
Apr-Jun 2022
Fertilizer View
PROVIDE VALUABLE INFORMATION OF GLOBAL FERTILIZER INDUSTRY
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News in Brief

UN Warns Global Food Crisis Could Turn into 'Catastrophe'

The global food crisis caused by the war in Ukraine could turn into a "catastrophe" by 2023.

"Food should never be a luxury; it is a fundamental human right. And yet, this crisis may rapidly turn into a food catastrophe of global proportions," a UN Crisis Response Group on Food, Energy and Finance report warned.

In 2022, up to 81 million people will be facing food crisis or worse conditions and up to 19 million more people are expected to face chronic undernourishment globally in 2023 if food exports from Russia and Ukraine continue to decrease, according to the UN.

"This year's food crisis is about lack of access. Next year's could be about lack of food," UN Secretary-General Antonio Guterres warned.

The UN report found that 94 countries, home to some 1.6 billion people, are currently exposed to at least one dimension of the crisis and unable to cope with it. *(Source: EFE)*

▲ *Out of the 1.6 billion, three quarters live in 'perfect-storm' countries, meaning countries that are severely exposed and vulnerable to all three dimensions of finance, food, and energy, simultaneously. (Photo: Tashiqa)*

Brazil Guaranteed to Receive Russian Fertilizers

▲ *Chinese President Xi Jinping (C) hosts the 14th BRICS Summit via video link in Beijing, China, June 23, 2022. /Xinhua*

Brazil, a global agri-food power, imports more than 80% of its fertilizers.

The Russian President Vladimir Putin assured his Brazilian counterpart by phone 25 June Zaich Bolsonaru Moscow "commits" to guarantee Brazil "uninterrupted supply" in fertilizer sabsolutely necessary for the strong agri-food sector of the largest Latin American country.

During a public event in Brasilia on 25 June, Bolsonaro said he had

discussed “food security” and “energy insecurity” with his counterpart, without elaborating.

The Kremlin, for its part, said in a press release that Putin had spoken during the meeting. “He stressed that Russia is committed to fulfilling its obligations and guaranteeing the uninterrupted supply of Brazilian fertilizers to Russian farmers.”

He also called for “Restore the architecture of the free trade in food and fertilizers, which has collapsed due to Western sanctions” imposed on Russia-Ukraine conflict.

Although it is global agri-food powerBrazil imports more than 80% of the fertilizer it uses, a rate that rises to 96% in terms of potassium, according to data from the Brazilian Ministry of Agriculture.

More than 20% of fertilizers imported into Brazil come from Russia, its main supplier.

Latin America’s largest economy is seeking to strengthen its supply chains, focusing mainly on Canada, Jordan, Egypt and Morocco. It is also trying to revitalize domestic fertilizer production.

Putin has said on several occasions that Russia is not to blame for the world food crisis, as it is Western sanctions that impede Russian exports because they hinder logistics, international payments and transportation. The Russian President has insisted that the European Union (EU) has sanctioned Russian fertilizers, while from Brussels they insist that this is not the case and that they have not sanctioned Russian agricultural products either. ***(Source: CyprusMediaNet)***

Morocco to Establish a Fertilizer Plant in Guatemala

Morocco To Establish a Fertilizer Plant in Guatemala.

The President of the Republic of Guatemala, Alejandro Giammattei, announced that Morocco has proposed the construction of a fertilizer factory on Guatemalan territory, with the aim of opening the door to distributing fertilizers generated in the Moroccan facility to Latin America.

Speaking at the third ordinary meeting of the National Council for Urban and Rural Development held on 22 June, Giamatti confirmed that Guatemala and Morocco are approaching an agreement for the manufacturing of low-cost fertilizers on Guatemalan territory and the delivery of the plant to farmers.

“It would be to supply Latin America and we would be benefited since they would give us a much lower cost because we don't have to pay for transportation or containers. It would be much cheaper with local production,” said the Guatemalan president.

Giamatti noted that the deal with Morocco’s King will be signed shortly as both a medium and long-term solution.

With this agreement, Guatemala will not “be subject to [fertilizers] coming from outside and to the payment of maritime freight, because we end up paying things that we should not,” he underlined.

According to Giammattei, the Guatemalan government is considering the prospect of importing European fertilizers from Morocco at lower prices despite recent drops in agro-input costs.

“We do not intend to earn a single penny, but rather that the fertilizers have a better price so that the farmers can have better harvests,” the Guatemalan president added. ***(Source: MLN MOROCCO LATEST NEWS, by Aya Benazizi)***

Thailand to Seek Fertilizer Supply from Saudi Producers

Thailand is planning to negotiate with Saudi Arabia for the supply of fertilizers as the country is currently facing a shortage, especially due to the high cost of imports.

The Thai Chamber of Commerce will coordinate with Saudi suppliers and a business event is to be held between three major Saudi-based fertilizer suppliers and Thai importers on June 29, Thai local media reported citing Commerce Minister Jurin Laksanawisit.

Thailand heavily relies on imports for its fertilizers, with only 8 percent coming from domestic sources and a usage of about 5 million tons of fertilizer a year.

Laksanawisit added that two Saudi suppliers were recently provided permission to sell fertilizers to Thailand.

Thailand heavily relies on imports for its fertilizers, with only 8 percent coming from domestic sources and a usage of about 5 million tons of fertilizer a year, according to the minister.

The country’s overall demand for fertilizer from Saudi Arabia is about 808,000 tons, the media report noted citing industry statistics. ***(Source: ARAB NEWS)***

UK’s Biggest Fertilizer Producer CF Industries to Shut Plant as Energy Costs Bite

Britain’s biggest fertilizer producer is to close one of its plants as soaring energy costs continue to bite.

US fertilizer group CF Industries said it would permanently shut its Ince plant in Cheshire and restructure its UK operations, leading to the loss of about 350 jobs.

The company is an important part of the UK food supply chain, supplying fertilizer for farmers as well as CO_2, which

The expected prices of natural gas in the future suggest that nitrogen fertilizer facilities in the UK and Europe will be "the world's high-cost marginal producers for the foreseeable future, presenting a constant challenge to the sustainability of current operations", said CF.

is used in the meat industry for slaughtering livestock, food and drink production and packaging.

Tony Will, CF's chief executive, said while the company had explored all possible alternatives including changing business models and seeking a buyer for the plant, the best way of "making sure we could maintain operations and provide critical products to the local market" was to close the facility. The move would make CF's Billingham plant in Teesside "viable for the long term", he added.

The Ince plant had been closed since September when soaring gas prices in Europe made the production of fertilizer uneconomical and CF shut down the facility, along with the Billingham plant. However, the closure also removed a large portion of the UK's CO_2 supply, which is a byproduct of the fertilizer manufacturing process, prompting warnings of chaos. ***(Source: WorldNewsEra, by Madeleine Bruder)***

A Surge in Fertilizers Prices Fuel Food Crisis in Africa

An increase in world fertilizer prices is adding to worries about food security across sub-Saharan Africa, where small-scale farmers depend largely on imports if they even use additional nutrients at all.

With prices tripling over the past 18 months, many farmers are considering whether to forgo purchases of fertilizers this year. That leaves a market long touted for its growth potential set to shrink by almost a third, according to Sebastian Nduva, program manager at researcher group AfricaFertilizer.Org.

That could potentially curb cereals output by 30 million tons, enough to feed 100 million people, he said.

Sub-Saharan Africa already has the world's lowest fertilizer application rates, averaging 12 kilograms per hectare compared with global average of 110 kilograms.

With usage set to fall as input costs rise, the threat to regional food security and political stability is growing, according to agriculture experts.

That will increase the region's dependence on imports at a time when food prices are near a record high. More than 20 million people across Sub-Saharan Africa are already on the brink of famine, according to the World Food Programme.

Soaring gas prices helped drive fertilizers prices higher in 2021, squeezing supply as increasingly costs shuttered plants while producers introduced export restrictions.. ***(Source: CGTN, By David Ochieng Mbewa)***

INDUSTRY OBSERVATION

Fertilizer and Food Prices

Could be High for Years

High demand and many supply interruptions have pushed fertilizer prices to record levels and the disruption will persist.

Russia and Belarus supply more than 20% of the world's fertilizers, in a market that was extremely tight.

Fertilizer is crucial to agricultural output and global demand for it rose by 6.3% in 2021.

This, combined with supply disruptions, took prices 78.6% higher year-on-year in 2021, according to the IMF.

After the outbreak of the Conflict between Russia and Ukraine, fertilizer prices soared to record highs.

Tighter Western sanctions on Belarusian fertilizer producers have heightened the supply-side risks.

What next:

The fertilizer market imbalance, like that in the semiconductor chip market, will last well beyond this year. Persistently higher fertilizer prices will reduce usage and thus lower crop yields into 2023. This will increase poverty and food insecurity, and dampen GDP growth and living standards.

Supply will fall faster than demand for fertilizer in 2022/23, keeping prices high and prompting self-sufficiency drives and supply chain changes. This may increase intra-regional trade in fertilizer.

Subsidiary Impacts:

• About 30% of the world's population lacked access to adequate food in 2020, the World Bank says, and the share could exceed that in 2022.

• Carbon dioxide produced as a by-product of fertilizer output is key to packaging fresh food; more CO_2 shortages will disrupt food packing.

• Fertilizer output, consumption and trade patterns will change as countries seek more self-sufficiency, creating chances for new suppliers.

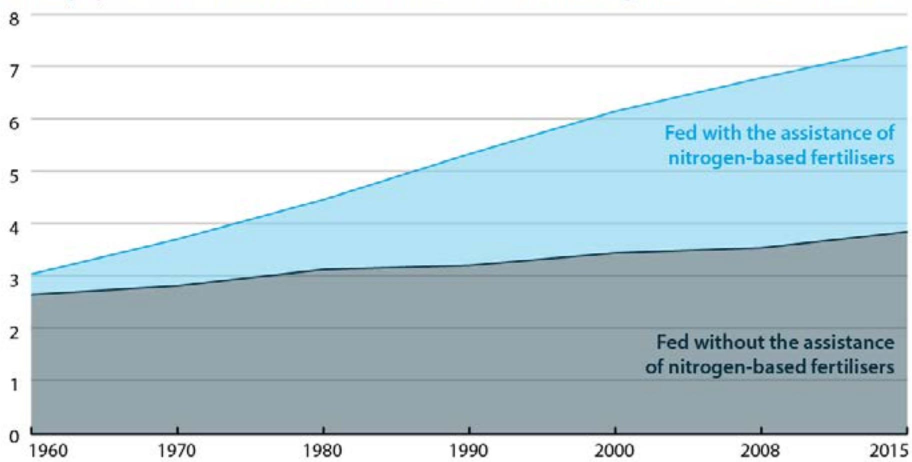
• Merger and acquisition activity will rise in the fertilizer market, likely raising market concentration and contributing to higher prices.

• Lower use of fertilizers will reduce emissions from their production and application, helping countries to meet climate targets.

Analysis

Fertilizer use has risen sharply since the 1960s, raising crop yields. In 1960, when chemical Fertilizer use was much rarer, crop yields without fertilizer assistance supported 87% of the world population. By 2015, just 52% of the world population could have been fed from crops grown without chemical fertilizer assistance.

World population fed with and without the assistance of nitrogen-based fertilisers (billions)



Source: Our World in Data

Demand for N-based fertilizer rose by 5.0% to 113.7 million tonnes in the 2020/21 farming year. Demand for P-based supplies rose by 6.8% to 49.7 million while demand for K-based supplies rose by 9.1% to 40.4 million.

N-based fertilizer, which accounts for roughly 55% of consumption, increases plant growth and must be applied every year. P- and K-based fertilizer increase crop quality. The three nutrients are mostly used in combination.

Demand

Global demand for fertilizer rose by 6.3% in the 2020/21 growing season (usually July-June), according to the International Fertilizer Association (IFA), having grown by less than 2% each year from 2015/16 to 2019/20.

In the last few years, several factors have boosted demand:

• Governments have sought to develop domestic agriculture to boost self-sufficiency and reduce reliance on global supply chains. The major economies are all trying to move towards this, albeit to different degrees.

• The self-sufficiency drive became more marked after the pandemic-related disruption of global supply chains. Eighteen countries have introduced 49 trade restrictions on food and fertilizers since the start of the pandemic, according to the Global Trade Alert.

• The growth of food prices in 2021 (by 129.1%, according to the IMF) created an incentive for farmers to raise output, which they did by using more fertilizer to maximise yields.

• There is anecdotal evidence that farmers brought fertilizer purchases forward in 2021 to guard against delays and changes in prices and exchange rates.

Demand for fertilizer rose everywhere in 2021 except Western and Central Europe and the Middle East.

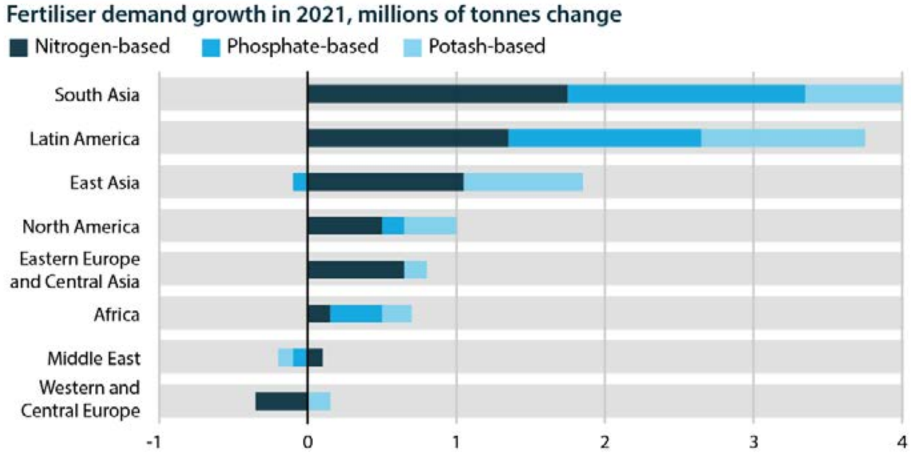
In the case of the EU, its 'Farm to Fork' strategy aims to improve farming sustainability and specifically to reduce chemical-based fertilizer use by 20% by 2030 to help reduce carbon emissions.

Both manufacture and use of chemical-based fertilizers create emissions.

Late last year the IFA responded to historically high prices by revising its forecast for fertilizer demand in 2021/22. It had forecast 2021/22 growth of 0.9% in August, but the price shock prompted it to downgrade this in November to a contraction of 2.7%, due largely to reduced affordability.

In its revised forecast, the IFA expects nitrogen-based

Fertiliser demand growth in 2021, millions of tonnes change

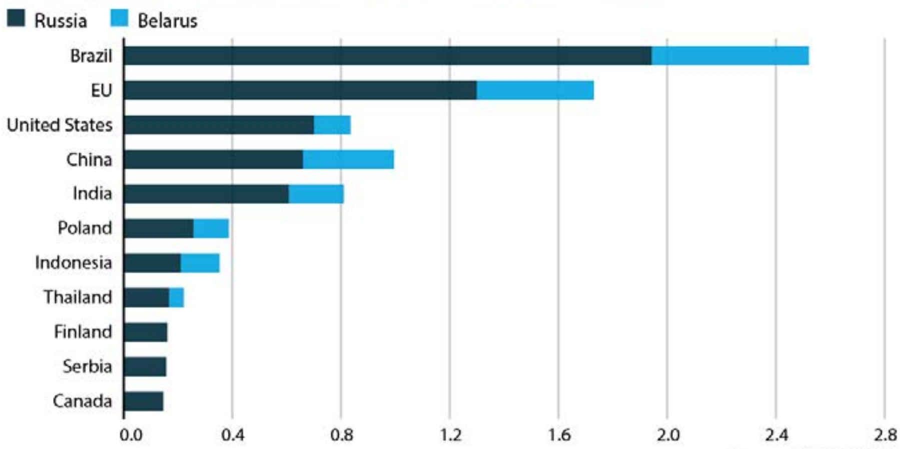


Note: Exact dates of the 2020/21 fertiliser year vary by country

Source: International Fertiliser Association fertilizer demand to fall by 2.1%, with falls of 3.3% and 3.8% for phosphate and potash fertilizers, respectively.

