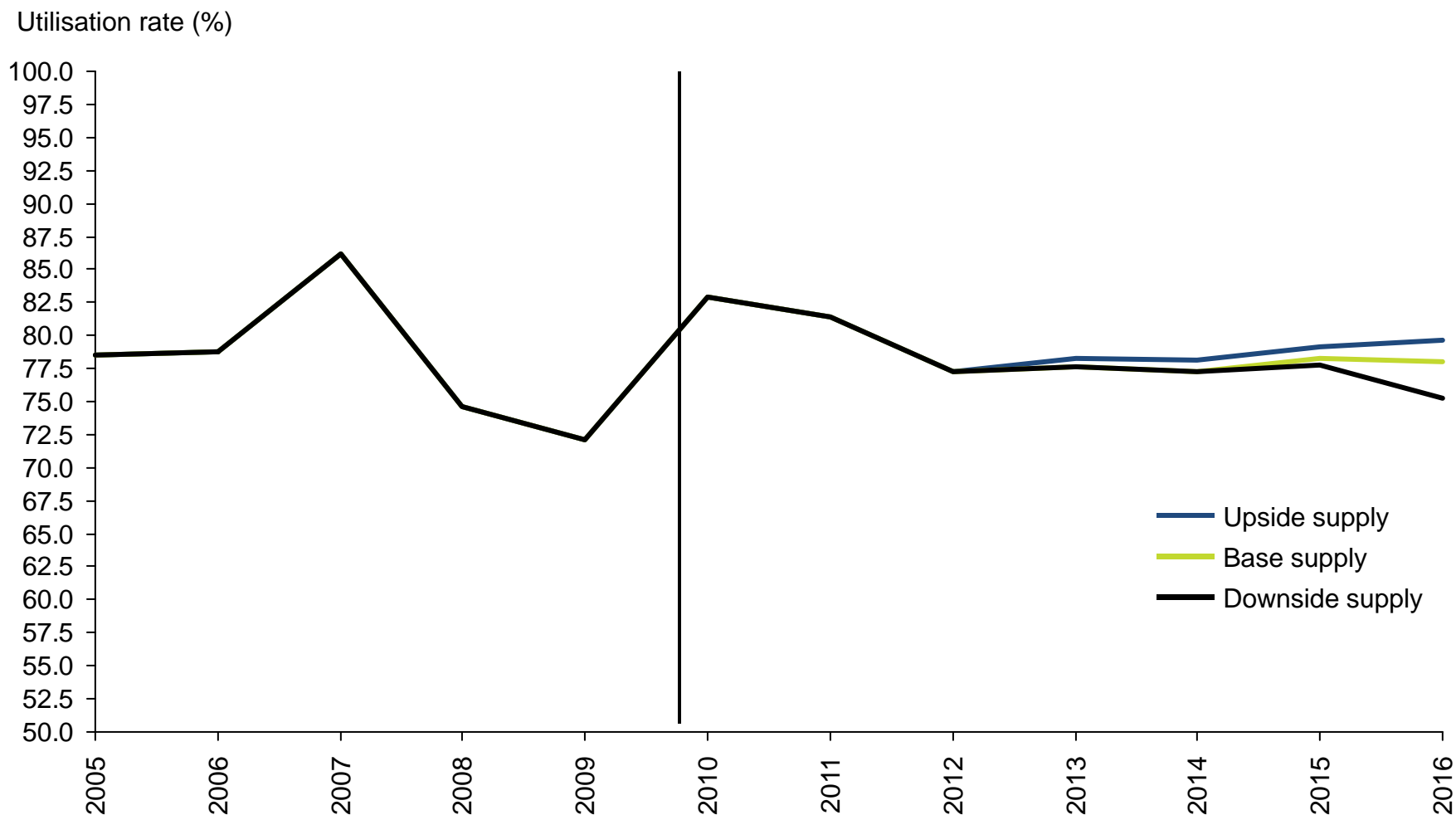
## Outlook: Phosphate rock market set to unwind through to 2016, though only significantly in the downside scenario

Utilisation rate (%)



Source: Integer

## Outlook: The global phosphoric acid market looks likely to be roughly balanced in the period to 2016



Source: Integer

- Strong profits normally stimulate new investment
- There are investments planned and in progress at each part of the supply chain: phosphate rock, phosphoric acid, and finished products
- The phosphate market still looks roughly balanced and any new investment is likely to be market sensitive
- Junior mining projects are still tackling financial hurdles
- The challenge for the industry will be to avoid over-investment

The logo for Integer Research, featuring the word "integer" in a white sans-serif font on a yellow square background.

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**Thank you!**

**For more information:**

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19<sup>th</sup> Annual AFA  
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PLATFORM

# SESSION III

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel



# *Scientific Review on Fertilizer Crops to Improve Human Health*

**Dr. Tom Bruuslema**  
 Director  
 IPNI, Canada

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**



## 19<sup>h</sup> AFA Annual Fertilizer Forum & Exhibition

**FERTILIZER FEEDS THE WORLD**

Feb. 26-28, 2013: Cairo, Egypt

# Fertilizing Crops to Improve Human Health: a Scientific Review

Tom Bruulsema, PhD, CCA  
Director, Northeast Region, North America Program



Agrium Inc.



Arab Potash Company



Belarusian Potash  
Company



CF Industries Holdings,  
Inc.



Compass Minerals  
Specialty Fertilizers



Incitec Pivot



International Raw  
Materials L TD.



Intrepid Potash, Inc.



K+S KALI GmbH



The Mosaic Company



OCP S.A.



PotashCorp



Qatar Fertiliser Company  
(QAFCO)



Simplot



Sinofert Holdings Limited



SQM



Uralkali

Formed in 2007  
from the Potash  
& Phosphate  
Institute, the  
**International  
Plant Nutrition  
Institute** is  
supported by  
leading fertilizer  
manufacturers.

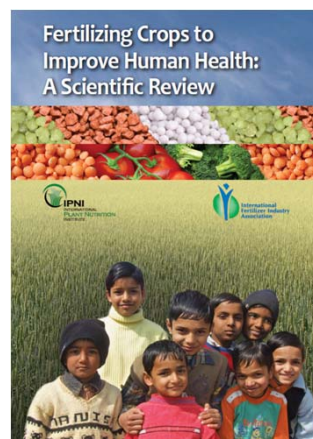
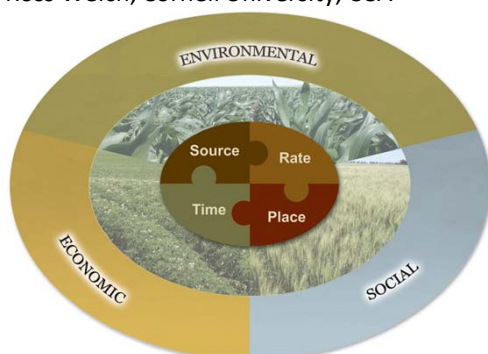




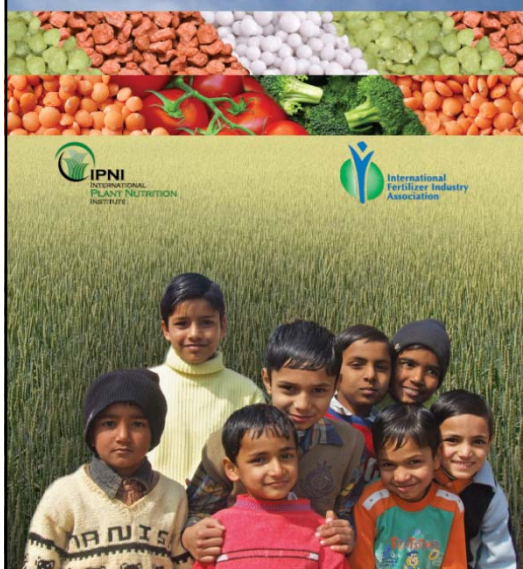
## Fertilizing Crops to Improve Human Health: a scientific review, edited by IFA & IPNI

### Editorial Committee:

- Patrick Heffer, IFA, France
- Tom Bruulsema, IPNI, Canada
- Kevin Moran, Yara, UK
- Ismail Cakmak, Sabanci University, Turkey
- Ross Welch, Cornell University, USA



## Fertilizing Crops to Improve Human Health: A Scientific Review

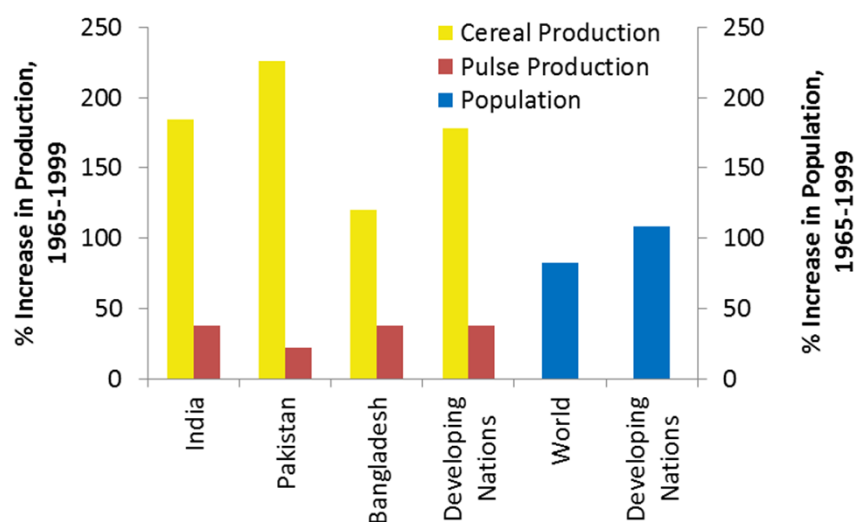


### Topics

- Food security
- Micronutrients
- Vitamins
- Functional foods
- Proteins, oils and carbohydrates
- Plant disease
- Farming systems
- Remediation of soil contaminated with radionuclides
- 11 chapters



## More cereals per capita, less pulses



Bouis, Boy-Gallego & Meenakshi

## Micronutrient Malnutrition (% prevalence)

Bouis, Boy-Gallego & Meenakshi

Region	Zn	Fe	I	Vitamin A
North America	8-11	18-29	11	2-16
Latin America	13-37	18-29	11	2-16
Europe	6-16	19-25	52	12-20
Sub-Saharan Africa	13-43	48-66	44	14-44
Southeast Asia	27-39	46-66	30	17-50
South Asia	18-36			
<b>Global</b>	<b>10-32</b>	<b>30-47</b>	<b>32</b>	<b>15-33</b>

## Enhancing the Nutritional Quality of Food Crops with Trace Elements – Welch and Graham

Table 1. Proportion of agricultural soils deficient in mineral elements (based on a survey of 190 soils worldwide – Sillanpaa, 1990).

Element	%
N	85
P	73
K	55
B	31
Cu	14
Mn	10
Mo	15
<b>Zn</b>	<b>49</b>

“...it is imperative that fertilizer technology be used to improve the nutritional quality of staple food crops that feed the world’s malnourished poor.”

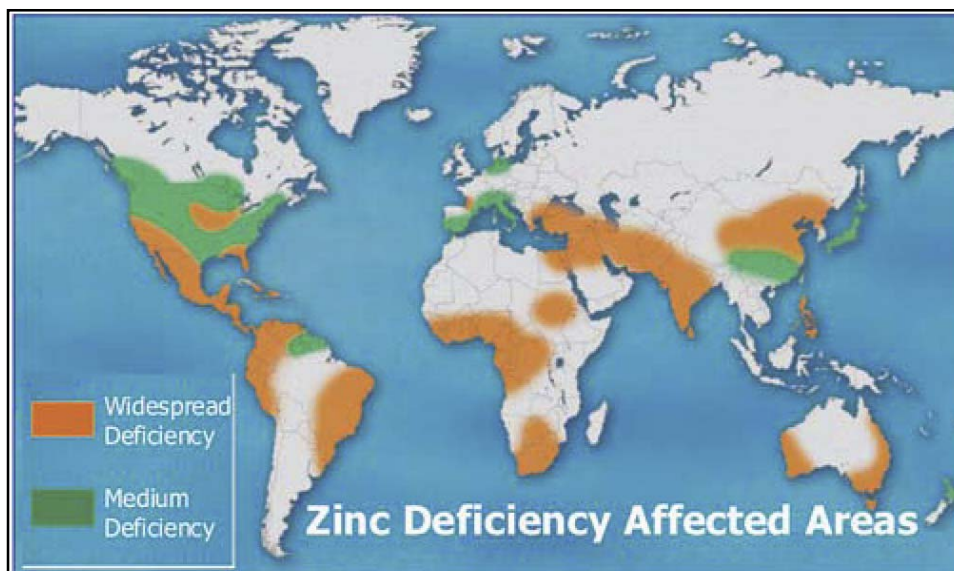


Figure 2: Global distribution of Zn-deficiency affected regions (Alloway, 2007)



## Urea coated with Zn increases yield and grain Zn

Fertilizer	Rice		Wheat	
	Grain yield, t/ha	Grain Zn, mg/kg	Grain yield, t/ha	Grain Zn, mg/kg
Prilled urea	3.99	30	3.72	40
Urea + 1% ZnO	4.46	36	4.14	46
Urea + 1% ZnSO <sub>4</sub>	4.67	39	4.25	49
Urea + 2% ZnO	4.95	43	4.39	49
Urea + 2% ZnSO <sub>4</sub>	5.15	48	4.53	51

“urea fertilizers coated with ZnSO<sub>4</sub> always produced better results than urea coated with ZnO” - *Lyons and Cakmak, Chapter 4*



## Selenium-Enhanced Foods in Cancer Prevention – Combs

- Selenoproteins – Se essential to the antioxidant enzyme glutathione peroxidase (GPX)
- In 1983, Finnish Ministry of Agriculture and Forestry directed that all agricultural fertilizers contain Se.
- By 1990, the per-capita intake of Se in the Finnish diet more than quadrupled.
- Average serum Se in Finnish adults increased from 70 to nearly 119 ng/ml
- Epidemiological studies have found Se status to be inversely associated with cancer risk. While relatively few clinical trials have been conducted, all but one have shown cancer risk reduction due to Se.



## Functional Quality of Fruits and Vegetables

- Jifon, Lester, Stewart, Crosby & Leskovar

- Foliar K with S enhanced sweetness, texture, color, vitamin C, beta-carotene and folic acid contents of **muskmelons**
- In pink **grapefruit**, supplemental foliar K resulted in increased lycopene, beta-carotene, and vitamin C concentrations
- Several studies have reported positive correlations between K nutrition and **banana** fruit quality parameters such as TSS, reducing sugars, non-reducing sugars, total sugars and ascorbic acid, and negative correlations with fruit acidity



## Concentration of isoflavones in soybean seeds in response to applied K fertilizer (two sites, three years, 1998-2000).

K <sub>2</sub> O application	Genistein	Daidzein	Glycitein	Total <sup>1</sup>
Spring banded	938	967	146	2,051
None	831	854	130	1,851
Increase due to K, %	13	13	12	13

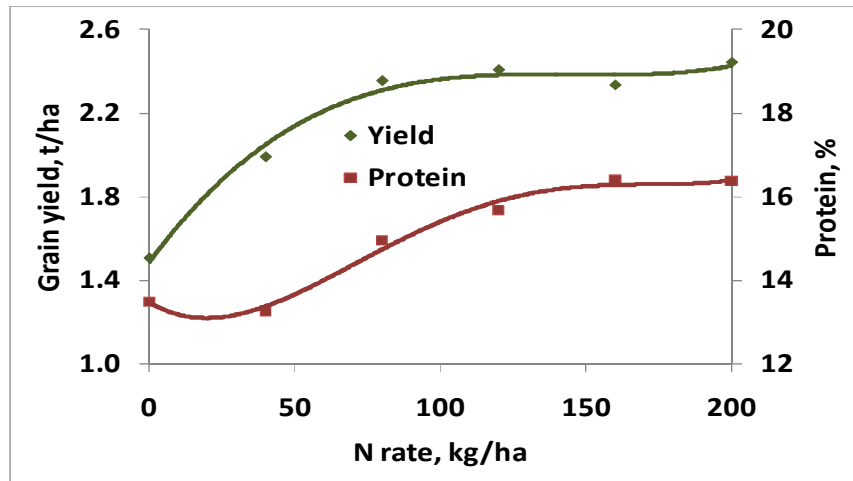
<sup>1</sup> Total isoflavone concentration expressed as aglycone; sum of three components; parts per million (ppm)

*Vyn et al., 2002. Journal of Agricultural and Food Chemistry, 50: 3501-3506.*



## Protein, Oil, Carbohydrate

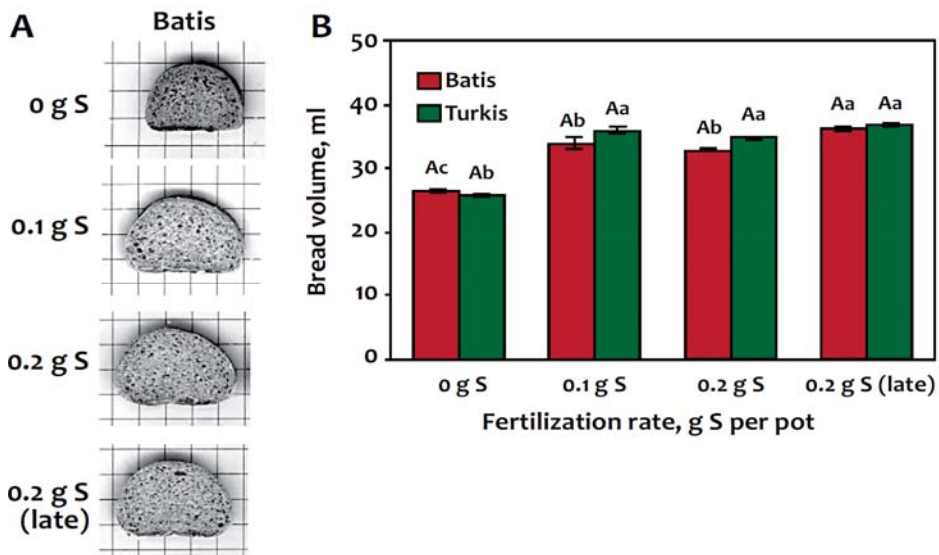
Grant & Bruulsema



Katepwa hard red spring wheat (Grant, unpublished)



## Sulphur and Wheat Bread-making Quality



## Potato starch and protein influenced by NPKS

N-P-K-S	Potato yield, g/pot	Starch, %	Crude protein, %	Protein biological value, %
2-3-3-3	124	70	8.3	89
4-3-3-3	317	72	12.9	80
6-3-3-3	266	69	15.9	75
4-1-3-3	134	68	14.9	74
4-4-3-3	454	74	10.3	81
4-3-1-3	50	59	22.9	65
4-3-4-3	332	68	11.5	82
4-3-3-0	173	65	14.7	45

Eppendorfer and Eggum, 1994



## Plant diseases, mycotoxins & food safety - Huber

Crop	Disease	Toxin	Nutrient
Cereals	Ergot ( <i>Claviceps sp</i> )	Ergotamine (alkaloid)	Cu
Grain, peanuts	<i>Aspergillus</i>	aflatoxin	Mn + ?
Cereals	<i>Fusarium graminearum</i> ( <i>Gibberella zae</i> )	deoxynivalenol zearalenone trichothecene	Mn + ?

1. Managing nutrition influences diseases and their control
2. Knowledge Gap: nutritional control of the plant diseases most relevant to food safety



## Plant Diseases – Huber

- Strategies to reduce disease through nutrition:
  1. **Nutrient-efficient cultivars** – Mn uptake ability in cereals
  2. **Balanced nutrition:** optimum levels
  3. **Form & Source:**  $\text{NH}_4$  versus  $\text{NO}_3$ , KCl versus  $\text{K}_2\text{SO}_4$
  4. **Timing:** apply N during conditions favoring plant growth
  5. **Integration:** tillage, crop rotation, soil microbes

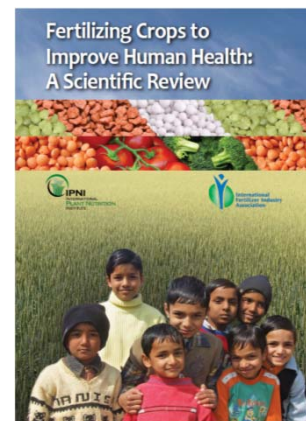


## Benefits to the industry

1. Compilation of benefits for public awareness.
2. Foundation to build on for further research.
3. Builds relationships with research scientists.

### Continuing efforts:

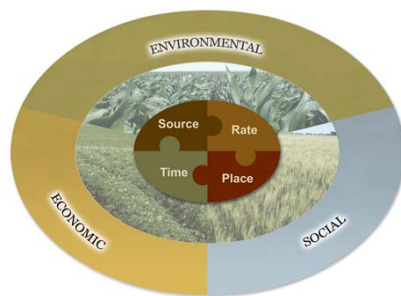
1. Encourage evaluation of impacts on human health in research supporting 4R Nutrient Stewardship.
2. Include human health impacts in messaging related to food and nutrition security.





## Summary

- Fertilizer contributes immensely to the health and well being of humanity.
  - Quantity & Quality
  - Protein, minerals, vitamins and nutraceuticals
- Research supporting 4R Nutrient Stewardship has great potential to improve human health.



