SUPER-G
SUSTAINABLE PERMANENT GRASSLAND

MEDITERRANEAN
BOREAL
ALPINE
PANNONIAN
CONTINENTAL
ATLANTIC

Demonstration of farm gate and soil surface nutrient balances

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- **DESCRIPTION:** Farm-gate and Soil surface balances are calculations made using farm data that provide evidence of the nutrient fluxes within a farm or a field. They have in common the approach, based on a mass balance between inputs and outputs to and from a system, and the possibility to highlight areas for improving farm practices and reducing their potential environmental impact, increasing resource utilisation efficiency and enhancing farm sustainability.
  A farm-gate balance (FGB) is the calculation of an input-output balance of nutrients (N, P and K) accounting for all inputs to the farm (seeds, fertilisers & manures, feed, litter, live animals, symbiotic N fixation, deposition…) and all outputs that leave the farm (sold vegetable products including hay and silage, animal products, live or dead animals, manure…). As it does not account for any internal N fluxes within the system boundaries, this balance is suitable for steady-state soil conditions, but it can also be used to highlight imbalances that will partly modify the soil status in the medium or long term, or are prone to losses and therefore threaten environmental quality.
  A soil surface balance (SSB) is the calculation of an input-output balance of nutrients (N, P and K) accounting for all inputs to a field (seeds, fertilisers, applied manures, direct depositions of grazing animals, symbiotic N fixation, …) and all outputs from a field (crop yield and removed residues, including grazed forages), and without accounting for changes in soil stocks. Therefore, the SSB can also indicate a possible excess or depletion of nutrients that will affect the soil, water and air quality, in a similar way to the FGB.

  Both balances are computed using information available on the farm through interview and access to the farm accounting system, although some entries can only be estimated using regional or bibliographic data (e.g. atmospheric deposition) or local measurements combined with standard tables (e.g. N fixation, grazed forages). The two balances differ in their system boundaries and the spatial detail of information that can be derived. Both are standard indicators used to compare agricultural systems through time or in space, and as policy instruments.

  Some countries have largely adopted these two balances to assess farm sustainability and guide farmers towards higher environmental goals, such as in the Netherlands. In the Netherlands, intake of grazed forages is calculated with an energy balance (energy requirement of herd based on milk/meat production minus energy in purchased feed and energy in harvested silage/hay). Other countries (e.g. Italy) calculate a SSB to verify compliance with the Nitrates Directive, but do not use the FGB as a policy instrument. A modified version of the SSB, where the surplus is set to zero or to a predefined acceptable low value, is also frequently used to compute the amount of fertiliser requirement, as a decision-support tool for nutrient management planning.

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- **RATIONALE:**

The advantage of using nutrient balances is that they provide easy estimates of nutrient losses – noticeably difficult to measure or estimate - using balance entries that are relatively easy to quantify. Both SS and FG Balances are generally considered as good indicators of farm environmental sustainability. Mass balances are in the category of pressure indicators, in the sense that they are direct and effective methods to show potential harm to the environment of an agricultural activity. The mass-balance approach that underlies the two calculations has been widely used at various spatial levels, including at regional, country and continental scales.

The balance between inputs and outputs, at both FG and SS scales, can be positive or negative. A positive balance indicates i) an accumulation of nutrient reserves on the farm, generally in the farm soils, and/or ii) a loss of nutrients from the farm. Surpluses can result in of the loss of nutrients through various pathways: N gaseous emissions (NH3, N2, N2O and NO), soluble N in ground and surface water (NO3-, NH4+ and dissolved organic N), P and K runoff and leaching, and NPK accumulations or immobilizations in soil. The balance can also be negative, thus indicating a depletion of internal reserves, i.e. generally meaning a loss of soil fertility.

The FGB is a good indicator for environmental losses when nutrient surpluses are equally distributed among fields within a farm, and all nutrient loss pathways are linearly related to the nutrient surplus. The entire farm analysis produces a picture of environmental pressure expressed on an area basis, but does not allow a detailed understanding of its internal effects. This can be achieved through the description of farm components, and in particular of each cropping system component (per area unit). The SSB goes into the detail of single fields and provides the net loading of N and P. In this case also, the soil nutrient content is not considered, therefore a positive balance might indicate an increase in soil reserves - not only losses to the environment - and a negative balance could indicate a depletion of soil fertility. Several SSBs can be calculated on a farm, by field or by cropping system. Then, the SSBs of all fields or cropping systems can be averaged (pro rata) to provide an overview of the whole farm. However, this indicator for the whole farm is conceptually different from the FGB.