Nitrogen-based fertilizer was expected to be least affected as it is the most used of the main chemical fertilizers for all main crops. It must be applied every year, unlike phosphate- and potash-based fertilizers. The IFA forecast that demand would rebound by 2.9% in 2022/23.

Total imports of fertiliser from Russia and Belarus in 2020 (USDbn)



Source: UNCOMTRADE

Supply

The high prices in late 2021 were partly a consequence of supply-side strains that had built up since 2020 :

• COVID-19-related shutdowns disrupted output worldwide. Bad weather last year disrupted US output, especially in Texas, which is a key producer of the nitrogen-based fertilizer compound ammonia and suffered a severe storm in February 2021.

• The high costs of shipping freight and raw material inputs such as natural gas raised producers' costs. Energy feedstocks account for 70-80% of the cost of producing nitrogen-based ammonia as a fertilizer.

Belarus sanctions

Belarus accounted for around 20% of global potash-based (K) fertilizer exports in 2019 and 2020. In October 2020 Western states applied sanctions on Belarus.

The potash sector was initially little affected, but over the last year multiple sanctions have been applied to fertilizer:

• In August 2021, the US administration announced that Belarus's two state-owned potash fertilizer producers -- Belaruskali, the potash miner, and Belarusian Potash Company, the exporter, would be sanctioned. US sanctions were enforced on Belaruskali from December 8,and apply to the Belarusian Potash Company from April 2022.

• On February 1, Lithuania banned Belarus from using its Klaipeda port. Previously this was the main port for Belarusian fertilizer exports. Finding new routes, largely through Russia, such as the Ust-Luga port, will raise costs and delivery times.

• Norway-based Yara, the world's largest fertilizer manufacturer, announced in January that it would phase out its imports of Belarusian potash. Belaruskali was Yara's largest potash supplier, and Yara bought 10-15% of its output.

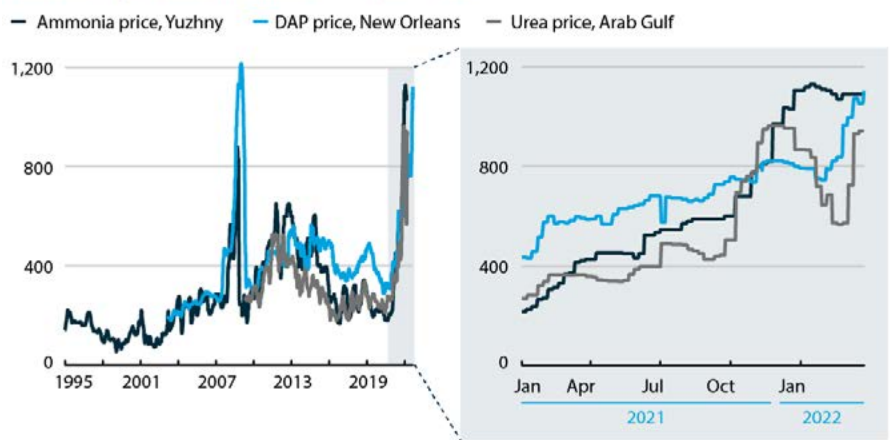
• In early March, the EU stopped potash imports from Belarus.

Impact of Russia-Ukraine Conflict

Fertilizer prices, already high coming into 2022, have soared since the Impact of Russia-Ukraine Conflict.

Western sanctions do not directly apply to Russian fertilizer firms. Nonetheless, supplies will be disrupted as Western traders try to avoid Russian supplies and shippers worry about costs, safety and insurance on the Black Sea route.

Prices of key chemical fertilisers (USD per tonne)



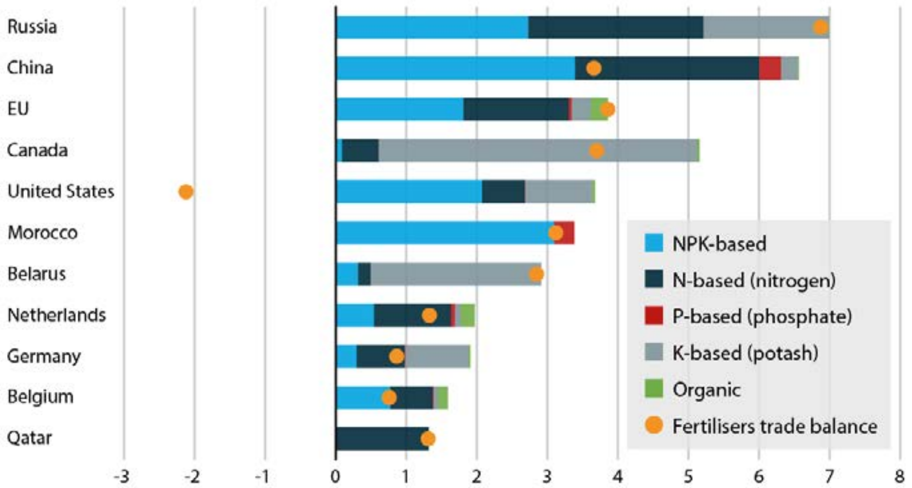
Source: Refinitiv

Until now, Russia accounted for a double-digit global share of each of the N-, P-, K-based and NPK (mixture) fertilizer markets. It was the world's largest exporter of fertilizer, earning USD7bn annually, and the only one of the largest exporters to be self-sufficient in every fertilizer.

Other key exporters

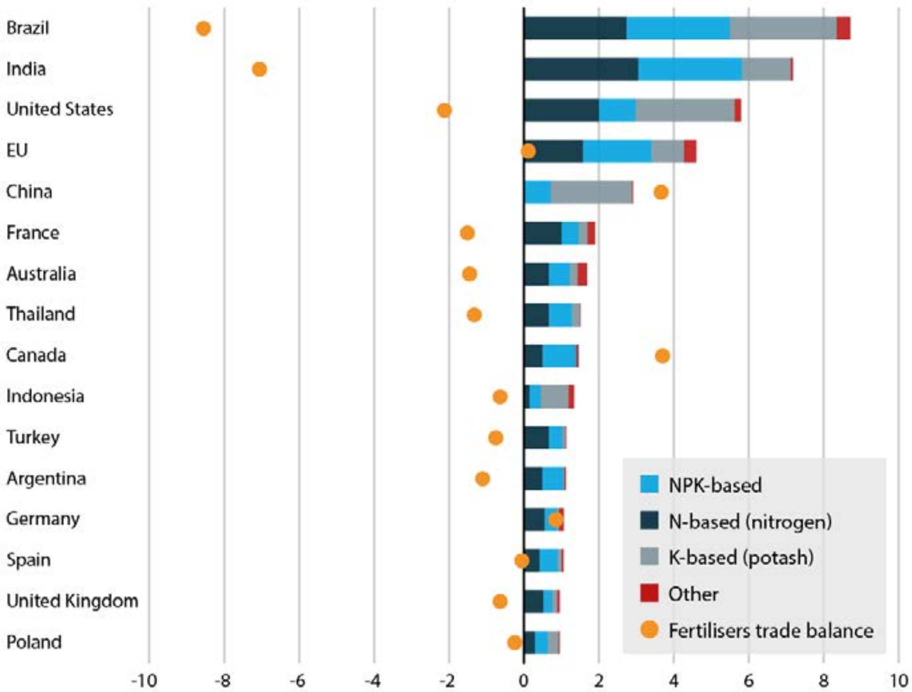
China and Canada are the second- and third-largest fertilizer exporters and run trade surpluses. However, although China is a large net exporter of N- and NPK-based fertilizer, it is a large net importer of K-based fertilizer, especially from Belarus, exposing it to disruption and higher costs.

Top exporters of fertilisers, by type, 2020 (USDbn)



Source: UNCOMTRADE

Top fertiliser importers, by type, 2020 (USDbn)



Source: UNCOMTRADE

Canada accounted for 36% of K-based fertilizer exports in 2020 and is raising its potash output this year to be in a position to fill some of the market gaps.

The United States is the fourth-largest fertilizer exporter, but runs a fertilizer trade deficit overall. It runs a surplus in NPK-based fertilizer but a deficit in N- and K-based fertilizer.

Key importers

Brazil and India are the largest net importers of fertilizer. Longer-term, farmers worldwide will look to produce more domestically or change suppliers but in the short term, they will consider using less fertilizer or planting less crops, thus reducing yields.

Smaller economies will suffer more than major economies. In South Africa, fertilizer makes up 35% of farmers' input costs and this share is likely higher in some other African countries.

Outlook

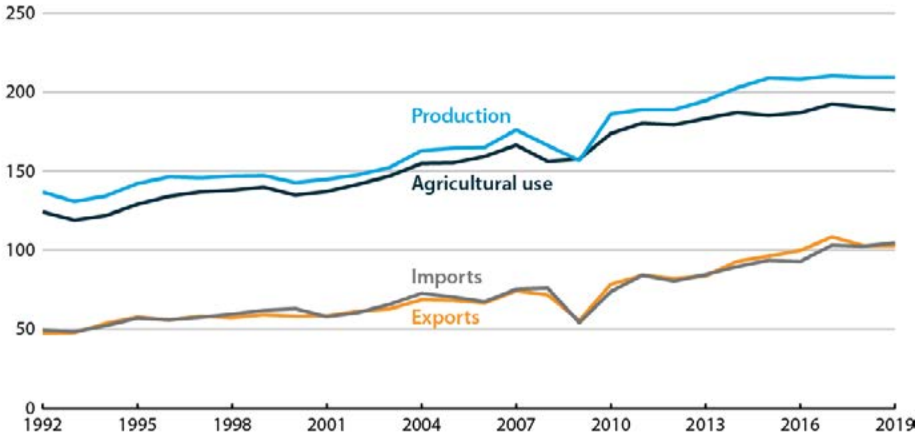
The fertilizer market has been stable over the past 30 years but the convergence of so many supply disruptions will disrupt it more, and for longer than the 2008-09 disruption did.

Fertilizer production, trade and demand will be lower. Yara, the world's second-largest ammonia producer, announced in early March that its ammonia and urea production would operate at 45% capacity this year due to supply disruptions.

Responses

The United States, Canada, Brazil and Tunisia are among countries planning to produce more fertilizer domestically. The US Department of Agriculture announced a USD250mn plan to support production, with funds expected to

World fertiliser indicators, 1992-2019 (million tonnes)



Source: Food and Agriculture Organisation

be awarded to projects from the end of 2022. Canadian giant Nutrien plans to raise potash output by nearly 1 million tonnes this year.

Brazil announced a National Fertilizer Plan last month, aiming to reduce import dependency from 85% to 45% by 2050. It wants to raise its nitrogen production capacity to 2.8 million tonnes by 2050, and to attract USD10bn of private investment to facilitate this. India increased the subsidisies it gives farmers to buy fertilizer.

It will take years for Western countries to reorient their supply chains towards allies. Meanwhile, prices of fertilizer and food will be volatile and historically high. This will increase the number of people facing poverty and food insecurity.

Rationalisation options

It is not axiomatic that reduced consumption of fertilizer will result in lower agricultural yields.

In many lower-income regions, fertilizer demand is lower than would be ideal for crop yields, due to inaccessibility and unaffordability. The United Kingdom used 169 kilograms of fertilizer per hectare of cropland in 2017 whereas China used 220 kilograms. In contrast, Nigeria used 11 kilograms per hectare and Bolivia 3.2 kilograms.

The fertilizer supply squeeze is likely to retard global development convergence, in common with other developments during the pandemic.

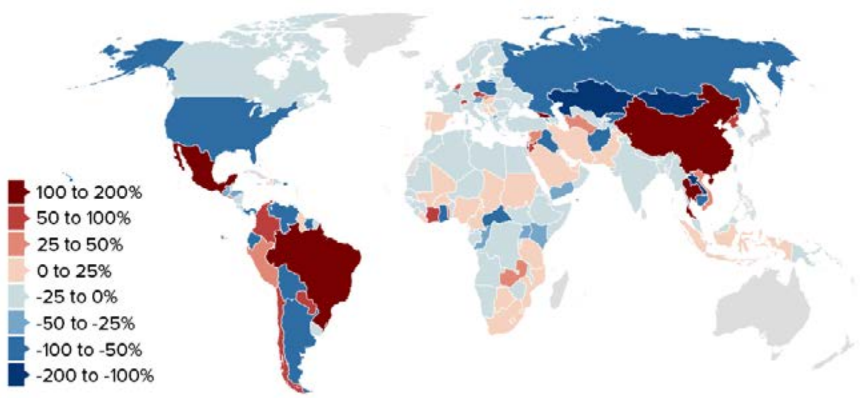
Sustainable farm management practices such as crop rotation are key. New technologies including drones and satellite imagery can help farmers know which parts of their farms need more or less fertilizer. Plant-breeding technologies capable of changing a crop's genetic make-up to aid fertilizer absorption could also grow in use.

Estimates see the agritech market doubling from less than USD17.5bn in 2019 to more than USD40bn in 2027. Private equity investment in agritech start ups has grown by more than 50% per year for the last four years. However, it will take years to roll these technologies out widely, and especially to lower-income countries.

There will be an environmental upside to lower production and consumption of fertilizers. Ammonia is made at high temperatures and accounts for 1-2% of global greenhouse gas emissions. Moreover, fertilizers produce emissions after application as crops only absorb around half the amount applied. The rest can damage the soil or run into waterways, disrupting biodiversity.

Growing shortages of fertilizer and food will have lasting ramifications for the global economy. WTO Director-General Ngozi Okonjo-Iweala said this month that "my worry is that we have a food crisis that is brewing". Fertilizer, which is key to food output, will be central to this. ***(Oxford Analytica Daily Brief)***

Countries over-applying nitrogen without gains in crop yields



Note: *This shows how much nitrogen pollution countries are causing compared with how much they reduce their yield gaps relative to directly neighbouring countries*

Source: Our World in Data

After Millennia of Agricultural

Expansion, the World has Passed 'Peak Agricultural Land'

The world produces more food than ever, but the amount of land we use is now falling. This means we can feed more people while restoring wild habitat.

Humans have been reshaping the planet's land for millennia by clearing wildlands to grow crops and raise livestock. As a result, humans have cleared one-third of the world's forests and two-thirds of wild grasslands since the end of the last ice age.

This has come at a huge cost to the planet's biodiversity. In the last 50,000 years – and as humans settled in regions around the world – wild mammal biomass has declined by 85%.

Expanding agriculture has been the biggest driver of the destruction of the world's wildlands.

This expansion of agricultural land has now come to an end. After millennia, we have passed the peak, and in recent years global agricultural land use has declined.

'Peak agricultural land'

Agricultural land is the total of arable land that is used to grow crops, and pasture used to raise livestock.