## Fertilizing Crops to Improve Human Health: A Scientific Review



Thank You

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# *Meeting Animals Nutritional Mineral Demands through Fertilizer Fortified Fodder Plants*

Prof. Dr. Ewald Schnug  
inst. Plant Production , Germany

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel





**Outline**

- Essential trace elements for ruminants and plants
- Trace element contents in fodder plants
- Factors influencing trace element contents in plants
- Trace element imbalances in animals
- Fertilization with organic and mineral fertilizers
- Supplementation of trace elements with mineral feed concentrates
- Conclusion

## Essential Trace Elements for Ruminants = Essential Trace Elements for Plants?

- Essential trace elements for animals (MacPherson, 2000):  
As, Co, Cr, Cu, F, Fe, J, Li, Mn, Mo, Ni, Pb, Se, Si, V, Zn
- Highly relevant (may cause deficiency symptoms):  
Fe, Mn, Zn, Cu, Mo, Co, Se, I
- Only partly identical with essential trace elements for plants:  
Fe, Mn, Zn, Cu, (Cl), B, Mo, (Co)
- Needs for trace elements of plants differ from those of animals, therefore deficiency may occur in animals even if plants are supplied adequately



## Essential Trace Elements for Small Ruminants = Essential Trace Elements for Plants?

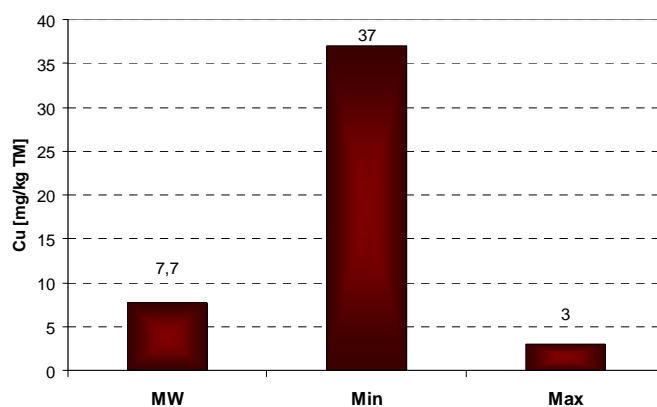


	Trace element content in mg/kg (DM)								
	Fe	Mn	Zn	Cu	Co	Mo	Se	J	B
Yield limiting value for grass at flowering stage <sup>1</sup>	50 - 60	40 - 50	20 - 50	5 - 10	--	0,3 - 0,5	--	--	5 - 6
Critical values at grazing stage <sup>2</sup> :									
<i>Lolium perenne</i> (Deutsches Weidelgras)	60	30	13	5		0,2			
<i>Trifolium repens</i> (Weißklee)	60	30	13	5		0,1			
Recommended concentrations in fodder (DM) for									
Sheep <sup>3</sup>	30 - 50	20 - 40	20 - 33	4 - 11	0,1 - 0,2	0,025 - 0,35	0,05 - 0,1	0,12 - 0,6	
Goats <sup>4</sup>	40 - 50	60 - 80	50 - 80	10 - 15	0,15 - 0,2	0,025 - 0,35	0,1 - 0,2	0,3 - 0,8	
Dairy cows and heifers <sup>5</sup>	50	40-50	40-50	10	0,2	0,1	0,15-0,2	0,25-0,5	
<sup>1,2</sup> Voigtländer and Jacob, 1987									
<sup>3</sup> NRC, 1985; Australian Agricultural Council, 1990; Whitehead, 2000; <sup>4</sup> GfE, 2003; Whitehead, 2000; <sup>5</sup> GfE, 2001									

## Trace element contents (mg/kg DM) in basic diet for ruminants

	Fe	Mn	Zn	Cu	Co	Mo	Se	J
<b>Basic diet fresh: legumes and grasses</b>								
<b>Legumes</b>								
Faba beans (in der Blüte)	169	38	70	11,3	0,31			
Peas (in der Blüte)	212	25	28	9,0	0,18			
<i>Onobrychis viciifolia</i> (Esparsette)	114	51	26	7,0	0,12	0,18		
<i>Medicago sativa</i> (Luzerne)	175	41	27	9,1	0,18	0,34	0,12	0,22
<i>Trifolium pratense</i> (Rotklee)	147	50	43	9,6	0,13	0,59	0,11	0,24
<i>Trifolium repens</i> (Weißklee)	186	51	25	8,6	0,15	0,64		0,32
<i>Vicia sativa</i> (Sommerwicke)	299	43						
<b>Grasses</b>								
<i>Dactylis glomerata</i> (Knaulgras)	102	109	26	9,2	0,14			0,23
<i>Lolium perenne</i> (Deutsches Weidelgras)	97	46	32	6,8	0,15	0,44		0,21
<i>Lolium multiflorum</i> (Weisches Weidelgras)	126	109	25	6,8	0,05			0,30
<i>Phleum pratense</i> (Wiesenschneggras)	42	34	19	6,1	0,15	0,50		0,20
<i>Festuca pratensis</i> (Wiesenschwingel)	156	60	25	8,1	0,20			0,15
<i>Agrostis alba</i> (Weißes Straußgras)	80	740	59	4,2				
<b>Basic diet dried: Hay</b>								
Red clover/grass mix, 1. cut (at flowering)	90	97	36	11,4	0,02			
Meadow, 1. cut (at flowering)	200	108	28	6,4	0,12		0,09	0,27
Meadow, 2. cut (at flowering)		94		7,0				
<b>Basic diet, silage</b>								
Red clover/grass mix, 1. Cut (at budding)		119		14,1				
Meadow, 1. cut (at flowering)		81		7,2				
Grass- and clover/grass silage (organic)	436	88	33	7,0			0,13	
<b>Recommended concentrations in fodder (DM) for</b>								
Sheep	30 - 50	20 - 40	20 - 33	4 - 11	0,1 - 0,2	0,025 - 0,35	0,05 - 0,1	0,12 - 0,6
Goats	40 - 50	60 - 80	50 - 80	10 - 15	0,15 - 0,2	0,025 - 0,35	0,1 - 0,2	0,3 - 0,8
Dairy cows and heifers	50	40 - 50	40 - 50	10	0,2	0,1	0,15 - 0,2	0,25 - 0,5

## Variability of Cu contents in grass silage (LUFA Nordwest, 2006)



Trace element contents in fodder plants vary considerably. In order to estimate the real trace element content of diets it is important to **analyze** the plants.

### Trace element contents (mg/kg DM) in grains, roots and bulbs

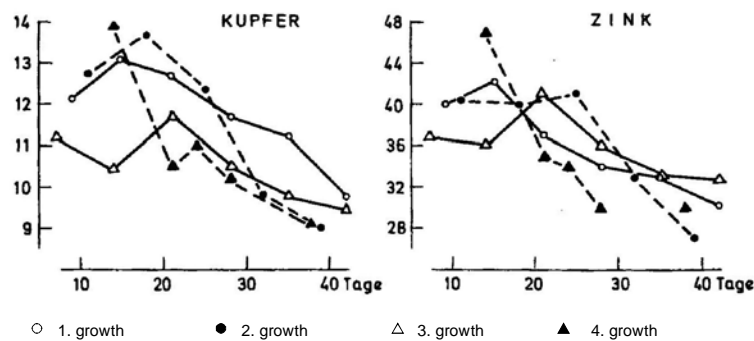
	Fe	Mn	Zn	Cu	Co	Mo	Se	J
<b>Grains and seeds</b>								
Faba beans ( <i>Vicia faba</i> )	86	33	46	12,3	0,03			
Peas ( <i>Pisum</i> )	64	17	24	7,5	0,21	0,79	0,27	0,15
Summer barley	44	18	32	6,1	0,10	0,49	0,17	0,28
Winter barley						0,49	0,08	0,28
Oats	65	48	36	4,7	0,07	0,80	0,22	0,11
Corn	32	9	31	3,8	0,13	0,63	0,10	0,38
Soy beans	15	23	37	7,7	0,22	2,30	0,21	0,50
Winter wheat	45	35	65	7,0	0,10	0,41	0,12	0,36
<b>Roots and bulbs</b>								
Feeding beets (high dry-matter)	131	83	32	7,2	0,16		0,03	0,36
Feeding beets (low dry-matter)	264	80	28	7,8	0,18			
Potatoes	45	7	24	5,4	0,09	0,17	0,07	0,22
Rooted turnips	117	40	14	7,3	0,07			
Carrots	60	23	33	6,3	0,16	0,68	0,03	0,33
Sugar beets	215	61	36	5,1	0,09			
Red beets	66	18	26	6,1	0,11		0,05	0,03
<b>Recommended concentrations in fodder (DM) for</b>								
Sheep	30 - 50	20 - 40	20 - 33	4 - 11	0,1 - 0,2	0,025 - 0,35	0,05 - 0,1	0,12 - 0,6
Goats	40 - 50	60 - 80	50 - 80	10 - 15	0,15 - 0,2	0,025 - 0,35	0,1 - 0,2	0,3 - 0,8
Dairy cows and heifers	50	40 - 50	40 - 50	10	0,2	0,1	0,15 - 0,2	0,25 - 0,5

### Factors influencing trace element contents in plants

- Soil element content / parent rock material
- Atmospheric inputs (mainly iodine)
- Availability of trace elements in soils (soil chemical parameters and climate)
- Annual variability (vegetation period)
- Development stage of plants
- Plant species and –genotype
- **Fertilization**



### Variability of plant trace element contents with time

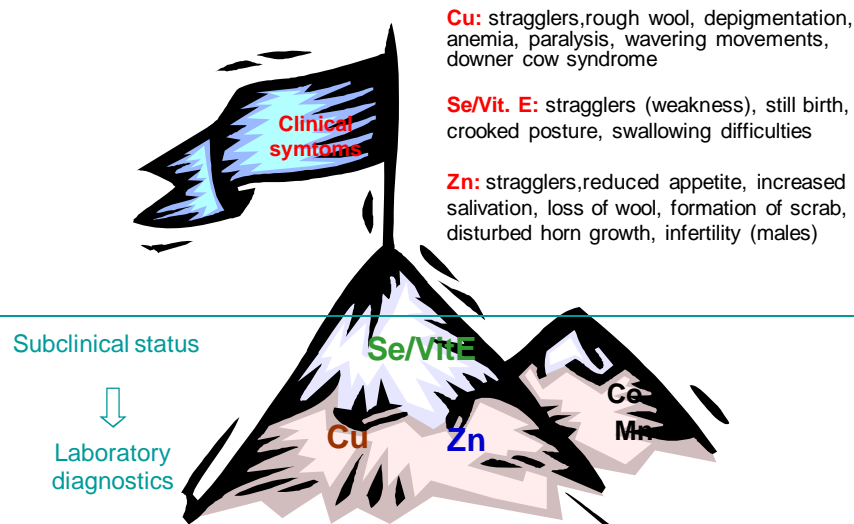


Cu- and Zn contents of *Lolium spec.* (in mg/kg DM) during growth and vegetation period (Kirchgessner et al., 1971 in Voigtländer and Jacob, 1987)

### Influence of development stage, plant species and genotype on trace element contents of plants

- Trend for **decreasing contents during individual plant development**, reasons: a) dilution effect (increase in biomass relatively higher than uptake of trace elements), b) changes in leave/stalk-ratio (higher contents in leaves, which decrease in their relative share during development while stalks increase) (MacPherson, 2000; Voigtländer and Jacob, 1987)
- Significant differences depending on **plant species**, including strong variability within species, => no clear trends ascertainable (such as „higher contents of Fe, Zn, Cu and Co in legumes compared to grasses“)
- Variability within a species often depends on **genotype** (e.g. Zn and Cu in *Lolium multiflorum*, *Lolium perenne*, *Festuca arundinacea* and *Dactylis glomerata*, MacPherson, 2000)

## Trace element imbalances in animals From „invisible“ deficiency to symptom



From: Humann-Ziebank, 2006

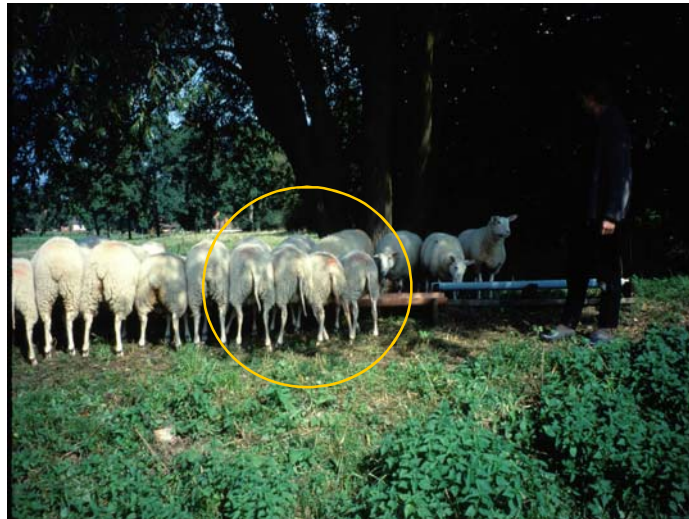
## Conspicuous clinical features e.g. stragglers in a herd (weaklings suffering from Cu/Zn/Se deficiency)



From: Humann-Ziebank, 2006



**Conspicuous clinical features**  
e.g. differences in growth due to Cu/Zn deficiency



From: Humann-Ziehank, 2006



**Conspicuous clinical features**  
e.g. loss of wool and formation of  
scab all over the skin due to Zn  
deficiency

From: Humann-Ziehank, 2006

## How can this discrepancy in trace element demands by plants and animals be overcome?

### 1. Fertilization with farmyard manure?

- Trace elements in farmyard manure usually in **organically complexed form** and are **not directly plant available**
- **Alkaline pH** in manure makes trace elements **insoluble**
- But: Promoting **microbial soil activity** helps to make trace elements better available
- Microbial activity is high in **warm, moist and well aerated soils** with **slightly acid to neutral pH**

### 2. Fertilization with mineral fertilizers?

#### Soil fertilizers

- granulated
- aims at basic supply for plants via the root path
- for long-term remediation of trace element deficiency in soils

#### Foliar fertilizers

- water soluble powder / micro granules
- solution
- suspension
- for supplementation under special conditions such as
  - growth period with higher demands
  - unexpected deficiency
  - stress (drought, cold)
  - avoid fixation of trace elements in soils

Alternative: Mobilization of soil reserves by lowering of soil pH through physiologically acid fertilization

## 2. Fertilization with mineral fertilizers?

- For example: **Selenium (Se)**, essential for animals, but not for plants
  - **Recommended value** for ruminants: 0,05-0,2 mg/kg Se in DM fodder
  - Typical **concentrations in fodder plants** are in the same range, however, in Se-deficient regions they are **often too low**
  - **Fertilization with Se?** E.g. by lime or multinutrient fertilizer with Na/Ba-selenate
  - **Phytotoxicity** depending on plant species (and soil pH), for example at >15-20 mg/kg DM (wheat) or >75 mg/kg DM (corn), Se-sensitive species such as clover suffer from toxicity at >5 mg/kg DM (Rani et al., 2005)
  - **Toxicity for animals** at >2-5 mg/kg DM fodder
- ⇒ **Very precise timing and dosage control** (taking into consideration the available soil reserves) is indispensable to prevent over supply for animals (Lorenz et al., [www.DLR-Eifel.rlp.de](http://www.DLR-Eifel.rlp.de))

## Trace element fertilization or supplementation?

- Trace element deficiencies in animals are often **not** caused by **low soil contents**, but by **limited availability of trace elements in soils**.
- Only **clearly identified trace element deficiency** in soil should be remediated by soil fertilization (alternative: physiologically acid fertilization to increase trace element availability).
- Increasing trace element contents in plants up to an adequate level for animals is most effectively done by foliar fertilization. However, this is often problematic, because
  - Unwanted **antagonisms** may occur during plant uptake (most typically between Fe, Mn, Zn, Cu, Mo and Se) and
  - **Harmful effects to plants** are possible (toxicity limits for plants must be accounted for!)
- Where an increase in plant contents by fertilization appears doubtful, systematic **supplementation** by concentrated mineral feeds are preferable.

### Supplementation with mineral feed concentrates

- Selection of a suitable mineral feed concentrate requires knowledge of trace element contents in plants (plant analysis!)
- Intake of supplements by animals is difficult to ensure for
  - a) nomadic pastoralism (e.g. sheep)
  - b) groups with distinct hierarchical structures (e.g. goats)
- Acceptance of supplements by animals depends on tastiness
- Monitoring the state of individual animals supplementation is indispensable (blood tests)
- Alternative options:
  - supplementation by injection (Se, Co, Fe; not possible for Cu)
  - administration of long-term boli into the rumen (cattle)

### Conclusion

In general, discrepancies between the trace element demand of animals of plants can be overcome. Highly variable conditions in different farms (soils, climate, plant composition, cropping system, animal species, living conditions for animals, expected performance) require a farm-specific analysis and the selection of appropriate measures.

**Sell the product with advice!**

**Thank you for your attention!**





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# *Importance of Micro-Nutrients in Agriculture in Africa and their Impact on Human Health*

Prof. Dr. Victor Chude  
University of Abuja – Nigeria

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel





# **Importance of Micronutrient in Agriculture in Africa and its Impact on Health**

## **By Chude\*, V. O., T. Ibia<sup>+</sup> and A. Nafiu<sup>\*</sup>**

*\*National Programme for Food Security, Abuja, Nigeria*

*+Department of Soil Science, University of Uyo, Nigeria*

### **Abstract**

Micronutrient deficiencies in African soils are assuming alarming rates and may be responsible for the declining yields and quality of crops. This has serious implications on the attainment of Millennium Development Goal-1 on halving people suffering from hunger and malnutrition in 2015 in Africa. These disorders are attributable to inherent poor soil fertility, use of high analysis NPK fertilizers containing lower quantities of micronutrient contaminants and the increase in cultivation intensity with high yielding crop cultivars that remove higher quantities of micronutrients from the soil.

Micronutrient malnutrition is now a massive and rapidly growing public health problem among nearly all poor people in Africa, leading to unproductive work force.

Molybdenum deficiency for instance leads to retarded weight gain, decreased food consumption, impaired reproduction; shortened life expectancy; neurological dysfunction; dislocated ocular lenses and mental retardation. Related deficiency symptoms of Arsenic, Iodine, Iron, Manganese and Zinc are fully discussed in this paper.

To alleviate micronutrient malnutrition, the paper identified the use of agriculture through the incorporation of micronutrient fertilizers in African farming systems, molecular alterations of plant genes to improve micronutrient supplies, increasing translocation, remobilization and deposition of micronutrients, improving the bioavailability of micronutrient in plant food and increasing the accumulation of vitamins in edible parts of food crops.

This paper identified several interventions commonly used to improve plant food nutritional quality and agricultural system to include the integration of micronutrient fertilizers in farming systems, genetic engineering and plant breeding programme and molecular alterations of plant genes to improve micronutrient supplies.

### **INTRODUCTION**

The soil remains the main medium of growth in which plants obtain essential nutrients for their growth, development and yield. Humans and animals obtain their nourishment through the plants for their growth, development and reproduction. The soil must therefore be in a good stead to support plants and animals including humans by producing highly in terms of yield and nourishment. Seventeen elements have been shown to be essential to plants. They are called macronutrients (N, P, K, Ca, Mg, S, O, H, and C) and micronutrients or trace elements (B, Fe, Co, Zn, Cu, Mn, Mo, and Cl). African soils have inherently poor fertility due to the fact that they are very old and lack volcanic rejuvenation (Bationo, 2009) and they have been constantly subjected to

inappropriate land use, poor management and lack of input utilization leading to continuous nutrient mining and attendant rapid decline in productivity.

Importantly, the primary source of all nutrients for humans comes from agricultural products. Low yield of crops are also associated with micronutrient deficiencies and humans start getting impacted negatively when their effort give suboptimal yields against their labour and sweat. If agricultural systems fail to provide enough products containing adequate quantities of all nutrients during all seasons, dysfunctional food systems result that cannot support healthy lives.

It is well established that the micronutrients obtained from the soil are vital components of the diet, and therefore managing them in the soil-plant systems is a vital component of sustainable agriculture as soil, plant, animal and human health are closely interrelated. Micronutrient malnutrition is now a massive and rapidly growing public health problem among nearly all poor people in many developing nations affecting about 40% of the world's people (Welch and Graham, 2004).

### **Geographical distribution of micronutrient problems in Africa**

In sub-Saharan Africa, micronutrient deficiencies or toxicities were first recognized in areas where cash crops were grown. Only in the last few decades has more emphasis been given to the micronutrient status of soils for other crops. Kang and Osiname (1985) provide examples of common micronutrient deficiencies in sub-Saharan Africa. The worldwide study by Sillanpaa (1982) provided data on micronutrient concentrations in selected soils of Africa. It illustrated that copper, zinc and molybdenum deficiencies are common in many coarse textured, acid soils of Ethiopia, Ghana, Malawi, Nigeria, Sierra Leone, Tanzania, and Zambia.

Boron deficiencies have been reported mainly from research on cash crop oil palm and cotton-growing areas in West and East Africa (Kang and Osiname 1985), and response to boron fertilization has been reported in forestry research. A statistically significant reduction of incidence of die-back of eucalyptus species was achieved through boron application (Kadeba 1990). In Zimbabwe, colemanite and borate fertilizers were applied on cotton and sunflower and were equally effective when incorporated in NPK fertilizers (Rowell and Grant 1975).

Few systematic studies have been undertaken to determine the distribution of chlorine in soils of sub-Saharan Africa, although a preliminary survey of savanna soils of Nigeria indicates that about eighty percent of these soils may be chlorine deficient (Raji and Jimba 1999).

Cobalt is required by nitrogen-fixing microorganisms. It is an essential element for N-fixing legumes. In animal health, the lack of cobalt in forage plants can lead to muscular 'wasting' and death in ruminants. In New Kenya this deficiency-induced disease is called 'Nakuruitis' (McDowell 1992). Cobalt deficiencies in grazing ruminants can be prevented or cured by treating pastures with 'cobaltized' fertilizers, or through oral application of heavy pellets (bullets) made of cobalt oxide and iron (McDowell 1992).

Copper deficiencies are common in many coarse textured acid soils in sub-Saharan Africa. Deficiencies of copper have influenced the growth of wheat on soils derived from



volcanic ash and pumice in Kenya and Tanzania (Nyandat and Ochieng 1976; Kamasho and Singh 1982) and copper deficiencies are also reported from peat and muck soils in various countries.

Iron deficiencies are rare in sub-Saharan soils due to the large pools of iron in weathered soils. However, areas that have been subjected to bush fires showed iron deficiencies. Burning resulted in increased soil pH and thereby reduced the plant-availability of iron. The ferrous form is the preferred form of Fe for micronutrient use. Ferric oxides like magnetite are not suitable as micronutrient source. Sources to successfully overcome iron deficiencies in high pH soils include Fe-chelates and organic materials, such as manure. Pyrite-enriched manure proved a good source for iron on alkaline soils (Bangar *et al.* 1985). Barak *et al.* (1983) successfully used finely ground basalt and volcanic tuff from a local quarrying operation that contain several percent Fe as Fe II to remedy chlorosis of groundnuts (*Arachis hypogaea*) in calcareous soils.

Although manganese deficiencies are rare in sub-Saharan Africa, high plant-available Mn can cause toxicities, especially in acid soils. Increasing soil pH through liming can prevent Mn toxicities. In parts of the world where Mn is deficient in soils, Mn sulfates, Mn carbonates or MnO have been applied successfully (Mordtvedt 1985).

Molybdenum, essential for nitrogen fixation through symbiotic microorganisms, is critical for many leguminous crops. Molybdenum deficiencies have been identified in some groundnut growing areas of Senegal, northern Ghana, and northern Nigeria (references in Kang and Osiname 1985). Martin and Fourier (1965) describe the positive effects of Mo application on sandy aeolian sands of West Africa leading to improved groundnut yields, nodulation and nitrogen fixation. Mo deficiencies and related problems can be expected in many parts of Africa, especially for legumes that have high Mo requirements like soybeans and groundnuts. Molybdenum deficiencies have also been observed on acid soils of Zimbabwe where maize is grown.

In contrast to deficiencies there are also Mo toxicities, especially in parts of the world with high molybdenum parent materials and poorly drained alkaline soils. Cases of molybdenosis (molybdenum toxicity), a disease in ruminants (stiffness of legs, loss of hair) feeding on forage containing more than 10 to 20 mg Mo kg<sup>-1</sup>, have been reported from North America and from Kenya (McDowell 1992).

Low zinc concentrations have been found to reduce maize yields in several parts of Africa, for example in Nigeria (Osiname *et al.* 1973), Zimbabwe, and Zambia (Banda and Singh 1989). Zinc deficiencies are also quite common with the cultivation of rice (Kanwar and Youngdahl 1985). There is growing evidence that Zn becomes gradually deficient in parts of Nigeria's savanna, especially in areas under continuous cultivation and phosphate fertilization (Lombin 1983; Agbenin 1998). Zinc is commonly supplied to crops as manufactured zinc sulfate fertilizers, but slowly dissolving zinc oxide has also been used successfully on wheat in South Africa (Dietricksen and Laker, cited in Mordtvedt 1985).

