Jan/Mar 2021

Fertilizer View

PROVIDE VALUABLE INFORMATION OF GLOBAL FERTILIZER INDUSTRY

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Provide Valuable Information of Global Fertilizer Industry

FSHOW 2021 | China International Fertilizer Show

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News in Brief

China MoARA Started Accepting Online Filing of 7 Chemical Fertilizers

The Chinese Ministry of Agricultural and Rural Affairs has recently launched the online filing system for 7 types of chemical fertilizers, namely water-soluble fertilizer containing nitrogen, phosphorus and potassium, water-soluble fertilizer containing calcium and magnesium, water-soluble fertilizer containing calcium and magnesium, magnesium-potassium chloride for agriculture use, magnesium-potassium sulfate for agriculture use, compound fertilizer (complex fertilizer) and compound fertilizer (complex fertilizer).

These fertilizers were recently excluded from existing registration requirements, aimed to abolish and decentralize administrative matters.

Once the filing is completed, the name of the producer, the generic name of the product, product form, technical indicator, filing number and time of filing will be publicly available. ***(Source: CHEMLINKED)***

The World's First Agrochemical Online Exhibition Successfully Held

At the beginning of March 2021, the world's largest agrochemical exhibition CAC online exhibition was successfully held. CAC Online attracted nearly 1,500 enterprises to participate. The exhibition covered pesticide, fertilizer, equipment, seeds, agri-aviation and irrigation, with more than 12,000 kinds of products on display and a total of 230,000 page views.

CAC Online has realized the functions of enterprise stores, product display, text & video chat, product inquiry, supply and demand release, etc., and has also held more than 30 online lectures in the same period.

Facing the uncertainty of Covid-19, CAC Online is a bold attempt in the field of agrochemical industry. Both enterprises and visitors are willing to participate in the online expo. Under the current circumstances, online expo makes up for the lack of offline meeting and shortens the distance between the supply side and the purchase side.

It is understood that CAC 2021 has been postponed to be held in Shanghai from June 22 to 24. The CAC Online will be opened again at the same time as the offline expo, so as to meet the participation needs of the international audience who can not be present. This will also be the first attempt of the online and offline exhibition in the field of agrochemicals. ***(Source: en.fshow.org)***

Conference on Seed Industry Held in South China

A conference focusing on the seed industry and winter crop breeding kicked off on Saturday in Sanya, south China's Hainan Province.

The 2021 China Seed Congress and Nanfan Agricultural Silicon Valley Forum consist of a main forum and 12 sub-forums, covering fields like rice, corn, vegetables, aquatic products, digitalization and intellectual property in the seed industry.

More than 20 Chinese academicians are participating in the five-day event and over 100 experts from home and abroad will deliver speeches.

During the conference, crop varieties including rice, corn, soybeans and cotton will be displayed at five sites for winter crop breeding in Sanya and the neighboring counties of Ledong and Lingshui.

The conference was previously held twice in Beijing in 2018 and 2019. This is the first time the event has been held in Sanya. *(Source: Xinhuanet.com)*

Yantai Port Enters Peak Fertilizer Handling Season

A cargo ship in Yantai Port unloads imported potash fertilizer. The port is an important distribution center for chemical fertilizer in China. (Photo: iqilu.com)

East China's Yantai Port entered its peak season for handling and distributing chemical fertilizers in March – an important time for spring agriculture and the start to ploughing across China.

A ship with 47,000 tons of imported potash fertilizer finished unloading on March 7 and the cargo will now go to China's agricultural market to ensure it meets the demand for spring agricultural materials.

China is the world's largest consumer of potash fertilizer and Yantai Port is an important distribution center for chemical fertilizers in China. Since the start of the year, Yantai Port has handled 103,000 tons of imported potash fertilizer.

In the peak season, the daily volume of domestic sales can reach more than 3,000 tons, benefiting agricultural customers within more than 100 square kilometers of Yantai. ***(Source: chinadaily.com.cn)***

Brazil Will Raise the Tax on Fertilizers From 2022

The taxation on agricultural fertilizers will see a gradual increase from 2022, according to a decision by the National Council for Farm Policy (Confaz) which was approved on March 10.

Confaz was formed by the Minister of Finance and the finance secretaries of the Brazilian states and defines concessions or revocations of tax benefits in the country.

With this decision, the Tax on Circulation of Goods and Services (state tax) on fertilizers will gradually increase from 1% to 4% from 2022 to 2025.

The decision represents an amendment to the 1997 Agreement 100, which reduces the ICMS calculation base on outflows of agricultural inputs traded between the states.

Under this agreement, the rates on other agricultural inputs, such as feed, pesticides and seeds, for example, remain unchanged.

"The renewal of the agreement occurs after a wide debate between the states and dialogue with entities in the agricultural sector, and involves a goal of growth of 35% in the production of the national fertilizer industry by 2025," Confaz stated in a release. ***(Source: g1.globo)***

Italpollina Changes Name to Hello Nature

Three years after a major image rebrand, Italpollina, a world leader in producing organic fertilizers, natural biostimulants, and beneficial microbials for use in agriculture, is pleased to announce that their company name is now HELLO NATURE®.

This announcement comes as the company marks its 50th year in business, becoming a 'historical brand' in Italy, with a name that had become synonymous with quality, professionalism, and competence. This development, not the result of an acquisition or change of ownership, exemplifies the company's progression, said Luca Bonini, CEO of HELLO NATURE®. "We have made a radical evolution from the fertilizer sector to becoming a world leader in the production of biostimulants, and 'Italpollina' no longer represents the complexity of our activity."

During their rebranding process in 2017, Italpollina decided the tagline of "Hello Nature" clearly expressed their position in the market and supported their founding principle of growing a sustainable future. The slogan was very well received and became the logical choice for the new company name. The 'Italpollina' name will continue to be used for their classic poultry manure fertilizer product.

With a name like HELLO NATURE® comes responsibility for processes and products as close to nature as possible. According to Bonini, "Our role is to be leaders, and from a practical approach, we must put environmental sustainability at the forefront of our company's activities." He adds, "This name change also strengthens our support of global strategies in place to improve food security, including the Farm to Fork strategy of the European Union, the Sustainable Development Goals of the United Nations, and the guidelines of the United Nations' Food and Agriculture Organization."

The full transition to the new name will roll out across the globe throughout 2021, and the company expects to see some crossover on branded materials during this time. Internationally, branches will adopt the name at different rates depending on various bureaucracy considerations of the region.

About the new name, Bonini says, "HELLO NATURE says it all. It communicates who we are and what we stand for, and it represents our leadership of sustainable inputs in agriculture." *(Source: Hello Nature)*

Researchers Solve Riddle of Plant Immune System

Team led by the University of Gottingen describes influence of molecular mechanisms

How do plants build resilience? An international research team led by the University of Göttingen studied the molecular mechanisms of the plant immune system. They were able to show a connection between a relatively unknown gene and resistance to pathogens. The results of the study were published in the journal The Plant Cell.

Scientists from "PRoTECT" – Plant Responses To Eliminate Critical Threats – investigated the molecular mechanisms of the immune system of a small flowering plant known as thale cress (Arabidopsis thaliana). PRoTECT is an International Research Training Group (IRTG) founded in 2016 with the University of Göttingen and the University of British Columbia in Vancouver. The aim of the study was to identify and describe a specific gene of a particularly disease-resistant plant. The team observed that plants that do not possess this previously little known gene strongly accumulate active acids. In addition, these plants show a significantly increased resistance to pathogens. However, this resistance is accompanied by extremely reduced growth.

Lennart Mohnike collecting leaf material from bacteria infected plants (Photo: Philipp William Niemeyer)

"We have succeeded in deciphering the molecular connection between the gene product and the inactivation of the acids during normal plant growth," says Professor Ivo Feußner from the Göttingen Centre for Molecular Biosciences (GZMB). Understanding this interaction provides scientists with a promising approach to improving the natural resistance of crops. "The basic results can be used to help breeders isolate less susceptible plants," says Lennart Mohnike, first author of the study. "This offers scientists an important way to increase food security and could lead to reduced pesticide use." *(Source: Seed Quest)*

INDUSTRY OBSERVATION

A Five-Step Plan

to Feed the World

When we think about threats to the environment, we tend to picture cars and smokestacks, not dinner. But the truth is, our need for food poses one of the biggest dangers to the planet.

Agriculture is among the greatest contributors to global warming, emitting more greenhouse gases than all our cars, trucks, trains, and airplanes combined—largely from methane released by cattle and rice farms, nitrous oxide from fertilized fields, and carbon dioxide from the cutting of rain forests to grow crops or raise livestock. Farming is the thirstiest user of our precious water supplies and a major polluter, as runoff from fertilizers and manure disrupts fragile lakes, rivers, and coastal ecosystems across the globe. Agriculture also accelerates the loss of biodiversity. As we've cleared areas of grassland and forest for farms, we've lost crucial habitat, making agriculture a major driver of wildlife extinction.

The environmental challenges posed by agriculture are huge, and they'll only become more pressing as we try to meet the growing need for food worldwide. We'll likely have two billion more mouths to feed by mid-century—more than nine billion people. But sheer population growth isn't the only reason we'll need more food. The spread of prosperity across the world, especially in China and India, is driving an increased demand for meat, eggs, and dairy, boosting pressure to grow more corn and soybeans to feed more cattle, pigs, and chickens. If these trends continue, the double whammy of population growth and richer diets will require us to roughly double the amount of crops we grow by 2050.

Unfortunately the debate over how to address the global food challenge has become polarized, pitting conventional agriculture and global commerce against local food systems and organic farms. The arguments can be fierce, and like our politics, we seem to be getting more divided rather than finding common ground.

Those who favor conventional agriculture talk about how modern mechanization, irrigation, fertilizers, and improved genetics can increase yields to help meet demand. And they're right. Meanwhile proponents of local and organic farms counter that the world's small farmers could increase yields plenty—and help themselves out of poverty—by adopting techniques that improve fertility without synthetic fertilizers and pesticides. They're right too.

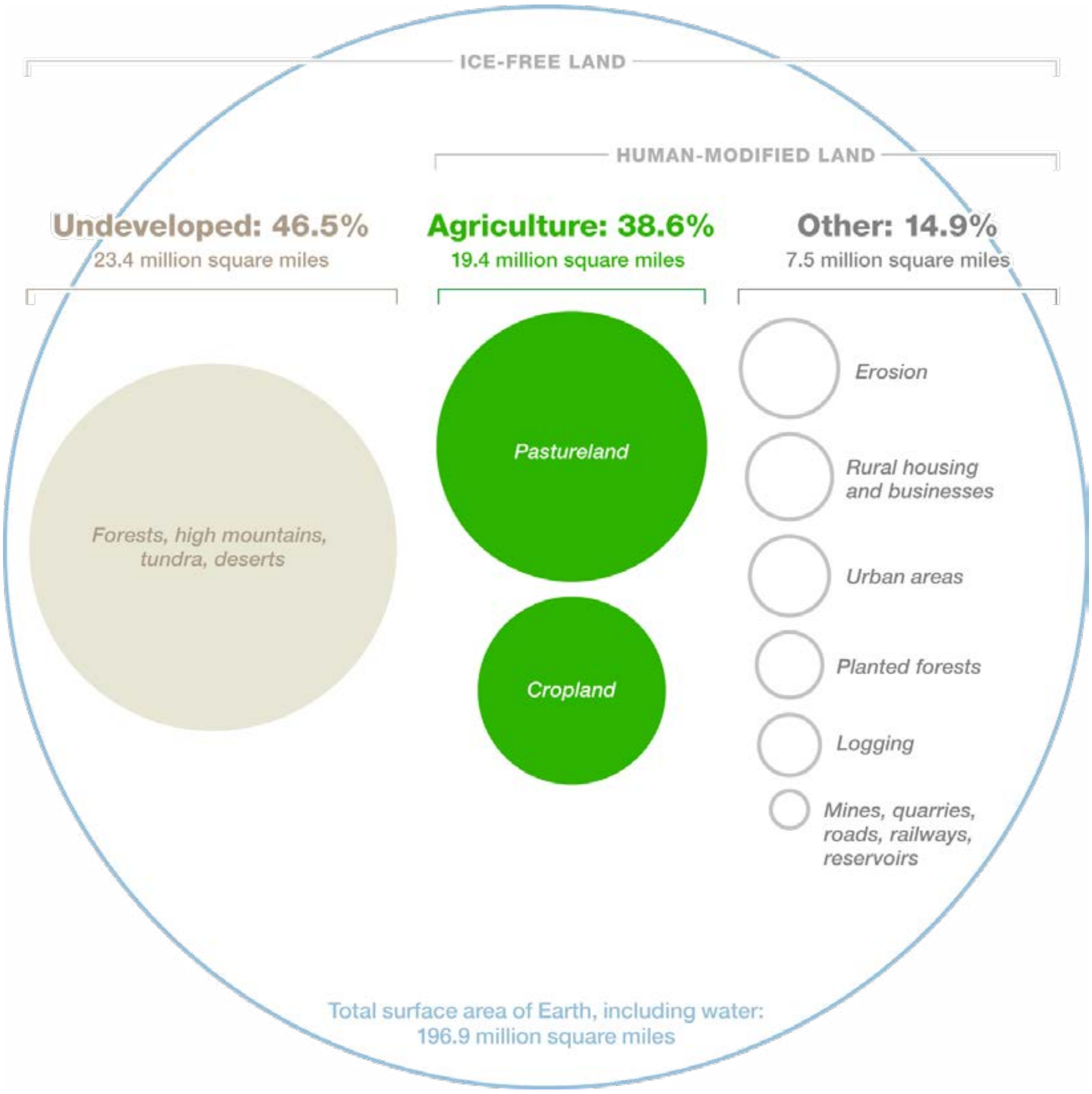
But it needn't be an either-or proposition. Both approaches offer badly needed solutions; neither one alone gets us there. We would be wise to explore all of the good ideas, whether from organic and local farms or high-tech and conventional farms, and blend the best of both.

I was fortunate to lead a team of scientists who confronted this simple question: How can the world double the availability of food while simultaneously cutting the environmental harm caused by agriculture?

After analyzing reams of data on agriculture and the environment, we proposed five steps that could solve the world's food dilemma.

Step one: freeze agriculture's footprint

For most of history, whenever we've needed to produce more food, we've simply cut down forests or plowed grasslands to make more farms. We've already cleared an area roughly the size of South America to grow crops. To raise livestock, we've taken over even more land, an area roughly the size of Africa. Agriculture's footprint has caused the loss of whole ecosystems around the globe, including the prairies of North America and the Atlantic forest of Brazil, and tropical forests continue to be cleared at alarming rates. But we can no longer afford to increase food production through agricultural expansion. Trading tropical forest for farmland is one of the most destructive things we do to the environment, and it is rarely done to benefit the 850 million people in the world who are still hungry. Most of the land cleared for agriculture in the tropics does not contribute much to the world's food security but is instead used to produce cattle, soybeans for livestock, timber, and palm oil. Avoiding further deforestation must be a top priority.



Step two: grow more on farms we've got

Starting in the 1960s, the green revolution increased yields in Asia and Latin America using better crop varieties and more fertilizer, irrigation, and machines—but with major environmental costs. The world can now turn its attention to increasing yields on less productive farmlands—especially in Africa, Latin America, and eastern Europe—where there are "yield gaps" between current production levels and those possible with improved farming practices. Using high-tech, precision farming systems, as well as approaches borrowed from organic farming, we could boost yields in these places several times over.

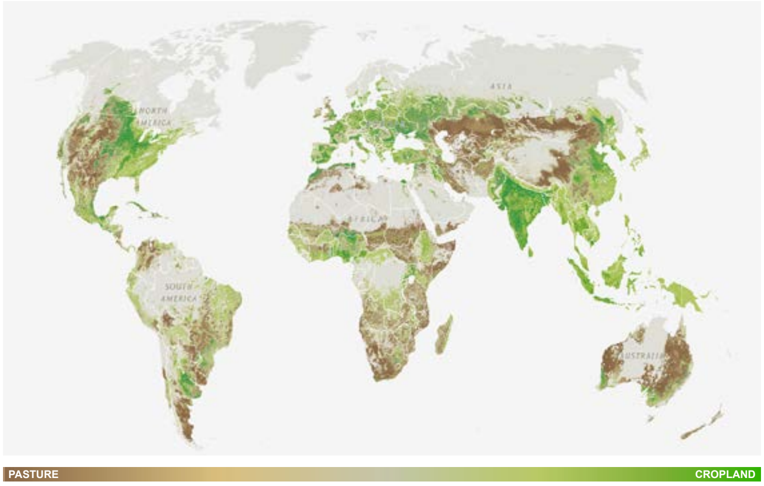
Step three: use resources more efficiently

We already have ways to achieve high yields while also dramatically reducing the environmental impacts of conventional farming. The green revolution relied on the intensive—and unsustainable—use of water and fossil-fuel-based chemicals. But commercial farming has started to make huge strides, finding innovative ways to better target the application of fertilizers and pesticides by using computerized tractors equipped with advanced sensors and GPS. Many growers apply customized blends of fertilizer tailored to their exact soil conditions, which helps minimize the runoff of chemicals into nearby waterways.

Organic farming can also greatly reduce the use of water and chemicals—by incorporating cover crops, mulches, and compost to improve soil quality, conserve water, and build up nutrients. Many farmers have also gotten smarter about water, replacing inefficient irrigation systems with more precise methods, like subsurface drip irrigation. Advances in both conventional and organic farming can give us more "crop per drop" from our water and nutrients.

