European Water Management Online
Official Publication of the European Water Association (EWA)

Martin Bach[1,2], Hans-Georg Frede[1]

Assessment of Agricultural Nitrogen Balances for Municipalities - Example Baden-Wuerttemberg (Germany)

ABSTRACT
For the implementation of the Water Framework Directive (WFD) the spatially differentiated evaluation of water eutrophication caused by non-point source nitrogen input constitutes a central issue. The nitrogen (N) balance surplus is a commonly used indicator for identifying areas vulnerable to nutrient pollution. The WFD recommends a minimum area of ca. 10 km² for the spatial resolution of river basin management plans, thus it is also appropriate to calculate the nitrogen balances with a comparable spatial resolution. In Germany municipalities (EU nomenclature: LAU level 2) are the smallest administrative units for which Agricultural Census data are available. However, it is necessary to replace numerous entities in the Agricultural Census records that were not published for reasons of data secrecy. The estimation of nitrogen mineral fertilizing quantities for regional units is considered to be the most critical point of a N balance. Using nitrogen surface balance calculations for the municipalities of the federal state of Baden-Wuerttemberg (Germany), approaches will be introduced for both points which lead to reasonable results.

Keywords: nitrogen, non-point source pollution, soil surface balance, spatial resolution, water framework directive.

1. SCOPE AND BACKGROUND
The calculation of regionally differentiated nitrogen (N) balances for agriculture was established to identify significant N water pollution from non-point sources. Such balances have already been implemented by many authors repeatedly (i.) in the form of farm gate balances (synonym: national, sector) and soil surface balances, (ii.) for nitrogen and phosphorus, (iii.) as well as for different administrative units such as ‘national territory’, ‘federal states’ (EU NUTS 2 level), and ‘counties’ (EU NUTS 3 level) (e.g. Bach and Frede, 1998; Behrendt et al., 2003; Crouzet, 2001; Hansen, 2000; Terres et al., 2003; OECD 2001a, Wit et al., 2002). Furthermore, the N balance surplus has become an important indictor for the evaluation of the sustainability of agriculture, for example, the verification of the implementation of European Union nitrate guidelines in Germany employs the long term modification of N surpluses as its criterion (Bach and Frede, 2001).

[1] *University of Giessen, Institute of Landscape Ecology and Resources Management, Giessen, Germany*
[2] *Contact: Dr. Martin Bach, Inst. Resources Management, H.-Buff-Ring 26-32, 35392 Giessen, Germany, phone +49 641 9937375, fax +49 641 9937389, email: martin.bach@agrar.uni-giessen.de*

In connection with the implementation of the EU's WFD, the quantity 'nitrogen balance surplus' is applied in numerous models (e.g. EUROHARP project, Schoumans and Silgram, 2003; MONERIS, Behrendt et al., 2002) to identify significant N inputs from non point sources into groundwater and surface waters. The WFD recommends a minimum area of ca. 10 km² for the spatial resolution of river basin management plans. In this regard it is also appropriate to calculate those nutrient balances with a comparable spatial resolution. The calculation of nitrogen surface balances has, until now, only been carried out in Germany on a routine basis for the municipality (EU LAU 2 level), as they are the lowest level of administrative units.

The regional distribution of the census-based physical quantities, which reverts to the Agricultural Census in the case of surface balances, is the restrictive factor for the spatial resolution of nutrient balances. The municipalities form the smallest (lowest) spatial aggregation unit of the Agricultural Census in Germany. However, at this point the problem of data protection arises: for restrictions due to data secrecy, results that refer to no more than three individual entries are not published. Thus, we often find a large number of table elements in the records of the Agricultural Census for the municipality level which do not contain the relevant values. Consequently, in addition to the calculation of N balances there is the task of 'filling in' the 'data-gaps' within the balance sheet.

