Gross soil surface nutrient balances: The OECD approach implemented under German conditions

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Abstract

Plant and therefore food and feed production require an adequate supply of nutrients. Efficient nutrient use is a major task to ensure economically and environmentally sound food production minimizing the impact of nutrients on ground water, the risk of eutrophication caused by rising nutrient concentrations in surface waters and the emission of trace gases such as nitrous oxide (N_2O) and ammonia (NH_3). Agri-environmental indicators (AEI) developed by the OECD shall identify and quantify the extent of impacts by agricultural management on the environment and track the effects of policy measures. Nutrient balances for nitrogen (N) and phosphorus (P) on the national level are two of these agri-environmental indicators used by the OECD to compare member states and draw conclusions about nutrient loads from agriculture into the environment.

OECD member states are required to calculate and provide gross soil surface nutrient balances for N and P on an annual base. The German N gross soil surface balance for the time period from 1992 to 2006 shows a surplus between 89 and 121 kg ha^{-1} a^{-1} N. Because nutrient balances are simplifications of complex and variable processes they comprise a series of uncertainties. These uncertainties are mainly associated with either the statistical data base or the coefficient library used to convert the statistical data into nutrient quantities. Therefore, it is essential to be aware that the absolute balance values do not reflect the actual situation in a country. Nevertheless, in case that a consistent method of balance calculation is used for all years a comparison between these years to derive trends in nutrient surpluses or deficits is possible.

Keywords: OECD guideline, nutrients, gross soil surface balance, data uncertainties, nitrogen coefficients

Zusammenfassung

Das Wachstum von Pflanzen und damit die Erzeugung von Nahrungs- und Futtermitteln erfordern eine bilanzorientierte Zufuhr von Nährstoffen. Die effiziente Ausnutzung von Nährstoffen ist für eine wirtschaftliche und umweltgerechte Nahrungsmittelproduktion entscheidend und ermöglicht die Einflüsse dieser auf das Grundwasser, das Eutrophierungsrisiko durch ansteigende Nährstoffkonzentrationen in Oberflächengewässern und die Emission von Spurengasen wie z. B. Distickstoffmonoxid (N_2O) und Ammoniak (NH_3) zu minimieren. Von der OECD entwickelte Agrar-Umweltindikatoren sollen den Einfluss der Landwirtschaft auf die Umwelt identifizieren und quantifizieren sowie dazu dienen, Auswirkungen politischer Maßnahmen zu verfolgen. Nationale Stickstoff- (N) und Phosphorbilanzen (P) zählen zu diesen Agrar-Umweltindikatoren, die von der OECD zur Bewertung von Nährstofffrachten aus der Landwirtschaft in die Umwelt herangezogen werden.

Mitgliedsstaaten der OECD sind verpflichtet, jährliche brutto Flächenbilanzen für N und P zu berechnen und bereitzustellen. Die Berechnung der N brutto Flächenbilanz für Deutschland zeigt N-Überschüsse zwischen 89 und 121 kg ha^{-1} a^{-1} im Untersuchungszeitraum von 1992 bis 2006. Da es sich bei Nährstoffbilanzen um die vereinfachende Zusammenfassung und Berechnung von komplexen und sowohl räumlich als auch zeitlich variablen Prozessen handelt, sind diese fehlerbehaftet. Die meisten Unsicherheiten beruhen entweder auf der statistischen Datenbasis oder der verwendeten Koeffizienten zur Umrechnung von statistischen Daten in Nährstoffmengen. Daher ist nicht davon auszugehen, dass die absoluten Bilanzsalden die tatsächliche Nährstoffsituation eines Staates wiedergeben. Jedoch sind jährliche Bilanzen geeignet um Trends in der Entwicklung von Nährstoffüberschüssen oder -defiziten zu verfolgen. Für vergleichende Betrachtungen muss allerdings sichergestellt sein, dass die Berechnungen mit einer konsistenten Methode erfolgen.

Schlüsselwörter: OECD Richtlinie, Nährstoffe, brutto Flächenbilanz, Datenunsicherheiten, Stickstoffkoeffizienten

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Introduction

Plant and therefore food and feed production require an adequate supply of nutrients. Cassman et al. (2003) reveal the complex relationship between nutrient availability, crop yield and nutrient efficiency considering the difficulty to meet food demands while protecting natural resources. Soils will lose their fertility if nutrient mining takes place over a longer period. Then again, nutrient loads from agriculture into the environment increase the risk of eutrophication in surface waters caused by rising phosphorus (P) concentrations, can have a severe impact on ground water quality by increasing nitrate (NO_3^-) or P concentration and can emit trace gases such as nitrous oxide (N_2O) and ammonia (NH_3) into the air. For a better protection of natural resources like for example soil and water, it is important to identify where and to what extent persistent nutrient surpluses or deficits occur.