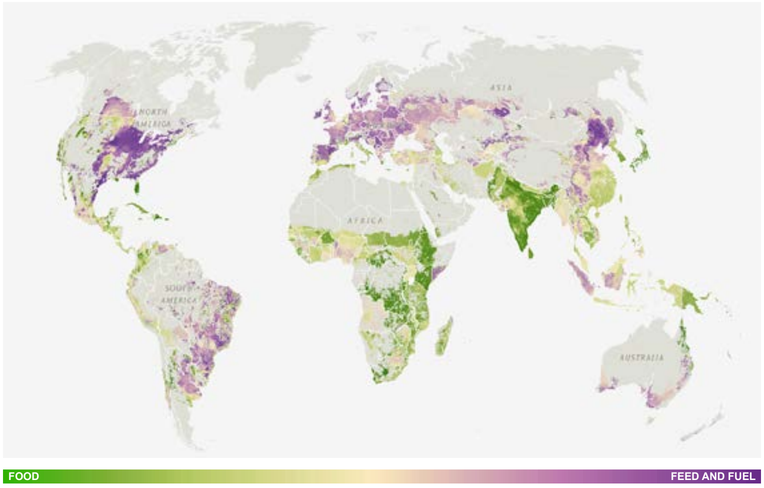
Step four: shift diets

It would be far easier to feed nine billion people by 2050 if more of the crops we grew ended up in human stomachs. Today only 55 percent of the world's crop calories feed people directly; the rest are fed to livestock (about 36 percent) or turned into biofuels and industrial products (roughly 9 percent). Though many of us consume meat, dairy, and eggs from animals raised on feedlots, only a fraction of the calories in feed given to livestock make their way into the meat and milk that we consume. For every 100 calories of grain we feed animals, we get only about 40 new calories of milk, 22 calories of eggs, 12 of chicken, 10 of pork, or 3 of beef. Finding more efficient ways to grow meat and



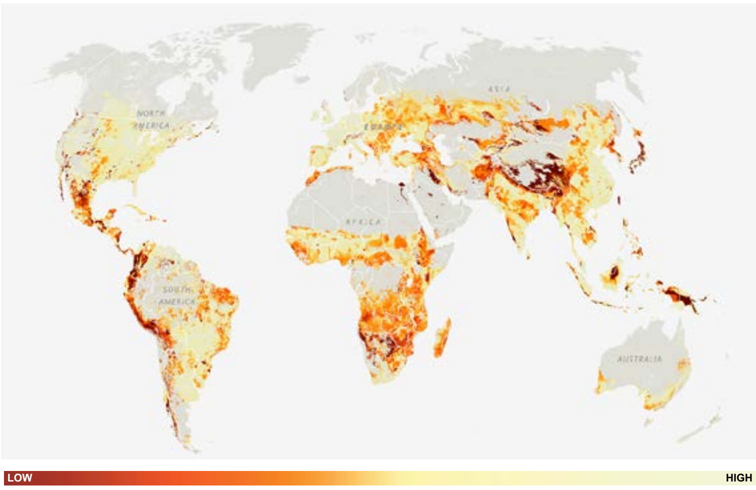
Where Agriculture Exists

Nearly all new food production in the next 25 years will have to come from existing agricultural land.



How Our Crops Are Used

Only 55 percent of food-crop calories directly nourish people. Meat, dairy, and eggs from animals raised on feed supply another 4 percent.



Where Yields Could Improve

Improving nutrient and water supplies where yields are lowest could result in a 58 percent increase in global food production.

shifting to less meat-intensive diets—even just switching from grain-fed beef to meats like chicken, pork, or pasture-raised beef—could free up substantial amounts of food across the world. Because people in developing countries are unlikely to eat less meat in the near future, given their newfound prosperity, we can first focus on countries that already have meat-rich diets. Curtailing the use of food crops for biofuels could also go a long way toward enhancing food availability.

Step five: reduce waste

An estimated 25 percent of the world's food calories and up to 50 percent of total food weight are lost or wasted before they can be consumed. In rich countries most of that waste occurs in homes, restaurants, or supermarkets. In poor countries food is often lost between the farmer and the market, due to unreliable storage and transportation. Consumers in the developed world could reduce waste by taking such simple steps as serving smaller portions, eating leftovers, and encouraging cafeterias, restaurants, and supermarkets to develop waste-reducing measures. Of all of the options for boosting food availability, tackling waste would be one of the most effective.

Taken together, these five steps could more than double the world's food supplies and dramatically cut the environmental impact of agriculture worldwide. But it won't be easy. These solutions require a big shift in thinking. For most of our history we have been blinded by the overzealous imperative of more, more, more in agriculture—clearing more land, growing more crops, using more resources. We need to find a balance between producing more food and sustaining the planet for future generations.

This is a pivotal moment when we face unprecedented challenges to food security and the preservation of our global environment. The good news is that we already know what we have to do; we just need to figure out how to do it. Addressing our global food challenges demands that all of us become more thoughtful about the food we put on our plates. We need to make connections between our food and the farmers who grow it, and between our food and the land, watersheds, and climate that sustain us. As we steer our grocery carts down the aisles of our supermarkets, the choices we make will help decide the future. ***(By Jonathan Foley, Photographs by George Steinmetz and Jim Richardson, Source: NATIONAL GEOGRAPHIC Magazine)***

FEEDING THE WORLD

By 2050 we'll need to feed two billion more people. How can we do that without overwhelming the planet?

▼ On the Vulgamore farm near Scott City, Kansas, each combine can harvest up to 25 acres of wheat an hour—as well as real-time data on crop yields. Most of the food Americans eat is now produced on such large-scale, mechanized farms, which grow row after row of a single crop, allowing farmers to cover more ground with less labor.

PHOTOGRAPHS BY GEORGE STEINMETZ

FACES OF FARMING

All around the world, small farms are playing a big role in feeding the world. These are a few of the men and women behind that effort.

▲ Mariam Kéita harvests peanuts on a farm in Siby, Mali. The green revolution's mix of hybrid seeds, fertilizers, and irrigation never took off in Africa. But sub-Saharan countries now offer a key opportunity to boost global food production, because their yields can be vastly improved.

PHOTOGRAPHS BY JIM RICHARDSON

▲ High in the Peruvian Andes, Estela Cóndor grows five different varieties of potatoes to sell in the market, along with a yellow tuber called mashua that she cooks for her family. Small farmers like Cóndor grow much of the food for people in the developing world.
PHOTOGRAPHS BY JIM RICHARDSON

Eliminating Synthetic Fertilizer

Won't Solve Agriculture's Nitrogen Pollution Problem

Nitrogen pollution is a pressing problem for ecosystem health and the climate. Large shares of nitrogen applied to farms as synthetic fertilizer or manure wash into rivers — causing algal blooms and killing off marine life — and contribute to greenhouse gas emissions. The impacts are so large that in 2018, a group of nitrogen experts determined that the world must halve the amount of nitrogen dumped into the environment to avoid the worst impacts on wildlife.

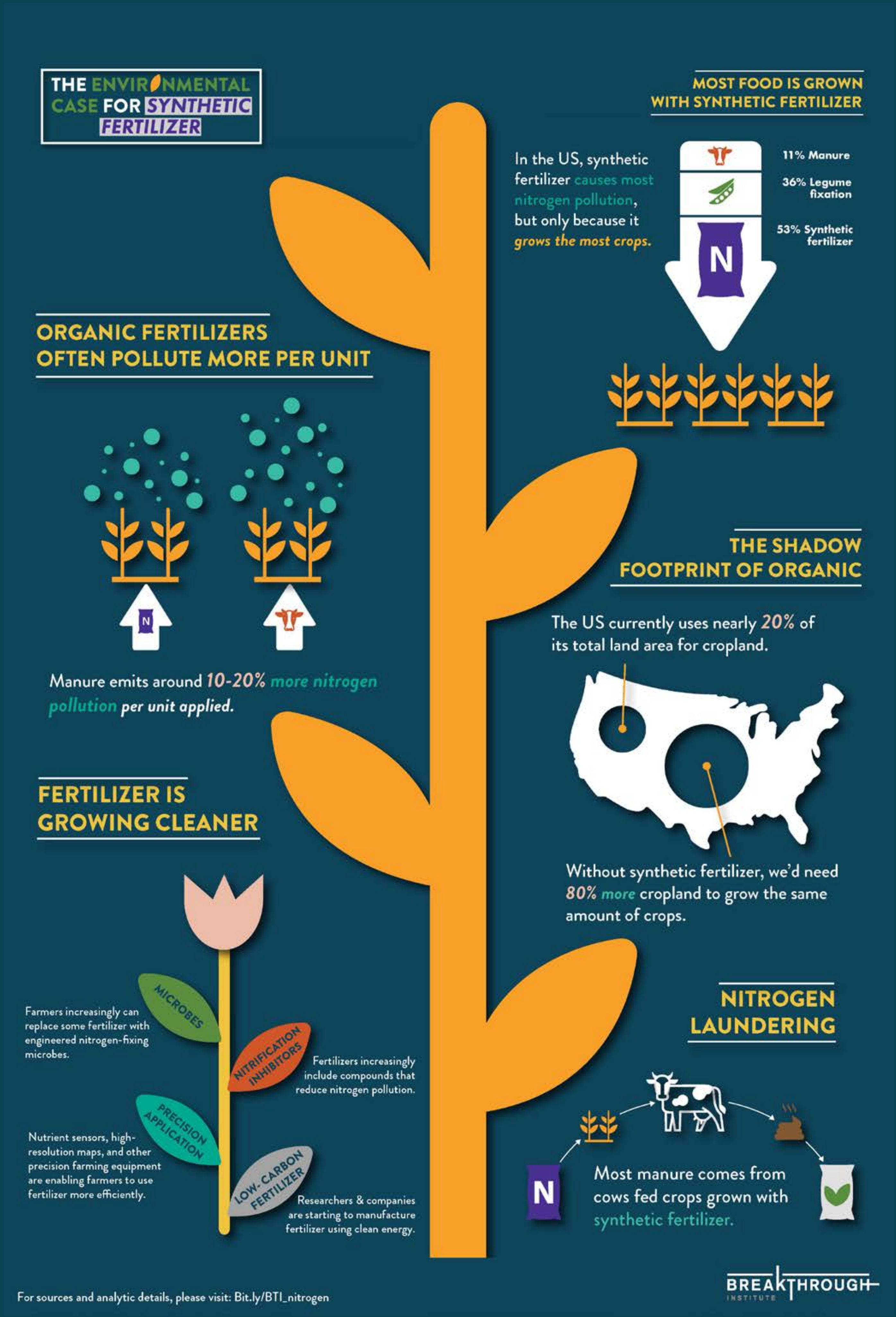
Many people argue that synthetic fertilizers are at the heart of the problem. Because synthetic fertilizers are the biggest contributor to nitrogen pollution, the thinking goes, we should rad-ically limit their use, if not eliminate them entirely from the food system. The solution, in other words, lies in organic fertilizers such as animal manure.

However, this would be ineffective, infeasible, and counterproductive for several rea-sons. There is a strong environmental case to be made for synthetic fertilizer, captured in the suite of infographics below.

First, while we should make the best possible use of animal waste, applying manure to crops often generates even more nitrogen pollution than synthetic fertilizer. Synthetic fertilizers are responsible for the most pollution only because they are the most used, not because they are worse for the environment.

Second, doing away with synthetic fertilizer would expand the footprint of agriculture, threatening ecosystems and worsening climate change. Because there isn't enough manure and compost, we would need to expand our use of other nitrogen sources (legumes and fallowing fields) that require extra land — a lot of extra land. Eliminating synthetic fertilizers would require an 80% increase in cropland.

Finally, focusing on replacing synthetic fertilizer overlooks more promising ways to reduce nitrogen pollution. For instance, farmers can adopt precision farming equipment that helps them apply just the right amount of fertilizer to their crops. These technologies include soil nutrient sensors, tractors with GPS and auto-steering, and machines that vary how much fer-tilizer they apply. Read more here about innovative ways to reduce nitrogen pollution from agriculture. ***(By Alyssa Codamon, Dan Rejto)***


THE ENVIRONMENTAL CASE FOR SYNTHETIC FERTILIZER
MOST FOOD IS GROWN WITH SYNTHETIC FERTILIZER
In the US, synthetic fertilizer causes most nitrogen pollution, but only because it grows the most crops.
11% Manure
36% Legume fixation
53% Synthetic fertilizer
N
ORGANIC FERTILIZERS OFTEN POLLUTE MORE PER UNIT
N
Manure emits around 10-20% more nitrogen pollution per unit applied.
THE SHADOW FOOTPRINT OF ORGANIC
The US currently uses nearly 20% of its total land area for cropland.
Without synthetic fertilizer, we'd need 80% more cropland to grow the same amount of crops.
FERTILIZER IS GROWING CLEANER
MICROBES
Farmers increasingly can replace some fertilizer with engineered nitrogen-fixing microbes.
NITRIFICATION INHIBITORS
Fertilizers increasingly include compounds that reduce nitrogen pollution.
PRECISION APPLICATION
Nutrient sensors, high-resolution maps, and other precision farming equipment are enabling farmers to use fertilizer more efficiently.
LOW-CARBON FERTILIZER
Researchers & companies are starting to manufacture fertilizer using clean energy.
NITROGEN LAUNDERING
N
Most manure comes from cows fed crops grown with synthetic fertilizer.
For sources and analytic details, please visit: Bit.ly/BTI_nitrogen
BREAKTHROUGH INSTITUTE

To Cut Nitrogen Pollution,

Move Past the Synthetic-Organic Debate

Modern farming feeds billions of people, in large part thanks to easily available nitrogen fertilizer. Nitrogen is an essential nutrient for all plants. A small number of plants, such as the legumes soy and clover, can get most of their nitrogen from the air. But most crops require people to add some type of nitrogen fertilizer. As we wrote about in an earlier essay, the majority of this nitrogen fertilizer used today — billions of pounds of it — is synthetic, manufactured in industrial facilities.

Unfortunately, nitrogen also contributes to many of today's greatest environmental challenges. Most nitrogen that is applied to crops — as much as 58% according to one recent estimate — escapes from farms and pollutes the environment. There is now about twice as much nitrogen cycling through cropland, forests, oceans and the rest of the environment than in pre-industrial times. Some of the nitrogen is emitted as nitrous oxide, a potent greenhouse gas responsible for nearly 50% of agriculture's greenhouse gas emissions in the US. And some nitrogen flows off farms into water bodies in a process known as nitrate leaching. Too much nitrogen in water can threaten human health and lead to eutrophication, an overload of nutrients that causes algal blooms and kills off marine life.

To address eutrophication and greenhouse gas emissions from fertilizer use, some advocate for expanding the use of organic farming. Organic farms don't use any synthetic fertilizer. Instead they largely rely on manure, nitrogen-fixing legumes, and compost for nitrogen. But do these organic fertilizers actually address the environmental problems that advocates hope to solve?

In short, the answer is no. Organic fertilizers are far from a silver bullet when it comes to both eutrophication and greenhouse gas emissions. But that doesn't mean that synthetic fertilizers alone are the answer either.

Arguing about whether organic or synthetic fertilizers are better for the environment is largely a dead end. Instead, the solution lies in getting past the organic-synthetic debate and focusing on measures to increase the efficiency of all fertilizers and to reduce nitrogen losses.

Reason 1: organic fertilizers are a mixed bag

Among the reasons why the organic-synthetic debate is unproductive is that organic fertilizers are a decidedly mixed bag, which makes any evaluation of them as a package misleading and unhelpful. To understand why, let's consider the two main organic fertilizers: manure and legumes.

Compared to synthetic fertilizer, manure is often more polluting. Farmers who use manure in the U.S. lose 46-72% more nitrogen (~10-20 more lbs) per acre to the environment than farmers not using manure. Most of this nitrogen pollution enters waterways, contributing to eutrophication.

The main reason manure has such large eutrophication impacts is that farmers need to use a lot of it to fertilize their crops. For example, U.S. farmers using manure apply 40-50 more lbs/acre of nitrogen than other farmers. The more nitrogen they add, the more leaches through the soil into groundwater or flows into rivers and streams.

But why would farmers apply so much manure if they're trying to be stewards of the environment? The answer lies not in the actions of farmers, but in the manure itself.

Plants simply can't use much of the nitrogen contained in most types of manure, leading to large nitrogen losses. For example, plants can only use 50-80% as much of the nitrogen from beef cattle manure as from synthetic fertilizer. One reason is that the nitrogen in manure is slowly released over many years, and often when plants don't need it. Another reason is that all types of manure, even liquid manure, can be challenging to spread across a field uniformly so that every plant gets the same nitrogen dosage. As a result, many farmers apply excess manure to ensure that all their crops are properly fertilized.

The practicalities of transporting manure also lead many animal producers to simply apply their manure supply to nearby cropland, which leads to high application rates, nitrogen losses, and eutrophication. Manure can contain over 100 times less nitrogen per pound than synthetic fertilizer, making it prohibitively heavy and expensive to move more than several miles. In addition, more and more livestock production occurs in places without enough cropland nearby to apply manure to. This means that farmers need to transport manure farther to apply it to cropland that can absorb it — a further disincentive to applying it at proper rates.

What about greenhouse gas emissions? Is manure worse than synthetic fertilizer in this regard too? The primary driver of nitrous oxide emissions is the amount of nitrogen applied. Since using manure involves applying more nitrogen to get the same crop yield (compared to synthetic fertilizer), it typically results in greater nitrous oxide emissions per unit of food produced.

Still, when we consider the big picture, synthetic fertilizer use is about as greenhouse gas–intensive as manure. Manufacturing synthetic fertilizer uses large amounts of natural gas. Even some of the most efficient fertilizer factories emit 2–4 tons of carbon dioxide–equivalent for each ton of nitrogen fertilizer produced. It may be feasible one day to use clean energy sources to make fertilizer and therefore cut emissions. But when emissions from manufacturing and application are both considered, food grown with synthetic fertilizer and manure currently have similar levels of emissions.

In other words, manure, compared to synthetic nitrogen, tends to increase eutrophication while emitting similar levels of greenhouse gases. If organic farmers relied exclusively on manure as fertilizer, eutrophication would likely worsen and pose a clear environmental threat. But because organic also encapsulates green manures, the picture is more complex. Green manures are legumes (plants that "fix" much of their own nitrogen from the atmosphere) that farmers grow and then till into the soil, providing nutrients to future crops. Using green manures is a common practice among organic farmers, with nearly ¾ of European organic farmers reporting use.

