Greetings from Guelph! I'm Tom Bruulsema, with Plant Nutrition Canada. It's great to have the chance to speak to you in this eighth global nitrogen conference. My topic is sustainable plant nutrition and nitrogen. To address it I'm going to describe a new paradigm developed by the Scientific Panel on Responsible Plant Nutrition.

The Panel was formed as an independent science think tank in early 2020. It is supported by IFA, the International Fertilizer Association. These 11 experts from different world regions have all contributed their perspectives to my talk here today. Our vision is that Responsible Plant Nutrition nourishes plants in a sustainable manner, enhancing earth's capacity to support healthy life.

SCIENTIFIC PANEL
ON RESPONSIBLE PLANT NUTRITION

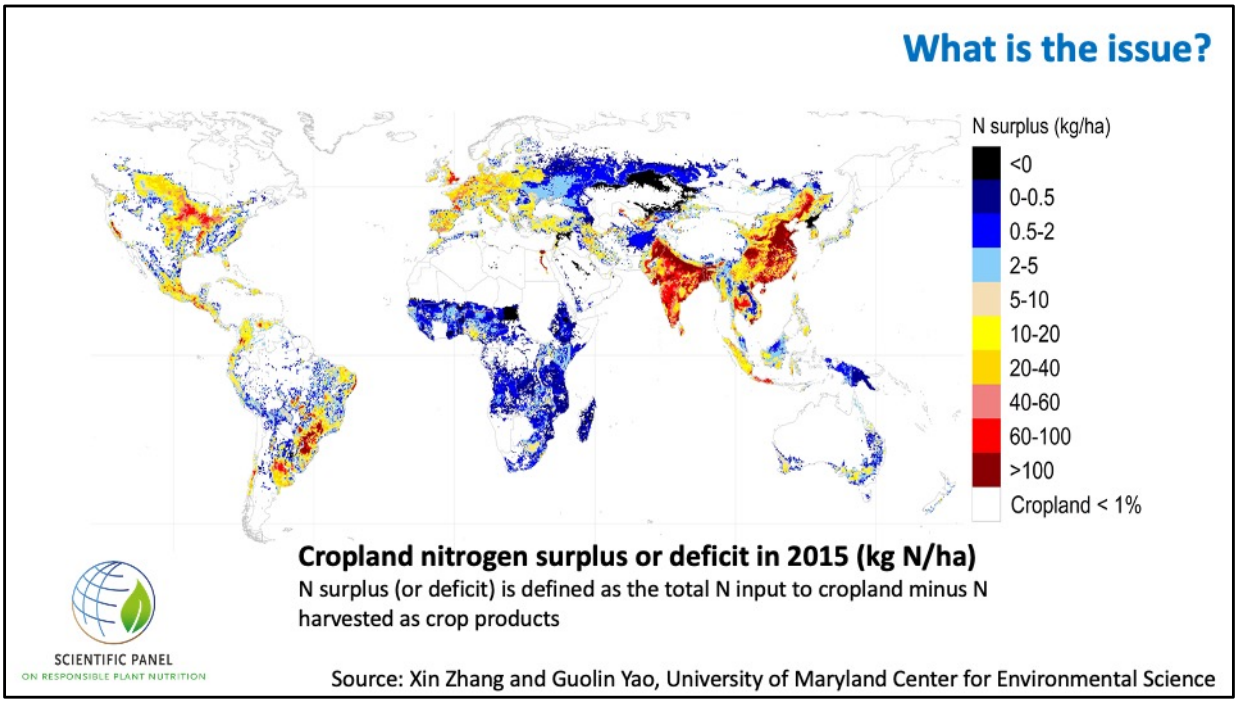
A NEW PARADIGM FOR PLANT NUTRITION

Issue Brief, November 2020

What is the issue?
What can be done?
Who needs to do what?
What will success look like?

https://www.sprpn.org/

The Panel, led by Achim Dobermann, produced an issue brief on a New Paradigm for Plant Nutrition at the end of last year. It aimed to provide a deeper scientific review of the issues involved and define its key elements. This brief has been accepted as a contribution to the UN Food Systems Summit.

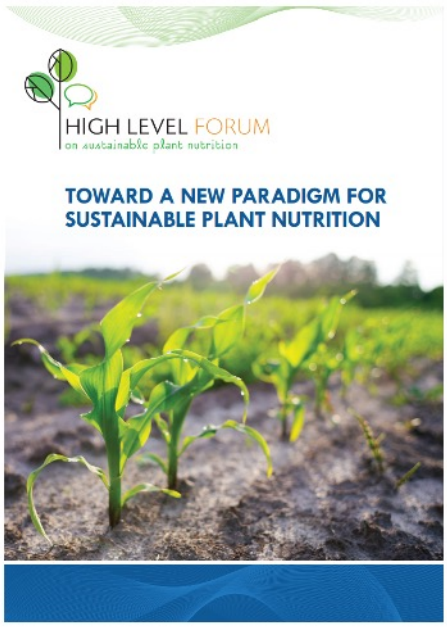


The “old paradigm” supported a massive increase in crop yields in many parts of the world. But rising crop production was closely coupled with rising input of nitrogen. This has led to a situation where some areas have large surpluses of nitrogen inputs over outputs *and environmental pollution,* and some have large nitrogen deficits *and soil mining*. There are significant environmental costs and there is an urgency to act now, particularly with regard to climate change and biodiversity.

