Towards global phosphorus security through nutrient reuse

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ABSTRACT: It is not widely recognised that the reuse of phosphorus will be crucial to achieving future food security, supporting farmer livelihoods and buffering against emerging geopolitical risks. All farmers need access to phosphorus fertilisers to grow crops, yet just five countries control 85% of the world's main source: phosphate rock. Morocco alone controls three-quarters of the world's remaining phosphate. These phosphate reserves are non-renewable, and becoming increasingly scarce and expensive. Already one in six farmers cannot access fertiliser markets. The 800% phosphate price spike in 2008 demonstrated the vulnerability of global and local food systems to even a short-term disruption in supply. At the same time, a staggering 80% of phosphorus is lost or wasted in the supply chain between mine, farm and fork. Much of this ends up in rivers and lakes, leading to widespread nutrient pollution and algal blooms. The good news is that phosphorus can be recovered and reused from all organic sources in the food system: food waste, human excreta, manure, crop waste. Indeed, there are over 50 low- to high-tech solutions. However, phosphorus vulnerability is very context-specific, and what works in one country may be inappropriate or ineffective in another region. This case study highlights a path forward, including examples from Vietnam, Malawi and Australia. Investing in phosphorus reuse creates locally available 'renewable fertilisers'. This simultaneously: reduces dependence on imports from geopolitically risky regions and therefore buffers against future price spikes and supply disruptions; reduces phosphorus waste in the food supply chain; and reduces the risk of nutrient pollution.

Keywords: phosphorus recovery, fertiliser price buffer, food security

This paper is about nutrient reuse in response to one of the biggest emerging global sustainability challenges for food security: global phosphorus scarcity. Without phosphorus we cannot grow food anywhere in the world. Hence we urgently need to be looking at innovative ways to recycle phosphorus and other nutrients. There are many dimensions to the global phosphorus challenge (e.g. Figure 1), including reuse of waste. Eighty per cent of phosphorus is lost between mine and farm and fork. Much of that lost nutrient ends up in waterways where it can feed toxic algal blooms.

Phosphorus is a resource that every farmer in the world needs; yet the world's high-quality mineral resources are finite and becoming increasingly

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This is an edited transcript of the presentation, with some of the powerpoint slides shown.

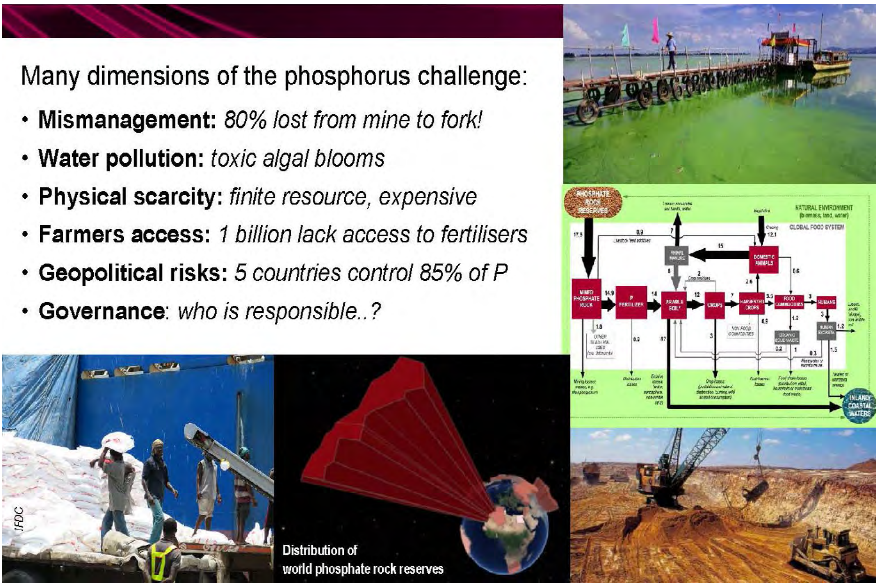

Figure 1. The global phosphorus challenge.

scarce and expensive. Several scientific studies suggest demand could exceed current supply by mid-century. Yet even today there are already up to a billion smallholder farming families in the world who cannot access fertiliser markets. In landlocked countries in sub-Saharan Africa in particular, farmers can pay 2–5 times more for their fertilisers than farmers do in, say, Europe.

Perhaps one of the most concerning dimensions of global phosphorus scarcity is the geo-political risk. Only five countries control 85% of the world's remaining phosphate rock, and one family alone controls three-quarters of that supply.

Given the gravity of this situation, it is quite concerning that there is scant or no effective governance on global, national or local scales to ensure phosphorus security into the future. We define phosphorus security as ensuring all farmers have access to phosphorus; that our soils are fertile and agriculture is productive; that up to 9.5 billion people have access to healthy diets; and that our rivers, lakes and oceans are clean, free from nutrient pollution.

