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FERTILIZER INTERNATIONAL
ISSUE 474
SEPTEMBER-OCTOBER 2016

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Hidden hunger

> **The deaths of 450,000 children under five are linked to zinc deficiency.**

Micronutrient deficiencies and accompanying yield losses can be simple enough to detect when crop symptoms are clearly visible – such as the yellowing of plant leaves (chlorosis), for example. Yet deficiencies can still be present, and drive down the yield and quality of farm produce, even when crops look healthy and exhibit no tell-tale signs of trace element shortfalls.

There are very real health and economic consequences to this invisible form of micronutrient deficiency. There is even a mournful name given to the malnutrition that results: **hidden hunger**. Regrettably, the evidence suggests this is a problem that is on the rise.

Although unnoticeable whilst crops are firmly rooted in the field, given time, hidden hunger may eventually manifest itself post-harvest with visible signs of deficiency emerging during distribution, storage and sale. This has economically damaging consequences for farmers, processors, distributors and retailers due to the spoilage, reduced shelf-life and higher food losses that result.

If this wasn't bad enough, hidden hunger, invisible though it is, has some highly pernicious consequences for human health, particularly for vulnerable, malnourished children. Yet, when it comes to feeding the world, the understandable priority is to produce more calories, leaving the nutritional value of food largely ignored, as *The Economist* reported in 2011:

"Nutrition has long been the Cinderella of development. Lack of calories – hunger – is the headline-grabber. But the hidden hunger of micronutrient deficiencies harms even more people and inflicts lasting damage on them and their societies. It, too, worsens as food prices rise: families switch from costly, nutrient-rich, fruit, vegetables and meat to cheaper, nutrient-poor staples."

Widespread and growing iron and zinc deficiency in humans has been detected by the World Health Organization (WHO) in recent decades. Similarly, iodine deficiency has been on the increase globally since the 1970s. Selenium deficiency also now affects large swathes of China and Africa.

Micronutrient mining is partly to blame, as some of these deficiencies are linked to the depletion associated with the 'Green Revolution' – the large increases in crop production achieved in the middle decades of the 20th Century.

Over three billion people on the planet are believed to be suffering the consequences of micronutrient deficiencies, with children being most vulnerable. Even mild cases of hidden hunger can impair mental and physical development, lower disease resistance and cause blindness and other ailments in children

A special issue of the The Lancet in 2008 helped reveal the scale of the human cost of micronutrient deficiencies. This showed that more than 450,000 children under the age of five die each year in developing countries are associated with zinc deficiency alone. So what can be done about this?

In 2008, the Copenhagen Business School gave eight Nobel Laureates an imaginary $75 billion and asked them to come up with 10 cost effective solutions to major global challenges, including malnutrition. Interestingly, one of their answers was to get extra micronutrients into crops. This is obviously a solution that the fertilizer industry can help deliver – and therefore whole-heartedly and categorically endorse.

What is striking about tackling micronutrient deficiency and its human consequences is the range of expertise that needs to brought to bear. It is an issue that involves international development, agronomy, geochemistry, soil science, medicine and economics. However, the rise of innovative, speciality fertilizers able to correct micronutrient deficiencies, effectively and economically, undoubtedly means crop nutrition has to be at the vanguard when it comes to tackling hidden hunger. ■

S. Inglesfield

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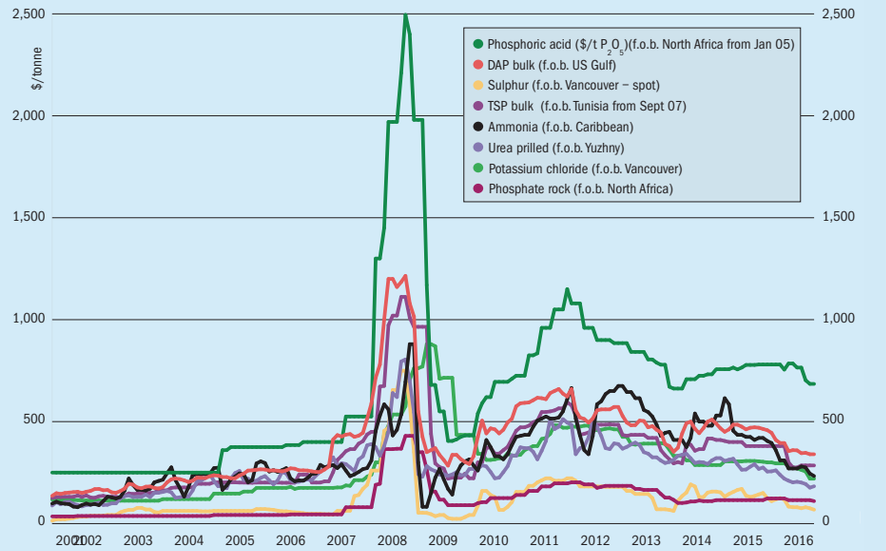
Market outlook

Historical price trends $/tonne



Source: BCInsight

Market insight courtesy of Integer Research

AMMONIA

The downward trend in the global ammonia price continued in August with the Yuzhny f.o.b. price crashing to $194/t, down by $49/t on July. Similarly, the September Tampa ammonia contract price was revised down by $30/t to $240/t cfr. The downward correction over the summer, in response to new US capacity and diminishing seasonal buying, may not be sufficient either. Market sentiment suggests September's Tampa cfr price for ammonia could drop by a further $15-20/t, reflecting the sheer weakness of the global ammonia market at present.

UREA

Global urea prices unexpectedly stabilised in most regions in August due to supply shortages. The Yuzhny f.o.b. price increased by $7/t to $183/t when OPZ shut down its two urea lines on 11 August after unplanned gas supply issues. African supply was also constrained. Indorama in Nigeria remained offline at the end of August due to unscheduled operating and loading issues, and Alexfert and Helwan in Egypt went down for maintenance on 1 August and 22 August, respectively. Chinese producers also added to the short-term supply shock by continuing to limit urea output to the global market in response to weak prices. Chinese export volumes in July (728,421 tonnes) were down by 27% year-on-year, with exports for first seven months of 2016 (5.8 million tonnes) down some 25% on last year. Its role as a swing supplier, and the fact that coal prices have begun to edge upwards over the last month, could see China continuing to limit exports. Chinese operating rates fell to just under 60% in August, down from around 70% earlier this year.

PHOSPHATES

Processed phosphate markets were subdued at the start of August with activity picking up only slightly during the month's second half. Price direction also remained mixed. Some firming was noted in North and South America and Europe, as expected, whereas prices continued to fall in East and South Asia, after an Indian tender finalised DAP awards at below $340/t cfr mid-month. This price, being associated with Chinese DAP, means f.o.b. levels in China were around $320/t. Stocks at Chinese export ports have been building at a time of dormant domestic demand. The behaviour of China over the next few weeks is therefore going to be key in determining the forward price direction for DAP. Operating rates in the country remain cut back at 50-60% overall. Ammonia and sulphur prices, meanwhile, continued to weaken, allowing producer margins to expand slightly in North America and North Africa compared to postings in July.

POTASH

The potash market has now stabilised after a period of dramatic price falls. The conclusion of 2016 contracts in China and India provided an anchor for prices in July and August. Average MOP prices in Vancouver have stayed at 228/t f.o.b. since July, while Baltic MOP prices have been $10/t lower, staying at $218/t f.o.b. in July and August. Brazil and Southeast Asia prices held at $230/t cfr for granular MOP and $240/t cfr for standard MOP.

SULPHUR

Global sulphur prices failed to stabilise in July, with the lacklustre processed phosphates market continuing to be the main bearish factor. Spot deals were scarce in August, although prices ticked up slightly in China and India. Middle East producers sought to hold prices with monthly contract postings ranging from the mid $60s/t to the low $70s/t f.o.b. Sulphur supply has remained stable so far this year, as contracts have absorbed increased output from the UAE's Shah gas project. High sulphur stocks at the nine major Chinese ports, standing at 1.8 million tonnes in Q3 2016, is another bearish factor. China sulphur imports have yet to decline this year, rising by some 12% year-on-year between January and July 2016. The main change has been higher tonnages from the UAE, although imports from Saudi Arabia, South Korea, Japan and Canada have also gained ground.

Market price summary $/tonne – Early-September 2016

Nitrogen	Ammonia	Urea	Ammonium Sulphate	Phosphates	DAP	TSP	Phosphoric Acid
f.o.b. Caribbean	200-210	n.m.	f.o.b. E. Europe 75-85	f.o.b. US Gulf	337-340	n.m.	n.m.
f.o.b. Yuzhny	185-190	192	-	f.o.b. N. Africa	338-353	270-285	530-840
f.o.b. Middle East	195-225	180-195**	-	cfr India	335-338	-	605*
Potash	KCl Standard	K_2SO_4	**Sulphuric Acid**		**Sulphur**		
f.o.b. Vancouver	190-240	-	cfr US Gulf	35-45	f.o.b. Vancouver	65-70	
f.o.b. Middle East	185-240	-			f.o.b. Arab Gulf	70-75	
f.o.b. Western Europe	-	€450-470			cfr North Africa	69-77	
f.o.b. FSU	180-235				cfr India	85-90+	

Prices are on a bulk, spot basis, unless otherwise stated. (= contract ** = granular). Phosphoric acid is in terms of $/t P_2O_5 for merchant-grade (54% P_2O_5) product. Sulphur prices are for dry material. (+ Quotes for product ex-Arab Gulf)*

MARKET DRIVERS

- **Ammonia outlook:** The global ammonia market is expected to remain bearish until the end of the year due to a combination of chronic oversupply and several further capacity additions. There is little evidence to support a price recovery over the next few months. Any seasonal upswing in demand will likely be outweighed by capacity additions in the US. Completion of capacity expansions in the US, like Dyno Nobel's site in Waggaman, Louisiana, will add to the amount of ammonia on sale. Further capacity additions are expected to be completed in Asia-Pacific and the Middle East by the end of the year.
- **Urea outlook:** Prices are expected to stabilise in September. Tight supply in August combined with scheduled seasonal maintenance work means major exporters are largely committed until mid- to end-month. In Yuzhny, OPZ remained down at the end of August with no restart date confirmed. Dnipro will also conduct maintenance work for one month beginning early September. Chinese urea producers will be focused on supplying upcoming domestic demand in mid-September. India will likely return to the market in mid to late-September which could support Arab Gulf prices. The US market will be supported by pre-river requirements until late September. The Nola urea price is likely to soften afterwards, given planned US capacity expansions.
- **Phosphates outlook:** Producers claim to be sold out into September, especially those in North America and Russia supplying improved US, Brazilian and Argentinian demand. North African producers are also said to be largely sold out. On the demand side, Pakistan and Bangladesh are active and Europe and Turkey have also been buying. Demand fundamentals remain robust, although the market remains competitive, capping major price increases. Reports of widespread flooding in India could potentially dampen forthcoming requirements there.
- **Potash outlook:** Prices have now hit a floor and it is unlikely that they will fall further in 2016. The average price achieved by K+S, PotashCorp, Agrium, Mosaic, ICL and Vale, the six key potash producers, was $202/t in January-June. This means some producers are either at or close to breakeven point currently. In August, Canpotex set its prices for new business at US$240/t cfr for standard MOP and US$260/t cfr for granular MOP for Southeast Asian customers. On demand, we anticipate increased buyer confidence for the remainder of 2016 now there is greater certainty in the market and lower reported inventories. On supply, there is likely to be a short reprieve as K+S has announced that first production from the Legacy mine is to be delayed until Q2 2017.
- **Sulphur outlook:** Sulphur prices are expected to remain stable in the short term, with potential to firm slightly into September/October. In the UAE, Adnoc posted a $7/t increase taking its September shipment price for the Indian market to $77/t f.o.b. However, a meaningful recovery in sulphur prices is unlikely to start until the processed phosphates market improves. End users in China remain comfortable with both ample stocks and local supply. Finished fertilizer stocks in India are also reportedly healthy. Demand from Sherritt's new acid plant in Cuba may provide limited support to Canadian and other producers. Morocco will also be a key hot spot in the latter part of 2016 as OCP's phosphates hub continues to ramp up. Looking ahead, new supply from Qatar, Iran and Saudi Arabia is anticipated in 2017. The Middle East will become the focus for the export market as the region is set to overtake North America as the world's top sulphur producer this year.

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CANADA

Agrium and PotashCorp in merger talks

Canadian fertilizer producers PotashCorp and Agrium have confirmed they are in preliminary talks about "a potential merger of equals."

The confirmation came in a joint statement issued on 30 August following media speculation. Both companies were keen to stress that the merger talks are at an early stage and that final agreement was far from certain.

"No decision has been made as to whether to proceed with such a combination, no agreement has been reached, and there can be no assurance that any transaction will result from these discussions," the joint statement said.

A potential marriage between the two major fertilizer players has provoked much comment and speculation within the industry and from investors. It is easy to see why. The merged company would have a combined worth of nearly $30 billion, and pairs PotashCorp, the world's largest crop nutrition company, with Agrium, North America's largest farm retailer.

Valuably, the merger would provide PotashCorp with direct access to US farmers through Agrium's retail stores, which command almost a fifth (17%) of the US market. It would also allow PotashCorp to grow without a foreign takeover, the issue that ultimately scuppered Australian miner BHP Billiton's attempted takeover of PotashCorp in 2010.

Both companies are of a similar size, PotashCorp being valued at $14.9 billion and Agrium at $13.2 billion, based on their respective 30 August share prices. The massive company created by the merger would be a dominant force in North American fertilizer production, controlling 62% of potash capacity, 30% of phosphate capacity and 29% of nitrogen capacity, according to some estimates. Such a concentration of supply is likely to attract the attention of North American regulators and unsettle some farmers.

Industry analysts and legal advisers were generally positive about a successful outcome to the merger. "From PotashCorp and the Saskatchewan's government's point of view, they would rather have PotashCorp and Agrium merge as a defensive measure so that someone like BHP Billiton doesn't look at the low dollar and think, 'let's take another run at it'," Mark Warner, a principal at legal firm MAAW Law, told *Bloomberg*.

Analysts Integer Research commented that there was "a need for consolidation in both the nitrogen and potash markets" and said "the merger makes sense in both cases". The merger should clear regulatory hurdles and was also sensible for defensive reasons in Integer's view. "I don't think this merger would produce enough concentration in any commodity to raise regulators' concerns. This is an industry that has become much more competitive and where there has been a lot of overinvestment in new capacity in response to the boom times, so this is partly a defensive move by the companies – but it also makes sense in terms of vertical integration," Oliver Hatfield, Integer's fertilizer director, told *Financial Times*, adding: "Agrium has been developing its downstream business and this would be a way of pushing more product through those distribution channels."

The merger is not solely about potash assets and retail distribution. A major consolidation in nitrogen production capacity would also result. PotashCorp owns ammonia and urea plants in Trinidad and Tobago, for example, in addition to its substantial North American potash, phosphate and nitrogen assets. The company's combined ammonia capacity is close to 4.1 million t/a, including US capacity of around 1.93 million t/a. Agrium is also a significant nitrogen market player with a total ammonia production capacity of 3.52 million t/a. It owns substantial North American nitrogen assets, including 2.4 million t/a of ammonia capacity in Canada and about 490,000 t/a of ammonia capacity in Texas. Agrium also part owns nitrogen capacity in Argentina and Egypt through its joint ventures.

News of the proposed Agrium-PotashCorp merger comes less than a year after PotashCorp dropped its takeover bid for German potash producer K+S (*Fertilizer International*, 469 p9). ■

Mosaic keeps Colonsay mine idle for rest of year

Mosaic's Colonsay potash mine in Saskatchewan will remain idle throughout 2016, the company confirmed on 17 July. Turnaround activities at the mine have been halted and around 330 employees have been temporarily laid off as a consequence.

Mosaic said the move, which effectively scales-back its production capacity by 2.6 million t/a for the remainder of the year, was a reaction to challenging potash market conditions. The company now intends to satisfy the short-term potash supply needs of customers from its lower-cost Esterhazy and Belle Plaine mines, and by drawing on current inventory.

"We continue to execute the difficult but necessary actions to ensure Mosaic will be as competitive as possible across the business cycle," said Joc O'Rourke, Mosaic's president and CEO. "Lower global potash demand and market prices require that we curtail production. Idling Colonsay will enable us to meet our customers' needs while reducing our production costs."

BHP may mothball Jansen Saskatchewan potash project

BHP Billiton may decide to mothball its Saskatchewan-based Jansen potash project towards the end of the decade, if market conditions are poor.

The company's board will weigh-up whether to finish the potash mine after its two mine shafts are completed in 2018/19, CEO Andrew Mackenzie, has confirmed. The shafts are around 60% complete currently, having reached a depth of about 600 metres with a further 300-400 metres of excavation remaining.

BHP Billiton estimates that sinking the two shafts will ultimately cost under $2.6 billion.

"It's certainly perfectly possible, if at that time the market is not going to be ready for potash, say, in three years subsequently, that we could mothball the shafts once we've completed them," Mackenzie told investors and analysts on 16 August. He added that mothballing might be the "more palatable" option compared to proceeding with a project that was not "economically attractive".

Spending more than $2 billion on constructing a mine without fully developing it would be an unprecedented decision for a major mining company to take. However, the option to mothball Jansen appears to be more about timing the start of production to coincide with favourable market conditions. "The cost of mothballing would be reasonably small," commented Mackenzie. "Obviously at that point we'd have to examine whether or not that was something we wanted to stay in for the long term. We have the flexibility to wait and time our entry into the market."

Mackenzie also confirmed that talks with potential outside partners for the Jansen project are continuing.

UNITED STATES

PotashCorp opens Hammond distribution centre

PotashCorp held the grand opening of its Hammond, Indiana, regional distribution centre on 31 August. The new $90 million centre includes a 100,000 tonne capacity warehouse. The company describes this as "like having a mini mine in the Midwest".

The new warehouse, completed in April 2016, is equipped with state-of-the-art equipment that can unload railcars two to three times faster than is possible at a conventional potash warehouse. 14 miles of track were also added to the centre's rail yard when the first phase of the Hammond project was completed in 2012. This has created track space for up to 1,000 railcars to stand loaded and ready to roll.

The distribution centre should help PotashCorp deliver crop nutrients to its US customers more quickly and reliably in future. The company now has the ability to hold a substantial volume of potash in a forward position, and will be able to cut its delivery times by circumventing bottlenecks at the busy Chicago rail corridor, 25 miles to the north.

"It improves our ability to efficiently deliver potash to our US market," said Bob Felgenhauer, PotashCorp's vice president of transportation and distribution. "Building this facility shows our customers we are committed to meeting their needs and are willing to invest in facilities to do that."

Further $2.5m for New Mexico polyhalite project

Polyhalite project developer IC Potash Corp received a second $2.5 million investment from Cartesian Capital Group in July.

This will fund the completion of a feasibility study examining the economics of mining polyhalite from IC Potash's Ochoa project in New Mexico. The funding is the second tranche of a strategic investment in the Ochoa project of up to $45 million agreed with Cartesian in February this year.

IC Potash is currently assessing the technical and economic feasibility of constructing a polyhalite mine and production plant near Hobbs, New Mexico. It is also conducting product and market studies to ascertain the potential of polyhalite as a direct-application multi-nutrient fertilizer, particularly the prospects for supplying the US Corn Belt.

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ITC to rule on alleged ammonium sulphate dumping

The US International Trade Commission (ITC) said there is "a reasonable indication that an industry in the United States is materially injured by reason of imports of ammonium sulphate from China" in its preliminary determination in July. It alleges that the Chinese government is subsidising prices so that the AS is being sold below cost price ('dumping'). The move follows a complaint from Pasadena Commodities International Nitrogen LLC of Texas, prompting an ITC investigation in May. The ITC says that it will continue to conduct its anti-dumping and countervailing duty investigations on imports of this product from China. A preliminary countervailing duty determination is due in August with a preliminary anti-dumping duty determination following in November this year.

CF's Port Neal plant nears completion

CF Industries says that it has achieved mechanical completion at its 2,200 t/d Port Neal ammonia plant. The facility is expected to begin production during 3Q 2016. Construction continues on the 3,500 t/d urea synthesis and granulation plant, which is expected to start up shortly after the ammonia plant, according to the company. Construction began in 3Q 2013 and had been expected to be complete in 2Q 2016. Company staff have already begun the detailed commissioning process which both plants must go through prior to production. CF also says that all new offsites and utilities have now been completed, including water collection and purification, power generation, the waste and fire water systems, cooling towers and various other functions.

TUNISIA

Protests halt CPG phosphate production

Tunisian phosphate rock mining company CPG (Compagnie des Phosphates de Gafsa) has suspended all production at its three main sites due to job protests, *Reuters* reported on 30 August.

"Gafsa phosphate production is completely halted after sit-in protests by jobless people demanding work," company official Ali Houchati told *Reuters*. "This is going to hit exports quickly because there are not that that much reserves."

CPG's production has been badly hit by protests and strikes triggered by the 'Arab Spring' uprising, which first began in Tunisia. The country produced 8.26 million tonnes of phosphate rock in 2010. But this fell to 4 million tonnes last year, with 1.86 million tonnes produced during the first six months of 2016, according to Tunisia's energy ministry.

The renewed protests will be an early test for the new government of Youssef Chahed, suggests *Reuters*. The recently-installed prime minister has promised to take a strong line against the sit-ins that have damaged Tunisia's economy over the last five years.

INDIA

Yara buys Tata Chemicals' urea business

Yara International has agreed to buy Tata Chemicals' Babrala urea plant and its Uttar Pradesh distribution business for $400 million.

The Babrala plant generated $350 million in revenues plus earnings worth $35 million (EBITDA) last financial year. The plant was commissioned in 1994 and produces 0.7 million tonnes of ammonia and 1.2 million tonnes of urea annually. It is also one of India's most energy efficient urea plants, with an energy performance equal to some of Yara's best plants, according to the company.

Yara has maintained a presence in India since the 1990s. Strong premium product sales in the country's south and west have delivered strong volume growth and margins for the company in recent years. The company said its latest acquisition would accelerate growth in India and provide its premium sales with a further boost.

"This acquisition represents another significant step in our growth strategy, creating an integrated position in the world's second-largest fertilizer market," said Svein Tore Holsether, Yara's president and CEO. "India has strong population growth and increasing living standards, and significant potential to improve agricultural productivity,"

Holsether praised the Babrala plant, especially its world-class health, environment, safety and quality (HESQ) standards. "This well operated plant and its highly skilled employees will make an excellent addition to Yara's global production system," he said.

The purchase is expected to close within 9-12 months, subject to regulatory and court approval in India.

SENEGAL

Baobab project in production

First production is underway at Avenira Limited's Baobab phosphate project in Senegal, the company confirmed on 25 August.

The first phosphate rock product from Baobab's processing plant, which is currently in commissioning, is being stockpiled on a drying pad. This is likely to be trucked to port within a matter of weeks, allowing maiden shipments to take place in either late September or October, the exact timing depending on wet season conditions.

The Baobab plant is designed to produce 500,000 t/a of phosphate rock concentrate. Avenira delivered the first $15 million stage of the project on time and on budget, paving the way for further capacity expansions at the site.

"The Baobab phosphate project continues to progress steadily and it is fantastic to see first production at this time," commented Cliff Lawrenson, Avenira's managing director. "The Project has moved from the construction stage to commissioning and is proceeding through production ramp-up. To have achieved first production in August, after starting mining activities in March, is outstanding by any measure."