Productivity and food security are still critical needs, but the new paradigm for plant nutrition must embrace a food systems approach with all of its sustainability dimensions, including

- **GHG emission reduction, carbon sequestration**
- **Pollution and biodiversity**
- **Waste and nutrient recycling**
- **Nutrition and health**

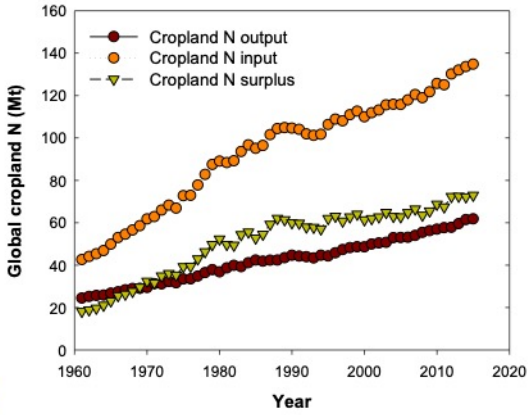
https://www.highlevelforum.org/
November 2019



Sustainability has also become a business necessity. IFA's High-Level Forum in 2019 moved toward a new paradigm for sustainable plant nutrition, including what industry must do. Embracing a food systems approach needs to address greenhouse gases, soil carbon, pollution, biodiversity, recycling, and human health. The big question is how to do this in different parts of the world, in different companies, in policy, and in science.

What is the issue?

1 **How can future growth in crop production be decoupled from growth in fertilizer consumption?**



Global trends in crop nitrogen inputs and outputs (million t)

N surplus = total N input to cropland minus harvested N as crop products

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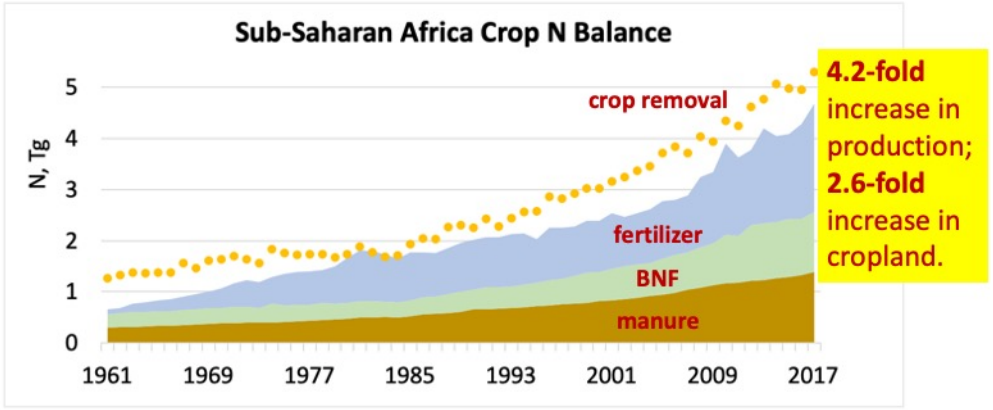
Source: Xin Zhang and Guolin Yao, University of Maryland Center for Environmental Science

The brief features ten tough questions that define the issue. The first is “How can future growth in crop
production be decoupled from growth in fertilizer consumption?” This means reducing the rate of fertilizer
consumption growth and increasing nitrogen use efficiency through better management at field scale, and more recycling. It means declining use of fertilizer in some world regions as compared to still having to massively increase fertilizer use in others.

What is the issue?

2 **What are the key measures to double or triple crop yields in Africa with increasing and balanced nutrient inputs?**



Crop N removal by far exceeds N inputs from fertilizer, manure and biological fixation (BNF) in sub-Saharan Africa. Source: IFA Nutrient Use Efficiency database, 1961-2017.

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The second tough question is “What are the key measures to double or triple crop yields in Africa with increasing and balanced nutrient inputs? ” Average crop yields remain low in most of Sub-Saharan Africa. Crop nitrogen removal has exceeded nitrogen inputs for many decades. Nitrogen use efficiency here is too high, indicating widespread and unsustainable levels of soil nutrient depletion, essentially mining the soil for its organic nitrogen. The four-fold increase in crop removal shown here comes largely from expansion of cropland area by 2.6 fold. Yields increased by less than 60 percent. Doubling or tripling those yields is a major challenge. The potential is there, and the need is urgent.