Impacts of agriculture and agricultural policies on the environment are a major issue in OECD (Organisation for Economic Cooperation and Development) member states. A set of agri-environmental indicators (AEIs) was developed by the OECD to identify and quantify the extent of these impacts and to better understand the effects of policy measures on the environment (OECD, 1999). Nutrient balances for nitrogen (N) and P calculated on the national level are commonly used as AEIs by policy makers. OECD member states are required to keep record about nutrient surpluses and deficits from agriculture on an annual base.

Nutrient balances can be calculated using different approaches. In addition to the gross soil surface balance calculation recommended by the OECD (OECD/EUROSTAT, 2003), these are the net soil surface balance, the livestock balance and the farm gate balance. Each of these approaches balances nutrients added to an agricultural system and nutrients removed from the system per hectare of agricultural land. Depending on the balance to be calculated nutrient input and output variables vary (Table 1).

Besides of different approaches to calculate balances they can also be calculated in a variety of spatial scales. Whereas for example Bach and Frede (1998) calculated N balances for Germany, Bach et al. (2003) and Osterburg and Schmidt (2008) calculated balances on a regional scale. An overview regarding some of the different approaches was published by Bach and Frede (2005). To evaluate fertiliser strategies on the farm level it is necessary to calculate balances for single farms or even better fields. This was shown by Quirin et al. (2004), who demonstrated how N surpluses could be tracked back to varying fertilisation practises on different fields of one farm. In Germany farmers are required to keep so called annual and multi-year nutrient management plans to record the farm nutrient in- and outputs.

Table 1:

Input and output variables of gross- and net soils surface balances, livestock balances and farm gate balances

	Gross soil surface balance	Net soil surface balance	Live-stock balance	Farm gate balance
Input				
Mineral fertiliser	+	+		+
Organic fertiliser	+	+		+
Livestock manure	+	+		
Atmospheric deposition[1]	+	+		+
Biological N-fixation[1]	+	+		+
Seed and planting material	+	+		+
Imported fodder			+	+
Fodder from domestic food industry			+	+
Fodder (internal production)			+	
Output				
Total harvested crops and fodder	-	-		
Cash crops				-
Livestock marked products			-	-
Livestock manure			-	
N emissions[1]		-		
N demand for turn over processes[1]		-		
Surplus/deficit	= Sum	= Sum	= Sum	= Sum

[1] for N balances only

Nutrient balances will be calculated as difference between input and output in the agricultural system. For the N and P balances similar statistical input variables and corresponding N and P coefficients are required. Whereas in N balances emission from agriculture into soil, water and air are included, these paths are not considered for P. The remainder of this paper emphasis on N balances. The OECD handbook on gross N balances was first published in 2003 (OECD/EUROSTAT, 2003) and is used as guidance for the calculation. The gross balance methodology is considered the appropriate indicator for OECD member states to allow comparisons. It ensures as far as possible a consistency of the used method between countries.

The aim of this paper is to outline the implementation of the OECD gross N balance for Germany. Assumptions and estimations made to overcome data shortages in the German data bases are highlighted and uncertainties critically discussed. The N gross soil surface balance for Germany is calculated for the years 1992 to 2006 and some interpretation avenues are shown.

Materials and method of the OECD nitrogen balance

The following calculations are based on data from 1992 to 2006 covering a 15 year time period after the German reunification. Calculations of N balances for years before and short after the German reunification need some special considerations because of the differences in data availability. This issue will not be discussed in this paper.

Statistical and other input data

Data required for the calculation of the national gross N soil surface balance are mineral and organic fertiliser, livestock manure, biological N fixation, seeds and planting material and the total harvested crops and fodder (Table 1). Each of these variables is further segmented (Table 2). Additional, land use data is required for calculations referring

Table 2:

OECD codes, in- and output variables, N coefficients and units used to calculate the gross N soil surface balances for Germany according to the OECD method