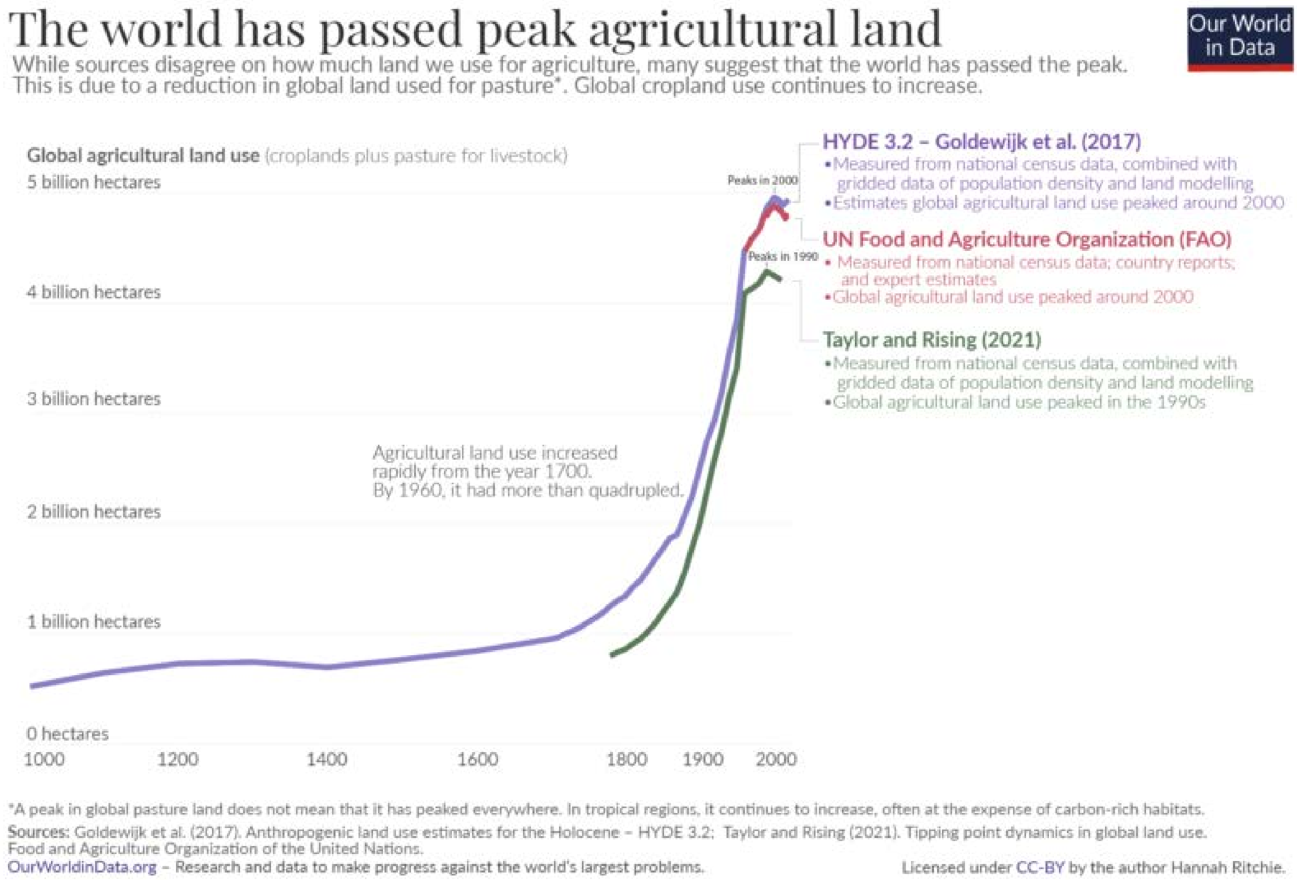
Measuring exactly how much land we use for agriculture is difficult.

If all farms were simply rows of densely-planted crops it would be straightforward to calculate how much land is being used. Just draw a square around the field and calculate its area.

But across much of the world, this is not how farming looks: it's often low-density; mixed in with rural villages; in tiny smallholdings that are somewhere between a garden and a farm. Where farmland starts and ends is not always clear-cut.

As a result, there are a range of estimates for how much land is used for agriculture.

Here I have brought together three analyses on the change in global land use – these are shown in the visualization. Each uses a different methodology, as explained in the chart.



The UN FAO produces the bedrock data for each of these analyses from 1961 onwards; however, the researchers apply their own methodologies on top, and extend this series further back in time.

As you can see, they disagree on how much land is used for agriculture, and the time at which land use peaked. But they do agree that we have passed the peak.

This marks a historic moment in humanity's relationship to the planet; a crucial step in its protection of the world's ecosystems.

It shows that the future of food production does not need to follow the destructive path that it did in the past. If we continue on this path we will be able to restore space for the planet's wildlands and wildlife.

A global decoupling of agricultural land and food production

Despite this reduction in agricultural land, the world has continued to produce more food. This is true of both crops and livestock.

We see this decoupling in the chart that presents the UN FAO's data. It shows that global agricultural land – the green line – has peaked while agricultural production – the brown line – has continued to increase strongly, even after this peak.

When we break each agricultural component out individually, or look at it in physical rather than monetary units, we find the same trend: a continued increase in output.

This shows that feeding more people does not have to mean taking habitat away from other wildlife. This decoupling means that we can produce more while giving land back to nature at the same time.

Global agricultural land has peaked, but cropland has not

Global pasture has peaked. Global cropland has not.

This might come as a surprise as global meat consumption is increasing. How, then, can pasture for livestock have peaked and now be falling?

The world produces three times as much meat as it did 50 years ago. But how this meat is produced and what types of meat we eat have shifted. First, we produce a lot of pork and chicken which are not fed on pasture.

Second, a lot of our beef production has moved from open pasture grazing towards more intensive farming methods; this has spared land.

This presents an important dilemma: grain-fed livestock is often more land-efficient than pasture-fed livestock, so you need less land overall; but the biodiversity on grazing lands is often better than intensive croplands.

What this means is that more and more animals are being fed from crops grown on croplands, rather than on pasture. In fact, almost half of the world's cropland is used to produce animal feed. Unfortunately, this conversion process from crops to meat is still an inefficient one, meaning we need a lot of land to produce a small amount of food.

Biofuels, too, have added additional pressure on croplands, especially in countries such as the US and Brazil.

Agricultural land use is still increasing in many countries – often at the expense of carbon-rich habitats

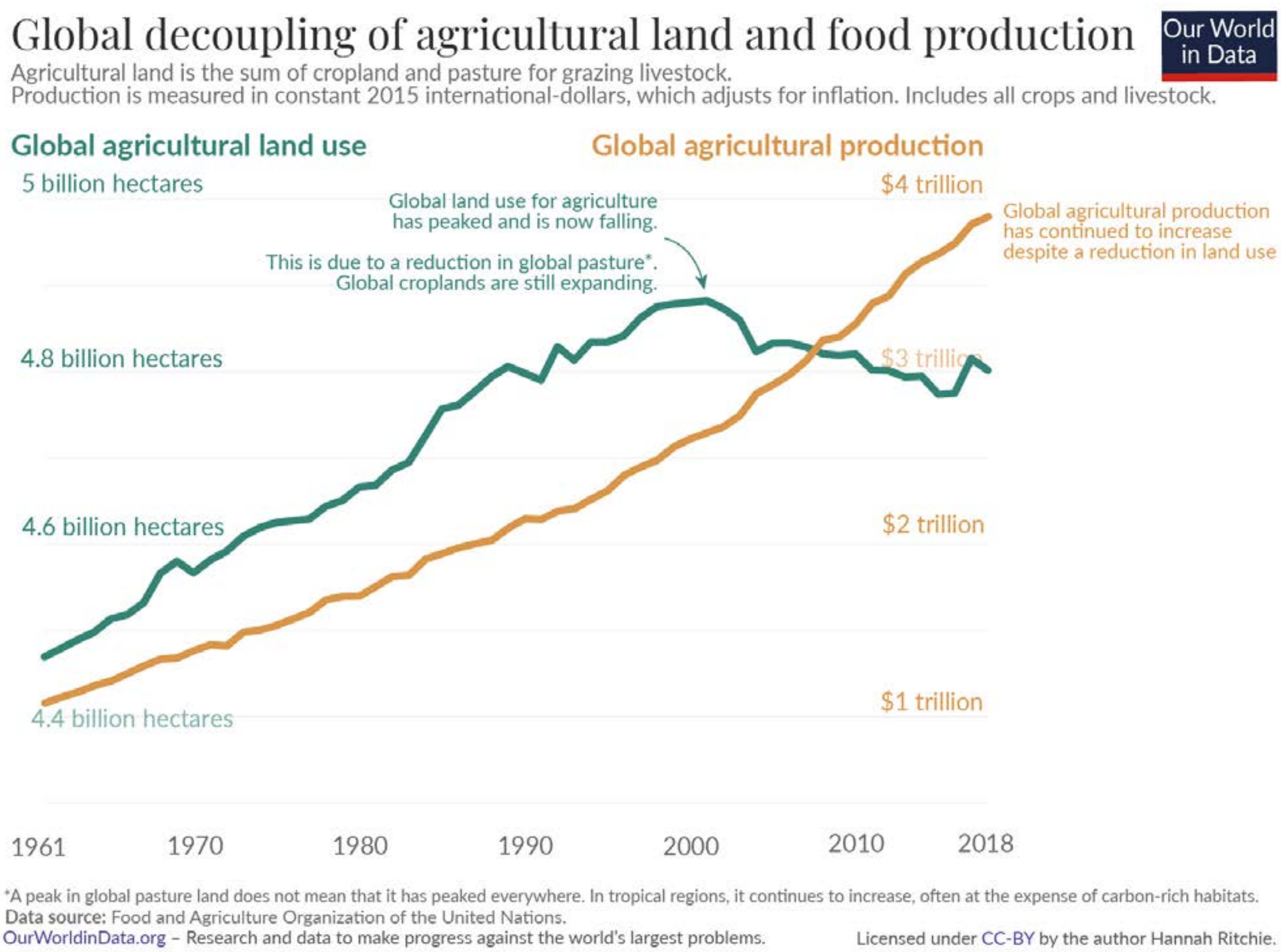
While this global picture is promising, there are several reasons why we should not be complacent about this development.

The first is that agricultural land use has definitely not peaked everywhere. Agricultural land use has decreased in some countries, but continues to increase in others.

The second is the distribution of these changes in land use across the world, and their implications for biodiversity loss and carbon emissions. The largest reductions in pasture have been across arid regions; temperate regions have also seen a reduction in recent decades; meanwhile pasture has continued to expand in many tropical countries.

Indeed, as I have covered elsewhere, the expansion of grazing land for beef production is still the leading driver of global (and tropical) deforestation.

The reason that this shift of pasturelands from arid and temperate to tropical regions is important is that the tropics are much richer in biodiversity and carbon. Over half of the world's species reside in tropical forests. Tropical forests



are also large carbon sinks, and can store a lot of carbon per unit area.

The third, as I mentioned earlier, is that global croplands are still expanding. We see this in the chart. Other sources suggest that this rate of increase might be even faster. The World Resources Institute looks at this research in more detail here.

Finally, quantifying the amount of land that is used for pasture is difficult. Here we have focused on reported agricultural land use data from the UN FAO based on census data; country reports and expert estimates, but this comes with uncertainty.

Improving our measurement of agricultural land use – potentially from satellite data – would allow us to monitor changes more closely.

Continued decline is not guaranteed: the future of land use rests on the decisions we make today

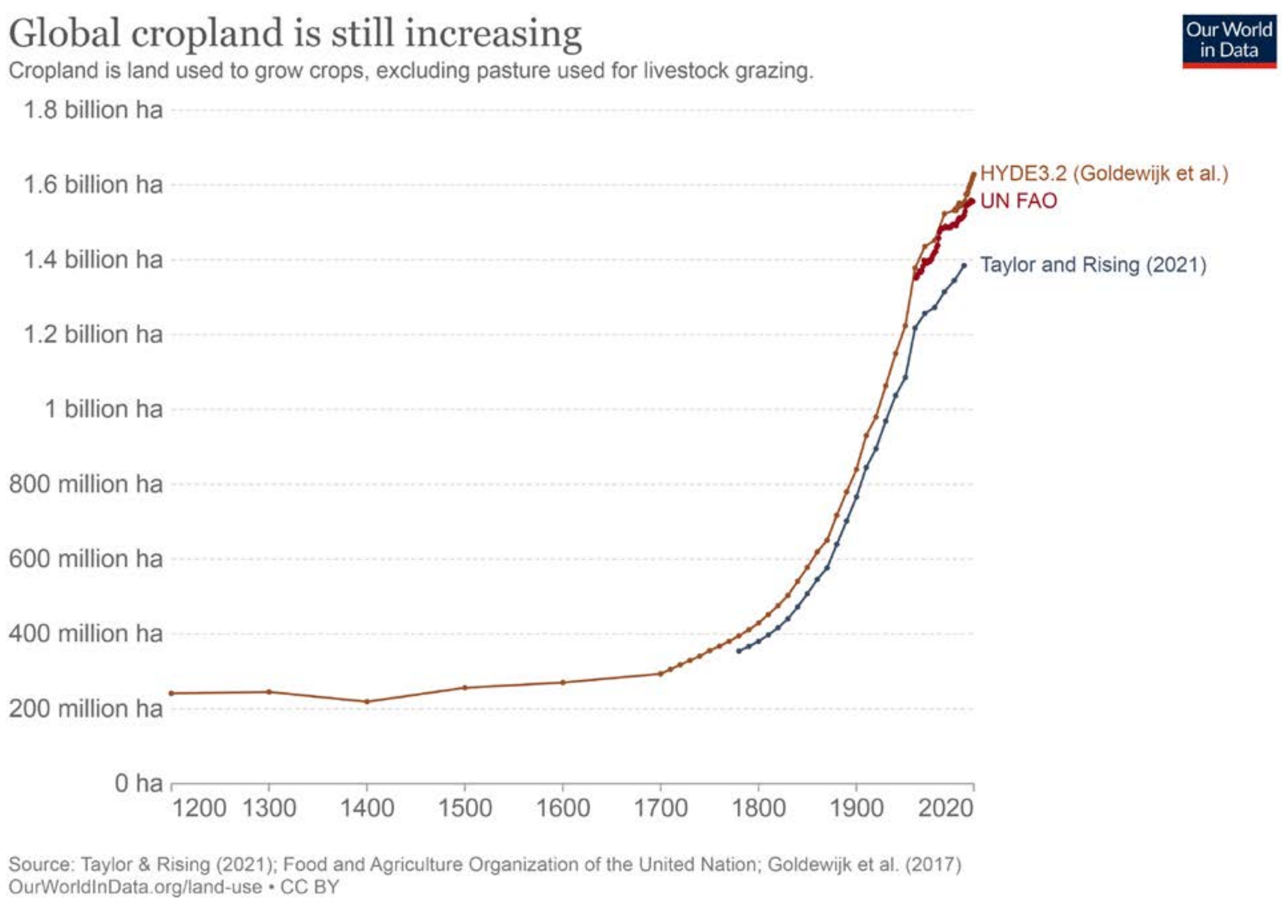
Several sources suggest that global agricultural land use has fallen in recent decades. However, a continued decline is not guaranteed.

As we see from the HYDE 3.2 series in the first chart, land use reached its highest levels in the early 2000s and has declined since then, but is seeing a small rebound in recent years.

Land use is still expanding across Sub-Saharan Africa and South America. As populations increase, and incomes rise, the pressure on land will continue.

This is why – as I argue here – improvements in crop yields and agricultural productivity are so important. Reducing land pressures by reducing meat consumption, and land dedicated to biofuels is also vital.

Fail to invest in these improvements and we risk reversing this global trend. We may end up with a short-lived and temporary peak. Make it a priority, and we can accelerate reaching this peak everywhere. ***(Source:Our World in Data, by Hannah Ritchie)***



Micronutrients: How Fertilizers

Help to Address the Problems of Hunger and Malnutrition

What are plant nutrients?

Plants need seventeen elements to grow:

• Non-fertilizer Elements: carbon (C), hydrogen (H), oxygen (O), which they obtain from the atmosphere and water;

• Macronutrients: nitrogen (N), phosphorus (P), potassium (K);

• Secondary Nutrients: sulphur (S), magnesium (Mg), calcium (Ca);

• Micronutrients: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chloride (Cl), nickel (Ni).