Using green manures does modestly increase some types of greenhouse gas emissions. By adding nitrogen to the

▲ *New cover crops in eastern South Dakota* soil, green manure crops increase nitrous oxide emissions in many circumstances. Farmers also need to burn more fuel operating their machinery to plant and manage the crops.

But the extra nitrous oxide emissions from green manures are far outweighed by their benefits. Using green manures reduces the amount of other fertilizers farmers must apply to future crops, and enhances carbon sequestration. Overall, this makes them carbon-negative. In addition, planting green manure crops generally reduces nitrate leaching from soil and often increases yields.

Given the wide use of animal manure and green manure on organic farms, it makes little sense to compare organic and synthetic fertilizers as monolithic categories. Manure disproportionately contributes to eutrophication while green manures provide clear benefits.

Reason 2: manure isn't going anywhere

Another reason that debates about organic and synthetic fertilizers are unproductive is that they rarely provide clear guidance on how to actually reduce agriculture's impacts. Though manure has environmental downsides, we can't just get rid of it. As long as people continue consuming animal products, there is no avoiding manure. Wherever there is confined livestock, dairy or other animal production, there is loads of manure and and all of it must be managed.

In fact, buying manure and using it as commercial fertilizer is likely better than the alternative, which is for producers to spread the manure on their own land. As we mentioned, animal producers typically have a limited amount of land, and so they often apply it at higher than recommended rates, leading to significant nitrogen losses. By contrast, when farmers buy manure from livestock producers, they help offload the excess manure and thereby reduce overapplication. So eschewing commercial manure just because it has environmental downsides would be a poor environmental option.

Reason 3: nothing can plausibly replace synthetic fertilizer

Similarly, even if synthetic fertilizers were worse in some ways, we can't simply replace them. If all the manure produced throughout the U.S. were applied to farmland, it wouldn't even replace half the synthetic fertilizer that is used today. And in reality, it would replace far less since much of the manure is excreted by animals on pasture and rangelands where it can't be collected and later used as fertilizer.

Green manure, compost, and other sources of organic fertilizer also couldn't replace all the synthetic fertilizer. Green manures may provide many benefits, but as we have written previously, they could only replace a fraction of today's synthetic fertilizer use — no more than 38% under the very best imaginable scenario and likely much less.

It's certainly possible that new innovations in fertilizer technology, such as microbial treatments and soil amendments, will someday replace the current variety of synthetic fertilizer we have. But for now, synthetic fertilizer is here to stay.

Because neither manure nor synthetic fertilizer are going away any time soon, it makes little sense to pursue a vision for the future of agriculture that rests on the supposed superiority of one type of fertilizer over another. The problem lies not so much in the type of fertilizer we use, but in how we use it.

The right question: how to use less fertilizer and minimize losses

Recognizing that organic-synthetic comparisons don't paint a clear path forward should encourage us to focus on broader ways to reduce nitrogen pollution from all types of fertilizer. Using less fertilizer and minimizing losses may not sound like a revolutionary or inspiring solution, but research indicates the benefits could be vast.

In many regions of the world, such as in parts of China and the American Midwest, farmers can reduce synthetic fertilizer application while maintaining or even improving yields. In some cases, providing farmers with more tailored advice on farm management practices and how much fertilizer to apply can make a large difference. For example, a recent initiative in China helped millions of small farmers reduce their nitrogen use about 15% while also increasing yields.

Farmers can also reduce nitrogen use by adopting precision farming equipment that helps them apply just the right amount of fertilizer to their crops. These technologies include soil nutrient sensors, tractors with GPS and auto-steering, and machines that vary how much fertilizer they apply. Many farmers have adopted several of these practices, but not all. For example, U.S. farmers have quickly adopted auto-steering tractors that can vary how much fertilizer they apply, but have been slow to experiment with nutrient sensors and newer precision technologies, illustrating that there is still much room for improvement.

There are many opportunities to reduce nitrogen losses from manure as well, particularly through increasing the use of waste-to-energy systems such as anaerobic digesters. Anaerobic digesters convert methane gas from manure into electricity, cutting emissions both from manure storage and energy use. Moreover, farmers can use the byproduct from electricity production, which is more nutrient-dense than raw manure, making it easier to transport and apply at recommended rates.

Composting manure can also reduce nitrogen losses and greenhouse gas emissions. Composting involves piling manure in rows or heaps, mixing it with other materials, and aerating it to accelerate the process of decomposition. This directly reduces nitrogen losses as well as concentrates the nutrients in manure, making it cost-effective to transport farther and apply at proper levels.

Additionally, though manure is more difficult to apply precisely, it can be applied more efficiently. For instance, farmers can use specially designed tractors to inject manure below the soil surface or use irrigation systems to deliver manure to crops' root zones. These two methods not only cut manure losses, emissions, and leaching, but also enable farmers to provide more nitrogen to crops with the same amount of manure, thereby reducing the need for other fertilizers.

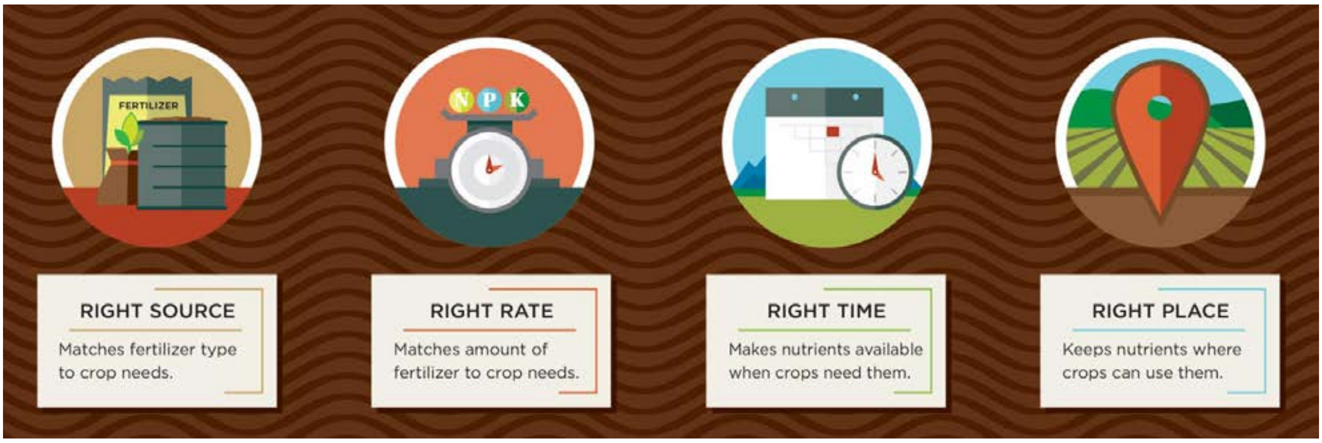
As many environmental groups note, shifting animal production closer to cropland could also reduce nitrogen losses from manure. Currently, nearly 300 counties in the U.S. have animal feeding operations that produce more manure than all the cropland in the county can absorb. There are reasons why this is the case — high degrees of specialization can generate economies of scale. Nevertheless, policies that incentivize livestock producers to own more cropland to spread manure on or to open facilities near areas of high crop production could have real environmental benefits.

Finally, changes in land management can also substantially reduce all types of nitrogen losses, whether from synthetic fertilizer or manure. For example, growing plants along the edges of fields (e.g. buffer strips) can suck up excess nitrogen, and practices like no-till farming can reduce soil erosion, which also contributes to nitrogen water pollution.

Moving forward: incentivizing change

In short, while we may be stuck with manure and synthetic fertilizer, we're not stuck with the extent of their environmental impacts. There are many options farmers and livestock producers have to reduce nitrogen losses, water pollution, and greenhouse gas emissions. The problem is not a lack of good solutions, but a lack of incentives. Installing anaerobic digesters or adopting manure injection systems is expensive and requires new types of technical expertise. To truly cut nitrogen pollution, we need government and market incentives for producers to adopt best practices and for researchers to bring the costs down. These incentives may take a number of forms: subsidies, government-sponsored farmer outreach (or "extension"), pollution taxes and regulation, and more.

There is a wide array of promising pathways for reducing pollution from agriculture, but simply replacing synthetic fertilizer is not one of them. ***(By Dan Blaustein-Rejto, Kenton de Kirby, Linus Blomqvist, Source: Breakthrough)***



Soil Health

Means Better Human Health

New research suggests soil health may have a surprising influence on your food.

It's late December in Boulder, Colorado, and I'm on the University of Colorado campus walking toward the Cooperative Institute for Research in Environmental Sciences (CIRES) lab. The native flora here is dormant, in a deep winter slumber, rendering the landscape in monochromatic tans. Almost nothing is growing outdoors.

That's not so inside CIRES, where billions of microorganisms are thriving. At the lab, Noah Fierer, a professor of ecology and evolutionary biology, introduces me to two graduate students who are hunched over workbenches, using pipettes to transfer batches of live bacteria from glass vials into a machine that will sequence their microbial DNA. In a nearby walk-in cooler, petri dishes are stacked on wire shelves – bacteria being cultivated for ongoing studies – along with a 12-pack of craft beer chilling on the floor. "You're not supposed to see that," Fierer quips.

As a preeminent soil scientist, Fierer is cited in scholarly journals perhaps more than any other researcher in the field. His efforts are focused on organisms that reside in the rhizosphere, the topmost soil layer where plant roots interact with microscopic organisms, among them viruses, bacteria, fungi, protozoa, and algae. It's a motley community, collectively termed the soil microbiome, and it functions as the lifeblood of plants – promoting germination, stimulating roots, accelerating growth, and bolstering resistance to disease.

Experts believe these soil microbes could also have a big impact on the nutritional content of our food. Moreover, the plants we eat and the dirt we come in contact with may also directly fortify our own gut microbiomes. The discovery of this link between soil health and human health has commanded the attention of big food companies, farmers, scientists, and environmental organizations, and it's sparked a research boom that may soon tell us whether soil microbes are as important to our longevity as daily exercise and a restful night's sleep.

It's not just dirt

The rhizosphere is habitat to a complex ecosystem that scientists call the "brown food web." At its foundation is the soil microbiome, which is involved in numerous processes that promote and sustain plant growth. Some microbes, for instance, act like stomachs, digesting and decomposing organic matter into nutrients that nourish plants. Another action involves mycorrhizae, silk-like fungi that form vast spindly webs that can span several miles underground. These filaments are like the internet of the soil microbiome: They facilitate communication between plants.

Experiments have demonstrated that when predators, such as aphids, attack a plant, it can warn its neighbors – signaling them through the mycorrhizal network – that a threat is imminent. The other plants will then engage their natural defenses, often a chemical produced in the leaves, to help repel invaders.

Soil bacteria and fungi also work in tandem to make minerals in the ground water-soluble. "And if they're soluble, a plant can suck them up with its roots," explains David Montgomery, a professor of earth and space sciences at the University of Washington in Seattle, and coauthor of The Hidden Half of Nature, about the soil microbiome. Microbes also enable plants to produce antioxidants. "Other bacteria and fungi partner together to pry things like phosphorus out of the soil and transport them into the fungal hyphae," Montgomery says.

Fungal hyphae form a network of weblike filaments (made of mycorrhizae) that perform a synergistic dance with a plant's roots. As the plant naturally secretes sugars into the soil during photosynthesis – sugars that help nourish the hyphae – the hyphae respond by providing the plant with nitrogen, phosphorus, and various other micronutrients, such as copper, zinc, magnesium, potassium, and iron. It's an equitable trade because plants – like people – need these minerals to exist.

A damaged soil microbiome, however, can disrupt this process, lowering the concentration of these nutrients in our food and, subsequently, in our diet. A lot of farmland today has been degraded. Montgomery tells me about studies that have tracked a rapid decline in the mineral content of fruits, vegetables, and grains over the past 50 years. One survey reported that zinc in vegetables had plunged 59%, magnesium fell 26%, and iron tumbled 83%. A similar analysis, published in the Journal of the American College of Nutrition, examined 43 crops, comparing present nutrient levels to those recorded in 1950 by the U.S. Department of Agriculture (the USDA has been collecting this data since 1892), and found that protein, calcium, iron, phosphorus, and vitamins B2 (aka riboflavin) and C had all dropped markedly.

"Mineral deficiency is estimated to afflict more than a third of humanity, causing health problems in both developed and developing countries," Montgomery says. "Mineral elements are essential for hundreds of critical enzyme reactions, and inadequate levels have been implicated in a wide range of maladies." These include cardiovascular disease, neurological disorders, anemia, increased risk of infection, and depression.

Scientists disagree about whether an ailing soil microbiome is partly or wholly responsible for the nutrient decline. (One explanation is that plant breeds are typically selected for productivity or pest resistance rather than nutritional density.)

The race to decode soil's secrets

While scientists believe that promoting healthy soil bugs could have a profoundly positive impact on human health, the problem is figuring out which microbes are intrinsic to our well-being and how to help them thrive. The diversity, and how relatively little is known about them, is mind-boggling. As Fierer explains while directing me down a staircase to the

CIRES basement, a soil sample from wild grasslands in Kansas could contain more than 20,000 distinct species of microorganisms. A second specimen taken from the same site a mere centimeter away could harbor an entirely different population of microbes, also numbering in the tens of thousands.

The sheer biomass of microbes within a single acre of healthy soil weighs more than 2.7 tons, equivalent to a large SUV. Fathoming the soil microbiome is like trying to chart every star in our galaxy since there are billions and billions of microbes. “We know they’re there,” Fierer says. “We just don’t know what most of them do and how they interact with each other.”

In the CIRES basement, we enter a mostly empty 800-square-foot lab where Fierer and graduate student Corrine Walsh are conducting an experiment on soil microbes favorable to wheat. What resembles a large white refrigerator sits in the center of the space. It is an environmental growth chamber for cultivating plants, illuminated with blinding-white LEDs. Fierer swings open its heavy door and a waft of humid, musty air escapes. He slides out a clear bin containing 12 square plastic plates lined with seed germination paper. On each sheet are eight wheat seeds in various stages of growth. Some are a couple of inches tall, with sprouts and roots clambering along the surface of the paper. Others appear stunted, and a few haven’t germinated at all.

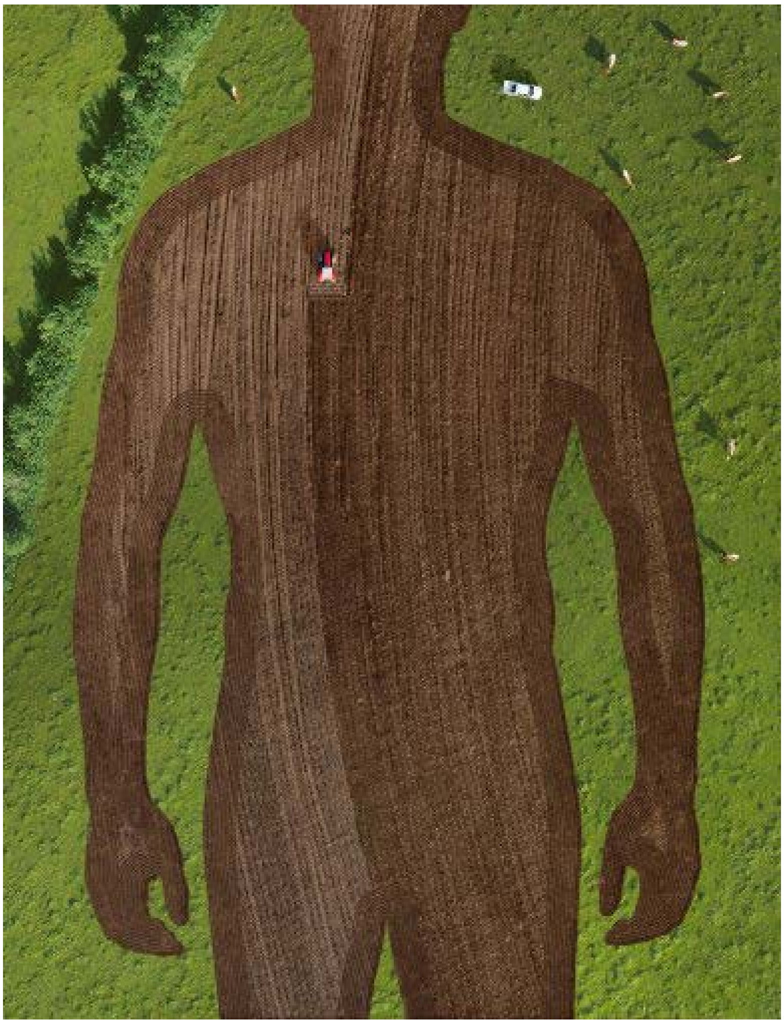
Walsh, who is leading the experiment, collected soil samples from 220 sites around the United States. “About half were from farms,” Fierer says, “and half were from unmanaged, natural systems, mainly forests and grasslands.” Walsh mixed each sample with water, concocting a slurry to douse onto individual wheat seeds. Later, she’ll use a gene sequencer to analyze the slurries applied to the seeds that sprouted the heartiest roots and shoots. “We’ll look to see if there are particular species of microbes that can explain why some wheat seeds grew better than others,” says Fierer, who plans to publish the results with Walsh later this year.

Their study is a step toward understanding which soil microbes influence plant growth and, in turn, how those organisms might affect another aspect of human health – the gut microbiome.

Benefits for mood and immunity

Dirt is where soil microbes live. Yet, they’re also peripatetic, hitching themselves to leaves, infiltrating root systems, entering through stomata (pores that let plants breathe carbon dioxide) and aqueous channels, which transport water and nutrients from the soil into the plants. Inside and out, plants are steeped in microbes, which we ingest whenever we munch on foods like broccoli, berries, or lentils.

“A single spinach leaf has over 800 different species of bacteria that it gets from the soil and the environment,” says Christopher Lowry, a professor of integrative physiology and neuroscience at the University of Colorado Boulder. Once in our intestines, these microbes can fortify the human gut microbiome.