OECD code	Variables and N coefficients[1]	Unit of N coefficients
L1	Total area	
L11	Total land area	
L111	Agricultural land (arable crop land, permanent crop land and permanent pasture)	
F1	Total fertilisers	
F11	Total inorganic fertilisers (N fertilisers)	
F12	Total organic products (sewage sludge [39.5], urban compost [14.3])	kg Mg^{-1} N
A1	Livestock manure production	
A11	Total cattle (calves for slaughter, other male and female calves (<1 yr) [25], male and female cattle (1-2 yrs) [47], male cattle, breeding heifers, heifers for slaughter (>2yrs) [59], dairy cows [115] and other cows [98])	kg $head^{-1}$ yr^{1} N
A12	Total pigs (piglets (<20kg [4] and 20-50 kg [13]), fattening pigs [13], breeding boars [13] and sows (>50 kg) [26])	kg $head^{-1}$ yr^{1} N
A13	Total sheep and goats (sheep [10], lambs [10] and goats [13])	kg $head^{-1}$ yr^{1} N
A14	Total poultry (broilers [0.29], layers [0.73] and other chickens [0.28]), ducks [0.55], turkeys [1.6] and other poultry [0.8])	kg $head^{-1}$ yr^{1} N
A19	Total other livestock (horses [68])	kg $head^{-1}$ yr^{1} N
C2	Total harvested crops and forage	
C21	Total harvested crops	
C211	Total cereals (spring wheat [18], winter wheat [22], durum wheat [18], barley [17], maize [15], oats [15], rye [15], other coarse grains [14], triticale [18] and others cereals [17])	kg Mg^{-1} N
C212	Total oil crops (sunflowerseed [28], rapeseed [33] and other oil crops [35])	kg Mg^{-1} N
C213	Total dried pulses and beans [39]	kg Mg^{-1} N
C214	Total root crops (potatoes [3.5])	kg Mg^{-1} N
C215	Total fruit area (fruit [44] and viticulture [25])	kg ha^{-1} N
C216	Total vegetables [2.9]	kg Mg^{-1} N
C217	Total industrial crops (sugar beet [1.8], tobacco [30] and hop [30])	kg Mg^{-1} N
C22	Total forage	
C221	Total harvested fodder crops (fodder beets [1.4], other fodder roots [1.4], clover [25], alfalfa [25], silage maize [3.8] and other harvested fodder crops [3.5])	kg Mg^{-1} N
C222	Total pasture consumption (temporary [24], permanent pasture consumption [22] and alpine pasture and rough grazing [15.5])	kg Mg^{-1} N
C23	Total crop residues removed from the field (straws [5] and other crops residues [3])	kg Mg^{-1} N
C11	Total seeds and planting materials	
C111	Total cereals (wheat [18], barley [16.1], maize [15], oats [15], rye [15] and other cereals [18])	kg ha^{-1} N
C112	Total oil crops (sunflowerseed [28], rapeseed [33] and other oil crops [35])	kg ha^{-1} N
C113	Total root crops (potatoes [3.5])	kg ha^{-1} N
C213	Total dried pulses and beans	kg ha^{-1} N
B1	Biological N fixation	
B11	Total area of legume crops (pulses [176], clover [198] and alfalfa [285])	kg ha^{-1} N
B12	Free living organisms (permanent pasture [30])	kg ha^{-1} N
D1	Atmospheric deposition	

[1] N coefficients are shown in [brackets] and are based on 86 % dry matter (DM) for cereals, 91 % DM for rapeseed and 28 % DM for silage maize

to the area unit. Most of these in- and output variables are provided by the Federal Statistical Office (Destatis). The annually published statistic for nutrition, agriculture and forestry builds most of the data base (exemplarily: Statistisches Jahrbuch, 2005). Since 2002/2003 on-line statistical tables (GENISIS) are used when available from the Destatis homepage (https://www-genesis.destatis.de/genesis/online/logon). Table 2 enlists the code of the OECD, the corresponding necessary variables and coefficients for the calculation and the units in which they are provided. Additional data for the atmospheric deposition, was derived from long term trends in deposition loads of air pollutants in Germany and was set to 23 kg ha^{-1} a^{-1} N (Gauger et al., 2002).

Nitrogen coefficients

All statistical livestock and crop production data needs to be converted into N equivalents which allow to sum up the total amount of N inputs and outputs and to balance these. To convert the various variables from their original recorded unit into common units, N coefficients are used. Most of the N coefficients are derived from the German Fertiliser Application Ordinance (MVV, 1996). In case of some animal coefficients, a different data source was used (VwV, 1996). Table 2 shows the used coefficients in brackets after the variables. Table 3 and Equation 1 reveal exemplarily the calculation of the N amount removed by 'total cereals'. It can be seen, that some of the OECD specified variables like e.g. rice and sorghum are not relevant for German balances. In other cases the German statistics and coefficient data base allow to improve the calculation by further diversification.