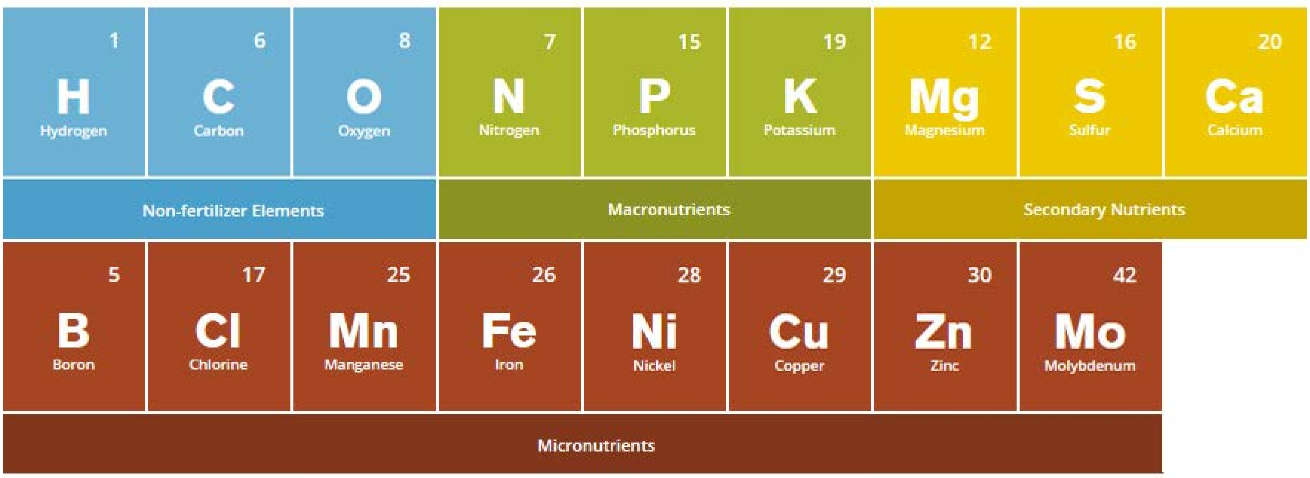
Macronutrients are found in plants at levels of 2 to 50 g/kg of dry matter or greater, while plant concentration of micronutrients range from 0.1 to 100 µg/kg.

Plant growth is limited by the essential element that is furthest below its optimum: if a single essential plant nutrient is available in insufficient quantity, it affects plant growth and thus the yield.

N, P and K are generally the most widely deficient elements but, nowadays, nutrients such as S, Zn and B are increasingly deficient in both soils and plants, becoming new limiting factors for crop yields throughout the world.

Some micronutrients essential to human health such as selenium (Se), iodine (I) and cobalt (Co) are not considered essential for plants, but can be taken up and accumulated by plants.

Mineral fertilizers provide essential macro-& micronutrients to plants, which in turn are passed on to people when consumed.



The importance of micronutrients for human health

There is a direct correlation between micronutrient deficiencies in soils and plants and micronutrient deficiencies in humans.

Micronutrients are essential for human health: they contribute to prevent chronic diseases and stunting, they strengthen our immune and reproductive systems and enhance our physical and mental abilities.

However, more than 2 billion people suffer from micronutrient malnutrition, sometimes referred to as "hidden hunger".

According to a report of the World Health Organization on the risk factors responsible for the development of illnesses and diseases, Zn and Fe deficiencies rank 5th and 6th among the 10 most important factors in low-income countries.

Children are the most susceptible to micronutrient deficiencies: 1 of 3 children in the world are stunted; and the WHO estimates that, in 2017, over 6.3 million children under 15 years old and 5.4 million of them under 5, died as a result of deficiencies in essential nutrients, particularly micronutrients (WHO, 2019).

The primary cause is diets poor in proteins and micronutrients, particularly iodine, Fe, vitamin A and Zn, or dietary changes associated to a lack of access to high-quality, micronutrient-rich foods. Stunting of children often begins before they are born, by poor quality of the diet of their mothers: micronutrient deficiencies can irreversibly affect development of children in the womb.

The potential risk of micronutrient deficiencies in the human population may be under-estimated considering that population surveys are done with human biomarkers, instead of surveys analyzing plant-available micronutrients in arable soils.

For instance, since most of the Earth's surface is iodine deficient, iodine deficiency disorders have the potential to affect a very large percentage of the world population.

Several agronomic problems have been linked to micronutrient deficiencies:

50% of world cereal soils are deficient in Zn, 30% of soils globally are deficient in Fe and most of the earth's surface is iodine deficient (Fuge and Johnson 2015). Owing to often insufficient micronutrient fertilization, the steady growth of crop yields in recent decades has compounded the problem by progressively depleting soils of their micronutrient pools.

The native soil properties, like alkalinity, can make micronutrients less available to plants, and some farming practices changing soil pH can aggravate or reduce the problem by making some micronutrients less or more available to plants.

Micronutrient deficiencies affect yields, either directly or indirectly by impairing physiological processes related to seed formation, synthesis and distribution of carbohydrates, biological N fixation and resistance to biotic and abiotic diseases.

Some micronutrients, especially B, Mg and Cu are involved in cell wall stability and strength and thus increase plant resistance against pathogen penetration.

There is a close correlation between micronutrient deficiencies in soils and plants and micronutrient deficiencies in humans (Figure 1):

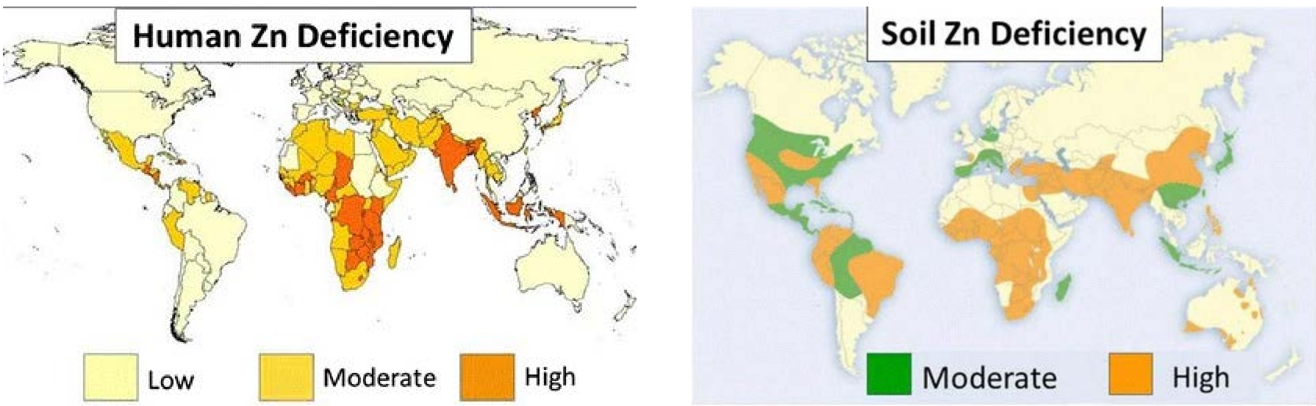


Figure 1: Geographical overlap of human Zn deficiency and soil Zn deficiency (Cakmak et al., 2017a, Plant and Soil, 411:1-4)

Micronutrient deficiencies can lead to the less efficient use of other essential plant nutrients potentially resulting in greater nitrogen losses to the environment and can lower crops' water use efficiency.

Zinc, Mg and Fe are needed by the plants to detoxify strong oxidant compounds, which cause important cell damage under conditions such as drought, heat, salinity and extreme temperatures.

Yield can be affected even if the crop is not showing overt deficiency symptoms, and micronutrient deficiency in crops often is not detected, unless farmers have access to a routine diagnostic service.

By consequence, in many places, micronutrients are applied too late, or not at all, because farmers are not aware that micronutrient deficiency is limiting their yield and response to fertilizers.

It is important to consider global micronutrient balances to improve crop yield and quality and human health. Studies have also shown the importance of balanced nutrient feeding for improving livestock productivity (FAO, 2012).

Ensuring optimal supply of Zn and B in a well-managed fertilizer program, can have a measurable increase in crop production and return on the farmer's investment, while the increased concentration of Zn in the plant will also be beneficial to human health.

The cost of micronutrient deficiencies in humans

Micronutrient deficiencies result in significant economic costs in developing countries: annual losses associated to them have been estimated to represent 5% of the GDP of certain countries, according to Gödecke et al (2018).

A World Bank report published in 2014 further estimated that losses in India linked to vitamin and mineral deficiencies were as high as $12 billion in GDP.

Economists estimate very high returns in terms of health, social and environmental development when micronutrient deficiencies are eliminated.

According to a Report by the World Bank and the Asian Development Bank, eliminating micronutrient deficiencies in the world could enhance the intellectual capacity of populations by more than 10% and worker productivity by 30% to 70%. In addition, maternal deaths could be reduced by up to 50%

Fighting "Hidden Hunger" with agronomic biofortification

People eating micronutrient-enriched crops or having diversified diets, including micronutrient-rich foods, are less likely to suffer from micronutrient deficiencies.

Mineral fertilizers that contain micronutrients can help address deficiencies in humans by increasing micronutrient density in the edible parts of plants.

Reflecting synergies between protein and Fe and Zn accumulation in grain, fertilization with N (a key element in proteins) can positively impact Zn and Fe accumulation in wheat grain (Kutman et al. 2010, Aciksoz et al 2011).

One of the quickest and most cost-effective strategies to minimize the extent of micronutrient deficiencies in human populations is the enrichment (biofortification) of staple food crops with micronutrients (Welch et al 2013, Cakmak and Kutman, 2018; Cakmak et al 2017).

Agronomic biofortification is defined as "the application of mineral micronutrient fertilizers to soils or plant leaves (foliar application) with the objective to increase the micronutrient content in the edible part of the crops".

Evidence suggests that agronomic biofortification with selected micronutrient fertilizers, such as Zn, Se and iodine is an effective and sustainable way to reduce deficiencies in populations around the world.

In a recently published paper using a simulated human digestive system it has been shown that iodine, Zn and Se in agronomically-biofortified wheat and rice are bioaccessible for use in the human body.

Foods (such as bread and cookies) made from cereals biofortified with micronutrients through fertilizer strategy contained sufficiently high micronutrient levels, indicating an effective transfer of micronutrients from the field to the grain (Cakmak et al., 2017; Cakmak et al., 2020).

A newly published human zinc absorption study conducted at ETH-Zurich demonstrated that wheat biofortified agronomically with Zinc has a significant role in dietary zinc absorption in humans and could be very helpful in counteracting the global burden of zinc deficiency (Signorell et al., 2019).

Agronomic biofortification has the advantage of getting a fast response with good bioavailability of the micronutrients applied, and it can be used in complementary manner with genetic fortification through plant breeding and food fortification (supplementing salt, flour or processed food with micronutrients).

An enabling environment is based on strategic cooperation with the fertilizer industry, who supplies the products, scientific organizations who assess the extent and impact of micronutrient deficiencies in soils, plants and human populations, governments, who stimulate the adoption of biofortification practices by farmers through economic incentives, subsidies and legislative mandates, and extension services, who contribute to assure technology and knowledge transfer.

Successes in agronomic biofortification

Supplementing fertilizers with selenium (Se), Finland Nordic countries are areas generally poor in Se.

In 1984, Finland decided to counter its extremely low Se intake through supplementing fertilizers with Se.

Almost all fertilizer used in Finland since then have contained Se and are currently required to contain 15 mg Se/kg.

Supplementation of fertilizers with selenate has increased Se concentrations in all major food and feed crops and benefitted human and livestock health (Alfthan et al. 2014).

While Finland has opted for a country-wide measure, the UK uses Se fertilization sporadically to improve human health and New Zealand supplements fertilizers with Se to improve livestock health.

Using Zn-enriched fertilizers

Half of the world's agricultural soils are deficient in Zn and one third of the world population is zinc-deficient (Alloway, 2008).

The use of Zn-enriched fertilizer (for instance Zn-coated urea or Zn-enriched NPK) in Turkey, Australia, South Africa or India has resulted in significant increases in yields and in zinc concentrations in rice and wheat (IFA and IPNI, 2012). The best performance to increase zinc density in grain is obtained through foliar applications (Cakmak and Kutman, 2018).

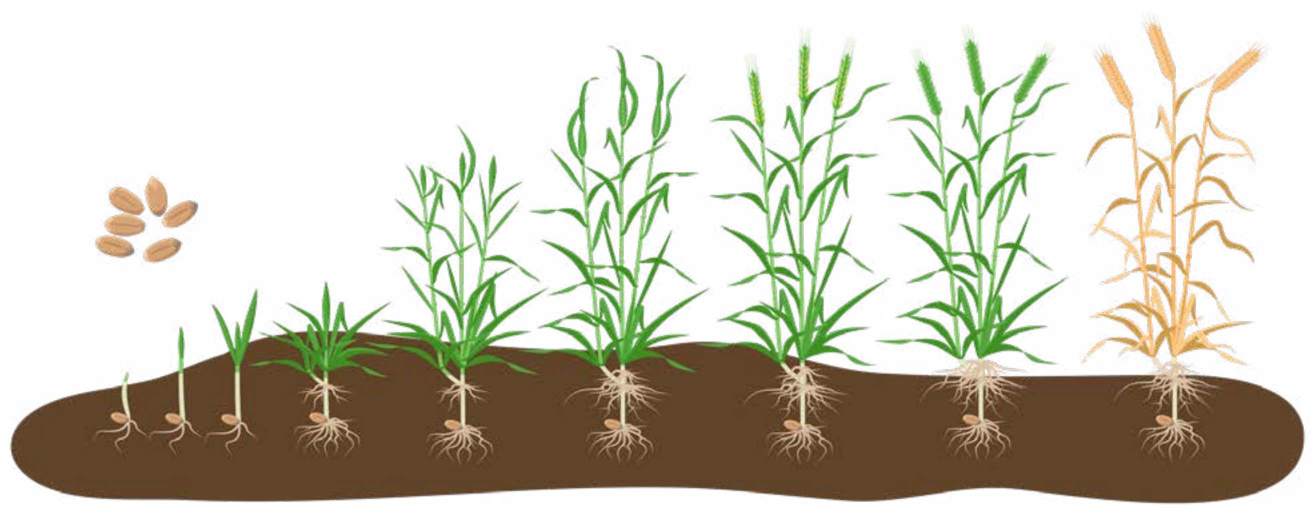
Increasing iodine density in cereals

A recent study has shown that: "agronomic biofortification using a foliar-applied fertilizer containing iodine, alone or in combination with Se and Zn, is effective in improving grain iodine concentration."

The study also examined potential iodine losses during the preparation of foodstuffs with the enriched grains and found that iodine levels had lowered but remained significantly higher than foodstuffs prepared with non-enriched grains (Cakmak et al, 2020).

HarvestZinc

The international project HarvestZinc (harvestzinc.org) has demonstrated that simultaneous foliar applications of Zn, iodine, Se and Fe in the same cocktail solution resulted in significant increases in Zn, iodine and Se concentration and modest ones in Fe in grains of different wheat cultivars under various agro-ecological conditions without grain yield tradeoff (Zou et al, 2019). ***(Source: IFA, International Fertilizer Association)***



INTERNATIONAL VIEW

Fertilizer Shortage

Puts Nepal on the Verge of Food Crisis

“There is no fertilizer. I have been making several rounds for weeks at a depot that sells chemical fertilizer at subsidized rates. The depot is empty. If fertilizer is not provided on time, I won’t be able to transplant rice. I am worried of losing production this year,” a farmer in eastern Nepal, Gajendra Bhattarai, told EFE.

The early onset of monsoon rains, which arrived a week ahead of time in the area where Bhattarai works, allowed thousands of Nepali peasants to began rice transplanting early.

In Nepal, rice is planted between early June and mid-August depending on the rains, Bhattarai said.

Farmers of the country – which imports chemical fertilizer worth $180 million every year and largely depends on imported products – require government subsidies to be able to purchase these key components.