The good news is it is possible to avert the crisis. Indeed, there is a whole toolbox of technologies and behavioural change options that we can think about, systematically through the food system. Examples (Figure 2) of this spectrum range from efficient phosphorus use on-farm, to changing diets, to recycling of phosphorus from manure or food waste, crop residues and human excreta.

Even for recycling phosphorus from human excreta, there are over 50 different technologies available, from the small-scale low-tech urine-diverting composting toilet which can be used, for example, to grow onions in Burkina Faso, right through to the large-scale high-tech expensive technologies like phosphorus recovery from wastewater treatment plants. The bottled white crystals (Figure 2,

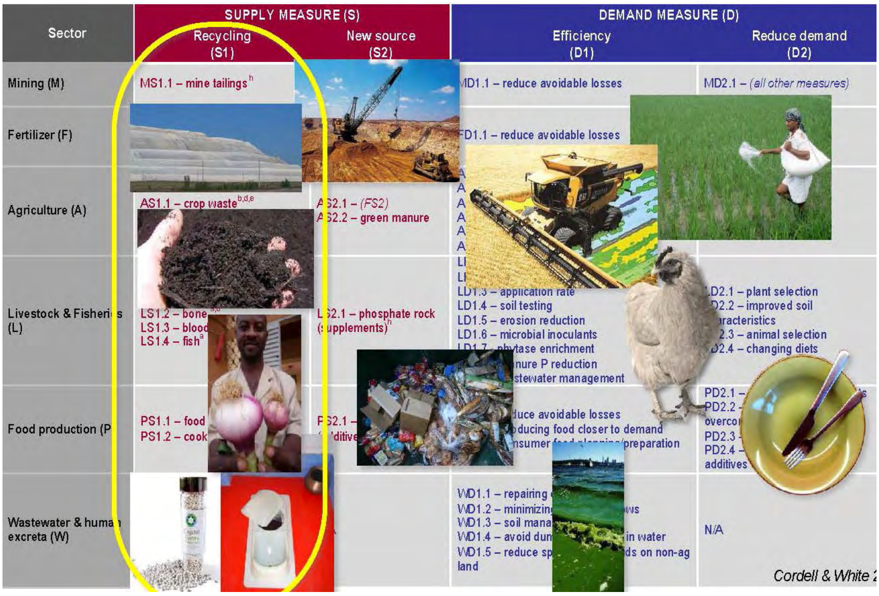

Figure 2. Toolbox of sustainable phosphorus supply and demand measures.
Source: Cordell & White 2013

bottom-left) are struvite, produced by dosing a side-stream of wastewater with magnesium; pure magnesium ammonium phosphate crystals emerge, which a wastewater treatment plant can bag and sell on-site.

These technologies are all context-specific. Although there is a suite of options, it is very important to implement only those that are most appropriate and cost-effective for a given city, country or region. Implementation also needs policy instruments, and for policy makers and other stakeholders to make the right technologies work effectively in practice.

Case studies of phosphorus recovery and recycling opportunities

Malawi

In Malawi, agriculture is largely based on subsistence maize farming. The fertiliser subsidy was scaled back somewhat in the last budget. The country is vulnerable to phosphorus scarcity, partly because it is landlocked and very heavily dependent on phosphate imports via their neighbours – hence good relations with neighbours such as Mozambique are important (Figure 3).

We have calculated that human excreta in Malawi contains roughly as much phosphorus as they are importing from Morocco, China and other countries. There is only one major fertiliser company in this country, and one product manager. There is an opportunity to see how Malawi might implement some of these phosphorus recovery options. While there was not much initial interest in phosphorus recovery from human excreta, it emerged that a major concern was the economies of scale: 'Don't talk to me about five tonnes a day. Come back when you've got a hundred tonnes a day and then we'll talk business.' So now we are looking at how we can mobilise action there.