Nitrogen coefficients for compost and sewage sludge are not provided by the German Fertiliser Application Ordinance (MVV, 1996), these coefficients are derived from other available sources. The N coefficients for compost were derived from the Federal Environmental Agency (Bannick et al., 2001) and for sewage sludge from the triennial compiled German report about sewage sludge for the European Commission (BMU, 2004; BMU, 2007). For the data presented in this paper an average of 39.5 kg Mg^{-1} N in sewage sludge was used for all years drawn from the 2004 report (BMU, 2004). If this series is continued it might be possible to use annual values instead of averages in future calculations.

Table 3:

Nitrogen coefficients to calculate the total harvested N from cereals

C211	Total harvested cereals [Mg]	N coefficient[5] [kg Mg^{-1} N]
C2111	Wheat	
C21111	Common wheat	
C211111	Spring wheat (SW_y)	18
C211112	Winter wheat (WW_y)	22
C21112	Durum wheat (DW_y)	18
C2112	Rice	
C2113	Coarse grains	
C21131	Barley[1] (B_y)	17
C21132	Maize (M_y)	15
C21133	Millet	
C21134	Oats (O_y)	15
C21135	Rye[2] (R_y)	15
C21136	Sorghum	
C21139	Other coarse grains[3] (CG_y)	14
C2119	Other cereals	
C21191	Triticale (T_y)	18
C21199	Other cereals types[4] (OC_y)	17

[1] winter barley; [2] winter rye; [3] brewing barley; [4] spring barley, [5] based on 86 % DM

$$\text{total cereals}_{[kg\,N]} = (SW_y * 18 + WW_y * 22 + DW_y * 18) + (B_y * 17 + M_y * 15 + O_y * 15 + R_y * 15 + CG_y * 14) + (T_y * 18 + OC_y * 17) \quad \text{[Equation 1]}$$

Data uncertainties

Statistical data

Statistical data published by Destatis have an effect on balance calculations mainly through the following three uncertainties: (i) input data are not recorded on an annual base, (ii) input data are estimations and (iii) by OECD requested input variables are not supported by the statistic. Depending on the proportion of the input variables on the gross N soil surface balance, their influence on the overall uncertainty can be substantial (Figure 1). As can been seen, mineral fertiliser and livestock manure are the major contributing input variables in the balance. Both data sources of these input variables have their uncertainties. Whilst the N input from mineral fertiliser is based on sales figures and not on the actual applied amount of N fertiliser, the input from livestock manure is calculated from animal numbers. Cattle and pigs are counted twice a year (May and November) and it was decided to use the November count in the balance. All other animals are not counted annually, whereas for years without counts, the number of the previous year is used. Because of the necessity to update the balance on an annual basis, it is not possible to use a mean value from a previous and following year, because the latter data is not available yet. Furthermore some data are only estimates, like the number of goats.

Sewage sludge and urban compost which are cumulated to the variable organic fertilisers are only erratically recorded in German statistics and therefore missing data were replaced by data of previous years.

The N output values are mainly driven by cereals, pasture and harvested fodder crops (Figure 1). Yields of crops, sugar and fodder beet leaves, pasture, fruits, viticulture and vegetables are estimated by the state statistical offices in Germany and reported to Destatis. In case of cereals, potatoes and winter rape actual yield values of selected fields (maximum of 10,000) are recorded and extrapolated onto the national level. Sugar beet yields are provided by the sugar industry and are based on the amounts of beets delivered to the sugar factory. Grape yields are also based on notifications about vintage to the viticulture register (Weinbaukartei). Calculations of fruit yields are based either on the cropping area or on tree yields. Yields of vegetables are estimated according to the cropped area.

A general major concern is the estimation of the pasture yields because of the large proportional influence of this variable (Figure 1). Not only is this variable estimated, it is further required to account for N losses during agricultural management. In Germany, a loss of 15 % in pasture yield is assumed, which is lower than the proposed 30 % of the OECD.

The amount of straw removed from the field needs to be considered in the calculation. Because of the lack of statistical data it is estimated that straw in the dimension of 10 % of the grain yield is removed annually from agricultural fields. This value might need to be reconsidered for future calculations because it can be expected that the rising demand on renewable energy sources will increase the straw collection practice of farms.