According to the department of agriculture, rice contributes around 40% of the calorie intake of food, and accounts for 7% of GDP, making local production a key factor.

▼ *Nepal is beginning to experience a food crisis triggered by a dramatic rise in prices of fertilizers and a global shortage - which could result in massive losses to the farmers of the Himalayan country. Kathmandu, Jun 14 (EFE).*

But “as most of the tenders got cancelled due to the cost factor after the russia-Ukraine conflict broke out, the global contractors were not able to supply the farm’s vital nutrients,” EFE was told by Pankaj Joshi, the deputy general manager of the Salt Trading Corporation, a state company that sells subsidized fertilizers.

The annual demand of chemical fertilizers in the country stands at around 600,000 tons, out of which 200,000 tons are required during the rice planting season spread over three months.

“We are not able to supply the fertilizer as per the farmers’ demand. The Russian-Ukraine war has increased the prices of chemical fertilizer by four times,” the official admitted.

Nepal used to purchase urea at $390 per ton from the global market until last year, but the price has now shot up to $1,025 per ton.

Similarly, the price of di-ammonium phosphate (DAP) stood at $375 per ton until last year, but now it costs $1,125 per ton, Joshi said.

The parliament of Nepal on Monday urged the government to supply chemical fertilizers to the farmers by any means, after the opposition presented an emergency motion of public importance demanding that the house take the issue seriously.

“Many farmers are crossing the border to smuggle fertilizer from India. The government’s warehouses are empty ahead of the rice transplanting period,” lawmaker Ganga Chaudhary told the Parliament, warning of an impending disaster.

Prakash Kumar Sanjel, the spokesperson for the ministry of agriculture and livestock development, told EFE that Kathmandu had recently signed an agreement with the government of India for the latter to supply fertilizers to Nepal.

“The Indian government has assured us to provide 90,000 tons of fertilizer to mitigate the immediate crisis. We are expecting that India will send the fertilizer by mid-July,” he said.

According to a report of the United Nations Conference on Trade and Development, higher energy costs, trade restrictions and a loss of fertilizer supply from the Russian Federation and Belarus have led to fertilizer prices rising even faster than food prices.

“If the war continues and high prices of grain and fertilizers persist into the next planting season, food availability will be reduced at the worst possible time, and the present crisis in corn, wheat and vegetable oil could extend to other staples, affecting billions more people,” it warned. ***(Source: EFE)***

▲ Rice contributes nearly 20% to the agricultural gross domestic product (AGDP) and almost 7% to GDP and supplies about 40% of the food calorie intake to Nepalese people. (Photo by David Mark via Pixabay)

In Sri Lanka, Organic Farming

Went Catastrophically Wrong

Faced with a deepening economic and humanitarian crisis, Sri Lanka called off an ill-conceived national experiment in organic agriculture this winter.

Sri Lankan President Gotabaya Rajapaksa promised in his 2019 election campaign to transition the country's farmers to organic agriculture over a period of 10 years. Last April, Rajapaksa's government made good on that promise, imposing a nationwide ban on the importation and use of synthetic fertilizers and pesticides and ordering the country's 2 million farmers to go organic.

The result was brutal and swift. Against claims that organic methods can produce comparable yields to conventional farming, domestic rice production fell 20 percent in just the first six months.

Sri Lanka, long self-sufficient in rice production, has been forced to import $450 million worth of rice even as domestic prices for this staple of the national diet surged by around 50 percent. The ban also devastated the nation's tea crop, its primary export and source of foreign exchange.

▲ Tea pickers remove weeds at an organic tea plantation in the southern district of in Ratnapura, Sri Lanka, on Aug. 3, 2021
ISHARA S. KODIKARA/AFP VIA GETTY IMAGES

By November 2021, with tea production falling, the government partially lifted its fertilizer ban on key export crops, including tea, rubber, and coconut. Faced with angry protests, soaring inflation, and the collapse of Sri Lanka's currency, the government finally suspended the policy for several key crops - including tea, rubber, and coconut - in February, although it continues for some others. The government is also offering $200 million to farmers as direct compensation and an additional $149 million in price subsidies to rice farmers who incurred losses. That hardly made up for the damage and suffering the ban produced. Farmers have widely criticized the payments for being massively insufficient and excluding many farmers, most notably tea producers, who offer one of the main sources of employment in rural Sri Lanka. The drop in tea production alone is estimated to result in economic losses of $425 million.

▲ *A worker carries leaves at a tea plantation in Ratnapura, Sri Lanka, on July 31, 2021. Ishara S. Kodikara/Afp via Getty ImagesIMAGES*

Human costs have been even greater. Prior to the pandemic's outbreak, the country had proudly achieved upper-middle-income status. Today, half a million people have sunk back into poverty. Soaring inflation and a rapidly depreciating currency have forced Sri Lankans to cut down on food and fuel purchases as prices surge. The country's economists have called on the government to default on its debt repayments to buy essential supplies for its people.

The farrago of magical thinking, technocratic hubris, ideological delusion, self-dealing, and sheer shortsightedness that produced the crisis in Sri Lanka implicates both the country's political leadership and advocates of so-called sustainable agriculture: the former for seizing on the organic agriculture pledge as a shortsighted measure to slash fertilizer subsidies and imports and the latter for suggesting that such a transformation of the nation's agricultural sector could ever possibly succeed.

Sri Lanka's journey through the organic looking glass and toward calamity began in 2016, with the formation, at Rajapaksa's behest, of a new civil society movement called Viyathmaga. On its website, Viyathmaga describes its mission as harnessing the "nascent potential of the professionals, academics and entrepreneurs to effectively influence the moral and material development of Sri Lanka." Viyathmaga allowed Rajapaksa to rise to prominence as an election candidate and facilitated the creation of his election platform.

Despite Viyathmaga's claims to technocratic expertise, most of Sri Lanka's leading agricultural experts were kept out of crafting the agricultural section of the platform, which included promises to phase out synthetic fertilizer, develop 2 million organic home gardens to help feed the country's population, and turn the country's forests and wetlands over to the production of biofertilizer.

Following his election as president, Rajapaksa appointed a number of Viyathmaga members to his cabinet, including as minister of agriculture. Sri Lanka's Ministry of Agriculture, in turn, created a series of committees to advise it on the implementation of the policy, again excluding most of the nation's agronomists and agricultural scientists and instead relying on representatives of the nation's small organic sector.

Then, just a few months after Rajapaksa's election, COVID-19 arrived. The pandemic devastated the Sri Lankan tourist sector, which accounted for almost half of the nation's foreign exchange in 2019. By the early months of 2021, the government's budget and currency were in crisis, the lack of tourist dollars so depleting foreign reserves that Sri Lanka was unable to pay its debts to Chinese creditors following a binge of infrastructure development over the previous decade.

Enter Rajapaksa's organic pledge. From the early days of the Green Revolution in the 1960s, Sri Lanka has subsidized farmers to use synthetic fertilizer. The results in Sri Lanka, as across much of South Asia, were startling: Yields for rice and other crops more than doubled. Struck by severe food shortages as recently as the 1970s, the country became food secure while exports of tea and rubber became critical sources of exports and foreign reserves. Rising agricultural productivity allowed widespread urbanization, and much of the nation's labor force moved into the formal wage economy, culminating in

Sri Lanka's achievement of official upper-middle-income status in 2020.

By 2020, the total cost of fertilizer imports and subsidies was close to $500 million each year. With fertilizer prices rising, the tab was likely to increase further in 2021. Banning synthetic fertilizers seemingly allowed Rajapaksa to kill two birds with one stone: improving the nation's foreign exchange situation while also cutting a massive expenditure on subsidies from the pandemic-hit public budget.

But when it comes to agricultural practices and yields, there is no free lunch. Agricultural inputs - chemicals, nutrients, land, labor, and irrigation - bear a critical relationship to agricultural output. From the moment the plan was announced, agronomists in Sri Lanka and around the world warned that agricultural yields would fall substantially. The government claimed it would increase the production of manure and other organic fertilizers in place of imported synthetic fertilizers. But there was no conceivable way the nation could produce enough fertilizer domestically to make up for the shortfall.

Having handed its agricultural policy over to organic true believers, many of them involved in businesses that would stand to benefit from the fertilizer ban, the false economy of banning imported fertilizer hurt the Sri Lankan people dearly. The loss of revenue from tea and other export crops dwarfed the reduction in currency outflows from banning imported fertilizer. The bottom line turned even more negative through the increased import of rice and other food stocks. And the budgetary savings from cutting subsidies were ultimately outweighed by the cost of compensating farmers and providing public subsidies for imported food.

Farming is, at bottom, a fairly straightforward thermodynamic enterprise. Nutrient and energy output in the form of calories is determined by nutrient and energy input.

For most of recorded human history, the primary way humans increased agricultural production was by adding land to the system, which expanded the amount of solar radiation and soil nutrients available for food production. Human populations were relatively small, under 1 billion people in total, and there was no shortage of arable land to expand onto. For this reason, the vast majority of anthropogenic changes in global land use and deforestation has been the result of agricultural extensification - the process of converting forests and prairie to cropland and pasture. Against popular notions that preindustrial agriculture existed in greater harmony with nature, three-quarters of total global deforestation occurred before the industrial revolution.

Even so, feeding ourselves required directing virtually all human labor to food production. As recently as 200 years ago, more than 90 percent of the global population labored in agriculture. The only way to bring additional energy and nutrients into the system to increase production was to let land lie fallow, rotate crops, use cover crops, or add manure from livestock that either shared the land with the crops or grazed nearby. In almost every case, these practices required additional land and put caps on yields.

Starting in the 19th century, the expansion of global trade allowed for the import of guano - mined from ancient deposits on bird-rich islands - and other nutrient-rich fertilizers from far-flung regions onto farms in Europe and the United States. This and a series of technological innovations - better machinery, irrigation, and seeds - allowed for higher yields and labor productivity on some farms, which in turn freed up labor and thereby launched the beginning of large-scale urbanization, one of global modernity's defining features.

But the truly transformative break came with the invention of the Haber-Bosch process by German scientists in the early 1900s, which uses high temperature, high pressure, and a chemical catalyst to pull nitrogen from the air and produce ammonia, the basis for synthetic fertilizers. Synthetic fertilizer remade global agriculture and, with it, human society. The widespread adoption of synthetic fertilizers in most countries has allowed a rapid increase in yields and allowed human labor to shift from agriculture to sectors that offer higher incomes and a better quality of life.

The widespread application of synthetic fertilizers now allows global agriculture to feed nearly 8 billion people, of whom about 4 billion depend on the increased output that synthetic fertilizers allow for their sustenance. As a result, the modern food systems that have allowed global agriculture to feed Earth's population are far more energy intensive than past food systems, with synthetic fertilizers accounting for a significant source of the energy for crops.

As synthetic fertilizers became increasingly available

▲ Workers are seen at a tea plantation in Ratnapura, Sri Lanka, on July 31, 2021. ISHARA S. KODIKARA/AFP VIA GETTY IMAGES

globally after World War II and combined with other innovations, such as modern plant breeding and large-scale irrigation projects, a remarkable thing happened: Human populations more than doubled - but thanks to synthetic fertilizers and other modern technologies, agricultural output tripled on only 30 percent more land over the same period.

The benefits of synthetic fertilizers though go far beyond simply feeding people. It's no exaggeration to say that without synthetic fertilizers and other agricultural innovations, there is no urbanization, no industrialization, no global working or middle class, and no secondary education for most people. This is because fertilizer and other agricultural chemicals have substituted human labor, liberating enormous populations from needing to dedicate most of their lifetime labor to growing food.

Virtually the entirety of organic agriculture production serves two populations at opposite ends of the global income distribution. At one end are the 700 million or so people globally who still live in extreme poverty. Sustainable agriculture proponents fancifully call the agriculture this population practices "agroecology." But it is mostly just old–fashioned subsistence farming, where the world's poorest eke out their survival from the soil.

They are the poorest farmers in the world, who dedicate most of their labor to growing enough food to feed themselves. They forego synthetic fertilizers and most other modern agricultural technologies not by choice but because they can't afford them, caught in a poverty trap where they are unable to produce enough agricultural surplus to make a living selling food to other people; hence, they can't afford fertilizer and other technologies that would allow them to raise yields and produce surplus.

At the other end of the spectrum are the world's richest people, mostly in the West, for whom consuming organic food is a lifestyle choice tied up with notions about personal health and environmental benefits as well as romanticized ideas about agriculture and the natural world. Almost none of these consumers of organic foods grow the food themselves. Organic agriculture for these groups is a niche market - albeit, a lucrative one for many producers - accounting for less than 1 percent of global agricultural production.

As a niche within a larger, industrialized, agricultural system, organic farming works reasonably well. Producers typically see lower yields. But they can save money on fertilizer and other chemical inputs while selling to a niche market for privileged consumers willing to pay a premium for products labeled organic. Yields are lower - but not disastrously lower - because there are ample nutrients available to smuggle into the system via manure. As long as organic food remains niche, the relationship between lower yields and increased land use remains manageable.

The ongoing catastrophe in Sri Lanka, though, shows why extending organic agriculture to the vast middle of the global bell curve, attempting to feed large urban populations with entirely organic production, cannot possibly succeed. A sustained shift to organic production nationally in Sri Lanka would, by most estimates, slash yields of every major crop in the country, including drops of 35 percent for rice, 50 percent for tea, 50 percent for corn, and 30 percent for coconut. The economics of such a transition are not just daunting; they are impossible.

Importing fertilizer is expensive, but importing rice is far more costly. Sri Lanka, meanwhile, is the world's fourth largest tea exporter, with tea accounting for a lion's share of the country's agricultural exports, which in turn account for 70 percent of total export earnings.

There is no conceivable way that export sales to the higher value organic market could possibly make up for sharp falls in production. The entire global market for organic tea, for example, accounts for only about 0.5 percent of the global tea market. Sri Lanka's tea production alone is larger than the entire global organic tea market. Flooding the organic market with most or all of Sri Lanka's tea production, even after output fell by half due to lack of fertilizer, would almost certainly send global organic tea prices into a spiral.

The notion that Sri Lanka might ever replace synthetic fertilizers with domestically produced organic sources without catastrophic effects on its agricultural sector and environment is more ludicrous still. Five to seven times more animal manure would be necessary to deliver the same amount of nitrogen to Sri Lankan farms as was delivered by synthetic fertilizers in 2019. Even accounting for the overapplication of synthetic fertilizers and other uncertainties, there is almost certainly not enough land in the small island nation to produce that much organic fertilizer. Any effort to produce that much manure would require a vast expansion of livestock holdings, with all the additional environmental damage that would entail.

Sustaining agriculture in Sri Lanka, for both domestic consumption and high-value export products, was always going to require importing energy and nutrients into the system, whether organic or synthetic. And synthetic fertilizers were always going to be the most economically and environmentally efficient way to do so.

While the proximate cause of Sri Lanka's humanitarian crisis was a bungled attempt to manage its economic fallout from the global pandemic, at the bottom of the political problem was a math problem and at the bottom of the math problem was an ideological problem - or, more accurately, a global ideological movement that is innumerate and unscientific by design, promoting fuzzy and poorly specified claims about the possibilities of alternative food production methods and systems to obfuscate the relatively simple biophysical relationships that govern what goes in; what comes out; and the economic, social, and political outcomes that any agricultural system can produce, whether on a regional, national, or global scale.

As farmers begin their spring harvest, the fertilizer ban has been lifted, but fertilizer subsidies have not been restored. Rajapaksa, meanwhile, has established yet another committee - this one to advise the government on how to increase organic fertilizer production in a further demonstration that he and his agricultural advisors continue to deny the basic biophysical realities that constrain agriculture production.

Much of the global sustainable agriculture movement, unfortunately, has proven no more accountable. As Sri Lankan crop yields have plummeted, exactly as most mainstream agricultural experts predicted they would, the fertilizer ban's leading advocates have gone silent.