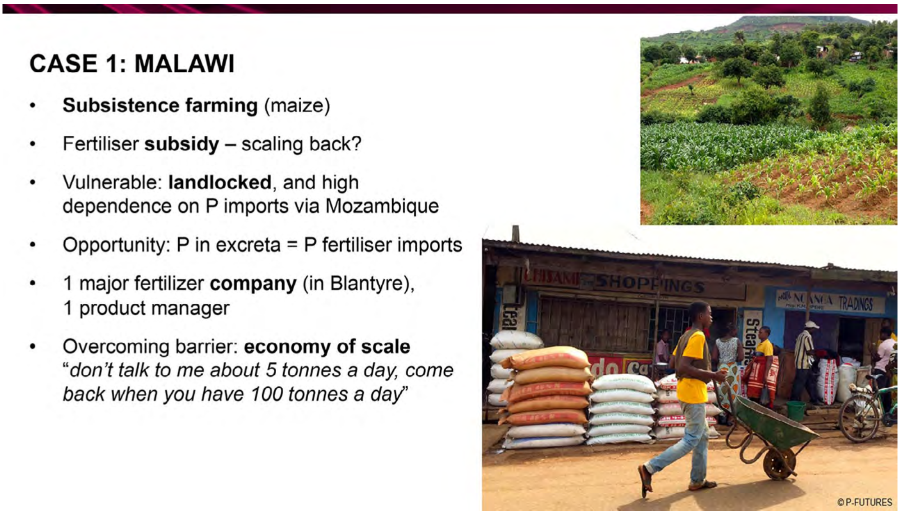

Figure 3. Phosphorus recycling opporunities in Malawi

Vietnam

The next case study comes from peri-urban Hanoi, in Vietnam (Figure 4). This city's jurisdiction recently expanded to 'Greater Hanoi' which now encompasses one-third of the province, including areas that used to be rural and that, because of the centralised governance in that part of the world, were designated 'safe food districts'. One district might be designated for fruit and vegetables, while another might be the livestock district. Traditional recycling of organic waste meant that there was some reuse of manures, but not much reuse of household organic waste, most of which went to landfill. However, in some instances, mixed municipal waste (topped with some sewage sludge) is composted but

Figure 4. Phosphorus recycling opporunities in Hanoi, Vietnam.

largely untested. So the levels of pathogens, heavy metals, etcetera, are largely unknown to farmers who are collecting the compost for free and using it on their farms.

Hanoi has an extremely ambitious and green '2030 Greater Hanoi Master Plan' which includes targets for 70% recycling of compost. Therefore, working with urban planners and other stakeholders in Hanoi can potentially fast-track phosphorus and nutrient recycling through these ambitious targets.

I want to stress the importance of engaging urban planners when we are talking about food consumers, who are largely in the cities. We need to be thinking about strategically designing waste-recycling systems upfront.

Australia

My final example comes from Australia (Figure 5). Although Australia is a net food-producing country and food exporter we are very vulnerable to phosphorus scarcity, though in a different way. Australia is a net importer of phosphorus, because while our soils are largely naturally phosphorus deficient we have invested quite heavily in phosphorus-intensive agricultural export industries. In our beef and live animals, wheat and dairy products, we are literally shipping phosphorus off our shores. Even if we were to recover all the phosphorus in human excreta in Australia, it would represent less than 5% of Australia's total phosphorus demand.

We need to think about different options in this country. Up to 90% of Australia's population lives in the cities, and they are therefore phosphorus hotspots for excreta and food waste and other sources. My team has been geo-spatially mapping those hotspots. We are also working with the major fertiliser retailer in the Sydney Basin.

This fertiliser producer has a really innovative business model, selling not a product but a service. When a customer comes to them asking for fertilisers,

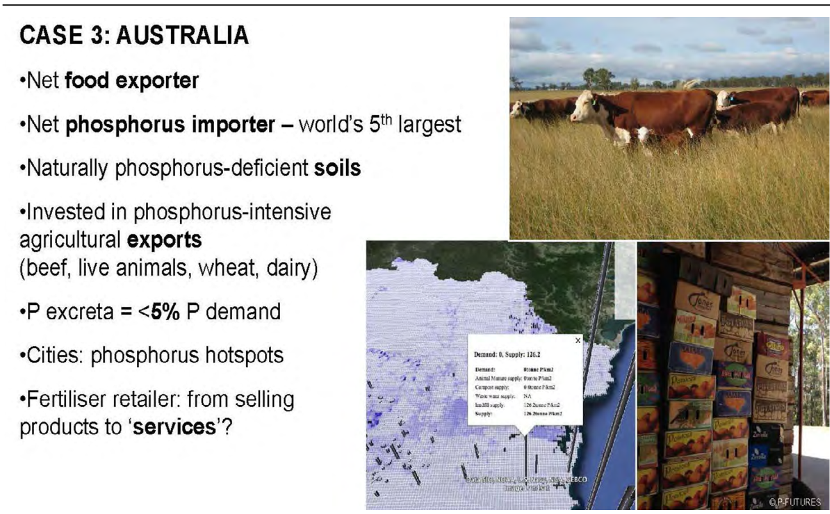

Figure 5. Phosphorus recycling in Australia may include innovative business models.

they only sell them fertiliser after they have tested the customer's soil. Most (99%) of the time the soil is already saturated in phosphorus largely as a result of the use of excess poultry manure in the Sydney Basin. This business is selling an agronomic service, and this is a really good business model which is a win–win for them and gives them a market edge. It is good for the farmer customer's productivity and it is good for the environment because it results in less phosphorus being applied to the soil to later run-off into our waterways.