What is the issue?

3. What data-driven technologies, business solutions and policies will accelerate the adoption of more precise nutrient management solutions by farmers?
4. Can nutrient losses and waste along the whole agri-food chain be halved within one generation?
5. How can nutrient cycles in crop and livestock farming be closed?
6. How can we improve soil health?
7. How should we manage nutrition of crops in changing climates?
8. What are options and targets for reducing fertilizer-related GHG emissions?
9. How can cropping systems deliver high quality, more nutritious food?
10. How can we better monitor nutrients and implement high levels of sustainability stewardship?

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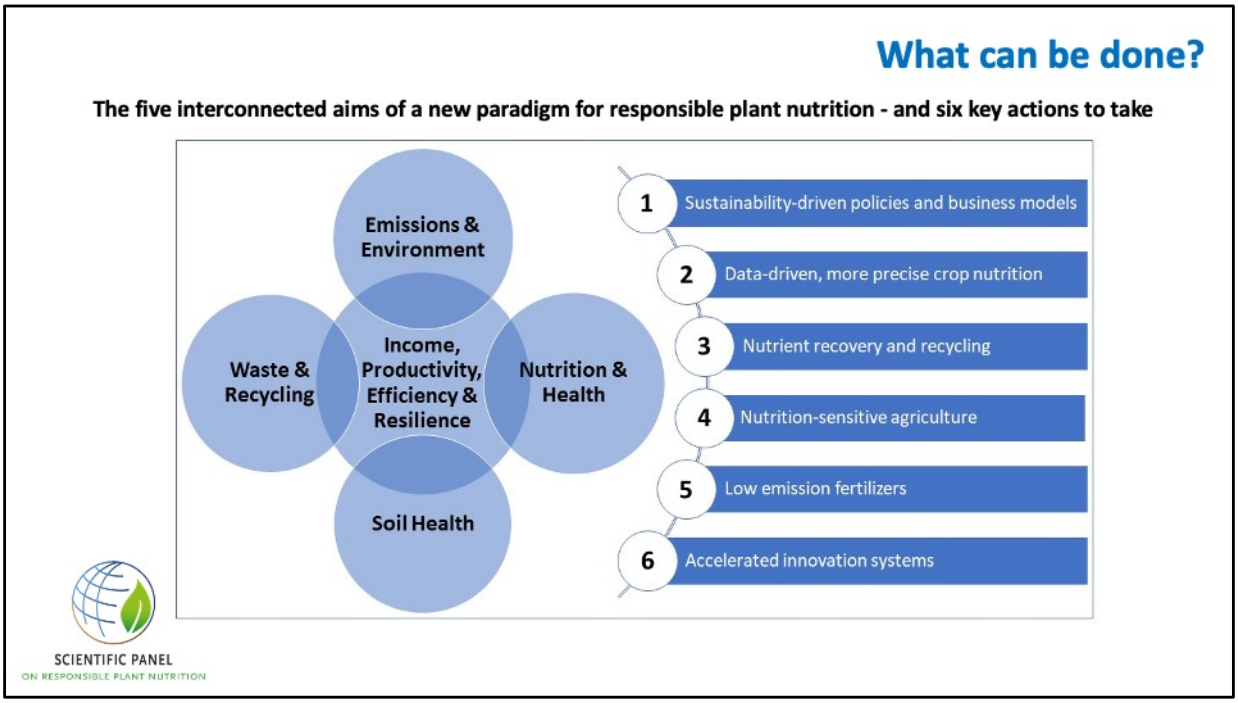
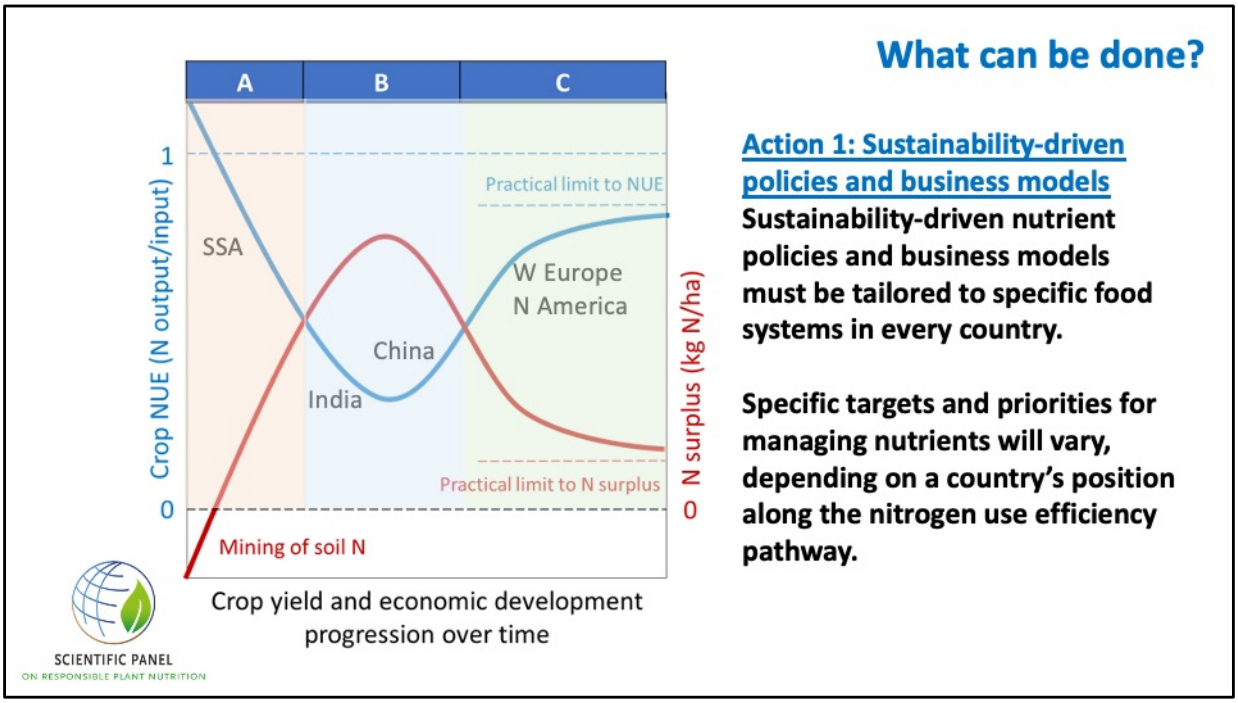
The Panel raised 8 other tough questions addressed by the new paradigm. All of them are relevant to nitrogen. I'll not go into detail on the questions today; but most are addressed by the actions I'm going to outline.