Soon enough, advocates will surely argue that the problem was not with the organic practices they touted but with the precipitous move to implement them in the midst of a crisis. But although the immediate ban on fertilizer use was surely ill conceived, there is literally no example of a major agriculture-producing nation successfully transitioning to fully organic or agroecological production. The European Union has, for instance, promised a full-scale transition to sustainable agriculture for decades. But while it has banned genetically modified crops and a variety of pesticides as well as has implemented policies to discourage the overuse of synthetic fertilizers, it still depends heavily on synthetic fertilizers to keep yields high, produce affordable, and food secure. It has also struggled with the disastrous effects of overfertilizing surface and ground water with manure from livestock production.

Boosters of organic agriculture also point to Cuba, which was forced to abandon synthetic fertilizer when its economy imploded following the Soviet Union's collapse. They fail to mention that the average Cuban lost an estimated 10 to 15 pounds of body weight in the years that followed. In 2011, Bhutan, another darling of the sustainability crowd, promised to go 100 percent organic by 2020. Today, many farmers in the Himalayan kingdom continue to depend on agrochemicals.

In Sri Lanka, as elsewhere, there is no shortage of problems associated with chemical-intensive and large-scale agriculture. But the solutions to these problems - be they innovations that allow farmers to deliver fertilizer more precisely to plants when they need it, bioengineered microbial soil treatments that fix nitrogen in the soil and reduce the need for both fertilizer and soil disruption, or genetically modified crops that require fewer pesticides and herbicides - will be technological, giving farmers new tools instead of removing old ones that have been proven critical to their livelihoods. They will allow countries like Sri Lanka to mitigate the environmental impacts of agriculture without impoverishing farmers or destroying the economy. Proponents of organic agriculture, by contrast, committed to naturalistic fallacies and suspicious of modern agricultural science, can offer no plausible solutions. What they offer, as Sri Lanka's disaster has laid bare for all to see, is misery. ***(By Ted Nordhaus, the executive director of the Breakthrough Institute, and Saloni Shah, a food and agriculture analyst at the Breakthrough Institute.)***

MARKET SCOPE

Global Food Crisis Looms

as Fertilizer Supplies Dwindle

Fertilizers are blended at Golden Fertilizers in Lagos, Nigeria. A fertilizer shortage is threatening the success of the world's crops and could lead to widespread food shortages, experts say. Photograph by Peter Essick, Nat Geo Image Collection

Think the global fertilizer shortage is someone else's problem? Take a look in the mirror. If you are reading this in North America, Europe, Latin America, or Asia, chances are that the bundle of amino acids staring back at you is alive today because of chemical fertilizers.

In fact, according to noted Canadian energy researcher Vaclav Smil, two-fifths of humanity—more than three billion people—are alive because of nitrogen fertilizer, the main ingredient in the Green Revolution that supercharged the agricultural sector in the 1960s.

The chemical fertilizer trifecta that tripled global grain production—nitrogen (N), phosphorus (P), and potassium (K)—enabled the greatest human population growth the planet has ever seen. Now, it is in short supply, and farmers, fertilizer companies, and governments around the globe are scrambling to avert a seemingly inevitable tumble in crop yields.

"I'm not sure it's possible any more to avoid a food crisis," says World Farmers' Organization President Theo de Jager. "The question is how wide and deep it will be. Most importantly, farmers need peace. And peace needs farmers."

Conflict between Russia and Ukraine was a body blow to an industry that has been hammered by various events for more than a year. Russia typically exports nearly 20 percent of the world's nitrogen fertilizers and, combined with its sanctioned neighbor Belarus, 40 percent of the world's exported potassium, according to analysts at Rabobank. Most of that is now off limits to the world's farmers, thanks to Western sanctions and Russia's recent fertilizer export restrictions.

"If you speak to a farmer in North America or Oceania, the main talk is fertilizers, specifically the price and availability of fertilizers," de Jager told a virtual conference on the subject recently. "Prices are more or less 78 percent higher than average in 2021, and this is cracking up the production side of agriculture.

In many regions farmers simply can't afford to bring fertilizers to the farm, or even if they could, the fertilizers are not available to them. And it's not just fertilizers, but agrichemicals and fuel as well. This is a global crisis and it requires a global response."

Most of the response thus far has been pretty ad hoc, with every farm and government for itself. But last week, the U.S. and global development banks announced a major "action plan" on global food security totaling more than $30 billion in aid, in hopes of staving off a repeat of the food riots that toppled governments during the last food price crises in 2008 and 2012.

U.S. farmers are feeling the burn

Rodney Rulon is better off than many farmers this year. A progressive farmer in Arcadia, Indiana, he has been using no-till techniques, cover crops, and chicken litter on his family's 7,200 acres of corn and soybean fields since 1992. Combined with extensive soil testing each year, he's cut his chemical fertilizer use 20 to 30 percent, he says—but it's still his largest input.

"We're making big cuts to what we're spending on fertilizer this year," Rulon says. "It's $1,200 a ton for P and K. It was $450 last year. Nitrogen was $500-550 a ton last year. Now it's well over $1,000. You just took our biggest expense and doubled it." He can't even get the 3,000 tons of chicken litter he normally uses in place of chemical phosphorus and potassium. He had a gentleman's agreement with his supplier to purchase his usual amount for $60 a ton, but it sold out to a higher bidder.

High fertilizer prices have caused a run on manure in many parts of the country as farmers scramble for alternatives and seek ways to cut their fertilizer bills. That

might not be a bad thing, says Antonio Mallarino, a soil scientist and plant nutrient expert at Iowa State University, who has been trying for decades to get farmers to stop overfertilizing.

"On 50 to 60 percent of fields in Iowa you could not apply P (phosphorus) and K (potassium) for 10 years and they'd be okay," Mallarino says.

Though corn prices broke $8 per bushel in February, close to the all-time high set in 2012, many farmers are switching to soybeans, which require fewer nutrients and so less fertilizer.

The USDA's planting survey, released on March 31, showed farmers intend to plant a record 91 million acres of soybeans this year, 4 percent more than last year, while corn acres fell to 89.5 million acres—the lowest in five years.

"If this situation continues it may be good for the environment," Mallarino says. "We may not have all this excess nitrogen and phosphorus going into the rivers and lakes."

Bert Frost has heard more than a few grumbles from farmers about fertilizer prices. He's the senior vice president for sales, supply chain, and market development for CF Industries, one of the largest producers of nitrogen fertilizers in the world. The smooth interplay of supply and demand that has kept nitrogen prices in a narrow range for the last 10 years is no longer working, he says—because both supply and demand have been hit by external shocks.

"What we have today is a confluence of all the factors not working in concert with each other," Frost says.

A rebound in industrial activity that uses the raw ingredients in fertilizer coming out of the pandemic, combined with low global inventories of food grains, have pushed demand through the roof.

Suppliers, on the other hand, have been knocked back by one extreme weather event after another.

Winter Storm Uri in February 2021 literally froze production at fertilizer plants from Iowa to Texas, knocking several offline for a month or more. Six months later, Hurricane Ida tore through Louisiana's chemical alley, damaging several fertilizer producers, including CFI's Donaldsonville complex. With its six ammonia and four urea plants (urea is a fertilizer chemically derived from nitrogen), it's the largest such facility in the world. The company was forced to cancel its contracts for a while.

"And I've got more," Frost says. "Then China and Russia impose export restrictions on fertilizer. China exports 10 percent of the urea supply in the world. Their exports went to zero. Then came the conflict between Russia and Ukraine, and all hell breaks loose."

The market was reeling, in other words, even before the war, the sanctions, and the Russian blockade of Ukraine's Black Sea ports.

"All the factors I laid out for you earlier, we haven't had those before," Frost says."So the logistics are screwed up. I don't think this resolves itself."

Latin America: running on empty?

North American farmers will eventually get the fertilizer they need this season, says Frost, even if they have to pay dearly for it. But it's the agricultural powerhouses in Latin America that are the most vulnerable to fertilizer disruptions, particularly Brazil, which imports about 85 percent of its fertilizer, a quarter of it typically from Russia.

If farmers there cut back on fertilizers and their yields fall, it could have a significant impact on global food supplies. Brazil is among the world's top three exporters of soybeans, corn, and sugar, as well as beef, chicken, and pork, according to a recent USDA report.

The major planting season in the Southern Hemisphere begins in September, and the Brazilian government is scrambling to find new fertilizer sources.

Earlier this year it even struck a barter deal with Iran—working around U.S. sanctions on that country—in which Iran would send 400,000 tons of urea to Brazil in exchange for corn and soybeans.

So critical are Russia's fertilizers to Brazil and the world food supply, the Biden administration carved out a loophole for them in its suite of Russian sanctions in late March. Although financial sanctions are still hindering deliveries, analysts hope the move will ease the pressure on global food prices.

"It's impossible to make forecasts on this situation," says Micaela Bové, farming solutions director for Yara Latinamérica, based in Buenos Aires. "I never imagined COVID would still be here, and yet it is. I never imagined this conflict would become a war, and yet it has. But farmers are the heroes in this. They were hit by everything that you can imagine, and they always produce food."

Bové says her division of Yara, the Norwegian fertilizer behemoth, is not seeing shortages in her region, which runs from the smallholder farms of Mexico to the vast estancias of Argentina, excluding Brazil. But the high prices are causing many to use less.

So she and her team are promoting tools and apps to help farmers use their product more efficiently. "Fertilizer decisions depend on the crop," she says, "And a maize farmer in Mexico has different needs than a citrus farmer or banana farmer elsewhere."

Africa: From little to none

African farmers on average use the least fertilizer per acre in the world and have some of the lowest yields, particularly for corn and other grains that provide the bulk of the continent's calories.

As a result, despite having 60 percent of the world's arable land, almost half the countries in Africa depends on imported wheat from Russia and Ukraine, with 14 African countries getting more than half their wheat from the two warring nations.

Rising food prices now threaten to push millions of African families into poverty and malnutrition.

And the distant war is not their only challenge, says Agnes Kalibala, the president of the Alliance for a Green Revolution in Africa (AGRA), a Nairobi-based non-profit that has worked with African governments and foreign aid agencies to increase the use of fertilizers and improved seeds to boost yields across the continent.

"The most important part to me, even before fertilizers, is how much farmers are suffering from a climate change perspective," says Kalibata, the former minister of agriculture for Rwanda. "In countries where it didn't rain last year, there was generally a depression in interest in fertilizers. So the question now is will that interest pick up as the rains are coming to some of those areas."

But even if countries can get fertilizer, farmers often can't afford it, she says. Governments that typically subsidize fertilizer are struggling with massive post-COVID debt that in some nations is more than 50 percent of their gross domestic product. Kalibata's group is working with the African Union, the African Development Bank, and the G7 nations to help with emergency funding, but also encouraging farmers to look at alternatives.

"In Africa our productivity is very low and we have high nitrate depletion in our soils," Kalibata says. "It's very difficult to grow maize or rice without nutrients. But there are other opportunities like fava beans, which are grown in Ethiopia and Sudan, that can fix 100 percent of their nitrogen needs. That is a fantastic opportunity."

Nitrogen fixation is a natural symbiotic process that distinguishes legumes from cereal grains, which are in the grass family. Rhizobia bacteria living on the plants' roots convert atmospheric nitrogen to ammonia that the plants can use, while the plants provide sugars to the bacteria. Beans are great nitrogen fixers: Soybeans supply up to 70 or 80 percent of their own needs. Common beans, a staple bean grown all over Africa, can fix up to 30 percent.

“So you still use nutrients, but you use less,” Kalibata says.

As always, climate is still the wild card. Without rain, fertilizer has little if any effect.

“If we can get rainfall in some of these areas, these countries should be able to find alternatives,” says Kalibata. “If they don’t, we’ll have multiple crises on our hands.”

Better off organic

About the only farmers who are not complaining about fertilizers this season are the rising number of organic growers.

Their mantra has long been to feed the soil, not the plant, and to eschew chemical fertilizers and pesticides for legume cover crops, diversified crop rotations, and promoting beneficial insects and microbes in their fields.

Some cover crops, like hairy vetch, can produce up to 300 pounds of nitrogen per acre, according to Jeff Moyer, executive director of the Rodale Institute in Emmaus, Pennsylvania.

Rodale, with help from the Pennsylvania State University, has been conducting side-by-side comparisons of conventional and organic cropping systems since 1981—the longest-running such field trial in North America.

After a five-year transition period, they found organic yields were not only competitive with conventional yields, they yielded up to 40 percent higher during drought. Most importantly, they earned farmers three to six times more profit, while releasing no toxic chemicals into rivers and streams.

“Fertilizer is just the tip of the spear of the problems farmers are facing,” Moyer says. “Look at Kansas and Nebraska. Both states are on fire this year and this is supposed to be their wet season. With weather patterns changing and energy costs going up and not coming down, we need to revolutionize our production models to minimize these impacts.”

Converting to organic takes time, however, and that’s something many of the world’s farmers are running out of as well. ***(Source: National Geographic, by Joel K. Bourne, Jr.)***

China Reaps Bumper

Summer Harvest Securing Food Security

* By 6 June, China had finished reaping winter wheat on 167 million mu (about 11.13 million hectares) of farmland, accounting for around 55 percent of its total winter wheat.

* Spanning from May to late June traditionally, the grain output in the summer harvest takes up about a quarter of the annual total, which is of great significance to China's food security.

* More than 1.5 million sets of agricultural machinery and over 280,000 farmers and agricultural technicians are joining in the harvest in Shandong, striving to keep the average loss rate under 2 percent.

* Nowadays, the traditional production methods have undergone huge changes as smart agricultural technology, drones, and high-yielding varieties of crops have been widely used.

JINAN, June 8 (Xinhua) -- About 16.5 million pieces of agricultural machinery are currently roaring on the vast farmlands of China, with over 3 million farmers and technicians taking part in the country's summer harvest.

By Monday, the country had finished reaping winter wheat on 167 million mu (about 11.13 million hectares) of farmland, accounting for around 55 percent of its total winter wheat, according to the Ministry of Agriculture and Rural Affairs.

Wheat harvest in southwest China's Sichuan Province and central China's Hubei Province has almost come to a close, while that in the provinces of Shaanxi, Shandong, Shanxi and Hebei will be in full swing soon.

China's summer harvest focuses on reaping winter wheat and oilseed rape. Spanning from May to late June traditionally, the grain output in the period takes up about a quarter of the annual total, which is of great significance to China's food security.

CUT LOSS

Minimizing the losses in the process of harvesting is one of the keywords of the summer harvest this year.

In east China's Shandong Province, China's second-largest wheat-producing area, a variety of loss-cutting activities have been carried out in each county and city with wheat plantation areas exceeding 33,000 hectares.

Meanwhile, more than 1.5 million sets of agricultural machinery and over 280,000 farmers and agricultural technicians are joining in the harvest in Shandong, striving to keep the average loss rate under 2 percent.

By reaching that goal, the whole province can save 300 million kg of wheat during the harvest, according to a local agricultural official.

Dong Huilong, a farmer in Yuncheng City, north China's Shanxi Province, feels jubilant these days.

"Although wheat was sown late, the harvest is expected better than last year thanks to better management afterward," said Dong, who grows over 8 hectares of wheat.

More than 7.3 million hectares of wheat were sown late in China's major summer grain powerhouses, including the provinces of Henan, Shandong and Shanxi, due to floods last fall.

Therefore, more than 6 billion yuan (about 900 million U.S. dollars) have been pooled to ensure the production of summer grain. Experts and technicians have been sent to the villages to help farmers overcome the adverse impacts of the late sowing.

"We made some adjustments in seed selection, sowing volume, and the amount of fertilization. Furthermore, we provided face-to-face guidance to local farmers in the farmland," said Lyu Fen, an agricultural expert in Yanhu District, Yuncheng.

TECH MAKES DIFFERENCE

The advancement of science and technology has boosted China's grain production capacity.

