Circularity indicators and their relation with nutrient use efficiency in agriculture and food systems

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Background

- Nutrient cycling receives large attention in recent years, but its relationship with nutrient use efficiency (*O/I*) is often ignored.
- Clear indicators are needed to monitor contribution of circularity to environmental performance and resource use efficiency of agro-food systems.

Objective

- To clarify how cycling and re-use of nutrients contribute to overall nutrient use efficiency (*O/I*) of a system, and how this contribution depends on system properties

Methodology

Output/Input, *O/I*, was split into contributions by direct flow and cycled flow respectively, with help of the cycle count indicator, *CyCt*. *CyCt* is the number of times that a unit of nutrient input (*I*) completes a full cycle in a circular system.

The ratio between *O/I* contributions from direct and cycled flows is 1:*CyCt*.

$CyCt_R$ = number of cycles that could be completed if exports were set to zero and thus nutrients were removed from the system by loss only.

Use count, *UseCt*, is the number of times a unit of nutrient input passes through the top trophic compartment of a system.

Results

The soil-crop system is largely linear and fertiliser-fed (Fig. 1). Internal losses are relatively small. If all exported grain would be returned to the field, a unit of original nutrient input would be used 3.3 (N) or 2.1 (P) times.

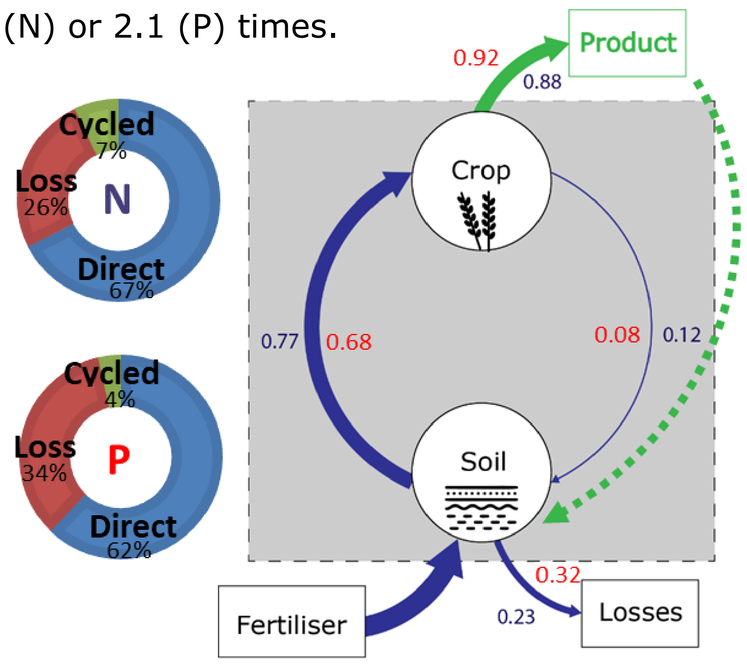

Figure 1. Simplified representation of partitioning coefficients of nutrient flows (blue for N, red for P) at Broadbalk, UK for field plots in the continuous winter wheat experiment where straw is returned to the field. Doughnut indicates input partitioning; for P, loss includes storage. Data source: Rothamsted Research, 2022

At the dairy system large N losses occur, P is less prone to losses (Fig. 2). If all nutrients exported in milk & meat would be returned to the farm, a unit of original nutrient input would be used 0.9 (N) or 6.2 (P) times. For N, the high environmental impact of intensive dairy farming cannot be resolved by recycling consumer waste. Rather, reducing N input would be more effective, besides measures to increase N retention by the system. P cycling, on the other hand, could be highly increased by returning external consumer waste P to the farm.

