DISCUSSION PAPER 2

Priority measures and mutual opportunities: Planetary boundaries and the food system in Australia and China

Stuart White, Dana Cordell and Bernardo Mendonca Severiano
Institute for Sustainable Futures, University of Technology Sydney
November 2024

1. Introduction

Transforming the food system towards net zero emissions and phosphorus resilience will require bold initiatives and cooperation across disparate sectors in the food system, from fertiliser producers to supermarkets, from livestock sector to consumers. The good news is that many initiatives are already underway which can be scaled-up and -out, many of which provide co-benefits for food security, job creation, public health, and biodiversity.

This Discussion Paper identifies several priority measures that could reduce the impact of the food system on two of the planetary boundaries in Australia and China, and the mutual benefits that could result from implementing these measures. The two planetary boundaries are climate change, because of increased greenhouse gas emissions, and the use of the critical nutrient, phosphorus.

As described in Discussion Paper 1 (White and Cordell 2024), achieving net zero emissions consistent with the Paris agreement will require decarbonising our food systems. The food and agricultural systems generate about a third of global human-made greenhouse gas emissions (Crippa *et al*. 2021).

The food system is also the largest single cause of widespread phosphorus nutrient pollution of our lakes, rivers and oceans, leading to fish kills and 'Dead Zones' (Brownlie *et al*. 2022). Further, while phosphorus is essential to growing food in the form of fertilisers, its global use currently depends on finite, risky and increasingly expensive supply chains (Cordell & White 2014).

The PACSAN project has sought to collaboratively identify and model the most powerful suite of sustainability measures that can simultaneously (a) reduce greenhouse gas emissions to meet the Paris targets and (b) ensure that phosphorus use supports food security and minimises disruptions to the natural phosphorus cycle and water systems. We are doing this by working together with food system stakeholders across both China and Australia.

2. PACSAN approach: measures to meet planetary goals

As part of this project, we have developed an interactive model that shows the greenhouse emissions and phosphorus demand in Australia (1990-2050) and China (1990-2060), including estimated projections of future use in a business-as-usual or reference case (www.pacsan.online). The model shows the greenhouse emissions and the phosphorus supply and demand by sector along the value chain, from fertiliser manufacture through the different agriculture sectors and through to food transport, retail, consumption and food waste, ultimately to wastewater generation.

The interactive model then enables users to see them impact of reduction of each sector, up to a manually determined 'set-point' representing a practical or bio-physical maximum, and also the shape of the reduction, rapid or linear, and what would be required to meet targets, such as the 2030 or 2050/ 2060 greenhouse reduction targets.

The PACSAN initiative has identified eight measures that will, in combination, enable these greenhouse and phosphorus targets to be met. The selection of these categories of measures has been based on an extensive review of the literature and previous work by the authors (Cordell, Drangert and White 2009, Cordell & White 2014).

TABLE 1: Measures to meet planetary goals for greenhouse gas emissions and phosphorus use across the food system in China and Australia.

Measure	Description
1. Renewable fertiliser	• Ammonia produced with renewable hydrogen • Recovery and recycling of phosphorus from manures, crop waste and sewage
2. Nutrient productivity	• On farm efficiency of fertiliser • Smart agriculture • Tapping legacy phosphorus, soil testing and mapping
3. Land management	• Reduced land clearing for agriculture • Revegetation to sequester carbon • Lock-up carbon in soils
4. Crop type	• Rice varieties to reduce greenhouse emissions • Crop varieties that maximise nutrient use efficiency
5. Livestock feed additives	• Feed additives for ruminants to reduce methanogenesis • Phytase additives to maximise phosphorus uptake
6. Energy productivity across food value chain	• Improving energy productivity along the food chain • Electrification incl mobility, food processing • increased renewables in the grid
7. Sustainable food choices	• Shifting food consumption from livestock to plant-based
8. Food waste avoidance	• Reducing avoidable food waste across the food chain

3. Results: potential impact of measures

The maximum potential impact of the eight measures was assessed using the interactive model. Each measure impacts on multiple sectors, for example, reducing food waste reduces the emissions back up the food value chain. Similarly, improving energy productivity impacts on multiple parts of the food value chain, including food transport (through electrification of mobility), food packaging, retail and consumption. Reducing livestock reduces the need for crop production and fertiliser production because a significant proportion of grain is used for livestock. The impact coefficients for each of the sectors, arising from each measure have been estimated and are provided in the document linked in Appendix 1: Model description.

FIGURE 1: Relative impact of eight measures to meet planetary goals for greenhouse gas emissions and phosphorus use across the food system in China and Australia (expressed as a percentage of the total for each category).