What can be done? The Panel identified five interconnected aims, and six actions. Farmers' income and productivity, with efficiency and resilience, are still critical needs, but the new paradigm must embrace a food systems and circular economy approach that addresses all sustainability dimensions, including:

- Emissions & Environment – losses affect the quality of water and air, greenhouse gases and biodiversity
- Improving human nutrition and health
- Improving soil health
- Minimizing waste and maximizing nutrient recovery and recycling

Six key actions are proposed, but the specific targets, roadmaps and concrete solutions will differ among regions and countries. Let's look more closely at these 6 actions.



Action 1 deals with sustainability driven policies and business models. A key metric is nitrogen use efficiency or surplus. The blue curve shows the typical progression of NUE over time, whereas the red curve illustrates the corresponding N surplus and risk of environmental pollution. At the early stages of crop intensification (A), nitrogen fertilizer use rises from a very low level and is driving crop yields and farming profits, but also generating a growing N surplus. Historically, this then leads to a longer period (B) during which NUE is very low and N surpluses may become excessive. In phase (C), more knowledge intensive N management approaches and technologies are being widely adopted, which in turn enable continued high crop yields and profitability through rising NUE, while decreasing the N surplus. There are practical limits for both NUE and N surplus. Countries, businesses, and farmers can do much to accelerate moving toward those limits. Continued crop yield improvement at this stage depends on massive investment in plant breeding and production technologies.

What can be done?

Action 2: data-driven more precise crop nutrition

Knowledge-driven solutions and novel technologies will allow tailoring nutrient formulations and applications to local needs in an increasingly precise manner.

They need to be upscaled to millions of farmers through digitally supported advisory systems and integrated business solutions.

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NUTRIENT EXPERT®

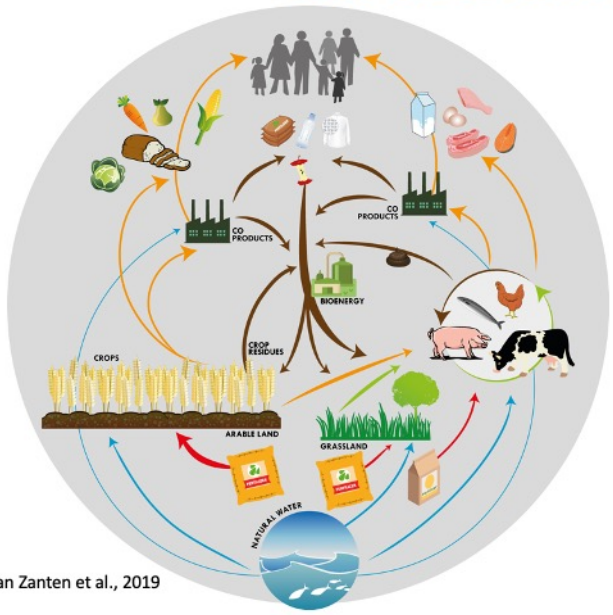
Action 2 is data-driven, more precise crop nutrition. Numerous good solutions have been developed for a more site-specific management of nutrients in different environments, and more can be developed now by taking full advantage of the innovation in digital technology and other areas. Nutrient Expert is an example of a decision support tool that has been applied to cropping systems in Asia and Africa. However, scaling up such tools to help millions of farmers change their nutrient management practices is the next frontier.