Changes in agricultural management practice also influence the provided statistical data, as crops which are not commonly or not any longer cultivated will be removed from the statistical data set. Fodder beet yields are for example not any longer published since 2003. This inconsistency in data series results in some inaccuracies when calculating balances. A further difficulty is the allocation of statistical data from management years (July to June) to balance years (January to December). Most variables are reported in balance years, but mineral fertiliser and seeds and planting material are listed for management years. Hence the data were assigned to the balance years as follows: It is assumed that the majority of mineral fertiliser and seeds and planting material bought in the management year is used to achieve the yield of the second named management year (e.g. management year 2004/2005 will be allocated to the balance year 2005).

Furthermore, the subsequent precision of statistical data causes confusions when comparing an actual balance of one time period to an older one and discovering that the surplus calculated for one of the previous years has been altered. Even though changes are generally minor considering the overall imprecision of the method, they tend to irritate users of nutrient balances.

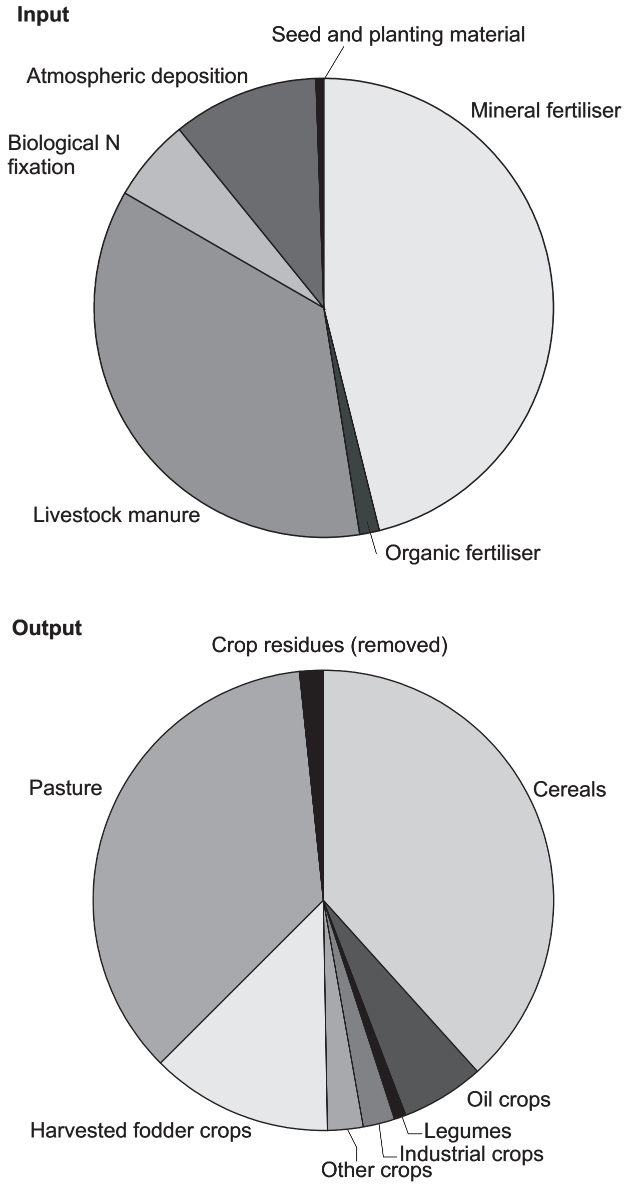

Figure 1:

Proportional share of N input and output variables on the N balance (average 1992 to 2006)

Nitrogen coefficients

Coefficients used for national balances are provided by the German Fertiliser Application Ordinance (MVV, 1996; DüV, 2007). These published values are derived from various sources like the German Agricultural Society (DLG) who publishes for example coefficients for N contents of animal manure (DLG, 2005).

Uncertainties in the balance are caused by the following inconsistencies when using N coefficients: (i) reported N coefficients are not congruent with the classification of variables and (ii) N coefficients are modified by revised legislations.

Examples for the non consistency between N coefficients and variables as classified by the OECD code are:

- Differentiation of the OECD variables into male and female cattle (1 to 2 yrs) is not matched by the German N coefficients (MVV, 1996) which are segmented depending on the feeding management, like for example grassland or forage cropping.
- The Fertiliser Application Ordinance (MVV, 1996) differentiates the N coefficients for cereals further than the variables of the OECD code are classified. For example, the barley production is summarized into one variable but German N coefficients for winter barley, malting barley and feeding barley are reported with 17, 14 and 17 kg Mg^{-1} N, respectively.
- The OECD code differentiates only between temporary and permanent grassland, whilst the German Fertiliser Application Ordinance (MVV, 1996) separates further into the number of annual grass cuts.