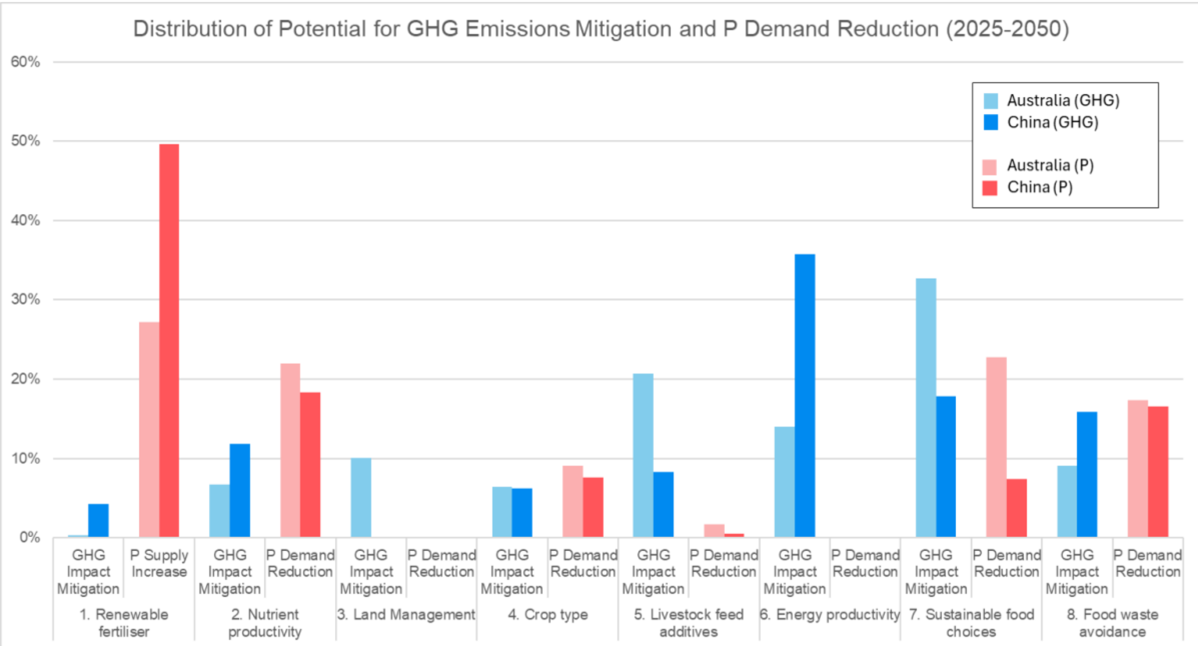


Table 2 shows these results in absolute terms, reflecting the maximum value of reduction in greenhouse gas emissions for the period 2025-2050, and increase in supply, or decrease in demand of phosphorus.

TABLE 2: Greenhouse gas reduction maximum potential and phosphorus demand and supply potential of eight measures to meet planetary goals for greenhouse gas emissions and phosphorus use across the food system in China and Australia.

	GHG reduction potential kt of CO2-eq (2025-2050)		P demand or supply potential kt of (2025-2050)	
	AUSTRALIA	CHINA	AUSTRALIA	CHINA
1. Renewable fertiliser	34,264	5,818,851	3,808	406,552
2. Nutrient productivity	890,894	19,339,894	3,078	150,175
3. Soil carbon	1,165,724	-	-	-
4. Crop type	748,045	8,448,963	1,269	62,162
5. Livestock feed additives	2,395,990	11,305,670	240	4,325
6. Energy productivity	1,622,696	48,845,780	-	-
7. Sustainable food choices	3,791,365	24,430,781	3,186	60,776
8. Food waste avoidance	1,056,843	21,632,173	2,424	136,035
Total	11,705,821	139,822,111	14,005	820,026

Table 3 summarises the 'Top 3' measures for Australia and China, for greenhouse gas reduction (GHG) and phosphorus supply and demand (P) respectively. Prior to sharing modelling results, participant expert views on priority measures were sought during collaborative workshops in Shanghai (May 2024) and in Sydney (Aug 2024) and also in a virtual network meeting (Oct 2024). Expert views aligned closely with the modelled results.

TABLE 3: Top 3 measures to meet planetary goals for greenhouse gas emissions and phosphorus use across the food system in China and Australia.