### **Importance and deficiencies of micronutrients in plants**

In agricultural soils, nutrient deficiencies occur when the rate of removal exceeds the reserves in the soil and the annual replenishment through natural processes (NRS, 2012). The increase in cultivation intensity with the increasing demand for higher yields with better quality has resulted in increasing demand for micro-nutrients. Moreover, plant productivity has increased along the years due to genetic development and selection of high yielding cultivars. These cultivars with intensive cultivation methods have been found to remove higher quantities of micro-elements from the soil, leading to deficiencies occurring in many soils

A summary of the functions and deficiency symptoms of micronutrients in plants has been made by FFD/FPDD (2011).

**COPPER (Cu):** Cu is obtained from the soil ( $\text{Cu}^{++}$ ) and absorbed by the plants through the roots.

Functions

- a) Constituent of cytochrome oxidase and component of many enzyme- ascorbic acid oxidase, phenolase, lactase, etc
- b) Promotes the formation of vitamin A in plants

Deficiency symptoms

- a) In cereals, yellowing and curling of the leaf blade, restricted ear production and poor grain set, indeterminate tillering
- b) In citrus, die back of new growth, exanthema pockets of gum develop between the bark and the wood, the fruit shows brown excrescences.

**IRON (Fe):** Fe is obtained from the soil ( $\text{Fe}^{++}$ ,  $\text{Fe}^{+++}$ ) and absorbed by the plants through the roots.

Functions

- a) Necessary for the synthesis and maintenance of chlorophyll in plants.
- b) Essential component of many enzymes.
- c) Plays an essential role in nucleic acid metabolism and affects RNA metabolism or chloroplasts.

Deficiency symptoms

- a) Typical inter-veinal chlorosis; youngest leaves first affected, points and margins of leaves keeps their green colour longest.
- b) In severe cases, the entire leaf, veins and inter-veinal areas turn yellow and may eventually become bleached.

**ZINC (Zn):** Zn is obtained from the soil ( $\text{Zn}^{++}$ ) and absorbed by the plants through the roots.

Functions

- a) Involved in the biosynthesis of indole acetic acid.
- b) Essential component of a variety of metallo-enzymes-carbonic anhydrase, alcohol dehydrogenase, etc.
- c) Plays a role in nucleic and protein synthesis.
- d) Assists the utilization of phosphorus and nitrogen in plants

### Deficiency symptoms

- a) Deficiency symptoms mostly appear on the 2<sup>nd</sup> or 3<sup>rd</sup> fully mature leaves from the top of plants.
- b) In maize, from light yellow striping to a broad band of white or yellow tissue with reddish purple veins between the middle and edges of the leaf, occurring mainly in the lower half of the leaf.
- c) In wheat, a longitudinal band of white or yellow leaf tissue, followed by inter-veinal chlorotic mottling and white to brown necrotic lesions in the middle of the leaf blade; eventual collapse of the affected leaves near the middle.
- d) In rice, over 15-20 days of transplanting, small scattered light yellow spots appear on the older leaves which later enlarge, coalesce and turn deep brown; the entire leaf becomes rust-brown in colour and dries out within a month.
- e) In citrus, irregular inter-veinal chlorosis; terminal leaves become small and narrowed (little-leaf); fruit-bud formation is severely reduced; twigs die back.

**MANGANESE (Mn):** Mn is obtained from the soil ( $\text{Mn}^{++}$ ) and absorbed by the plants through the roots.

### Functions

- a) A catalyst in several enzymatic and physiological reactions in plants; a constituent of pyruvate carboxylase.
- b) Involved in plant's respiratory processes.
- c) Activates enzymes concerned with the metabolism of nitrogen and synthesis of chlorophyll.
- d) Controls the redox potential in plant cells during the phases of light and darkness.

### Deficiency symptoms

- a) Chlorosis between the veins of young leaves, characterized by the appearance of chlorosis and necrotic spots in the inter-veinal areas.
- b) Grayish areas appear near the base of the younger leaves and become yellowish to yellow orange.

**BORON (B):** B is obtained from the soil ( $\text{BO}_3^-$ ,  $\text{B}_4\text{O}_7^{--}$ ) and absorbed by the plants through the roots.

### Functions

- a) Affects the activities of certain enzymes.
- b) Ability to complex with various polyhydroxy-compounds.
- c) Increases permeability in membrane and thereby facilitates carbohydrate transport.
- d) Involved in lignin synthesis and other reactions.
- e) Essential for cell division.
- f) Associated with the uptake of calcium and its utilization by plants.
- g) Regulates potassium/calcium ratio in plants.
- h) Essential for protein synthesis

#### Deficiency symptoms

- a) Death of growing plants (shoot tips)
- b) The leaves have thick texture, sometimes curling and becoming brittle.
- c) Flowers do not form and root growth is stunted.
- d) “Brown heart” in root crops characterized by dark spots on the thickest part of the root or splitting at centre.
- e) Sensitive plants include tobacco, cotton and legumes.

**MOLYBDENUM (Mo):** Mo is obtained from the soil ( $\text{MoO}_4^{--}$ ) and absorbed by the plants through the roots.

#### Functions

- a) Associated with nitrogen utilization and nitrogen fixation.
- b) Constituent of nitrate reductase and nitrogenase.
- c) Required by ***Rhizobia*** for nitrogen fixation.

#### Deficiency symptoms

- a) Chlorotic inter-veinal mottling of the lower leaves, followed by marginal necrosis and infolding of the leaves.
- b) In cauliflower, the leaf tissues wither leaving only the midrib and a few small pieces of leaf blade (“whiptail”).
- c) Molybdenum deficiency is markedly evident in leguminous plants.

#### **Micronutrient assessment of when deficiencies are suspected**

Soils all over the landscape have varying nutrient supplying power, depending on the amount of total reserves, on mobilization and accessibility of the chemically available nutrients to plants. The process of determining the nutrient status of soils or their capacity for prevailing nutrients in order to guide effective fertilizer application can be referred as “**Soil Fertility Assessment/Evaluation**”.

#### Impact of climate change and soil

Communities around the world are feeling the effects of climate change, but African and Asian communities being the poorest are more vulnerable and the hardest hit. They are the least equipped to recover from the devastation that can result from weather extremes such as storms, floods, eroding coastlines, heat waves, and droughts. Climate change impacts soil nutrients thus affecting fertility and productivity, food security and human health.

Edward Joy, (2011) reports that over-cultivated soils will often suffer mineral deficiencies, particularly in systems where nutrients and organic wastes are not returned to the soil. Heavy rains can wash micronutrients below the root systems or into water courses if soils are unprotected, have low organic matter content and poor structure. Agricultural practices can be tuned to improve crop micronutrient uptake, and to reduce leaching from the system. When soils are excessively leached, flooded or submerged, or become dry soil fertility and productivity become impaired nutrients become removed, converted or unavailable. These in turn affect food security.

Changes in temperature and precipitation associated with continued emissions of greenhouse gases will bring changes in land suitability and crop yields. Changes in climate and increases in some extreme weather events, such as floods and droughts,

could disrupt stability in the supply of food and people's livelihoods making it more difficult for them to earn a stable income to purchase food.

Climate change can result in substantial decline in labour productivity and inability to cultivate crops and raise animals and may increase poverty and even mortality among the populace. It has the potential to affect different diseases, including respiratory illness and diarrhea. Decreased water availability and quality in some areas are likely to result in increased health and sanitation problems, such as diarrheal disease. This, together with changes in the patterns of vector-borne disease, has the potential to increase malnutrition by negatively affecting food production and utilization.

### **Soil Management for enhanced fertility and micronutrient availability**

Therefore, the soils need special attention in their management and utilization particularly for agricultural production. Such management requirements (Chude, 2011) for overall soil fertility include:

- (i) Increased and more efficient mineral fertilizer use;
- (ii) Exploitation and use of locally available soil amendments;
- (iii) Maximum recycling of organic products, both from within and from outside the farm (crop residues, animal manures, urban wastes, compost, etc and
- iv) "Improved" land use systems, based on both indigenous and science-based technologies, adaptable to local situations, etc.

### **FORMS OF MICRONUTRIENTS AVAILABLE FOR USE IN THE SOIL**

Several groups or forms of micronutrient fertilizer available for use in soils (SFN, 2006) include:

**Sulphate (salts):** The sulphate form of micronutrients such as: Cu, Zn, Fe and Mn, represents a water-soluble form that is plant available. Borate is the equivalent plant available form for B. Sulphates are the most commonly used form for field crops. Sulphates can be applied to the soil or foliage.

**Oxysulphate:** An oxysulphate is an oxide of a micronutrient that has been partially reacted (acidulated) with sulphuric acid. Water solubility of oxysulphates which vary greatly is important when using oxysulphates. In general, the higher the water solubility portion, the better.

**Oxide:** Oxides are micronutrient elements (Cu, Zn, Fe, and Mn) bonded with oxygen. The bonds with oxygen are very strong, meaning these products are not soluble in water and are not in plant available form. An oxide of a micronutrient needs to be converted to a plant available form in the soil before being taken up by the plant. For crop response during the growing season, plant available forms (water-soluble forms) of micronutrients need to be used.

**Chelate:** Chelates are micronutrients such as Cu, Fe, Mn, and Zn held within ring-type compounds. Chelated micronutrients remain in plant-available form longer because the chelated structure slows the micronutrient reaction with soil minerals. Chelated micronutrients can be soil or foliar applied.

**Manure:** Livestock manure can be a source of micronutrients such as Cu and Zn.

**Other forms:** Carbonates and nitrates and mixtures with elemental forms are examples of other forms of micronutrients, but are seldom used.

## **ISSUES IN ANIMAL AND HUMAN HEALTH**

In animals and humans, micronutrients are dietary nutrients (14 trace elements essential elements) and 13 vitamins that are required by humans in very small amounts (Welch and Graham, 2004).

There is no doubt that agricultural production of staple foods (particularly cereals and starchy tubers) has improved by applying the “green revolution” approaches of developed countries in Africa and Asia. According to UN-ACCSN (1992), what has resulted is massive production and utilization of energy giving foods causing unforeseen nutritional imbalances and problems particularly among pregnant women, infants and children. These have been traceable to low micronutrient intake among others.

### **Deficiencies and impacts on humans:**

#### **DEFICIENCY SYMPTOMS IN ANIMALS**

Deficiency symptoms associated with micronutrients in animal diets have been documented by National Research Council, (1989); Nielsen, (1992); World Health Organization, (1996) and Welch and Graham, (2004) as shown below:

**Arsenic:** impaired fertility and increased perinatal mortality; depressed growth; conversion of methionine to its metabolites; methylation of biomolecules

**Boron:** impaired Ca utilization in bone; more severe signs of vitamin D related rickets; decreased apparent absorption of Ca, Mg, and P; impaired mental functions in older women and men (>45 years old).

**Chromium:** impaired glucose tolerance; impaired growth; elevated serum cholesterol and triglycerides; increased incidence of aortic plaques; corneal lesions; decreased fertility and sperm count; potentiates insulin action

**Copper:** hypochromic anemia; neutropenia; hypopigmentation of hair and skin; impaired bone formation with skeletal fragility and osteoporosis; vascular abnormalities; steely hair; metal cofactor in numerous metalloenzymes, e.g., cytochrome oxidase, caeruloplasmin, superoxide dismutase, etc

**Fluorine:** status as an essential trace element debated; beneficial element because of its effects on dental health

**Iodine:** wide spectrum of diseases including severe cretinism with mental retardation; enlarged thyroid (goiter); essential constituent of the thyroid hormones

**Iron:** iron deficiency erythropoiesis with low iron stores and with work capacity performance impaired; iron deficiency anemia with reduced hemoglobin levels and small red blood cells; impaired immune function; apathy; short attention span; reduced learning ability; constituent of hemoglobin, myoglobin and a number of enzymes

**Manganese:** poor reproductive performance; growth retardation; congenital malformations; abnormal bone and cartilage formation; impaired glucose tolerance; metal activator of many enzymes, e.g., decarboxylases, hydrolases, kinases, and transferases; constituent of pyruvate carboxylase and superoxide dismutase in mitochondria

**Molybdenum:** retarded weight gain; decreased food consumption; impaired reproduction; shortened life expectancy; neurological dysfunction; dislocated ocular lenses, mental retardation; cofactor (molybdopterin) in sulfite oxidase and xanthine dehydrogenase

**Nickel:** depressed growth and reproductive performance; impaired functioning and body distribution of several nutrients e.g., Ca, Fe, Zn, vitamin B 12 ; cofactor for an enzyme that affects amino acids and odd-chained fatty acids derived from the propionate metabolic pathways

**Selenium:** endemic cardiomyopathy (Keshan disease); white muscle disease; endemic osteoarthropathy (Kashin-Beck disease) with enlargement and deformity of the joints; liver necrosis; exudative diathesis; pancreatic atrophy; growth depression; depressed activity of 5'-deiodinase enzymes that produce triiodothyronine (T 3 ) from thyroxine (T 4 ); impaired immune response to viral infections; anticarcinogenic activity; essential component of glutathione peroxidase and "selenoprotein-P"

**Silicon:** depressed collagen content in bone with skull structure abnormalities; long bone abnormalities; decreased articular cartilage, water, hexosamine, and collagen; decreased levels of Ca, Mg, and P in tibias and skulls under Ca deficiency conditions

**Vanadium:** death proceeded by convulsions; skeletal deformities; increased thyroid weight; participates in oxidation of halide ions and/or the phosphorylation of receptor proteins

**Zinc:** loss of appetite; growth retardation; skin changes; immunological abnormalities; difficulty in parturition; teratogenesis, hypogonadism; dwarfism; impaired wound healing; suboptimal growth, poor appetite, and impaired taste acuity in infants and children; diarrhea; impaired immune function; constituent of numerous enzymes; cellular membrane stability function.

### **Malnutrition and disease incidence.**

Micronutrients compose of the mineral and vitamin components of a healthy diet, required in small quantities, but essential for good health. In developing countries particularly in Africa, since the beginning of the early 1990's, micronutrient deficiencies (also known as "hidden hunger") have been put high up on the international public health agenda (Edward Joy, 2011). Two causes of micronutrient deficiencies are inadequate intake of micronutrient-rich foods (including fruit, vegetables, meat, eggs and dairy) and general health problems associated with humans.

Micronutrient malnutrition not only affects the health, well being and livelihood of all those individuals and families afflicted, but it also adversely impacts programs to control population growth, societal stability and national development efforts. If widespread within a population, deficiencies of any micronutrient can diminish economic growth, societal stability, and national development. Unfortunately, in many nations, introduction of high yielding cereal crops and trends to less heterogeneous farming systems has resulted in reduced diversity of food available to low-income individuals and families, and therefore, decreased access to and increased cost of more diverse food sources in the market place especially for the poor. As stated previously, this trend of less food diversity could be a contributing factor in the spread of micronutrient malnutrition among poor women, infants and children in developing nations.

Optimum nutrition can be provided by assuring dietary diversity and food abundance for all to ensure that adequate and balanced amounts of all micronutrients are available for consumption. To treat micronutrient deficiencies to large numbers of people relatively quickly interventions using micronutrient supplements and food fortificants are important programs currently being used globally. While this should continue to be used as short- to medium-term interventions for decreasing micronutrient malnutrition, agriculture should remain the primary intervention tool if we are to eliminate "hidden hunger" in sustainable ways (Welch *et al.*, 1997) by improving plant food nutritional quality and the nutrient output of agricultural systems.

## **IMPROVING PLANT FOOD NUTRITIONAL QUALITY AND THE NUTRIENT OUTPUT OF AGRICULTURE SYSTEMS**

Several actions are commonly used to improve plant food nutritional quality and nutrient output of agricultural systems. These include cultural practices, variety selection, crop improvement programmes, incorporation of Indigenous and traditional food crops of high nutritive value in the farming systems, genetic engineering and plant breeding programmes and molecular alterations of plant genes to improve micronutrient supplies.

### **Cultural practices**

**Fertilizers and soil amendments:** Both macronutrient fertilizers containing N, P, K, and S, and certain micronutrient fertilizers containing, for example Zn, Ni, and Se, can have significant effects on the accumulation of micronutrients in edible plant products (Allaway, 1986; Grunes and Allaway, 1985). The use of farm-yard manures and other forms of organic matter can also change plant-available micronutrients by changing both the physical and biological characteristics of the soil. In many circumstances these changes improve soil physical structure and water holding capacity, resulting in more extensive root development and enhanced soil microflora and fauna activity. All of these can affect available micronutrient levels in soil for plants (Stevenson, 1991; Stevenson, 1994).

**Variety selection:** Using micronutrient-dense staple food crop varieties in cropping systems is one approach that could be used to increase the micronutrient output of farming systems albeit this approach has never been used to date (Bouis, 1996; Combs *et al.*, 1996; Graham and Welch, 1996).

**Crop management:** Crop management is another tool that can be used to improve the micronutrient output of farming systems. For example, using certain legume crops in



rotation with cereal crops can result in substantial increases in the concentration of Zn in cereal grain in areas where soil-Zn is currently limiting wheat production (Holloway, 1997, cited in Welch and Graham, 2004).

Selecting micronutrient dense food crops and cultivating micronutrient-dense staple plant food varieties should be a major goal of agriculturalists in developing countries where micronutrient deficiencies among people are common.

**Indigenous and traditional food crops of high nutritive value:** Within many developing nations, certain indigenous food crops are being displaced and lost as important nutritional components of traditional diets. The production of many of these traditional crops has decreased even further because of importation of and subsidies paid for millions of tons of wheat, rice and maize that are sold at lower prices. Many traditional crops are much richer sources of micronutrients than the introduced cereal crops that are displacing them.

Designing cropping systems for maximum nutrient output to improve nutrition and health should become an integral part of agriculture's goals and government policies.

**Genetic engineering and plant breeding** Plant breeding options have been documented (Welch and Graham, 2004), which shows that the dominant staple crops can be enriched (i.e. 'biofortified') with micronutrients using plant breeding and/or transgenic strategies, because micronutrient enrichment traits exist within the plant genomes that can be used for substantially increasing micronutrient levels in these foods without negatively impacting crop productivity. 'Biofortification' is a word coined to refer to increasing the bioavailable micronutrient content of food crops through genetic selection via plant breeding.

Developing micronutrient-enriched staple plant foods, either through traditional plant breeding methods or via molecular biological techniques (GMF), is a powerful intervention tool that targets the most vulnerable people (resource-poor women, infants, and children; Combs Jr *et al.*, 1996). Welch and Graham (2004) reports that current breeding efforts to screen large numbers of promising micronutrient-dense lines of staple plant foods (rice, maize, wheat, beans, and cassava) at several CGIAR Centres (IRRI, CIMMYT, CIAT, and IITA) for bioavailable Fe are in progress.

There must therefore be a resolve of the agricultural community, the nutrition community, public health officials, private industry, and government policy makers to use agriculture as a primary means in alleviating micronutrient malnutrition.

These can be done through:

**Molecular alterations of plant genes to improve micronutrient supplies:** Modern molecular biological techniques could be used to genetically alter food plants with increased bioavailable concentrations of micronutrients in edible portions. However, this requires detailed knowledge of various physiological and biochemical processes in plants.

**Increasing efficiency of micronutrient uptake:** The mineral nutrition of plants is under genetic control and the mechanisms by which plants accumulate micronutrient elements are under genetic regulation. Selecting for the ability to accumulate more micronutrient elements from nutrient-poor soils is the first step in breeding for micronutrient-dense staple food crops.

**Increasing translocation, re-mobilization and deposition of micronutrients:** The second step in increasing the density of micronutrient in staple foods involves altering the genes that control the translocation of root-accumulated micronutrient elements to shoots. Once more micronutrients are accumulated in plant shoots, they must be re-translocated out of stems and leaves to reproductive organs before they can be deposited in developing seeds and grains.

**Improving the bioavailability of micronutrients in plant foods:** An understanding of how micronutrients are stored and in what forms they occur in edible seeds and grains is also an important consideration for increasing the bioavailable content of micronutrients in edible plant parts.

**Increasing the accumulation of vitamins in edible parts of food crops:** Current molecular biological techniques are available that would allow for rapid genetic alterations of plant foods in ways that would increase vitamins in these foods once the biosynthetic pathways and their genetic regulation are understood (New York Academy of Sciences, 1996).

## **CONCLUSION**

Considering the widespread incidences micronutrient deficiency in Africa, the region is huge market for the sale of micronutrient fertilizers.

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# *Food, feed and Plant Nutrition: an Intricate Relationship*

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**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**

19<sup>th</sup> AFA Conference  
Sharm El Sheikh (26-28 February, 2013)

## **Food, Feed and Plant Nutrition: *An Intricate Relationship***

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19<sup>th</sup> AFA Conference  
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### **Introduction**

- N. East arid, semi-arid Region( limited land & water).
- Irrigated agriculture is the major sector for meeting the increased food demand. (inputs, fertilizers).
- **Fertilizers** are responsible for ≥ 55 % of the increased agricultural output during last 30 yrs (FAO, 1998).
- Region was self-sufficient in the 1960's in cereals.
- Arab countries largest importers of cereal in the world  
> 58 million metric tons in 2007 .
- EGYPT imports some 9 million tons of wheat annually.

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**Basic Soil – Plant Relationships**

Essential Nutrients for Plants

- 17 Essential Elements (macro & micro- nutrients)
- Source of nutrients: air, water, soil & mainly fertilizers
- Balanced fertilization: all essential elements available.  
Ratios N:P:K = 5:2:1 (existing imbalance 5:1: 0.5)
- Many N-factories (Urea for export); few P-factories;  
and only one K-factory in Jordan (1.5 m tons of K Cl)
- Bias against K and minor elements (Fe, Zn, Mn, Cu).
- Overall NPK rates is 70 kg/ha, World average 120 kg.
- Huge Impact for increasing fertilizer use by 50 kg/ha.

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**Human Food vs. Animal Feed & Plants**

- Most basic requirements for these THREE are similar.
- Some are essential for animals and not for plants, like Se.
- Micro nutrients and vitamins are essential for all,  
(Mad Cow Disease is an animal nutrition-based disease).
- In Europe, the ranges are spread with Se compounds for  
the benefit of grazing animals.
- A Soil-deficient element (Zn) would produce a forage  
deficient in Zn.
- Reported case in New Zealand about Mo deficiency in  
soils, affecting school children coloring teeth.



## 19 th. AFA Conference Sharm El Sheikh (26-28 February, 2013)

### Balanced Fertilization

- \* **FAO** advocated the Integrated Plant Nutrition System (IPNS) and Good Agric. Practices (GAP) for max agric. production and environment protection ( spec. N)
- \* Rational use of applied fertilizers (fertigation /control systems, and waste recycling, etc).
- \* FAO approach deals with the problem at the *Source*, or at Upstream (preventive).
- \* Balanced fertilized crop would produce a good –value, safe and healthy food item (Man) and/or a good animal feed.
- \* This is quite different from the UNICEF approach (food fortification/supplementation programmes).

