

Inefficiency and Environmental Risks associated with Nutrient Use in Agriculture within China and the UK

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Key Messages

- The stocks and flows of nitrogen (N) and phosphorus (P) were quantified for five case studies, representing contrasting agricultural systems in China and the UK.
- The input of nutrients exceeded the output of nutrients in agricultural products for all five systems, although to varying degrees between individual case studies.
- Excessive input of nutrients for each system increases the risk of negative environmental impacts on soil, air and water quality.
- Soils accumulate nutrient stocks due to excessive nutrient inputs, representing an under-exploited nutrient reserve that could contribute to future agriculture production.
- Livestock and crop production are increasingly disconnected in China. Manure application was limited to high-value fruit and vegetable crops in the systems analysed, but often without adequate accounting for the nutrient content of the applied manure.
- Pathways to improve the efficiency of nutrient use include:
 - **Curtailling persistent over-fertilisation**, especially for high value crops within China.
 - **Fully accounting for nutrient sources beyond synthetic fertiliser**, including manure, crop residue, atmospheric deposition, biological N fixation and soil nutrient content.
 - **Improving nutrient management practices**, including the rate, timing and technology for nutrient application to land, but also how nutrients are redistributed within a given area when recycling material such as livestock excreta to land.
 - **Re-integrating livestock and crop production systems**, closing nutrient loops at local scales through application of manure/slurry to arable, fruit and vegetable systems.
 - **Optimising irrigation practices**, in order to minimise nutrient losses through leaching, protect groundwater resources and optimise water use efficiency.

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The importance of this briefing paper

The management of synthetic fertiliser in China has implications for Chinese national priorities, but also for fertiliser price and availability globally. The use of synthetic fertilizer in China increased fourfold from 1978 to 2012, and China uses more fertiliser than any other country (FAOSTAT, 2014¹). Increased use of chemical fertilisers and other inputs has contributed to increased productivity in China since 1978 (Carter et al., 2012²; FORHEAD, 2014³). However, returns on increasing fertilizer use are diminishing in the most intensively farmed areas. Reductions in fertiliser use would support Chinese national priorities to reduce water pollution and greenhouse gas emissions, and could reduce farm costs. In addition, whilst currently a net exporter of phosphorus fertiliser, predictions indicate that production of high-grade phosphate rock in China may begin to decline from the late 2020s onwards. As internal sources of fertiliser diminish, the role of China on the global fertiliser market is likely to change significantly, initially through reductions in net exports and ultimately through imports of fertiliser to meet demand. Therefore, beyond implications for the profitability of farm businesses and for local environmental conditions within China, fertiliser use in China has potentially important implications for nations that rely on fertiliser imports to meet their demands, including the UK.

This policy brief summarises research that has used system flow analyses (SFAs, Figure 1) to examine nutrient use within case studies in China and the UK. The SFAs enable inefficiencies within production systems and the risks of nutrient export to the atmosphere, surface water and groundwater to be identified. SFAs are relatively simple in conceptual terms, have lower data requirements than many other modelling approaches, and provide effective communication tools to support engagement and discussion with a range of stakeholders.