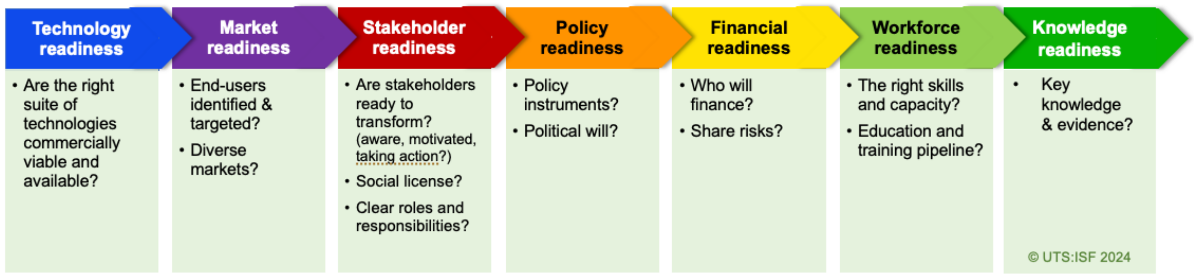
]

	CHINA	AUSTRALIA
GHG	1. **Energy productivity** opportunity is spread across sectors downstream of the farm 2. **Sustainable food choices** 3. **Food waste avoidance** in single sector (household)	1. **Sustainable food choices** predominantly related to one sector (livestock) 2. **Livestock feed additives** also in single sector (livestock) 3. **Energy productivity** benefits spread across multiple sectors
P	1. **Nutrient productivity** 2. **Sustainable food choices** 3. **Food waste avoidance**	1. **Sustainable food choices** 2. **Nutrient productivity** 3. **Food waste avoidance**

4. Readiness to transform

Section 3 indicates priority measures in terms of materiality alone. That is, those measures with the greatest potential to reduce future tonnes of GHG emissions or tonnes of phosphorus supplied/reduced. However, transformations to sustainable futures requires a suite of other preconditions or factors. For example, the implementation of these measures in either country would require a range of policy instruments, changes in investment priorities, social licence or other enabling factors to be mobilised. These factors can be usefully outlined on a 'readiness scale' analogous to the technology readiness level or commercial readiness level commonly used in innovation and research and development fields. Figure 2 provides an example of transformational readiness preconditions that can be deployed to assess the measures, and the component initiatives or actions that make up the measure.

FIGURE 2: A proposed set of 'readiness preconditions for implementing the measures that have been identified. The collaborative network could help to identify ways to improve readiness in these various dimensions.



5. Opportunities for action: mutual benefit

One of the key objectives of this project, is to identify and pursue opportunities for collaboration between Australia and China, that can advance progress for the measures that can address the planetary boundaries.

Apart from the obvious advantage that accrues to both countries in addressing the planetary boundaries and meeting the global goals, there are specific opportunities worth pursuing.

The model results and expert views suggest that these can be categorised to include the following:

- **Trade** opportunities
- **Research** opportunities
- **Policy** opportunities
- Joint **study** programs

Examples of the opportunities include:

- Export of green ammonia from Australia, produced from hydrogen from renewable energy sources, and export of hydrogen electrolysers from China.
- Trade in alternative proteins between Australia and China, and the development of new products that can reduce the emissions and phosphorus uses associated with livestock production.
- Joint research, development and demonstration of methods to improve nutrient productivity in cropping and horticulture, with the aim of reducing the requirements for application of nitrogenous fertiliser, and reducing phosphorus use and runoff.
- Comparative analysis of education programs, policies and guidelines for reducing food waste at the pre-consumer and post-consumer parts of the food chain.
- Joint research and development of opportunities for increasing electrification in the food chain, including electrification of agricultural machinery, delivery vehicles as well as electrification of heat through application of heat pump technologies. This would include trade in equipment and knowledge exchange, joint research and PhD programs.

- Analysis for policy development in labelling, carbon border adjustment mechanisms and other forms of carbon pricing, data on provenance and nutrient use, and joint development of modelling platforms for scenario development for land use, agriculture, biodiversity and water quality.

Based on the model results, stakeholder workshops and other dialogue, PACSAN Network members identified four core priority areas which provide mutual benefit: Energy productivity, Food waste avoidance, Nutrient productivity, and Traceability as a cross-cutting theme.

Energy Productivity

Energy productivity is the **top measure** to reduce **GHG emissions** from the food system in China in terms of potential kt of CO2 eq over the next 25 years, and third most promising for Australia.

In China the opportunity is predominantly at the end of the food chain – in **household consumption**. While in Australia the opportunity is distributed across multiple sectors, including food transport, retail (cold chain) and consumption (cooking and refrigeration).

Energy productivity is a **policy priority** in both countries, especially decarbonising the energy supply system.