We're also exposed to these bugs through soil itself. The biology at play isn't entirely understood, but studies have shown that people who live and work in farming and rural communities, where they have regular contact with dirt — and the microbes it contains — are more resistant to allergies and asthma, while mice experiments have demonstrated that even modest soil exposure can strengthen the immune system's response to harmful pathogens, including parasites, bacteria, and viruses.

Rob Knight directs the Center for Microbiome Innovation at the University of California San Diego and cofounded the American Gut project and the Earth Microbiome Project, which are studying the trillions of organisms associated with humans and soils, primarily by sequencing the DNA of the microbes. He's not sure yet whether there is a direct link between the bugs in dirt and human health and longevity — the science is still emerging — but his research has revealed that people who eat a diverse array of fruits and vegetables tend to have a more diverse gut microbiome.

Also, studies suggest that individuals with diseases linked to chronic inflammation, such as obesity, cancer, heart disease, asthma, and diabetes, tend to have lower diversity.

Lowry, who has been investigating how soil microbes can impact our immune system and even our emotions, agrees: "There is a wide consensus that enhancing gut microbiome diversity is good, even if we don't understand all the reasons why. The safest bet to do that is through consuming a varied diet of plants – and consuming plants frequently."

He points to a questionnaire given to volunteers in the American Gut project. The participants were asked how many different types of plants they consumed in a typical week and then were asked to provide a stool sample for analysis. The fecal data revealed that volunteers with the highest variety of good gut bacteria were also those who ate the broadest range of fruits and vegetables.

"When I learned that, I went to Whole Foods, picked out 30 different plants and threw them in a blender," he says. "Now I have 4 tablespoons every night with dinner."

For the past two decades, Lowry has been particularly interested in a species of microbe called Mycobacterium vaccae, common in almost every soil around the world. He and his collaborator, Graham Rook, a professor of medical microbiology at University College London, wanted to know whether M. vaccae was among the gut microbes that could dispatch signals to the brain. (The notion of a gut-brain axis – meaning that our intestinal bugs can somehow "talk" to our central nervous system – has been pondered and studied for several centuries.)

The two scientists conducted experiments in mice, injecting them with M. vaccae, which under a microscope looks like translucent yellow maggots. "The bacteria activated a very specific subset of serotonin-containing neurons in the brain. These neurons are known to govern emotions, especially depression," Lowry tells me. "People were taken aback by the idea that bacteria from the soil could have antidepressant-like effects." Lowry and Rook published their results in 2007, and a media deluge followed. Here was tangible evidence that microbes from the soil, when introduced into the body, could potentially impact health.

Lowry and Rook continued experimenting, homing in on the biological mechanism responsible for the antidepressive effects. It turns out that M. vaccae triggers a kind of emotional armor. "It protects against inflammation in the brain in response to stress," Lowry explains.

By 2016, he was able to demonstrate in animal studies that M. vaccae could alleviate symptoms in a range of psychiatric disorders, such as stress-induced colitis and post-traumatic stress disorder. Lab rats can be conditioned to react to fear using behavioral training. A mild shock or sudden puff of air is paired with a light; eventually, the rats will flinch when seeing only the light. Once a fear response is established, it can take weeks or even months to undo. "But the rats that received the bacteria extinguished their fear within 24 hours," Lowry says. "It was mind-blowing to me."

Lowry and his colleagues also wondered if M. vaccae could mitigate the precipitous mental decline that occurs in about 40% of people undergoing major surgery after age 60. It's called postoperative cognitive dysfunction, or POCD, and it's believed to result from a powerful inflammatory response during and after surgery. They developed a series of cognitive tests to gauge the impact of surgery on aged rats and then inoculated them with M. vaccae before surgery. "The bacteria completely prevented this cognitive impairment," he says.

So I ask Lowry: Why aren't we all taking M. vaccae supplements? Granted, the results need to be replicated in humans. The short answer is that the strain of M. vaccae he studied is not available as a supplement, at least not yet. Like other soil scientists I spoke with, Lowry also reckons that bacteria exhibit strength in numbers – it takes legions of them orchestrating in unison to build a hardy disease-quelling gut microbiome. And it will take more research to tease all that out.

Regenerating diversity

Humans evolved in lockstep with soil bacteria. This likely explains why our microbiomes share similar microbial DNA – as well as some of the same strains of bacteria. Lactobacilli, for instance, can be found in both soil and humans. Those beneficial probiotic bacteria (present in foods like yogurt) help break down food and release nutrients inside our gut; their role in soil is the same.

A 2019 study published in the journal Microorganisms documented this unique kinship between human and soil microbiomes: "They contain the same number of active microorganisms," the authors noted, adding that "it may be useful to adopt a different perspective and to consider the human intestinal microbiome as well as the soil/root microbiome as 'superorganisms,' which, by close contact, replenish each other with inoculants, genes, and growth-sustaining molecules."

The researchers also analyzed the variety of microbes in humans and soils and found that not only is the diversity of both plummeting but it's also occurring at roughly the same rate. They identified several reasons for the decline: our transition from an agrarian society to an industrial one, modern hygiene, and our Western diet filled with low-fiber, highly processed foods. When we changed our farming practices, stopped growing our own food – which involved touching a lot of dirt – and began eating more Big Macs than plants, we fractured the beneficial relationship between ourselves and the soil.

Build healthy soil

The focus now is on repairing that relationship. Phil Taylor, who earned a doctorate in global ecology from the University of Colorado (Fierer was a member of his dissertation committee), is the cofounder and executive director of Mad Agriculture, a consulting firm that "helps farmers build healthy soil and make money doing it," as he puts it. Taylor suggests I read about Sir Albert Howard, an English botanist who traveled the world during the early 20th century.

"He wanted to know whether soil health translates into healthy food," Taylor explains. While Howard couldn't identify the exact mechanism, after visiting hundreds of communities he had enough anecdotal data to answer the question for himself unequivocally: Soil microbes forged a conduit between healthy crops and healthy humans. Initially ridiculed for his theories, Howard would become a pioneer in organic cultivation and soil microbiology, advancing methods that Taylor employs for his clients.

These days, Taylor says, "the science is playing catch-up to what some farmers already understand to be true." More specifically, he means that the soil microbiome flourishes — and conveys the biggest benefit to humans — when farmers embrace a hands-off approach and let the brown web do its job.

His advice to farmers who hire him generally hinges on time-tested regenerative-farming principles, which increase the abundance and diversity of microorganisms in the rhizosphere. In practice, this entails minimizing plowing, maintaining living roots in the ground year-round (via cover crops), cultivating a variety of plants, and integrating livestock onto the land (grazing and manure foster soil microbes).

Science appears to support this approach. A recent review of 56 studies published in the journal PLoS One found that soil from farms that didn't till or use synthetic chemicals and employed practices like cover cropping, biodiversity, and crop rotation contained 32% to 84% more microbial mass (an indicator of healthy soil) than that from conventional farms. Research at the Rodale Institute found that oats, peppers, tomatoes, and carrots grown on organic or regeneratively managed farms contained 18% to 36% more minerals and antioxidants than their conventional counterparts. (Healthy soil also has other benefits, such as promoting carbon sequestration and water retention, which can help mitigate climate change.)

Plant-growth-promoting microorganisms (PGPMs) have also come on the scene. They're part of a newer class of fertilizers, called biofertilizers. Think probiotics for dirt, which, as it turns out, is a booming industry, despite the absence of evidence proving which microbes work best.

Even so, the notion that a farmer could resuscitate barren soil with a microbial cocktail is not outlandish. Numerous agricultural start-ups are pursuing PGPMs, including Boston-based Indigo Agriculture, which has hired Fierer to run a yearlong study to develop a microbial inoculant that can turbocharge crop growth. Other firms are creating "biotic" fertilizers. Like vitamins for the soil microbiome, biotic fertilizers typically are developed from a type of blue-green algae called cyanobacteria.

There are no quick fixes, but there is a real movement under way to undo the damage and bring the bugs back. On my way out of the lab, Fierer shows me two large framed photos hanging on the wall. The images were taken in 2017 in Antarctica; he and his research team spent two months there collecting soil samples from exposed ground in the Transantarctic Mountains.

"We wanted to see what types of microbes can live in the extreme conditions found in this area — cold, dry, and salty soils," he says. Indeed, they found bacteria and fungi surviving in areas that had recently been covered in ice. He discovered that soil microbes are terrestrial diehards. After all, they have been around for an estimated 4 billion years.

Nutritious food starts with the soil

The relationship between soil microbes and plants is symbiotic. One example is nitrogen fixing. Nitrogen gas is plentiful in our atmosphere; it accounts for 78% of the air we breathe. Plants need it to grow, but they lack enzymes to break down nitrogen. In legumes, for example, soil bacteria called rhizobia attach to legume roots and perform this task. In return, the plant establishes a dense root system that benefits the bacteria and feeds them carbon that it draws out of the atmosphere, which is also important for reducing greenhouse gases.

Fungi in the soil help plant roots tap into nutrients, such as phosphorus and zinc, among others. Plants require these minerals to generate chlorophyll, essential for photosynthesis, which produces glucose. Some of that glucose gets secreted back into the soil, where it feeds the fungi.

When soil has fewer microbes, this natural symbiosis can be disrupted, leaving plants nutrient-deficient and, subsequently, less nourishing to the humans who eat them. • ***(By Michael Behar, Successful Farming)***

World Food Production

Depends on Phosphorus. Are We About to Run Out?

> *"New research suggests soil health may have a surprising influence on your food."*

The plants and cultivation methods used by modern agriculture are entirely dependent on fertilizers, where two of the most important components are nitrogen and phosphorus. Nitrogen fertilizers can be produced in factories and are in practice a renewable resource.

But the same is not true of the phosphorus in fertilizers.

Currently, phosphorus is mined from rocks that contain the substance — called rock phosphate — that are mined in a few places around the world, especially in China and the Moroccan-occupied territory of Western Sahara.

And these resources cannot last forever.

Some predict just decades left

In 2008, some calculations predicted that the world would begin to experience scarcities of rock phosphorus as early as 2030. The consequence would first be dramatically increased fertilizer prices, and gradually declining crops.

In recent years, scientists have regularly sounded warnings of a looming crisis. In 2019, for example, the British newspaper The Guardian wrote that we only have a few decades of consumption left.

But the information on the topic can be confusing.

Others say 2000 years

Representatives from fertilizer producers themselves do not foresee any crisis.

“We have enough phosphorus for at least 2000 years at today's levels of consumption,” wrote Anders Rognlien from Yara, a fertilizer manufacturer, in an opinion piece in the Norwegian national newspaper Aftenposten in 2010.

Some researchers agree.

For example Pedro Sanchez, a researcher at Columbia University in New York, was quoted in a 2013 blog post as saying, “In my long 50-year career, once every decade, people say we are going to run out of phosphorus. Each time this is disproven. All the most reliable estimates show that we have enough phosphate rock resources to last between 300 and 400 more years."

So is there a crisis or not?

Eva Brod, a researcher at the Norwegian Institute of Bioeconomy Research (NIBIO) studies phosphorus in agriculture. So does Professor Petter Jenssen at the Norwegian University of Life Sciences (NMBU).

They both conclude that we're not about to immediately run out of phosphorus.

Nevertheless, they agree we need to do something about it.

More than 250 years

"The latest overview of the world's phosphate reserves was conducted by Håkan Jönsson at the Swedish University of Agricultural Sciences", says NMBU's Jenssen.

"His assessment shows that we have more than 250 years at current levels of consumption."

But these kinds of estimates are often uncertain. They give an indication of the size of the deposits where rock phosphate is currently being mined, and the projections are based on how much phosphorus can be extracted using current technology and at a reasonable cost.

However, that doesn't mean these are the only sources of rock phosphate. There may be many reserves elsewhere on the globe that are not being mined because they are more inaccessible, are less concentrated or are of lower quality.

▲ *In BouCraa, Western Sahara, huge amounts of crude phosphate are excavated for use in artificial fertilizers. What happens when these reserves are used up?* ***(Photo: REUTERS / Youssef Boudlal / NTB Scanpix)***

Modern agriculture depends on fertilizers. ***(Photo: Criniger kolio / Shutterstock / NTB scanpix)***

the largest reserves are in Morocco and the occupied part of Western Sahara.

"Europe and India have no viable phosphorus reserves as of today," Jenssen says.

"We are consequently dependent on imports, and only China and Western Sahara have large quantities to export. China has introduced an export tariff to ensure they have enough for domestic use," he said.

Thus, if major events such as war or conflict affect these areas, the world may still have trouble obtaining enough phosphorus.

Toxic and radioactive

"For example, a lot of rock phosphate is contaminated with cadmium or uranium," says Brod from NIBIO.

If phosphorus from these kinds of sources is to be used in fertilizers, it must first be treated so that the soil is not contaminated with heavy metals or radioactive substances. It's too costly right now for this kind of decontamination to be worthwhile.

But if the best rock phosphate begins to run out — and technology evolves — lower quality sources may suddenly become of interest nonetheless.

That means that agriculture will still have access to fertilizers, but farmers will have to pay more for it. And this extra cost will be passed on to consumers, so we will have to pay more for food.

Mined in just few places now

"A rich country like Norway will not have trouble getting enough phosphorus," at least not the way things stand today, Brod says.

However, it is worth noting that the world's reserves of rock phosphate are very unevenly distributed, from a geographical standpoint. By far

A number of reasons to change

This is one reason why the world might need to look for other ways to meet the need for phosphorus, even if there is no immediate crisis. And it's not the only reason.

Today's use, for example, is not sustainable forever, even though there might be as much as 2,000 years of rock phosphate reserves. The environment is also an issue.

The release of nitrogen and phosphorus from agriculture leads to significant pollution of waterways across the globe.So what should society do? Where can we find large enough deposits of phosphorus?

Nutrients from agricultural fertilizers often end up in rivers and streams. This can cause major problems for ecosystems. ***(Photo: BMJ / Shutterstock / NTB scanpix)***

The answer is surprisingly trivial.

Do like nature does

Nature deals with phosphorus by recycling it. That's what we should do too, the researchers say.

"It's important to remember that phosphorus is an element. There's plenty of it on Earth, and it never truly disappears," Brod says.

This element — along with others — are necessary building blocks in the cells of all living beings.

Plants absorb nutrients in water from the soil and build them into their cells. Then animals obtain the substances by eating plants or other animals.

But the phosphorus is not used up. Both animals and plants constantly return phosphorus and other nutrients back to the soil through excrement and dead tissue.

In this way, a forest or natural field is fertilized all the time, so that it never runs out of phosphorus.

Manure, garbage and sewage

But agriculture is a different matter. Here we remove plants — and their phosphorus — from fields every year.

The soil loses a little phosphorus for every crop that is harvested. Instead of returning the nutrients back to the soil, we deposit them elsewhere — in manure pits, in food waste, in sewage, or in the sludge from a fish farming facility.

Brod and Jenssen believe these resources contain more than enough phosphorus to meet the needs of Norwegian agriculture — if we could only find good ways to return these nutrients to farmers' fields.

Long and heavy from manure pit to field

"As things stand today, recycling and reusing these resources is not practically possible", says Brod. "For example, one challenge is that livestock production takes place mostly in western Norway and along the coast, while the need for phosphorus is greatest inland," she says.

Livestock manure contains a lot of water, and it is expensive and impractical to transport it very far. And farmers don't necessarily have the equipment to use manure instead of fertilizer.

It is also no easy matter to use sewage as fertilizer. Today's purification processes for cleaning sewage sludge make the phosphorus in the sludge difficult for plants to use.

In order to achieve solutions that work in practice, animal manure, sludge from fish farming and sewage from humans has to be processed.

But it's not just a matter of drying the waste and using it as fertilizer, says Brod.

"Different types of treatment alter the quality of the phosphorus, and heat treatment is not that good," she said.

These processes can also be expensive and require a lot of equipment and energy. But that may change in the future, the researchers believe.

Bacteria can capture phosphorus

"We are just at the beginning phase of studying phosphorus recycling," says Jenssen.

But things are starting to happen.

"NMBU has several projects underway, including processing waste from food and toilets," he said.

"And a treatment plant HIAS in Hamar has been a pioneer in recycling phosphorus from wastewater."

The Hamar treatment plant captures phosphorus in the sewage using bacteria. The bacteria absorb and concentrate the phosphorus so that phosphorus fertilizers can be made in solid form. These fertilizers can be applied to fields with the same equipment used to apply today's fertilizers.

"I think this model will be used by many countries and industries, in Norway and internationally," says Jenssen.

He says that attempts are also underway to use algae in the same way: The algae can grow on our waste, and then we can use the algae for, for example, fertilizers or fish feed.

Great interest in recycling

Jenssen also believes we will someday have toilets and sewerage systems that make it easier to extract nutrients from our waste.

Manure can be a great source of nutrients. But it's not always so practical to use. For example, manure contains a lot of water and is heavy and can be expensive to transport over large distances. ***(Photo: Bernhard Richter / Shutterstock / NTB scanpix)***

"Vacuum toilets are being used in new apartment blocks in an EU project that NMBU and NIBIO have in Fredrikstad," Jenssen says.

A similar effort is underway in Hamburg, Germany.

"That makes it easier to extract resources from faeces and organic household waste. These products can be transformed into both biogas and fertilizers, something we are working on in the EU project," he said.

Jenssen says that there is great interest in recycling and reuse of nutrients from wastewater, but researchers are still at the starting phase of studying how best to do it. Currently, only a few solutions are profitable enough to compete with fertilizers.

But that can change quickly as the best rock phosphate reserves disappear. Or sources of other nutrients, for that matter.

Fields need other nutrients, including potassium and sulphur.

"We rarely talk about the fact there may also be shortages of these substances," Jenssen said.

Nevertheless, "even though it doesn't look like we are immediately facing the horrifying scenario of running out of phosphorus, there's no reason not to focus on recycling," he said.