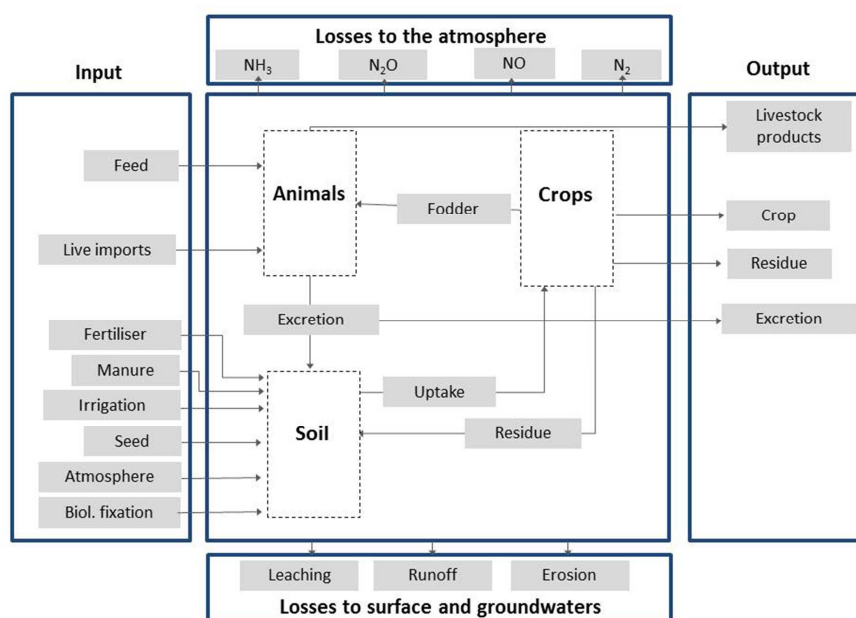


Figure 1: Conceptual diagram of a system flow analysis (SFA) for the agricultural case studies reported in this policy brief.

¹ FAOSTAT, 2014. Statistics Division of the Food and Agriculture Organization of the United Nations. FAOSTAT Database. <http://faostat3.fao.org/faostat-gateway/go/to/browse/R/RF/E>, accessed 27th June 2014.

² Carter, C., Zhong, F., Zhu, J., 2012. Advances in Chinese agriculture and its global implications. *Applied Economic Perspectives and Policy*, 34, 1-36.

³ FORHEAD, 2014. Food Safety in China: A Mapping of Problems, Governance and Research. Forum on Health, Environment and Development (FORHEAD), Working Group on Food Safety.

The approach and results

SFAs have been constructed and interpreted for five contrasting, representative catchments across China and the UK (Figure 2). These SFAs consider the macronutrients nitrogen (N) and phosphorus (P) for one year, combining two crop seasons in Chinese double-cropping systems⁴. The SFAs for the Chinese case studies are reported in Figures 3-6, with the UK SFA reported in Figure 7.

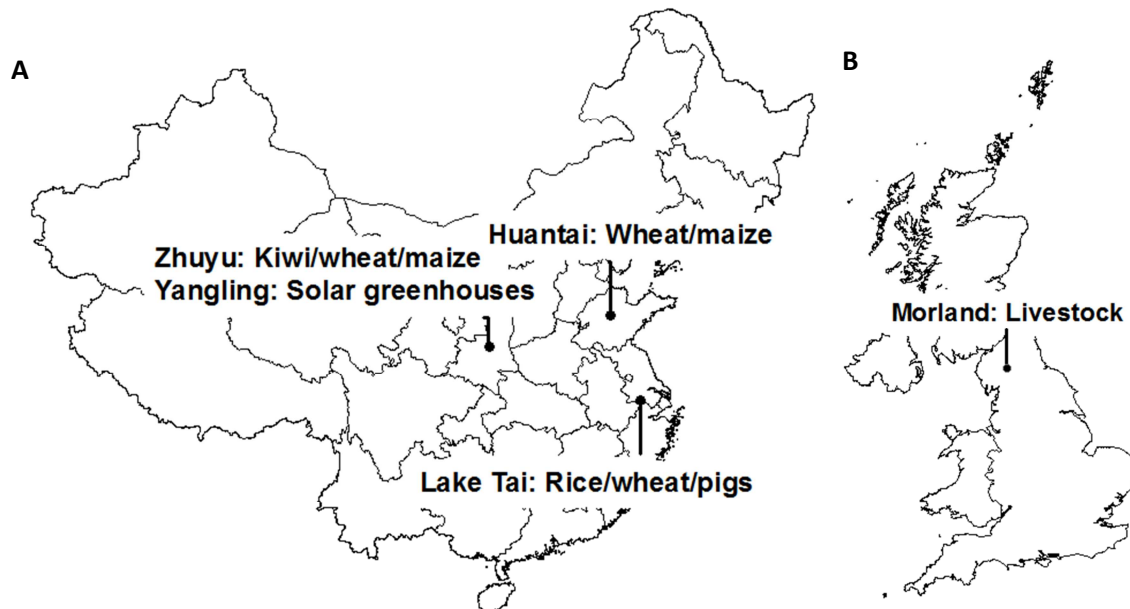


Figure 2: A: Location of the case study systems in China and dominant production system in each case study. B: Location of the Morland case study in the River Eden catchment within the UK.