BRAZIL

Yara buys Catalão blending unit

Adubos Sudoeste's NPK blending unit in Catalão, Goiás State, Brazil, has been bought by Yara International.

Yara announced it had signed a contract to purchase the 300,000 t/a unit on 25 August. The strategic move expands Yara's presence in Brazil's fast-growing midwest agricultural market. It follows EuroChem's purchase of a controlling stake in Brazilian fertilizer distributor Fertilizantes Tocantins in July (*Fertilizer International*, 473 p10)

The blending unit mainly supplies soybean, corn, bean, tomato, potato, onion and garlic producers in Goiás State, although supplying farmers in Tocantins state is also an option. Goiás State is largely responsible for the production of Brazil's main export crops, such as soybean and corn, and is at the centre of Yara's strategy for the country, according to Lair Hanzen, president of Yara Brazil.

"To invest in fertilizer distribution in Goiás is strategic for Yara and reinforces our commitment to provide the best solutions to Brazilian farmers," said Hanzen. "Besides that, we maintain our efforts to increase fertilizer production in order to reduce the national dependence on imports of raw materials."

Yara has invested around $1.5 billion in Brazil to date. This including the acquisition of Bunge Fertilizantes in 2013 and the joint venture with Galvani announced in 2014. It also includes construction and refurbishment of industrial blending units in Sumaré and Porto Alegre. Yara also announced substantial investment in its Rio Grande complex at the beginning of this year.

Finalisation of the Adubos Sudoeste deal will require the approval of Brazil's Administrative Council for Economic Defense (Cade).

CHINA

K+S buys Chinese magnesium sulphate producer

K+S Group is to spend more than €10 million purchasing Huludao Magpower Fertilizers (Magpower), a Chinese producer of magnesium sulphate fertilizers.

The German potash producer said the acquisition was an important step forward in its expansion into Asia. The exact purchase price was not disclosed although a statement from K+S did confirm it was for a "euro amount in the low double-digit millions range".

Magpower is one of China's largest producers of synthetic magnesium sulphate (SMS), a product used for industrial purposes and as a fertilizer for oil palm, soybean and sugar cane.

The purchase provides K+S with the ownership of a modern 90,000 t/a SMS production plant "with an attractive cost structure" in Huludao City in the northeast Chinese province of Liaoning. The company believes the plant's capacity could be doubled to 180,000 t/a in future.

"We are bolstering our competitive position in the specialties area by means of this acquisition and can therefore better tap into the growth markets of South-East Asia," said Norbert Steiner, the chairman of K+S. "We see great sales potential for magnesium sulphate products to the agricultural sectors in China and South-East Asia which we can't service adequately from our German sites."

K+S currently produces natural magnesium sulphate fertilizers from several sites in Hesse and Lower Saxony. The SMS produced by the Huludao plant will add a synthetic type of magnesium sulphate to the company's current product range. SMS products have a positive effect on root development, water absorption, yields and plant quality parameters, according to K+S.

The Magpower deal is expected to close by the year's end. Both sides have agreed not to disclose any further details of the transaction at this stage.

ERITREA

JPMorgan invests in Danakali

JPMorgan Chase & Co has become a shareholder of Danakali, the Australian potash developer behind the Colluli potash project, a 50:50 joint venture with the Eritrean National Mining Company.

News that the US investment bank had taken a 9.12% stake in Danakali, via a AUD 6.7 million ($5.1 million) pri-

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Sulphuric acid pools in Dallol, Ethiopia.

vate placement, emerged in an Australian stock exchange announcement on the 12 August. The sum raised will go towards development of the Colluli project, Danakali's flagship sulphate of potash (SOP) mining venture in Eritrea.

"This placement is testimony of how the international profile of the Colluli project is growing and is a clear endorsement of the project, the jurisdiction and the company," said Paul Donaldson, Danakali's managing director. "It further demonstrates the attractiveness of the Colluli Project and Danakali as an emerging agri-commodity company."

JP Morgan's stake gave Danakali "its seal of approval", commented Somers & Partners, the brokerage company which arranged the deal between the pair. Somers & Partners pointed out that the JP Morgan already has a successful track record in Eritrea through its investment in Nevsun Resources, the operator of the country's Bisha copper mine.

A definitive feasibility study for Colluli released by Dankali at the end of last year revealed the company's plans for producing SOP from the large-scale reserves within its mining concession

"Danakali now has a strong supportive cornerstone investor to help grow the business as well as the funds to commence early-stage engineering works at Colluli," Somers & Partners told *Mining Journal*, adding: "We expect the mining licence to be approved later this calendar year with funding and offtake to follow that."

REPUBLIC OF CONGO

SQM invests $20m in Elemental Minerals

SQM announced it is investing $20 million in Elemental Minerals Limited (ELM), the Australian mining junior developing potash reserves at Sintoukola in the Republic of Congo. The investment is in exchange for 17% stake in Elemental and the right of first refusal for around 20% of future potash production.

Chilean potash producer SQM is not the sole investor. The State General Reserve Fund of Oman and Summit Private Equity are also investing a further $20 million and $10 million, respectively.

The $50 million investment stake from the three backers – particularly from an experienced incumbent producer such as SQM – is a major step forward for Elemental and a sign of confidence in its flagship Kola venture, one of Africa's most promising greenfield potash projects (*Fertilizer International*, 468 p58). The company also has less advanced plans for a solution mine to exploit the nearby Dougou potash deposit.

The new investment will fund definitive feasibility studies for Elemental's potash project slate. These could be delivered within two years, according to SQM, and be fully-financed with the amount of capital provided. SQM expects Elemental's initial production capacity in the Republic of Congo to be around two million t/a, and eventually grow to as much as four million t/a.

"Initial studies suggest that these are high-quality deposits and are therefore consistent with SQM's strategic position as a low cost producer in all of its major business lines," commented Patricio de Solminihac, SQM's CEO, in a statement on 1 September. "These projects would grant SQM access to potassium at the low end of the cost curve. We believe that our expertise in processing potassium chloride, as well as our knowledge of the market and our existing logistics infrastructure, will be fundamental in the development of the ELM project."

The proximity of the potash deposit to the coast, being located just 18-35 km from Atlantic ports capable of shipping to Brazil, also makes development of the Republic of Congo's reserves attractive to SQM.

"We believe in the long-term fundamentals of this market," added de Solminihac. "And while other producers have new capacity projects in the pipeline, we believe there is space in the market for a new low-cost project."

IRAN

Start-up for Marvdasht plant

The Marvdasht ammonia-urea plant at Shiraz has been inaugurated, bringing Iran's total nitrogen capacity to 4.5 million t/a of ammonia and 5.5 million t/a of urea. The new unit, which provides 680,000 t/a of ammonia and 1,075,000 t/a of urea of that total, was inaugurated at a ceremony attended by Marzieh Shahdei, Managing Director of Iran's National Petrochemical Company (NPC), and the country's First Vice-President Es'haq Jahangiri, as well as Minister of Petroleum Bijan Zanganeh, and representatives of licensors and engineers Casale and Japan's Toyo Engineering Company. The project was completed at a cost of $750 million, most of that paid in euros, according to the company. The Managing Director of the Shiraz Petrochemical Facility, Kianoush Kazemi, said the complex had created 500 jobs directly and a further 5,000 indirectly. ■

Iran is monetising its gas reserves.

Global Fertilizer Day

The first Global Fertilizer Day will take place on 13th October this year and is being marked by a launch in London. ***Jana Graso*** *and* ***Mark Cryans*** *of Fertilizers Europe explain its purpose, and why raising awareness about fertilizers is vitally important.*

Fertilizers have changed the world. Now an integral part of our agriculture, they account for 50% of global food production. They have improved economic standards in poverty-stricken areas around the world and keep billions of people fed every day. However, the world's population has tripled over the past fifty years and will increase by a further one billion in the coming decade. How can we ensure that agricultural technology keeps pace with this to feed our growing world?

October 13th 2016 marks the 108th anniversary of the Haber-Bosch patent for the "synthesis of ammonia from elements", a turning point which helped create fertilizer from atmospheric nitrogen. This date will mark the first Global Fertilizer Day – a celebration of one of the most revolutionary inventions of our time. An invention that has fed billions and set in motion some of the most important improvements in agriculture to date. Through locally organized events, this day will raise awareness of fertilizer around the world, marking the anniversary of an invention that is deemed one of the most significant in human history.

The purpose of Global Fertilizer Day is to unite the agriculture industry in celebrating innovation, and the role of fertilizers in creating a sustainable future for agriculture and farming. Global Fertilizer Day will have world-wide significance as the invention of fertilizer has offered a global solution to food scarcity around the world. Fertilizer will also make a key contribution to the betterment of agriculture in future. We call on all fertilizer manufacturers, users, and distributers to use this day to educate the public about the importance of plant nutrients for world agriculture and food production.

The launch of Global Fertilizer Day will take place in London from 12-13th October. Some of the biggest thought leaders in Europe's agricultural and fertilizer industries will gather for two days of creative discussions. Spreading awareness of fertilizers and innovation in agriculture will be the major priority. The more organisations that join globally, the greater the impact will be in terms of increasing awareness and public knowledge of fertilizers. Such a cause is fundamental for the future of the world's food supply.

All agriculture professionals are invited to join the launch of Global Fertilizer Day and make an impact on 13th October. Let us create an event that will contribute to the widespread knowledge of an essential invention and bring people together for a discussion on the future of our food. ■

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Dr Burkhard Lohr is to replace Norbert Steiner when he retires as chairman of the board of executive directors of K+S Group on 12 May next year. Dr Lohr, who is 53, currently serves as the group's CFO. The company's supervisory board announced the appointment on 24 August.

"Dr Burkhard Lohr is an excellent manager with long term experience beyond the financial area and a strong management track record," said Dr Ralf Bethke, K+S supervisory board chairman. "We are convinced that generational change and the success of the company will be driven forward with Dr Burkhard Lohr at the helm of the company."

The supervisory board will also decide on two other key executive board appointments (group CFO and the director of the potash and magnesium products business unit) in due course, K+S also confirmed.

Jeppe Christiansen has been named as Haldor Topsoe's new board chairman. He was elected following the unfortunate resignation of the current chairman, Henrik Topsøe, due to ill health.

The company has also confirmed that Jakob Haldor Topsøe will be taking over as one of the Haldor Topsoe's two vice chairmen, taking on the role vacated by Jeppe Christiansen. The chairmanship now consists of Jeppe Christiansen, Jakob Haldor Topsøe and the company's other vice Chairman, Jørgen Huno Rasmussen.

Having been seriously ill with cancer for some time, Henrik Topsøe decided to resign as chairman on 12 August. "Even though I regret leaving the exciting work in the board, I am also delighted to be able to hand over a well-managed company to my successor," said Henrik Topsøe. "We are all very happy that Jeppe Christiansen has accepted the task as chairman of the board. He is not only inspiring to work with; he has a deep-rooted knowledge of the company and has done an excellent job."

Michael Höllermann and **Johan P. Cnossen** joined the management board of thyssenkrupp Industrial Solutions on 1 August. Höllermann, CEO of the South American regional headquarters since 2012, will be the new Chief Human Resources Officer (CHRO). Cnossen, who joined Industrial Solutions in May, will hold the new position of Chief Operating Officer.

"By appointing Michael Höllermann and Johan P. Cnossen we have gained two very experienced managers to drive forward the reorganisation of Industrial Solutions in a difficult market environment and focus our organization even more firmly on the needs of customers," said Jens Michael Wegmann, CEO of the Industrial Solutions business area.

Stefan Gesing has been in place as the new CFO of Industrial Solutions since 1 June. Dr Hans Christoph Atzpodien is also on the board and covers marine systems management. ■

James Byrd is AIChE's 2016 Engineer of the Year

James Byrd, process manager at Jacobs' Lakeland Process Group, was named 2016 Engineer of the Year at this year's annual Clearwater Convention in Florida. He was awarded this highly-regarded accolade by the AIChE's Central Florida Section at the Sheraton Sand Key Resort on 11 June

James holds a degree in chemical engineering from the University of South Florida, a psychology degree from Florida State University and an MBA from the University of Miami. He has over 20 years of experience in the fertilizer industry with a strong background in phosphoric acid plant operations and design.

James has presented numerous papers at CRU conferences, Symphos and the annual Clearwater Convention over the course of his career. The theme of these presentations have ranged from phosphoric acid reactor technology to Jacobs' new patented iron removal process. James has also held various board positions on AIChE's Central Florida Section including the role of chairman.

As part of his process lead role at Jacobs, James has evaluated the efficiencies of a wide range of phosphoric acid plants globally. Notably, he was process lead on the front end engineering design (FEED) for Ma'aden's Umm Wu'al phosphoric acid plants. ■

Erratum: *an incorrect photo of James Byrd accompanied the Clearwater Convention report in our July/August issue. We apologise to Jacobs and James Byrd for this error.*

Calendar 2016

SEPTEMBER

25-27
TFI World Fertilizer Conference,
SAN DIEGO, California, USA
Contact: Linda McAbee
Tel: +1 202 515 2707
Email: lmcabee@tfi.org

OCTOBER

10-12
CRU Africa Fertilizer Agribusiness 2016,
DAR ES SALAAM, Tanzania
Contact: CRU Events
Chancery House, 53-64 Chancery Lane,
London WC2A 1QS, UK.
Tel: +44 (0) 20 7903 2444
Fax: +44 (0) 20 7903 2172
Email: conferences@crugroup.com

11-13
29th AFA International Fertilizer Technology Conference & Exhibition,
TUNIS, Tunisia
Contact: Arab Fertilizer Association
Fax: +20 2 2305 4454
Email: info@afa.com.eg

25-27
IFA Production and International Trade & IFA Crossroads Conferences, SINGAPORE
Contact: IFA Conference Service
Tel: +33 1 53 93 05 00
Email: ifa@fertilizer.org

NOVEMBER

7-11
IFDC Granular Fertilizer Production Workshop, BANGKOK, Thailand
Contact: IFDC
Tel: +1 256 381 6600
Email: training@ifdc.org

TFI welcomes you to San Diego

The Manchester Grand Hyatt in sun-drenched San Diego, California, is the venue for The Fertilizer Institute's 2016 World Fertilizer Conference this September.

Sunny San Diego, California, plays host to this year's World Fertilizer Conference, the leading annual event organised by The Fertilizer Institute (TFI). More than 800 industry delegates from across the globe are expected to congregate in the city for the three-day programme between 25-27 September.

The conference's exceptional guest speakers and the unparalleled opportunities for business networking have attracted delegates in ever larger numbers in recent years.

This year's conference will formally open with an evening welcome reception on Sunday 25 September. As is usual, a high-calibre keynote speaker will then address the conference during the breakfast session on the following day.

The US Presidential election is taking place just six weeks after the conference ends. TFI has therefore secured James Carville, one of America's best-known political consultants, as the morning breakfast speaker on Monday 26 September. James is frequent political commentator and contributor to CNN and also serves as a Professor of Practice at Tulane University in New Orleans, Louisiana. He will no doubt provide some sharp observations and insights into the 2016 race for the Whitehouse.

Delegates will then be treated to a high-level panel discussion during the breakfast session on Tuesday 27 September. Distinguished experts will share their knowledge on building sustainable food systems in what promises to be a lively morning event. ■

TFI CONFERENCE SCHEDULE

SUNDAY 25 SEPTEMBER

TFI Registration & Table Top Exhibits
8:00 a.m. – 5:30 p.m.
TFI Hospitality Center (all welcome to network)
8:00 a.m. – 5:30 p.m.
Nutrients for Life Foundation Board of Directors Meeting
2:00 p.m. – 3:30 p.m.
FertPac Reception
5:00 p.m. – 6:00 p.m.
TFI Welcome Reception
6:00 p.m. – 7:30 p.m.

MONDAY 26 SEPTEMBER

TFI Registration & Table Top Exhibits
6:30 a.m. – 5:30 p.m.
TFI Hospitality Center (all welcome to network)
8:00 a.m. – 5:30 p.m.
TFI Breakfast Session
7:15 a.m. – 8:45 a.m.
Welcome and Opening Remarks
Chris Jahn, President, The Fertilizer Institute
KEYNOTE ADDRESS:
A Look at Politics and the 2016 Race for the White House
James Carville, Political Consultant
TFI Board of Directors Luncheon (by invitation only)
12:30 p.m. – 1:30 p.m.
TFI Board of Directors Meeting (immediately following lunch)
1:30 p.m. – 3:30 p.m.
TFI Reception
6:00 p.m. – 7:30 p.m.

TUESDAY 27 SEPTEMBER

TFI Registration & Table Top Exhibits
6:30 a.m. – 10:00 a.m.
TFI Breakfast Session
7:15 a.m. – 9:00 a.m.
Session Opening Remarks
Garrett Lofto, President, Agribusiness Group, Simplot
Food Panel Discussion
Jere Sullivan, Vice Chairman, International Public Affairs, Edelman
TFI Hospitality Center (all welcome to network)
8:00 a.m. – 5:30 p.m.

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The future of fertilizer logistics in Brazil

Brazil has emerged as the global economy's agricultural powerhouse in recent years, on the back of outstanding improvements in crop production and exports. Addressing logistical challenges will be necessary, however, if Brazil's agricultural sector is to continue to flourish and realise its full potential, as **Débora Simões** of Agroconsult explains.

Brazil has become more and more relevant to world food markets in recent years, to the extent that the country is now described as global agriculture's powerhouse (*Fertilizer International*, 472 p30). Brazil's agribusiness sector has flourished against a backdrop of ever growing global demand for agricultural products – itself driven by world population growth, economic expansion, biofuels incentives, shifts in food consumption and rising incomes. Brazilian grain production, for example, more than doubled between 2000/01 and 2014/15, according to data from the National Supply Company (Conab), increasing from 100.3 million tonnes to 209.5 million tonnes.

However, continuing expansion of Brazil's agricultural sector, particularly the supply of fertilizers underpinning this, is hampered by poor logistics infrastructure. Facing up to this logistical challenge and planning accordingly will be necessary if Brazilian agriculture is to continue to flourish and realise its full potential.

Growing grain output, rising fertilizer demand

Agribusiness in Brazil is forecast to continue to grow over the coming years. Leading Brazilian agricultural consulting company Agroconsult expects the country's grain production will eventually approach 300 million tonnes by 2025. A favourable climate and the high availability of arable land make harvests on this scale feasible and achievable. Such natural advantages allow Brazil to produce a wide range of internationally competitive agricultural commodities – and are encouraging development, investment and technological improvement in the farming sector.

Despite the above mentioned advantages, the addition of large amounts of fertilizers to widespread poor and acid soils is generally necessary when farming in Brazil. An average NPK application rate of 140 kg/ha is needed to achieve world class soybean yields in Brazil, for example, compared to an average rate of just 37 kg/ha in the US (*Fertilizer International*, 472 p30). Consequently, the expected future growth in Brazilian agricultural production, and the land area expansion and yield improvements which will accompany this, will certainly require a proportional increase in fertilizer availability and supply.

Table 1: **Current Brazilian port infrastructure investments for fertilizers, 2016-2025**

Port / Facility	Investment	Timing	Total extra-Capacity ('000 t)
Paranaguá (PR)	Additional berth dedicated to fertilizers shipments and construction of a new terminal in Antonina.	2016-2020	2,950 (500,000 t/a plus 450,000 t in 2018)
Rio Grande (RS)	Improvements in port operations and dredging as well as investments in fertilizer blending.	2016-2020	1,000 (200,000 t/a)
São Francisco do Sul (SC)	Build up of a new berth with a total capacity of 3,000 Kt for all merchandises.	2021	342 (maintaining fertilizer share in total movement through the port)
Santos (SP)	Improvements in Tiplam Terminal and construction of Outeirinhos Terminal for fertilizer, which is included in the PLI 2015-2018.	2017-2020	1,845 (990,000 t in Tiplan and 855,000 t in Outeirinhos
Itaqui (MA)	Construction of a fertilizer terminal with total capacity of 4,300 Kt as stated in PLI 2015-2018.	2018-2020	2,250 (750,000 t/a)
Santarém (PA)	Construction of a fertilizer terminal with total capacity of 1,600 Kt as stated in PLI 2015-2018.	2020-2022	1,440 (half by 2020 and half by 2022)

Notes: Capacity calculated considering a usage rate of 90%.
Timeline for operations are estimated.
This list is not exhaustive. Only investments already announced are considered.

Source: Agroconsult

Agroconsult estimates that Brazilian fertilizer product demand will need to rise to about 41.0 million tonnes by 2025 – an increase of 10.8 million tonnes on 2015 deliveries – if the forecast growth in agricultural output and expected improvements in the country's agribusiness performance are to be achieved.

Domestic fertilizer production, meanwhile, is expected to rise by only 1.5 million tonnes by 2025. As a result, imports will continue to make a vital contribution to Brazil's fertilizer demand in the next 10 years, accounting for more than 70% of domestic supply. Fertilizers imports are expected to rise significantly over the next ten years to the extent that the amount purchased overseas could reach 30.4 million tonnes by 2025, an increase of more than 25% on the record import levels seen in 2014.

The logistical challenge

The growing dependence on imports to supply the domestic fertilizer market means Brazil's ports, roads, rail and waterways will have to transport much larger volumes of fertilizer between the coast and the interior in future. Effective logistics planning – deciding where, what type and how much infrastructure investment is needed – to cope with increased fertilizer flows is therefore vital, if Brazil's farmers and agricultural companies are to retain their competitiveness.

> **"Improved logistics will be necessary if Brazil is to realise its full potential.**

Fertilizer imports and grain exports already face challenges and bottlenecks at present, due to poor and inefficient logistics infrastructure in Brazil. As well as the normal charges associated with imports (sea freight, insurance and port costs and the AFRMM tax) fertilizer importers often incur additional demurrage costs. These are fines for the delays that occur when vessels are prevented from berthing and discharging cargo within a stipulated period. Delays typically occur during the seasonal peak in import deliveries between June and September every year. But they are also a consequence of operational problems at ports, such as a lack of space for berthing, insufficient port storage capacity, lack of equipment and bureaucratic delays.

The World Bank's most recent Logistics Performance Index (LPI) in 2016 ranks Brazil 55th out of the 160 countries surveyed. Moreover, for aspects directly related to imports, namely customs and international shipment, the situation is even worse, with Brazil ranked 62nd and 72nd, respectively.

Brazil's poor logistics performance has a very real price. Demurrage cost totalled $42.2 million in the ports of Paraná during 2015, for example, according to a survey by the Union of Fertilizer Industry.

The long distances between those regions where demand is largest and the main importing ports is another critical factor affecting fertilizer trade and distribution within Brazil. To supply Mato Grosso, Brazil's main fertilizer consuming state, for example, imported fertilizers must travel around 2,200 kilometres on average. That is the distance between

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the Port of Paranaguá – Brazil's main import hub – and Sorriso, the state's major soybean producing region. The freight cost for that route is about $54/t, although total logistic costs may reach as much as $100/t. This represents a significant cost burden. Relative to the average 2016 f.o.b. prices of Brazil's main imported fertilizer products, total logistic costs are equivalent to 40% of the urea price, 27% of the MAP price and 41% of the MOP price.

