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Quantifying the environmental performance of individual dairy farms - the Annual Nutrient Cycling Assessment (ANCA)

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Abstract

Dairy farming is characterised by extensive fluxes of nitrogen (N) and phosphorus (P): large amounts of these elements cycle via feed, manure, soils and crops. Losses and exports in the form of milk, meat and manure are compensated for by purchased feeds and fertilisers. At this moment, farmers lack accurate insight into the impact of their management on the functioning of these cycles. We therefore developed the model ANCA, based on the results of the pilot farm network 'Cows & Opportunities' and the experimental farm 'De Marke'. The ANCA model quantifies the main performance indicator related to the nutrient cycles. The ANCA model is based on verifiable input data that can be collected with little effort, as the model is to be used by commercial farmers whilst being fraud resistant. The model outcomes help dairy farmers to demonstrate towards authorities and the dairy industry that they have produced their milk in accordance with sustainability standards. From 2015 onwards, ANCA will serve as a licence to produce for any dairy farm in The Netherlands with a manure surplus (about 70% of the number of farms).

Keywords: ANCA, nutrient cycling assessment, dairy farming, sustainability standards

Background and objectives

Dairy farms in the Netherlands are around 70% reliant on home-grown feed. In turn, feed crops receive nearby 65% of their nitrogen (N) and 100% of their phosphorus (P) requirements from the dung and urine excreted by the dairy herd (Aarts *et al.*, 2008). Therefore, dairy farming system are characterised by cycling of N and P. Losses from the cycles to the environment and exports in the form of milk, meat and manure are compensated for by purchasing feeds and fertilisers. A more efficient use of nutrients in home produced and purchased feeds and fertilisers reduces losses and the need for purchases and manure export, and it thus approaches even further the idea of cycling. Efficiency is partly governed by conditions that cannot be affected by the dairy farmer, such as weather conditions. However, management generally is the most dominant factor. Improving nutrient management starts with awareness of the actual farm performance. To find out where exactly the adjustment of management leads to improved use efficiency, the analysis must take due account of the extensive internal flows of home-produced forages and manures.
The flow model ANCA (Annual Nutrient Cycle Assessment) was constructed to provide indicator values for the utilisation of feeds and fertilisers, including manures, and for losses of harmful products. Reference and normative values are presented as comparisons. Reference values are the average values, as achieved by a group of farms under more or less similar

conditions. Normative values are limits given by national legislation. With the farm specific values of the performance indicators, dairy farmers can justify their farm management towards authorities and the milk processing industry. Therefore, ANCA has to be fraud resistant, implying that input data have to be easily collectable and verifiable.

Construction of ANCA and generated indicators values

Since 1992, nutrient flows into, inside and from dairy farms have been extensively studied on the experimental farm De Marke and, since 1999, on commercial pilot farms in the project Cows & Opportunities (Oenema, 2013; Verloop, 2013). Both projects are directed to a better understanding of processes involved and the identification of opportunities for improvement. Their results provided the basic information needed to design and test the ANCA model. Information from other sources was added. The attendant equations and their interrelationships, as implemented in the ANCA model, are reported by Schröder *et al.* (2014).

The ANCA model starts with the livestock component, in which the energy requirements of the dairy herd, including young stock, are estimated on the basis of normative values for each of the animal categories. The ration has to achieve these requirements. The composition of the ration is calculated from purchased feed (mainly concentrates) and consumed conserved forages, calculated from periodic inventories of changes of amounts of forages in stock, made by an accredited company. Fresh grass intake, by grazing, is estimated by subtracting consumed conserved feed (concentrates and forages) from energy requirements. The N- and P-consumption is estimated by chemical analyses of the components of the ration. From there, the excretion of N and P is calculated as feed intake minus the production of milk and meat.