Concentrated animal feeding operation – Lake Tai, China (Figure 3)

- Livestock production relies on externally-derived feed and is disconnected from crop production.
- Livestock slurry was historically discharged to surface water with associated environmental impacts.
- Barriers to recycling of livestock slurry within the catchment include concerns over slurry pathogen content.
- Nutrient flows between livestock and crop production are disconnected. For producers of large volumes of livestock slurry, standards with respect to nutrient and contaminant content could support greater recycling.

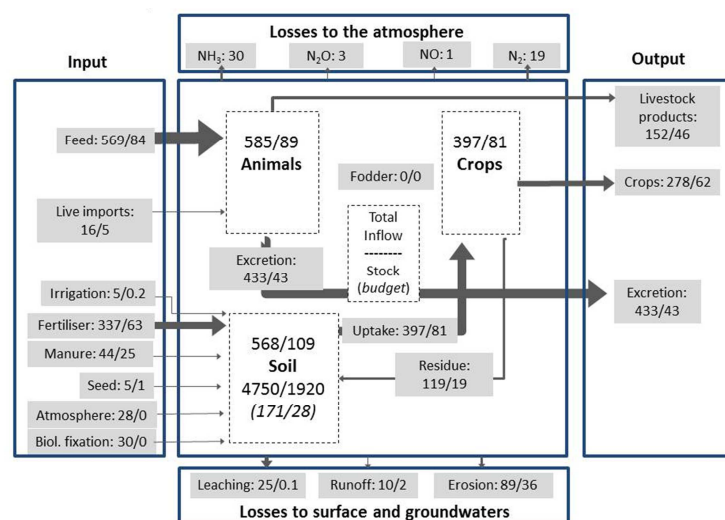


Figure 3: Lake Tai SFA in kg (N/P)/ha/year.

⁴ Further detail regarding the basis to each SFA is provided in: Defra (2015) Substance flow analyses of nutrient use in agricultural sub-catchments within the UK and China. Internal Defra report.

High value crop systems – Yangling and Zhuyu, China (Figures 4 and 5)

- High value vegetable and fruit orchard systems analysed in China continue to be significantly over-fertilised, through a combination of synthetic fertiliser and manure application.
- High N input leads to high emissions of N to the atmosphere and to high losses of N into the sub-surface through leaching.
- Aqueous losses of nutrients via surface runoff either do not occur or are minimised, due to enclosure of the growing area by greenhouse walls or by soil bunds.
- Nutrient accumulation within the soils is extremely high, as a result of significant over-fertilisation.
- Manure and fertiliser application could be substantially reduced without risking a reduction in yield.