What can be done?

Action 3: Nutrient recovery/recycling

Crop-livestock integration, less food waste, by-products use and increased nutrient recycling are key measures to optimize nutrient use efficiency across the full food chain.

Political incentives, novel technologies and shifts in behavior will drive greater nutrient recovery from multiple waste streams, as part of circular, bio-based economies.



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Re-drawn and modified from van Zanten et al., 2019

Action 3 is nutrient recovery and recycling. Essentially this involves making nutrient flows more circular in crop-livestock-human systems. Paying more attention to the nitrogen flows associated with the brown arrows in the center of the diagram can reduce nitrogen leakages and improve full-chain efficiencies.

What can be done?

Action 4: Nutrition-sensitive agriculture includes the targeted enrichment and application of fertilizers to deliver nutrients of importance to crop, animal and human health (e.g., N, Fe, Zn, Se, I).

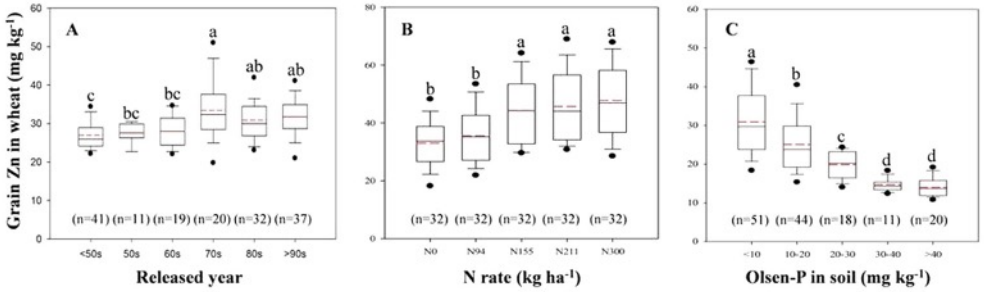

Figure 2. Measures of the "Green Revolution" including historical shift of varieties (**A**), N application rate (**B**) and elevated soil P concentration due to continuous application of P fertilizer (**C**) affect grain Zn in wheat grown in China. These historical varieties were grown in the same field at the North China Plain. And their grain Zn

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Chen, X.-P., Y.-Q. Zhang, Y.-P. Tong, Y.-F. Xue, D.-Y. Liu, et al. 2017. Harvesting more grain zinc of wheat for human health. Sci. Rep. 7(1): 7016. doi: 10.1038/s41598-017-07484-2.

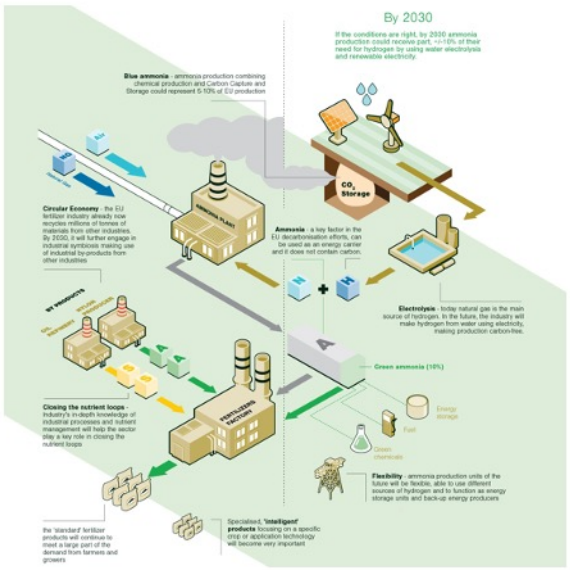
Action 4 is nutrition-sensitive agriculture, applying nutrients not only for yield but also for specific nutritional qualities of the product. In this example from China, the concentration of zinc in wheat grain was found to be positively associated with nitrogen fertilizer rate, but negatively with phosphorus levels in the soil.
While it can't be generalized that more nitrogen always improves quality, the point is that responsible plant
nutrition pays attention to nutritional quality as well as yield, and addresses the needs of animals and hmans for micronutrients.

What can be done?