## 19 th. AFA Conference Sharm El Sheikh (26-28 February,2013)

### A Global Concern for Food Safety

- \* Global Concern on Food Safety : WHO and FAO jointly introduced Codex Alimentaris Commission (169 Member Countries) that deals with food standards and specs through legislation, quality control and trade terms and standards.
- \* Food and Drug Admin in most Arab Countries exists for control of food quality and safety. (over 50 new codes)..
- \* Food Security is still a big concern (almost 1 billion in hunger and malnutrition worldwide).
- \* New terms are common like GAP., EUREGAP, Organic Products, HACCP (Hazard Analysis &Critical Control Points).



19 th. AFA Conference  
Sharm El Sheikh (26-8bruary,2013)

***Role of Micro-nutrients in Plant and Animal***

- Fe in green leaves is an important source of Fe-supply to humans;
- Mn contents in food and fodder are important-quality for carotene and Vitamin C;
- Cu fertilization increases the Cu- in plants and gives a better-quality particularly its taste for animals;
- CGIAR reports 1/2 of world people suffer Micronutrients Deficiency . Zn-deficiency in humans estimated at 2 billion - Cakmak).
- Mo-supply raise protein content and quality of legumes.
- Selenium role in human and animal body is associated with cancer-prevention as an anti-oxidant agent.

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***Fertilization and Product Quality***

- Controlled Fertilization through Fertigation and Precise Agriculture..
- Value of Naturalism ? Back-t-o Nature? How about Outputs?
- Role of Chem. Fertilizers 55% Agric. Output Growth (Indispensible).
- Low Fertilizer Use Rate in the Region (70)vs. World Rate of 120 kg/ha NPK.
- Pesticides &Fertilizers are NOT THESAME; Urea is feed additive (46% N)
- Organic Agric: Do we have adequate Org . Fertilizers?
- Organic food, org. cotton, org. furniture (ORGANIC – a marketing term?).

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**Addressing Nutrients Deficiency**

**(BETTER QUALITY– MORE OUTPUT)**

- A. **Fertilization- Soil Enrichment: IPNS; Precise Agric. (point source; sustainable; economic)**
- B. **Classical Breeding/Super Crops: safe, sustain, dense wheat, rice, potato, cassava, others.**
- C. **Commercial Food Fortification: (line source; bio-availability; cost; sustainable)-UNICEF.**
- D. **GMO: Public concern; Potential risk; Gene-pollution; Property Right; etc. C.**

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**A. Fertilization- IPNS**

**B. Classical Plant Breeding**

- **Defined: manipulation to create desired genotypes via controlled pollination (away from GMO's)**
- **Green Revolution is good example of breeding for HYV of cereals , Borlaug –Noble Prize'70 (saved 1 billion people from starvation) .**
- **HYV major advantage- Response to Fertilizers**
- **Increased yields in 20<sup>th</sup> Century due to : Synthetic Fertilizers (N,P); Machinery; pesticides;HYV.**
- **Hybrid rice help feed more than 20 % of world's population using just 10 % of world's arable land.**
- **IRRI: Hi Fe& Hi Zn is a Convention- bred Rice**

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Addressing Micronutrients .....

C. Food Supplementation - Line Source Approach

- Global Alliance Improved Nutrition (GAIN) Programme started 2002 (\$ 353 M in 13 countries).
- Gates Foundation \$50 M at start+ \$ 20 M in 2006.
- Four programmes: Vit. A; Fe; Zn; and Folate addition
- GAIN target reach 500 Million –fortified foods.
- Defense: easy and cost-effective (25 cents/person/yr)  
Criticism: bio-availability, access to rural areas, high costs; sustainability; *links with big food corporations*

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Addressing Micronutrients....

D. GMO's

- **Defined:** altering the gene make-up of plant, animal, bacteria. Gen. Modified/Transgenic.
- **In 2009: 134 Million ha planted with GMO crops.**
- **Main players (90%): US, ARG, BRAZ, CANADA.**
- **Main Crops: soybean, maize, canola, cotton.**
- **Main concern: potential human and environmental risks, Intellectual Rights, ethics, food security & safety.**
- **More alarming: genetic pollution and genetic mutations.**
- **No real valid evidence of human health hazard been reported.**

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**Concluding Remarks**

- a. Give due attention for conducting more research on role of micro-nutrients in plant, animal and human nutrition.
- b. Encourage dialogue and joint research programmes among scientists and researchers in plant, animal and human nutrition for identifying those intricate relationships.
- c. Call upon Governments to produce safe and healthy human food and animal feed for having a proper food chain.

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**Concluding Remarks**

- -Urge private sector (specially the R&D Depts. in Feed and Fertilizer-producing industries) to allocate adequate funds for studying micro-nutrients role in plant and animal nutrition health. Such research findings should be shared through a Regional Network, with technical assistance from FAO. Urge private sector (specially the R&D Depts. in Feed
- and Fertilizer-producing industries) to allocate adequate funds for studying micro-nutrients role in plant and animal nutrition health. Such research findings should be shared through a Regional Network, with technical assistance from FAO.

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**Concluding Remarks....**

- c- Urge Fertilizer-producing industries to allocate adequate funds for investigate micro-nutrients role in plant and animal nutrition health.
- d- Promote adopting Balanced Fertilization Programmes that can produce healthy plant and animal food items.
- e- Encourage joint research programmes among scientists and researchers in plant, animal and human nutrition for identifying those intricate relationships .
- F- Support establishing a Regional Information Network on Micronutrients in the Region for exchange of knowledge and experiences.



الإتحاد العربي للأسمدة  
Arab Int'l. Organization  
Arab Fertilizer Association  
Since 1975



19<sup>th</sup> Annual AFA  
Fertilizer Forum

A GLOBAL  
FERTILIZER  
PLATFORM

# SESSION IV

Feb. 26 – 28, 2013

Savoy Sharm El Sheikh Hotel





# *Nutrients Management with Treated Wastewater Irrigation and Feed Quality*

Dr. Munir Rusan  
 Middle East Consulting Director, IPNI

**Feb. 26 – 28, 2013**

**Savoy Sharm El Sheikh Hotel**



## **Nutrients Management with Treated Wastewater Irrigation & Feed Quality**

**Feb 26-28, 2013  
Sharm EL-Sheikh – Egypt**

**Munir Rusan  
International Plant Nutrition Institute, IPNI  
Jordan University of Science & Technology, JUST**



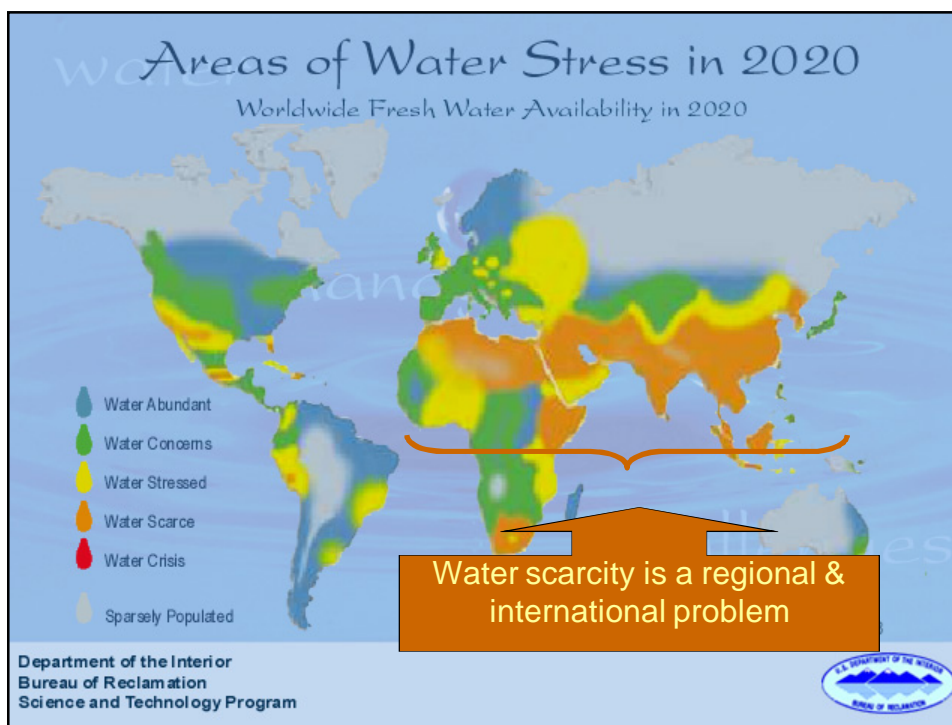
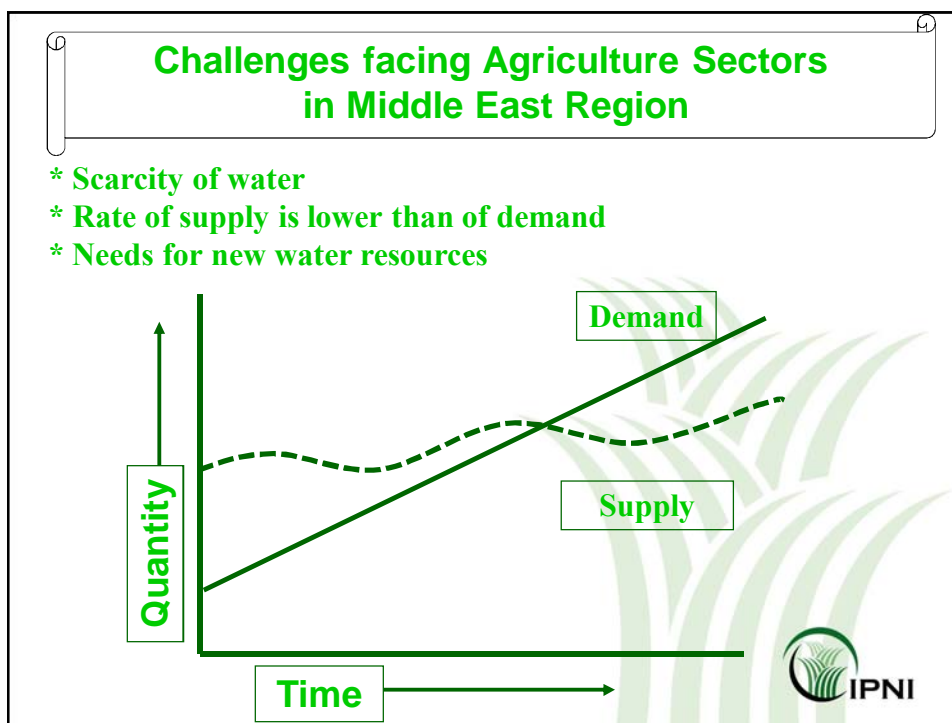
**TWW = Treated Wastewater**

**Raw Municipal wastewater treated to certain**

**Quality level to meet the guidelines for further**

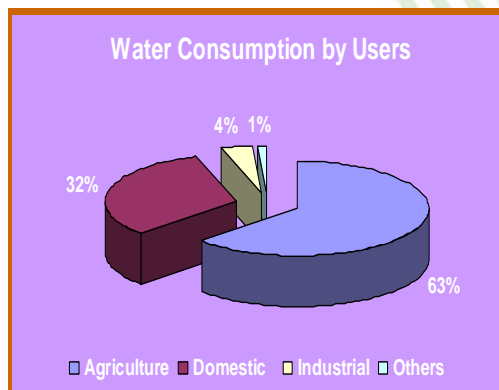
**reuse**





### Users of Water Resources:

- Strong competition for water
- Least priority for Agric.
- Agric. Need to use untraditional resources (TWW, BW, SW, GW)
- Treated Wastewater (Jordan/2011)  $\approx 80$  MCM  
Account for  $\approx 15$  % IW
- Treated Wastewater (Jordan by 2020)  $\approx 200$  MCM



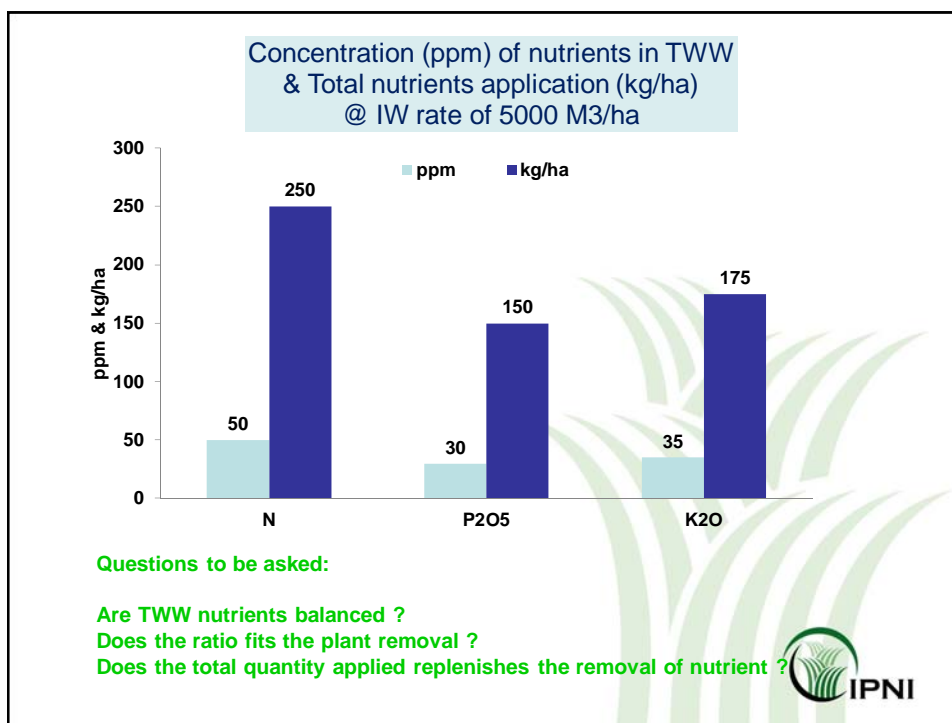
### Additional Benefits - WW Reuse

- ✓ Conserves potable water
- ✓ Safe & cheap disposal method
- ✓ Pollution abatement
- ✓ Economically attractive
- ✓ Source of nutrients

### Health and Environmental

- x Surface water Eutrophication
- x Ground water contamination
- x Heavy and toxic substances
- x Quality of products
- x Aesthetics & health hazards
- x Soil salinization & nutrient imbalance in the soil

So TWW can't be managed as a traditional IW



**Nutrients Uptake by Crops  
Compared to  
Nutrients Applied with TWW**

**250    150    175**

Group	Crops	Yield, t/ha	Nutrient uptake, kg/ha		
			N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Fruits	Apple	25	100	45	180
	Banana	40	250	60	1000
	Citrus	30	270	60	350
Vegetables	Cabbage	70	370	85	480
	Carrot	30	125	55	200
	Cauliflower	50	250	100	350
	Cucumber	40	70	50	120
	Onion & garlic	35	120	50	160
	Tomato	50	140	65	190
	Potato	40	175	80	310
Tuber crops	Sweet potato	40	190	75	340
	Sugarcane	100	130	90	340

*Source: Potash: its need & use in modern agriculture, 2002 (PPI-PPIC publication)*

### Different scenarios for nutrient balance with WW irrigation

#### -----Nutrient-----

A: (Input = Output) → sustainable system  
→ balanced system

B: (Input > Output) → soil fertility increase  
→ imbalanced system

C: (Input < Output) → nutrient depletion  
→ imbalanced system

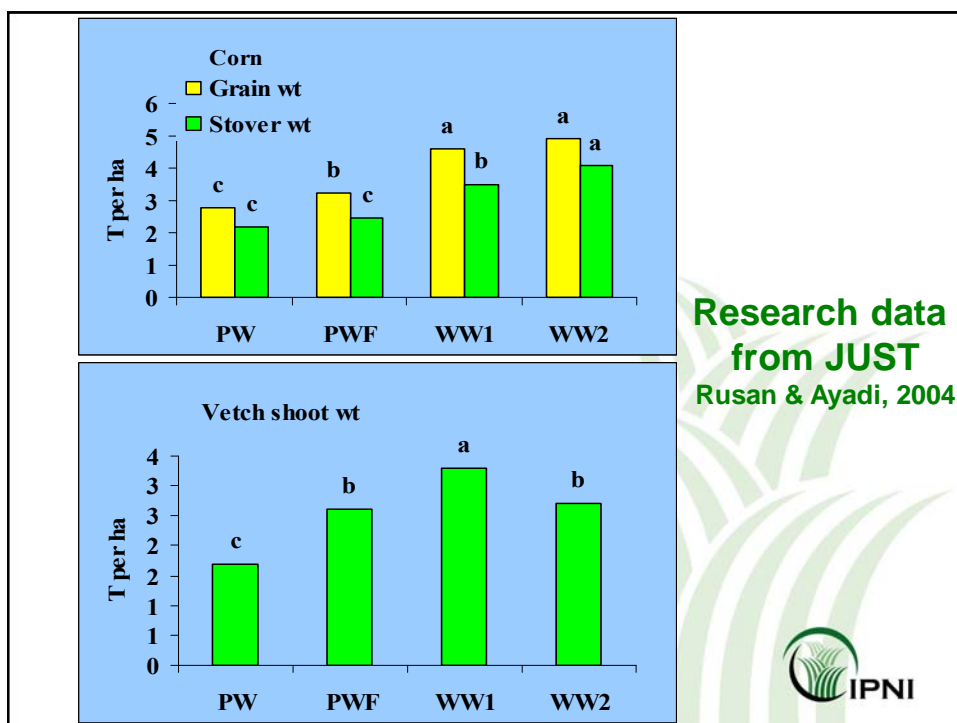
B + C →→→→→→→→→→ Soil degradation

So, with TWW & other organic sources of nutrients, we can't control inputs and outputs, but this can be achieved only with mineral fertilizer & using organic sources as supplements



**Can we produce forage crops with acceptable quality  
using TWW as a source of water and nutrients ?**





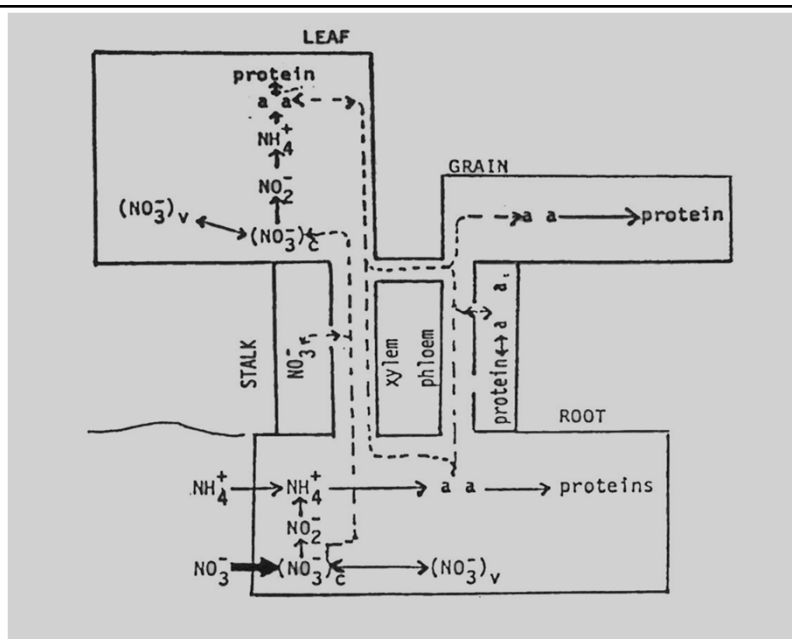
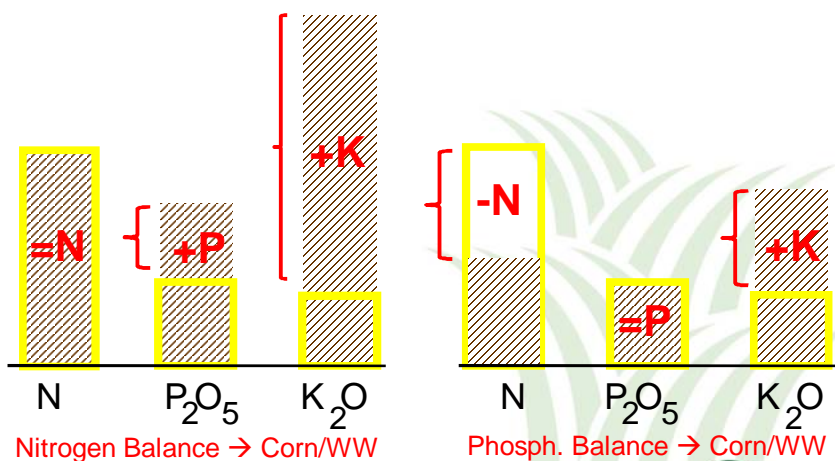
**Plant Nutrients Uptake (kg/ha), Rusan & Ayadi, 2004**  
(PW=potable water; PWF=PW+fertilizer; WW1 and WW2 rates of wastewater application)

TRTs	PW	PWF	WW1	WW2	
<b>Corn:</b>					<b>Nutrient Balance</b>
N: Stover	19.8 c	20.2 c	35.30 b	46.1 a	+250 kg N with WW
Grain	41.9 b	43.3 b	69.30 a	76.9 a	- 123 kg N crop uptake
					127 kg accumulation
P: Stover	3.30 b	4.92 b	10.85 a	14.3 a	+150 kg P <sub>2</sub> O <sub>5</sub>
Grain	6.07 b	6.10 b	14.23 a	15.7 a	- 30 kg P <sub>2</sub> O <sub>5</sub>
					120 kg accumulation
K: Stover	25.5 b	30.0 b	110.9 a	123.8 a	+175 kg K <sub>2</sub> O
Grain	5.0 b	6.1 b	11.9 a	15.2 a	- 139 kg K <sub>2</sub> O
					36 kg accumulation

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## Crop Nutrient Imbalances

Mismatch between WW nutrients and crop requirements



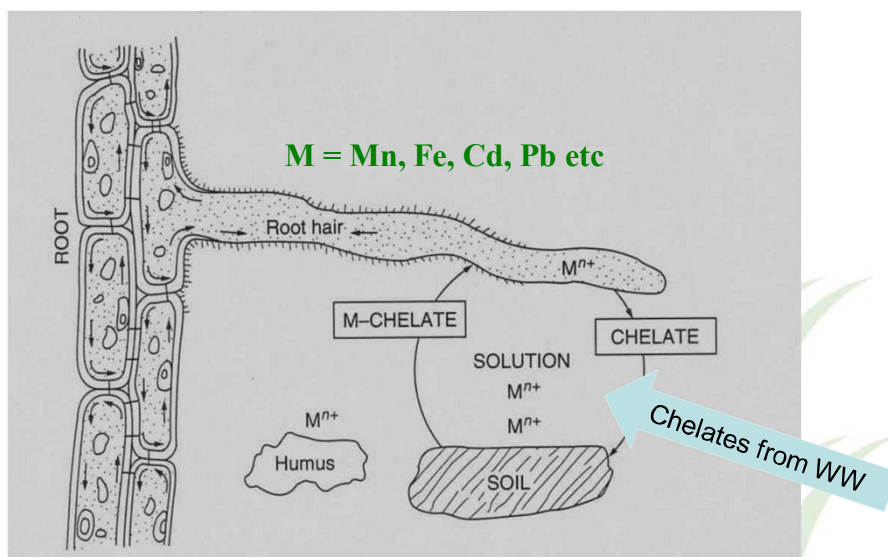
Besides, WW can provide plants with high conc. of  $\text{NH}_4$  and/or  $\text{NO}_3$  especially at later stages when rate uptake is more than assimilation rate, which reduces the forage quality