Expected port terminal investments

Logistics chain problems, especially supply delays and high demurrage and freight charges, impose major penalties on fertilizers consumers, as they dramatically raises the costs associated with the internal distribution of fertilizer products within Brazil. However, two effective measures could help minimise logistical difficulties and costs in Brazil, and are therefore worth assessing and adopting:

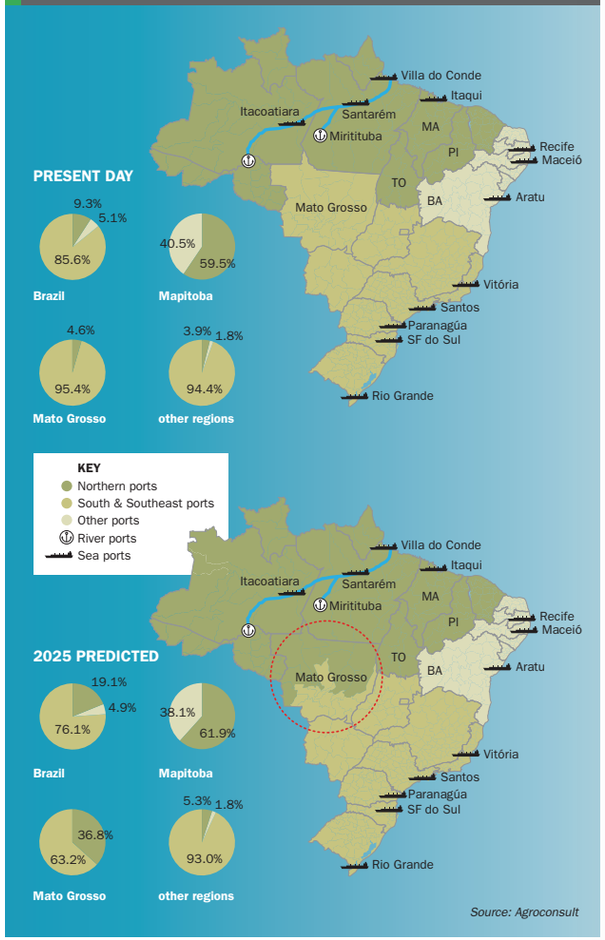
1) Improvements in port operations and processes aimed at decreasing demurrage expenses.
2) Investments in new infrastructure and port capacity, especially those targeting the development of the 'Northern Arc' corridor, to ease supply in some markets and help debottleneck the southern ports.

The 'Northern Arc' generally refers to ports (operational and planned) on the Amazon River and the northern Atlantic Coast. These look set to play a particularly vital role in soybean exports in the near future. It includes the ports of Itacoatiara (AM), Santarém (PA), Vila do Conde (PA), Itaqui (MA) and Mirituituba (PA).

Increasing the import capacity of Brazilian ports is arguably of the utmost importance and the highest priority for the fertilizer sector. Although not entirely adequate, existing port infrastructure is still sufficient to meet 2016 and 2017 demand levels but is likely to be below capacity by 2018, unless action is taken.

With this in mind, the second phase of the federal government's 2015-2018 Logistic Investments Programme (PIL), announced in June last year, is helping to modernise the country's transport infrastructure, largely through private sector initiatives. Four port terminals dedicated to fertilizer handling are among the proposed PIL projects: two in the Port of Santos, one in the Port of Santarém and the other in the Port of Itaqui. A new berth in São Francisco do Sul could also expand that port's fertilizer import capacity. In addition to the projects planned under PIL, new private investments are also planned for the Port of Paranaguá – an expansion of the terminal in Antonina – and for the Port of Rio Grande. Current fertilizer infrastructure investments are summarised in Table 1.

Fig 1: **Port share of total imports for selected regions and their area of influence: present day vs 2025**



Source: Agroconsult

Fertilizer import flows

Many fertilizer companies are establishing or expanding their presence in the Brazilian market, or are planning to do so. This is due to the positive outlook for Brazil's fertilizer supply sector and the expectation of continuing growth in coming years. Finding suitable ports for fertilizer terminal construction or expansion is a major priority for many of these investors.

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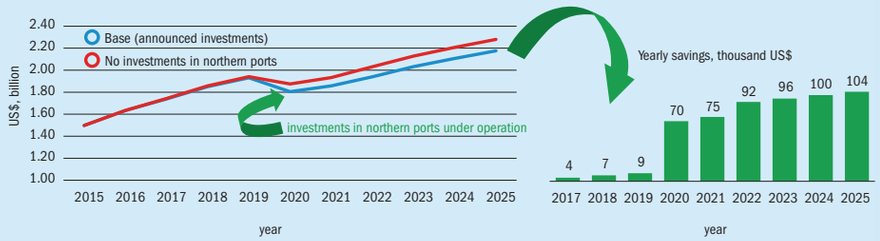
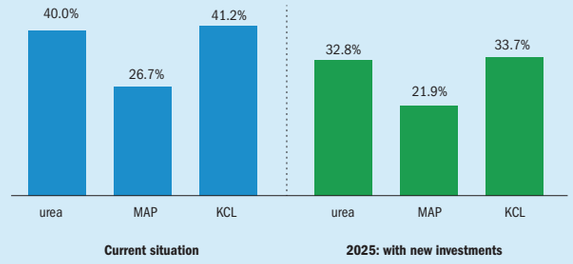
Fig 2: **The total logistic cost for the import of fertilizers into Brazil and potential savings opportunities, 2015 to 2025**



Source: Agroconsult

Fig 3: **Example of fertilizer distribution savings from port infrastructure investment: total logistic costs for fertilizer products in Sorriso, Mato Grosso, 2015 vs 2025**



Source: Agroconsult

Although competitive investment opportunities exist in many of the country's ports, the so-called 'Northern-Arc' ports are currently in the spotlight and attracting most investor interest, mainly because of the large forecast rise in fertilizer demand expected in this part of Brazil.

Between 2015 and 2025, for example, while national demand for imported fertilizer is expected to increase at 3.9% annually, arrivals through Northern-Arc terminals is likely to grow by 10.7% each year. Under this scenario, fertilizer imports through Northern-Arc ports would more than double by 2025 accounting for almost a fifth (19.1%) of national fertilizer imports compared to their current share of under 10%.

Fertilizer imports through southern ports, in contrast, will grow at an annual rate of just 2.8%, although they will continue to have a vitally important role in meeting future fertilizer demand. Even though their share of total imports is set to decline, southern ports will still account for more than 75% of Brazil's fertilizer imports in coming years. Competition between fertilizer terminals in the south is, however, likely to intensify in future, as regional demand shifts northwards creating idle port capacity elsewhere.

Expected changes to the flow of fertilizers through Brazil's ports over the next decade are summarised in Figure 1. Regionally, it is Mato Grosso state which is likely to be most affected by the changes to fertilizer supply that will occur as a consequence of new infrastructure investments. Over the coming years, Mato Grosso's fertilizer demand will increasingly be met by supply through northern ports, reaching a total volume of about 2.8 million tonnes by 2025, over one-third of the state's total demand (36.8%). The northern and eastern part of the state are most likely to benefit from these supply changes.

In other major fertilizer-consuming regions, the outlook is mixed with the flow of fertilizers through ports expected to increase in some parts of Brazil and decline in others in future. Further investment in inland fertilizer distribution will still be necessary in any case. Investments to improve road quality, rail and waterways usage and fertilizer storage capacity will be needed to take advantage of future port expansions and profit from the opportunities this provides. A number of existing routes will demand particular attention due to the significant increases in fertilizer transport volumes expected in future. This is the certainly the case for routes between the Port of Itaqui and the MAPITOBA region – as the volume of fertilizers transported along these could more than double by 2025.

Saving opportunities

Total logistics costs will alter over the next decade as a direct consequence of the shifting pattern of fertilizer distribution between ports of origin and destination regions in Brazil, as discussed above. Encouragingly, all agricultural regions in the country will benefit as a result of new infrastructure. On average, Brazil's fertilizer logistic costs will fall between $1.00 and $12.10 per tonne by 2025, relative to current levels, with Pará, Mato Grosso and MAPITO benefitting the most.

If it assumed that all of the Brazil's currently planned port investment goes ahead, the logistics cost for importing fertilizers between 2015 and 2025 would be $20.57 billion in total. For comparison purposes, this cost would reach $21.13 billion over the same period, if there was no investment in northern ports, and the supply of imports continued to rely on ports in the south instead (see Figure 2).

This analysis suggests that announced Brazilian port investments, if delivered in full over the next decade, could provide opportunities to cut fertilizer logistics costs by as much as $558 million. Moreover, even greater logistics savings should be possible beyond 2025, as the northern ports are closer to those regions where agriculture and fertilizer demand are expected to grow most strongly, particularly the northern and eastern parts of Mato Grosso state.

Returning to the example mentioned earlier in this article, logistic costs to supply the region of Sorriso, located in the northern part of Mato Grosso state, currently contributes 40% to urea prices, 27% to MAP prices and 41% to MOP prices. In future, importing fertilizers through the Port of Santarém instead would reduce these costs to 33%, 22% and 34%, respectively, to the benefit of farmers and blenders (see Figure 3).

Other challenges

Investments in fertilizer logistics are extremely important in Brazil, given that the country's distribution capacity needs to keep pace with the expected rapid rise in fertilizer demand. Our analysis suggests that developing the infrastructure of the 'Northern-Arc' region will be particularly beneficial, as it will debottleneck southern ports and benefit both farmers and blenders.

Most NPK blending companies are currently clustered in Brazil's southern regions near the traditional ports of Rio Grande, Paranaguá and Santos. The industry must therefore invest in building new NPK blending units in other regions in coming years, if it is to capitalise on the extra volumes of fertilizers that are expected to flow through northern-ports. Interestingly, new entrants in the Brazilian fertilizer market are targeting the 'Northern-Arc'. That is partly because the 'Big Four' companies that control more than 80% of the Brazilian market (Yara, Mosaic, Heringer and Fertipar) have less of a presence there compared to the centre-south of the country.

Despite the potential boost to fertilizer supply, it is important to bear in mind that investment in northern port infrastructure alone will not accelerate the development of the 'Northern-Arc'. Realising the region's full potential also requires improvements to the quality of roads, faster ports operations to reduce demurrage costs, less bureaucracy and productivity improvements across the whole value chain.

Government must also play its full role in fostering and enabling infrastructure investment, as this strongly influences business confidence. Brazil's political and economic situation is currently causing investors to pull out, badly affecting the start-up of new projects in the country. However, investment conditions may improve in Brazil now that the presidential impeachment process has ended, and the confidence of international markets and rating agencies recovers.

To summarise, the fertilizer logistics challenge in Brazil is not small, but it is highly worthwhile. There is a lot of urgent work that needs to be done now. So, hands on, it is time to get started!

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Policy stability fuels modest growth

PHOTO: GILAXIA / ISTOCKPHOTO.COM

Biofuels demand has been sustained in recent years by blending mandates in producing countries and high levels of fuel consumption globally. The finalisation of biofuel policies in three key markets, the US, EU and Brazil, last year should ease short-term uncertainties and help boost global output by around one sixth by 2020. Low oil prices are also delaying the switchover from conventional crop-based production to advanced biofuels synthesised from waste biomass.

BP's 2016 Energy Outlook published in February reveals that the world's thirst for liquid fuels shows no sign of being quenched. Biofuels and natural gas liquids (NGLs) look set to deliver almost half of the 19 million barrels per day (bbl/d) increase in global supply expected over the next two decades.

Such forecasts might suggest the biofuels industry can look forward to a healthy expansion – especially as prospects for the renewables sector as a whole also look increasingly strong. BP has raised its renewable power forecast in every successive annual outlook since 2011. It now expects renewables to make a 35% higher contribution to our energy needs in 2030, compared to what was predicted five years ago, with the upward revision in this year's outlook being the largest to date.

Yet BP's latest prediction about how much of the world's energy will come from non-fossil fuels by 2030, somewhat paradoxically, is actually lower than its forecast of five year ago. This is a result of the weakening outlook for both biofuels and nuclear power. "The lower profile for biofuels reflects both slower-than-expected technological progress on advanced biofuels and weaker adoption in transport fuel," comments BP.

The International Fertilizer Association (IFA) has also warned that biofuels face "slower growth and persistent policy challenges" over the medium-term[1].

Energy security and cutting carbon

The biofuels market that has emerged globally since the early 2000s largely owes its existence to national policies designed to foster the production and use of renewable transport fuels. Over the last 15 years, a number of key countries and regions have encouraged the uptake of biofuels as a means of improving energy security and reducing greenhouse gas (GHG) emissions. Governments have backed the biofuels industry using a variety of policy measures such as fuel blending mandates, exemptions from gasoline and diesel fuel taxes and investment support. Others factors that have shaped and influenced the growth of the biofuels market include sustainability criteria, fuel quality standards and ethanol and biodiesel import tariffs[2].

Globally, biofuels production has expanded rapidly since the start of the new millennium, driven by a combination of rising gasoline prices, favourable prices for crop inputs (corn, sugarcane and oilseeds) and policies mandating their use. Indeed, biofuels production for the three largest producers, the US, Brazil and the EU, increased 462% between 2001 and 2013[3]. At the same time, a global trade in biofuels has also developed, with the US and Brazil emerging as major exporters and the EU becoming a biofuels importer to help meet its policy goals.

Table 1: **US EPA final Renewable Fuel Standards for 2014, 2015 and 2016**

	2014	2015	2016
Final renewable fuel volumes			
Cellulosic biofuel (million gallons)	33	123	230
Biomass-based diesel (billion gallons)	1.63	1.73	1.90
Advanced biofuel (billion gallons)	2.67	2.88	3.61
Renewable fuel (billion gallons)	16.28	16.93	18.11
Final percentage standards			
Cellulosic biofuel (%)	0.019	0.069	0.128
Biomass-based diesel (%)	1.41	1.49	1.59
Advanced biofuel (%)	1.51	1.62	2.01
Renewable fuel (%)	9.19	9.62	10.10

Source: US EPA

Biofuels industry enters its second phase

Growth in world biofuels production divides into two main phases with 2011 being a watershed year[3]. Consumption and production advanced rapidly in the decade prior to 2011 but have slowed markedly over the subsequent five years, particularly in the main ethanol-producing countries.

The large increase in gasoline and diesel prices between 2001 and 2010 – of 65% and 69% respectively in the US – helped trigger a rapid expansion in biofuels output. US biofuels production, for example, rocketed from 6.70 billion litres (1.77 billion gallons) to 51.63 billion litres (13.64 billion gallons) ever this period – with ethanol accounting for 50.35 billion litres (13.30 billion gallons) of the 2010 total. Yet production subsequently rose to just 55.38 billion litres (14.63 billion gallons) by 2013, with much of this increase coming from biodiesel production[3].

Since 2011, some producers have struggled to remain profitable even though crop input prices have declined significantly. (Corn prices fell by 36%, sugar prices by 45% and soybean and rapeseed oil prices by 34% between 2011 and 2013, for example.) This has made policies mandating the production or consumption of biofuels increasingly important to sustaining demand in recent years[3].

The fact that the US is approaching the so-called ethanol 'blend wall' – the maximum permitted percentage of ethanol that can be mixed with the gasoline used by conventional vehicles – has been another important market factor. Since 2010, the limits placed on domestic demand from the blend wall, coupled to rising Brazilian and EU market demand, has seen the US emerge as a net ethanol exporter. The US and Brazil – the world's second-largest biofuel producer and another net exporter – engage in a two-way trade in biofuels. Ethanol imports into Brazil reached record highs in 2011 and 2012 after domestic production was hit by a combination of high sugar prices and a weather-related reduction in sugarcane yields[3]. US Ethanol production also slipped back by around 5% in 2012 due to record maize feedstock prices resulting from a severe drought (*Fertilizer International*, 456 p26).

The EU, backed by stringent renewable transport fuel policies, has become the world's third largest producer and a major importer of biofuels. By 2020, at least 10% of transport energy used in EU member states must come from renewable sources, as required under the 2009 Renewable Energy Directive and the Fuel Quality Directive. The EU also strengthened its sustainability criteria for biofuels by amending both directives last September. Restrictions on US and Brazil trade means the EU relies on imports from other countries such as Malaysia, Pakistan and Peru.

Short term policy certainty

2015 was an important year for biofuel policy decisions. The finalisation of policies in three key markets should ease some uncertainties over the future of the sector – at least in the short term[2]. In Brazil, for example, taxes were amended to favour hydrous ethanol (E100) over 'gasohol' – a mixture of gasoline and anhydrous ethanol. The country's mandatory anhydrous ethanol blending ratio was also increased from 25% to 27%. Brazil's biodiesel mandate is also expected to remain fixed at 7% by volume. In the European market, Renewable Energy and Fuel Quality Directive revisions adopted by the EU will cap renewable fuels sourced from food and feed crops at 7% by 2020. After long delays, the US Environmental Protection Agency (EPA) also finalised its biofuel rules for 2014-16 – the Renewables Fuel Standard – last November. The new rules permit conventional biofuel volumes of up to 16.28, 16.93, and 18.11 billion gallons for 2014, 2015, and 2016, respectively (Table 1). The standard permits growth of more than 1.8 billion gallons in the US biofuels market by the end of this year, some 11% higher than actual 2014 volumes, but considerably down on the original 2007 projection of 22.25 billion gallons by 2016. There is also plenty of scope for increased cellulosic biofuel production in the US. The 230 million gallon volume for set by the EPA for 2016 is seven times higher than the 2014 volume, although cellulosic biofuel volumes are still very small compared to the country's maize-based ethanol output.

Biofuel mandates and support policies were also strengthened in India, Indonesia and Malaysia during the past year. Lower oil prices – by triggering the removal of fossil fuel subsidies in several countries – could also help make biofuels a more attractive option[4].

Current market situation

World ethanol and biodiesel prices continued to decline in 2015 due to weak crude oil and feedstock prices. Demand was sustained by blending mandates in major world markets and overall levels of fuel use globally[2].

Global biofuel production increased by 8% in 2014 to 127 billion litres, about 4% of world transport fuel consumption, of which around three-quarters was attributable to ethanol (97 billion litres) and one-quarter to biodiesel (30 billion litres). This increase was led by a rebound of US ethanol production in the US, spurred on by a bumper maize harvest which lowered production costs.

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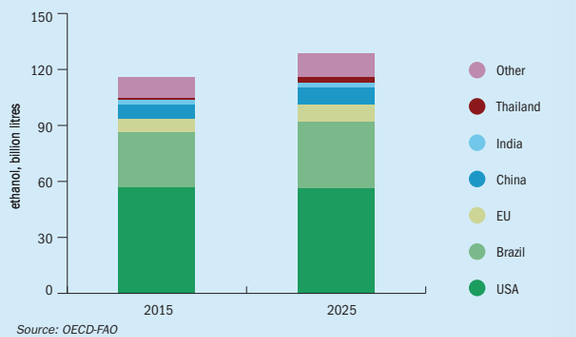
These production figures were issued by the International Energy Agency (IEA) in its latest biofuels outlook published last October[4]. Over the medium-term, IEA expects global biofuel production to reach 144 billion litres by 2020, almost one sixth higher than in 2014. The rise in biodiesel output by 2020, of just under a quarter to 37.5 billion litres, is forecast to outpace the 10% growth in ethanol production to 107 billion litres over this period. Overall, the IEA's five-year outlook paints a relatively stable picture with biofuels accounting for 4.3% of global transport fuels in 2020, on an energy basis, only slightly more than the current share. Over the short-term, the IEA expects the biofuel market to expand by 7% in 2015, largely driven by greater ethanol output from Brazil, followed by more modest growth of 2% this year.

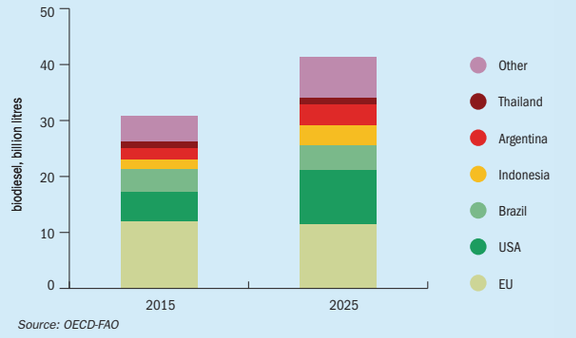
US fuel ethanol production grew last year reaching more than 55 billion litres. Brazil's biofuel output also reached a record 516 kilobarrels per day in 2015, following a good sugarcane harvest, and should eventually rise to around 675 kb/d by 2021[1]. Ethanol production in China, the world's third largest producer after the US and Brazil, is forecast to reach 3.15 billion litres this year, a rise of nearly 3% on last year, driven by consumption in provinces with blending mandates. Raising national ethanol output could also help China reduce its huge maize inventories, as well as consume poor quality maize which is unsuitable for animal feed. Chinese biodiesel production is expected to remain flat at 1.14 billion litres in 2016[1].

Fig 1: **World ethanol production**



Source: OECD-FAO

Fig 2: **World biodiesel production**



Source: OECD-FAO

Longer-term outlook

The OECD-FAO published its latest ten-year outlook for biofuels in July[2]. Although there is a broad consensus over the state of the market and its future direction, the OECD-FAO baseline figure for 2014 world biofuel production (144 billion litres) is considerably higher than the IEA's estimate (127 billion litres).

World ethanol production looks set to rise by more than 10% over the next decade, predicts the OECD-FAO, from 115.6 billion litres in 2015 to 128.4 billion litres by 2025 (Figure 1 and Figure 3). More than half of this production increase is likely to come from Brazil, largely to supply increasing domestic demand.

The OECD-FAO also expects global biodiesel production to increase by more than a third over the next decade, from 30.9 billion litres in 2015 to 41.4 billion litres by 2025 (Figure 2 and Figure 3). This expansion will be driven by policies already in place in the US, Argentina, Brazil and Indonesia. The EU is expected to remain the major producer of biodiesel supplemented by significant production from the US, Brazil, Argentina and Indonesia and Thailand.

One notable finding from the OECD-FAO outlook is that production in two major markets will peak over the next four years and decline thereafter. US ethanol production from maize could even peak as early as this year, as the country's maize-based ethanol mandate ('conventional gap') is expected to reach a high of 54.9 billion litres in 2016 only to fall back 50.7 billion litres by 2025. Ethanol produced for fuel in the EU from wheat, coarse grains and sugar beet is also projected to reach a maximum of 9.7 billion litres in 2020 but then decrease to 9.3 billion litres by 2025. Likewise, EU biodiesel production is projected to reach a maximum of 12.6 billion litres in 2020 but fall back to 11.5 billion litres by 2025, below current productions levels.