Nowadays, the traditional production methods have undergone huge changes as smart agricultural technology, drones, and high-yielding varieties of crops have been widely used.

Data shows that during China's 13th Five-Year Plan period (2016-2020), about 13 million tonnes of food had been saved annually during processes after production.

"China has used scientific and effective management means to ensure the food security," said Wang Juanling, vice president of Shanxi Agricultural University. ***(Source: Xinhua, by huaxia)***

▲ Aerial photo taken on June 12, 2022 shows a harvester working in the field in Dongjiazhuang Village of Difang Township in Pingyi County, Linyi City, east China's Shandong Province. (Photo by Wu Jiquan/Xinhua)

▲ *Villagers dry wheat in Dalijia Village of Shangzhuang Township in Rongcheng, east China's Shandong Province, June 13, 2022. (Photo by Li Xinjun/Xinhua)*


BULL

▲ Aerial photo taken on May 25, 2022 shows harvesters loading wheat onto a truck in Duanchong Village of Xiaomiao Township, Hefei City, east China's Anhui Province. (Photo by Chen Sanhu/Xinhua)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Nutrien to Build World's Largest

Clean Ammonia Production Facility

Nutrien Ltd. has announced that it is evaluating Geismar, LA as the site to build the world's largest clean ammonia facility.

Building on the company's expertise in low-carbon ammonia production, clean ammonia will be manufactured using innovative technology to achieve at least a 90 percent reduction in CO_2 emissions.

The project will proceed to the front-end engineering

▲ *Nutrien, Exmar to collaborate on ammonia-fuelled vessel development. As part of the agreement, the companies will choose an ammonia engine and supply system manufacturer. Credit: Craig Bradford on Unsplash.*

design (FEED) phase, with a final investment decision expected to follow in 2023. If approved, construction of the approximately US$2 billion facility would begin in 2024 with full production expected by 2027.

The new clean ammonia plant would leverage low-cost natural gas, tidewater access to world markets, and high-quality carbon capture and sequestration infrastructure at its existing Geismar, LA facility to serve growing demand in agriculture, industrial and emerging energy markets.

The plant is expected to have an annual production capacity of 1.2 million metric tonnes of clean ammonia and capture at least 90 percent of CO_2 emissions, permanently sequestering more than 1.8 million metric tonnes of CO_2 in dedicated geological storage per annum.

The new plant will use auto thermal reforming technology to achieve the lowest carbon footprint of any plant at this scale and has the potential to transition to net-zero emissions with future modifications.

“Our commitment to the development and use of both low-carbon and clean ammonia is prominent in our strategy to provide solutions that will help meet the world’s decarbonization goals, while sustainably addressing global food insecurity. Leadership in clean ammonia production will play a key role in achieving our 2030 Scope 1 and 2 emissions reduction goals, as part of our Feeding the Future Plan,” said Ken Seitz, Nutrien’s Interim President and CEO.

Nutrien has signed a term sheet with Denbury Inc., a trusted partner for nearly a decade, that would allow for expansion of the existing volume of carbon sequestration capability in the immediate vicinity of its Geismar facility, if selected as the final site of construction.

“Nutrien is optimally positioned to supply global emerging clean ammonia markets and grow a pathway for a decarbonized supply chain,” said Raef Sully, Nutrien’s Executive Vice President and CEO of Nitrogen and Phosphate.

“We are pleased to partner with Denbury on this initiative given our established track record of cooperation. It is another example of how we are building on our expertise in low-carbon ammonia to decarbonize the agriculture industry while helping to sustainably feed and fuel the future.”

Nutrien has also signed a Letter of Intent to collaborate with Mitsubishi Corporation for offtake of up to 40 percent of expected production from the plant to deliver to the Asian fuel market, including Japan, once construction is complete.

Nutrien is committed to leading the development of low carbon and clean ammonia to rapidly accelerate the decarbonization of hard-to-abate sectors such as agriculture, industrial use of ammonia, power generation, and maritime fuel.

As one of the world’s largest ammonia traders by marine transportation, Nutrien announced in 2021 a collaboration agreement with EXMAR to jointly develop and build one of the first low-carbon, ammonia-fueled maritime vessels to help decarbonize shipping.

Nutrien is also involved with the US Department of Energy and other partners to explore flexible clean ammonia production using air, water and variable renewable electricity. ***(Source:www.nutrien.com)***

Kingenta International

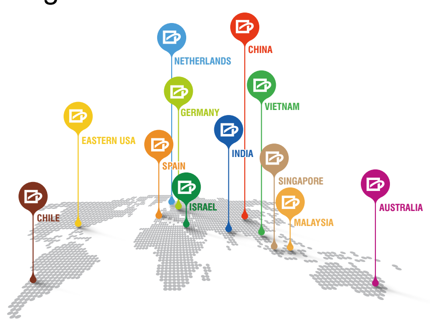
Kingenta Ecological Engineering Group Co., LTD

Founded in 1998, Kingenta Ecological Engineering Group Co., Ltd is devoted to R&D, production and marketing of compound fertilizers, slow/controlled-release fertilizers (SCRF), water soluble fertilizers (WSF), and other new fertilizers. Kingenta has the world' s largest slow/controlled-release fertilizer production base with total assets of more than RMB 11 billion, over 10,000 employees and annual production capacity of 7 MMT. In 2010, Kingenta was listed in the Shenzhen Stock Exchange (stock code 002470). In 2016, Kingenta' s sales revenue reached RMB 18.7 billion and total pre-tax profit of RMB 1.01 billion.

Kingenta is a key national hi-tech and innovative enterprise involved in drafting industrial and national standards for the SCRF industry. Kingenta is also a leader of the National SCRF Industry Technology Innovation Strategic Alliance. Kingenta has established production sites in Linshu, Shandong Province,Heze, Shandong Province, Changfeng, Anhui Province,Dancheng, Henan Province,Zhumadian, Henan Province, Tieling, Liaoning Province, Weng' an, Guizhou Province, Jinning, Yunnan Province,Dezhou, Shandong Province,Yingde, Guangdong Province along with branches in America,Norway,Israel,Germany,Vietnam, and Hong Kong.

Kingenta' s sales network expends beyond China and reaches Asia, Europe, Africa, North America, Latin America and Oceania. Kingenta has established cooperation agreements with international universities and research centers throuhout the world.

Kingenta can supply all range of fertilizers such as compound fertilzers, slow / Controlled-release fertilizers, water soluble fertilizers and other new fertilizers According to client' s requirments.



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FRONTIER OF SCIENCE & TECHNOLOGY

Phosphate Solubilizing

Bacteria as Plant Biostimulants

Phosphorus (P) is one of the most important macronutrients required for plant development.

It accounts for between 0.2 and 0.8% of the dry weight of plants, and it is second only to nitrogen among mineral nutrients most commonly limiting the growth of crops.

The availability of phosphorus for plants in the soil is limited because of its fixation as insoluble compounds and even if P fertilizers are applied up to 90% of this phosphorus can become fixed in the soil in insoluble forms (e.g., tricalcium phosphate in calcareous soils), rendering it unavailable for plant uptake.

Insoluble soil P can be made available for plant uptake through the action of soil microorganisms, like bacteria, which are able to solubilize inorganic phosphates or mineralize organic pools.

Phosphorus functions in plants

Phosphorus is present in many vital compounds of a plant like DNA and RNA, enzymes, coenzymes, nucleotides, and phospholipids.

P is essential in every aspect of plant growth and development, from the molecular level to many physiological and biochemical plant activities including photosynthesis, development of roots, strengthening the stalks and stems, formation of flowers and seeds, crop maturity and quality of crop, energy production, cell division and enlargement and transformation of sugar to starch.

Phosphorus deficiency symptoms in plants

Phosphorus is a mobile element in the plant and, consequently, P deficiency symptoms usually occur first on the lower (older) leaves of the plant in the form of a uniform reddish color (Figure 1).

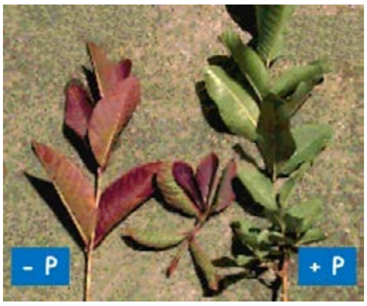

Figure 1: Phosphorus deficiency symptoms

Another symptom of P deficiency is the reduction of root growth which leads to less root mass to reach water and nutrients (Figure 2).

Figure 2 Reduction of root growth due to P deficiency

Availability of phosphorus in the soil

Plant roots mainly take up P in the forms of phosphate anions mainly HPO42− or H2PO4– depending upon soil pH.

Phosphorus is a reactive element and availability of soluble forms in the soil is limited of due to fixation as insoluble compounds.

P gets immobilized by cations such as Ca2+ in calcareous or normal soils to form a complex calcium phosphate and with Al3+ and Fe3+ in acidic soils to form aluminum phosphate and ferrous phosphate.

These are insoluble forms and consequently unavailable for plant uptake (Figure 3).

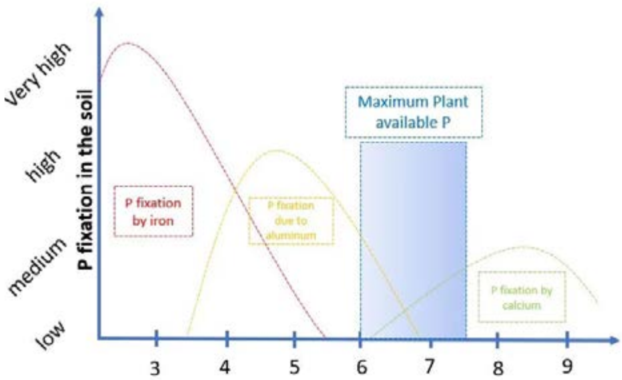

Figure 3: Interaction of soil pH and phosphorus availability

Although application of P fertilizers is usually fundamental to secure crop growth and productivity, application of P fertilizers to the soil may be not enough to satisfy plant needs due to the soil P fixation.

It is estimated that usually about 75–90% of the supplied chemical P fertilizer is precipitated and rapidly becomes fixed in soils; the buildup of insoluble P in soil may have a long-term impact on the environment enhancing the risk of eutrophication, soil fertility depletion, and carbon footprint associated with the applications of P fertilizer.

Therefore, it is important to avoid the excessive buildup of P into the soil through the use of appropriate agronomic practices including the enhancement of P solubilizing bacteria.

Phosphate solubilizing bacteria (PSB)

Plant growth promoting rhizobacteria (PGPR) which demonstrate higher P-solubilizing abilities, have been categorized as Phosphate solubilizing bacteria (PSB).

This group of bacteria is able to convert organic and inorganic unavailable phosphorus compounds to soluble forms, that can easily be assimilated by plants.

Bacterial species belonging to several genera such Pseudomonas spp., Agrobacterium spp., and Bacillus spp., can be used as plant biostimulants to increase P availability and therefore improve phosphorus use efficiency with economic and environmental benefits.

How do PSB make phosphorus available for plants uptake?

1 – Lowering soil pH

The principal mechanism for solubilization of soil P is lowering of soil pH by production of organic acids.

In alkaline soils, phosphate can precipitate to form calcium phosphates, including rock phosphate (fluorapatite and francolite), which are insoluble in soil. Their solubility increases with decreases in soil pH.

PSB increase P availability by producing organic acids that lowers the soil pH.

For example, organic acids such as lactic, malic, acetic, oxalic, and gluconic are produced by different bacterial species such as Serratia sp., Bacillus sp., Enterobacter sp. and Azospirillum sp.

2 – Secretion of P-mineral dissolving compounds

Organic and inorganic acids produced by PSB dissolve the insoluble soil phosphates by chelation of cations and competing with phosphate for adsorption sites in the soil. The hydroxyl and carboxyl groups of the acids chelate the cations bound to phosphate, thereby converting it into soluble forms.

Other mechanisms of P solubilizing bacteria include the release of protons and the production of inorganic acids (e.g., sulphuric, carbonic, and nitric acids) and chelating substances such as siderophores.

3 – Mineralization

Organic phosphate contained in plant and animal remains and in soil organic matter is transformed into utilizable form by PSB through process of mineralization.

PSB mineralize soil organic P by the production of phosphatases like phytase that hydrolyze organic forms

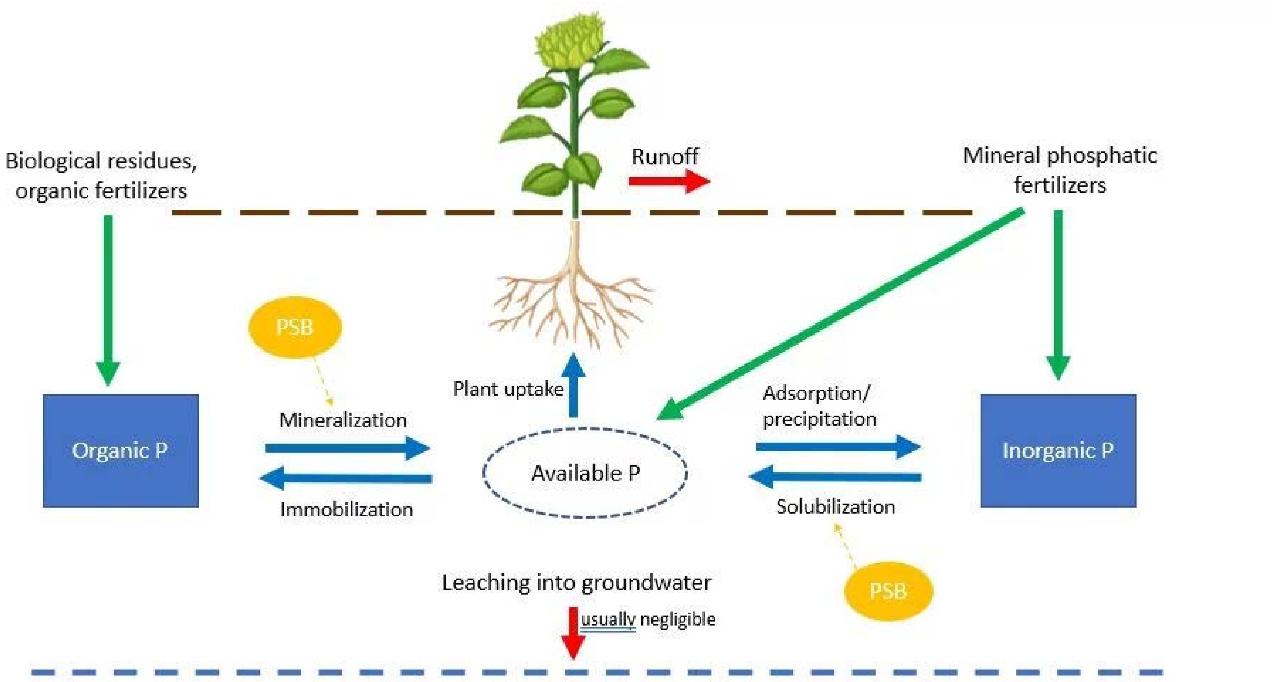

Figure 4 Phosphorus cycle in the soil and role of PSB

of phosphate compounds, thereby releasing inorganic phosphorus that will be immobilized by plants.

Field application of PSB

PSB are promising tools for increasing P content in plants making available the P already contained in the soil in the inorganic and organic pool.

For example, different strains of Bacillus megaterium have been reported to increase soil P solubilization and soil-available P and most notably increased sugarcane yield by 12.6% over an uninoculated control, while allowing for a 25% reduction in P fertilizer application without reducing yields compared to a full P application rate.

In another study, the presence of PSB Micrococcus sp. (strain F3), Pantoea sp. (strain C1) and Pseudomonas (strain F1G) on tomato and corn decreased the pH by 1.89 (from 5.64 to 3.75) on average, compared to the control. In turn, the soluble P concentration increased by 313% on average after PGPB treatment compared to that in the control.