"We need political approaches to make sure that we use the phosphorus we have in a better way. Then there will be no crisis," Brod said. ***(By Ingrid Spilde, Jurnalist of sciencenorway.no)***

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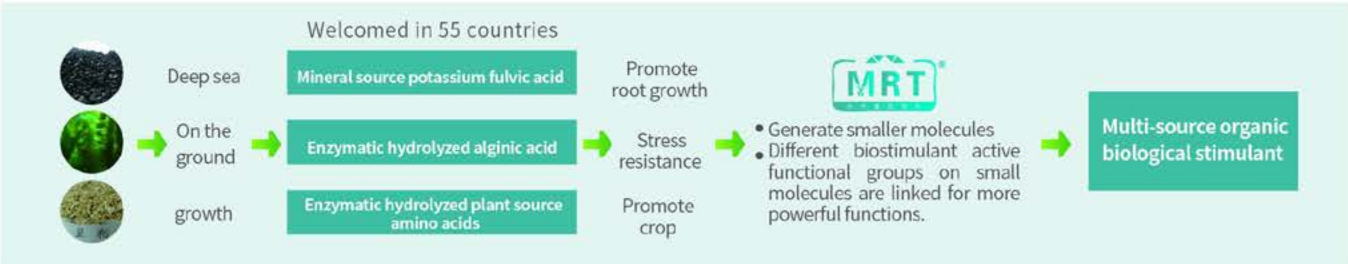

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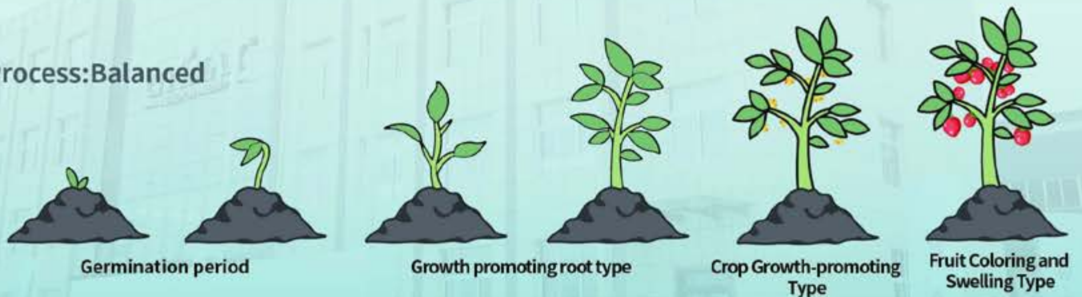
Humicare is a kind of functional liquid fertilizer with synergistic effect of organic and inorganic nutrients. It adopts the unique MRT molecular recombination technology to obtain small molecular organic matter, and perfectly integrates with nitrogen, phosphorus, potassium and other nutrients to meet the needs of different nutrients in different growth stages of crops. It also has the functions of high resistance to hard water, activating soil, strong rooting, stress resistance and promoting growth, and improving quality.

Whole Process:Balanced



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INTERNATIONAL VIEW

Africa's Fertilizer

Sector and the Bank's High 5s

Introduction:

According to the UN's 2019 State of Food Security and Nutrition in the World, hunger is on the rise in almost all African sub-regions, making the continent the region with the highest prevalence of undernourishment, at nearly 20%. The continent is still not able to feed itself, and there is an urgent need to improve agricultural productivity. Although fertilizer is one of the most needed inputs in agriculture, its use remains below the 2006 Abuja Declaration objective of at least 50 kg of nutrients of fertilizer use per hectare of arable land. Through this Declaration on Fertilizer for the African Green Revolution, African leaders resolved to fast-track farmers' access to affordable fertilizers as well as to increase the level of fertilizer use.

From manufacturer to farmer, the fertilizer value chain must become an integral part of the entire agricultural value chain. With the support of stakeholders in the public and private sector and from within and outside the Bank, the Africa Fertilizer Financing Mechanism can contribute to achieving four of the African Development Bank's High 5 objectives, namely Feed Africa, Industrialize Africa, Integrate Africa and Improve the Quality of Life for the People of Africa. This paper aims to show the connections that exist between the development of the fertilizer sector and the advancement of these priorities of the Bank.

Feed Africa

Despite its vast agricultural potential, and the fact that the majority of the labour force works in agriculture, Africa remains a net food importer and has a food trade deficit. This increases Africa's vulnerability, especially in crisis times. Moving away from an unsustainable food system in which Africa spends $64.5 billion annually on importing food that could be produced by African farmers, is an important goal.

Feeding our soils to feed Africa

The African Development Bank, through its Feed Africa strategy, is working to achieve this. The strategy aims to transform African agriculture into a globally competitive, sustainable, inclusive and business-oriented sector, creating wealth, generating employment, and improving quality of life. Ensuring food security for a growing population can only happen if measures are taken to increase large scale production in Africa. This requires that farmers have access to vital agricultural inputs including fertilizer, seeds, irrigation and crop protection products. In this regards, the African Development Bank developed the Technologies for African Agricultural Transformation (TAAT) programme, with the objective of raising agricultural production and productivity through the deployment of appropriate technologies, including nutrient-dense crop varieties and outreach training and campaigns.

As we enter a new decade, access to and use of critical agricultural inputs remains underdeveloped in Africa. For example, the average application of fertilizer per hectare of cultivated land in sub-Saharan Africa is 17 kg of fertilizer nutrients, compared to a global average of 135 kg.

Supporting the fertilizer value chain

Strong support to the fertilizer value chain will accelerate the Bank's journey towards a more competitive agriculture sector. Success depends on smallholder farmers being able to access inputs which requires adequate finance as recommended by the 2014 Malabo Declaration on Agriculture through which regional member countries "commit to enhance investment finance, both public and private, to agriculture".

While the TAAT programme is focused on promoting the use of improved seeds, the Africa Fertilizer Financing Mechanism (AFFM), hosted by the Bank, seeks inclusive financial solutions to help all the actors along the fertilizer value chain. The Mechanism intends not only to facilitate access to quality inputs but also to ensure farmers have the knowledge to apply them effectively. Collaboration between Bank departments, regional member countries, the financial and fertilizer sectors will have a significant impact in efforts to achieve the Feed Africa priority.

Industrialize Africa

The low use of fertilizer in Africa is also due to Africa's failure to establish a strong and powerful fertilizer value chain to meet the needs of the agriculture sector. A fast-growing population requires large-scale fertilizer production to ensure better productivity. In line with the African Development Bank's industrialization strategy 2016-2025, the mission of the Africa Fertilizer Financing Mechanism is to attract and channel funding into infrastructure and projects related to the fertilizer sector. The strategy aims to develop the fertilizer value chain in Africa, which still largely depends on imported raw materials to manufacture fertilizer locally. This is due to the lack of low-cost raw materials for fertilizer production, low domestic demand, low capacity utilization and high capital requirements for investment in production facilities.

Supporting large scale production of fertilizer

With the continent's vast reserves of mineral and gas resources needed to produce different fertilizers, there is a need to design and support projects to improve Africa's capacity to produce straight and blended fertilizers. For example, in 2018, the Bank lent $100 million to Nigeria's Indorama Eleme Fertilizer & Chemicals Limited for the production of 1.4 million metric tons of urea per year from natural gas, boosting fertilizer production, a foundation of agricultural growth. In the same vein, the Bank approved a loan of $200 million in 2018 to Morocco's OCP Africa for the expansion of its activities.

Large-scale production will allow economies of scale, and hence make fertilizers more affordable within countries and at the regional level.

Supporting the development of fertilizer SMEs

Also needed is specific support to small and medium scale enterprises (SMEs) in fertilizer production in Africa. These are constrained by the lack of affordable financing to purchase raw materials for blending. The fertilizer blending industry must be developed to ensure that the necessary blended or compound fertilizer is produced and brought closer to farmers. As recommended by the fourth pillar of the Bank's industrialization strategy 2016-2025, investment and lending to SMEs as well as the provision of technical assistance to strengthen SME-focused entities, are essential.

The availability and accessibility of affordable fertilizer will lead to increased food production and hence will have a significant impact on food processing industries.

Integrate Africa

The free movement of people, goods and services is critical for Africa's development. It is also crucial for a vibrant fertilizer industry in Africa. Recognized as a "strategic commodity without borders" in the Abuja Declaration on Fertilizer for the African Green Revolution, fertilizer movement across Africa should be promoted. This will expand markets for African producers and improve the access of landlocked countries to fertilizers. Transportation costs represent 30% to 60% of the farm gate price of fertilizer, therefore improving road and railway networks will contribute to making fertilizer more affordable.

Promotion of regional road infrastructure

The Bank's objective of enhancing the construction or rehabilitation of 10,000 kilometers of cross-border roads to improve intra-continental connectivity will go a long way to benefit fertilizer movement across Africa. It also represents a huge opportunity to improve the service provision and to boost fertilizer trade in Africa. However, all this can only be efficient if the main transport corridors can facilitate linkages to smallholder farmers who struggle to access fertilizer. Therefore, African governments should also make the development of rural infrastructure a priority.

Harmonization of regional policies on fertilizers

Integration also requires the harmonization of fertilizer standards and regulations at a regional level. As a joint African Union, AFFM and UN Economic Commission for Africa study in 2018 showed, "If fertilizer policies are harmonized at a regional level, a regional inspection of fertilizer will allow for shipments to be approved once upon entry into a region." Where it is not the case, fertilizer is subject to pre-shipment inspections at ports and border crossings, which introduces delays due to multiple controls. Harmonization of standards is also key in the context of the implementation of the African Free Trade Continental Area launched in 2019. Intra-Africa trade will increase the flow of fertilizers throughout regional economic communities according to their agricultural calendar.

Building regional platforms to strengthen the fertilizer value chain

A regional perspective also has the potential to contribute to the better organization of the fertilizer sector in different regions of the continent. AFFM is working to bring together fertilizer sector stakeholders to develop sustainable financing solutions to the fertilizer value chain at a regional level. Creating a regional platform where the sector can meet and discuss is an opportunity to advance the industry further. For example, the 2019 West Africa Fertilizer Financing Forum brought together about 60 fertilizer companies to discuss their priorities and connect with different financing possibilities in the region.

Improve the quality of life for the people of Africa

Access to quality fertilizer can accelerate efforts to improve the quality of life for the most vulnerable people in our societies.

Increasing smallholder farmers' revenue

The majority of sub-Saharan farmers are subsistence and smallholder farmers and the use of fertilizers and improved seeds to increase their agricultural productivity would have a tremendous impact on their yields, and therefore their revenues.

Closing the gender gap in the fertilizer value chain

An efficient fertilizer value chain can also improve the quality of life of Africans by closing the gender gap in the agriculture sector. According to UN Women, gender gaps in productivity arise because women have unequal access to agricultural inputs. All interventions should, therefore, work towards creating an inclusive fertilizer value chain where access to financing to buy inputs is facilitated for women. The Bank's flagship pan-African initiative, Affirmative Finance Action for Women in Africa (AFAWA) can also play a significant role in ensuring that women in the agricultural sector have access to finance to purchase key inputs like fertilizers and seeds.

Improving food nutrition on the continent

Adequate fertilizer use can also improve the quality of soil health, which, in turn, will help produce quality food to ensure people's health. Indeed, improving the quality of food through its intake of micronutrients can accelerate Africa's efforts towards ending malnutrition. The application of mineral fertilizers to soils or plant leaves can increase micronutrient content, essential for human growth and development. Supporting the sector can go a long way in fighting malnutrition, a scourge which affects millions of African children.

Conclusion

Increased support to the fertilizer sector could be the game-changer for Africa - accelerating its objectives in the areas of food security and nutrition, as well as in other key development areas. Access to quality and affordable fertilizer is essential to transforming the agriculture sector and improving smallholder farmers' livelihoods. Interventions for integrated support to the fertilizer value chain should prioritize capacity building among farmers, to ensure their ability to use agricultural inputs to achieve the potential increased productivity. The AFFM can play a role in channeling Bank's support to smallholder farmers and SMEs and in bridging financing through commercial banks involved in fertilizer sector financing. ***(Source: African Development Bank)***

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SCAN CODE

Agricultural Trends

in the World

The challenge of increasing productivity in world agriculture definitely involves the incorporation of new technologies into its production processes, which allow improving the yield of crops and, at the same time, reducing the costs of inputs and labor.

Agricultural or agricultural innovation uses a term to group the new emerging technologies called "AgTech". This concept includes ten innovations that, according to the projections of world experts in the field, will have a strong impact on the development of the agricultural sector, promoting the growth of its productivity.

1. Sensors, big data and management software

This innovation or AgTech is based on sensorization for the monitoring of agricultural variables or that influence the agricultural cycle, the processing of large volumes of information and App's, so that farmers can make better decisions regarding management of their crops.

Data-driven farming, or smart farming, is here, and in the near future we can only hope that it will continue to evolve and improve land management.

2. Robotics

Robots for agricultural applications in the world, are already an important reality and in development in recent years; from expert robots in sowing, fertilization and plant protection processes, to harvesting robots. The use of robots allows relevant increases in yields, reduction of costs of productive inputs and labor.

Within the family of robots can be included drones, which are being used in the agricultural industry for various functions; from disease diagnosis, to pollination processes, to livestock control and fire prevention. Drones are a technology whose performance-price ratio increases at accelerated rates, therefore it is to be expected that their use will also intensify.

3. Autonomous tractors

This technology allows the farmer of a farm to control the tractor from a computer or a tablet, with simple instructions, programming his tasks so that it later operates autonomously, while the farmer can dedicate his time to other tasks on the farm. The operation of these tractors is based on real data collected autonomously by the tractor, through sensors or provided by external systems, which allows them to make much more precise decisions, in real time, minimizing risks and costs.

4. Biotechnology and biological big data

Agricultural biotechnology is not exactly new to agriculture. Since ancient times, farmers have selected the best species, both animal and vegetable, which gave productive, qualitative and quality advantages to the products. On the other hand, Biological Big Data allows genetic and molecular discoveries in plant and animal species at a speed never known before. For example, the discovery of genes that directly intervene in specific biological processes of crops, increasing their resistance, improving their productivity and the quality of their fruits.

5. Shared economy

The UBER phenomenon has reached agricultural machinery. In Europe, numerous platforms have emerged that allow farmers to rent machinery to other farmers for hours, days or weeks, when they are not using them.

A simple idea, which allows both parties to benefit: some because they get the most out of their stopped machine, and others because they can incorporate technology into their crops without making large investments.

6. Vertical farms for the cities of the future

This technology is based on the idea of transforming urban spaces, of large cities, into high productivity gardens. These vertical, hyper-robotized and ultra-productive farms have been operating in Europe since 2016, proving that this idea is fully feasible.

On the other hand, these farms are characterized by: low human labor, absolute control of all cultivation parameters, maximum food safety, high technology and incredible productivity.

7. Cellular agriculture and livestock

Complementing the idea of vertical farms, the concept of a smart city arises, where vertical farms put vegetables and laboratories put animal protein.

This concept began to sound strongly when the German scientist Mark Post, created in 2013 the first hamburger "in vitro". From here, numerous startups have emerged in the United States and Europe that have launched into investigating how to produce meat and dairy products without resorting to livestock.

8. Satellite technology

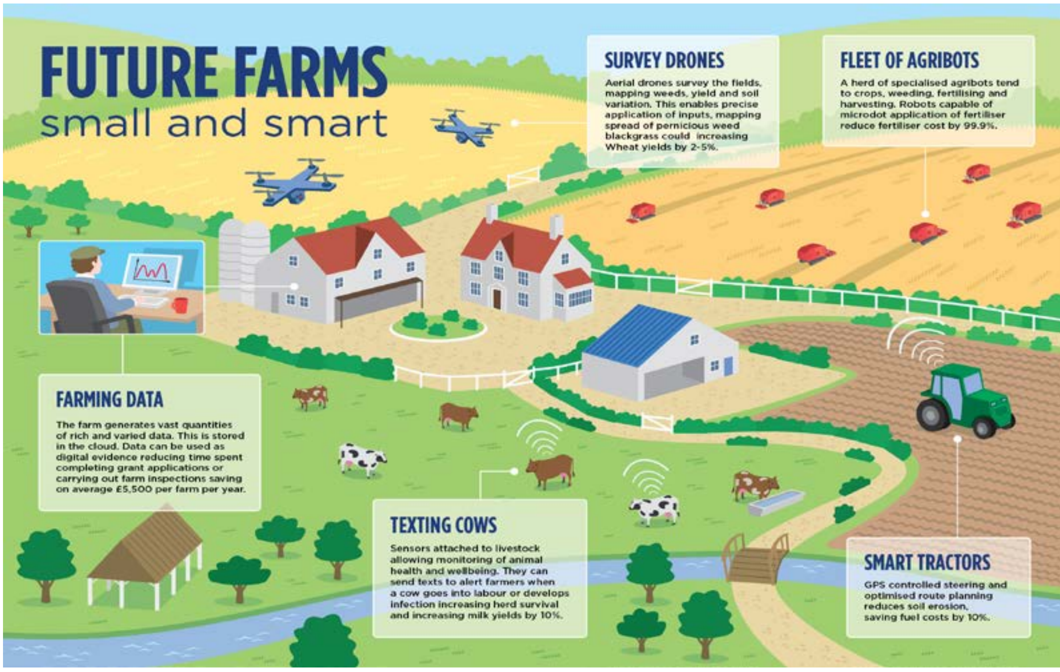
NASA is betting on satellite technology to predict droughts and thus help farmers; For its part, the European Space Agency is developing applications based on the same technology to monitor agricultural droughts and predict harvests.

Numerous applications have been developed that allow combining NASA images and information with knowledge from other information sources, such as the "US Department of Agriculture" .

9. More natural inputs and agriculture

Biological control emerges as an alternative to pesticides and chemical substances for pest control, mainly due to the fact that consumers in developed countries have begun to be environmentally conscious and ask farmers for more natural and sustainable products.

This trend, in practice, translates into the substitution of chemical-based fertilizers for natural-origin fertilizers; developing natural solutions to combat pests, using substances present in nature or biological control.