The OECD-FAO outlook is, however, based on a number of assumptions:

- Advanced biofuels are unlikely to take off during the next 10 years
- The 10% ethanol blend wall in the US will continue to limit growth in ethanol use, whereas biodiesel use will expand due to a stronger advanced mandate
- Cellulosic ethanol will not be available on a large scale in the US and the country's

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Fig 3: **Biofuel production** 2007-2015

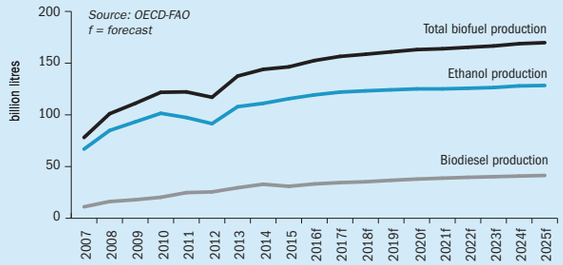
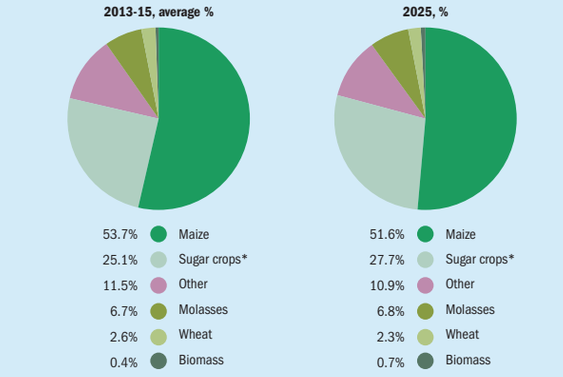


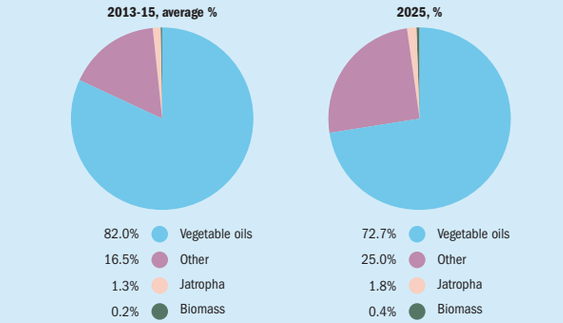
Fig 4a: **Volumetric share of global ethanol production by crop size**



** includes sugar cane and sugar beet*

Source: OECD-FAO

Fig 4b: **Volumetric share of global biodiesel production by crop size**



Source: OECD-FAO

- cellulosic mandate will be mostly met with renewable compressed natural gas and renewable liquefied natural gas instead
- The proportion of total transport energy accounted for by biofuels In the EU will reach 6.3% by 2020, with the rest of the 10% Renewable Energy Directive target being met using electric cars and other renewable energy sources
- Prices will favour hydrous ethanol over gasohol and sustain ethanol demand in Brazil, which will be mostly met by domestic production
- Indonesian biodiesel production will be used mainly to meet domestic mandate-driven demand
- The introduction of new policies in India, designed to compensate sugar mills for high sugar prices, will encourage ethanol production from molasses
- Biofuel trade will remain limited with most ethanol exports originating in the US due to the limits on domestic demand imposed by the blend wall
- Biodiesel exports will mainly flow from Argentina to the US to help meet the country's biodiesel and advanced mandates
- Indonesian biodiesel exports will remain marginal due to the high tariffs imposed by importing countries

Crop mix

Coarse grains and sugarcane will remain the dominant ethanol feedstock over the longer term, predicts the OECD-FAO, and vegetable oils will also continue to be the feedstock of choice in biodiesel production. Biofuel production is expected to consume 10% of coarse grains, 12% of vegetable oil and 22% of global sugarcane production globally by 2025, although the mix of crops used as feedstock will alter somewhat over the next decade[2]. Maize-based ethanol, for example, will decline slightly from 54% of global production volumes currently to 52% by 2025, whereas the share of global production derived from sugarcane will rise slightly from 25% at present to 28% by 2025 (Figure 4). The proportion of global biodiesel production based on vegetables oils will also decline significantly from 82% currently to 73% by 2025[2].

The use of molasses in Indian ethanol production looks set to increase in future. Greater biodiesel production based on non-agricultural feedstock – from waste oil and tallow in particular – is also likely to occur

Table 2: **Fertilizer demand from biofuels** 2009-2010

	N (million tonnes)	P_2O_5 (million tonnes)	K_2O (million tonnes)	Total nutrients
US maize ethanol	2.04	0.67	0.60	3.30
Brazil sugarcane-ethanol	0.32	0.11	0.27	0.70
Other ethanol crops	0.47	0.16	0.17	0.80
EU rapeseed-diesel	0.48	0.10	0.13	0.70
Other biodiesel crops	0.14	0.10	0.25	0.39
Total for biofuel crops	3.45	1.13	1.32	5.90
Biofuel demand, share of world consumption (%)	3.4	3.0	5.6	3.6
World consumption	**102.6**	**37.5**	**23.5**	**163.7**

Source: IFA (2011)

in the EU and US. Advanced biofuels production based on ligno-cellulose biomass will, however, remain in its infancy and is projected to account for less than 1% of world ethanol production by 2025[2].

Fertilizer demand

The most comprehensive industry study of fertilizer demand from biofuels production dates back to 2011[5]. In total, some 5.90 million of nutrients were applied to biofuel crops in 2009/10, according to IFA estimates, equivalent to around 3.6% of world fertilizer consumption. This breaks down into 3.45 million tonnes N, 1.13 million tonnes P_2O_5 and 1.32 million tonnes K_2O – equivalent to 3.4%, 3.0% and 5.6% of global consumption, respectively (Table 2). These figures assumed that 37% of US maize, 55% of Brazilian sugarcane and 55% of EU rapeseed production were consumed as biofuel feedstock.

> **Large scale commercial production of advanced biofuels will be necessary in future, according to the IEA, as part of moves to decarbonise the transport sector.**

Maize grown for ethanol in the US accounted for the lion's share of N (60%), P (60%) and K applications (45%) to biofuel crops globally in 2009/10. US maize-ethanol production required a total of 3.3 million tonnes of nutrients in 2009/10, compared to 0.7 million tonnes nutrients each for both Brazilian sugarcane-ethanol production and EU rapeseed-biodiesel production. IFA forecasts that world N consumption by biofuel crops could increase to above 4.5 million tonnes N by 2019, just under 4% of world demand, although this estimate dates from 2010.

A stable future?

The IEA expects biofuels production to stabilise at 4% of road transport demand by 2020. Although biofuels policies have recently been strengthened in key markets such as Brazil, India, Indonesia and Malaysia, mandates may be re-examined if the oil price continues to remain low. "A continued low oil price environment may lead to increased scrutiny of support policies for biofuels going forward and the decline in gasoline and diesel prices has already affected discretionary blending economics in certain markets," comments the IEA.

A relatively stable outlook for biofuels over the remainder of this decade is likely to mean that associated fertilizer demand will also remain broadly constant at around 3-4% of world consumption – with the caveat that this estimate is five years out of date. The biofuel market outlook beyond 2020 is more problematic due to the increasing levels of uncertainty. However, the OECD-FAO is forecasting that EU crop-based ethanol and biodiesel production will decline over the longer-term, as will US maize-derived ethanol production.

One of the main long-term risks to fertilizer demand for biofuels will be the eventual switch from conventional crop-based production to advanced biofuels produced from biomass wastes, such as wheat, barley and rice straw, tall oil, cornstover, corncobs and sugarcane bagasse. Large scale commercial production of advanced biofuels will be necessary in future, according to the IEA, as part of moves to decarbonise the transport sector.

The current low oil price is, however, delaying this transition by holding up research and development and making advanced biofuels less economic. "Since 2013 advanced biofuels have made good progress, with nine commercial-scale plants commissioned, seven of these in 2014-15," comments the IEA. "New projects may require oil prices around $100/bbl or above to be attractive. There is significant potential to reduce costs. But a sustained long-term policy commitment would be needed, which may face risks from the lower oil price environment." ■

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Circular arguments about EU fertilizers

Jyrki Katainen, commission vice president in charge of jobs, growth, investment and competitiveness.

How fertilizers are traded and sold in the European market will change dramatically if rule changes proposed by the European Commission are adopted. We review the EU's new draft fertilizers regulation and its potential impact on what remains one of the world's major fertilizer markets.

The EU fertilizer industry is an important part of Europe's economy. The sector generates an annual turnover of €12.5 billion from more than 120 production sites across the continent and employs around 93,000 people. The industry also supports innovation and invested €66 million in research and development last year. Europe is also a sizeable market for fertilizers exported from Russia, North Africa and North America. The region's farmers apply 16-17 million tonnes of nutrients annually to around 130 million hectares of farmland. EU fertilizer imports have grown since the 1990s as the region's production base has contracted (*Fertilizer International*, 471 p25).

The rules governing how domestic and imported fertilizers are traded and sold across the EU are about to change, sparking criticism from regional and global fertilizer trade bodies. Fertilizers Europe calls some of the regulatory changes unacceptable, whilst the International Fertilizer Association (IFA) warns they could potentially block EU imports of phosphate rock from countries such as Algeria, Egypt, Morocco, Peru, Senegal and Togo.

The stakes are high, as Javier Goñi del Cacho, Fertilizers Europe's president makes clear: "Ultimately, we are talking about the availability of food in Europe and beyond. The mineral fertilizer industry is an integral part of European agriculture, providing products that offer better yields for Europe's farmers."

New rules for EU fertilizers

The European Commission finally published its draft fertilizers regulation on the 17 March, the culmination of review process which first began six years earlier[1]. The central purpose of the new regulation is to provide fertilizers made from organic, recycled or recovered materials with free and unrestricted access to the single European market, thereby creating a level playing field with mineral fertilizers. "This will create new market opportunities for innovative companies while at the same time reducing waste, energy consumption and environmental damage," claims the commission. Currently approved mineral fertilizers will be allowed to remain on the market, subject to compliance with newly-introduced safety and quality requirements.

The draft fertilizers regulation is the first legislative outcome of the ambitious new 'Circular Economy Package' adopted by the EU last December. In a circular economy – unlike the conventional 'take-make-dispose' linear economy – waste is kept in economic circulation as a valued resource. This is achieved by turning waste into secondary raw materials or by re-using discarded products. Changes to manufacturing can also 'design out waste' by making products easier to take apart, repair, refurbish and re-use.

The commission claims the new regulation will help recycle nutrients and create valuable fertilizers from organic waste: "Very few of the abundant bio-waste resources are transformed into valuable fertilising products. Our farmers are using fertilisers manufactured from imported resources or from energy-intensive processes," said Jyrki Katainen, the European Commission's vice-president for jobs, growth, investment and competitiveness. "This regulation will help us turn problems into opportunities for farmers and businesses."

Organic fertilizers and cadmium limits

Fertilizers, like many products traded in the European single market, need to carry a CE (Conformité Européene) mark to confirm they meet minimum safety, health and environmental standards. The draft regulation overhauls the CE mark for fertilizers, widening its scope to include organic fertilizers for the first time. Critically, it also introduces strict limits for cadmium in phosphate fertilizers.

In future, both organic and mineral fertilizer products freely traded within the EU will need to comply with a revised set of safety, quality and labelling requirements – and meet limits for physical impurities and organic and microbial contaminants – before qualifying for a CE-mark. Controversially, to reduce health and environmental risks, the cadmium content of phosphate fertilizer will be limited to 60 mg/kg initially, and then progressively tightened to 40 mg/kg after three years and finally to 20 mg/kg after 12 years.

The commission's overall ambition is "to help create level playing field" for all types of fertilizers while at the same time ensuring high standards of safety and environmental protection. In summary, the proposal:

- Provides rules for free movement of CE marked fertilizers across the EU
- Updates current requirements for CE marked mineral fertilizers
- Introduces new quality, safety and labelling requirements for CE marked fertilizers, liming materials, soil improvers, growing media and biostimulants.
- Allows manufacturers to opt-out of CE compliance for fertilizers sold and traded nationally within a single member state
- Streamlines the compliance process for fertilizer manufacturers by modernising declaration of conformity and conformity assessment procedures
- Enables fertilizers derived from properly processed animal by products to move freely within the EU single market
- Introduces 'end of waste' recovery rules allowing certain bio-wastes (composts, digestates) to be transformed and sold as components of marketable fertilizer products

In its rationale for the new draft fertilizers regulation, the European Commission sets out the two main policy objectives it wishes to achieve. Firstly, it wants to allow **innovative fertilizer products** made from recycled and recovered nutrients to be more widely distributed and sold across Europe. Secondly, the commission also wants to tackle potential **environmental contamination** that may result from fertilizer use, as the existing regulation fails to properly address this in its view.

Innovative fertilizers

Innovative fertilizer products have difficulty accessing the EU's internal market currently, particularly those containing nutrients recovered from waste or based on recycled organic matter.

This is because they fall outside the scope of the current EU-wide fertilizer regulation and are covered instead by different rules and standards applied at a national level.

The current EU regulation was almost exclusively designed with mineral fertilizers in mind. "Virtually all product-types currently included in the existing fertilisers regulation are conventional, inorganic fertilisers, typically extracted from mines or chemically produced," points out the commission. "Also, the chemical processes for producing for example nitrogen-based fertilisers are both energy consuming and CO_2-intensive."

In contrast: "Around 50 % of the fertilisers currently on the market… are left out of the scope of the regulation," the commission adds. "This is true for a few inorganic fertilisers and for virtually all fertilisers produced from organic materials, such as animal or other agricultural by products, or recycled bio-waste from the food chain."

The existing EU fertilizer regulation – because it covers consistent quality mineral fertilizers sourced from primary raw materials – lacks proper controls and safeguards needed to create trust in fertilizers made from variable secondary and organic raw materials.

This is discriminatory, distorts competition and is preventing investment in the circular economy in the commission's view. "In summary, the playing field in the competition between those fertilisers sourced from domestic organic or secondary raw material in line with the circular economy model and those produced in line with a linear economy model is tilted in favour of the latter," it concludes.

There is also a pressing need to recycle more nutrients in the EU, argues the commission, largely due to resource security concerns over phosphorus. Because of the EU's dependency on resources outside of the EU, the commission classifies phosphate rock as a critical raw material. More than 90% of the phosphate fertilizers used in the EU are imported, mainly from Morocco, Tunisia and Russia.

"Domestic waste (in particular sewage sludge) contains large amounts of phosphorus, which – if recycled in line with a circular economy model – could potentially cover about 20-30% of the EU's demand for phosphate fertilisers," reports the commission. Yet the investment potential of recycled phosphate technology remains "largely unexploited" because recycled phosphate fertilizers have difficulty accessing the EU's internal market.

The European Commission hopes that increasing production and trade in innovative fertilizers, by expanding the range of different fertilizers available to farmers, will also make EU food production less costly and more resource efficient.

Environmental contamination

The commission's second policy objective is to introduce a single cadmium limit for EU-traded phosphate fertilizers to minimise "the negative impact of fertiliser use on the environment and on human health". It describes the presence of cadmium in mineral-based phosphate fertilizers as a "well-recognised issue" and hopes a new EU-wide limit will reduce cadmium accumulation in soil, water and food.

The move has become necessary, in the commission's view, because current EU regulation "fails to address environmental concerns arising from contamination by fertilisers of soil, inland waters, sea waters, and ultimately food". Some member states, in the absence of an EU-wide limit values, have also unilaterally imposed their own cadmium limits for fertilizers, causing the single European market to fragment. The environmental risks from contaminants in nutrients recycled from sewage sludge pose similar problems, especially as these are also regulated at national level currently. The commission is particularly concerned about polymer, metal and glass contamination in fertilizers derived from bio-waste.

The draft regulation also sets out conditions under which fertilizers produced from waste and animal by products can be exempted from other EU controls, such as regulation 1069/2009, thereby allowing them to be placed on the European market and freely circulated as CE marked fertilizers.

Industry reaction

Fertilizers Europe wrote to the commission on 11 May setting out in detail its reaction to the proposed regulation (see box). In particular, Europe's fertilizer trade body expressed deep concerns over the proposed cadmium limits and a new biodegradability requirement for controlled release fertilizers (CRFs). These parts of the regulation "can simply not be accepted by our manufacturers", Fertilizers Europe warned.

In its response to the commission, the International Fertilizer Association (IFA) also focussed on the CRF biodegradability proposals and the new cadmium limits for phos-

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Fertilizers Europe's policy position

Quality first

In its consultation response to the European Commission's proposals, Fertilizer Europe points out the massive issues at stake: "Ultimately, this piece of legislation is about food production and food security in the European Union and beyond." Europe's fertilizer industry trade body advised the commission that the new regulation's first priority "must be to ensure the quality of fertilizing products, and especially mineral fertilizers". The proposed legislation must also help the EU's farmers make informed choices about fertilizer selection, in its view, if crop profitability is to be increased and environmental impacts minimised.

Unacceptable provisions

Fertilizers Europe is deeply concerned about the commission's proposals. In its view, the draft regulation places "the availability of key mineral fertilizers at stake" and will have a negative impact on the international competitiveness of Europe's farmers "This is specifically the case for the overly ambitious limits proposed for cadmium in phosphate fertilizers and for the unrealistic biodegradability requirements foreseen for Controlled Release Fertilizers," says Fertilizers Europe, adding: "Here the provisions of the draft Regulation can simply not be accepted by our manufacturers."

Clearer definition

In particular, Fertilizers Europe advises that the proposal would have "the curious consequence" of allowing fertilizers with up to 7.5% organic carbon to be classified as inorganic, raising question marks about the quality of the inorganic/mineral fertilizer product category as a whole. To remedy this, it suggests capping the organic carbon content of mineral fertilizers at 1% maximum (excluding carbon present in coatings or derived from urea condensates), and also wishes to see the following definition inserted into the regulation: "An inorganic fertilizer shall contain nutrients other than nutrients from animal or plant origin, unless processed into a mineral form."

Nutrient availability

The total nutrient content declaration in the new regulation is also potentially misleading, according to Fertilizers Europe, because farmers may assume that all of these nutrients are plant-available. The trade body wants to see only plant available nitrogen declared as part of the new regulation, together with a minimum solubility level for phosphate fertilizers to guarantee P availability.

Access to phosphate at stake

The progressive reduction of the cadmium limit in phosphate fertilizers introduced by the new regulation – from 60 mg/kg P_2O_5 initially to 40 mg/kg P_2O_5 after three years and finally to 20 mg/kg P_2O_5 after 12 years – would "significantly and negatively affect competition and prices of finished phosphate fertilizers", according to Fertilizers Europe. It points out that, because Europe relies on external sources for 90% of its phosphate rock, the proposed cadmium limit would place supply in the hands of "a limited number of phosphate rock suppliers" and "put at stake the access to phosphate rock in the EU".

Gravely, the trade body also warns of serious, negative consequences, including job losses, if the European Commission was to proceed with the regulation in its current form: "It would endanger the future of phosphate fertilizer producing companies operating nitrophosphate and TSP/SSP processes. They would not be able to meet the overly ambitious [cadmium] limits proposed. These manufacturing processes represent one third of fertilizers' manufacturing in Europe. Overly ambitious limits on cadmium would also affect the European NPK fertilizer industry very negatively, and would lead to job losses in the EU."

Fertilizers Europe has told the commission that a cadmium limit of 60 mg/kg P_2O_5 strikes "a reasonable balance" between concerns over availability and environmental considerations. "This is supported by the lack of economically viable, industrial-scale decadmiation processes and technologies… The industry could therefore accept higher limits, but will not support lower limits," in its view. It also cites the findings of the recent 'Smolders Study' which concluded that a cadmium level of 80 mg/kg P_2O_5 in fertilizers does not lead to accumulation in soils.

Controlled release fertilizers

The commission is proposing that the polymer coatings of controlled release fertilizers (CRF) will need to comply with new biodegradability criteria three years after the regulation's introduction.

This requires the conversion into carbon dioxide of at least 90% of the organic carbon from polymer coatings present in soil within 24 months at 25°C (+/- 2°C). However, Fertilizer Europe's position is that:

- The proposed degradation is unachievable for any polymer coating currently on the market
- The function of CRF requires slow degradation
- The proposed requirement is not supported by an impact assessment
- CRFs ensure an efficient use of nutrients

Biodegradability criteria

Fertilizer Europe is calling for the introduction of CRF biodegradability criteria to be delayed for up to five years. In the interim, it wants to see the immediate launch of a research programme to devise a standard test for polymer coating degradability, followed by an impact assessment on the economic, environmental and social consequences of the EU's biodegradability requirement.

Fertilizers Europe is also concerned about possible confusion and overlap between plant protection products and fertilizers in the new regulation. It argues that only those materials which provide nutrients or improve nutrient efficiency – such as fertilizers, liming materials, soil improvers, growing media, agronomic additives and plant biostimulants – should fall within the scope of the new regulation.

Market reality

While welcoming the commission's approach to the circular economy and the use of alternative sources of nutrients, especially for phosphate, Fertilizers Europe is pressing for clear rules on contaminants and pathogens to ensure the "use of waste that poses risks to the environment and that does not serve an agronomic purpose" is disallowed.

Fertilizers Europe also points out that, whilst manure and slurry can meet part of EU agricultural sector's nutrient requirements, organic fertilizers are insufficient to cover the total nutrient needs of Europe's farmers, especially for nitrogen. Mineral fertilizers currently represent around 80% of the EU fertilizer market by product value, whereas organic fertilizers are "primarily used locally" with only "very small amounts traded on the market", according to Fertilizers Europe. This is largely a consequence of "their high water content, limited nutrient levels and variable nutrient content" in its view. ■

phate fertilizers. IFA points out that many polymer coatings used in CRFs are composed of vegetable oil, and that controlled-release technology also reduces the environmental impact of fertilizers by ensuring higher nutrient use efficiency. Although it agrees with the objective of reducing polymer accumulation in soil, IFA suggest that an impact assessment is necessary first, due to the lack of scientific data on the degradation of polymers used in fertilizer granule coatings.

On cadmium limits, IFA comments that: "While preventing cadmium build-up in agricultural soils may be a legitimate objective, it appears that the cadmium limits currently proposed have been set arbitrarily. IFA recommends that any new regulation should be based on sound scientific information."

The association also draws attention to the conclusions of the Scientific Committee on Problems of the Environment (SCOPE) which found "no conclusive evidence of an adverse impact of the cadmium in phosphate fertilizer on human health, even in Australia which has a long history of application of phosphate fertilizer with a high cadmium content".

IFA warns that: "If low [cadmium] limits were widely adopted [by the EU], the use of most rocks from Algeria, Egypt, Morocco, Nauru, Peru, Senegal, Syria, Togo and Tunisia would be excluded, to the evident detriment of these countries' developing economies. It would also exclude phosphate rock from certain areas of the United States."

Crop production threat

The commission's plan to limit supply to low-cadmium phosphate fertilizers is, says IFA, "scarcely appropriate, given the great variation in soil conditions leading to cadmium uptake by plants" and the low risk of exceeding the ceiling for cadmium uptake by humans. "If set too low, the impact of a universally adopted standard limit on the cadmium content of phosphate fertilizers, could seriously threaten crop production in many developing countries and the economies of some phosphate rock-producing countries," IFA concludes

Instead of resorting to regulation, IFA recommends using 4Rs nutrient stewardship – using the right nutrient, at the right rate, at the right time, in the right place – as an effective tool for cadmium management, particularly when choosing the right source of phosphorus and the right application rate. However, the 4Rs are likely to have a limited role in improving cadmium management, in the view of Fertilizers Europe, as it is already a long-standing practice in EU farming.

Identifying high cadmium soils and then modifying crop management techniques accordingly is also vital, suggests IFA. The association advises that liming, applying fertilizers supplemented with zinc, and cultivating crops with low cadmium uptake, are "simple measures to reduce risks of cadmium transfer to the food chain".

Europe's farmers are also concerned about the commission's proposals on cadmium limits. Pekka Pesonen, the secretary-general of European farming body COPA-COGECA, warned of the following consequences: "Should the maximum level of cadmium become too strict, the price of phosphate, mainly from Russia, would increase sharply, putting pressure on the depletion of phosphorus in European soils." ■

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Sustainability matters

We review current international initiatives and cooperation on nitrogen use efficiency and phosphorus sustainability.