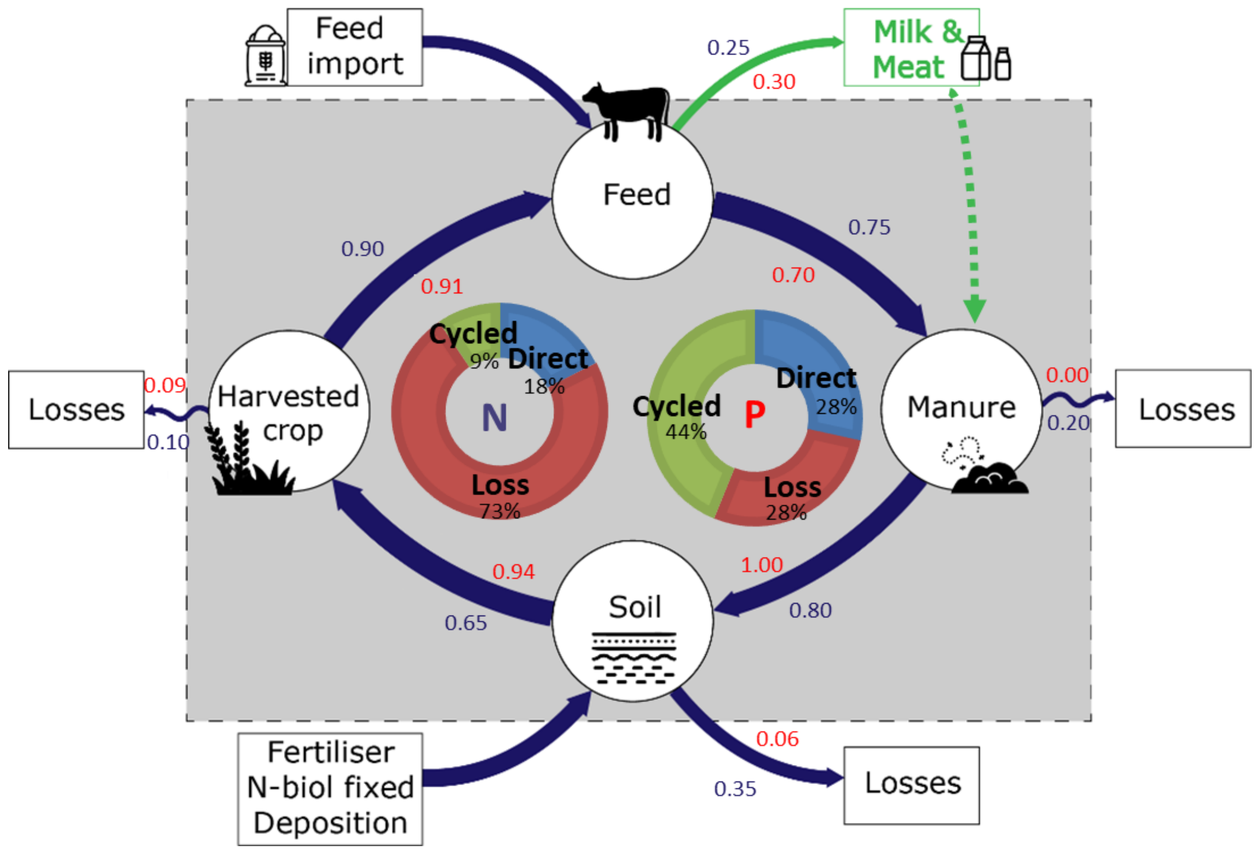

Figure 2. Simplified representation of partitioning coefficients of nutrient flows (blue for N, red for P) at De Marke experimental dairy farm Hengelo, the Netherlands. Doughnut indicates input partitioning. Data sources: Oenema (2013) and Aarts (2000).