10. Regenerative agriculture

Due to concerns about climate change and weather volatility, more consumers are pushing organizations and individuals to adopt regenerative agriculture practices. This broad term refers to practices that increase soil carbon sequestration, such as reduced tillage and the use of cover crops. While professionals debate whether regenerative agriculture will be a solution for climate change mitigation, scientists agree these practices increase soil health and fertility. *(Source: laverdadnoticias.com)*

MARKET SCOPE

Beyond the Pandemic:

Harnessing the Digital Revolution to Set Food Systems on a Better Course

A marketplace in Kenya. ***(Photo: © Sambrian Mbaabu/World Bank)***

One of the most striking images of the coronavirus pandemic is the contrast between farmers dumping milk, smashing eggs, and plowing vegetables back into the soil and consumers facing empty store shelves and long lines at food distribution centers. How is it possible to have over-abundance on one hand and scarcity on the other?

This article argues it is vital to correct pervasive information asymmetries and transaction costs across a vast food system (Figure 1) to move toward a more inclusive, resilient and sustainable model. While large-scale industrial food production accompanied by just-in-time supply chains have produced many gains, the hazards of this system are increasingly visible on the horizon. The digital revolution offers the possibility of an alternative equilibrium, one where small-scale, flexible organizational and production systems flourish and nimbly navigate a changing operating environment.

All of us, 7.7 billion and counting, participate in the food system in one way or another. We make decisions about the food we consume, the clothes we wear and the products we use – much of which originate in agriculture. Agricultural goods are produced on 570 million farms, most of them small, run by families, and located in developing countries. Food systems are local, an essential feature in communities—but also global, linked through trade and sophisticated financial and insurance markets.

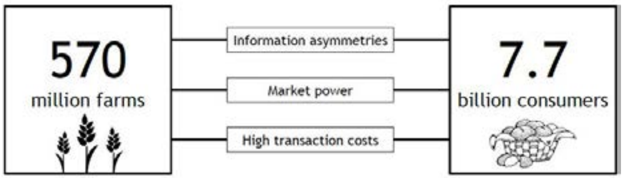


Figure 1: Information Asymmetries and Transaction Costs Plague the Food System. ***(Source: World Bank)***

All of us, 7.7 billion and counting, participate in the food system in one way or another. We make decisions about the food we consume, the clothes we wear and the products we use – much of which originate in agriculture. Agricultural goods are produced on 570 million farms, most of them small, run by families, and located in developing countries. Food systems are local, an essential feature in communities—but also global, linked through trade and sophisticated financial and insurance markets.

Despite providing food for a world population that has more than doubled over the past 50 years, the food system is severely off course in helping us achieve Sustainable Development Goals related to hunger, poverty, health, land use and climate change. Although we're producing plenty of food globally, the number of undernourished has been rising since 2014 (Figure 2). One in five children under the age of five is stunted producing lifelong negative consequences on productivity. Some two billion people are overweight or obese, resulting in noncommunicable diseases of dietary origin that compromise resistance to new diseases such as the coronavirus. Agriculture contributes 24 percent of greenhouse gas emissions, consumes 70 percent of fresh water, and has caused the loss of 60 percent of vertebrate biodiversity since the 1970s. The cost of these negative externalities is $12 trillion according to the Food and Land Use Coalition, outweighing a market value of $10 trillion.

Now, an additional 100 million people are under threat of poverty because of the economic impacts of the pandemic, according to the June 2020 Global Economic Prospects report, pushing us further from our goals by shrinking incomes and creating food and nutrition access challenges that may result in large-scale famine according to the World Food Programme.

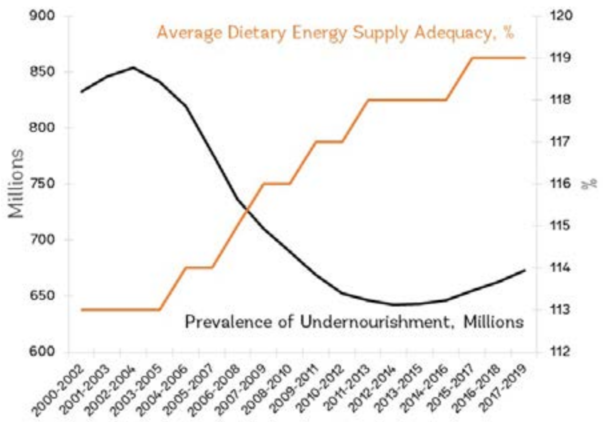


Figure 2: The Food System Is Not on Course to End Hunger. ***(Source: FAOSTAT (2020)***

How can we set a new course for the food system – one that reduces hunger and delivers healthy people, a healthy economy, and a healthy planet?

Imagine the planetary system on which the food system depends as an overloaded boat becoming increasingly 'tippy' with each additional piece of cargo – population growth, climate change, loss of biodiversity, pollution, land degradation and so on. With two food security crises in a decade, albeit of completely different origin, we're wobbling and getting closer to the tipping point. And solving this won't be accomplished by only jettisoning the latest piece of cargo – the coronavirus. Multiple factors need addressing. Fortunately, Mother Nature is amazingly resilient and, combined with human ingenuity, will enable us to recover from the current crisis, as it did from previous ones. Let's take it as an opportunity to shift the course of the food system.

Today, the rapid development and deployment of digital technologies and networks promises to accelerate food system transformation by overcoming long-standing market and policy failures. Earlier course shifts in agriculture and food industries, marked by several agricultural revolutions, raised agricultural productivity, increased food supply, reduced real food prices, helped free up labor and capital resources for investment in other sectors, paved the way for urbanization and the industrial revolution, and led to the corporatization of agri-business. Unlike prior revolutions that originated with on-farm innovations before spilling over to rural communities, and then firms up and down the value chain (think of the use of the cast iron plough during the British Agricultural Revolution; or enhanced seed and fertilizer packages during the Green Revolution), today's digital innovations are promoting efficiencies at multiple points along the food value chain.

Digital technology drives change on multiple fronts at accelerated rates by collecting, using, and analyzing massive amounts of machine-readable data about practically every aspect of the food system at nearly zero marginal cost. Digital platforms from Alibaba to YouTube are disrupting traditional business models across the system and Venture capital investors poured $2.8 billion into agtech startups across the globe in 2019.

But digital innovation is only as good as its purpose. To yield positive outcomes, public policy must boost complementary infrastructure and human capacity, address gender access disparities, and pay close attention to environmental benefits. In this article, we focus on just three recommendations to accelerate the shift towards a more sustainable food future. Public policies should seek to ***D***e-concentrate markets and supply chains, ***D***ecentralize traceability, and ***D***isseminate data.

The first D: De-concentrate markets and supply chains

The contrast between food surplus on farms and food shortages in retail markets during COVID-19 lockdowns highlighted high transaction costs and information asymmetries that have long plagued the food system. Highly concentrated and segmented markets and supply chains generate enormous efficiency gains but make it hard and costly for sellers and buyers to find each other and transact. Concentration can take many shapes and forms – from concentrated physical markets to concentrated market shares. Both are perilous, particularly in times of crisis. The Titanic was the biggest, most luxurious state-of-the-art passenger ship when she set sail on her maiden voyage. Everyone thought it was "too big to sink" and we all know how that ended.

In Peru, 80 percent of merchants at a major central fruit market in Lima tested positive for coronavirus. Although it was identified as a point of contagion, authorities felt they could not afford to close the market because it would result in significant food shortages. In the United States, the retail food sector is increasingly concentrated in a small number of large companies (Figure 3) that may be less agile in adapting to changes in consumption patterns and less resilient to demand shocks. Still in the United States, the impact of coronavirus on meatpacking workers underscored the scale of meat operations and the very high market concentration of the meat industry, with impacts from closed meat packing plants in Illinois rippling up and down the supply chain. These problems will likely only get worse as trends toward increasing concentration and segmentation are accentuated by geography and trade politics, contributing to the unique coronavirus-induced surpluses and shortages we are experiencing today.

Figure 3: Retail food markets in the US are thinning. ***(Source: USDA ERS, Calculations from U.S. Census Bureau Monthly Retail Trade Survey, Industry reports; It is updated and adapted from Steve Wood, Revisiting the US food retail consolidation wave: regulation, market power and spatial outcomes, Journal of Economic Geography, Volume 13, Issue 2, March 2013, Pages 299–326)***

The role of public policy is to prevent accumulation of market power by digital platforms. It is currently unclear whether digital platforms are creating new, highly concentrated market powers that favor incumbents or whether transparent competition is enabling a fair distribution of value.

On the one hand, several factors contribute to increased concentration in digital platform markets such as economies of scale, switching costs and network effects. Consider Alibaba or Amazon, companies that have grown exponentially in the last decade and are producing a market for consumers and producers to interact across the globe. On the other hand, economist Barbara Engels makes the case that digital platforms support competition. She argues that product ranges (such as sales of varieties of apples by different producers) provide for competitive conditions and that platform market conditions are regularly disrupted by innovation (new varieties of apples displacing established ones as market reach expands) and so are perhaps less susceptible to the accumulation of market power as more conventional exchange mechanisms. This has not been proven for the food value chain and justifies further research.

The second D: Decentralize traceability

Like previous zoonotic diseases such as HIV/AIDS and West Nile Virus, COVID-19 has brought to the fore the strong linkages between animal health, human health and planetary health, and the important role that human activities play by putting people in closer contact with wildlife. Poor management of livestock, unsafe food handling, ecosystem degradation and encroachments on wildlife habitats are responsible for a growing number of ills and illnesses.

Tracing food throughout the supply chain in a decentralized manner creates opportunities for safer, more sustainable food. Safer sourcing of food is important because some 600 million people fall ill after eating contaminated food each year, costing low and middle-income countries $110 billion in lost productivity and medical expenses each year. Knowing where food comes from and how it was produced allows consumers to make more informed decisions about the impact of the food they consume on their health and the health of the planet. More sustainably sourced food also earns a price premium from environmentally and health conscious consumers who can afford it. This price signal, when transmitted to various actors along the value chain, could in turn incentivize sustainable production practices.

Open access distributed ledger technologies have the potential to transform food supply chains, fingerprinting location, animal welfare, environmental and social inputs, contracts, processing and many other key areas. Given the complexity of the food system, in addition to technical issues associated with scalability, privacy, and data architecture, this can only be fully realized by ensuring that traceability is fully inter-operable (i.e. the different parts can talk to each other) and governance prevents a race for concentration of market power. De-centralization of traceability throughout the supply chain will improve incentives for safe, high quality, and socially and environmentally responsible food production and consumption.

The third D: Disseminate open data

Think of the impact of releasing the genetic sequence of coronavirus COVID-19. More than 150 possible vaccines are now being developed by the private and public sectors, some using traditional technologies and others unproven ones. Open data dissemination throughout the complex food system is also essential to correct information asymmetries, encouraging innovation, and increase the efficiency of public spending.

Kenya, for example, is starting to see a boom in applications that make use of open data promoted under the Kenya Open Data Initiative. With agriculture as a pillar of the economy and food security an over-riding concern, the government decided in 2011 to make core developmental, demographic, statistical and expenditure data available in a useful digital format for researchers, private companies, ICT developers and the public. The website opendata.go.ke supplies the public with some 942 datasets. Today, Kenya is leading Africa in the agricultural technology space, with the top-rated digital ecosystem and 30 percent of disruptive agricultural technologies in the continent. The impact of breakthrough technology such as the Global Positioning System developed by the U.S. Department of Defense to assist military forces and now distributed for free is another example of open data delivering significant positive impacts in everything from precision agriculture that allows farmers to put just the right amount of fertilizer in just the right place, to reviews which allow tourists and foodies to locate restaurants in a matter of minutes.

Person using GPS-enabled sensor to track performance of machinery in rice paddy in Pakistan. ***(Photo credit: Flore de Preneuf/World Bank)***

Person using GPS-enabled sensor to track performance of machinery in rice paddy in Pakistan. Photo credit: Flore de Preneuf/World Bank

Open data also promises to enhance the efficiency of the public sector's support for the food system, at a time when more than a half trillion dollars are invested annually in countries tracked by the OECD. Open data enables sharing data between different public agencies, improving the performance of public processes and increasing efficiency of providing public services. In 2020, the EU28 is expected to save €1.7 billion in public administration costs thanks to the use of open data. Open data encourages innovative service delivery—NGOs and public agencies can use open data to develop new mobile applications to better serve the population. Data from farmers helps track the implementation of various measures such as sustainable production and land use plans. And consumer-reported data can help authorities identify food safety issues in close to real time.

Many existing policies, notably in Europe since 2003, prescribe that public sector data – or, data that are of a public-good nature - should be open and reusable. But several data-related risks may prevent digital technologies from fulfilling their promise: uncertainty about data protection, ownership, security, access, and control; questions of veracity, validation, and liability, and the imbalance in value chains. Public policy can improve data protection and clarify data ownership, address unfair data practices in agricultural policies, and reduce imbalances in the value chain and related information asymmetries. It can also promote the sharing of data by the private sector when data is of public interest, monitor and increase the impact of public data, and improve the governance of data sharing.

The coronavirus pandemic hit most countries in early 2020, at a time when the food system was already overdue for a major course correction to improve nutritional and environmental outcomes, and to quicken poverty reduction. By accelerating the move to digital technologies, physical lockdown measures could provide an unexpected tail wind and usher welcome change. This is a call for all hands-on deck now, to make sure the policy environment is conducive to digital solutions that bring us closer to achieving our Sustainable Development Goals by favoring de-concentration, decentralized traceability and dissemination of open data. If we succeed, we'll be able to leverage the creative energy, innovation and daily needs of the 7.7 billion farmers, businesspeople and consumers that make up the global food system in shifting course toward a more sustainable future. ***(By: Julian Lampietti, Ghada El Abed, and Kateryna Schroeder)***

Manganese:

Critical for Crop Production

Despite requiring small quantities, micronutrients play a complex role in crop development and health. Manganese (Mn) as a critical micronutrient is widely accepted, playing a key role in several biochemical reactions; particularly photosynthesis. Manganese producing countries are responding to this demand and delivering high quality $MnSO_4$ to the agriculture marketplace. Vast amounts of resources in the Andes Mountains, coupled with their reputation for quality business practices and rich mining history, are positioning Peru and Chile to actively compete in the US agriculture market.

Manganese: the element

The use of manganese dates back to the Stone Age where it can be seen in cave paintings. Belonging to the transition series of elements, manganese is second only to iron (Fe) in abundance. It commonly forms several minerals including pyrolusite (MnO_2), rhodochrosite ($MnCO_3$), manganite (MnO). It is also widely distributed as an accessory element.

Manganese ore containing more than 20% manganese has not been produced domestically since 1970. South Africa accounts for over 75% of the worlds identified resources, with Ukraine accounting for another 10%.

Manganese is closely related to iron, and to a lesser extent zinc, copper, magnesium and calcium. Due to their similarity, manganese and iron can compete for plant uptake.

Coincidently, their deficiencies/toxicities also have similar visual symptoms: interveinal chlorosis of the young leaves. The only true way to distinguish between iron and manganese deficiency is through diagnostic testing [which is also a NOP/OMRI requirement for organic use].

The behavior of Mn in soil is very complex, and is impacted greatly by the pH conditions and organic matter. In addition, the level of Mn is controlled by the geochemistry of the source rock and the redox conditions of the environment.

Country	Production	Resources
South Africa	4,700	200,000
China	3,000	43,000
Australia	2,500	91,000
Gabon	2,000	22,000
Brazil	1,100	116,000
India	950	52,000
Ghana	480	12,000
Ukraine	320	140,000
Mexico	220	5,000
Malaysia	200	n/a

(data in '1000 MT)

Form	Chemical Formula	% Mn
Manganese Carbonate	$MnCO_3$	31
Manganese Chelate	MnEDTA	12
Manganese Chloride	$MnCl_2$	17
Manganese Dioxide	MnO_2	63
Manganese Oxide	MnO	41-60
Manganese Sulfate	$MnSO_4$	28-32

Left: Table 1. Stats from USGS most recent report.
Right: Table 2.

Manganese: agronomy

Although plants rely on manganese primarily for photosynthesis, a variety of other biological functions require manganese including chlorophyll synthesis, nitrate assimilation, lipid metabolism, enzyme activation

and vitamin formation. In photosynthesis, Manganese (Mn) plays an important electron transport role in redox reactions. It also plays a role in building carbohydrates and metabolizing nitrogen, especially in corn. As a cofactor, Mn reportedly activates over 35 enzymes necessary for plant health and vigor including lignin, phytoalexins, peroxidase and superoxide dismutase. Impairment of these functions in crops increases susceptibility to pathogen attack and reduces stress tolerance. Most of the Manganese used by the plant comes from the soil solution and reaches plant roots by a process called mass flow and diffusion. Deficiencies occur in neutral-to-high pH soils.

Crop	Deficiency	NI	Toxicity*
Alfalfa	15-25	26-150	>300
Corn	<15	26-150	>200
Cereal crops	<10	26-150	>300
Potato	<10	20-200	>400
Soybean	<15	20-100	>250

*in ppm.

Factors	Balance	Availability
pH	pH< 5.5	enhance Mn uptake
pH	pH> 7.0	reduce Mn uptake
Organic Matter	High OM	reduce Mn uptake
Iron (Fe)	High iron	reduce Mn uptake
Silicon (Si)		reduce Mn uptake
Nitrogen (N)	Low nitrogen	reduce Mn uptake
Sulphur (S)	Low sulphur	reduce Mn uptake
Moisture	"waterlogged"	enhance Mn uptake

Top: Table 3
Bottom: Table 4

Manganese: application

Manganese sulphate is the most common form used in plant and animal feed industries. Manganese fertilization is recommended if soil tests < 10ppm. In-row bands (1-5lb/A) or foliar (1-2 lb/A) applications in soil. Broadcast applications are not recommended because manganese that is not concentrated quickly converts to unavailable formats. As manganese toxicity often results from an acidic soil pH, lime or dolomite can be applied to raise the pH. Correcting drainage issues that have lead to waterlogging will also remove one element impacting manganese toxicity.