Resource efficiency makes economic and environmental sense. In manufacturing, for example, maximising product output whilst simultaneously minimising water, energy and material inputs cuts costs and reduces the consumption of non-renewable resources. It can also help reduce exposure to commodity price volatility and minimise resource security risks in the supply chain.

What also makes efficient resource use a compelling idea is its ability to bring together common economic and sustainability goals. Indeed, the need for better resource efficiency and resource stewardship is an issue that environmental campaign groups, industry and policy makers all seem to agree on.

The efficient use of resources also goes to the heart of the debate about fertilizer sustainability. The statistics on average nutrient use efficiency – the proportion of nutrients actually used by crops in the first year after application – are stark. For fertilizers applied to major cereal crops, nitrogen efficiency is around 40-65%, potassium efficiency in the region of 30-50% and phosphorus efficiency just 15-25%[1].

The above figures are for plots managed by agronomic researchers. Values for nitrogen use efficiency on fields managed by farmers are even less encouraging. Up to 70-80% of applied N can be lost in rain-fed conditions and 60-70% lost in irrigated fields, when fertilizers are not managed properly. Judging nutrient use efficiency over a one year time scale is somewhat arbitrary, however, especially in the case of phosphorous, as applied P can remain available to crops for a decade or longer[1].

Nitrogen and phosphorus use efficiency have emerged as issues of international importance in recent years, due in part to the UN-brokered agreement on Sustainable Development Goals (see box). Yet it is impossible to set goals on efficient nutrient use, let alone monitor progress on this, without first agreeing how it is defined, measured and indicated.

Focus on nitrogen use efficiency

Fresh recommendations on nitrogen use efficiency (NUE), and how it is best measured and indicated, emerged in Europe and North America last year in a report[2] by the EU Nitrogen Expert Panel and a position paper[3] by the Global Partnership on Nutrient Management (GPNM).

The GPNM is an authoritative, UN-supported international partnership of government, private sector, scientific and civil society organisations. In May 2013, It put together a 'task team' to investigate NUE and nutrient performance indicators and report back on this after a workshop convened in Washington at the end of 2014. The task team's remit was to:

- Develop definitions and parameters for NUE
- Establish baseline NUE data at global and regional level
- Offer a suite of nutrient performance indicators
- Establish NUE targets for major crops

In its position paper, the GPNM task team links the efficient and effective use of nutrients to both food security and reducing losses to the environment[3]: "While balanced nutrition is important, nitrogen in particular is fundamental to raising crops and animals to feed the world now and in the future. Much of the increase in food production over the past half century can be attributed to the use of synthetic nitrogen fertilizers."

Partial nutrient balance has merits

The task team recommended using **partial nutrient balance (PNB)** – a type of output/input ratio – to measure NUE (see box). PNB is essentially a 'removal-to-use' indicator, being derived from:

- **The sum of nitrogen removed** in all of the products from the field, including harvested crops or livestock products and stover or other materials removed, and
- **The sum of all inputs of nitrogen** to the field, farm or region, including fertilizers, imported animal manure, compost, green manure, other soil amendments, imported animal feed and biological nitrogen fixation

When measured in this way, NUE values above one indicate a deficiency whereas values less than one indicate a surplus.

"When NUE < 1, more N is being applied than is being removed, and the N not removed could either be stored in the soil and/or flow through to the environment causing ecosystem degradation," comments the task team, adding: "When NUE > 1, more N is being removed than is being supplied, which indicates that the soil is being mined of nutrients, eventually depleting soil fertility."

What makes partial nutrient balance valuable as an indicator, according to the task team, is that it allows NUE to be used in two different ways:

- Firstly, as a **benchmark** "to show the current starting point" and
- Secondly, as a **progress indicator** "from which future improvements can be assessed"

This NUE indicator can be applied at many different scales from individual farms to whole countries. Examples of how NUE can improve relative to an initial benchmark are shown in Figure 1. Progress from the upper left quadrant to the lower right quadrant on this diagram benefits both farmers and the environment.

Rather than being assessed in isolation, the task team suggests that NUE – because it relates to both crop production and soil health – needs to put in context and used in combination with other indicators.

Patience may also be necessary, as NUE improvements do not always provide an immediate environmental dividend. "Significant lags between improvements in NUE and reductions in N pollution of groundwater and surface waters may

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Spotlight on nutrient use and efficiency

Efficiency goals urged

2013 was arguably the year in which nutrient efficiency began to garner high-level international attention as an issue, and sustainability in the fertilizer industry gained fresh impetus. The joint *Our Nutrient World* report released that year by the Global Partnership on Nutrient Management (GPNM) and the International Nitrogen Initiative (INI) was particularly influential. As an aspiration, this report suggested that every country should set a goal to improve its NUE by 20% in 2020 relative to a 2008 baseline. It recommended using two complementary indicators to achieve this:

1. **Crop NUE:** This would require each country to improve its nutrient use efficiency in the crop sector by 20% relative to its baseline – as a step towards achieving an eventual crop NUE target of at least 70%.
2. **Full-chain NUE:** This would require each country to improve its nutrient use efficiency across the 'full chain' of food production activities by 20% relative to its baseline – as a step towards achieving an eventual full-chain NUE target of at least 50%.

The UN Sustainable Development Solutions Network (SDSN) also published its *Sustainable Agriculture and Food Systems* report in September 2013. In terms of goals for nitrogen and phosphorus efficiency, it concluded that: "For countries with low full-chain efficiency an aspirational target could be to reach, by 2030, a 30% increase relative to current levels." This goal would apply to countries with high levels of nutrient consumption relative to their actual yield.

The SDSN report then went further by proposing an increase in crop NUE of 30% relative to current levels "in countries with low efficiency". It linked this with the overall aim of seeing: "Unsustainable soil nutrient depletion halted and reversed in countries with insufficient nutrient use, resulting in increased crop production and economic return."

Sustainable Development Goals provide impetus

The UN-brokered process to agree a set of Sustainable Development Goals (SDGs) has also placed nutrient efficiency under the spotlight. Around 100 'global monitoring indicators' (GMIs) will be used to monitor progress towards meeting the 17 SDGs by 2030. The SDSN's November 2014 draft report *Indicators and a monitoring framework for Sustainable Development Goals* suggested developing two nutrient indicators for SDG Goal 2. This highly ambitious goal aims to: end hunger, achieve food security and improve nutrition, and promote sustainable agriculture.

One of the suggested indicators (No 12) was for "crop nitrogen use efficiency (%)" and the other (No 13) was for "excessive loss of reactive nitrogen [and phosphorus] to the environment (kg/ha)". Later on in the process, however, only a single indicator (No 15) on "nitrogen use efficiency in food systems" was proposed in the finalised May 2015 report – although this was complemented by the development of a national indicator on "phosphorus use efficiency in food systems".

The fertilizer industry itself has also risen to the challenge of how best to measure and improve nutrient efficiency. The International Fertilizer Association (IFA) published its *Addressing Nutrient Performance Management* report in June 2014, for example. This was followed in August 2014 by the the release of a *Nutrient Performance Indicators* review by the International Plant Nutrition Institute (IPNI).

Defining nitrogen use efficiency

It is impossible to set goals on nitrogen use efficiency (NUE), and monitor these, without first defining and agreeing on how it will be measured. This is not a straightforward matter as NUE can be defined and indicated in a number of different ways (Table 1). Each NUE indicator has its own individual merits and demerits, although all are essentially just different types of output-to-input ratio. The four main choices are as follows:

- **Partial Factor Productivity (PFB)** This is a useful and simple-to-measure expression of the yield of a particular crop in comparison to nutrient input. For cereals, typical values range from 40-80 units of yield per unit of nitrogen input.
- **Agronomic Efficiency (AE)** This indicator is similar to PFB except that it compares the yield response instead of the total yield and is usually limited to research situations.
- **Partial Nutrient Balance (PNB)** Also known as removal-to-use ratio, this is a relatively crude but useful metric. Values in excess of one indicate an eventual N deficiency as the soil is being depleted or mined by successive crops. Values well below one, in contrast, indicate the accumulation of surplus N.
- **Recovery Efficiency (RE)** This measures the ability of crops to access and take-up applied nutrients. ■

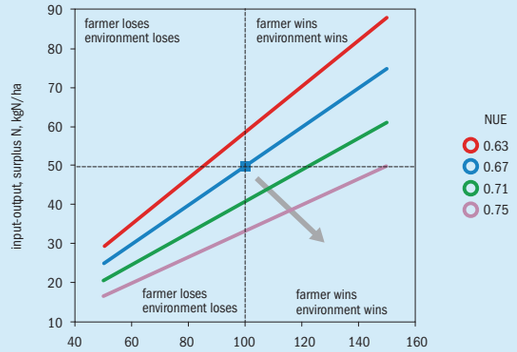
Table 1: **Four main indicators of nutrient use efficiency**

Indicator	Calculation and units	Typical values for wheat and maize
Partial Factor Productivity (PFP)	PFP =Y/F [kg grain / kg N]	40-80
Agronomic Efficiency (AE)	AE = $(Y-Y_0)/F$ [kg grain / kg N]	10-30
Partial Nutrient Balance (PNB)	PNB = R/F [kg N / kg N]	>1 = deficiency <1 = surplus
Recovery efficiency (RE)	RE = $(U-U_0)/F$ [%]	0.3-0.5

Note: Y = yield, F = fertilizer, R = removal, U = uptake

Source: GPNM task team

Fig 1: **Nitrogen input-output diagram showing trajectory for NUE from an initial benchmark**



Source: GPNM task team

occur," explains the task team. "But nevertheless, increases in NUE and reductions of surplus N in agriculture should eventually lead to lower N pollution."

Difficulties in target setting

The task team does not specify targets for NUE, but recommends avoiding extreme values instead. "Neither a high nor a low NUE is an implicit target, but raising low values, which usually indicate inefficient use of added nitrogen, and lowering very high values, which usually indicates mining of soil nitrogen, will require appropriate interventions at the farm level," concludes the task team.

It adds: "While it is very difficult to establish hard and fast NUE goals, we can generalize that when NUE < 0.5, there is probably a large opportunity for improving NUE. At the other extreme, when NUE > 0.9, it is likely that efficiency cannot be improved further without risking mining of soil nutrients."

Reaching the conclusion that NUE values of between 0.5 and 0.9 are generally acceptable is, however, a problematic judgement. "Many of the countries that fall between 0.5 and 0.9 NUE… are likely to have potential for further improvements," comments the task team.

It also needs to be recognised that mineral fertilizer application and nutrient management may not be the only or most important influence on use efficiency either. The variation in NUE between countries may reflect "differences in the crop grown, the use of manures and the importance of legume-based rotations, as much as differences in nutrient management practices" in the task team's view.

A tiered approach

The task team recommends a tiered system for collating NUE values, similar to the approach used by the Intergovernmental Panel on Climate Change for greenhouse gas emissions accounting. This has the merit of allowing NUE values to be classified according to the availability and quality of nitrogen input and output data. The following three-tier system is proposed:

- **Tier 1:** NUE estimated from global default values for nitrogen content of inputs and outputs (crop products, fertilizers, manures etc.) combined with local or national data on yield (bushels/acre, tons/hectare etc.) and input rates (fertilizer application rates, manure application rates, feed supplement rates etc.)
- **Tier 2:** NUE determined using available site-, regional-, or national-level nitrogen data for inputs and outputs.
- **Tier 3:** NUE values obtained (at farm scale or larger scales) from a validated nitrogen input and output model, incorporating factors such as economic conditions, commerce, soils, climate, crop performance characteristics, available technology etc.

EU Nitrogen Expert Panel

The independent EU Nitrogen Expert Panel (*Fertilizer International*, 463 p12) was convened in 2014, at the invitation of trade body Fertilizers Europe, with the aim of:

- Communicating a vision and strategies on how to improve nitrogen use efficiency in food systems
- Generating new ideas, and recommending effective proposals and solutions
- Acting as referee during controversies and communicating with authority on nitrogen issues

The NUE indicator proposed by the EU expert panel in its 2015 report – in keeping with the GPNM task team's recommendation – is based on a **nitrogen output/input ratio**[2]. The panel also recommended that this NUE indicator should be interpreted alongside values for **nitrogen output** (productivity) and **nitrogen surplus** (the difference between nitrogen input and harvested nitrogen output).

The NUE values derived from these indicators are simple to plot on an input-output graph (Figure 2) as the panel makes clear: "The NUE indicator is easily presented via… an input–output diagram. This allows the presentation of NUE, nitrogen output and nitrogen surplus… together with possible reference or target values."

Tassos Haniotis of DG Agriculture at the European Commission, who co-chaired the expert panel, endorsed the proposed indicator: "The NUE indicator is simple, useful and applicable to all systems. It allows decision makers to examine differences in NUE between farms, between specific systems, between countries, and between years… As such, NUE can serve as a valuable indicator for monitoring sustainable development in relation to food production and environmental challenges".

Monitoring SDGs

The NUE indicator was linked to UN Sustainable Development Goals (SDGs) by one of the EU report's authors, Professor Achim Dobermann of Rothamsted Research: "Concrete targets, pathways and indicators need to be developed at country scale and below for monitoring the SDGs. The proposed NUE indicator framework is suitable for setting realistic targets and monitoring of progress in that context".

Nutrient use efficiency is one of the proposed 'global monitoring indicators'

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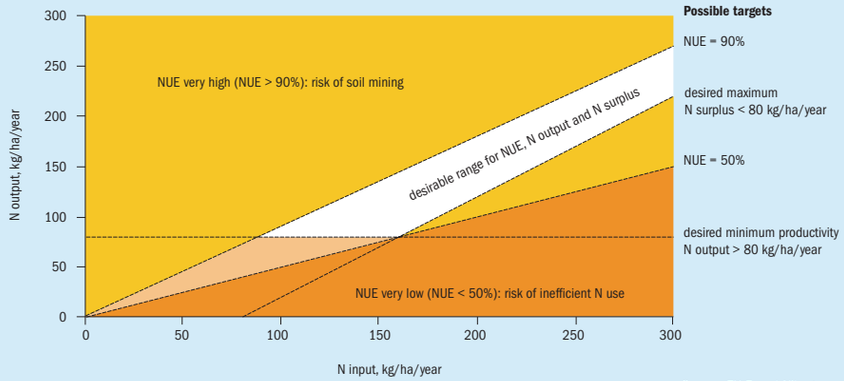
Fig 2: **Nitrogen input-output diagram with possible targets for NUE, N output and surplus**



Source: EU Expert Nitrogen panel

(GMIs) for SDG Goal 2, complemented by a national indicator for phosphorus (see box). However, although recommended by both UNEP's GPNM task team and the EU Nitrogen Experts Panel, the suggested NUE indicator is not used widely at present[4]. Tracking nitrogen use efficiency will demand major improvements in data collection, according to the Sustainable Development Solutions Network (SDSN), including:

- Annual nutrient use and crop removal statistics for fertilizers and other nutrient sources at sub-national level and by crop type
- Regular field monitoring of nitrogen use efficiency and related indicators for soil fertility and nutrient stewardship

"We believe that nitrogen and phosphorus are the two most important nutrients to track, but we underscore that sustainable food systems will require sound management of many other nutrients, including potassium and soil organic matter," concludes the SDSN.

Phosphorus rises up the agenda

The Global Partnership on Nutrient Management (GPNM) operates under the aegis of the United Nations Environment Programme (UNEP) and its Global Programme of Action (GPA) to protect the marine environment from land-based activities. The GPNM's main focus to date has been on nitrogen use efficiency and its associated environmental impacts. Nitrogen sustainability is also being addressed at the global level through collaborations such as the International Nitrogen Initiative (INI). Yet, until recently, no comparable global initiative on phosphorus existed.

Fortunately, this situation has now changed with the GPNM's launch of a phosphorus 'task team' at an inaugural meeting in Edinburgh last September. The meeting garnered wide support with representatives of the International Fertilizer Association (IFA), the International Plant Nutrition Institute (IPNI), Virtual Fertilizer Research Center, the European Sustainable Phosphorus Platform (ESPP), the Global Phosphorus Network all attending. The proposed action plan and remit for the task team which emerged from the meeting included:

- Developing an agreed model for the phosphorus cycle
- Addressing full-chain (mine-to-fork) phosphorus use efficiency
- Proposing indicators on phosphorus sustainability in food production and collating reliable data
- Assessing opportunities for the recycling and use of phosphogypsum

Compared to nitrogen use efficiency, meaningful measurement of an equivalent use efficiency indicator for phosphorus is in its infancy. The GPNM's formation of an international task team on phosphorus with UNEP's backing should, however, spur progress.

North American Partnership for Phosphorus Sustainability

Europe has been at the vanguard of phosphorus sustainability internationally, thanks in large part to the long-standing European Sustainable Phosphorus Platform (ESPP). Following the Second European Sustainable Phosphorus Conference (ESPC2) held in Berlin in March 2015, the ESPP has been influencing EU policymaking by pressing for action in 12 specific policy areas.

One of the ESPP's main objectives is to make phosphorus stewardship, reuse and recycling a central part of the EU's Circular Economy Policy Package – something it has arguably already achieved (see p28). It is also pressing for effective European-wide policy measures to reduce phosphorus losses from agriculture, including precision nutrient management, buffer zones along watercourses and mitigation of soil erosion.

The ESPP has also provided a successful template for others to copy and adapt. In 2014, the US-based Phosphorus Sustainability Research Coordination Network (P RCN) unveiled plans for a similar sustainable phosphorus initiative, the North American Partnership for Phosphorus Sustainability (NAPPS). This relatively new endeavour is modelling itself on the ESPP and was established with seed funding from Arizona State University.

NAPPS' remit is to implement P sustainability in the private and public sector, take on a strategic role in policy creation and tackle decision-making bottlenecks. In practice, this is likely to involve activities such as:

- Formulating a shared vision for P sustainability in North America.
- Highlighting emerging opportunities in P sustainability
- Building networks on phosphorus management
- Evaluating new P efficiency and recycling technologies
- Aiding the development of regulations in areas such as water, waste and environmental management and agriculture
- Representing North America at international meetings and initiatives
- Preparing funding proposals for demonstration projects

To date, NAPPS has decided on its organisational structure, drawn up a strategic plan and appointed a board of directors and an advisory board. Its newly-appointed board met for the first time in Washington in May last year. NAPPS is coordinating its work in North America by networking with other international sustainability initiatives, including the Global Phosphorus Network, the Global Phosphorus Resource Initiative, Global TraPs, the Japan Phosphorus Recycling Council, the ESPP and national Nutrient Platforms in Germany, the Netherlands and the UK.

> **"China's zero growth fertilizer policy will require a step change in nutrient use efficiency.**

Looking ahead

Nutrient sustainability and stewardship are also becoming priority issues in Asia. China, for example, played host to the 5th Sustainable Phosphorus Summit (SPS 2016) in August. China's recent announcement of a policy to achieve zero growth in mineral fertilizer consumption by 2020 also has major implications, and will require a step change in nutrient use efficiency if it is to be achieved.

Admirably, the International Fertilizer Association (IFA) is continuing to provide much-needed leadership on sustainability. The association published a report on *Phosphogypsum: Sustainable Management and Use* in January and a guide to *Fertilizers and their Efficient Use* in May.

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IPNI in South Asia

Our correspondent **David Hayes** reviews the South Asia programme of the International Plant Nutrition Institute (IPNI) in an exclusive interview with Dr Kaushik Majumdar, the programme's director for the last seven years.

The South Asia programme of the International Plant Nutrition Institute (IPNI) has come a long way over the past two decades. It's presence in India over this period has coincided with government efforts to expand food production by educating farmers in modern husbandry methods. This has resulted in greater use of mineral fertilizers and other improvements in agricultural technology across the country.

IPNI – or rather its predecessor bodies the Potash & Phosphate Institute (PPI) and the Potash & Phosphate Institute of Canada (PPIC) – first became involved in South Asia in 1989. Today, India remains an important part of IPNI's global activities due to the scale of the country's agricultural sector, its large rural economy, huge population and geographical size.

IPNI's Dr Kaushik Majumdar.

The early years

PPI/PPIC spent its early years in India, the period from 1989 to 1996, becoming established in the country, working with the Indian Council of Agricultural Research and about 10 agricultural universities. Fruitful relationships all over India have been established since then. IPNI now works with about 30 agricultural universities, and many other organisations besides, on a wide range of schemes designed to improve crop yields and the nutrient management skills of farmers.

"At the start it was PPI/PPIC and the focus was P and K as nutrients for a whole host of crops. The crop focus was maximum yield research (MYR), the projects we funded were in different universities," explained Dr Kaushik Majumdar, the long-standing director of IPNI's South Asia programme until his recent promotion. Dr Kaushik became IPNI's vice president for Asia and Africa at the beginning of July, after seven years in charge of IPNI's work in the South Asian region.

"The programme [then] transitioned from MYR to Maximum Economical Yield Research (MEYR) as the yield curve tapers off and excess nutrients do not give the same rate of return. The focus then became at which point is nutrient application most economical."

Site Specific Nutrient Management

"After MEYR came the time for Site Specific Nutrient Management (SSNM) which we started based on soil tests," said Dr Majumdar. "SSNM is a buzzword now but PPI/PPIC and IPNI brought this into India – we started with different crops and working with different agencies."

IPNI's partners on SSNM include the government's National Agricultural Research and Extension System (NARES), an umbrella organisation for all agricultural universities and institutes. The Project Directorate of Cropping Systems Research, under the Ministry of Agriculture, has been another important partner.

"SSNM research showed that farmers can produce nearly 16 tonnes of rice and wheat per hectare per cropping cycle. That opened people's eyes here as it is a very high yield, so SSNM took off very well," Dr Majumdar said.

Rice and wheat are grown entirely for human consumption in India, whereas about 80% of maize is grown for animal feed and the remaining 20% is used for human consumption.

Crops and cropping systems vary state by state in India, and the diversity of the country's agriculture is recognised as one of the sector's major challenges.

"Little wheat is grown in South India as it is not suitable, but rice, maize, pulses and many other crops grow over the whole of India. Wheat is mainly [from] central, northern and eastern India," Dr Majumdar noted.

Access to soil testing

Although SSNM is well established in India, the access of farmers to soil testing varies considerably in different parts of the country. Encouragingly, however, the number of soil testing laboratories continues to grow, in keeping with the government's long term target for all farmers to have access to soil testing. The recent launch of the government's Soil Health Card initiative last year is also helping to improve soil testing availability.

"The availability of soil testing has gone up over the last 10 years. The government is concerned about soil health and wants to increase food production, so they need science-based testing to increase food output," Dr Majumdar said.

"The Soil Health Card is a flagship project, the goal being for all farmers to have their farm soil tested to reach that food production target. If fertilizer is used without soil testing, there can be an economic loss, and if there is imbalanced application it can pollute the atmosphere and surface water.

"That's why the government is focused on soil health and soil nutrient recommendations. The Soil Health Card programme launched last year has given us more opportunity to work with the government."

Turn of the decade expansion

IPNI's agricultural collaborations across India developed in parallel with its increasing interest in neighbouring South Asian countries. The culmination of this was the expansion of IPNI's programme in 2009 to cover India, Bangladesh, Pakistan, Sri Lanka and Nepal. This led to its work in the region being retitled the South Asia programme that year.