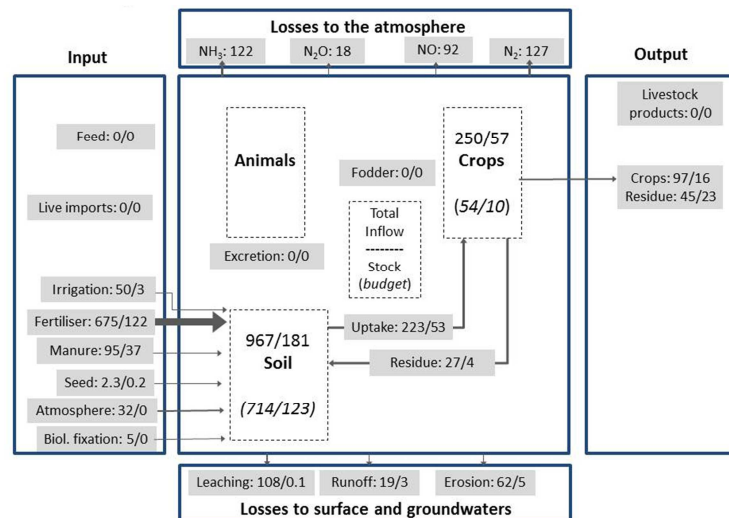


Figure 4: Zhuyu SFA in kg (N/P)/ha/year.

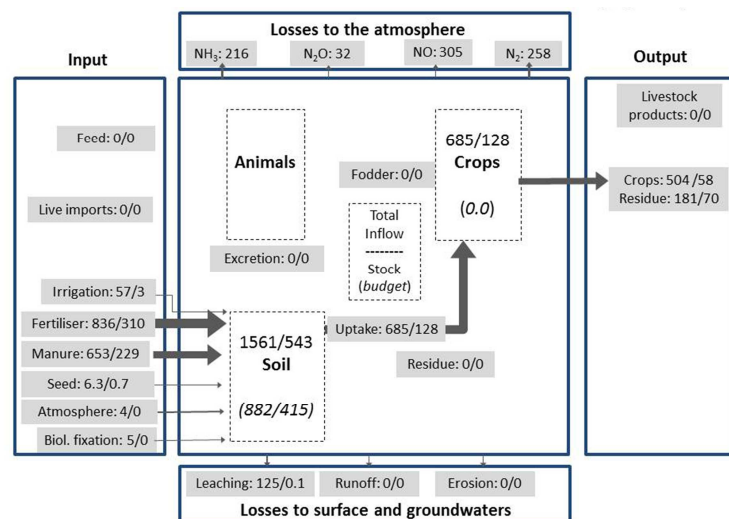


Figure 5: Yangling SFA in kg (N/P)/ha/year.

Cereal systems – Lake Tai, Huantai, and Zhuyu, China (Figures 3, 4 and 6)

- Primary nutrient source is synthetic fertiliser, with Lake Tai the only case study in which some manure is imported and applied to cropland.
- Systems are relatively well optimised with respect to the input of synthetic fertiliser, but do not account for other substantial nutrient sources, including biological N fixation, atmospheric deposition and the return of crop residues. These sources need to be properly considered when deciding on nutrient application rates to reduce excessive nutrient application.
- Substantial accumulation of nutrients within soils leads to an increased risk of nutrient export to the atmosphere and to water. Calcareous soils in Huantai and Zhuyu have a significant P sorption capacity. Therefore, whilst substantial gross excesses of P application at the soil surface occur, much of this excess P may be unavailable to crops. However, soil nutrients should be exploited to their full extent, including through alternative management practices to enhance availability of soil nutrients.
- The main application of nutrients occurs during seed drilling, which for mobile N should be better timed according to the crop nutrient demand.
- Flood irrigation is commonly used to water cereals and to introduce later broadcast N applications into the root zone. This increases the risk of N leaching into the sub-surface. Irrigation practices should be optimised to conserve both nutrient and water resources.