Changes of coefficients in the German Fertiliser Application Ordinance result also in inconsistencies when balances are calculated with the emphasis to evaluate long term trends. This is actually the case with the newly published Fertiliser Application Ordinance, coming into effect 2007 (DüV, 2007). The presented results are calculated using the coefficients of the former Fertiliser Application Ordinance (MVV, 1996). Comparisons of N balances calculated with the same statistical input data but old and new coefficients showed, that the gross N soil surface balances from 1992 to 2006 would have been in average 3.8 kg ha^{-1} N lower when calculated with the newer coefficients. This poses the question how to proceed after changes in the coefficient library especially when balances over long time periods are compared and interpreted. It can be expected that, on grounds of changes in crop varieties, cultivation and management practices, several adoptions of coefficients will have been taken place over the last decades. It is therefore questionable, if actual coefficients can be used for longer time periods. In cases when different coefficients for certain time periods are used, it is necessary to quantify the changes and to comment these in the interpretation of the balances. Otherwise changes in balances can be misleading and the use as evaluation tool for policy measures is restricted. The second possibility would be to use the actual coefficients in retrospective. This would also need to be commented in the balance interpretation. Both methods are obviously unsatisfactory, but unavoidable when longer time series will be studied.

A further critical point is the comparison of OECD balances internationally caused by the differences in N coefficients of the member states. The OECD therefore enforces a harmonisation of the coefficient library as far as possible, but this task is still in process. An absolute agreement will probably not be achieved because of regionally specific influences on the coefficients.

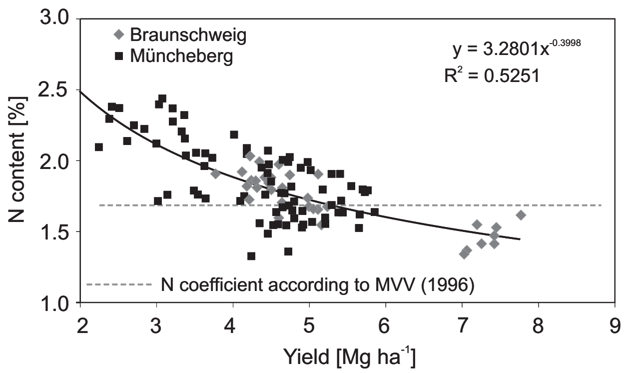

Figure 2:

Relationship of yield and N content of spring feeding barley derived from long-term field experiments in Müncheberg and Braunschweig, Germany, 1976 to 2005

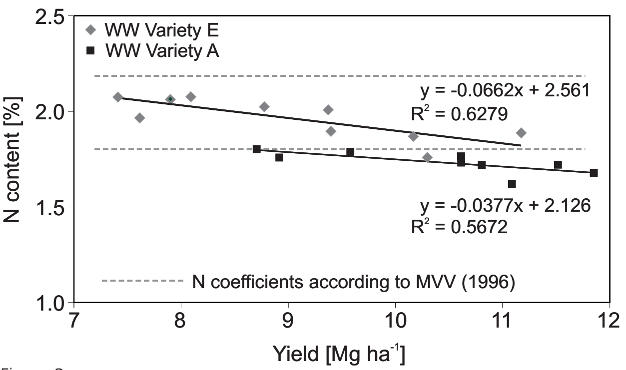

Figure 3:

Relationship of yield and N content of two winter wheat varieties in Clauen, Germany 1995 to 2007. The data was provided by the Federal Office of Plant Varieties in Germany and derived from the variety testing database

Additionally, it has to be clear that coefficients are generally mean values agreed on and can vary substantially for example between regions, years, fields, varieties and fertilisation management. Figure 2 demonstrates the dependency of N content in spring feeding barley and yield level. It can be seen that with increasing yield the N content of spring feeding barley grain decreases. Obviously, a single N coefficient used for the calculation of N balances can not comprehend the variability of grain N contents. This can also be seen in a second example when comparing two winter wheat varieties (Figure 3). As expected are the N contents of variety A lower as of variety E. Figure 3 also confirms that winter wheat yield and the N content of grain are correlated negatively.

Considering the variety and nature of the above mentioned uncertainties it can be concluded, that some of these could be improved like for example the annual data availability. Others will always be a compromise and agreement of common knowledge, like N coefficients. Because of these uncertainties it is most important that the calculation of nutrient balances is kept as transparent and open as possible to allow users of the balance insights into the calculation parameters.