Toxicity

Manganese (Mn) toxicity is associated with waterlogged soils where anaerobic conditions are present, or acidic soil conditions where the pH < 5.5. Anaerobic conditions cause higher oxides of manganese to be reduced to plant-available Mn^{2+}. At a pH <5.5, manganese and oxygen react spontaneously.

Similar to boron toxicity, manganese toxicity begins with the burning of the tips and margins of older leaves or as necrotic spots. Due to an induced iron deficiency, manganese toxicity also frequently causes pale or yellow patches between veins in younger plants (interveinal chlorosis). These necrotic lesions can spread until the entire leaf area is compromised. Eventually leaves turn yellow and are shed.

CROPS SUSCEPTIBLE TO TOXICITY

- Asparagus
- Legumes
- Mint
- Tea
- Potato

CROPS WITH HIGH MN REQUIREMENTS

- Beans
- Lettuce
- Oat
- Onion
- Radish
- Raspberry
- Soybean
- Spinach
- Sorghum
- Wheat
- Barley

HIGH RESPONSE CROPS

- Alfalfa
- Cauliflower
- Beets
- Cauliflower
- Citrus
- Cotton
- Large-seeded legumes
- Lettuce
- Onions
- Potatoes
- Small grains
- Sorghum
- Soybeans
- Spinach
- Sweet corn
- Tobacco

SOIL CONDITIONS AFFECTING MANGANESE UPTAKE

- Sandy, leachable soils
- Soils with a water pH reading below 5.0 or above 6.5
- High-organic matter or muck soils
- Saturated or waterlogged soils
- Soil during drought, cold or wet growing conditions

Deficiency

Manganese deficiency negatively impacts dry matter and yields, weakens resistance to pathogens and reduces drought and heat tolerance. Due to low phloem mobility in plants, manganese deficiency can mimic iron; first symptoms develop in younger leaves in the form of interveinal chlorosis. Deficiencies are most likely to occur in neutral-to-high pH soils that are also high in organic matter or as a result of low fertilizer application rate.

(by Christian Schmalz, Marketing Director, UlexAndes-USA)

Because of the "Quality" Problem,

This Company Has Gotten into Trouble Internationally

Company Overview:

Founded in 2009, Shandong Cocoly Fertilizer Co., Ltd, is an agricultural enterprise integrating R&D, production, and sales of granular water-soluble fertilizer. After years of development, our company launched the world's first granular water-soluble fertilizer, Cocoly. Cocoly created a new category of granular water-soluble fertilizer, which changed the characteristics of water-soluble fertilizers as liquid and powder.

As the "the founder of granular water-soluble fertilizer", the company devotes all its energy to the development of the brand, cocoly, which is recognized by the majority of domestic and foreign distributors and ordinary people and is well known by the agricultural industry’s peers. Since it was launched, Cocoly company has established a complete brand sales network and institutions and actively participated in professional agricultural exhibitions at home and abroad. Now the trademark "Cocoly" has been registered in more than 70 countries in the world, and Cocoly granular water-soluble fertilizer has been exported to 22 countries and regions.

Why did Cocoly's sales volume increase instead of decreasing during the coronavirus?

2020 is a special year, all industries are seriously affected by the coronavirus, and agricultural companies are reshuffled. There is a rising star but upstream, Cocoly Fertilizer Company outstanding encircling, constantly showing the charm of Chinese agricultural brand and the power of focusing on a single product. "So clumsy, we only focus on granular water-soluble fertilizer" said Mr. Sun, CEO of Cocoly Company. Let's reveal the secret through today's interview. Why has Cocoly Fertilizer Company only focused on one product for many years, but has achieved great success?

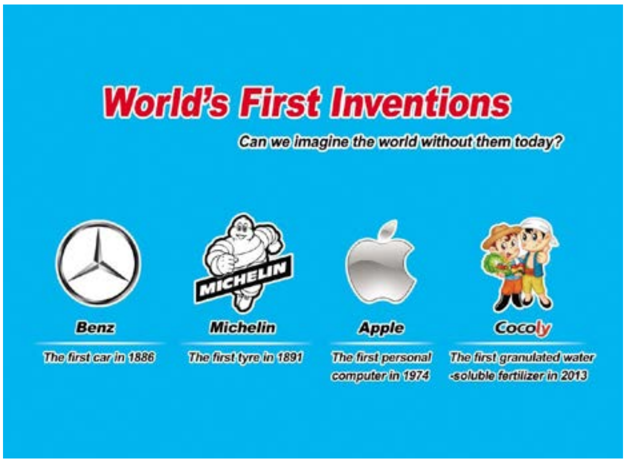
Our company has been focusing on a single product, Cocoly since it launched the new category, granular water-soluble fertilizer, and continues to lead the development of the granular water-soluble fertilizer industry. In the past 8 years, we have been constantly improving the product quality and upgrading the formula. We only have one product, so providing customers with the best quality product is the focus of the company's 200 employees.

"Crisis is made up of two words, danger and opportunity." In the face of the coronavirus, Cocoly company has not been in turmoil, it seized the opportunity, continued to firmly believe, and intensified its publicity and promotion efforts around the core brand Cocoly. During the coronavirus, we launched a new promotion model, using live broadcast platforms to promote our brand online. At the same time, we also used the influence of Cocoly's brand to help farmers sell unsalable agricultural products, expand sales channels, and solve their practical problems. Through the online live broadcast of Cocoly, flowers in Yunnan, litchi in Guangdong, and kiwifruit in Sichuan had good sales.

As the leader of granular water-soluble fertilizer, our goal is to let global agriculture get good harvest. Even during the coronavirus, our pace of opening up new markets internationally has not stopped. The agent from Peru was the one we met during the coronavirus, He said, "Due to the coronavirus, many products lack competitiveness, leading to a decline in sales. We have been looking for a special product with guaranteed quality for many years to help us improve the market competitiveness and promote the development of our company. At this time, Cocoly appeared."

In the face of many uncertain factors, if a company does not have a clear strategic layout and an overall view of danger in times of peace, whether it is a coronavirus, a

trade war, or a natural disaster, any small tipping point can bring down an immature company. As a Chinese agricultural brand exported to 22 countries, Cocoly has been leading the development of granular water-soluble fertilizers. Cocoly shoulders the mission, makes the strategic layout in advance, always focuses on Cocoly a single product as the core. No matter what kind of adversity can not overwhelm us, this will only become the driving force for our growth.



Why only focus on one product , "Cocoly"?

In the early stage of Cocoly company's establishment, it had hundreds of products, covering almost all categories of fertilizers. In 2013, this company created a new category of granular water-soluble fertilizer and named it "Cocoly". We made a difficult decision that we cut off all the products and only focus on the single product Cocoly. After making this decision, many customers asked us to send other products, but we all refused because we were determined to only focus on Cocoly.

When Cocoly granular water-soluble fertilizer appeared for the first time, everyone asked, what is granular water-soluble fertilizer? Such a category never heard of, how can you convince others? But 8 years later, thousands of imitation products appeared constantly on the market. And granular water-soluble fertilizers have entered thousands of households. In the agricultural industry, Cocoly is also known as the founder of granular water-soluble fertilizer. This proves that we have made the right choice.

Cocoly company focuses on the development of one product, gives play to the spirit of craftsman, and constantly improves the quality and service of product centered on one product, Cocoly. As a pioneer in this industry, we continue to lead the development of the granular water-soluble fertilizer category.

Cocoly exports 22 countries. What is the strategic layout of Cocoly in the international market?

In 2015, in response to the national “The Belt and Road” policy, Cocoly actively explored overseas markets. In the past, China's agricultural companies mainly exported raw materials. And Cocoly chose to export as a brand, and let Cocoly, the founder of granular water-soluble fertilizer, go abroad, and into the world.

Through visiting countries along the Belt and Road, we found that most countries’ agriculture is in the development stage, and farmers do not have the concept of granular water-soluble fertilizer. As the founder, we

shoulder the mission of letting the global agriculture get good harvest. To promote the new category, farmers need to see the actual effect of the product, and to export the brand, we need to wake up the brand awareness of agents and teach them how to promote the brand.

Therefore, we will position the overseas promotion strategy as brand exports. We have brought a series of mature plans of domestic brand building to foreign countries and taught them to agents without reservation so that farmers all over the world can use Cocoly. A customer from Egypt said, "Our planting level in Egypt is relatively low, and we are not very accepting of products at high prices. I have imported the best fertilizers from many countries, but it is difficult to find such a good product that has unique effect as Cocoly fertilizer, they are willing to go to Egypt to teach me the team to promote the brand".

Cocoly has brought the joy of increasing production and income to developing agricultural countries, bringing new hope to local farmers, and also confidently opening up the agricultural market of high-tech countries. Brazilian customer told us: "Cocoly has shown magical effects on a variety of crops, and the emerging technology of granular water-soluble fertilizer provides convenience for Brazilian agriculture." At the same time, our product is also used in hydroponics, seed treatment, and other strict requirements on product quality of agricultural technology.

Now Cocoly granular water-soluble fertilizer has been exported to Brazil, South Korea, Peru, Mexico, Egypt, India, and other 22 countries and regions, so that local farmers feel the joy of harvest! The constant feedback from abroad has also given us the confidence to focus on granular water-soluble fertilizer.

Cocoly cultivates the market carefully. As the founder of granular water-soluble fertilizer, we believe that as long as a product is done to the extreme, we can overtake in this segment of the curve, relying on its excellent quality and brand influence to bring Cocoly to every corner of the world.


FRONTIER OF
SCIENCE &
TECHNOLOGY

Why Nutrient Transport

Is Key to Optimal Crop Development

Plants are living, breathing and producing organisms. Just like any other living creature, they require nutrients with which they maintain their physiological processes and continue to develop.

These crucial compounds are transported around the plant through complex piping systems. Understanding the factors that affect these systems can enhance the well-being of a crop, producing larger, higher quality yields.

In nature, the plant's equivalent of food is found in the ground with the most basic building blocks being nitrogen, phosphorous, potassium, calcium, sulphur, magnesium, oxygen, hydrogen and carbon. These compounds are taken in along with the water absorbed by the roots, with the exception of carbon, which is absorbed by leaves as carbon dioxide in the air, as part of the plant's respiratory system.

Nutrients are transported by water moving through the plant, from root to leaf, bringing them to the plant cells in which they are needed. The hollow tubes transporting the nutrient-rich water are called "xylem", a type of vascular tissue.

Upward flow through the xylem

Water molecules are connected by a bond known as a "hydrogen bond". This type of bond strongly connects the separate water molecules into one body of water. The resulting cohesion means that once water starts to flow, the rest follows, even when seemingly defying gravity.

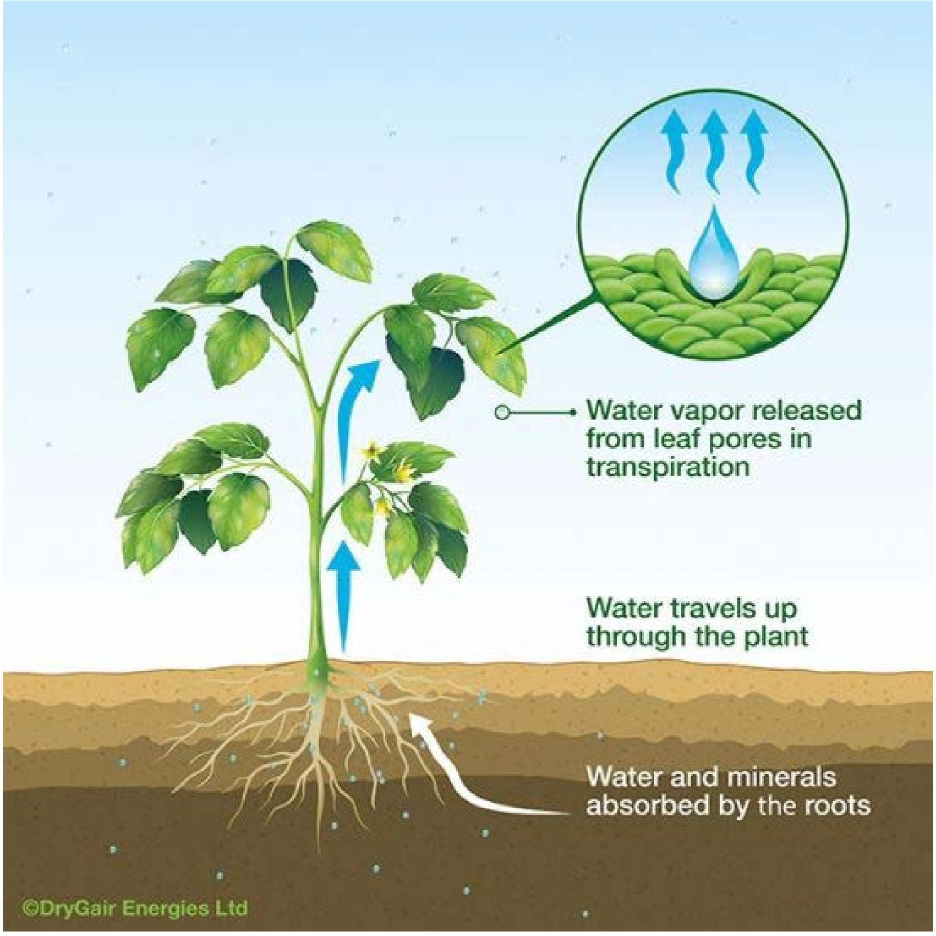
In order to initiate the flow of water through the xylem, there needs to be an initial force. This is called the "xylem pull". When water evaporates from the leaves, it causes the rest of the water to be pulled through the xylem. If evaporation were to stop, the pull would stop, nutrients would cease to arrive at their destinations and the plant would no longer be able to continue development.

Therefore, evaporation from the leaves is a key part of plant development. Transpiration is made possible through two forces. The first, being the sun, or an alternative light source, causes the stomata found on the leaves to open up, thus allowing water to evaporate. The second force is what determines the transfer rate of water to the air – the relative humidity of the air surrounding the leaf.

What is "relative humidity"?

Relative humidity is a measurement of saturation with regards to water vapour in the air. When relative humidity reaches 100 percent, the air is completely filled with all the water molecules it is able to hold. This is a basic physical property of air, and not one which is lost on growers, most of whom are well aware of the effects of humidity on their crops.

Due to the constant transpiration performed by plants, the air immediately surrounding a plant is very humid. This is known as the "boundary layer". In a greenhouse setting, where there are many plants in an enclosed space, the boundary layers overlap, and without proper management, relative humidity may quickly reach 100 per cent.



When the air reaches complete saturation, it cannot contain any more water molecules, which means water no longer evaporates from the plant's stomata and the xylem pull is broken. When water ceases to flow upwards through the plant, the nutrients cease to arrive where they are needed as well. If this situation lasts long enough, the plant may die. But even if the relative humidity level is later reduced, plants are affected by the lapse, eventually leading to a smaller, lower quality product. This is especially true when it comes to fruits and vegetables, which require larger amounts of nutrients to properly develop.

With all things taken into consideration, it appears that humidity in the growing space is a serious factor affecting the well-being of the plant and the quality of the product.

Treating humidity on a large scale

There are two fundamental methods for lowering relative humidity. The first approach is to deal with humidity through heating. As warmer air has the capacity to contain larger quantities of water molecules, heating the air effectively lowers the relative humidity, the air's saturation level. But heating the air does not actually remove water, it only raises the threshold known as the "dew point". Saturation will inevitably be reached. Another flaw in this method is that heating may also take a toll on the plants themselves, which require a specific optimum range of temperatures in order to develop properly.

The second approach involves the actual removal of water. The traditional method of humidity reduction is based on a combination of heating and ventilation. On one hand, ventilation reduces the overall water vapour found in the space, while heating increases the air's vapour capacity. This method is relatively inefficient, and not always effective. Maintaining an optimal temperature is crucial for the plants regardless of humidity, and there isn't always room to adjust in order to deal with humidity as well. Additionally, when air is heated, energy is invested into it, and throwing it out due to excess moisture can be extremely wasteful.

Modern agriculture is more conscious of efficiency, especially when it leads to higher quality outputs, while reducing costs. Along with a better understanding of the greenhouse ecosystem, a new generation of humidity reduction technologies have taken the forefront. Dehumidifying systems can actively remove water vapour from the growing space, thus reducing the relative humidity and stimulating nutrient transport in the plants, without resorting to heat.

Designing a greenhouse system in which temperature and humidity are dealt with separately, also gives growers much greater control over the climate in their facility. Allowing for optimal humidity levels to be achieved alongside comfortable temperatures, without compromise, helps ensure plant health and optimal development. *(By Rom Meir, Source: Greenhouse Canada)*

Plant-Soil Interactions:

Nutrient Uptake

> *Changes in root architecture, induction of root-based transport systems and associations with beneficial soil microorganisms allow plants to maintain optimal nutrient content in the face of changing soil environments.*

Introduction

Plant growth and development largely depend on the combination and concentration of mineral nutrients available in the soil. Plants often face significant challenges in obtaining an adequate supply of these nutrients to meet the demands of basic cellular processes due to their relative immobility. A deficiency of any one of them may result in decreased plant productivity and/or fertility. Symptoms of nutrient deficiency may include stunted growth, death of plant tissue, or yellowing of the leaves caused by a reduced production of chlorophyll, a pigment needed for photosynthesis. Nutrient deficiency can have a significant impact on agriculture, resulting in reduced crop yield or reduced plant quality. Nutrient deficiency can also lead to reduced overall biodiversity since plants serve as the producers that support most food webs.

Changes in the climate and atmosphere can have serious effects on plants, including changes in the availability of certain nutrients. In a world of continual global climate change, it is important to understand the strategies that plants have evolved to allow them to cope with some of these obstacles.

Two classes of nutrients are considered essential for plants: macronutrients and micronutrients. Macronutrients are the building blocks of crucial cellular components like proteins and nucleic acids; as the name suggests, they are required in large quantities. Nitrogen, phosphorus, magnesium, and potassium are some of the most important macronutrients. Carbon, hydrogen, and oxygen are also considered macronutrients as they are required in large quantities to build the larger organic molecules of the cell; however, they represent the non-mineral class of macronutrients. Micronutrients, including iron, zinc, manganese, and copper, are required in very small amounts. Micronutrients are often required as cofactors for enzyme activity.