Action 5: Low-emission fertilizers

Fertilizers will increasingly be produced in an environmentally friendly manner and they will embody greater amounts of knowledge to control the release of nutrients to the plant.

A new "green ammonia economy" could feed and power the world in a whole new, decentralized manner.



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Fertilizers Europe

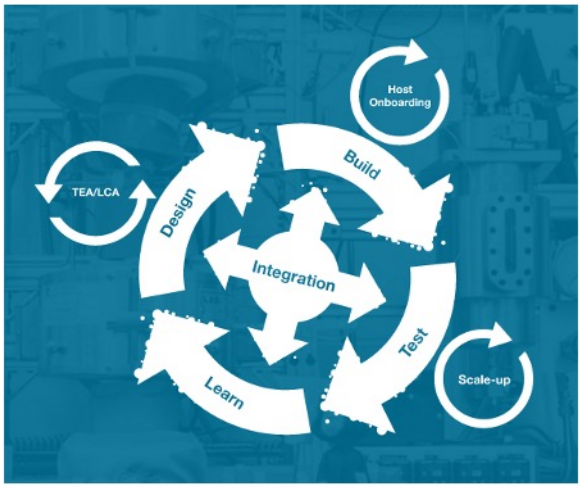
Action 5 is low-emission fertilizers. Fertilizers can be more friendly to the environment. Nitrification inhibitors and controlled-release forms reduce nitrous oxide emission more than they increase nitrogen use efficiency. Fertilizer manufacturing footprints can also be reduced. In the past year, several of the world's largest fertilizer producers have announced investments, on the order of hundreds of millions of dollars, into production of green and blue ammonia. A vision for Europe suggests that by 2030 up to 10% of all ammonia could be produced from renewable electricity by using renewable hydrogen feedstock.

What can be done?

Action 6: Accelerated, more open innovation systems for faster translation of new ideas into practice

This requires more investment, collaboration, risk taking and entrepreneurship by industry, but also a massive culture change in science and science funding.

Science → Invention → Innovation



https://agilebiofoundry.org/

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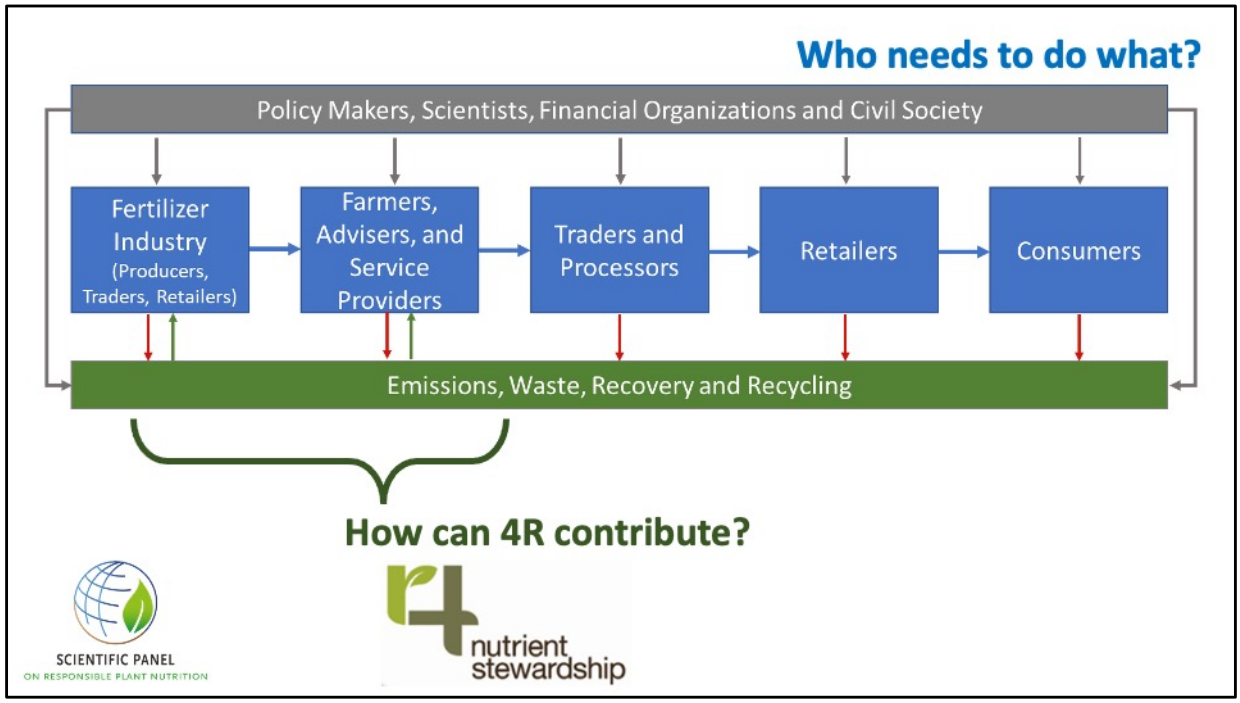
Action 6 is accelerated innovation. We need more investment in research and development by public and private sectors, but we also need leaner science to innovate, codevelop and scale up faster. Science can have much more impact by adapting elements of problem-driven entrepreneurship and startup culture. Farmers have always been innovators; agriculture service providers need to innovate too, and can play a role in disseminating innovations among farmers.