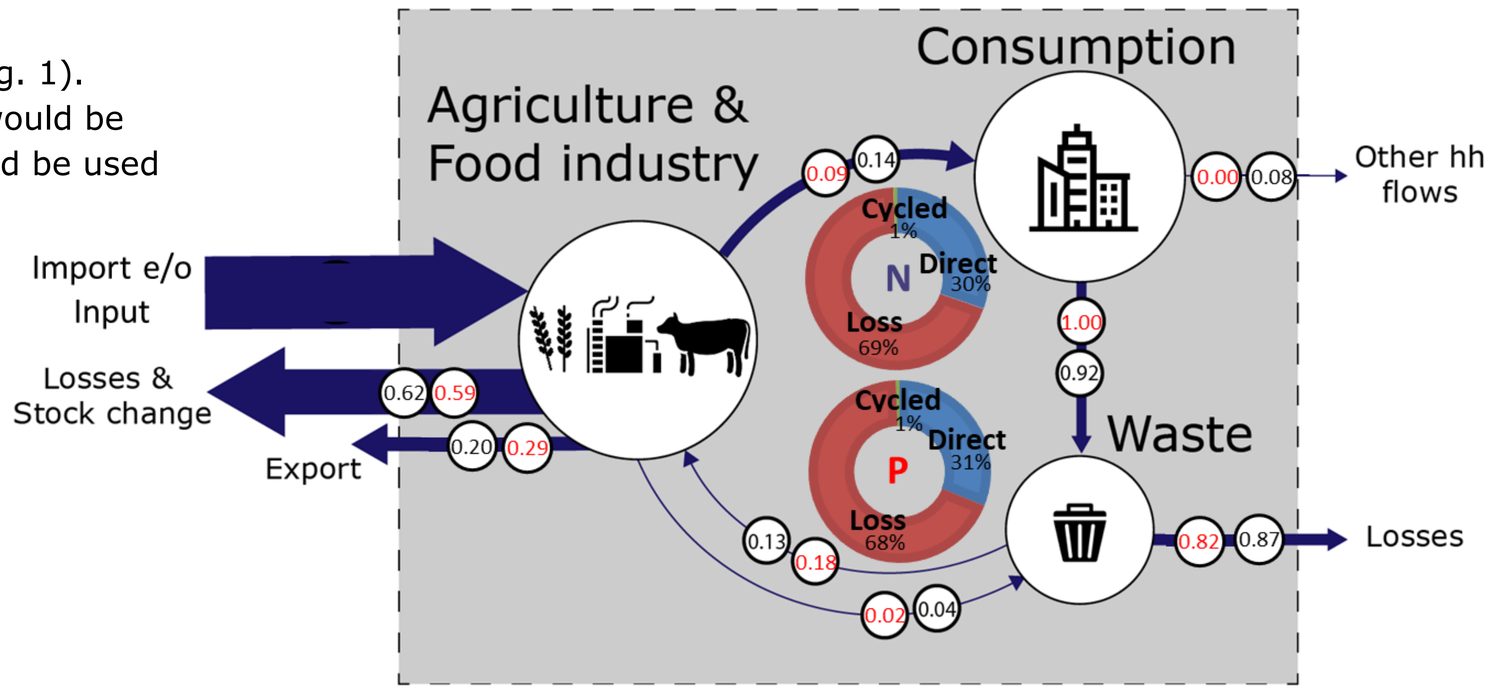

Figure 3. Simplified representation of partitioning coefficients of nutrient flows (black for N, red for P) at Flanders, Belgium agro-food system. Doughnut indicates input partitioning; loss includes storage. Data source: Papangelou & Mathijs, 2021

The flanders regional agro-food system does not recycle nutrients to a great extent, due to large export and loss terms (Fig. 3). Only 31% (N) or 32% (P) of nutrient imports will ever be consumed by humans in Flanders or elsewhere. Its complement is lost or stored. If all nutrient export flows were fully returned, still hardly any cycling would occur, only 5% (N) and 9% (P) of original nutrient inputs would complete the full cycle (instead of 1%, see Fig. 3).

Conclusions

- *CyCt* can help to predict how *O/I* will respond to changes in system properties, and - for $CyCt_R$ - to retrieval of external waste flows.
- *UseCt* can replace *O/I* as a measure of nutrient use efficiency in food systems with the human consumer as top trophic level.
- Comparison between *CyCt* and $CyCt_R$ may help prioritize between measures that minimize losses from within the system, and measures that increase the return of external consumer waste back to the system.

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