Gross soil surface nitrogen balance for Germany 1992 to 2006

The gross soil surface N balance was calculated for the years 1992 to 2006 (Figure 4). Therefore the results exclude issues like the above mentioned influence of the altered N coefficients of the new legislation (DüV, 2007). Further, the incomparability of statistical data compiled by the two former German countries until 1989 and the transition years of 1990 and 1991 are irrelevant. Data in nutrient balances always refers to the agricultural land use area (AL).

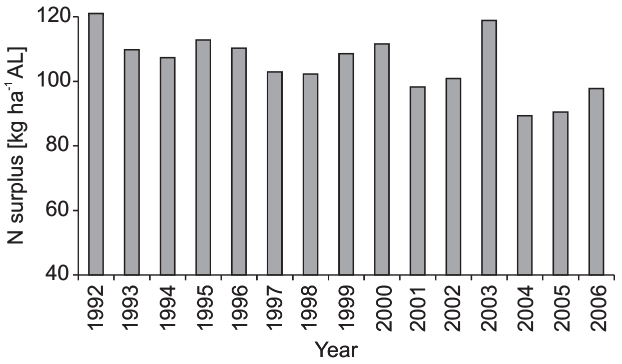

Figure 4:

Gross soil surface N balance for Germany 1992 to 2006 calculated according to the OECD method

During this 15 year time period the agricultural land use, including arable land, permanent crop land and permanent pasture (Table 2) was reduced from 16,950,072 to 16,939,300 ha, which equals a reduction of less then 0.1 %. The annual N surpluses show a slight overall declining trend, hence with constant outliers. The year 2003 had an exceeding high N surplus, which was caused by unusual weather conditions. While the years 1999 to 2003 were classified as too wet, the summer of 2003 was exceptional hot and dry. Average weather conditions at the beginning of the year supported farmers to average nutrient supply, but the hot and dry weather throughout Germany during the summer resulted in high yield losses (Figure 5) which returned the high N surplus.

Whereas the yearly fertiliser and manure application are controlled by the farmers and based on average yield expectations, the subsequent yield depends on weather conditions and is therefore difficult to predict. Because of this, long term trends are much more reliable than single or short term calculations and therefore the only source to verify policy measures.

The results of N balances are in regards to input variables mostly affected by the amount of mineral fertiliser and manure application. Nitrogen deposition is accounted for with a constant factor and the N input from sewage sludge, urban compost, biological N fixation and seed and planting material contributes in average only a small amount with together about 18 % (Figure 1). The changes in N input by mineral fertiliser and livestock manure in kg ha^{-1} from 1992 to 2006 are shown in Figure 5.

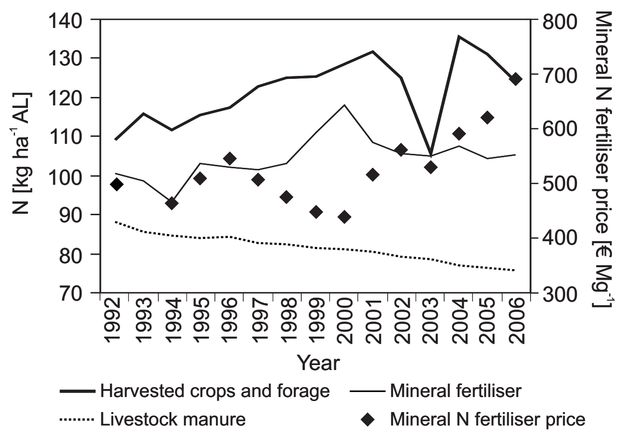

Figure 5:

Changes of the N input variables mineral fertiliser and livestock manure, the N output variable harvested crops and forage and the mineral fertiliser price from 1992 to 2006

The amount of livestock manure and therefore N input with manure decreased during this time period, caused by a decrease in total animal production (Figure 6). While the manure production of pigs, sheep and poultry remained on a constant level, the number of cattle was reduced from 16,207,340 head in 1992 to 12,676,800 head in 2006. Nevertheless, cattle manure contributes 22 % N as input to the balance. The sales numbers of mineral fertiliser varied for the same time period between 93 and 118 kg ha^{-1}. Mineral fertiliser application rates are influenced by a number of factors. Besides the implementation of good agricultural practice it can be seen that for example mineral fertiliser prices bias the application rates. This is obvious for the year 2000, for which higher fertiliser application rates are correlated to lower prices of mineral N fertiliser (Figure 5).