Why recycle phosphorus and nutrients

Recycling can and must play a role in achieving future phosphorus and food security, both in this country and in the rest of the world, because it creates locally available renewable fertilisers.

We talk about renewable energy, and we really need to become serious and talk about *renewable fertilisers* as well. Human excreta alone can contain 3 million tonnes every year of elemental phosphorus, globally. The opportunities are right there.

Recycling also would facilitate what we can call 'phosphorus sovereignty', particularly for communities around the world where farmers have poor access to fertilisers.

At the national scale, renewable fertilisers can reduce countries' dependence on imports from some of the geo-politically risky areas where phosphate is being produced, and so buffer against some of the future price spikes and supply disruptions. You may not have been aware that in 2008 there was an 800% price spike in phosphate. It had dramatic consequences around the world, including in Australia.

With the shorter phosphorus cycles in a circular economy, of course we have less waste and potentially less lifecycle energy – and of course less risk of phosphorus run-off to waterways, feeding algal blooms.

Important considerations

Finally, a few considerations we need to keep in mind on this pathway towards nutrient recycling and phosphorus security (Figure 6).

- **Context matters**. We have all these technologies available, and we cannot import solutions from one country to another. Therefore there needs to be a framework for thinking about the most cost-effective and appropriate measure for each situation.
- **End-user preferences matter**. In designing new products, we need to engage the market end-user to understand their needs and preferences, because that is often where some of the barriers are.
- **Look for partnership opportunities**. In a circular economy, we need to be forming new partnerships between the sectors and stakeholders in the circular value chain. As I mentioned, those partners also need to include the urban planners when talking about cities.
- **Look for new business models**, such as selling services instead of products. Using 'Uber farm machinery' (Gulati, this Proceedings) is another example.

- **Context matters** - assess which of 50+ nutrient recovery technologies are appropriate, cost-effective & optimal
- Product design: need to understand **market end-user** (farmer)
- New potential **partnerships** between fertiliser sector, sanitation sector, urban planners, scientists, etc (whole reverse supply-chain in a circular economy)
- New **business models** – from selling a 'product' to a 'service' (e.g. nutrient security)
- **Cost-competitive** with fertilisers? Consider not just market price of P, but farm-gate price

Figure 6. Considerations on the pathway to nutrient recycling and phosphorus security.

- **Cost competitiveness**. Is recovering nutrients cost-competitive with fertilisers based on rock phosphate? It is not appropriate to compare fertilisers on the basis of the market price alone, because for the farmers it is the farm-gate price that matters. If recovered nutrients are compared to rock phosphate fertilisers at the farm-gate price, then there are opportunities to show that recovered phosphorus can be a cost-competitive product that has the added advantages of building food security, environmental integrity and livelihood security as well.

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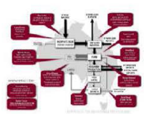

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Dana Cordell leads and undertakes international and Australian research projects on sustainable food and resource futures. Many projects involve high-level stakeholder engagement to improve the policy relevance and impact, and foster mutual-learning. Dr Cordell leads the collaborative P-FUTURES project across Australia, Vietnam, Malawi and the US, which, together with local stakeholders, aims to identify how urban food systems can cope with or transform in response to the emerging global phosphorus challenge. In 2008, Dr Cordell co-founded the Global Phosphorus Research Initiative – the first global platform to undertake research, policy and public engagement to ensure food systems are resilient to the emerging global challenge of phosphorus scarcity. Dr Cordell currently leads the Mapping Sydney's Potential Foodsheds project, which brings together key stakeholders such as NSW Farmers, Department of Primary Industries, Department of Planning and RDA-Sydney. The project aims to increase the resilience of Sydney's food system to global and local challenges (from climate change to urban growth) through participatory stakeholder workshops and geospatial mapping scenarios. As a global food security expert, Dr Cordell provides expert advice and commentary to the United Nations Environment Programme (UNEP), Australia's Chief Scientist and the UK Parliament. She most recently joined UNEP's Global Environment Outlook team as a global food security contributor. Dr Cordell's research contributions have led to numerous prestigious recognitions, including one of Australia's top science prizes, the Eureka Prize for Environmental Research (2012). She has been named as one of the 100 Women of Influence (*Australian Financial Review*/Westpac 2013) and the Top 100 Most Influential People (*Sydney Magazine* 2012). She is frequently interviewed for the media, including Radio National, ABC *Lateline*, and *The Times* in UK.