### Micronutrient uptake ( $\text{g ha}^{-1}$ ) by corn, Rusan et al., 2004

(PW=potable water; PWF=PW+fertilizer; WW1 and WW2 rates of wastewater application)

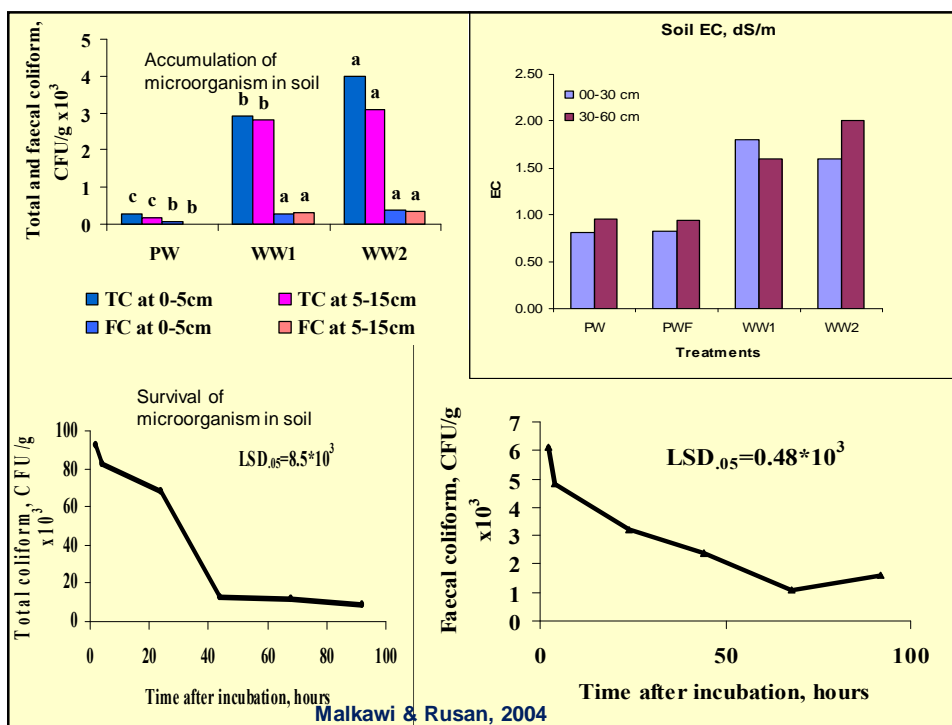
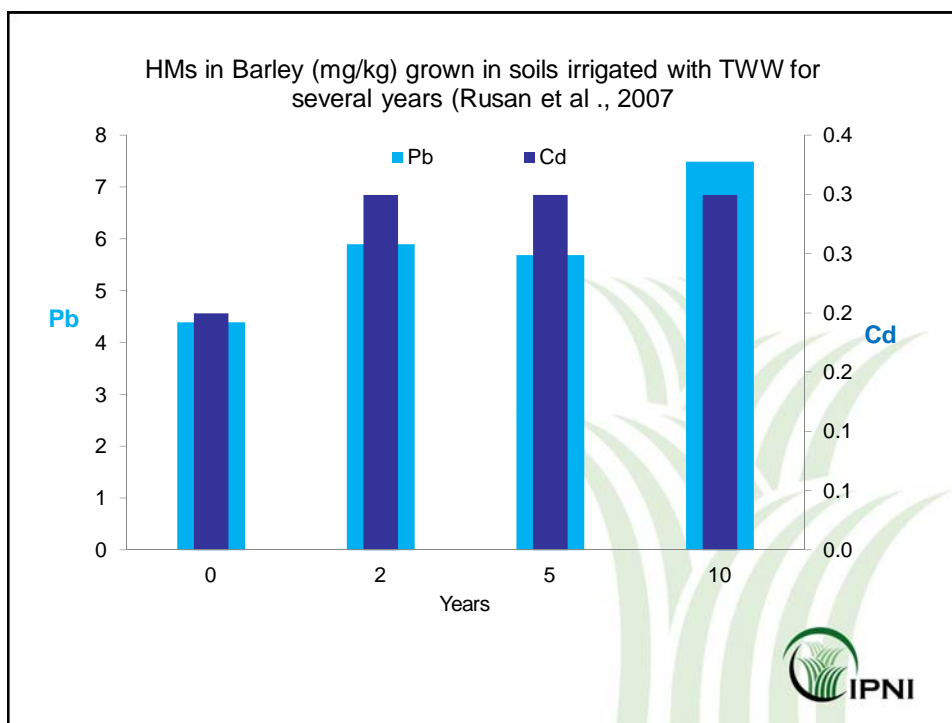
	Treatments			
	PW	PWF	WW1	WW2
<b>Fe: Stover</b>	386 b	470 b	1009 a	1081 a
<b>Grain</b>	136 b	156 b	245 a	254 a
<b>Mn: Stover</b>	259.1 b	283.1 b	422.2 a	451.5 a
<b>Grain</b>	18.18 b	18.29 b	32.82 a	35.70 a
<b>Zn: Stover</b>	211.1 b	250.3 b	329.4 a	324.3 a
<b>Grain</b>	67.58 b	73.17 b	99.70 a	110.0 a
<b>Cu: Stover</b>	21.32 b	25.27 b	31.11 a	31.48 a
<b>Grain</b>	24.32 b	27.17 b	38.32 a	40.74 a

**What is the source of the micronutrients/HMs ?  
Is it the SOIL or WW ?**



**Possible WW Effect on Bioavailability**





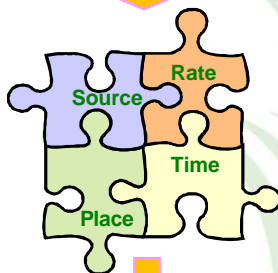


**How TWW irrigation can be managed sustainably and to produce good quality feed ?**

**Answer : TWW-Best Management Practices (BMPs)**



The foundation of this BMPs is the "4R Nutrient Stewardship" that is to apply the right source, right rate, right time, and right place of nutrient application to assure of the sustainability and efficiency of the system



**Sustainable and Efficient System**



## Right Source

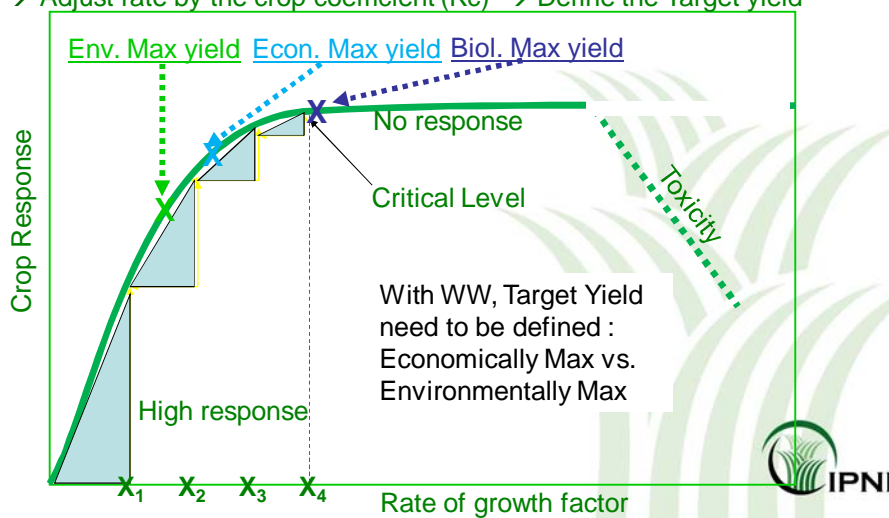
- WW composition greatly varies
- WW must be treated
- WW should contain no toxic substances
- WW should supply nutrient in available forms
- WW should suit soil physical and chemical properties



## Right Rate

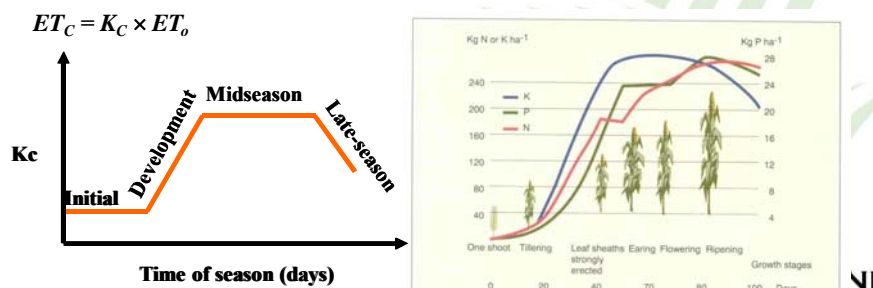
To define the right rate, one needs to assess:

- Water requirement → Plant nutrient demand → WW nutrient content ratio
- IW requirement & Irrigation frequency → Consider the EC of WW and LF
- Adjust rate by the crop coefficient (Kc) → Define the Target yield



## Right Time

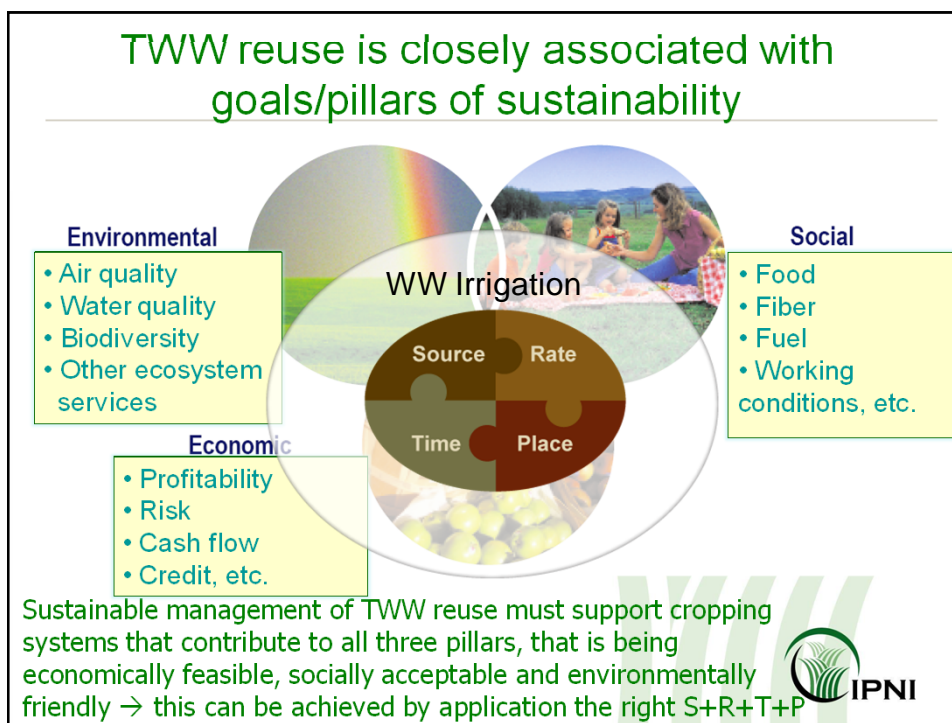
- Match timing of crop uptake
- Assess dynamics of soil nutrient supply
- Consider nutrient mobility in the soil and plant
- Consider possible accumulation of certain nutrients in products
- Frequency of WW irrigation
- Consider  $K_c$  of each growing stage :



## Right Place

- Recognize root-soil dynamics.
- Limit potential off-field transport of nutrients
- Method of irrigation (sprinkler is not allowed)
- Soil physical and chemical conditions:
  - Texture, Structure, Soil Cracking CEC, Slope, distance from Urban .. etc





## Conclusions

- TWW can be used as source of water and nutrients
  - TWW irrigation should be managed based on nutrient content
  - Nutrients management affects feed quantity&quality & animal health
  - TWW irrigation may lead to nutrient imbalance in soil-plant system
  - Nutrient supply & nutrient balance can be controlled more with mineral fertilizers not with TWW or other organic sources
  - The 4R Nutrient Stewardship concept in TWW management assures the successful & sustainable TWW irrigation management
- IPNI**





# *India's Struggle for Food Security & Efforts for Sustainable Fertilizer Usage*

**Dr. MP Sukumaran Nair**  
 Director

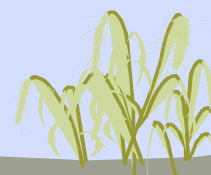
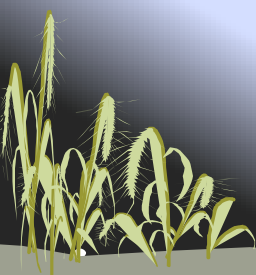
**Center for Green Technology & Management , India**

**Feb. 26 – 28, 2013**

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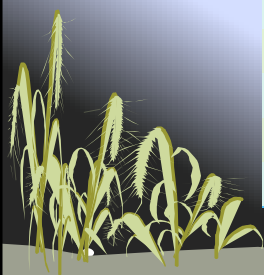
# India's struggle for food security and efforts for sustainable fertilizer usage

Dr MP Sukumaran Nair  
Centre for Green Technology & Management, India

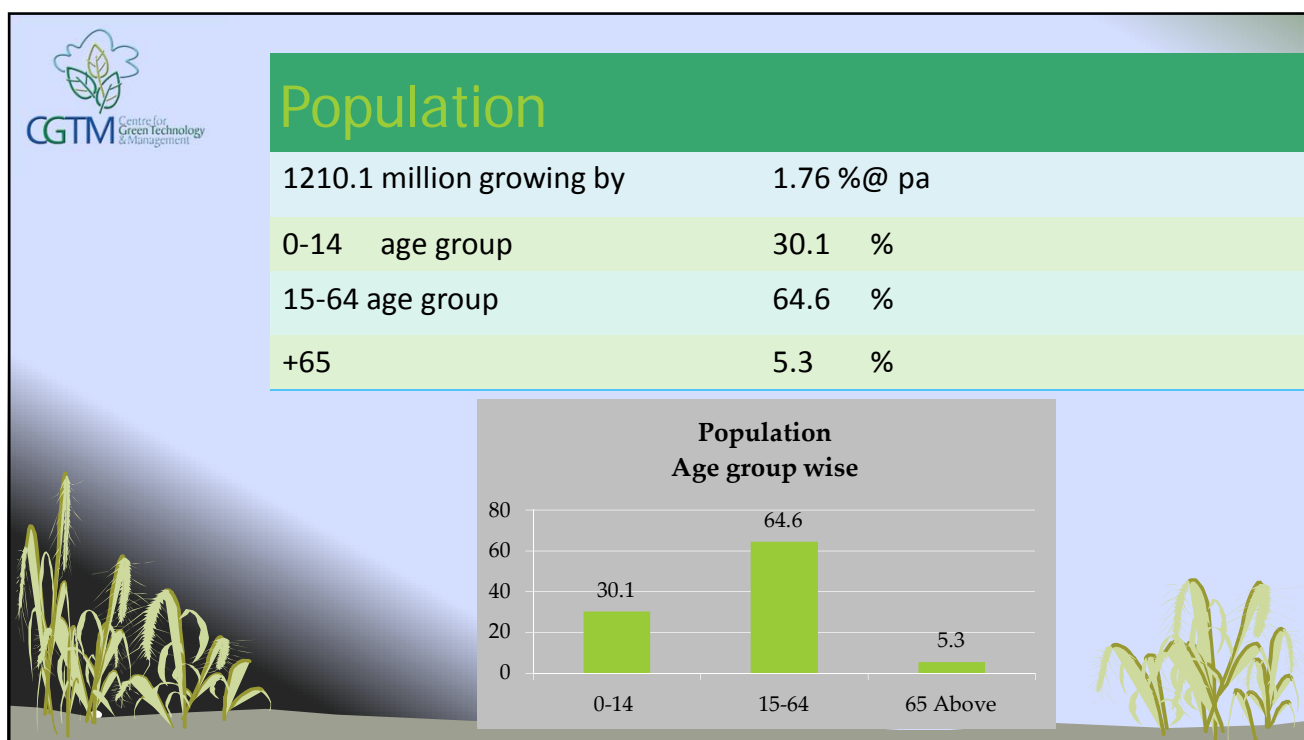
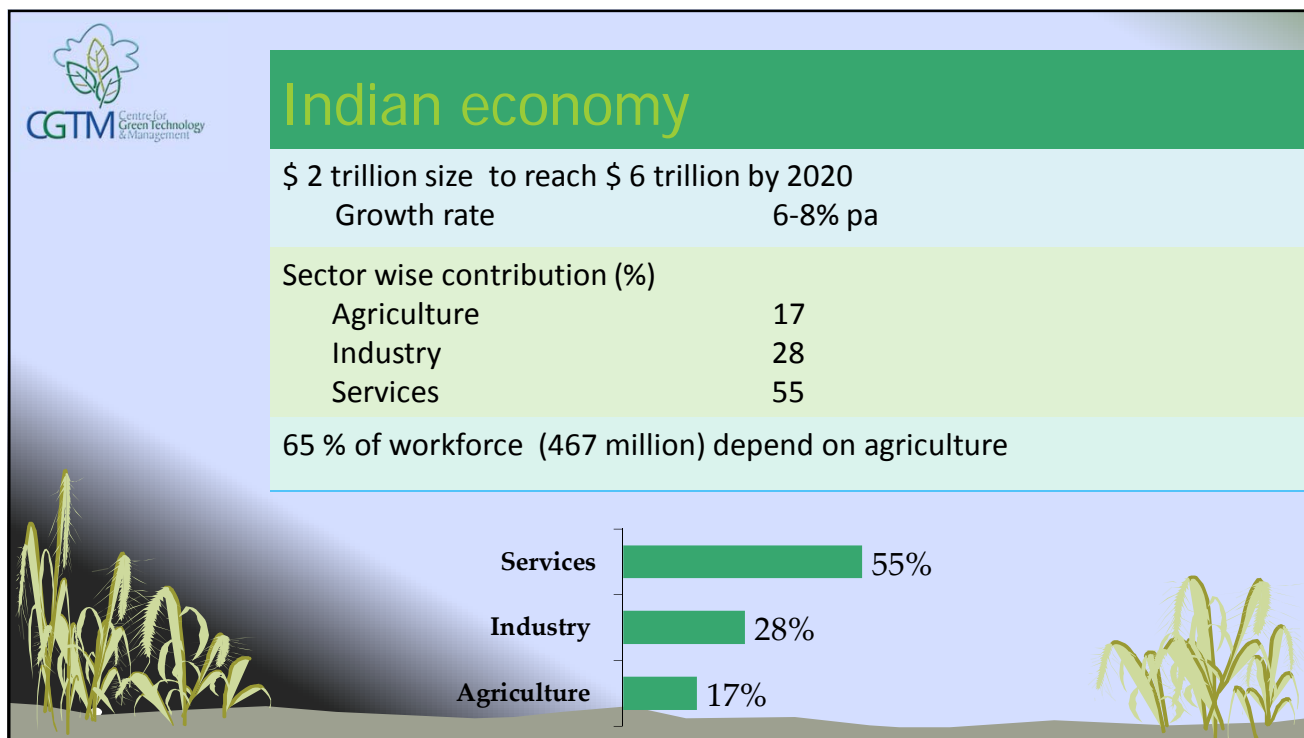


## Agenda

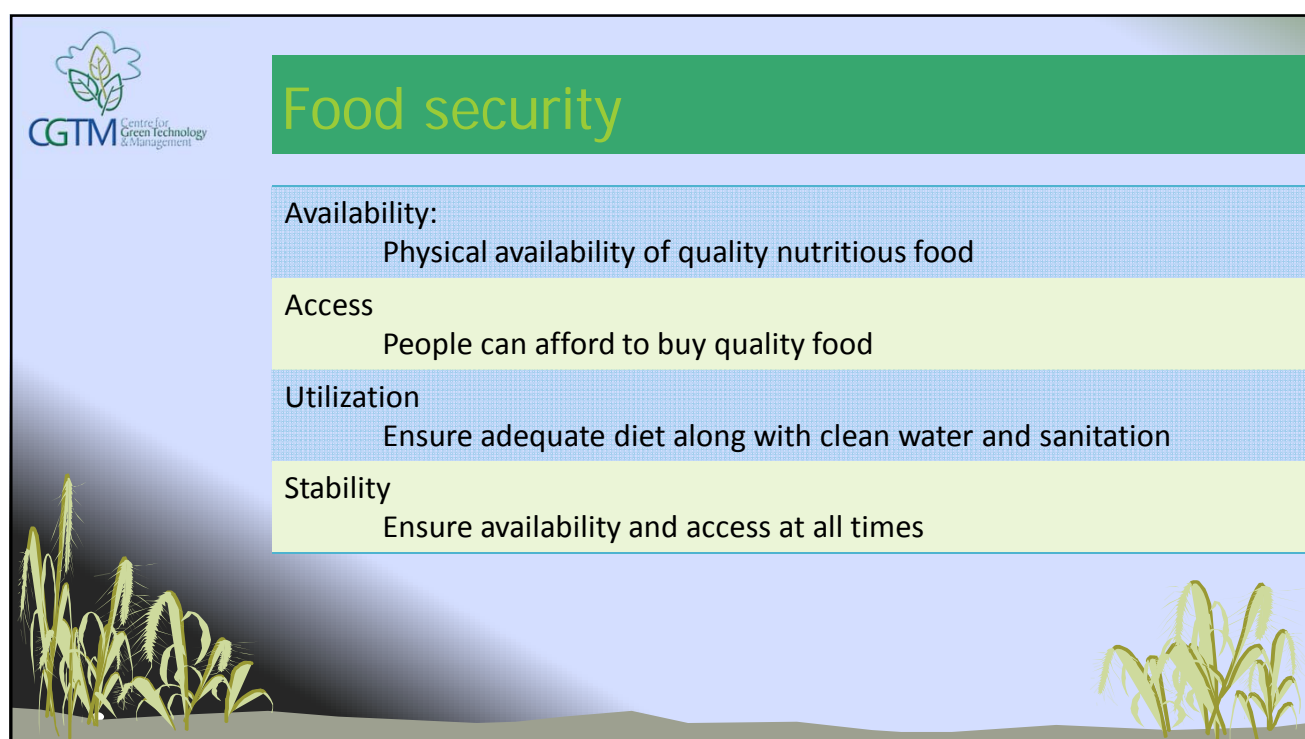
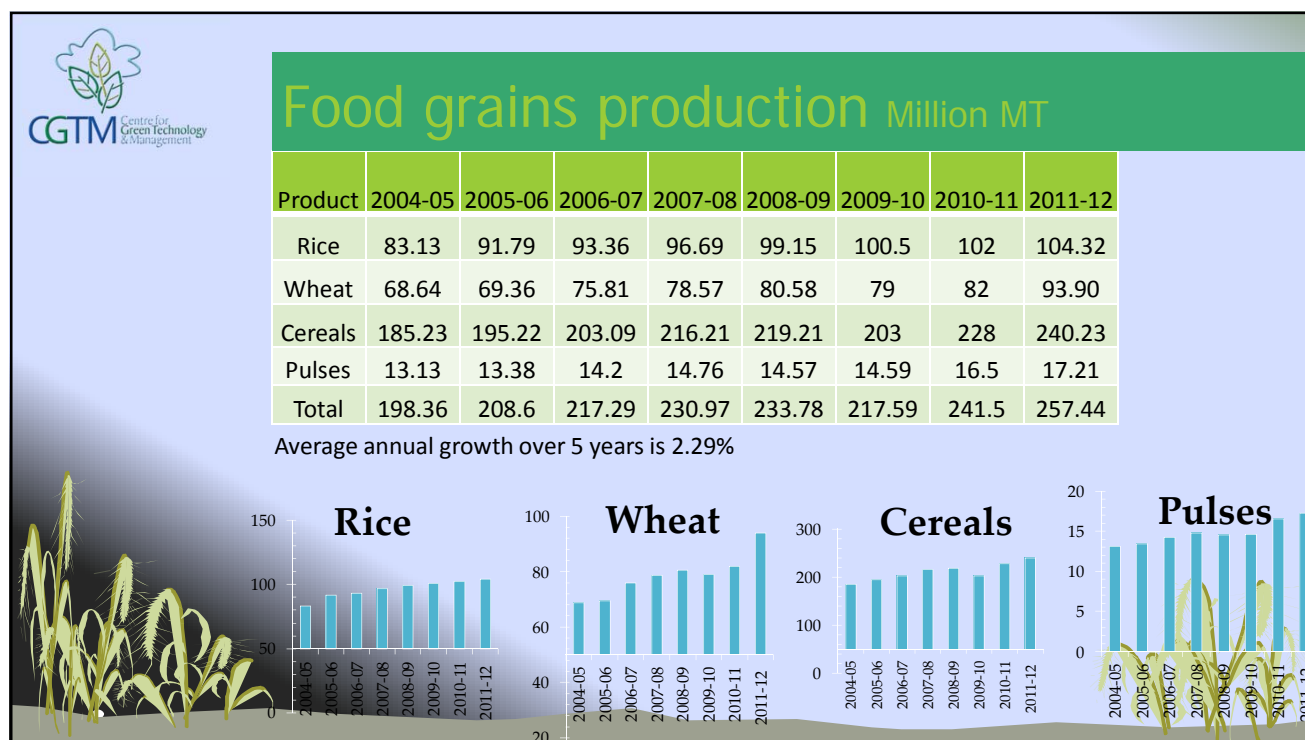
- India's economy- an overview
- Agriculture development
- Food grain production & demand
- Food security
- Fertilizer situation
- Agriculture & Fertilizer issues and concerns
- Farm Productivity
- Nutrient Based Pricing Scheme
- Subsidy administration
- Investment climate
- Way forward













## Food Security Bill 2012

Despite high growth in the last decade, India's social indicators still remain poor.