Responsible plant nutrition is a complex and global challenge which can only be tackled through concrete action by all those directly involved in the nutrient cycle, and those influencing it. This figure depicts the agri-food chain from a nutrient management perspective. Blue boxes show actors who directly contribute to nutrient use and losses at different stages. Red arrows show those losses from all parts of the chain. Green arrows show opportunities to increase nutrient recovery and return to farming and industry. The grey box shows the influencers, those who drive innovation or set the societal framework for action. Currently, the Panel is working on two big issues. One is biodiversity, the other is the future of 4R. We are asking, **How can 4R Nutrient Stewardship contribute to Responsible Plant Nutrition**? While its focus on nutrient applications limits its reach, it plays an important role. We may need to redefine its principles to increase its focus on a wider range of nutrient sources, and a wider range of impacts.

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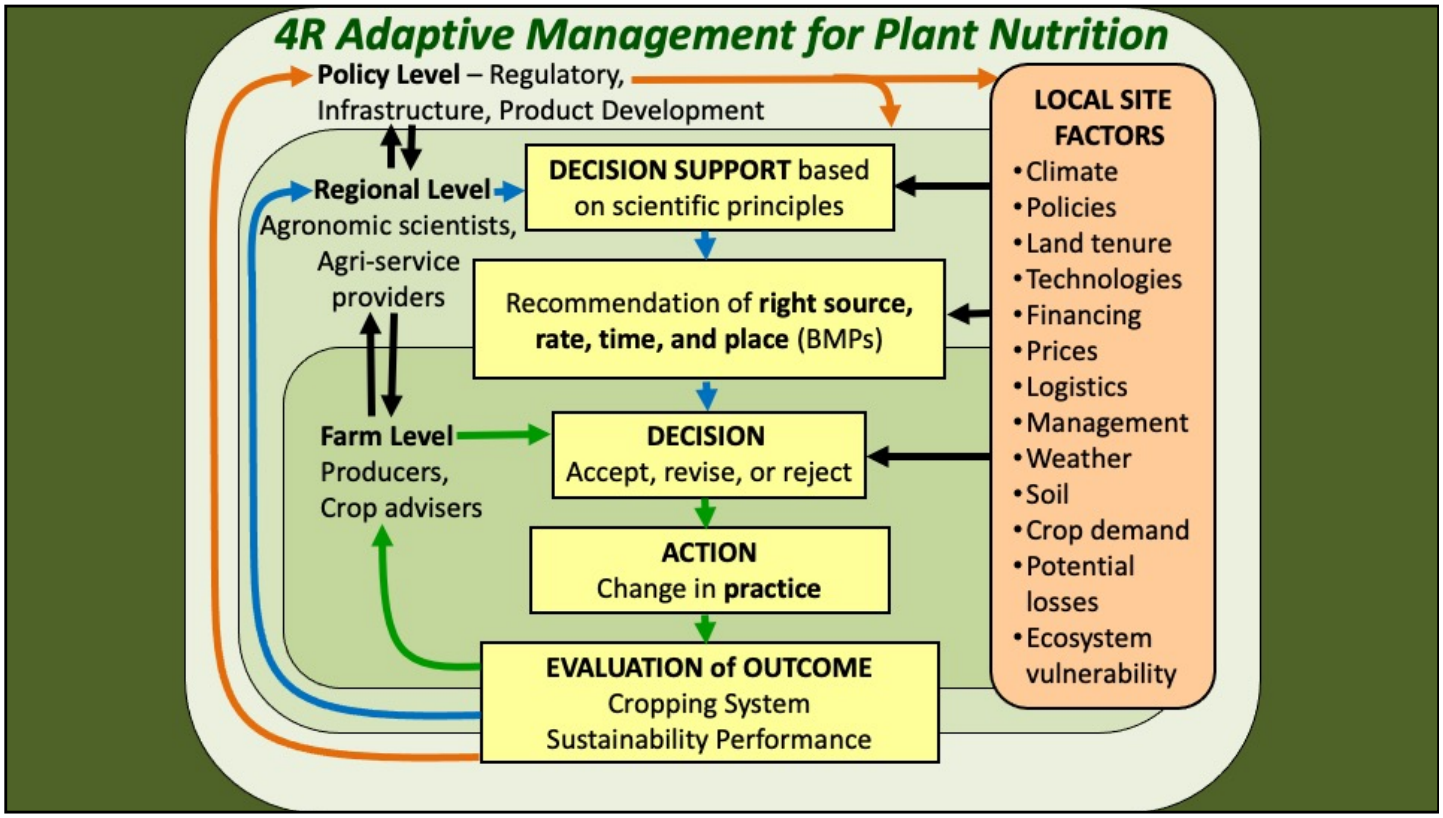
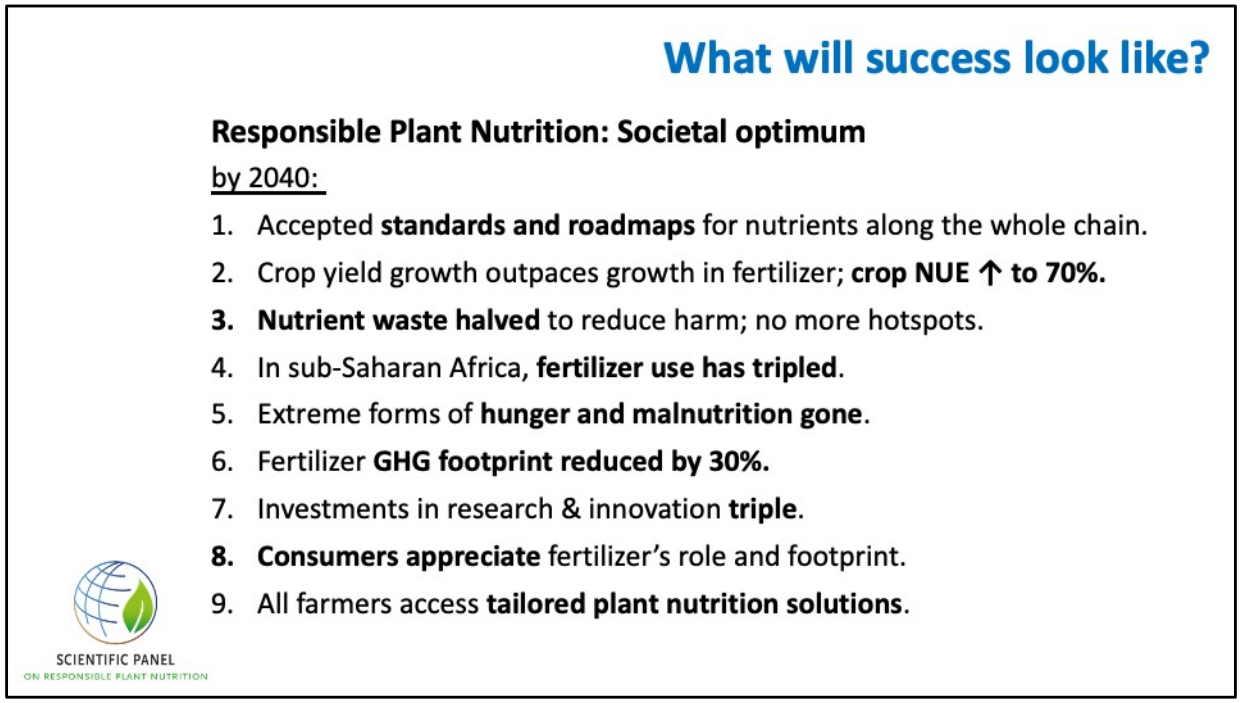