Fig.1: Application of slurry and manufactured fertilizers are the main nutrients inputs to most grasslands, while purchased feed can be one of the main nutrient inputs at farm level
photos: Stanislav Hejduk

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- **MECHANISM OF ACTION:**

The standard equations to calculate the two balances are:

FGB = (NPK in purchased: fertiliser, concentrates, fodder, live animals, manure, animal bedding, seeds; N-fixation; atmospheric deposition) – (NPK in sold: live animals, animal products, manure, crops, crop residues, forages)

SSB = (NPK in mineral fertilisers, manure applications, dung and urine of grazing animals, atmospheric deposition, seeds, N-fixation) – (NPK in removed: yield and crop residues; harvested and grazed forages)

However, despite several attempts to standardise the equation, some items are sometimes disregarded, to simplify calculations. For example, atmospheric deposition is often omitted at farm scale. Some data at both field and farm levels is available through national or regional accounting systems, but if this is not possible, an interview is needed to calculate both FGB and SSB. A few hours are generally sufficient to gather the required farm data, depending on its complexity. A specific software or spreadsheet is also helpful to standardise calculations and literature-derived reference data.

Fig.2: Overfertilizing leads to eutrophication of swards and surface water
photos: Stanislav Hejduk

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Potential for applying the management option

Several tools exist that can help farmers calculate a FGB or a SSB. Some of them are commercial, some others free and provided by the local extension services or public authorities devoted to support environmental-friendly farming practices. As most entries are also in common with the Farm Registry Book, some software devoted to record farm economic and technical aspects can provide the basis for the calculation of such balances. Generally, the farmer needs some support by an extension service to correctly interpret the calculation results and highlight the key areas for improvement – single fields or, more generally, farming practices - where an intervention is needed.

Farmers should receive all data regarding their farms, with all details needed to identify management options that could be introduced or improved. In addition, a useful practice is to compare the farm balance with anonymous data from other similar farms, so that each farmer can also see the ranking of his/her farm in the context of similar farms in the area (i.e. benchmarking).

Practical considerations

In grassland farms, two entries are difficult to quantify, resulting in specific problems.

One is the NPK deposition by grazing animals. Unfortunately, there is a lack of data regarding the deposition of dung and urine excretion, as it varies remarkably depending on animal species, breed, age, weight, status, nutrition and grazing management. Some reference data are available for N, but P and K are generally disregarded. Consequently, an important input of nutrients for the SSB is generally not quantified with sufficient precision.

Another important input, common to both the FGB and the SSB, is biological N-fixation. According to current literature, it can provide the soil with 10-300 kg of N, depending on the legume species, contribution to the sward, soil type and weather conditions. In a grass-legume mixture, the proportion of legumes should be assessed. In addition, the legume contribution to a sward can vary remarkably between years and in the same year with the season. Therefore, any measurement should be repeated frequently. If there are high levels of soil mineral N, plants rely on this source of N, and N fixation is typically reduced, as symbiotic fixation is a process that consumes considerable energy. Therefore, the exact contribution of N fixation to grassland nutrition can only be estimated.

Despite the difficulties in estimating these two important entries, the method can be applied using standard values, although the user should be aware of potential inaccuracies in the resulting nutrient balance.

Support

External support is often needed for accurate data entry, and to analyse and interpret the results. Therefore, a local extension service, whether public or private, would be of great help in the adoption of this good practice.

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Example of good practice

An accounting system (Annual Nutrient Cycle Assessment- ANCA) that calculates FGB and SSBs is compulsory for nearly all dairy farmers in the Netherlands that deliver milk to a dairy processing company. This has helped many farmers reduce the use of mineral fertilisers, better distribute manure across the farmland area, develop a map of the possible sites where manure in excess could be relocated, and set targets for improvements in farm management. This system was firstly used for N balances, was extended to P, and now also includes greenhouse gas emissions.

The Monitro research project, in Piedmont (NW Italy) successfully introduced a field-scale SSB spreadsheet calculation on pilot farms. The SSB included N, P and K, and the main aim of the project was to increase farmer awareness of nutrient management issues. A new free web version is under development for more widespread use.

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