IFPRI's Global Hunger Report-2011 ranks India at 67<sup>th</sup> place in a ranking of 81 countries.

The National Food Security Bill (NFSB) aims to address these challenges of food security and undernourishment of Indian public and provide basic food to majority of the population.



## Features of Bill

It seeks to cover about 67.5% of India's 1.2 billion people, expanding an existing food subsidy scheme that covers about 180 million of India's poorest people who receive about 4 million tonnes of grain every month through licensed "fair price shops".

Nearly 75% of the rural population, or 630 million people, and 50% of urban people, or 180 million people, will be eligible to receive grains at cheaper rates.

The bill identifies 46% of the rural beneficiaries and 28% of urban beneficiaries as "priority" households

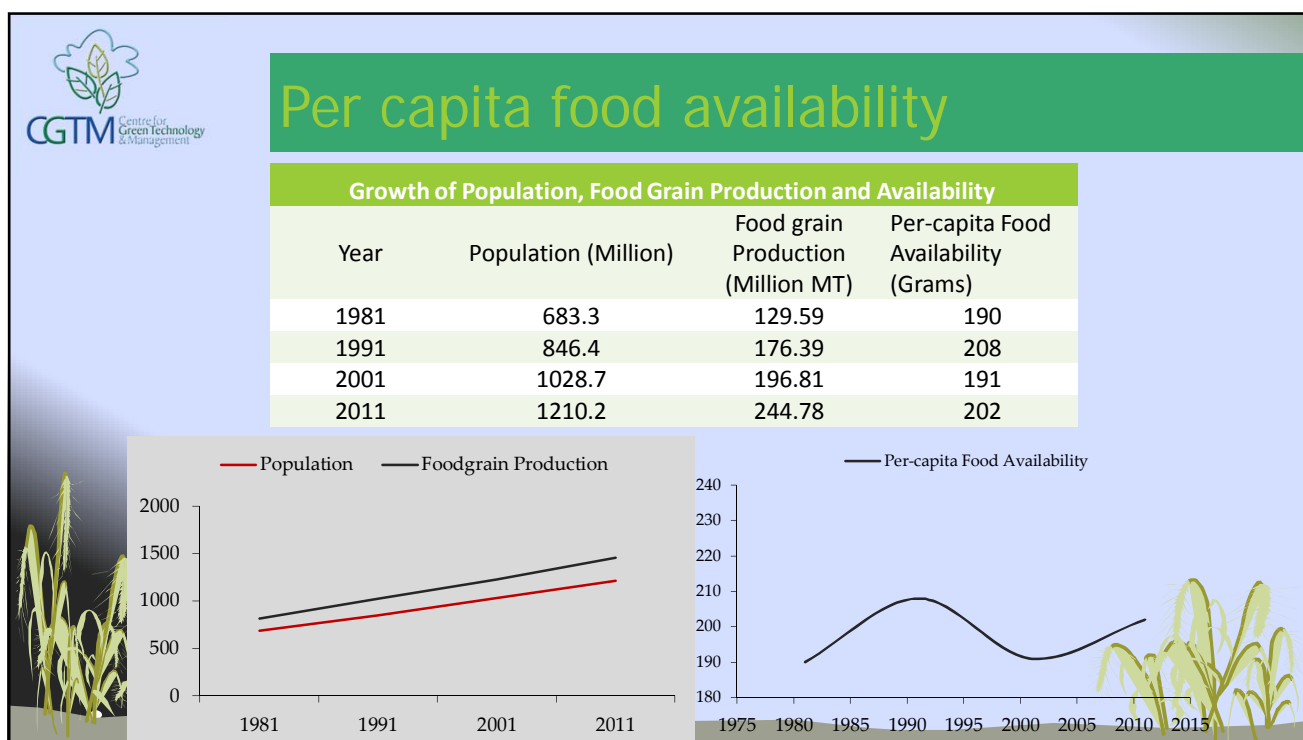
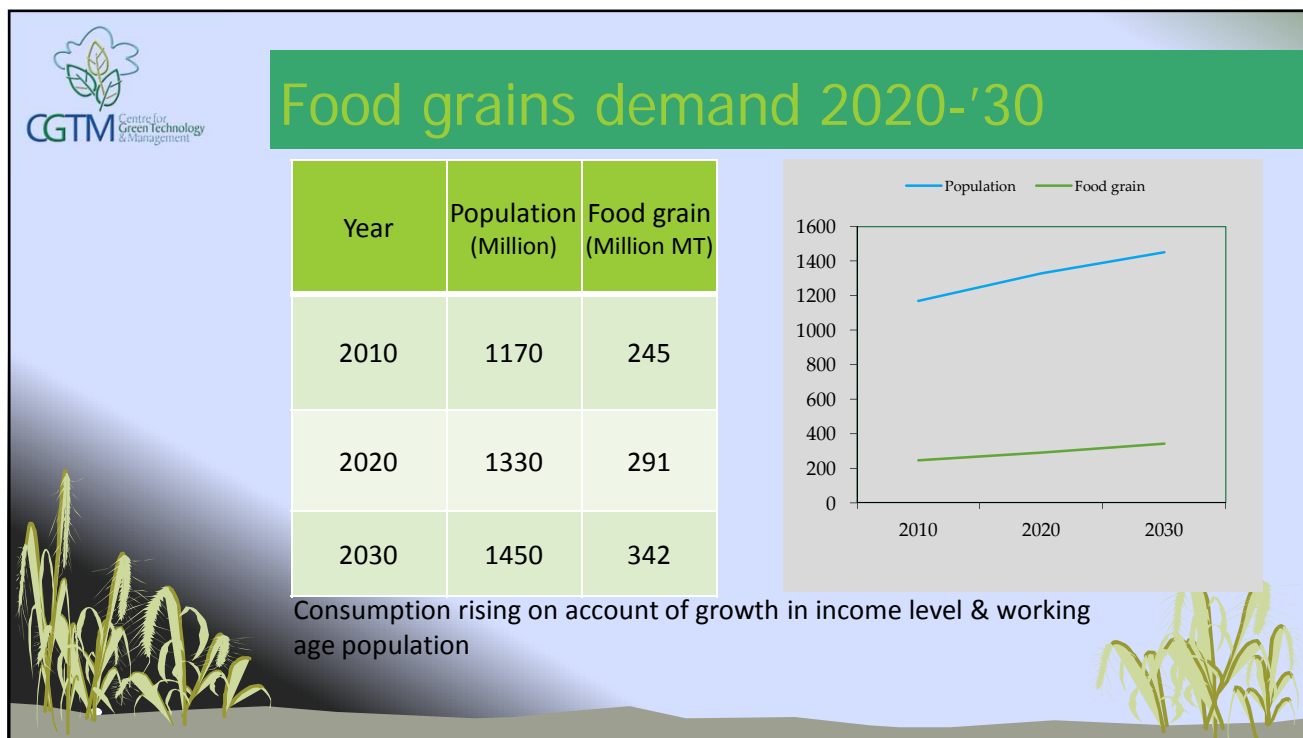
The "priority" group will get 7 kg grain per month per person rice at a fixed 3 rupees a kg, wheat at 2 rupees a kg and coarse grain at 1 rupee a kg.


The general category, both in rural and urban areas, will get grains 3 kg per person per month at half the procurement price to farmers.

Govt of India estimate

The annual requirement for rice and wheat under the proposed act will be at least 61 million tonnes.

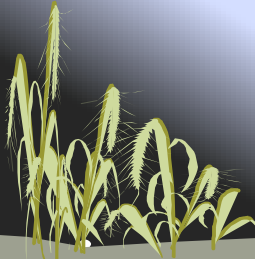

Total bill for grain supply: around 20-30 billion \$ (including states' share)





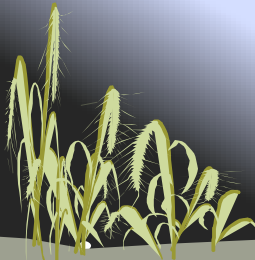
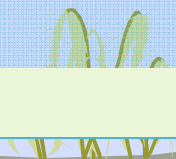
## Increasing food production-GoI efforts


- National Food Security Mission
  - Outlay 1 Billion \$ for XI plan
  - Increase production of Rice-10 MMT and Wheat by 8 MMT by 2011-12
- National Agricultural Development Programme
  - Outlay 5 Billion \$ for holistic development of Agricultural sector
- Mission mode approach for
  - Horticulture
  - Cotton
  - Oil seeds
  - Pulses
- Increase in MSP in Government procurement
- Irrigation for additional 10 MM Hectares
- Infrastructure improvements for
  - Soil testing
  - Fertilizer testing
  - Marketing
  - Food Processing

## Fertilizer related challenges Indian agriculture

- Declining productivity
- Imbalance in nutrient use
- Disparity in nutrient pricing
- Micro nutrient deficiency
- Part implementation of NBS
- Subsidy pay out to farmers directly
- Investment policy
- Natural gas availability



## Production and wastage of food

Food production is limited by

- Natural resources –fertile land, fresh water
- Eco-system services- nutrient recycling, soil, stability, pollinators

Ecological foundation of food production system under threat


- Pressure on water, soil, biodiversity, energy intensity
- Contamination of ground water, surface water, GHG emissions

Restore environmental sustainability of agriculture, conserve food & reduce wastage

Near to 2 million tonnes of food produced runs to waste  
IMEchE, United Kingdom Report 2013

Harvest handling, transport, storage, distribution

More investments in agriculture

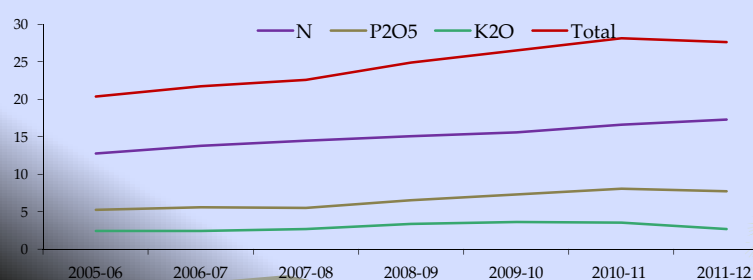


## Nutrient consumption (Kg/Ha)

Country	N+P+K
India	156.1
Pakistan	204.9
Bangladesh	188.3
China	396.0
Korean Republic	284.0
Egypt	375.0
Sri Lanka	122.1
Indonesia	101.0
U.S.A	114.0
World Average	107.0

## Fertilizer usage Million MT

Nutrient	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
N	12.72	13.77	14.42	15.09	15.58	16.56	17.31
P <sub>2</sub> O <sub>5</sub>	5.2	5.54	5.51	6.51	7.27	8.05	7.66
K <sub>2</sub> O	2.41	2.43	2.64	3.31	3.63	3.51	2.66
Total	20.33	21.74	22.57	24.91	26.48	28.12	27.63
Kg/hectare	106	112	115	127	135	144	145

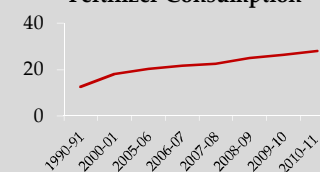


## Fertilizer use efficiency

Year	Fertilizer Consumption		Food grain Production	
	MMT	growth rate %	MMT	growth rate %
1990-91	12.5	8.5	176.4	3.1
2000-01	18.1	4.1	209.8	1.9
2005-06	20.3	10.6	208.6	5.2
2006-07	21.6	4.4	230.7	1.6
2007-08	22.6	4.4	230.7	6.2
2008-09	24.9	10.4	234.5	1.6
2009-10	26.3	5.6	218.2	6.7
2010-11	28.1	6.8	241.5	9.6

Declining productivity of soil Imbalance in nutrient distribution

Fertilizer Consumption



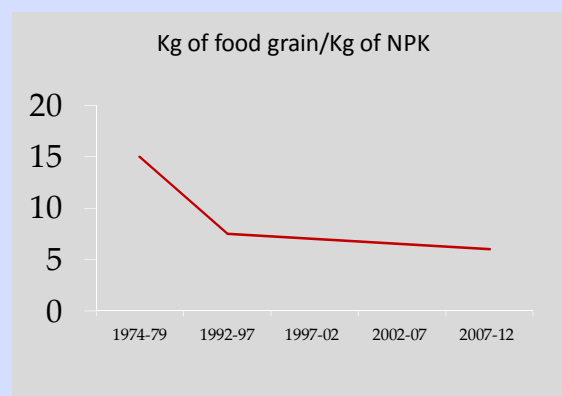
Food grain Production





## Crop response to fertilizer

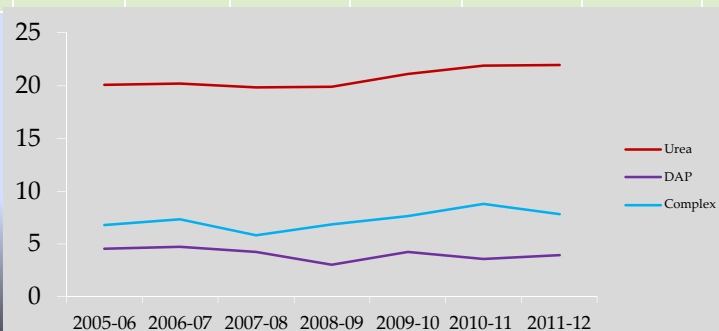
Year	Kg of food grain/Kg of NPK
1974-'79	15
1992-'97	7.5
1997-'02	7
2002-'07	6.5
2007-'12	6

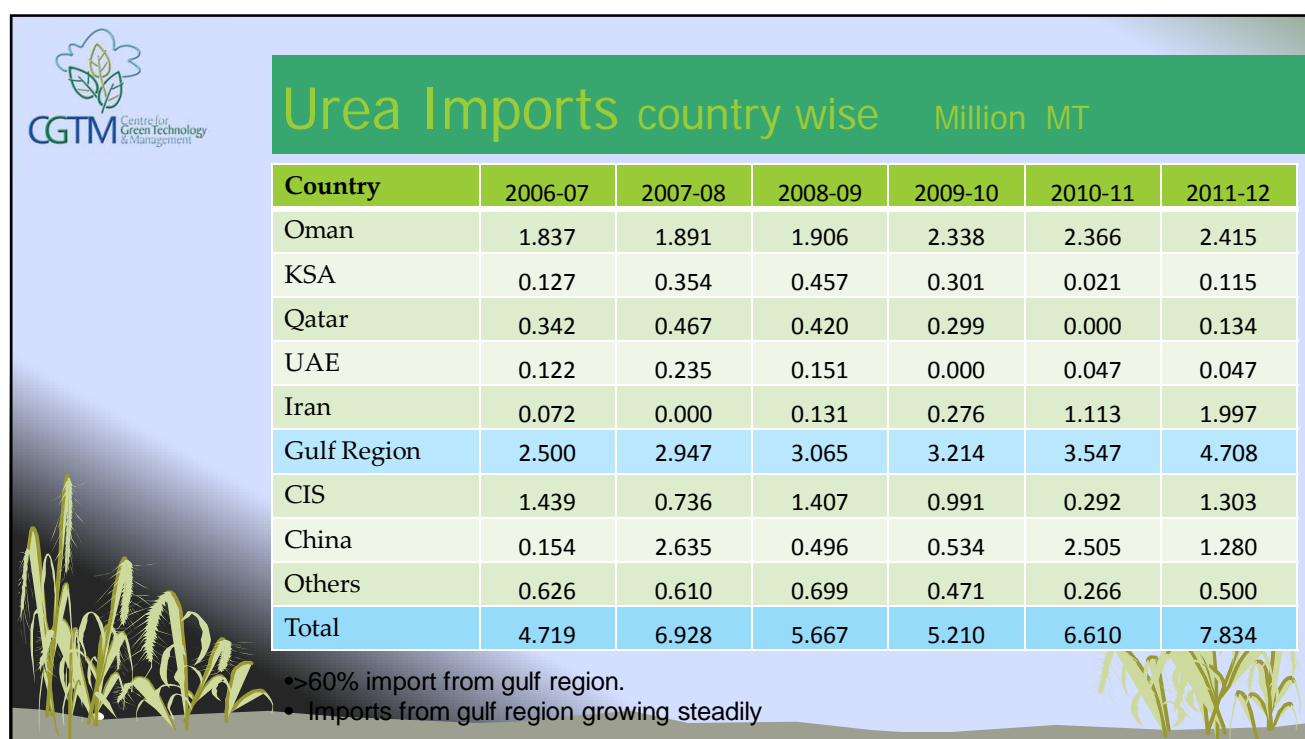
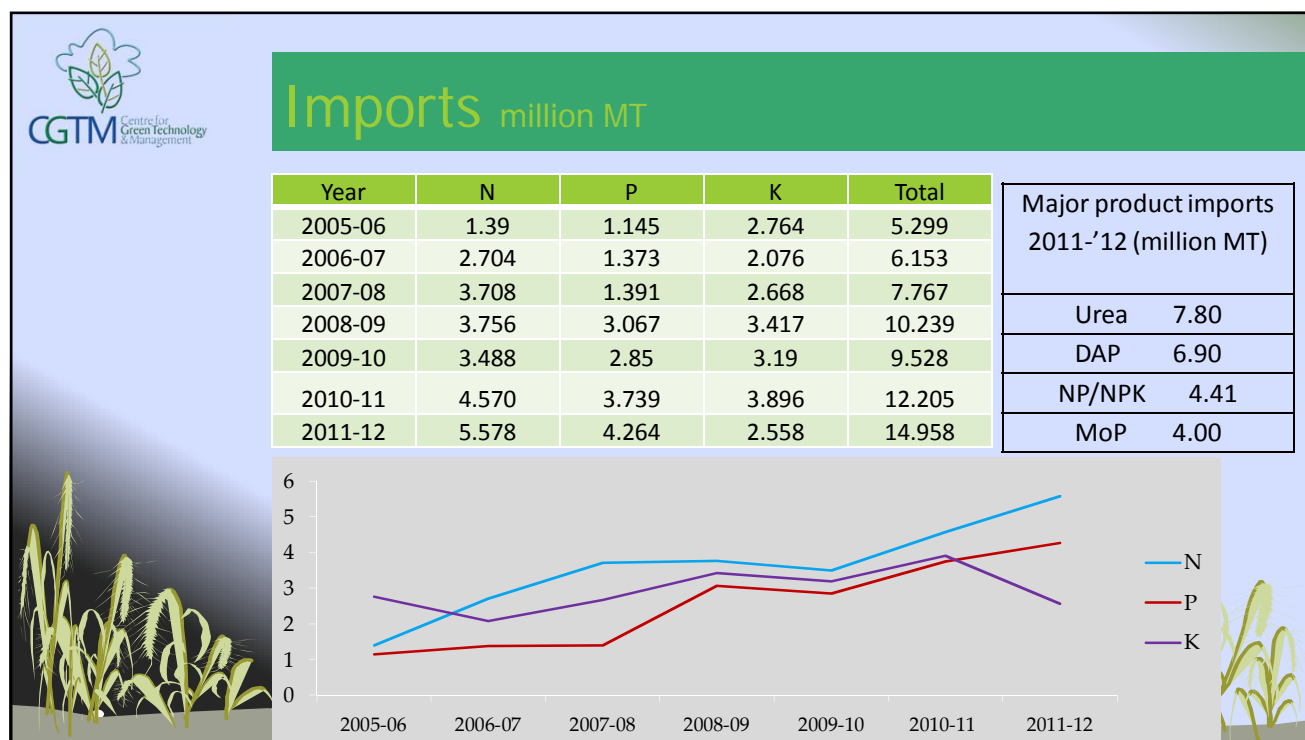


Fast declining productivity !