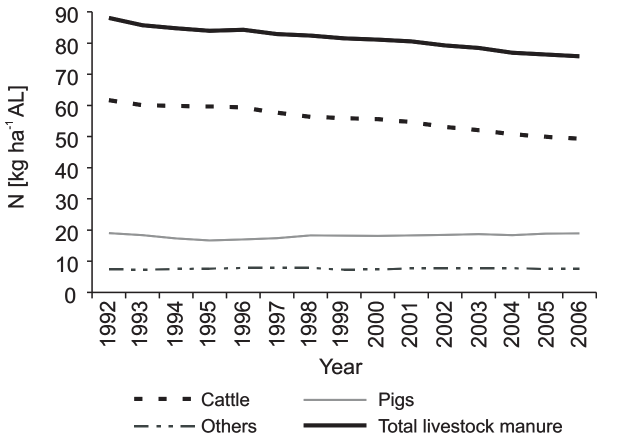

Figure 6:

Changes of the N input by total livestock manure as well as split for cattle, pigs and others (sum of sheep and goats, poultry and horses) from 1992 to 2006

Implementation issues of soil surface nutrient balances

Langeveld et al. (2007) summarized that agri-environmental indicators (AEIs) should (i) refer to relevant issues, (ii) be based on sound science, (iii) be quantifiable, (iv) be relevant for target groups involved, (v) be easy to interpret, (vi) be cost-effective, and (vii) facilitate communication. These demands will be used in the following as a guideline to evaluate the gross soil surface balance approach as AEI for Germany on the national level and in the context of international comparisons like between OECD member countries.

Based on the knowledge about the potential risk nutrient surpluses impose on the environment and natural resources like for example soil and water, the quantification of this risk is a relevant task. Obviously, to ensure that risk assessments based on nutrient balances can be reliable, the science should be sound. Unfortunately, national nutrient balances will always be a compromise. Besides of the lack of statistical data for certain variables or years, the N coefficients used are not able to reflect regional distinctions between land use and management practice, varieties used or annual variations caused by weather dependent yield fluctuations. Two main issues arise from the used coefficients. First, because nutrient balances need to be calculated over longer periods to be meaningful, changes in the coefficient library caused by changes of coefficients in official data bases can result in inconsistencies of the calculations. Second, if national balances are used to compare countries, like it is the case with the OECD balances, different coefficients are used in the calculation of different countries. This poses some risk in the interpretation of national balance in an international context. Therefore the OECD aims to define a common coefficient library, but this is not yet available.

Nutrient balances are a tool to quantify nutrient surpluses and they can be used to demonstrate trends in the development over longer time periods. Nevertheless, because of the lack in data and coefficient availability and accuracy the absolute N surplus calculated comprises a high uncertainty which is difficult to overcome. On the contrary the comparison between years calculated with the same method can be evaluated considering weather conditions, prizes for fertilisers and crops as well as policy measures introduced. Cautious interpretations and conclusions can be drawn if all influencing factors are considered.

National nutrient balances are one of the AEIs relevant for policy makers and researchers and build the base to communicate developments in environmental performance and to perform risk assessments. Farmers need to compile their own nutrient management plans to ensure that they comply with the German Fertiliser Application Ordinance (MVV, 1996; DüV, 2007) and to assess the applied fertilisation strategy. Quirin et al. (2004) discussed the use of these farm and field related balances. The costs to calculate national nutrient balances are moderate after the sources for statistical data and coefficients are explored, the calculation method is adopted and adjustments of the method to the available data are made. As long the statistical data base and coefficient library are not altered the annual update of the balance involves only an extension of the data input and can be considered as minor.

Because of the uncertainties inhered in the calculation of nutrient balances it is inevitable to keep the calculation procedures as well as input and output data as transparent as possible. On base of this insight into the calculation a sound communication between users of nutrient balances is possible. Even though, this bears the risk that instead of focusing on much-needed solutions to overcome nutrient surpluses or deficits, discussions around insufficient databases and coefficients develop.

Conclusions

Gross soil surface nutrient balances are influenced by numerous uncertainties in the data base and the coefficient library. To be able to use nutrient balances as AEIs it is essential to be aware that the absolute balance values do not mirror the actual situation in a country. Nevertheless, in case that a consistent method of balance calculation is used for all years a comparison between these years to derive trends in nutrient surpluses or deficits is possible.

Finally it can be followed the conclusion of Langeveld et al. (2005), that gross soil surface balances should be used with care and that always be kept in mind that indicators are simplifications of complex and variable processes.

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