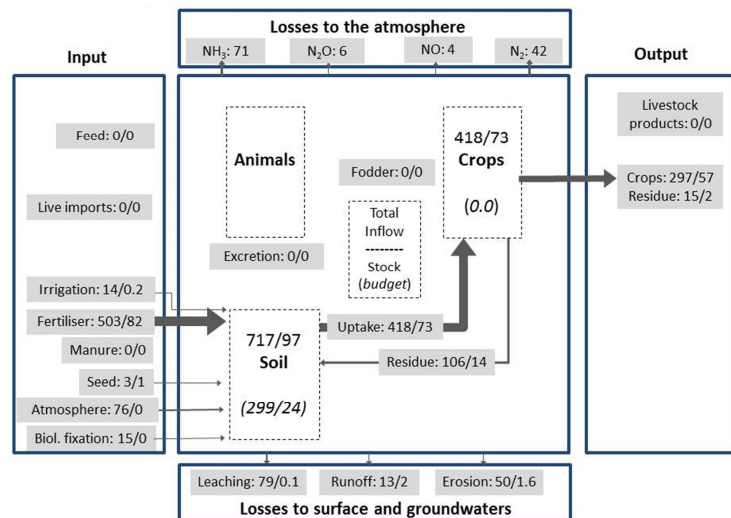


Figure 6: Huantai SFA in kg (N/P)/ha/year.

Extensive livestock, Morland, UK (Figure 7)

- Most significant nutrient input to the catchment is animal feed followed by fertiliser. Continued optimisation of feed management is important for efficient nutrient use.
- Strong coupling between soil, crop and animal compartments. Spatial distribution of excreta return to land is important for optimal nutrient management.
- Soils are accumulating a significant stock of N and P due to inputs exceeding uptake and losses. A proportion of this stock may support future production. The soil stock also creates a legacy risk of nutrient export from the catchment.

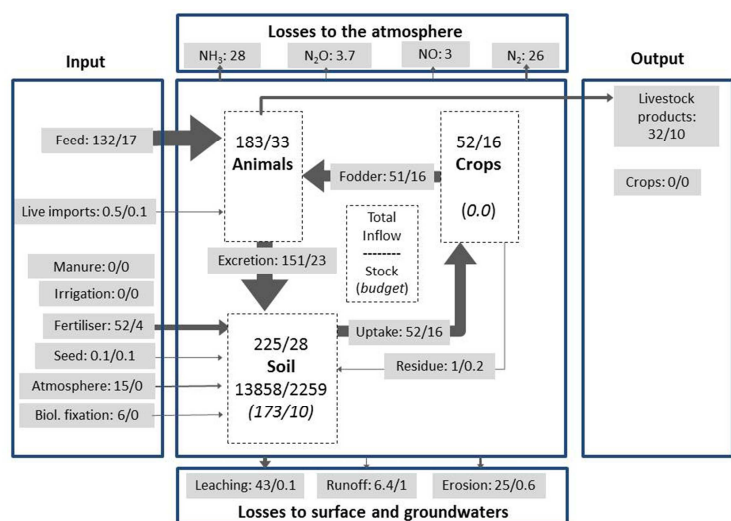


Figure 7: Morland SFA in kg (N/P)/ha/year.

In Conclusion

The SFAs reported in this policy brief highlight the potential to increase nutrient use efficiency at catchment scales within China. The analysis reveals opportunities to address excessive application of synthetic fertiliser, particularly to high-value crops, to re-connect livestock and crop production systems, and to draw on a range of nutrient sources beyond synthetic fertiliser to support production. Similar challenges faced the UK following the rapid intensification of agricultural production that began in the 1940s. A transition in regulation, advice and financial incentives for UK farming has begun to rebalance the importance of productivity alongside the stewardship of natural resources and broader protection of the environment. Evidence of this rebalancing is found in the reduced rate of synthetic fertiliser application to both cropland and grassland in the UK over the last 30-40 years⁵. Whilst this rebalancing continues in the UK, particularly in response to the historical legacy of nutrient accumulation in agricultural soils, stimulating and managing a similar transition in China are important challenges. Learning from the UK experience can help to address these challenges. However, the nature of government, research, extension, farm business operation and land ownership present scenarios that are often specific to China. Such issues are the subject of parallel research in this SAIN project and of a separate SAIN policy brief. Integration of the outputs from SFAs with analysis of the policy, advice and incentives that surround agricultural production in China is required to provide the basis for transitioning towards more sustainable nutrient management.

⁵ Defra (2013). The British survey of fertiliser practice. Fertiliser use on farm crops for crop year 2012.