In terms of technology, key opportunities relate to **electrification of mobility and gas use**, use of **heat pumps** and **smart information technology systems**.

Mutually beneficial opportunities might therefore consider: **trade of green technologies** (e.g. heat pumps) from China to Australia, **co-investment of clean energy incubators** including venture capital, and platforms to **share knowledge and expertise**.

Food Waste Avoidance

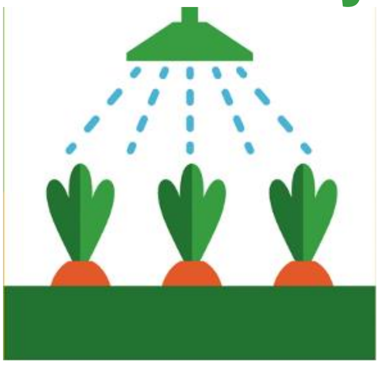
For both China and Australia, food waste avoidance is a '**top 3'** most promising measure to meet **future phosphorus demand** for food production. It is also a 'top 3' measure in China to potentially reduce **GHG emissions**.

In China the opportunity to reduce food waste is predominantly at the end of the food chain – in **consumption**. While in Australia the opportunity is distributed across multiple sectors, including **food consumption**, **food retail** and **livestock production**.

Halving food waste by 2030 is a national **policy priority** in Australia. There has been a particular focus on behaviour change in households, and the role of food packaging.

Mutually beneficial opportunities might therefore consider sharing and dissemination of **lessons learnt from evidence-based behavioural change strategies**, and packaging re-design (e.g. through the World Packaging Organisation).

Nutrient Productivity



Improving nutrient productivity is the **top opportunity** (China) and second largest opportunity (Australia) to improve **phosphorus security**. It is also important in potentially reducing GHG emissions in China in agriculture (including fertiliser use), and Australia in the livestock sector. Indeed, it was estimated that there is CN¥ 550 billion worth of excess (legacy) phosphorus locked up in China's agricultural soils.

However, the best strategies to improve nutrient productivity may differ somewhat in each country. In China, **tapping the 'legacy' phosphorus** and thereby reducing phosphate fertiliser application rates might focus on smart agricultural practices and improving resource efficiency, especially phosphorus use efficiency. The use of renewable fertilisers (e.g. from manure) to reduce environmental pollution is also on the Chinese government's agenda. Addressing sustainable crop types like legumes that can for example mobilise phosphorus from the soil (and reduce external inputs) may be mutually beneficial in both countries. In Australia the role of legumes for example in nutrient-specific crops is crucial, and the importance of soil mapping for targeted nutrient application necessary. A spotlight on legumes can address multiple intersecting issues: sustainable protein source to reduce GHG emissions, reduce environmental pollution associated with nutrient runoff from agricultural soils, and reduce fertiliser application rates.

Areas of mutual benefit may relate to a shared priority research program, which could include **study visits** to each country (of agricultural practitioners and researchers), and **technology transfer** in addition to **knowledge transfer**.

Traceability

Improving traceability, transparency and tracking was identified as a cross-cutting theme that can facilitate **ESG accountability** in addition to **improved productivity** in both Australia and China, especially for larger corporations. This could include instruments like labelling, distributed ledgers and support for carbon border adjustment measures.

Specifically, this could range from analysis and reporting of companies' carbon emissions to food labelling to support more sustainable food choices, with NGOs or government agencies as independent watchdogs.

References

White, S. and Cordell, D. (2024) *Discussion Paper 1: Planetary boundaries and the food system in Australia and China: Sustainable futures and mutual benefits,* Institute for Sustainable Futures, University of Technology Sydney, August 2024. Available at: https://www.pacsan.online/resources

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F.N. and Leip, A., (2021) "Food systems are responsible for a third of global anthropogenic GHG emissions," *Nature Food*, vol. 2, pp. 198-209.

Brownlie, W.J., Sutton, M.A., Heal, K.V., Reay, D.S., Spears, B.M. (eds.), (2022) *Our Phosphorus Future*. UK Centre for Ecology and Hydrology, Edinburgh. doi: 10.13140/RG.2.2.17834.08645. Available at: https://www.opfglobal.com/

Cordell, D. and White, S. (2014) 'Life's bottleneck: sustaining the world's phosphorus for a food secure future' *Annual Review of Environment and Resources,* 39(1) 161–188.

Cordell, D., Drangert, J.O., White, S. (2009) "The story of phosphorus: Global food security and food for thought" *Global environmental change* 19(2), 292-305

APPENDIX 1: MODEL DESCRIPTION

The model description document can be viewed and downloaded at this link