Subsequently, ANCA models the soil-crop component. First, the production of home-grown feed is calculated by subtracting the amounts of purchased feed from the total feed consumption, taking due account of the pertinent normative losses associated with grazing, harvesting and conservation. These losses are specific for energy, N and P. Finally, the N and P yields are divided by the total input of N and P onto and into the soil (i.e. manures, fertilisers, deposition and estimated N-fixation by clover) to arrive at the use efficiency of the soil-crop subsystem. Inputs of mineral fertilisers are known from purchases. Inputs of slurry, urine and dung are calculated from total excretion, intensity of grazing, normative gaseous losses of N from housing and storages, and from exports of manure, if the latter is applicable. Ammonia losses from applied fertilisers and manures are calculated using standard emission factors depending on the method of application, the composition of the manure and the type of mineral fertiliser. Nitrate leaching is calculated from the N-soil surplus, with crop- and soil-type specific normative values for denitrification (Schröder *et al.*, 2014).

The major output of ANCA consists of the farm-specific indicator values as presented in Table 1. Values are presented for successive years, allowing the user to discern the development over time. The required input can almost entirely be derived from data that are digitally recorded and stored by suppliers, purchasers, authorities and other organisations related to the dairy farm. Therefore, most of the indicator values can be generated without requiring input from the farmers themselves, which makes the system easy to use and fraud resistant (Holster *et al.*, 2013).

The underlying normative parameters now apply to the 80% conventional specialised Dutch dairy farms only. The remaining 20% of farms are mixed with other agricultural activities or managed in an atypical way (e.g. by producing solid manures instead of the common slurries). ANCA will be improved to apply also to these farms.

How ANCA is implemented and utilised

Almost all organisations that are involved in Dutch dairy farming cooperate in the implementation of ANCA. A common structure is being developed for data collection and storage. Farm specific input data that are already recorded by suppliers, purchasers, authorities and other parties are sent to a central database, governed by the dairy industry. Calculated values for the performance indicators (Table 1) will be stored in this database, checked and made available to the farmer, milk processing industry and authorities.
Milk processors want to provide buyers with a certificate showing that the processed milk has been produced in a sustainable way. This includes efforts to minimize harmful emissions and an efficient use of scarce resources. From the beginning of 2015 onwards, the use of ANCA is mandatory for all Dutch dairy farms that produce more manure than they are permitted to apply on their own fields; this is a licence to deliver milk to the processing industry. For the remaining 30% less intensive farms, the use of ANCA will probably become mandatory in the near future.
The ANCA model offers possibilities to differentiate generic environmental legislation to specific farm conditions and performances. National excretion standards, as prescribed by the Nitrates Directive, are based on average farm data. The ANCA model serves as a verifiable tool to calculate farm-specific N or P excretions. If its outcome is below the national standard, authorities accept the farm-specific outcome, allowing the farmer to reduce the amount of manure he is expected to export. The Dutch generic application standards for manures and fertilisers are based on average soil conditions and crop yields. The ANCA model can be used as a tool providing an underpinned differentiation between farms doing more justice to what crops need or the environment requires. In view of the above, a pilot has been set up investigating the possibilities for farm-specific fertilisation standards.

Table 1. Indicators quantified by the ANCA model

1	Excretion	N and P excretion of cattle (kg ha^{-1})
2	Use efficiency of feed by the herd	Conversion of N and P from feed into milk and meat (%)
3	Ammonia losses	Divided over housing, manure storage, grazing, manure spreading and mineral fertiliser application (kg ha^{-1})
4	Crop yields	Grassland and maize land: dry matter, N, and P (kg ha^{-1}) and energy (kVEM ha^{-1})
5	Use efficiency of fertilizers by the crops	Conversion of N and P from chemical fertilisers and organic manures into crop yield (%)
6	Soil surpluses	Amounts of N and P as inputs minus outputs at crop level (kg ha^{-1})
7	Nitrate leaching	NO_3 content of upper groundwater (mg l^{-1})
8	Losses of GHG	Emission of the gases methane (CH_4) and nitrous oxide (N_2O)
9	Farm surpluses	Amounts of N and P as inputs minus outputs at farm level (kg ha^{-1})
10	Use efficiency of farm as a whole	Conversion of N and P from purchased product (mainly feeds and fertilisers) into sold milk and animals (%)

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