## Fertilizer Industry : Production Million MT

Product	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Urea	20.09	20.22	19.84	19.92	21.12	21.87	21.99
DAP	4.55	4.71	4.21	3	4.25	3.54	3.95
Complex	6.77	7.31	5.83	6.86	7.61	8.77	7.80







## DAP Imports country wise Million MT

Country	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Jordan	0.374	0.466	0.675	0.535	0.606	0.458
Morocco	0.000	0.000	0.000	0.238	0.345	0.609
USA	1.960	1.822	1.902	3.020	2.430	2.060
CIS	0.471	0.088	1.238	1.362	0.950	0.619
China	0.000	0.271	0.400	0.460	2.525	2.427
Others	0.070	0.077	1.977	0.274	0.555	0.732
Total	2.875	2.724	6.192	5.889	7.411	6.905

## Fertilizer developments since 1978

1960s Food Shortages

1970s Grow more Food campaign

1978- Retention Pricing Scheme

1992- Decontrol of P&K fertilizers

2005- Balanced use of fertilizers

2007- New Pricing Scheme (NPS) for Urea

2008- Customized/fortified products

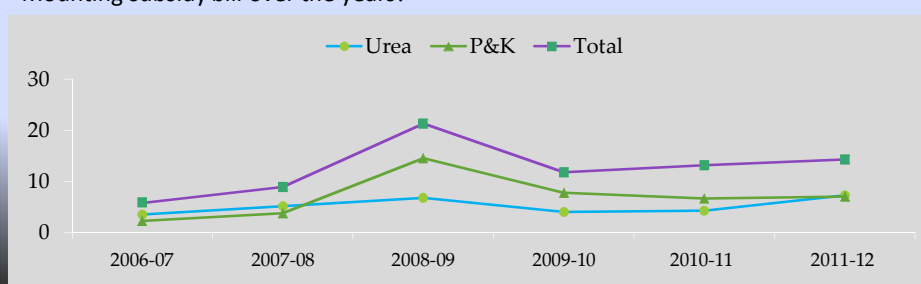
2010- Nutrient based Pricing (NBS) for P & K

New investment policy for Urea

## Fertilizer Subsidy Billion \$

Product	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Urea	3.539	5.124	6.777	4.001	4.30	7.26
P&K	2.288	3.763	14.522	7.767	6.70	7.00
Total	5.827	8.887	21.299	11.768	13.17	14.26

Mounting subsidy bill over the years!

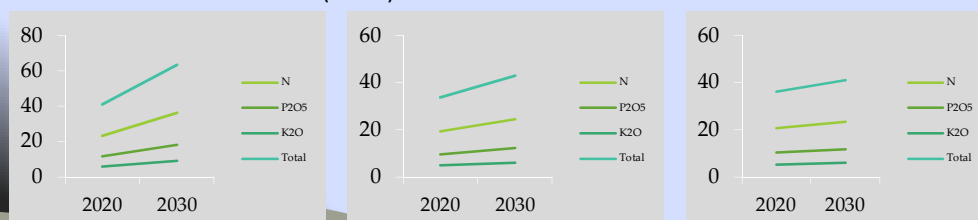


## Fertilizer Demand Million MT

Nutrient	CAGR 4.5%		CAGR 2.5%		Meeting FG demand	
	2020	2030	2020	2030	2020	2030
N	23.31	36.21	19.21	24.59	20.64	23.39
P2O5	11.65	18.11	9.61	12.29	10.32	11.69
K2O	5.83	9.05	4.8	6.15	5.16	5.89
Total	40.79	63.37	33.62	43.03	36.12	40.97

\* CAGR 4.5 % is based on trend in the last 5 years

\*\* Assume a soil nutrient (N:P:K) ratio of 4:2:1



## Addl urea capacity needed MMT

Year	2010-11	2011-12	2012-13	2013-14
N demand	15.85	16.31	16.76	17.22
N supply by Urea*	12.68	13.01	13.41	13.78
Urea requirement	27.56	28.28	29.25	29.96
Present prodn	21.25	21.25	21.25	21.25
Short supply	6.31	7.03	8	8.71
No plants** reqd	4	5	5.5	6

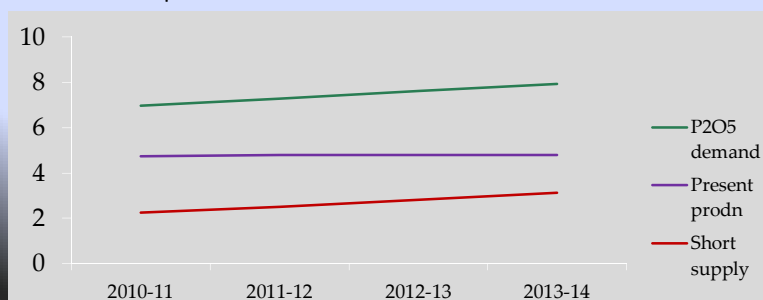
\* estimated 80% by urea


\*\* Std plant 1.5 MMTA (2500 TPD ammonia & 2X2250 TPD urea)

## Addl P2O5 capacities needed million MT

Year	2010-11	2011-12	2012-13	2013-14
P2O5 demand	6.98	7.29	7.61	7.93
Present prodn	4.73*	4.80	4.80	4.80
Short supply	2.25	2.49	2.81	3.13

\* 0.36 million MT expected from JV of TIFERT SA


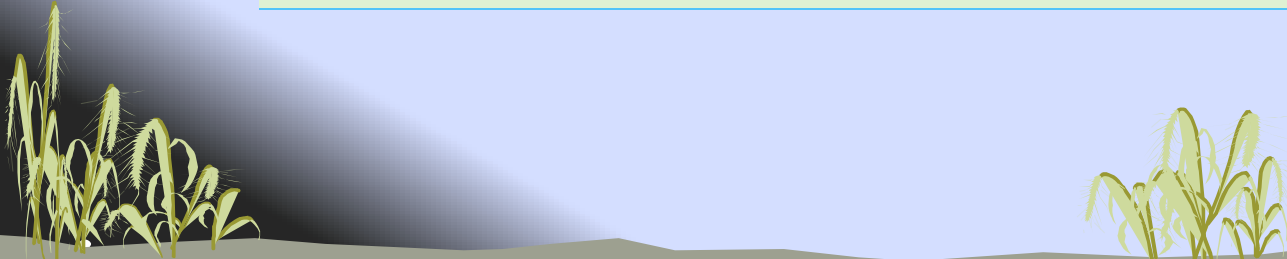




## K2O scene

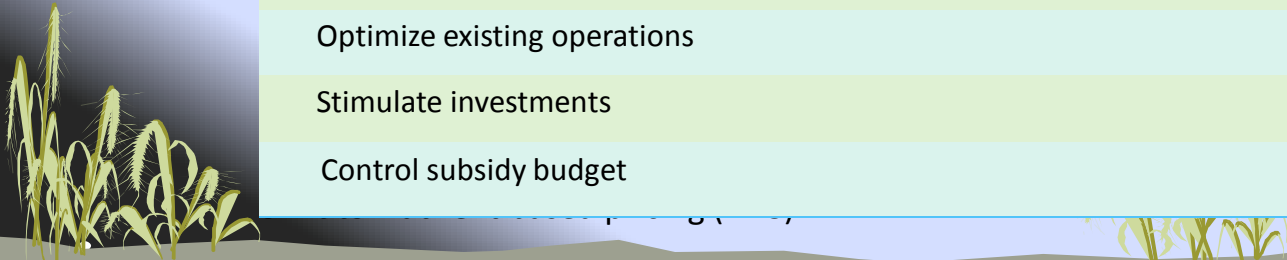
Consumption 2010-'11 (MMT)	
MoP	3.932
SoP	0.0193


No domestic resources  
Depend fully on imports



## Fertilizer pricing: new outlook

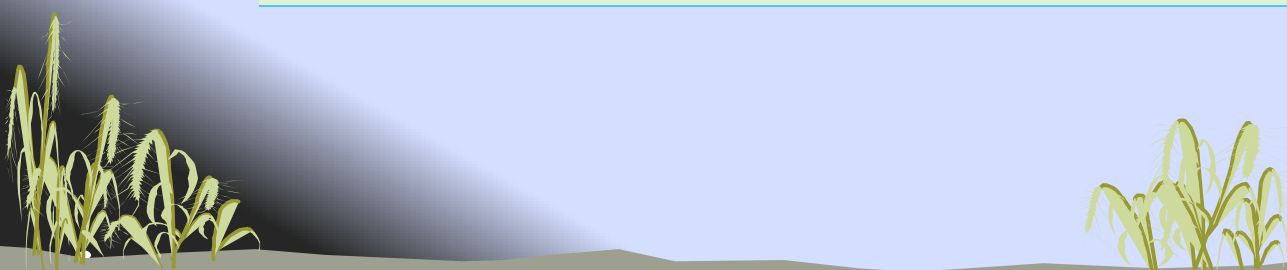

- Achieve balanced fertilizer use
- Reduce environmental burden
- Address micronutrient deficiency
- Shall overcome impediments to growth of industry
- Optimize existing operations
- Stimulate investments
- Control subsidy budget





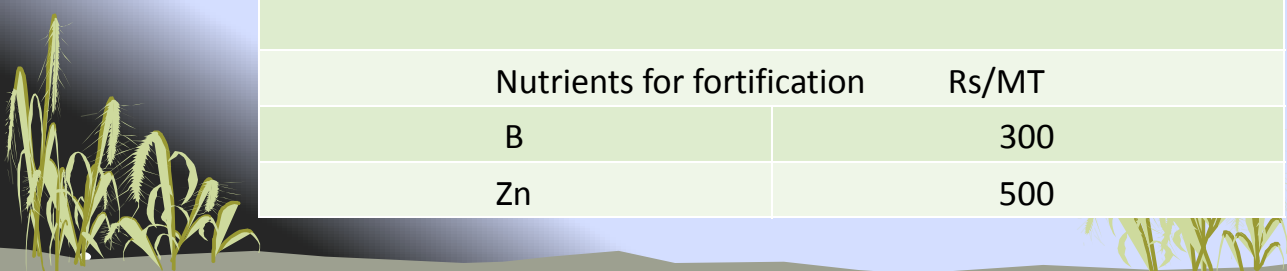
## Nutrient Based Pricing Scheme for P & K

- Per unit price of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O will be same in all complex fertilizers.
- Fixed subsidy per MT will be decided by Govt.
- Farm gate price is left open.
- Manufacturers can revise selling price depending on market situation.

## NBS rates 2012-13

Nutrient	Rs /Kg
N	24
P	21.804
K	24
S	1.677
Nutrients for fortification	Rs/MT
B	300
Zn	500





## Price rise after NBS

Since NBS open market price of  
 DAP increased by 2.5 times  
 Potash increased by 3.75 times  
 SSP doubled

May 2010	Dec. 2012 (\$/MT)
DAP 199	499
MoP 101	425



## Issues with NBS

Open market price show increasing trend.


Subsidy too low and reducing.

Farmer spending on the rise.

Deficiencies of other nutrients such as calcium, magnesium, chlorine, copper, iron, manganese and molybdenum remain unaddressed.


Nationwide soil testing facilities lacking.

Over use of low cost urea (still under APM) prevail and upset soil nutrient ratio.



## Investment climate

- Full scale NBS for all fertilizer products.
- Gas availability.
- Price stabilization mechanism for decontrolled products.
- Revamp of closed down units- coastal locations.
- Promotion of micronutrients & fortified formulations.
- Incentives for coal/petcoke/vacuum residue utilization.
- Streamlining disbursement of subsidy.



## New Urea investment policy

1. Gas price pass through of US \$ 14/mmbtu for new projects
2. Provides cost plus mechanism (minimum RoE of 12% )and upside benefit through IPP linked pricing (maximum RoE of 20%) mechanism.
3. New RLNG projects to improve domestic gas availability.



## Direct transfer of subsidy to farmers

Scheme developed by Unique Identification Authority of India (UIDAI).

Ph-I: Creation of online database of movement of fertilizer along the supply chain to retailers.

Ph-II: Subsidy transfer to retailers and later to farmers based on AAdhaar (Unique Identification Number).

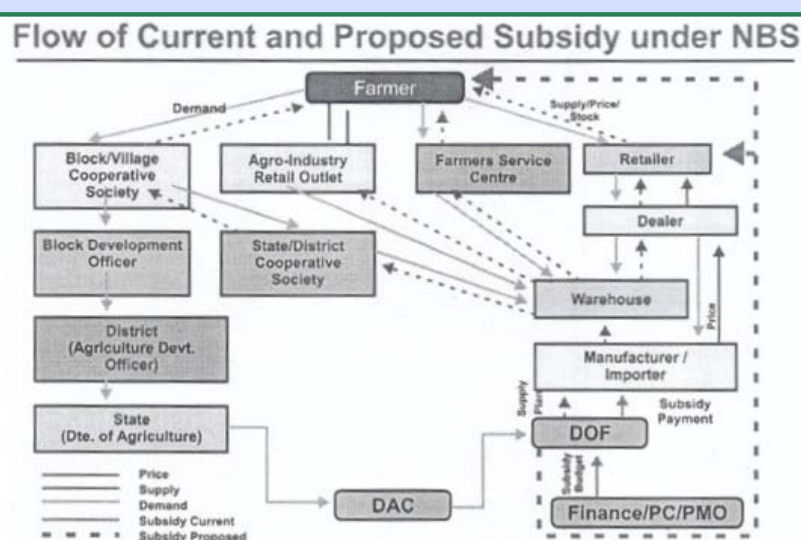
Quantum of subsidy depends on farm size, nature of crops & ceiling on quantity & subsidy amount.

Issues: retailer working capital, storage facilities, farmers credit, delay in subsidy disbursal.


Foolproof system to evolve.



## Direct administration of subsidy








## Opportunities

- Product suppliers**  
Large imports in N, P and K likely in the medium term
- Technology providers**  
Cost effective & environment friendly technologies for Greenfield/brown-field plants and JVs
- Retrofits/revamp of existing plants**  
Upgrading existing plants-process, equipment, catalysts
- Revival of closed plants**  
Full scale utilization of infrastructure available, natural gas connectivity and allocation
- Equipment suppliers**  
Replacement, addition etc



## Way forward

- Achieve sustainable farm productivity
- Government may increase price support to fertilizers to maintain them within the reach of farmers
- See that fertilizer consumption improves under NBS
- Establish nationwide soil analysis facility
- Educate farmers on scientific and sustainable farming practices and diligent use of mineral fertilizers
- Bring urea also under NBS



الإتحاد العربي للأسمدة  
Arab Fertilizer Association  
19<sup>th</sup> Annual AFA  
Fertilizer Forum  
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# *Increasing Salinity Tolerance of Crops through Appropriate Fertilizer Use Technologies*

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**Savoy Sharm El Sheikh Hotel**



**INCREASING SALINITY TOLERANCE  
OF CROPS THROUGH ROPER  
FETLILIZERS USE**

By

**El-Zanaty, A.A. Abou El-Nour & El-Fouly M.M.**

Fertilization Technology Dept. National Research  
Centre

## Outline

- Salinity definition and its effects
- Traditional methods in combating salinity
- New technologies used
- Quick look on halophytes
- How to manage fertilization on saline soils
- conclusions

## *Salinity*

Refers to the presence of high concentration of soluble salts in the soil moisture of the root zone

## *Effects*

These concentrations of soluble salts through their high osmotic pressures affect plant growth by restricting the uptake of water by the roots. Salinity can also affect plant growth because the high concentration of salts in the soil solution interferes with balanced absorption of essential nutritional ions by plants

### Common salt compounds

Salt compound	Cation (+)	Anion (-)
NaCl	Sodium	Chloride
Na <sub>2</sub> SO <sub>4</sub>	Sodium	Sulfate
MgSO <sub>4</sub>	Magnesium	Sulfate
NaHCO <sub>3</sub>	Sodium	Bicarbonate
CO <sub>3</sub> Na <sub>2</sub>	Sodium	Carbonate
CaSO <sub>4</sub>	Calcium	Sulfate
CaCO <sub>3</sub>	Calcium	Carbonate

Some crops are very sensitive to salt in the soil solution, while others can tolerate much higher concentration

**Electrical conductivity expected to produce a specific  
Yield reduction for field crops**

Crop	Relative yield reduction %			
	0	10	25	50
Barley	8.0	10.0	13.0	18.0
Sugar beets	7.0	8.7	11.0	15.0
Wheat	6.0	7.4	9.5	13.0
Sorghum	4.0	5.1	7.2	11.0
Soybean	5.0	5.5	6.2	7.5
Corn	1.7	2.5	3.8	5.9
Bean	1.0	1.5	2.3	3.6

Source: Cardon *et al*, 2003

**Electrical conductivity expected to produce a specific  
Yield reduction for vegetable crops**

Crop	Relative yield reduction %			
	0	10	25	50
Cucumber	2.5	3.3	4.4	6.3
spinach	2.0	3.3	5.3	8.6
cabbage	1.8	2.8	4.4	7.0
Potato	1.7	2.5	3.8	5.9
Sweet corn	1.7	2.5	3.8	5.9
lettuce	1.3	2.1	3.2	5.2
onion	1.2	1.8	2.8	4.3
Carrot	1.0	1.7	2.8	4.6

Source: Cardon *et al*, 2003

### Electrical conductivity expected to produce a specific Yield reduction for fruit crops

Crop	Electrical			
	0	10	25	50
apple	1.7	2.3	3.3	4.8
apricot	1.5	2.0	2.6	3.7
grape	1.5	2.5	4.1	6.7
peach	1.7	2.2	2.9	4.1
pear	1.7	2.3	3.3	4.8
strawberry	1.0	1.3	1.8	2.5
plum	1.5	2.1	2.9	4.3

Source: Amacher *et al.* 1997

Source:Horneck et al, 2007

### Classification of salt-affected soils

Classification	Electrical conductivity (dS/m)	Sodium adsorption ratio	Exchangeable sodium (%)
None	Below 4	Below 13	Below 15
Saline	Above 4	Below 13	Below 15
Sodic	Below 4	Above 13	Above 15
Saline-sodic	Above 4	Above 13	Above 15

Source:Horneck et al, 2007



**Plants can withstand high salinity by either salt exclusion or salt inclusion**

Salt exclusion



Excluders



Have the ability to exclude salts from the entire plant or from a certain organ



In this case



Membran selectivity favor uptake of K over Na

Salt inclusion



Salt accumulators



Able to cope with the uptake of high salt concentration through



Tolerating high levels of intercellular salts by resistant cell membrane

removal of excess salt entering the plant

In such cases high tissue Na to K is evident

## Saline soils effect on plants

- ❖ **Stunted growth**
- ❖ **Wilting**
- ❖ **Bluish-green color**
- ❖ **Necrosis of leaf tips**
- ❖ **Drought stress symptoms**

### Effect of different salinity levels (NaCl) on some growth parameters of wheat

Growth parameter	Growth stage	NaCl Concentration (ppm)				
		Control (%)	3000 (%)	6000 (%)	9000 (%)	LSD 5%
Dry weight (g/plant)	<b>Tillering</b>	0.230 (100)	0.173 (75)	0.125 (54)	0.102 (44)	0.012
	<b>Pre-heading</b>	1.040 (100)	1.014 (98)	0.885 (85)	0.574 (55)	0.072
	<b>Heading</b>	2.511 (100)	2.420 (96)	1.857 (74)	1.309 (52)	0.109
<b>No. of tillers</b>	<b>Tillering</b>	2.881 (100)	2.700 (94)	1.167 (41)	1.000 (35)	0.068

Source: Ebad *et al.*, 1992

## Solutions

To improve crop growth and production in the salt-affected soils, the excess salts must be removed from the root zone. Methods commonly used in reclamation of these soils are scraping, flushing and leaching. These methods were found to be very expensive

### Estimated water application needed to leach

% Salt reduction	Amount of water required
50 %	6 inches
80 %	12 inches
90 %	24 inches

Inch = 2.54 cm

Source: Cardon *et al*, 2003

**For example:** if soil electrical conductivity is 8 dS/m, and you want to reduce it to 4 dS/m. This represent a 50% reduction. Therefore, 6 inches of water would require

## Recently

- ❖ Attention was given to use other new technologies of combating salinity, among them using halophytes
- ❖ Another approach to minimize the harmful effect of salinity through nutrient management

- 1-The use of foliar feeding of nutrients.
- 2- Soil applied nutrients.

*Growing period, %Na in plant dries matter and NaCl uptake*

Scientific name	Common name	Growth period		Na % DM	NaCl uptake Kg/ha.
		Months	Days		
Beta vulgaris cycla	Spinach beet, chard	Oct.- May	120	6.0	389
Cynara cardunculus	Cardoon	Jan.- May	120	3.7	246
Atriplex hortensis	Orach	Jan.-April	90	3.1	204
Tetragonia tetragiodes	New Zealand Spinach	Jan.- June	150	10.8	713
Atriplex halimus	Salzmelde. (Ger)	Perennial	250	8.25	2185

Source: Final report Salt Control Project, 2003

Selecting nutrient sources that have a relatively small osmotic effect in the soil solution can help reducing salt stress

*Salt index of various fertilizer sources (Sodium nitrate =100)*

Material and analysis	Salt index	Salt index/unit of plant nutrient
<b>Nitrogen</b>		
<b>Ammonium nitrate, 34% N</b>	<b>105</b>	<b>3</b>
<b>Ammonium sulfate, 21.2% N</b>	<b>69</b>	<b>3.3</b>
<b>Calcium nitrate, 15.5% N</b>	<b>65</b>	<b>4.3</b>
<b>Sodium nitrate, 16.5% N</b>	<b>100</b>	<b>6.1</b>
<b>Urea, 46.5% N</b>	<b>75</b>	<b>1.6</b>

Source: Boman and Stover, 2012

<i>Salt index of various fertilizer sources (Sodium nitrate = 100)</i>		
Material and analysis	Salt index	Salt index/unit of plant nutrient
<b>Phosphorus</b>		
Normal super phosphate, 20% $P_2O_5$	<b>8</b>	<b>0.4</b>
Concentrated superphosphate, 45% $P_2O_5$	<b>10</b>	<b>0.2</b>
Monoammonium phosphate, 12%N, 62% $P_2O_5$	<b>30</b>	<b>0.4</b>
Dioammonium phosphate, 18%N, 46% $P_2O_5$	<b>34</b>	<b>0.5</b>
Source:Boman and Stover,2012		

<i>Salt index of various fertilizer sources (Sodium nitrate = 100)</i>		
Material and analysis	Salt index	Salt index/unit of plant nutrient
<b>Potash</b>		
Potassium chloride 60% $K_2O$	<b>116</b>	<b>1.9</b>
Potassium nitrate, 13% N, 46% $K_2O$	<b>74</b>	<b>1.2</b>
Potassium sulfate, 46% $K_2O$	<b>46</b>	<b>0.9</b>
Source:Boman and Stover,2012		

Sources of phosphorus fertilizers generally have low salt index and they usually present little problem

Salt index of both nitrogen and potassium should be considered

## Example

The solution which has the same content (8-0-8) which made from ammonium nitrate and potassium chloride showed salt index 31% greater than that made from ammonium nitrate and potassium nitrate

Effect of spraying with micronutrients on the dry weight of tomato plants grown under different level of NaCl salinity

Treatment	Dry weight (g/pot)						
	Leaves	%	Stem	%	Root	%	Root/shoot
Control	2.50	100	1.85	100	2.12	100	0.49
1000 ppm NaCl	2.13	85	2.07	112	2.14	101	0.51
2000 ppm NaCl	1.23	49	1.15	62	1.19	56	0.50
3000 ppm NaCl	1.11	44	1.31	71	1.16	55	0.48
Control + MN	2.37	95	2.26	122	2.14	101	0.46
1000 ppm NaCl + MN	2.20	88	2.17	117	2.64	125	0.66
2000 ppm NaCl + MN	2.03	81	1.63	88	1.93	91	0.53
3000 ppm NaCl + MN	2.20	88	1.92	104	2.17	102	0.53

Source: El-Fouly *et al.*, 2003



*Effect of spraying silicon solutions on yield and its component of bean grown on soil of 7.5 dS/m*

Foliar application	Straw g/plant	Root weight g/plant	Basic branch	Pods No/plant	Pods weight g/plant	Seed yield	
						g/plant	Kg/ fed.
Control	43.27	33.00	3.00	9.28	35.06	25.14	453
K-silicate	83.47	46.64	4.44	16.39	78.90	54.40	979
Mg-Silicate	79.51	45.92	4.33	14.61	70.87	47.85	861

*Source; Abou-Baker et al, 2011*

Nadia Gad and Halla Kandil, 2011 found that cobalt concentration in irrigation up to 12 ppm resulted in increasing both of Ca and Mg content of wheat shoots and roots , while both Na and Cl decreased.