IPNI's South Asia programme is one of the institute's five large international programmes, the others being the China, Southeast Asia, Sub-Saharan Africa and North Africa programmes. IPNI currently runs the South Asia programme through three offices in India. The Gurgaon office covers northern and western India, Pakistan and Nepal, while the Kolkata office covers eastern India and Bangladesh. Finally, IPNI's Hyderabad office covers southern India and Sri Lanka. The programme has three permanent staff, including the programme director, but employs other temporary and consulting staff as required.

As well as being renamed in 2009, IPNI set some fresh objectives for the South Asia programme in order to extend its outreach to a wider audience of farmers.

"In 2009, with three permanent staff in India, IPNI wondered whether it would be better to work with fewer crops with extension staff or multiple crops," Dr Majumdar said. "The second issue was: who should benefit from the nutrient management advice as our research was based on soil testing – were there other ways to give nutrient recommendations?

"At that time, India's soil testing laboratories met 25% of farmer demand. So would recommendations only be for that 25% – what would happen to the rest, the other 75% of farmers?"

To address this quandary, IPNI decided to focus on rice, wheat and maize, as these crops are grown on a large-scale, accounting for about 100 million hectares of India's 143 million hectares of cultivatable land.

Nutrient Expert

Importantly, IPNI also took the decision in 2009 to develop a decision support tool, one that was designed to make fertilizer recommendations for rice, wheat and maize. The 'Nutrient Expert for Rice, Wheat and Maize' software, commonly known as *Nutrient Expert*, was developed in India in collaboration with IPNI's other regional programmes. This software tool was developed over a four year period before its release in 2013. It is now being transferred to web-based platforms to allow access by smartphones and similar mobile devices.

The release of *Nutrient Expert* for free public use was preceded by large field trials. After initial data gathering, algorithms and nutrient recommendation rules were developed. More fieldwork was then carried out after this to ensure the new software worked correctly in different geographical locations.

"*Nutrient Expert* was developed on Microsoft Access but we are now transferring it to web platforms to allow smartphones and other devices to access it. It's an ongoing transfer," Dr Majumdar said.

Building on this success, IPNI is now developing a software tool for rice nutrient recommendations, due to be officially released later this year, as well as equiva-

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lent software tools to provide nutrient recommendations for India's cotton farmers and soya bean growers supplying the edible oil industry.

"With web platforms we will have the analytical capability to study *Nutrient Expert* software tool use," Dr Majumdar explained. "Already we have tracked how many farmers we are reaching – we estimate we have reached 1.8 million farmers with *Nutrient Expert* in the last three years. There are an estimated 160 million farmers in India, so we are happy with the start."

IPNI's local partners in India are helping increase general awareness of the *Nutrient Expert* software tool in the agricultural sector by providing advice and recommendations for using the tool.

> **"The Indian fertilizer industry and farmers are using our Nutrient Expert tool – it's a huge achievement.**

"The Indian fertilizer industry, the seed industry, state agricultural universities, government research institutes, NGOs, farmers clubs, even educated farmers with computer knowledge, are using our *Nutrient Expert* tool. It's a huge achievement," Dr Majumdar said.

Nutrient Expert for Rice, Wheat and Maize has already received several awards. Last year, for example, *Nutrient Expert* received an Indian government award for being the best available ICT tool for increasing farm livelihoods, beating a large number of other candidates. In addition, Farming First selected *Nutrient Expert* as one of top 13 worldwide innovations able to help women farmers.

Nutrient Expert has also been selected by a French initiative helping maintain global food security by countering the effect of climate change on crop yields. "Climate Change and Food Stability, a programme of the Consultative Group of International Agriculture Research, has chosen our *Nutrient Expert* to use in their climate smart villages across Asia," said Dr Majumdar. "It's a huge recommendation for our tool."

Field trials

IPNI is also involved in a number of schemes in India aimed at improving nutrient management and crop yields.

"We have field trials going on across India with different partners looking at nutrient responses in different soils and crops," Dr Majumdar said. "These help us to decide how best to use nutrients and evaluate the economic response. Crops include rice, wheat, maize, cotton, pulses, soya bean, sunflower, sugar cane, potato, ground nut and citrus fruits."

He continued: "The moment there is a change in fertilizer prices, people wonder about the economics of fertilizer use. We can compare variations in nutrient application compared to gain or loss in yield of the crop value."

IPNI's Global Maize Programme, part of a multi-country initiative to intensify maize production, includes two sites in India. One site is in Ranchi in Jharkhand, eastern India, and the other is in Dharwad in Karnataka, southern India.

"IPNI's Global Maize Programme has had a huge impact in India. In Jharkhand our maize production is two tonnes per hectare but in our experiments we are reaching seven tonnes per hectare," Dr Majumdar said.

He added: "We are looking at applying N at different times and rates, and also looking at what is the long term impact of not applying N, P, K, S and other nutrients. In Jharkhand we are working with Birsa Agricultural University while in Karnataka we are working with the University of Agricultural Sciences."

Six types of farmer

The application of balanced nutrients ultimately relies on decisions by individual farmers about which fertilizers to apply and how much, a choice influenced by a variety of factors. To better understand this decision process, IPNI is currently researching how socio-economic circumstances influence the choices South Asian farmers make on fertilizer selection and use. This work is supported by funding from the International Maize and Wheat Improvement Centre in Mexico.

"We wondered when recommendations are given to farmers, why they may not use them, so we are looking at how best to provide nutrient recommendations to smallholders based on their different financial resources. We are matching fertilizer application with farmers' pockets," Dr Majumdar explained.

This research originally started in eastern India but has since expanded to include southern India and Nepal.

"We started this project in 2012. There are huge regional differences, farmer groups are very different," Dr Majumdar noted. "We took 200 farmers in West Bengal growing maize with 1 to 1.5 hectares of land each and divided them into six farmer types.

He elaborated: "Type 6, who were categorised as resource rich, were overusing fertilizer because they had the money but did not have knowledge on how to apply balanced nutrients. They often over apply N and under apply K, and other nutrients like S and micronutrients, through a lack of awareness."

Type 5 farmers were traditional maize growers who obtained the highest yields among the six groups due to their long-term experience and knowledge. Type 3 farmers, in contrast, had the lowest maize yields. These farmers were new to growing maize, having converted from another crop such as winter wheat. Their low yields were a reflection of inexperience in growing maize, according to Dr Majumdar.

"Type 1 farmers, commercial maize growers with moderate financial resources, did pretty well with their yields," Dr Majumdar said. "[However,] Type 2 farmers, those with large holdings and large families, do not get very high yields, probably because they do not farm full time."

Initially, IPNI monitored the starting yield of the group of 200 West Bengal maize farmers. It then provided these farmers with individual nutrient recommendations obtained using *Nutrient Expert* software and monitored any changes in yields for the six different farmer types.

"When we deployed *Nutrient Expert* we increased yields by 37% to 73% for the different farmer group types," Dr Majumdar said. "The largest yield increase was 73%, these were the new maize farmers."

He added: "Our advice across all six farmer groups was to increase nutrient investment by up to $10 per hectare or [conversely] to reduce by up to $16 per hectare depending on their usage."

Getting the message

IPNI uses field days to promote balanced nutrient use as they are a useful way to get its message across. Field days are popular with farmers in India, as they are in many other countries. They are organised by IPNI's partners who invite between 50 and 500 farmers, depending on the field trial and location.

IPNI also makes efforts to improve the knowledge of its extension workers, and so assist in their role in educating farmers about balanced fertilizer application.

"We provide booklets and other materials for extension workers. We also publish in different Indian dialects and produce different videos for fertilizer companies to show in villages," Dr Majumdar said.

These materials include IPNI's 4R Nutrient Stewardship Manual. The 4Rs stress that the right source of nutrients should be applied at the right rate, at the right time, by the right method. "IPNI has produced a manual telling farmers, scientists and extension specialists about the 4Rs. We promote this among our partners and postgraduate agricultural students, so they know about this," Dr Majumdar said.

Future trends

Because of its large size and population, India and South Asia will remain an important part of IPNI's global programme – as efforts continue in future to provide sufficient food for the region's large population.

"India is one of the biggest fertilizer markets. The lack of fertilizer knowledge among farmers and the imbalance in fertilizer use are reasons that IPNI will always have a place here," Dr Majumdar said.

"Agricultural production is growing – it has to otherwise India cannot feed its growing population. Farmland is decreasing as its being built on, so India will have to produce more from less land and less water: agriculture has to be driven by precision."

Looking ahead, Dr Majumdar signalled that strategies for spreading information about balanced nutrient management – especially improving the knowledge of farmers about this – will play an increasing important part of IPNI's South Asia programme in future. "Right now we are looking for strategies to reach large numbers of farmers in South Asia with things like *Nutrient Expert* to meet their needs," Dr Majumdar said.

He continued: "Another area we are planning to focus on is speciality fertilizers and the 4Rs of those strategies. For example, we are now designing research programmes to measure application by different broadcasting techniques.

"Other areas include how to use new platforms like smartphones to provide information for farmers at their fingertips. Over 50% of Indian farmers have a mobile phone. There are 684 million mobile phone users in India, which has a 1.2 billion population, and some 116 million farmers."

Growing patterns are also changing in India. Maize output has risen over the past 10 years as demand for animal feed has grown. This is linked to trends in food consumption with more meat being eaten in India as economic growth lifts family incomes in many parts of the country.

Water supply and climate change are other important topics affecting agriculture. "Water supply is a big issue for Indian agriculture and will be a big challenge in future, especially in northwest and central India. Water management must be more precise – there are large opportunities to cut down water use and use it more carefully," commented Dr Majumdar.

The sector is also witnessing an outflow of labour with many young people choosing not to work on the land, preferring to take up other better paid employment instead. "In many cases the young generation do not want to farm if there are other opportunities," Dr Majumdar said. "In most cases farming is not lucrative, especially in areas where the farm size is small." ■

SOUTH ASIA REPORT

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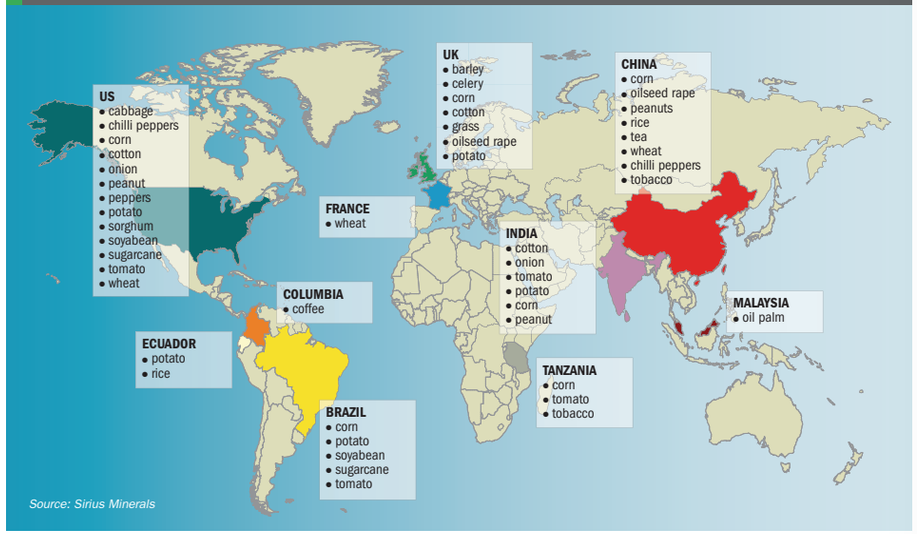
The agronomic benefits of polyhalite

Fig 1: **Sirius Minerals agronomy programme**



Sirius Minerals has conducted 150 polyhalite fertilizer trials on 24 crops in 13 countries over the last five years. We report on the latest findings of the company's crop study programme in China and Brazil, and summarise the main agronomic benefits of this multi-nutrient fertilizer.

Sirius Minerals is hoping to break ground on a 10 million t/a polyhalite mine in the North Yorkshire region of England later this year, following planning approval from the UK government in 2015 and the publication of a definitive feasibility study in March (*Fertilizer International*, 472 p12). Construction of the $2.9 billion mine could begin as early as September, if the finance is all in place, with the start of production currently scheduled for 2021 (*Fertilizer International*, 473 p11).

POLY4: a balanced fertilizer

POLY4, the polyhalite product Sirius Minerals will produce from its UK mine, provides "a single source of bulk nutrients as a foundation for more balanced fertilization". The key qualities that make polyhalite agronomically attractive, according to Sirius Minerals, include:

- The presence of four (K, S Mg and Ca) of the six macro nutrients and valuable micronutrients
- These nutrients are readily available
- Polyhalite can be used straight or as part of a fertilizer blend
- It does not change soil pH or negatively influence soil conductivity
- The product is low in chloride

The scope for substituting polyhalite for a range of fertilizers, including kieserite, SOPM, SOP, SSP, AS, MOP-NPK and straight MOP, means that, in theory, *POLY4* has a "total contestable market" of 376 million tonnes, according to the company's calculations. That is almost ten times higher than the 20 million t/a of UK polyhalite production capacity that Sirius Minerals ultimately hopes to deliver.

The demand for low-chloride fertilizers, and polyhalite's ability to correct soil magnesium and sulphur deficiencies, allows *POLY4* to be targeted at a number of sizeable niche markets globally. Sulphur deficiency alone accounts for 60 million t/a of worldwide demand potential for *POLY4*, according to Sirius Minerals.

Global programme

Now in its fifth year, Sirius Minerals has been conducting a crop study programme that is truly global in scope. The company has teamed up with leading agricultural universities, research institutions and commercial partners to carry out agronomic studies across five continents (Figure 1). The company's overall objective is to demonstrate "the use *POLY4* as an effective multi-nutrient fertilizer suitable for widespread use in commercial farming" and validate the product's technical, agronomic and commercial worth.

"The scope and scale of the research demonstrates our long-term commitment to further developing the agronomic understanding of *POLY4*," comments Sirius Minerals. "So far, we have directed over 150 trials on 24 crops in 13 different countries."

To date, a range of crop trials have directly compared the efficacy of *POLY4* against other potassium-based fertilizers, both in straight applications and as a component of NPK blends. Sirius Minerals claims: "Results consistently show that *POLY4* outperforms muriate of potash (MOP) and sulphate of potash (SOP) in both crop yield and quality, demonstrating the agronomic advantage provided by *POLY4's* multi-nutrient content." Sirius Minerals has also validated *POLY4's* physical and chemical characteristics, including its compatibility, solubility, low chloride content and crush strength.

"Our on-going global agronomy programme is designed to deliver commercial and scientific information to highlight the market-changing potential of *POLY4* and support on-going discussions with customers around the globe," comments JT Starzecki, sales & marketing director at Sirius Minerals. "Our agronomic work, which develops year-on-year, is not there to prove polyhalite works as a fertilizer – the nutrients it contains are well known in agronomy – it's more about helping our customers to fully understand their value."

China and Brazil

Sirius Minerals is continuing to fund a substantial agronomy programme in China. Major Chinese crops are being trialled in collaboration with Sichuan Academy of Agricultural Science (corn, tea, tobacco, chilli peppers), Yunnan Agricultural University (tea, tobacco), Shandong Agricultural University (corn, peanuts) and the Chinese Academy of Sciences in Nanjing (oilseed rape, rice, wheat). The company's interest in the Chinese market is understandable, given that the 1.74 billion tonnes of crops produced by the country in 2013 contributed $873 billion to the world economy.

The company is promoting a polyhalite-based NPK fertilizer called *SUPER6*, a blended mixture of *POLY4*, MAP, urea and SOP, for use in Chinese agriculture. This NPK blend combines "six nutrients in one bag" and – by improving yield and nutrient use efficiency – has the potential to help China deliver its policy of zero growth in fertilizer use by 2020, in Sirius Minerals' view. The application of *SUPER6* also leaves a 'nutrient legacy' in soils by elevating residual levels of secondary nutrients (Mg and Ca) after harvest.

2016 has been a landmark year for Sirius Minerals' crop study programme. The company published the first finding of its Chinese agronomic collaborations in May. These highlighted field trial results for chilli pepper, oilseed rape and tea. These results followed the release of Brazilian soybean and sugarcane trial findings in February. We review these 2016 agronomic trial results below.

Chilli peppers

The global fresh chilli pepper market is thought to be worth $29 billion. China is the leading grower internationally, producing 15.8 million tonnes of fresh chilli peppers in 2013, equivalent to a 39% share of the global market by value. Growing is concentrated in Hainan, Hunan, Sichuan, Guangdong and Jiangxi provinces which collectively account for 94% of Chinese chilli pepper production.

Chilli peppers require relatively large amounts of magnesium and potassium, preferably sourced from low-chloride fertilizers. In the chilli pepper field trial performed by the Sichuan Academy of Agricultural Science, a *POLY4*-based NPK blend (15:10:15) was assessed against a SOP-based NPK blend. (15:10:15).

Using *POLY4* in the NPK blend doubles sulphur content from 5% to 10% and also supplies additional magnesium (2% MgO), calcium (5% CaO) and micronutrients. Four potassium application rates (53, 88, 175 and 263 kg K_2O/ha) were trialled on 15 m^2 plots to compare the SOP- and *POLY4*-based blends. All plots were given a top dressing of urea (90 kg N/ha) at the flowering stage.

Based on these trial results, Sirius Minerals concludes that *POLY4* can offer chilli pepper growers a number of distinct advantages. The key findings are as follows:

- Overall, the *POLY4*-based blend, by acting as a combined source of Mg, Ca and K, is well-suited to chilli pepper plant needs
- The *POLY4*-based blend outperformed the SOP-based blend, increasing yields by 5% at the recommended application rate (175 kg K_2O/ha), due to the additional Mg and Ca provided (Figure 2)
- Significant improvements in two components of yield – chilli pepper numbers and weight – were achieved with both increasing by 12% and 5%, respectively
- Quality parameters – soluble solids, amino acids and vitamin C content – were all significantly higher when using the *POLY4* blend
- The *POLY4*-based blend also improved fruit colour, capsaicin content and leaf nutrient status
- *POLY4* had no observable negative effect on either soil pH or electrical conductivity, and boosted residual levels of Ca, Mg and S in plot soils

Oilseed rape

Results of a second Chinese-based crop trial, this time for oilseed rape, were also released in May. This crop is widely-grown globally and a total of 73 million tonnes was harvested from a land area of 36 million hectares in 2013. A large international market exists for a diverse range of processed oilseed rape products, such as rape oil and dairy and pig feed. China is a major world producer with a 30% share by value of the massive $41 billion global oilseed rape market.

Potassium and sulphur, both of which are present in *POLY4*, are important determinants of yield in oilseed rape. Chinese oilseed rape is grown on more than 7.5 million hectares of farmland and estimates of potash demand (80 kg K_2O/ha) translates into a potential *POLY4* requirement of 4.3 million tonnes.

The oilseed rape trial conducted by Nanjing's Institute of Soil Science was designed to evaluate the performance of *POLY4* relative to MOP. Three different potassium application rates (40, 80 and 120 kg K_2O/ha) were applied to 36 plots of 24 m^2 each.

Results show that *POLY4* can be an effective fertilizer for oilseed rape, concludes Sirius Minerals, as it helps ensure good crop quality and yield. Key trial findings are as follows:

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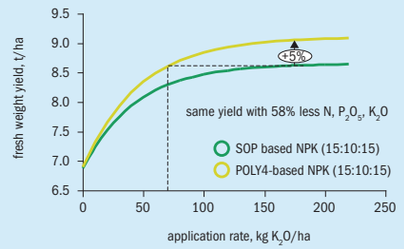
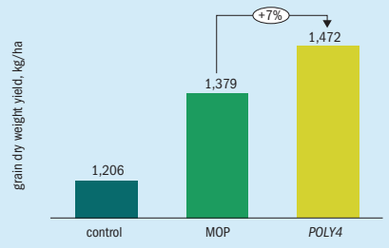
Fig 2: **Chilli pepper yield**



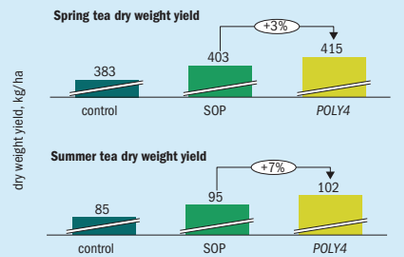
Source: Sirius Minerals

Fig 3: **Oilseed rape yield**



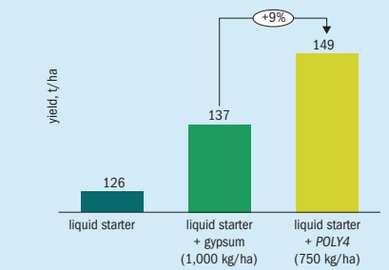
Source: Sirius Minerals

Fig 4: **Tea yield**



Source: Sirius Minerals

Fig 5: **Sugarcane yield**



Source: Sirius Minerals

- *POLY4*, by improving grain macronutrient uptake, delivers a 7% yield improvement over MOP (Figure 3) and also increased pod weight by 6%
- *POLY4* and MOP applications both resulted in broadly similar outcomes for other yield and quality characteristics such as chlorophyll content, oil content and the percentage of sterile seeds/pods
- *POLY4* improves seed nutrient uptake of N, P, K, Ca, Mg and S in comparison to MOP
- Delivering nutrients into seeds is important for yield and oil quality at harvest
- Notably, *POLY4* supports plant oil production by satisfying oilseed rape's high sulphur demand
- *POLY4* also improved Ca (+12%), Mg (+25%) and S (+14%) uptake during early seed development – a peak period for nutrient demand – compared to MOP
- Use of *POLY4* satisfies Mg, S and Ca crop needs, extra to standard NPK applications, and is particularly beneficial in marginal soil conditions

Tea

Tea is the most popular hot drink in the world and some 4.8 million tonnes of this valuable global commodity was consumed in 2013. A total of 5.1 million tonnes of tea is grown globally on 3.5 million hectares of land. China produced 36% of the world's tea in 2013 and took a 72% share by value of the $13 billion global tea market. Chinese domestic tea consumption is also on the increase, rising at 5% per annum currently. Tea growing requires a tropical climate with warm and wet conditions. It is also a perennial crop requiring long term nutrient availability. Potassium is a key driver of yield and is commonly supplied by SOP due to tea's chloride-sensitivity.

Because it requires a low-chloride fertilizer, tea represents a particularly valuable market opportunity for *POLY4*. In the Sichuan Academy of Agricultural Science trial commissioned by Sirius Minerals, the relative performance of *POLY4* and SOP were compared for four different potassium application rates (90, 135, 180 and 270 kg K_2O/ha) over a growing area of 800 m². In all treatments, nitrogen (240 kg N/ha) and phosphorus (120 kg P_2O_5/ha) was supplied using urea and MAP. In comparison to SOP, the application of *POLY4*:

- Improved the spring and summer dry weight yield for tea by 3% and 7%, respectively (Figure 4)
- Maintained tea quality throughout the growing season, as measured by taste (polyphenol/amino acid ratio), leaf protein content and water extractable solids
- Lowered soil electrical conductivity by 9% and raised soil pH by 7% after the trial
- Improved the residual levels of Ca, Mg and S in soils by 7%, 30% and 4%, respectively, increasing secondary nutrient availability for future crops

Soybean

In February, Sirius Minerals released a complex set of results from four Brazilian

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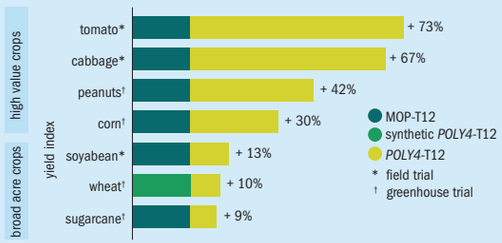
soybean trials carried out by the University of São Paulo. Brazil produced 82 million tonnes of soybean in 2013 and is the world's second largest producer after the US. Soybeans cultivated on 27.9 million hectares of land generate billions for Brazil's economy.