The 4Rs have always included adaptive management, applying to farm, regional and policy levels. This diagram, too, identifies a range of actors playing important roles. Here we have farmers, crop advisers, agri-service providers, agronomic scientists, governments, and industry leaders. To further the contribution of 4R to **responsible plant nutrition**, we need to get more specific about the roles each of these actors can play.



The outcome of Responsible Plant Nutrition will be a new societal optimum rather than a purely economic one. By 2040, we envision:

1. Accepted standards and roadmaps for nutrients along the whole chain.
2. Crop Nitrogen Use Efficiency increased to a global average of 70%, from the 50% of today.
3. Nutrient waste halved to reduce harm; no more hotspots.
4. In sub-Saharan Africa, fertilizer use has tripled.
5. Extreme forms of hunger and malnutrition gone.
6. Fertilizer greenhouse gas footprint reduced by 30%.
7. Investments in research & innovation tripled.
8. Consumers appreciate fertilizer's role and footprint.
9. All farmers access tailored plant nutrition solutions.

So far despite many scientific and technical solutions that have existed for decades, we have failed to achieve these nine outcomes. Achieving it now, within one generation, will require a far more concerted effort by everyone involved, including the fertilizer industry, farmers, agricultural and food supply chains, scientists, and consumers.

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Thank you

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Thank you for listening. For more detail on the New Paradigm, please see the Issue Brief itself.