On the other hand, cobalt treatments resulted in increasing macro- (N, P, K, Mg and Ca) and micronutrients (Zn, Mn and Cu) contents in wheat shoots and stimulated all growth parameters.

**Effect of *macronutrients* (compound containing 10%N+4%  $P_2O_5$  + 7%  $K_2O$  + 0.02%  $MgO$ ) foliar application under NaCl-saline water irrigation on spinach beet growth**

Treatment	Growth characteristic								
	Shoot DW (g/pot)			Root DW (g/pot)			Root/shoot ratio		
	NF	WF	Mean	NF	WF	Mean	NF	WF	Mean
Control	4.79	4.01	4.40	1.77	1.39	1.58	0.37	0.34	0.36
50 mM NaCl	3.65	3.04	3.35	1.42	1.07	1.25	0.39	0.35	0.37
100 mM NaCl	2.38	1.70	2.04	1.07	0.74	0.91	0.45	0.44	0.45
<b>Mean</b>	3.61	2.91		1.42	1.07		0.41	0.38	

Source: El-Fouly *et al*, 2004      NF= nutrient foliar      WF = water foliar

**Effect of chloride and nitrate concentrations in the nutrient solution on chloride content (% DW) in the leaves of two avocado rootstocks**

Rootstock	NO <sub>3</sub> (meq/l)	Chloride concentration (meq/l)				Average
		2	4	8	16	
<b>Mexican</b>	<b>2</b>	<b>0.68</b>	<b>1.08</b>	<b>0.88</b>	<b>1.97</b>	<b>1.15</b>
	<b>8</b>	<b>0.56</b>	<b>0.41</b>	<b>0.70</b>	<b>1.51</b>	<b>0.80</b>
	<b>16</b>	<b>0.53</b>	<b>0.53</b>	<b>0.78</b>	<b>1.11</b>	<b>0.74</b>
	<b>Average</b>	<b>0.59</b>	<b>0.68</b>	<b>0.79</b>	<b>1.54</b>	<b>0.90</b>
<b>West Indian</b>	<b>2</b>	<b>0.48</b>	<b>1.11</b>	<b>0.76</b>	<b>1.59</b>	<b>1.06</b>
	<b>8</b>	<b>0.33</b>	<b>0.61</b>	<b>0.82</b>	<b>1.42</b>	<b>0.80</b>
	<b>16</b>	<b>0.33</b>	<b>0.37</b>	<b>0.78</b>	<b>1.02</b>	<b>0.65</b>
	<b>Average</b>	<b>0.38</b>	<b>0.70</b>	<b>0.79</b>	<b>1.45</b>	<b>0.83</b>

Source: Bar *et al*, 1987

***Effect of chloride and nitrate concentration in the nutrient solution on chloride content (%DW) in roots of two avocado rootstocks.***

Rootstock	NO <sub>3</sub> (meq/l)	Chloride concentration meq/l			
		2	4	8	16
Mexican	2	1.00	1.05	0.80	1.58
	4	0.81	0.83	0.93	0.90
	8	0.83	0.58	0.71	0.76
	Average	0.88	0.82	0.82	1.08
West Indian	2	1.00	1.22	1.42	1.33
	8	1.03	1.07	1.30	1.57
	16	0.93	0.92	0.94	1.09
	Average	0.99	1.07	1.16	1.33

*Source: Bar et al., 1985*

**Fresh and dry weights of carrot as affected by NO<sub>3</sub> versus Cl nutrition**

NO <sub>3</sub> /Cl	Fresh weight		Mean	Dry weight		Mean
	KCl	CaCl <sub>2</sub>		KCl	CaCl <sub>2</sub>	
100/0	44.31	54.06	49.19	4.45	5.59	5.02
90/10	103.53	78.47	91.00	11.79	8.16	9.98
80/20	118.15	118.02	118.09	12.85	12.36	12.61
70/30	119.56	115.39	117.48	12.37	12.11	12.24
60/40	98.17	128.70	113.43	12.15	14.64	13.40
LSD 5%						
Cl source	NS			NS		
NO <sub>3</sub> /Cl	44.22			5.14		
Interaction	NS			NS		

Source: Inal *et al.*, 1998

High rates of salt can contribute to plant nutrient imbalances

For example

Na displaces K and to lesser extent Ca in the soil solution



This can leads to K and Ca deficiencies



Additional supply of these nutrients can minimize this problem

### Conclusion

1-since, the addition of nutrients as soil application may either increase or decrease crop salt-tolerance depending upon the level of salinity and extent by which the nutrient in the system is limiting, foliar feeding is recommended.

2- It is also important to apply the nutrient in the right source, method, time and quantity to elevate the hazard effect of salinity.

3- Under salinity condition, increasing the frequency of fertilization with lower rates/application is recommended to reduce concentration of fertilizer salts in the soil at any time

4- Keep soil wet to prevent increasing salinity

5- Companies should provide the market with special fertilizers to be applied in case of salt affected soils  
These fertilizers should contain cobalt, calcium, magnesium and silicon



# **INCREASING SALINITY TOLERANCE OF CROPS THROUGH PROPER FERTILIZER USE**

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## **ABSTRACT**

Salt stress is considered one of the most serious limiting factors in crop production in arid and semi-arid regions. Soil salinity in agriculture soils refers to presence of high concentration of soluble salts in the soil moisture of the root zone. These concentrations through their osmotic pressures affect plant growth and productivity by restricting the uptake of both water and nutrients by plant roots, resulting also in nutrient imbalances. To mitigate such negative effect, there are traditional methods such as soil leaching, scraping and applied chemical amendment. These methods were found to be very costly and needs time. Recently, nutrient management through fertilization has been found to counteract salinity problems of either soil or irrigation water. This paper will give highlights on such method.

## **INTRODUCTION**

Soil salinity is a major constraint limiting agricultural productivity on about 20% of the cultivated area and half of the irrigated area worldwide (Zhu, 2001; Lobell *et al.*, 2007; Haque, 2006). Soil salinity is usually expressed by electrical conductivity of a saturated paste extract (ECe), and soils with ECe more than 4 dS/m at 25°C. Salinity stress usually delays and reduces germination and emergence rates, decreases shoot growth and may finally lead to reduced yield and yield quality (Ashraf and Harris, 2004, Khorsandi and Anagholi, 2009). Plant growth under salt stress conditions is a complex mechanism and the way it is affected by the stress is not fully understood because the response of plants to excessive salinity is multifaceted and involves changes in plant's morphology, physiology and metabolism (Hilal *et al.*, 1998; Rhoades, 1993). Excess of soluble salts in root zone negatively affects plant growth and yield through osmotic effects, nutritional imbalances and specific ion toxicities (Grattan and Grieve, 1999; Munns, 2005; Tahir *et al.*, 2006). Salinity influences plant physiology by changing the water and ionic status of the cells (Sultana *et al.*, 1999; Hasegawa *et al.*, 2000). Salts present in the soil solution exert an osmotic pressure and reduce the soil water potential making water unavailable to plants (Munns *et al.*, 2006). Ionic imbalance takes place in the cells due to excessive buildup of Na<sup>+</sup> and Cl<sup>-</sup>, which affects the uptake of other mineral nutrients (Cramer and Nowak, 1992; Khan, 1998; Grattan and Grieve 1999; Lutts *et al.*, 1996). High Na<sup>+</sup> disturbs K<sup>+</sup> nutrition and inhibits activities of many enzymes (Jaleel *et al.*, 2007).

Several chemical, physical and biological approaches are used for better crop production in saline soils. To improve crop growth and production in salt affected soils, the excess salt must be removed from the root zone. Methods commonly used in reclamation such soils are scraping, flushing and leaching. These methods were found to be very expensive. Recently, attention was given to use other new technologies of combating salinity; among them managing nutrients applied to feed plants either as soil or foliar application. This review covers research work to minimize the harmful effect of salinity on plant growth and yield through proper nutrient management,

### **Classification of salt-affected soil**

Saline and sodic soils can significantly reduce the value and productivity of affected land. Soil salinity and related problems generally occur in arid or semi-arid climates where, rainfall is insufficient to leach soluble salt from the soil or where surface or internal soil drainage is restricted. Salinity problems can also occur on irrigated land, particularly when using brackish or saline water for irrigation. Ions most commonly associated with soil salinity include the anions Cl, SO<sub>4</sub>, CaCO<sub>3</sub>, HCO<sub>3</sub> and sometimes NO<sub>3</sub> and the cations Na, Ca, Mg and sometimes K. Salt affected soils are divided into three groups depending on amounts and kind of salt present (Table 1).

*Table 1 Classification of salt affected soil*

<b>Classification</b>	<b>Electrical conductivity (dS/m)</b>	<b>Sodium adsorption ratio</b>	<b>Exchangeable sodium (%)</b>
None	Below 4	Below 13	Below 15
Saline	Above 4	Below 13	Below 15
Sodic	Below 4	Above 13	Above 15
Saline-sodic	Above 4	Above 13	Above 15

*Source: Horneck et al, 2007*

### **Nutrient management to control salinity effect on plant growth and nutrient contents**

It is well known that under salt stress condition, Soils are frequently characterized by extreme ratios of Na/K, Na/Ca and Cl/NO<sub>3</sub>. That leads to plant nutrient imbalances or deficiencies (Schmidhalter, 1999). Almost, all macro- and micronutrients content decrease in the roots and shoots with increasing NaCl concentration in the growth medium. El-Fouly *et al*, 2002 found that Na uptake significantly increased with increasing NaCl in tomato growth medium (1000-3000 ppm NaCl). Also they found, all macro- and micronutrients uptake were negatively affected with increasing NaCl concentration. However, Foliar feeding with micronutrients could partially counteract the negative effect of NaCl on nutrient uptake through improving root growth.

The soil salinity as well as saline irrigation water depresses all growth parameters of the plant, especially, the more sensitive one.

### **Micronutrients Fertilizers**

Fertilizers either applied dry or as a solution influence the TDS concentration (Boman and Stover, 2012). So, it is important to select the source of applied nutrient that have a relatively small osmotic effect in the soil solution for reducing salt stress. Table 2 shows salt index of various fertilizer sources.

*Table 2 Salt index of various fertilizer sources (Sodium nitrate + 100)*

Material and analysis	Salt index	Salt index/unit of plant nutrient
<b>Nitrogen</b>		
Ammonium nitrate, 34% N	105	3
Ammonium sulfate, 21.2% N	69	3.3
Calcium nitrate, 15.5% N	65	4.3
Sodium nitrate, 16.5% N	100	6.1
Urea, 46.5% N	75	1.6
<b>Phosphorus</b>		
Normal super phosphate, 20% P <sub>2</sub> O <sub>5</sub>	8	0.4
Concentrated superphosphate, 45% P <sub>2</sub> O <sub>5</sub>	10	0.2
Monoammonium phosphate, 12% N, 62% P <sub>2</sub> O <sub>5</sub>	30	0.4
Dioammonium phosphate, 18% N, 46% P <sub>2</sub> O <sub>5</sub>	34	0.5
<b>Potash</b>		
Potassium chloride 60% K <sub>2</sub> O	116	1.9
Potassium nitrate, 13% N, 46% K <sub>2</sub> O	74	1.2
Potassium sulfate, 46% K <sub>2</sub> O	46	0.9

Source: Boman and Stover, 2012

El-Fouly *et al* 2002 found that the dry weights of different plant organs of tomato were reduced in response to increasing NaCl level in the root growth medium. However, 1000 ppm NaCl slightly decreased tomato leaves dry weight (15%), 2000 and 3000 ppm NaCl showed dramatically depression in dry weight of all plant organs. They also found that spraying tomato seedlings with a chelated micronutrient compound containing 2.8% Fe + 2.8% Zn + 2.8% Mn at rate of 1.5 g/l had a positive effect in increasing the dry of different plant organs (Table 3) The same trend was obtained by Salama *et al*, 2004 (Table 4) and El-Fouly *et al*, 2011 on wheat .

*Table 3 Effect of spraying with micronutrients on the dry weight of tomato plants grown under different levels of NaCl salinity.*

Treatment	Dry weight (g/pot)					
	Leaves	%	Stem	%	Root	%
control	2.5	100	1.85	100	2.12	100
1000 ppm NaCl	2.13	85	2.07	112	2.14	101
2000 ppm NaCl	1.23	49	1.15	62	1.19	56
3000 ppm NaCl	1.11	44	1.31	71	1.16	55
Control + MN	2.37	95	2.26	122	2.14	101
1000 ppm NaCl+ MN	2.20	88	2.17	117	2.64	125
2000 ppm NaCl+ MN	2.03	81	1.63	88	1.93	91
3000 ppm NaCl+ MN	2.20	88	1.92	104	2.17	102
LSD 5%	0.83		0.50		0.48	

Source: El-Fouly *et al*, 2002



*Table 4 Influence of spraying different concentration of micronutrients compound before and after salinity treatment on dry weight of wheat plants (g/pot)*

NaCl ppm	Concentration of spraying solution				
	0.00	0.10 %		0.15%	
		Before salinity	After salinity	Before salinity	After salinity
Aerial parts					
0.00	1.69 (100)	1.99 (118)	2.06 (122)	1.86 (110)	2.23 (132)
1000	1.58 (100)	1.57 (99)	1.74 (110)	1.88 (119)	1.91 (121)
2000	1.24 (100)	1.46 (118)	1.58 (127)	1.54 (124)	1.84 (148)
5000	1.10 (100)	1.41 (128)	1.35 (132)	1.45 (132)	1.72 (156)
Roots					
0.00	0.29 (100)	0.32 (110)	0.33 (114)	0.39 (135)	0.36 (124)
1000	0.29 (100)	0.30 (104)	0.31 (107)	0.33 (114)	0.27 (93)
2000	0.21 (100)	0.29 (1380)	0.28 (133)	0.30 (143)	0.24 (114)
5000	0.17 (100)	0.22 (129)	0.23 (135)	0.29 (171)	0.22 (129)

Source: El-Fouly *et al*, 2011

Zinc application has been found to improve growth in salt –stressed tomato plants (El-Shreif *et al*, 1990). Spraying maize plants with iron found to improve the nutritional status of maize seedlings grown under salinity stress (Salama *et al*, 1996).

Moreover Nadia Gad and Halla Kandil, 2011 found that cobalt concentration in irrigation up to 12 ppm resulted in increasing both of Ca and Mg content of wheat shoots and roots , while both Na and Cl decreased. On the other hand, cobalt treatments resulted in increasing macro- (N, P, K, Mg and Ca) and micronutrients (Zn, Mn and Cu) contents in wheat shoots and stimulated all growth parameters.

In spite of silicon has not been proven to be an essential element for higher plants, silicon has been shown to mitigate the adverse effects of biotic and abiotic stresses including salt stress, metal toxicity and nutrient imbalance (Ma,2004). In this connection, Abou-Baker *et al*, 2011 carried out a field experiment on saline soil of 7.5 dS/m to test the effect of different sources of silicon solutions as shown in table 5 on bean plants. Results a great significant increments in all studied parameters.

*Table 5 Effect of spraying different silicon solution on yield and its component of bean.*

Foliar application	Straw g/plant	Root weight g/plant	Basic branch	Pods No/plant	Pods weight g/plant	Seed yield	
						g/plant	Kg/ fed.
Control	43.27	33.00	3.00	9.28	35.06	25.14	453
K <sub>2</sub> SO <sub>4</sub>	83.47	46.64	4.44	16.39	78.90	54.40	979
Mg <sub>2</sub> SO <sub>4</sub>	79.51	45.92	4.33	14.61	70.87	47.85	861
KSO <sub>4</sub>	68.82	39.01	3.22	11.45	55.35	37.04	667
MgSO <sub>4</sub>	71.58	39.04	3.56	11.84	58.65	40.05	721
LSD at 5%	2.08	1.56	0.27	0.89	2.06	0.98	18

Source; Abou-Baker *et al*, 2011

## Macronutrient fertilizers:

### • Calcium

Awada *et al*, 1995 exposed seedlings of *Phaseolus vulgaris* to NaCl or Na<sub>2</sub>SO<sub>4</sub> of 0, 15, 45 and 60 mM/l combined with either 15 or 30 Mm/l of Ca SO<sub>4</sub> or CaCl<sub>2</sub>. They found that increasing Na concentration decreased dry weight, number and weight of pods and number of nodules. Also, they reported that calcium sulphate treatments ameliorated Na-induced salinity in snap bean more than did comparable CaCl<sub>2</sub> treatment. Another study conducted by Horneck *et al*, 2007 confirmed the importance of calcium in sodic soil reclamation, as it will displaced sodium and reduce the exchangeable sodium percentage (ESP) and sodium absorption ratio ( SAR). They found that calcium nitrate or calcium chloride can be used to reclaim sodic soils.

### • Nitrogen

It is also important to note that to increase plant tolerance to salinity; the source of nitrogen can play an important role. Bar *et al*, 1987 found that low nitrate concentration in the soil was followed by uptake of higher chloride quantities than those taken up when the nitrate concentration was high. This leads to conclusion that under salinity condition it is prefer to apply nitrogen in the form of nitrate to decrease chloride toxicity (tables 5 and 6).

*Table 5 Effect of chloride and nitrate concentration in the nutrient solution on chloride content (%DW) in leaves of two avocado rootstocks.*

Rootstock	NO <sub>3</sub> (meq/l)	Chloride concentration meq/l			
		2	4	8	16
Mexican	2	0.68	1.08	0.88	1.97
	4	0.56	0.41	0.70	1.51
	8	0.53	0.53	0.78	1.11
	Average	0.59	0.68	0.79	1.54
West Indian	2	0.48	1.11	0.76	1.59
	8	0.33	0.61	0.82	1.42
	16	0.33	0.37	0.78	1.02
	Average	0.38	0.70	0.79	1.45

Source: Bar *et al*, 1987

*Table 6 Effect of chloride and nitrate concentration in the nutrient solution on chloride content (%DW) in roots of two avocado rootstocks.*

Rootstock	NO <sub>3</sub> (meq/l)	Chloride concentration meq/l			
		2	4	8	16
Mexican	2	1.00	1.05	0.80	1.58
	4	0.81	0.83	0.93	0.90
	8	0.83	0.58	0.71	0.76
	Average	0.88	0.82	0.82	1.08
West Indian	2	1.00	1.22	1.42	1.33
	8	1.03	1.07	1.30	1.57
	16	0.93	0.92	0.94	1.09
	Average	0.99	1.07	1.16	1.33

Source: Bar *et al*, 1987

In this connection, El-Mutawa and El-Katony, 2001 studied the response of wheat cultivars Giza-157 and Sakha-8 grown hydroponically under greenhouse to different levels of salinity ( 0, 75 and 150 mM NaCl in the nutrient solution containing either NH<sub>4</sub> or NO<sub>3</sub> as sole nitrogen source at concentration of 12 mM. They found that growth of both cultivars particularly, Sakha-8 was better under nitrate than under ammonium nutrition. Ammonium-fed plants were poorly developed with distinctly lower root/shoot ratio (table 7). Most of studies confirmed these results

among them Kafkafi *et al*, 1982 found that an increase in Cl concentration in the nutrient solution led to reduction in NO<sub>3</sub> content of the tissue of tomato plants, while increasing of NO<sub>3</sub> in the nutrient solution from 7.5 to 20 meq/l in the absence on Cl had no effect on NO<sub>3</sub> concentration in plant tissue. Also , Imad, 2007 found that ammonium nutrition reduce the proportion of plant K and Na retained by maize roots where, ammonium nutrition retarded uptake of K and enhanced uptake of Na and vice versa in case in case of nitrate nutrition.

*Table 7 Dry weight (DW) of shoot and root of wheat under different levels of salinity with either ammonium or nitrate as sole nitrogen*

N-source	mM NaCl	Giza- 157		Sakha-8	
		Shoot DW mg/plant	Root DW mg/plant	Shoot DW mg/plant	Root DW mg/plant
NH <sub>4</sub>	0	56.5	14.0	57.0	15.6
	75	44.8	12.6	44.0	12.0
	150	45.4	12.8	44.0	12.4
NO <sub>3</sub>	0	70.0	36.4	76.2	35.7
	75	58.6	32.9	52.2	29.0
	150	50.7	28.9	52.9	30.9

Source: Al-Mutawa and EL-Katony, 2001

### Potassium Fertilizers

Recently, Shaaban and Abou El-Nour (2012) observed that despite drastic reductions in leaf N-concentrations in response to salinity, calcium nitrate increased N-concentrations in wheat shoots grown under moderate salinity of irrigation water to the normal level.

Under saline conditions, Achilea and Barak,1999 mentioned that potassium nitrate is an ideal fertilizer for save crop nutrition regime. The ratio of the two nutrients (N & K) is similar to the optimal ratio found in many crops. Furthermore, considering the positive contribution of NO<sub>3</sub> and K against the deleterious effect of Cl and Na, respectively. Achilea,2002reported that, the use of enhanced potassic plant nutrition is an efficient method of preventing sodium-induced stress in many crops, In addition, the use of enhanced nitrate fertilization is a potent tool in precluding chloride stress in many crops. He concluded that the application of Multi-K (potassium nitrate) is shown as a very sufficient method of combating the aforementioned stresses and enhancing crops performances under saline conditions.

### Phosphorus fertilizers

In some cases, salinity decreased the P concentration in plant tissue (Sharpley *et al*, 1992, Shaaban *et al*, 2010), in others salinity increased P or had no effect. This variation between studies could occur because P concentrations may vary in different experiments and other nutrient interactions. Champagnol (1979) concluded that it is unlikely that Cl<sup>-</sup> and H<sub>2</sub>PO<sub>4</sub><sup>-</sup> ions are uptake competitive. Zhukovskaya (1973) found that Cl<sup>-</sup> and sodium salts reduce P-uptake in barley and sunflower. Papadopoulos and Rendig (1983) concluded also that Cl<sup>-</sup> suppressed P uptake and accumulation in tomato.

When plants are P-deficient, they may be more sensitive to salinity. Gibson (1988) found that P-deficient wheat plants were more sensitive to salinity than those with adequate P and that deficient plants had a lower cellular tolerance for the accumulated ion.

Phosphate additions to crop plants grown under salinity stress may increase phosphorus concentrations in their tissues. Shaaban *et al* (2010) found that foliar application of sugar beet plants with potassium mono-phosphate increase P-leaf concentrations.

## Conclusion

- Science, the addition of nutrients as soil application may either increase or decrease crop salt-tolerance depending upon the level of salinity and extent by which the nutrient in the system is limiting, foliar feeding is recommended.
- It is also important to apply the nutrient in the right source, method, time and quantity to alleviate the adverse effect of salinity.

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