In two greenhouse pot trials and two subsequent field trials, *POLY4* was substituted for the SSP component of NPK blends. Sirius Minerals concluded that the presence of *POLY4* provides soybean crops with a balanced, efficient supply of nutrients. Key findings are as follows:

- In the two greenhouse trials, *POLY4* blends increased soybean sulphur uptake (by 127% in sand and 12% in soil) and nitrogen fixation and uptake (by 68% in sand and 29% in soil)
- The presence of Mg and micronutrients in *POLY4* also helped improve above ground soybean biomass in greenhouse trials
- In field trials, using *POLY4* as part of pre-planting starter blend (2:28:6) improved soil nutrient status (K, Ca, Mg and S) after cropping
- Pre-planting with the *POLY4* starter blend, by lowering the K application rate needed to maintain yield, also delivered a potential $27/ha cost saving
- Using *POLY4* instead of MOP as part of a 0:14:14 blend delivers equivalent soybean crop results at a potential saving of $33/ha

Fig 6: **Crop trial results for *POLY4* as part of a T12 (12:12:12) NPK blend**



Source: Sirius Minerals

Sugarcane

University of São Paulo sugarcane trial results were also published by Sirius Minerals in February. Brazil is the world's largest producer of sugarcane. The 10.2 million hectares dedicated to sugarcane in the country is responsible for around 40% of the 1.9 billion tonnes of sugarcane produced globally.

In the University of São Paulo trial, the applications of *POLY4* and gypsum on sugarcane plots were compared. Gypsum treatment is commonly used in Brazil to improve soil conditions and provide plant nutrients. *POLY4*, similar to gypsum, supplies both calcium and sulphur, but also provides potassium and magnesium. Conditions were as follows:

- Gypsum sugarcane plots received 150 kg K_2O/ha, 280 kg CaO/ha and 240 kg S/ha
- The plots treated with *POLY4* received 255 kg K_2O/ha, 127 kg CaO/ha, 45 kg MgO/ha and 143 kg S/ha
- Both plots were treated identically with liquid NPK (6:15:15) and therefore received the same nitrogen (60 kg N/ha) and phosphorus (150 kg P_2O_5/ha) application rates

Brazilian soils are often weathered, low in nutrients and so require inputs such as lime, gypsum and fertilizers. Sirius Minerals concluded that *POLY4* is capable of delivering higher sugarcane yields than gypsum by supplying potassium and magnesium in support of crop production. It also improved soil nutrient status. Substituting smaller amounts of *POLY4* for gypsum can also increase sugarcane revenues, even though lower total nutrient levels are supplied. Compared to the gypsum treatment, the 'liquid NPK starter plus *POLY4*' fertilizer plan:

- Improved both cane yield (9%) and sugar yield (10%) (Figure 5)
- Improved nutrient uptake for Ca (5%) and S (28%)
- Improved post-crop soil nutrient status of K (37%), Mg (54%), Ca (23%) and S (24%)

Just a snapshot

These newly-released crop trial findings for chilli pepper, tea, oilseed rape, soybean and sugarcane add to an impressive and growing body of agronomic information about the benefits of polyhalite, especially its ability to improve crop yields, nutrient uptake and soil nutrient status. Other field and greenhouse trials using *POLY4* as part of a T12 (12:12:12) NPK blend have also shown impressive yield improvements for tomato (73%), cabbage (67%), peanuts (42%) and corn (30%) (Figure 6).

"The repeated impressive results from our crop trials continue to confirm that *POLY4* is a valuable and effective multi-nutrient fertilizer," comments JT Starzecki. "Our crop trial programme is designed to be wide ranging in terms of geography, crops and soil types. This reflects the breadth of discussions we have with customers, and their likely needs, in locations around the world."

Polyhalite can also improve disease resistance in the field. Research by Sirius Minerals suggests that *POLY4* applications can:

- Reduce the severity of sheath blight on corn by over by 71%, in comparison to MOP
- Reduce tomato leaf spot incidence by 48%, in comparison to MOP
- Reduce tobacco black shank incidence by 35%, in comparison to SOP
- Reduce tobacco wilt incidence by 20%, in comparison to SOP

ICL Fertilizers has also extensively trialled *Polysulphate*, a UK-mined polyhalite product successfully launched on the market last year. The company has obtained excellent agronomic results with cabbage, cauliflower, mustard and winter wheat (*Fertilizer International*, 468 p36).

Looking ahead, JT Starzecki said: "Sirius Minerals intends to continue its global agronomy programme to validate the performance of *POLY4* in key geographical markets and for a large variety of crops."■

Full details of the trial results discussed in this feature are available on the agronomy programme page of Sirius Minerals' website: siriusminerals.com/polyhalite/agronomy-programme/

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phosphates & potash **INSIGHT**

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PHOTOS: K+S KALI

K+S enters a new world

K+S's flagship Legacy project, Canada's largest mining venture, is being commissioned over the summer and is set to reach two million tonnes of potash production capacity by the end of next year. We profile this enormous engineering undertaking in advance of the first tonne of potash production, now expected sometime in the second quarter of 2017.

Table 1: **Legacy project timetable: major milestones and engineering achievements**

2011	
December	Project gets the green light
2012	
June	Construction officially starts
November	Permanent water supply becomes operational
December	Design supply contract signed with Veolia for ECC
2013	
February	Main construction and major drilling commences
April	K+S increases capital expenditure
July	KSPC and Canadian Pacific (CP) sign rail distribution deal
November	Basic engineering completed
December	Plant piling commences
2014	
February	Test cavern and first 72 production boreholes completed
	Engineering and construction management contract with AMEC
	Natural gas supply to site becomes operational
April	Pacific Coast Terminals (PCT) and KSPC sign an agreement for a new potash handling and storage facility
2015	
June	Construction of potash handling and storage facility commences
August	Exclusive potash supply agreement signed with Koch Fertilizer
2016	
August	Symbolic start of commissioning

Source: K+S

2016 looks like being a milestone year for independent German potash producer K+S Group, and its subsidiary K+S Potash Canada (KSPC), as it moves closer to completing its landmark Legacy project, Canada's first new greenfield potash mine in more than 40 years. The large-scale solution mine is located at Bethune, 50 km north of Moose Jaw in the prairies of Saskatchewan. The mine, situated deep in Canada's remote interior, is some 2,000 km to the east of Vancouver and separated from the Pacific by the provinces of Alberta and British Columbia.

Ulrich Lamp, KSPC's president and CEO, highlighted three essential aspects of the Legacy project – its railway, port and social licence to operate. "To build a site in the prairies means you need a rail connection that delivers your products to customers, domestically but also overseas. Then to access your overseas customers you need a port facility, the Pacific Coast Terminal in Vancouver. And lastly, as a mining company, you need a social licence. That means that, as a company, you must be recognised for good citizenship by the government but also by your neighbours."

On track and on budget

The Legacy project has come a long way since KSPC first broke ground for the solution potash mine in June 2012, and the open prairie site at Bethune has changed

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Processing plant steel work and equipment.

Inside the huge potash warehouse at the site.

PHOTOS: K+S KALI

dramatically over the last four years. Project progress has been swift and the list of major milestones met and engineering feats achieved over the intervening years is impressively long (see Table 1). All the project's major contracts were awarded by the end of 2015, with local companies benefitting significantly. Around 55% of Legacy's direct contractors and 31% of its direct suppliers are from Saskatchewan, for example.

K+S described 2015 as "a year of outstanding progress" for the CAD 4.1 billion Legacy project. More than 60% per cent of construction was completed by the year's end with planned activities "wrapped up on time and on budget".

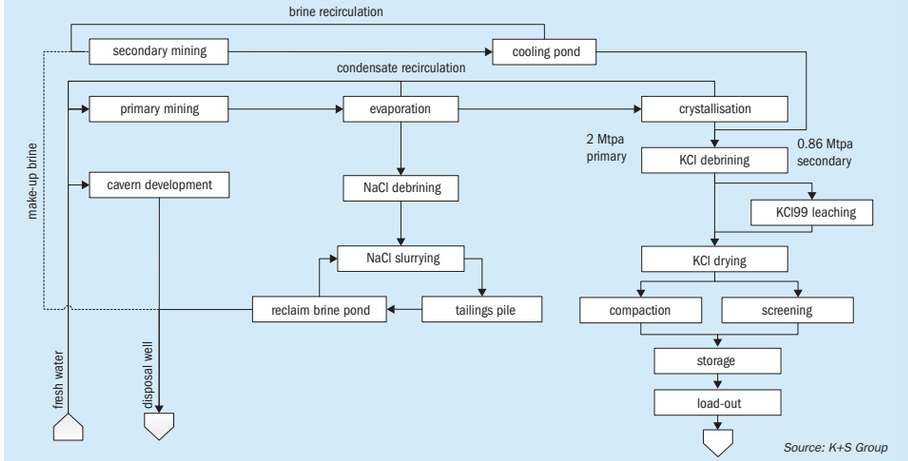
By the end of last year, project engineering had been completed, the procurement was substantially done and the construction phase was progressing according to schedule. This included major ancillary rail and port construction work being carried out by Canadian Pacific (CP) and Pacific Coast Terminals (PCT), respectively. The 550 railcars needed for the project were also ordered from National Steel Car last year.

CP has been tasked with constructing the 30 km rail spur which will link the Legacy site with the existing rail track near Belle Plaine. KSPC is also building a 14 km line to connect this spur to a loop at the potash mine's loading facilities, as well as an adjacent 6 km storage track alongside this line.

"With a unit train loop track and high speed loading capabilities, the Legacy project will have the most modern rail infrastructure of all the Saskatchewan potash mines," says John Brooks, CP's vice president for marketing & sales. "The freight trains will consist of a mindboggling 177 cars pulled across the Rockies by five locomotives, adding up to a total length of about 2.6 kilometres," adds Steffen Brill, KSPC's senior logistics and supply chain manager. "Each trip of about 1,800 km will take three to four days."

The final destination for these freight trains is what K+S is calling "the world's

Fig 1: **Legacy project process flowsheet**



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most modern potash handling facility". This is being built by PCT, another key project partner, at Port Moody in British Columbia. This facility includes a new automatic rail-car unloading station, covered conveyors, systems to control dust emissions and a new 160,000 tonne capacity potash storage warehouse. Water treatment facilities and ship-loading equipment are also being upgraded at the port.

"There's very much a sense of accomplishment as we look back at 2015 and head into the final stretch," says Kevin Brown, project director for Amec Foster Wheeler, the contractor in charge of managing construction at the Legacy mine site. "A big project like this comprises a large number of independent pieces. During 2015, many of those pieces were completed."

Amec Foster Wheeler has been Legacy's major contractor since the end of 2011 and been a key player in delivering the project over the last four to five years. It was initially tasked with providing basic engineering, project management, detailed engineering and construction management services for the mine – including earthworks, first piling activities, production cavern facilities and plant utility works.

Under its current contract, Amec is managing the project's detailed design and implementation phase all the way through to Legacy's start-up. Its responsibilities include detailed engineering, construction management, commissioning, supply chain and project management services for mining, processing and site infrastructure. Amec also manages health, safety, security and environment (HSSE) at the site.

Building the Eiffel Tower five times over

Structural steel work – a truly mammoth task – was the centrepiece of the project's 2015 above-ground construction programme. Surface structures being built at Legacy will require roughly five times the amount of steel used to construct the Eiffel Tower and made the biggest visible changes to the site last year (photo).

KSPC calculates that building the mine will require 35,000 tonnes of steel and 75,000 cubic metres of concrete foundation – rising to over 100,000 cubic metres of concrete if piling and backfilling are also included. More than 30 cranes were assembling steel structures at the Legacy site at one stage last year. "The construction programme really took off during the first quarter of 2015," comments Brown. "This is when the project started to display its vertical dimension."

Much of the steel and foundation work is taking place at the processing, production and storage facilities. This is where the dissolved potash extracted from caverns underground will go through an evaporation and crystallisation process before being dried, sized and shipped to customers (Figure 1). Early construction of an on-site 'tank farm' has also been necessary to manage the water and brine used in cavern development.

Once steel work for a particular section of the plant is finished, cladding contractors move in to enclose the area, allowing other workers to install mechanical, piping and electrical equipment. Modularisation has been widely used during Legacy's construction. 71 pipe rack modules and 44 conveyor gallery modules were all built off-site, for example, as were the modular electrical rooms that will power the plant.

PHOTO: B&W PGG CANADA CORP

Road haulage of evaporators.

One of the site's most visible structures are the massive 'glulam' wooden arches (photo) supporting the roof of the two 100,000 and 40,000 tonne product warehouses, both of which are now 95% complete. Although it may seem an old-fashioned choice, wood was specifically selected as a construction material because of its resistance to potash corrosion.

Closely coordinated working has been an essential part of project delivery, as Gerd Dalhoff, vice president of controls at KSPC, one of the three managers overseeing the project, makes clear: "KSPC has formed integrated teams with both Amec Foster Wheeler for the Legacy project and contractor CH2MHILL for the Potash Handling Facility in Vancouver. Together, these teams work to ensure that we are on track to achieve our main goals, the first being to commission the plant in 2016 while maintaining our budget."

Evaporators, crystallisers and dryers

2015 also saw the completion of equipment manufacturing and material fabrication, including the installation of six mammoth evaporators. These giant vessels needed to be carefully transported along local highways before being carefully emplaced in permanent positions on-site (photo). The first two evaporator units, which are supplied by Veolia Water and assembled by Babcock & Wilcox (B&W) at a plant in Melville, Saskatchewan, arrived at the site in November 2014. Each unit is 30 metres long, 10.5 metres wide, 11 metres high and weighs 209,000 kg. "Due to their girth, SaskPower provided an escort to ensure their safe navigation under and near power lines," says Olaf Goitzsch, KSPC's logistics manager. "We ordered six evaporators of this size. Two are delivered, and the rest will come in sections to be assembled on site."

The evaporators were not the only large pieces of equipment transported by road to the Legacy site. Three large dryer drums and two crystalliser vessels were also delivered in late 2014 and early 2015. These items are central components of KSPC's solution mining flowsheet (Figure 1). "The evaporators and dryer drums, along with the crystallizers, will form the heart of the plant at KSPC's potash solution mining operation," says Karl Krenn, KSPC's area manager for evaporation, clarification and crystallization. "We get the liquid out of the earth and we evaporate and do the crystallisation."

Early cavern development

Solution mining at Legacy is being carried out beneath ground on an equally impressive, albeit less visible, scale. The mine's well field, located several kilometres to the east of the main plant, consists of six well pads spaced a couple of kilometres apart sitting above the potash ore body. When the Legacy mine enters production during 2017, each well pad will house the control centre for nine large underground caverns situated around 1,500 metres below ground.

The caverns are created using a combination of directional drilling and water injection, a process that is more akin to an oil and gas operation than conventional

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potash mining. The caverns will be enormous when completed, says Sam Farris, general manager of operations at KSPC: "Each one of them will be bigger than an entire football stadium."

The launch of the early cavern development (ECD) programme during 2015 was Legacy's major milestone last year, according to Amec's Kevin Brown. ECD began in early March 2015 with the injection of water into production wells, symbolically marking the start of mining operations at the Legacy site. ECD involves drilling wells and using a powerful pumping system to inject raw water into the mile-deep caverns underground. The potash-rich brine obtained is then returned to the surface to supply Legacy's processing plant.

ECD initially focussed on the 18 caverns beneath well pads 2 and 3. It is these caverns which will supply the initial feed to the processing plant when the mine goes into production. "We need to have those first 18 caverns in place for start-up," says Sam Farris. "And it takes about a year to fully develop a cavern for potash production." By September last year, ECD had further expanded to include an additional 18 caverns beneath well pads 4 and 5.

ECD on well pads 6 and 7 was scheduled to begin this spring and construction of well pads 8 and 9 – the first to be built by KSPC – was also given the go-ahead last year. "Well pads 6 and 7 signify the end of drilling for the Legacy project," comments Darren Hrynkiw, the well field manager at KSPC. "From now on, we're drilling to sustain on-going operation for K+S."

Cold water injection is initially used to create and grow the underground caverns during ECD. Subsequent primary mining (Figure 1), in contrast, uses hot water as this maximises the potash content of the brine obtained. "After about three months of hot water mining of those four pads [2,3, 4 and 5], we'll be ready for our first potash production," says Trevor Dyck, KSPC's production manager. "We're right on schedule," concludes Farris. "Some of the caverns are ready for hot water mining and the others are in various stages of development."

Commissioning and start-up

Preparing for start-up and the early operation of the processing plant, especially the hiring and training of the staff involved, has been a major challenge, says Farris: "It's a big project requiring more than 200,000 person-hours of work. The time needed to develop and deliver training alone will be about 100,000 person-hours."

As the project approaches its final lap, KSPC and its contractors still need to complete a number of final but highly necessary tasks during the current year, including:

- The gradual commissioning of well pads 6 and 7
- Completing the construction of the Northern Tank Farm, storage buildings and de-brining, drying and compaction plant
- Completion of both rail and port facilities
- Readying evaporation, clarification and crystallisation (ECC) for production

Speaking last November, Ulrich Lamp listed the final steps required to prepare Legacy for its first tonne of potash production. "Construction of the last two pads is coming to the end – that will be done in the second quarter of 2016. Then we will have constructed all six pads needed for the ramp-up phase. We also have to build and complete the north part of our tank farm, then the de-brining, drying, compaction and storage buildings – these are under construction. Then we have to complete the rail connection, which is well underway, and our port facilities. And [finally] we have to make our evaporation and crystallisation plant ready for production."

In a progress update in June this year, Lamp added: "We are reaching the final milestones on the road to production. Our team has worked hard to keep our project on time and on budget, and I'm so proud of what we've accomplished. The progress has been incredible."

KSPC's Sam Farris also added: "Many milestones have been achieved to get us where we are today – close to being fully operational. Now, we're all looking forward to commissioning the mine end of August."

Commissioning of the Legacy mine will proceed in phases this summer, beginning with two of the plant's three boiler systems. These boilers need to be working to heat the primary mining caverns in readiness for production. Brine processing equipment also needs to be fully commissioned in time for the start-up phase.

Summing up progress, Lamp confirms that the project has kept on schedule and on budget: "It's clear that engineering has been completed, that procurement is substantially complete and that construction is progressing really well. We have demonstrated a capability to construct a highly complex project in the prairies of Saskatchewan. We are really convinced that the project will be completed as planned – and we will also do it on budget."

Almost there

About 90% of Legacy's total CAD 4.1 billion budget has now been invested. With commissioning of the mine approaching at the end of August, the construction workforce – engaged on what is the province's biggest engineering project currently – expanded to 4,500 in June. KSPC now expects to produce the first tonne of potash from Legacy in the second quarter of 2017, and not the end of this year as originally forecast.

The production schedule was revised following a site accident on 17 July. "A process vessel became detached from its mounting during a routine test and fell to the floor causing considerable damage to property," K+S said in a statement. "Nobody was injured. Intensive efforts have already been made together with the partners involved to assess and repair the damage." The company still plans to reach potash capacity of two million tonnes by the end of 2017, before eventually ramping-up production to final target capacity of 2.86 million t/a. However, the delay to the start of production means Legacy is likely to undershoot the one million tonnes of production originally expected next year. ■

A potash producer on two continents

The Legacy mine will significantly strengthen K+S's raw material and production base, and expand this globally, when it enters production next year. Importantly, the greenfield project will extend its mining presence from Europe to North America and – by providing access to virgin potash resources on the other of the Atlantic – increase the company's average mine life.

Competitive costs and customer proximity

Speaking at the company's Capital Markets Day last November, K+S chairman Norbert Steiner explained why the Legacy project was so important for the company's future. "Why is it important for our business? K+S will be the only supplier with production on two continents. With Legacy we'll have a competitive cost base and customer proximity. Legacy will mean access to high-quality resources for generations – and will give us the opportunity to participate in growth in the potash market long after our German mines will be depleted."

Steiner also took the opportunity to set out the production timetable and the mine's product mix: "How do we plan the ramp up for Legacy? After getting the first tonne [second quarter 2017] we will steadily increase production up to 2.9 million tonnes of products in 2023. Starting in 2018 we are able to produce about 20% to 30% of the total output in the form of industrial potash."

The Legacy mine will provide K+S with clear cost advantages. The new solution mine should also breakeven relatively quickly, as Andreas Radmacher, the former head of potash and magnesium products at K+S, was keen to make clear: "Our production cost per tonne by 2023 [at Legacy] will be around CAD 90, with roughly half of that energy and gas costs. Our logistic cost per tonne will be around CAD 65 – that includes transport from the mine to Vancouver and to the various destinations into the markets. EBITDA [earnings] breakeven will be reached in 2018."

Capex to cash

Also speaking at last November's Capital Markets Day, group chief financial officer Burkhard Lohr was equally candid about the value of Legacy to K+S. He put the project at the heart of the company's ambitions over the next five to 10 years, emphasising its vital role in the future success of K+S. In particular, he explained how large-scale investment in the project is expected to lead to a surge in cash flow in future years – a strategy he calls 'Capex to Cash' (*Fertilizer International*, 470 p48).

Legacy not only adds to the company's share value, in Lohr's view, it should result in a major rise in earnings by 2020 and beyond, as its production output increases. "We want to take the opportunity to confirm our view that the value of the Legacy project is between €11 and €21 per share," said Lohr. "In 2020, we expect €1.6 billion EBITDA [earnings]. And remember that Legacy is not even fully ramped up by 2020 – so we have three more years with growing volumes from Canada."

The company's salt business is expected to generate over €400 million earnings in 2020. K+S has refused to put a precise figure on Legacy's earnings potential – except to say it will account for a "huge proportion" of the remaining €1.2 billion earnings forecast for 2020.

Reduced investment risk

The investment risk for the project is now virtually nil, suggested Lohr, as the majority of the project's CAD 4.1 billion capex programme has been spent: "The peak of the construction and the capex programme is already behind us, the peak years were 2014 and 2015. Almost 100% of the procurement is done. That is very crucial for such a big project and means the project is significantly de-risked." ■

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Asia and Latin America drive the market

The feed phosphates market is expanding thanks to strong global demand for animal feed, particularly in Asia and Latin America, which in turn is linked to rising pork and poultry production. World feed phosphates consumption has been growing at 1.4% per annum on average over the last decade, a trend that is expected to continue this year and into 2017. Ma'aden's entry into the market next year could hit prices, if it were to supply large volumes of feed phosphates to Southeast Asia, India and East Africa. Integrated feed phosphate producers able to offer high quality products should enjoy a competitive advantage in what is already an oversupplied market. Strong distribution networks and comprehensive customer service also hold the key to this lucrative niche market.

Calcium phosphates are widely used as feed additives in livestock and poultry nutrition and provide a readily-available digestive source of phosphorus and calcium. They help maximise meat, egg and milk production by building and maintaining a strong animal skeleton and aiding muscle growth. The main inorganic feed phosphates sold globally are MCP (monocalcium phosphate), MDCP (monodicalcium phosphate), DCP (dicalcium phosphate) and DFP (defluorinated feed phosphate). These are generally assessed by their phosphate content and how digestible this is (Table 1).