Mineral nutrients are usually obtained from the soil through plant roots, but many factors can affect the efficiency of nutrient acquisition. First, the chemistry and composition of certain soils can make it harder for plants to absorb nutrients. The nutrients may not be available in certain soils, or may be present in forms that the plants cannot use. Soil properties like water content, pH, and compaction may exacerbate these problems.

Second, some plants possess mechanisms or structural features that provide advantages when growing in certain types of nutrient limited soils. In fact, most plants have evolved nutrient uptake mechanisms that are adapted to their native soils and are initiated in an attempt to overcome nutrient limitations. One of the most universal adaptations to nutrient-limited soils is a change in root structure that may increase the overall surface area of the root to increase nutrient acquisition or may increase elongation of the root system to access new nutrient sources. These changes can lead to an increase in the allocation of resources to overall root growth, thus resulting in greater root to shoot ratios in nutrient-limited plants (Lopez-Bucio et al., 2003).

Plants are known to show different responses to different specific nutrient deficiencies and the responses can vary between species. As shown in Figure 1, the most common changes are inhibition of primary root growth (often associated with P deficiency), increase in lateral root growth and density (often associated with N, P, Fe, and S deficiency) and increase in root hair growth and density (often associated with P and Fe deficiency).

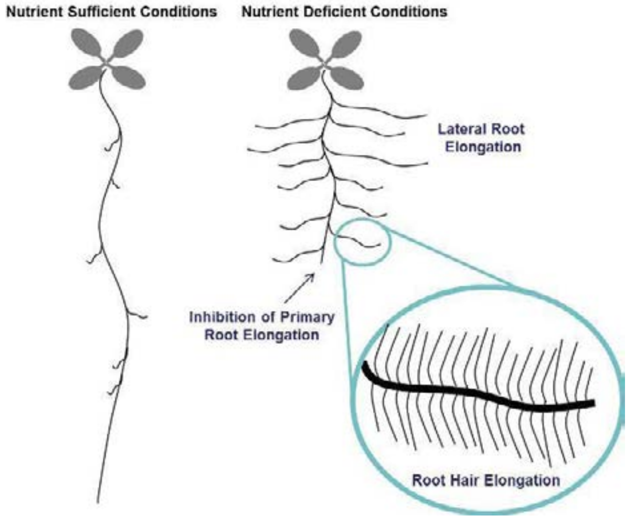


Figure 1: Overview of root architecture changes in response to nutrient deficiency.

*Plant roots exhibit a variety of changes in response to nutrient deficiency, including inhibition of primary root elongation and increased growth and density of lateral roots and root hairs. These responses are species-, genotype-, and nutrient-specific, but they are generalized in this figure to demonstrate all potential effects. (**© Nature Education All rights reserved.**)*

While nutrient deficiencies can pose serious threats to plant productivity, nutrients can become toxic in excess, which is also problematic. When some micronutrients accumulate to very high levels in plants, they contribute to the generation of reactive oxygen species (ROS), which can cause extensive cellular damage. Some highly toxic elements like lead and cadmium cannot be distinguished from essential nutrients by the nutrient uptake systems in the plant root, which means that in contaminated soils, toxic elements may enter the food web via these nutrient uptake systems, causing reduced uptake of the essential nutrient and significantly reduced plant growth and quality.

In order to maintain nutrient homeostasis, plants must regulate nutrient uptake and must respond to changes in the soil as well as within the plant. Thus, plant species utilize various strategies for mobilization and uptake of nutrients as well as chelation, transport between the various cells and organs of the plant and storage to achieve whole-plant nutrient homeostasis. Here, we briefly describe a few examples of strategies used by plants to acquire nutrients from the soil.

Plant acquisition of nutrients: direct uptake from the soil

Potassium. Potassium (K) is considered a macronutrient for plants and is the most abundant cation within plant cells. Potassium has a number of important functions within plants, including balancing the charges of cellular anions, enzyme activation, control of stomatal opening/closing and serving as an osmoticum for cellular growth.

Potassium deficiency occurs frequently in plants grown on sandy soils resulting in a number of symptoms including browning of leaves, curling of leaf tips and yellowing (chlorosis) of leaves, as well as reduced growth and fertility.

Potassium uptake processes have been the subject of intense study for several decades. Early studies indicated that plants utilize both high and low affinity transport systems to directly acquire potassium from the soil. Low affinity transport systems generally function when potassium levels in the soil are adequate for plant growth and development. This process is mediated by ion channels in the plasma membrane of root cells, allowing passive transport of K^+ from areas of relatively high external concentration into the plant cells where the concentration of K^+ is lower. The expression of these low affinity transporters does not appear to be significantly affected by potassium availability.

Iron. Iron is essential for plant growth and development and is required as a cofactor for proteins that are involved in a number of important metabolic processes including photosynthesis and respiration. Despite the fact that iron is the fourth most abundant element in the earth's crust, it is often limiting for plants due to the fact that it tends to form insoluble complexes in aerobic soils of neutral to basic pH (Guerinot & Yi, 1994). It is thought that iron limitation is a problem for plants on as much as 30% of soils worldwide. Iron-deficient plants often display interveinal chlorosis, in which the veins of the leaf remain green while the areas between the veins are yellow (Figure 2). Due to the limited solubility of iron in many soils, plants often must first mobilize iron in the rhizosphere (a region of the soil that surrounds, and is influenced by, the roots) before transporting it into the plant. Two distinct mechanisms have evolved that are utilized by plants to acquire iron from the soil, termed the Strategy I and Strategy II responses (Connolly & Walker, 2008).

Figure 2: Iron-deficiency chlorosis in soybean.
The plant on the left is iron-deficient while the plant on the right is iron-sufficient.

Strategy I is used by all plants except the grasses (Figure 3A). It is characterized by three major enzymatic activities that are induced in response to iron limitation and that are located at the plasma membrane of cells in the outer layer of the root.

First, strategy I plants induce the activity of H^+-ATPase, which uses the energy of ATP to pump protons out of the root cells and into the rhizosphere. This activity thus serves to acidify the rhizosphere and the drop in rhizosphere pH solubilizes ferric iron (Fe^{3+}), making it more available for subsequent uptake by the plant. Second, strategy I plants induce the activity of a plasma-membrane-bound ferric chelate reductase. Ferric chelate reductase activity reduces ferric iron to the more soluble ferrous form (Fe^{2+}) of iron. Finally, plants induce the activity of a ferrous iron transporter that moves ferrous iron across the plasma membrane and into the plant.

In contrast, the grasses utilize strategy II to acquire iron under conditions of iron limitation (Figure 3B). Following the imposition of iron limitation, strategy II species begin to synthesize special molecules called phytosiderophores (PSs) that display high affinity for ferric iron. PSs are secreted into the rhizosphere where they bind tightly to ferric iron. Finally, the PS-ferric iron complexes are transported into root cells by PS-Fe(III) transporters.

Interestingly, while both strategies are relatively effective at allowing plants to acquire iron from the soil, the strategy II response is thought to be more efficient because grass species tend to grow better in calcareous soils (which have a high pH and thus have limited iron available for uptake by plants).

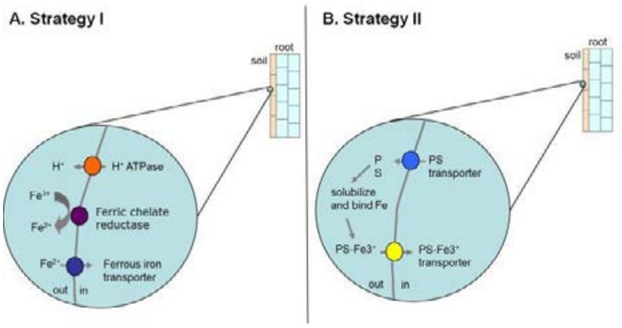


Figure 3: Strategy I and Strategy II mechanisms for iron uptake.

A. Strategy I plants induce the activity of a proton ATPase, a ferric chelate reductase, and a ferrous iron transporter when faced with iron limitation. B. In contrast,Strategy II plants synthesize and secrete phytosiderophores (PS) into the soil in in response to iron deficiency. The PSs bind ferric iron with high affinity and the resulting PS-Fe^{3+} complexes are transported from the soil into the plant root.

Plant acquisition of nutrients: symbioses with soil-based microorganisms

Nitrogen and phosphorus are among the elements considered most limiting to plant growth and productivity because they are often present in small quantities locally or are present in a form that cannot be used by the plant. As a result, the evolution of many plant species has included the development of mutually beneficial symbiotic relationships with soil-borne microorganisms. In these relationships, both the host plant and the microorganism symbiont derive valuable resources that they need for their own productivity and survival as a result of the association.

Nitrogen Fixation. Despite the fact that nitrogen is the most abundant gaseous element in the atmosphere, plants are unable to utilize the element in this form (N_2) and may experience nitrogen deficiency in some soils that have low nitrogen content. Since nitrogen is a primary component of both proteins and nucleic acids, nitrogen deficiency imposes significant limitations to plant productivity. In an agricultural setting, nitrogen deficiency can be combated by the addition of nitrogen-rich fertilizers to increase the availability of nutrients and thereby increase crop yield. However, this can be a dangerous practice since excess nutrients generally end up in ground water, leading to eutrophication and subsequent oxygen deprivation of connected aquatic ecosystems.

Plants are able to directly acquire nitrate and ammonium from the soil. However, when these nitrogen sources are not available, certain species of plants from the family Fabaceae (legumes) initiate symbiotic relationships with a group of nitrogen fixing bacteria called Rhizobia. These interactions are relatively specific and require that the host plant and the microbe recognize each other using chemical signals. The interaction begins when the plant releases compounds called flavanoids into the soil that attract the bacteria to the root (Figure 4). In response, the bacteria release compounds called Nod Factors (NF) that cause local changes in the structure of the root and root hairs. Specifically, the root hair curls sharply to envelop the bacteria in a small pocket. The plant cell wall is broken down and the plant cell membrane invaginates and forms a tunnel called an infection thread that grows to the cells of the root cortex. The bacteria become wrapped in a plant derived membrane as they differentiate into structures called bacteroids. These structures are allowed to enter the cytoplasm of cortical cells where they convert atmospheric nitrogen to ammonia, a form that can be used by the plants. In return, the bacteroids receive photosynthetically derived carbohydrates to use for energy production.

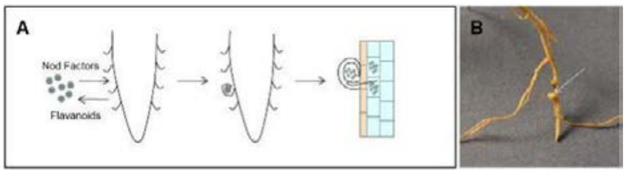


Figure 4: Nodulation of legumes.

A. Process of root cell colonization by rhizobacteria. B. Nodule formed by nitrogen fixing bacteria on a root of a pea plant (genus Pisum).

Mycorrhizal interactions with plants.

In addition to symbiotic relationships with bacteria, plants can participate in symbiotic associations with fungal organisms as well. Current estimates of the frequency of plant-mycorrhizal associations suggest that around 80% of all plants establish some type of mycorrhizal symbiosis, and many studies indicate that these relationships are millions of years old (Karandashov & Bucher, 2005; Vance, 2001). There are two main classes that are generally regarded as the most common and therefore, the most ecologically significant. The endomycorrhizae are those fungi that establish associations with host plants by penetrating the cell wall of cortical cells in the plant roots. By contrast, ectomycorrizae develop a vast hyphae network between cortical cells but do not actually penetrate the cells.

The most common endomycorrhizal interaction occurs between arbuscular mycorrhizal fungi (AMF; also called Vesicular-Arbuscular Mycorrhiza or VAM) and a variety of species of grasses, herbs, trees and shrubs. When phosphate is available in the soil, plants are able to acquire it directly via root phosphate transporters. However, under low phosphate conditions, plants become reliant on interactions with mycorrhizal fungi for phosphorus acquisition. Mycorrhizal spores present in the soil are germinated by compounds released from the plant. Hyphae extend from the germinating spore and penetrate the epidermis of the plant root. Inside the root, the hyphae branch and penetrate cortical cells, where highly branched structures called arbuscules develop (Figure 5). Externally, hyphae extend into the soil beyond the area accessible to the root.

Since plants take up phosphorus at a much higher rate than phosphorus diffuses into the soil surrounding the root, a phosphorus depletion zone is quickly established, limiting uptake of phosphorus by the plant. However, AMF hyphae form a bridge between the internal root environment and the area beyond this depletion zone enabling the plant to acquire significantly more phosphorus through its symbiotic partner than it could on its own (reviewed by Karandashov & Bucher 2005).

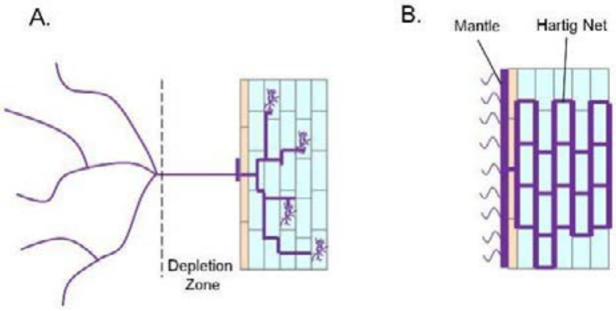


Figure 5: Plant-mycorrhizal fungus interactions.
A. Diagram of arbuscular mycorrhizae colonization of a plant root showing the extension of hyphae beyond the phosphorus depletion zone and the presence of arbuscules in cells of the root cortex. B. Diagram of Ectomycorrhizal fungi showing growth of hyphae around cortical cells, a mantle sheath on the outside of the root, and hyphae that extend into soil around the root. ***(© Nature Education All rights reserved.)***

Ectomycorrhizal fungi (EcM) form associations with many tree species (birch, oak, spruce, pine, fir), making these microorganisms an important component of the biodiversity found in forest ecosystems, particularly temperate and boreal forests in the northern hemisphere. Although the molecular mechanisms underlying initiation of EcM-plant interactions are not well defined, it is clear that signaling molecules are released by both symbiotic partners, resulting in fungal hyphae growth towards compatible plant roots. The EcM forms an extensive hyphal sheath, or mantle, around the root cap and a hartig net of hyphae that extends into the root itself and surrounds the cells within the root cortex. Hyphae from the mantle extend into the surrounding soil, providing availability and storage of nutrients like phosphorus and nitrogen for the plant. This is particularly important for trees growing in forest soils because a large portion of the nutrients available are located in the litter layer and are not accessible to the roots of these trees. The EcM produce enzymes that can digest this organic material and also have the ability to mobilize the nutrients to the hartig net, making them available to the plant. In this way, the interaction between trees and EcM is not only beneficial, but in many cases, is essential .

As is the case with bacterial symbioses, the benefit to the fungal partners in these relationships involves transfer of photosynthetic carbohydrates from the plant to the microorganism for metabolism and energy production. However, the nutritional advantage for plants of such symbiotic relationships far outweighs the energetic cost imposed by hosting microorganisms like rhizobacteria, AMF, and EcM.

Summary

Although plants are non-motile and often face nutrient shortages in their environment, they utilize a plethora of sophisticated mechanisms in an attempt to acquire sufficient amounts of the macro- and micronutrients required for proper growth, development and reproduction. These mechanisms include changes in the developmental program and root structure to better "mine" the soil for limiting nutrients, induction of high affinity transport systems and the establishment of symbioses and associations that facilitate nutrient uptake. Together, these mechanisms allow plants to maximize their nutrient acquisition abilities while protecting against the accumulation of excess nutrients, which can be toxic to the plant. It is clear that the ability of plants to utilize such mechanisms exerts significant influence over crop yields as well as plant community structure, soil ecology, ecosystem health, and biodiversity. ***(By: Jennifer B. Morgan (Science Department, York Technical College) & Erin L. Connolly (Department of Biological Sciences, University of South Carolina), Source: Nature Education)***

瑞丰生态

Guangdong Ruifeng Ecology and Environment Technology Co.,Ltd. is headquartered in Nansha Free Trade Zone in Guangzhou. It is a national high-tech enterprise focusing on soil repair & agriculture of quality, integrating scientific research & development, production & sale, and project industrialization. The two major production bases locate in Nansha, Guangzhou, and Xuancheng, Anhui, with a total annual production capacity of 800,000 tons of new functional fertilizers plus high tower compound fertilizers and other products.

Ruifeng adheres to the concept of developing green ecology, high-quality and high-yield agriculture, has always attached importance to independent innovation in science and technology, and has maintained close cooperative relations with scientific research institutions & agricultural research & development institutions such as the Chinese Academy of Agricultural Sciences and South China Agricultural University for a long time. Soil repair & crop nutrition protection institutions, new functional fertilizer engineering research and development center were established, which formed a large-scale production capacity of various di□erentiated and innovative special fertilizers. The main new-type functional fertilizers and high tower compound fertilizers are sold in 21 provinces and autonomous regions including Guangdong, Hainan, Yunnan, Liaoning, Shandong, Guangxi, and Zhejiang, etc.

Since 2017, Ruifeng have been successively reached deep strategic cooperative relations with companies and R&D centers in Norway, Spain, Germany, Japan, South Korea, Malaysia, Thailand. It achieved gratifying results in terms of technology research & development, brand cooperation & product production, service promotion, etc.

Being ahead, pioneer and innovate. Ruifeng will adhere to the enterprise positioning of "China soil repair system solution provider ", and always implement both product development and agrochemical services. The company's guidelines are dedicated to the maintenance of Chinese soil and the new era of agriculture with green, healthy, high-quality and high-yield agricultural products.

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- Soil Conservation Institute
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- Crop Nutrition Protection Institute
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- Vice Chairman Unit of China Green Ecological Environment Repair Alliance

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