The microbes stimulated more shoot growth than root growth especially in tomato than in corn. These strains increased the plant biomass of both species mainly under low P availability rock phosphate fertilizer, these results were related to the ability of PGPB to solubilize P from recalcitrant sources and to the improvement of root traits.

In conclusion, PSB have tremendous potential as plant biostimulants.

Solubilizing soil inorganic and organic phosphorus compounds, they increase phosphorus bioavailability for plant use and allow to reduce the use of synthetic fertilizers with economic and environmental benefits. Additionally, they promote plant growth and development by releasing biologically active substances.

The use of PSB promotes sustainable agriculture, minimize pollution of waterways and improves soil fertility and thus increases crop productivity. ***(Source: www.biostimulant.com)***

Salt Scourge: The Dual Threat

of Warming and Rising Salinity

As rising seas increase saltwater intrusion and soaring temperatures cause greater evaporation, scientists say that the mounting levels of salt in waters and in soils pose a major climate-related danger and could become a leading cause of climate migration globally.

The Mekong Delta is under a chemical threat arguably more deadly for the long term than the Agent Orange deployed across it during the Vietnam War half a century ago. By the middle of this century, it could be engulfed by a toxic onslaught from which there is no recovery — salt.

As sea levels rise, salty ocean water is pushing ever further into the delta, one of Southeast Asia's most densely populated and productive rice-growing regions. During this year's spring dry season, the salinity boundary — where salt levels exceed 4 grams per liter — reached up to 40 miles upstream, more than 10 miles further than it has historically.

The saline influx is in part caused by faltering flows of fresh water coming down the Mekong River into the delta, as China fills giant hydroelectric dams far upstream. But a new and pioneering modeling study of the delta, which is home to more than 20 million people, has concluded that by around 2050, rising sea levels in the South China Sea will be the dominant driver of salinization, making wide areas uninhabitable for rice farmers long before they are inundated by the ocean itself.

Co-author Piet Hoekstra, an expert on coastal dynamics at Utrecht University in the Netherlands, says the study is the first to combine a range of natural processes, from climate change and land subsidence to river and sediment flow, to predict the future of a major delta. "We think it will become a benchmark for other delta studies," he says.

Hotspots for climate change-induced salinization include Australia, Mexico, South Africa, the U.S. Southwest, and Brazil.

A lot will hang on the outcome of such studies. For the Mekong is one of dozens of large, fertile river deltas — many the breadbaskets of their national economies — that face similar salt invasions.

And climate change will drive salt scourges far from the ocean too, especially in arid regions, where climate scientists warn that higher temperatures will result in much faster rates of evaporation. This will combine with longer dry seasons and more pervasive droughts to desiccate continental interiors, raising the current trace levels of naturally occurring salt to concentrations where crops will die and freshwater ecosystems will collapse.

Among the vulnerable places are the Mediterranean countries of Southern Europe, where temperatures are already rising faster than the global average and climate models predict a 25-30 percent decline in rainfall by 2080. Ecologist Erik Jeppesen of Aarhus University in Denmark recently reported that a coming buildup of salt in the region's lakes, wetlands, and rivers poses "a major threat to the functioning and biodiversity of inland aquatic ecosystems." Crops will die, too. And many underground water reserves on which the region's half-billion people depend may become undrinkable, warns Micol Mastrocicco, an expert on water pollution at the University of Campania Luigi Vanvitelli in Italy.

There is a surge in saltiness across all inhabited continents today. Climate change is far from the only cause. Deltas are left wide open to incursions of seawater by dams upstream, by pumps that remove fresh water from underground for faucets and irrigation, and by sand

▲ Farmer Abdul Majed was forced to switch from growing rice to raising shrimp after saltwater intruded into his paddies in Khulna, Bangladesh. ORJAN F. ELLINGVAG / CORBIS VIA GETTY IMAGES mines that lower river beds. And in dry regions, irrigation systems delivering water to crops bring salt onto fields, which is left behind in soils as the crops absorb the water.

Humans also add salt directly to landscapes too, for instance by pouring saline drainage water from mines into rivers and by dosing roads with rock salt to prevent icing in winter. "In cold regions, road de-icing salts can be the major contributor to rising salinity of freshwater ecosystems," says William Hintz, an ecologist at the University of Toledo.

But in the Mekong, the Mediterranean, and elsewhere, there is growing concern that climate change is replacing these local factors as the dominant cause. "It will affect almost every human populated region around the globe," says Hintz.

A modeling study using climate, soil, and hydrological data — carried out by Amirhossein Hassani and colleagues at the University of Manchester and the Hamburg University of Technology and published in 2020 — pinpointed hotspots for climate change-induced salinization across wide areas of southern and western Australia, Mexico, South Africa, the U.S. Southwest, and Brazil — with central India, the desert soils of Mongolia and northern China and the Mediterranean countries of Spain, Morocco and Algeria not far behind.

The damage is likely to be so severe that salinization will become a major cause of environmental refugees, as people flee land that will no longer sustain them. Low-lying Pacific islands may become uninhabitable because their fresh water turns salty long before the waves engulf them, the U.S. Geological Survey has warned. In the giant delta of the rivers Ganges, Brahmaputra, and Meghna, which occupies much of Bangladesh, salinization is already a more important cause of migration than the much more heavily publicized exoduses from floods and other natural disasters, development economists Joyce Chen of Ohio State University and Valerie Mueller of Arizona State University wrote recently.

More than two million hectares of farmland in Australia is damaged by salt, including in the Murray-Darling basin, the nation's breadbasket.

Of course, some ecosystems are adapted to saline environments. Many lakes and wetlands in arid regions are naturally salty. But even here the desiccation caused by climate change is raising salinity and altering the balance between saline and fresh water, creating growing

▲ *Farmer Abdul Majed was forced to switch from growing rice to raising shrimp after saltwater intruded into his paddies in Khulna, Bangladesh. ORJAN F. ELLINGVAG / CORBIS VIA GETTY IMAGES* problems for ecosystems, lake fisheries, crop growing, and sometimes human health.

Hintz reported in February that salt has triggered a "massive loss of important zooplankton" in lakes in North America and Europe. This loss has a "cascading effect," resulting in blooms of algae at almost half the sites studied. Once salt gets into wetlands, he says, it is "incredibly difficult to get out, even assuming you've stopped the source of salt pollution. It can persist for decades or longer, depending on how long the water in a lake or wetland sticks around."

A third of U.S. rivers have become more salty in the past quarter-century, according to an analysis by Sujay Kaushal, a biochemist at the University of Maryland, College Park. The highest salt levels are often downstream of mining areas, such as the northern Great Plains, that discharge large volumes of saline water from underground into rivers, and in the irrigated regions of the Southwest, where salty drainage water concentrates in soils and rivers.

The Rio Grande has seen a fourfold increase in salinity, according to John Olson, a freshwater ecologist at California State University Monterey Bay. In the Colorado basin and California, salt buildup results in crop losses put at billions of dollars per year. De-icing salt alone, by one estimate, causes $1,000 in structural damage, mostly through corrosion, for every ton spread onto roads and parking lots.

In Australia, more than 2 million hectares of farmland is damaged by salt, primarily in Western Australia and the heavily irrigated Murray-Darling basin, the country's breadbasket in the east. This has an estimated economic impact of more than $700 million per year. A growing part of the problem is a reduction in rainfall that is widely blamed on climate change, and leads to desiccation of the land. A federal government audit of the country's drylands predicts a threefold increase in soil salinity by 2050.

But while economic impacts have sometimes been assessed, researchers admit they often don't have a good handle on the gravity of the growing salt threat to freshwater ecosystems. A recent international analysis of published research, headed by David Cunillera-Montcusi, an aquatic ecologist at the University of Barcelona, found that while there had been 93 studies of salinization of freshwater ecosystems and its causes in North America since 2017, there had been only five studies in all of Africa and six in South America.

Health problems too are seriously under-investigated. Salty drinking water is a major public health problem in many regions. It was water from a salty local river that mobilized lead in old water pipes, poisoning supplies in Flint, Michigan. Around the Aral Sea, a victim of decades of water abstraction for irrigating cotton in Central Asia, salty underground waters and salt-rich dust storms from the dried-up seabed have left the majority of the population suffering from anemia.

▼ A stockpile of winter de-icing salt in Middlewich, England. Christopher Furlong / Getty Images

Salty drinking water in coastal Bangladesh causes up to 10,000 deaths a year, according to a 2015 study.

Mofizur Rahman, an environmental scientist currently at the Cologne University of Applied Sciences, says that in his native Bangladesh, high levels of salt, especially sodium, in water supplies are causing epidemics of pre-eclampsia and hypertension, which affects one in three women in parts of southwest Bangladesh. A 2015 study by Jacob Levi, then at Imperial College London, estimated that salty drinking water in coastal Bangladesh causes up to 10,000 deaths a year, a figure that climate change will dramatically increase.

As climate change gathers pace, salt will be a growing threat to the world's food supplies, particularly where farmers rely on artificial irrigation. Water poured onto fields always contains some salt, eroded from mountains where the rivers rise. But when plants absorb the water, they leave the salt behind in the soil, where it eventually forms a white, toxic crust.

Around a third of the world's food is grown in irrigated fields, and a fifth of those fields are reckoned to be salt-contaminated. Climate change will dramatically worsen this, researchers agree, because in a hotter, drier world, more crops will need more irrigation water, aggravating the buildup of salt.

In some places, farmers are leaving their lands. Saline intrusion in Bangladesh, as sea levels rise and storm surges from the Bay of Bengal become more intense, has reduced rice production by up to 30 percent in the past 15 years, according to Rahman. It is fueling an exodus of farmers to the country's capital, Dhaka.

Similarly in Pakistan, saline waters have intruded more than 30 miles into the delta of the Indus River, forcing hundreds of thousands of people to depart for nearby Karachi. This has contributed to the influx of people into Dhaka and Karachi, which have, partly as a consequence, become two of the fastest growing megacities in the world, adding 11 million and 7 million to their populations, respectively, in the last two decades.

Other farmers try to adapt to saltier waters and soils. In both Bangladesh and the Mekong delta, rice growers have switched to raising prawns in brackish ponds. But there are downsides to this adaptation strategy. The ponded water only adds to soil salinity in the surrounding areas, note Chen and Mueller.

Taking a different approach, plant breeders are working on more salt-tolerant crops, either by genetic engineering or by searching among existing crop varieties for those that are most tolerant of their salt. The Dutch aid agency Cordaid has been working with crop scientists and farmers to identify and plant varieties of carrots, potatoes, and cabbages that can grow in the increasingly saline soils of coastal Bangladesh.

But adaptation can only go so far. The salt has to be held back. In the United States, Hintz says, it is urgent to curb the spreading of de-icing salt onto roads. Controls of drainage from mines could often help too. On many rivers round the world, including the Mekong, improved management of upstream dams could maintain river flows to deltas during the dry season when saline invasion from the ocean is most intense. And there is huge potential for better management of irrigation systems so they require less water and have drains to remove salt from soils.

But ultimately only a halt to climate change will be capable of ending the great salinization. *(Source: Yale Environment 360, by Fred Pearce)*

▲ A girl collects rain, the main source of drinking water in Shyamnagar, Bangladesh, where waters are highly saline. Probal Rashid / Lightrocket via Getty Images Bangladesh. Orjan F. Ellingvag / Corbis via Getty Images

A Future Without Fertilizers?

Four Ideas that Someday Could Impact Nitrogen Needs.

Pressure from Costs, Availability, Regulations and Environmentalists Continue to Squeeze Synthetic Fertilizer Into a Complicated Future. Today Farmers Simply have Limited Alternatives. Tomorrow, The Answer Might be Much Different. Here are Four Ideas that Someday Could Impact Nitrogen Needs.

A mucus-like gel and bacteria can help some varieties of corn fix atmospheric nitrogen. Alan Bennett/UC Davis

A FIXER UPPER

Announced in 2018, researchers from University of California, Davis, the University of Wisconsin and Mars Inc., continue to study a tropical variety of corn from Mexico that can fix atmospheric nitrogen using a mucus-like gel and bacteria from what looks like brace roots along the stalk.

“I knew about this corn for a long time, but there was no way to approach it,” says Alan Bennett, University of California professor. “All of a sudden, through advances in DNA sequencing technology there was an aha moment that we can do this now.”

They’ve found that the corn can generate somewhere between 30%and 80% of needed nitrogen from this unique genetic trait. Now researchers are seeing if that ability can be transferred, replicated, or improved in other varieties of corn.

“The microbes are everywhere, and you need to have the right genetics in order to attract and harbor those microbes in a supportive environment,” Bennett says.

Bennett isn’t sure synthetic fertilizer use can go to zero, but cutting it in half could be a huge win for farmers around the world.

“The gains will be economically important in the United States, but they'll be dramatically more significant in places like Africa, where they may not have the option of synthetic fertilizer,” Bennett says.

EXCRETE TO SUCCESS

Ammonia Excreting BacteriaAt Washington State and Wisconsin, university researchers are busy engineering nitrogen-fixing bacteria called Azotobacter vinelandii as a replacement for traditional fertilizer.

“The bacteria fix nitrogen all the time (even in the presence of synthetic fertilizer) but depending on how we manipulate the genes we also end up with bacteria that can excrete ammonia in really large quantities,” says Florence Mus, assistant research professor at Washington State University.

Mus and team used gene editing to engineer the bacteria.

They’ve also found a way to regulate the amount of ammonia produced knowing some crops need more fertility than others.

“Different crops have different nitrogen needs so we can customize the amount of ammonia a bacteria will excrete for a specific plant,” Mus says.

When asked about a future without synthetic fertilizer, Mus says it’s possible.

“We still have some work to do, but bacteria are already being used as biofertilizer in the cells we have engineered,” Mus says. “So, I think it's doable.”

HOW MULCH MORE

Cotton growers in certain areas of the country may be able to go without needing synthetic fertilizer right now, says Nicholas Basinger, University of Georgia's Department of Crop and Soil Sciences.

"In a cotton crop we can replace all of the nitrogen that we need," Basinger says. "We only need toPlanting into Living Mulch supplement with P&K."

He's part of a team that has been studying the benefits of living mulch. While he's a weed scientist and has seen significant benefits from a living, growing mat of Durana White Clover, there are also fertility benefits from the nitrogen-fixing legume.

"We know that the perennial living mulch will provide about 100 lb. an acre of nitrogen," Basinger says. "One thing we don't know is exactly when or how all of that N is released in cotton. In corn, it's a slow-release from planting on into the growing season as the corn shades out the living mulch."

Seeded as a cover crop in the fall, at spring planting furrow strips are killed ahead of the planter. The clover between the rows continues to feed the seedling's roots. Basinger says the biggest limiting factor to wide adoption is water.

"Some of the trade-offs we have with this system is it has to be in the South and on irrigated land," Basinger says. "Yes, we get weed suppression, yes, we get our nitrogen fixation, but it's not without the cost of competition for water resources."

WHAT'S OLD IS MANURE AGAIN

Biological innovations are pouring into the industry from all corners of the globe, but Purdue University agronomist Tony Vyn says don't forget the classics.

"I do not see a future without synthetic fertilizers," Vyn says. "I do see a future using more biologicals and preferably while we're also making much better use of manure and manure-based fertilizers."

Nitrification inhibitors and nutrient monitoring have helped to keep manure a serious contender. He advocates for focusing on the 4R's, using legumes, organic matter and soil health. However, Vyn is excited about the incremental improvements seed companies are making in nitrogen use efficiency.

"Modern hybrids are capable of capturing more of the nitrogen applied," Vyn says. "How much fertilizer nitrogen did you put on the field and how much nitrogen are you removing from the field. Those nitrogen harvest index numbers are improving every decade." ***(Source: Agweb, By Clinton Griffiths)***

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Fertilizer View

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