Although a niche market accounting for about 10% of overall phosphate use globally, feed and industrial phosphates represent a significant and valuable market for certain producers such as PotashCorp, the world's largest fertilizer company. "Within PotashCorp, for 2015 sales, feed and industrial is going to make up about 39% of our sales whereas fertilizer will constitute approximately 61%. We feel that gives us a little bit of diversification," comments Clay Hackney, PotashCorp's former international sales director and its current national accounts manager[1].

Underlying growth drivers

The fortunes of the feed phosphate market are inextricably linked to the underlying growth prospects for animal feed globally. Fortunately, world animal feed production grew at a healthy 3.2% per annum between 2011 and 2015, currently standing at around 982 million tonnes. Feed production has grown particularly fast in Asia-Pacific (7.4% p.a.), the Middle East and Africa (6.0% p.a.) and Latin America (4.6% p.a.) over this period[2]. In terms of market share, Europe (24.1%) is currently the leading regional animal feed market followed by North America (19.5%), China (18.1%), Asia-Pacific (17.1%), Latin America (15.3%) and the Middle East and Africa (5.8%).

Animal feed consumption in turn depends on livestock farming, aquaculture and the growth in animal protein production. Because of this, feed phosphate demand over the next five years is likely to be driven by rising pork and poultry production in Asia and Latin America[1] (Figure 1). "Looking at pork and poultry production, a common theme emerges – it's all Asia and Latin America where the growth is taking place," comments Hackney. "With respect to poultry we see [average annual production] growth of 2.7% from 2015 to 2020 and with respect to pork it's just under 2%." The industrialisation of China's hog sector – particularly the rise in the number of large commercial farms over the last 15 years – is one factor fuelling the growth in Asian feed consumption.

Beef production has also been on the rise globally over the last five years, with the majority of world growth occurring in Latin America – as exemplified by year-on-year increases in Brazil's beef exports

Table 1: **Four main types of inorganic feed phosphates**

Abbreviation	Full name	Chemistry	Total P content (%)	Available P* (%)
MCP	Monocalcium phosphate	$Ca(H_2PO_4)_2$	22.7	20.7
MDCP	Monodicalcium phosphate	$CaHPO_4.2H_2O+Ca(H_2PO_4)2.H_2O$	21.0	17.4
DCP	Dicalcium phosphate	$CaHPO_4.2H_2O$	18.0	15.3
DFP	Defluorinated feed phosphate	$Ca_4Na(PO_4)_3$	18.5	11.1

For poultry. Source: Becker (2016)

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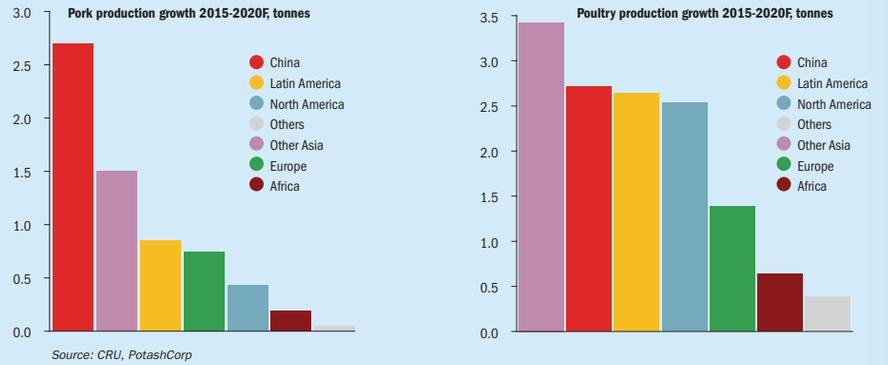
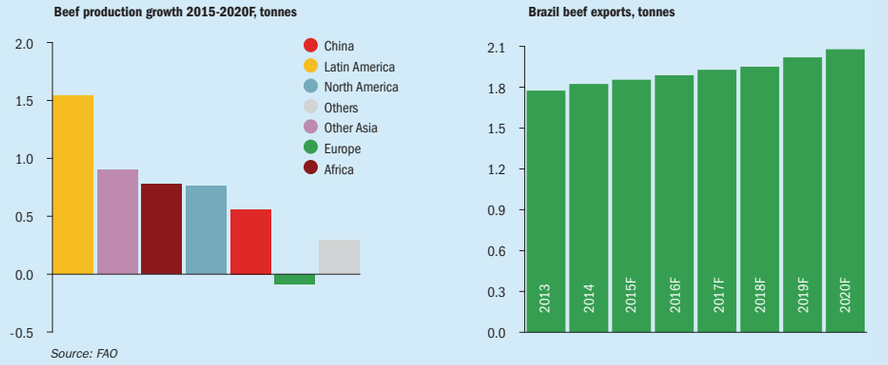
Fig 1: **Global pork and poultry production forecast** 2015-2020



Source: CRU, PotashCorp

Fig 2: **Global beef production forecast and beef export forecast for Brazil**



Source: FAO

(Figure 2). "With beef production, there's not quite the growth you'll see in poultry and pork but – looking at both Latin America and in Asia – it is still growing," comments Hackney. "In Brazil, where a lot of the beef production is taking place, we have about 20% overall growth, going back from 2013 and through to 2020."

Aquaculture is emerging as a particularly "exciting and faster growing" market for feed phosphates, suggests Hackney. "In Southeast Asia, in southern Chile, in Northern Europe, although less so, in those three areas you have a significant amount of aquaculture. That is where some of the major growth has already taken place and is going to be taking place in the next few years. In Asia you've got Vietnam, Thailand, China [for example]."

Growing Latin American and Asian demand

World feed phosphate consumption is 8.2 million tonnes (41% P_2O_5 basis) with China, Europe, and the Americas being the main regional markets, collectively accounting for over three quarters of the global market[2] (Figure 3). World demand has been growing at 1.4% per annum on average over the last decade – a trend that is expected to continue this year and into 2017. In future, the main growth potential is likely to come from Latin America, Brazil in particular, and Asian countries (Figure 4). Demand is also likely to grow in the Former Soviet Union, the Middle East and Africa[2].

Feed phosphate capacity is largely in the hands of around 22 producers operating in distinct regional markets (Figure 5). The top 10 global producers in order of capacity are PotashCorp, Mosaic, Timab Phosphates, Vale, Yara, Yunnan Phosphorus Chemicals (YPC), EuroChem, EcoPhos, Sinofert Yunlong and OCP (Figure 6).

All of North America's 1.6 million t/a of feed phosphate capacity is operated by

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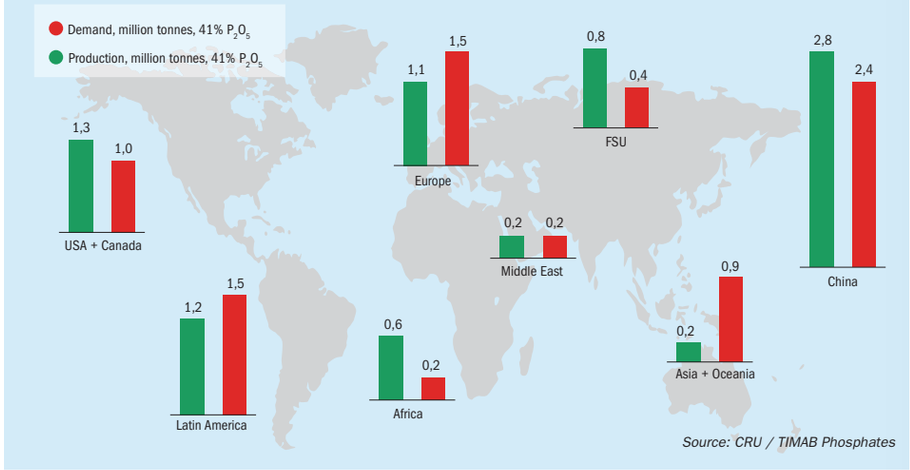
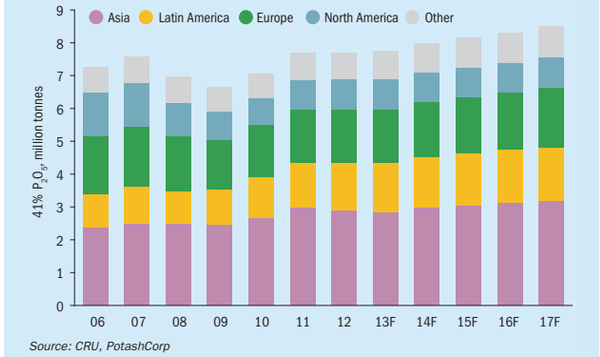
Fig 3: **Regional supply / demand balance for feed phosphates**



just three large producers, PotashCorp, Mosaic and JR Simplot. China, in contrast has a starkly different feed phosphate production profile. Its three major producers, YPC, Sichuan Lomon and Sinofert Yunlong control less than a quarter of the country's massive 5.6 million t/a of production capacity (Figure 5). "[Looking at] major producing regions and producers, one of the interesting things is China," comments Hackney. "They have many, many small producers. Contrast that with the United States where you basically have three producers."

Despite growing demand, the feed phosphates market is in a state of oversupply with around 14 million tonnes (41% P_2O_5) of capacity globally supporting an 8.2 million tonne market[2]. This means feed phosphates has been "a business where you have enough capacity to run at 55-60% and satisfy all the demand in the world" according to Hackney. Global average operating rates have varied during the last decade, with surplus feed phosphate capacity being brought into production when demand has allowed. Operating rates fell from above 65% in 2006 to almost 50% during the 2009 recession, before rebounding to around 55% currently[1]. However, curtailments and closures, and recent downgrades to capacity growth forecasts, could see operating rates recover to close to 70% over the medium term.

Fig 4: **Feed phosphate demand by region**



Growth in global feed phosphate capacity continues to be driven by major expansions in China, Morocco and Saudi Arabia. This includes over one million tonnes of extra capacity from the opening of several new, large-scale, vertically-integrated plants dedicated to exports[2]:

- 300,000 t/a of production capacity from OCP in 2013
- 500,000 t/a of production capacity from Yunnan Phosphorus Chemicals in 2015
- 250,000-300,000 t/a of production capacity from Ma'aden expected in 2017

"There's a lots coming on-stream in China and the Middle East, a few in Latin America and also in Russia. For me, the ones to pay attention to – that will have a significant impact – will be Middle Eastern and North African producers," advised Clay Hackney. "Whereas in China, most of that expansion will either replace curtailed production or be consumed from internal growth."

Fig 5: **Major phosphate producers and market shares by region**

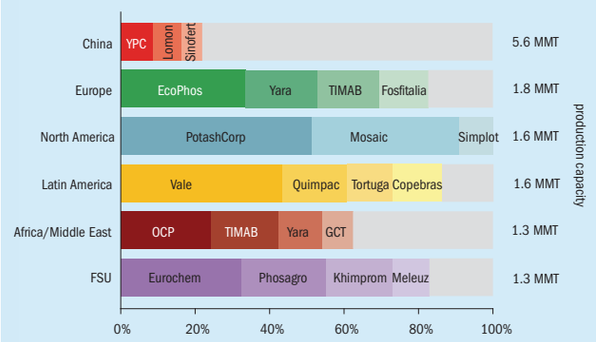
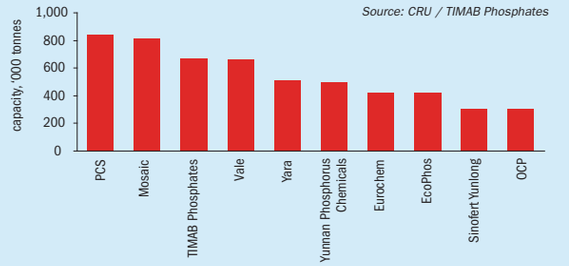


Fig 6: **Top ten global feed phosphate producers by capacity**



The entry of Ma'aden and OCP

Saudi Arabia's entry into the feed phosphate market next year could well impact on prices. MCP and DCP production from the soon to be completed Wa'ad Al-Shamal project, a joint venture between Ma'aden, Mosaic and SABIC, will be targeted at Southeast Asia, India, East Africa and Oceania. "The majority of feed phosphate produced at the facility will enter the export market so this kind of extra capacity could have a significant impact on global inorganic feed phosphate prices when the plant is operational," Juan von Gernet, phosphate team leader at CRU, told *FeedNavigator* last year. "Of course it depends on how Ma'aden wants to play it. If they push it all out at once onto a region that is already well-supplied then prices could tumble – but the Saudi player might take a different road altogether."

OCP has also moved to increase its foothold in the Brazil's feed phosphates market with DCP and MDCP produced at its 300,000 t/a capacity Safi chemicals complex. Crucially, the Moroccan producer has strengthened its distribution network in the country, improving its ability to store and deliver feed phosphates, by setting up a subsidiary company, OCP Fertilizantes. In countries such as Brazil, good logistics and the ability to offer a complete service package are the key to being a successful feed phosphates market player, according to CRU. "The producers with the highest animal feed market penetration have proven to be responsive to feed manufacturers' needs and ship the product where, when and how the customer wants it," concludes CRU's Juan von Gernet. Yara International, which has invested heavily in its Latin American phosphate business, is one producer which has successfully married feed phosphate sales to a comprehensive customer service package.

Curtailments and closures

Capacity expansions have been partly negated in recent years by a number of plant closures which have cut global feed phosphate capacity by around 500,000 tonnes (P_2O_5)[1], including the loss of:

- 270,000 tonnes P_2O_5 from Tessenderlo's Ham plant closure in Belgium in 2014
- 115,000 tonnes P_2O_5 from Mosaic's Riverview plant write-off in the US
- 51,000 tonnes P_2O_5 from PotashCorp's Sao Vicente plant closure in Brazil in 2013

This has affected the market significantly, according to Clay Hackney: "We see oversupply and get this sense that capacity is going to outgrow demand. Interestingly enough, in the last few years a number of curtailments have come about – the Tessenderlo shutdown counted for quite a bit – decreasing capacity by half a million tonnes P_2O_5."

Hackney continues: "With some recent curtailments and with [2014-2017] capacity growth not being quite being what was anticipated – previously it was forecast at 2.2 million – we're currently expecting one million tonnes of production capacity growth (around 750,000 tonnes net) through to 2017."

Roullier rules the roost

Restructuring and closures have affected European feed phosphate production markedly in recent years. Tessenderlo Group, previously one of the world's largest producers of inorganic feed phosphates, ceased production at its Ham plant in Belgium in 2013 and sold off its Rotterdam Aliphos feed phosphate plant to EcoPhos. Innovative Belgian producer EcoPhos is planning to expand its global feed phosphate production capacity to one million t/a by 2020, including the opening of a 220,000 t/a capacity plant in Dunkirk, France, next year (*Fertilizer International*, 473 p38).

Timab Phosphates, part of Roullier Group, strengthened its position in Europe by purchasing two Spanish feed phosphate sites – the Flix DCP plant and Cartagena MCP plant with a combined production capacity of 200,000 t/a – from Ercros in 2014.

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This added to Timab's existing 470,000 t/a of DCP, MDCP and MCP capacity provided by its Saint-Malo plant in France (200,000 t/a) and its GABES 1 and GABES 2 plants in Tunisia (270,000 t/a). The Flix plant produces 100,000 t/a of "extremely pure di-hydrated DCP", according to Roullier.

A change in preference from DCP to MCP has accompanied Roullier Group's increasing dominance in Europe, according to CRU. "Consumers are choosing to switch to superior quality products such as MCP in a market where Roullier now rule the supply roost, following Tessenderlo's exit in 2014," suggests CRU's Juan von Gernet.

Norway's Yara and Italy's Fosfitalia are the other important players in the European phosphate market. Russian producer PhosAgro also supplies feed phosphates to the European market from the 240,000 t/a capacity Balakovo MCP plant operated by its Apatit subsidiary. PhosAgro, Russia's only MCP producer currently, should benefit from future rises in European import demand.

The quality of European feed phosphates, high by global standards, is particularly valued by the aquaculture sector. "EU-sourced feed phosphates come with a high level of solubility which allows a reduction in phosphorus residues in water and enables fish producers in other markets to meet tight environmental controls," according to CRU.

China the key global marketplace

China is the world's largest producer and consumer of feed phosphates. The country's consumption more than doubled between 2001 and 2011 and currently stands at around 2.4 million t/a. The bulk of production is for poultry and swine feed phosphates, although the aquaculture market is of growing importance. "Chinese families eat a lot of freshwater fish," comments senior CRU consultant, Isaac Zhao. "The feeding of freshwater fish and shrimp is significant and generates huge demand for inorganic feed phosphates, mostly MCP."

The country currently produces around 2.8 million t/of DCP, MCP and MDCP. Production capacity is mainly located in the central and southern provinces of Yunnan (40%), Sichuan (34%), Hubei (10%) and Guizhou (7%). Transportation distances can be large as feed production is generally concentrated in east coast provinces such as Shandong and Guangdong.

Raw materials supply is a key factor affecting the competitiveness of the Chinese feed phosphate industry, as many of the country producers are non-integrated and reliant on external sources of phosphate rock. Although currently in a state of oversupply, China's ability to export feed phosphates is likely to become increasingly constrained due to a combination of rising domestic demand and production curtailments. China is unlikely to become a major destination for Moroccan feed phosphates and forthcoming Saudi Arabian exports, according to CRU, although this partly depends on production costs.

Recent additions to Chinese feed phosphate capacity include the construction of a 50,000 t/a capacity TCP plant by Wengfu and a Japanese partner in 2013. The plant, the country's first TCP plant, is dedicated to Japanese export production. The opening of a vertically-integrated 500,000 t/a capacity DCP plant in Yunnan province by Yunnan Phosphorus Chemicals (YPC), the mining subsidiary of Yuntianhua Group, has been the most significant supply development in China in recent years.

Regional imbalances and trade flows

Although the industry is becoming increasingly global, 85% of feed phosphate demand globally is still met by capacity within regions[2]. A shake-up to the supply side of the feed phosphates market looks increasingly likely, however, with excess production capacity in some regions opening up opportunities to supply other parts of the world. In particular, trade patterns are likely to change over the next few years as production from OCP and Ma'aden starts to make its presence felt.

"The Middle East and North African producers, look like being players of the future – they are obviously going to be producing more than they need, " comments Clay Hackney. "US producers are still in surplus and have opportunities to play into markets where they are currently located, specifically their domestic market but also to export to Latin America and Southeast Asia."

In terms of the changes in trade flows expected between 2014 and 2017, Hackney concludes there will be "quite a change" from the previous situation: "The Middle East will go from a net importer to 15% of trade, Africa's exports will increase by 94%, Latin America's imports will increase by 34%, China's exports will decrease by 30%. In the EU, which has traditionally been in oversupply, imports will increase by as much as 3-4 times."

Looking ahead

The attractiveness of the feed phosphates market and the ability of producers to make sales to farmers is linked to product affordability. The costs of grain and profits on the sale of meat being key, as Hackney explains: "Obviously, grain and meat prices have an impact on feed phosphate consumption. From the end of 2012 throughout 2013, when grain prices were higher, we saw feed phosphate demand decrease, at least on the international markets. There were other things going on there too, such as avian flu, but it did have an impact."

Product pricing has generally remained stable in recent years, enabling feed phosphate producers to generate consistently high margins on their sales. This has not always been true of Southeast Asia and China, however, where price volatility has generally been the norm.

The addition of new capacity to an already oversupplied market remains a challenge for the industry globally[2] – although recent curtailments, closures and a scale-back in planned new capacity may provide some scope for industry operating rates to increase.

Feed phosphate producers are monitoring the impact of substitute products on their businesses, particular alternatives such as phytase and DDGS (distillers dried grains with solubles), a by-product of ethanol production. Fortunately, the current low oil price environment, due to its influence on the ethanol market, should limit the ability of DDGS to capture market share from feed phosphates for the time being.

Phytase substitution, in contrast, has already hit feed phosphate consumption in mature markets such as the US. "I'm not sure that phytase has reached its full potential," comments Clay Hackney. "It could have an impact on our business and that's something we must keep an eye on. On US feed phosphate sales, going back all the way to 1994, you can see what happened when phytase came into play."

Hackney was referring to the effect of phytase on US feed phosphate consumption. This peaked at around 1.6 million t/a in 1994 but has declined to 0.6-0.8 million t/a over the following 15 years. The contraction in the US market has been linked to a number of factors, including the introduction of phytase and the increased availability of DDGS from ethanol production – although the leap in the corn price to $7 a bushel and the US drought five years ago also played a role.

Competitive advantage

Integrated feed phosphate producers and manufacturers of high quality products should enjoy a competitive advantage going forward. "The feed business is a difficult business: you're operating in an environment where plants are running at 60% capacity and could easily overproduce and put too much product into the market," comments Clay Hackney. "But when it comes to product quality you can differentiate yourself from competitors – there is definitely a niche market for quality producers."

Hackney added: "Obviously a fully integrated producer is going to have an advantage. If you're mining rock to supply your phosphoric acid plants all the way through to your feed plants there's going to be savings along the way. It is very difficult to imagine buying-in raw materials without having some other strategic [supply chain] advantages – you'd need to be close to water, have good freights rates, have a good partner supplying your raw material, that would be key." ■

PRODUCT TRENDS

Global feed phosphate consumption has been affected by two distinct and opposing market trends, according to IHS Markit. In developed countries, inorganic calcium phosphate demand has declined in recent years, due in part to the increased cost of inorganic feed phosphates, substitution by phytase and the usage of other forms of protein in feed diets. In contrast, increasing disposable income and meat consumption has driven a rise in calcium phosphate consumption in developing countries.

IHS Markit expects global consumption of feed phosphates to grow at 2.0% annually during 2015–20, led by China at 4.6%, Africa and the Middle East at 2.5%, and the US at 0.9%.

Consumption in several other countries and regions, in contrast, is projected to decline over the next five years, including Japan, Latin America, and Western Europe.

The feed phosphates market is broadly divided between dicalcium phosphate (DCP), monocalcium phosphate (MCP) and tricalcium phosphate (TCP), according to IHS Markit, with a global share of 64%, 29% and 7%, respectively. The globally important DCP market will grow by over 1.5% annually during 2015–2020, suggests IHS Markit, led by a projected growth rate of 4% in China. Outside of China, however, world DCP consumption is projected to decline at 0.7% annually over the same period. Declines in DCP consumption have been particularly marked in the US, linked to decreasing domestic production and MDCP substitution.

The growth prospects for MCP and TCP are more positive with IHS Markit expecting world consumption to grow by an average of 2.5% annually over 2015–2020. MCP growth will be led by China at about 7% per annum and 3.5% annual growth in the rest of Asia . MCP consumption is also on the rise in Africa and the Middle East, the US and Latin America. Western Europe remains the leading consumer of MCP currently, with just over a quarter share of the world market. The US, China, Central and Eastern Europe, Africa and the Middle East are also sizeable markets.

Most TCP consumption is for poultry. Central and Eastern Europe and China are the largest consumers, with a global market share of 34% and 25%, respectively, reports IHS Markit.

The US, Japan and Latin America are the other main TCP markets internationally. Future demand growth in TCP is expected to come from China (7% annually) and the US (3% annually) up to 2020. Consumption is forecast to decline elsewhere. ■

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