2. CALCULATION SCHEME OF NITROGEN BALANCES

When calculating nutrient balances the surplus of the *soil surface balance* (balancing of the plant/soil production) must be differentiated from the surplus of the *farm gate balance* (synonyms: national balance, sector balance); the methodological background is presented in OECD (2001b) and also in Bach and Frede (1998). The calculation of nitrogen surface balances for municipalities in Baden-Wuerttemberg follows equation l. The coefficients for livestock nutrient excretion (Table 1), for nutrient content in harvest withdrawal (Table 2), and for legume N fixation date from MusterVwV (1996). Most of the coefficients are identical to the corresponding values of the OECD handbook. State-specific figures taken from the Agricultural Administration of Baden-Wuerttemberg were only used for a few coefficients.

Chemical fertilization (inorganic fertilizer)
\+ Organic fertilization (livestock manure)
\+ Organic secondary raw material
\+ Atmospheric nitrogen deposition
\+ Biological nitrogen fixation by legumes
\- Harvest withdrawal
= Soil surface balance surplus [1]

Organic fertilization: Livestock manure nitrogen production is calculated by multiplying the number of animals in the municipality by the mean nitrogen excretion per head (Table 1). The N losses by volatilization during storage and application of manure depend on livestock species, type of manure and manure storage system. Average portions of plant-available N are given in column 3 of Table 1. The transfer of manure between farms across the municipality's borders is only taken into account in the balance providing that the arrangement for this transportation is organized by a manure stock market and is therefore recorded in the statistics.

Table 1: Nitrogen in livestock manure production (ref. OECD, 2001b; MusterVwW, 1996).

Livestock unit	kg N per head and year	Nitrogen availability[b]
Dairy cows	101	66 %
Other[a] bovines	50	66 %
Fattened pigs (> 50 kg)	10,2	69 %
Breeding sows	31	69 %
Other[a] pigs	4	69 %
Sheep, goats (all ages)	10	60 %
Laying hens (> ½ year)	0,73	64 %

[a]) 'Other ...': remaining difference between the number of 'general species total' minus the number in the species categories mentioned explicitly.
[b]) Plant-available nitrogen fraction in the organic fertilizer after subtraction of N-losses by volatilization during the storage and application of animal wastes.

Organic secondary raw material (sewage sludge, compost) is set at 4 kg N/ha AA (the average value for Germany) in all municipalities due to the lack of spatialized information.

Atmospheric nitrogen deposition: Data from the EMEP program (EMEP, 2002) was used for the calculation of the N deposition from the atmosphere, which is available in Germany with a grid cell resolution of 50 km * 50 km and was overlaid with the municipalities.

Biological nitrogen fixation: 20 kg N/ha is calculated for pasture, 160 kg N/ha for legumes, and 65 kg N/ha for other varieties of forage crops.

The *harvest withdrawal* of the field crops is calculated by multiplying the crop acreage with either (a) the average crop yield (data available only for the counties) and the N content in the harvested product, or (b) for crops without statistical data for the yield, by fixed withdrawal quantities per area under crop (Table 2). The harvest withdrawal of by-products (straw, sugar beet leaves) is considered proportionally to the stocking of livestock.

Table 2: Nitrogen content and amount in harvest withdrawal (ref. OECD, 2001b; MusterVwV, 1996).

Crops *with* yield data	Nitrogen content kg N/t
Wheat	20
Rye	15
Winter barley	17
Spring barley	14
Oats	16
Triticale	18
Straw	5
Potatoes	3,5
Sugar beet	1,8
Sugar beet leaves	4
Rapeseed	33
Maize silage	3,8

Crops *without* yield data	Nitrogen amount kg N/ha
Pasture	140
Viniculture	30
Legumes	150
Other[b] row crops	120
Other[b] forage crops[a]	200
Vegetable, orchards	30

[a]) Alfalfa, clover, etc.

3. ESTIMATION OF CHEMICAL FERTILIZATION QUANTITY

The crucial methodological problem for regionalized nutrient balancing, at the same time the most sensitive factor for the nutrient balance surplus, and thus, the most critical point of all, is posed by the estimation of *mineral fertilization.* There are no reliable statistical data available from regional units (NUT 2 or lower) below the national level (i.e. for Germany as a whole) concerning the amount of mineral fertilizer usage in agriculture. Therefore, quantities of mineral fertilizers have to be estimated for *all* regionalized balance-approaches for Germany. This problem appears, as far as is known, in the same way in many EU states.

The estimation of mineral fertilizer usage starts with the N demand of planted crops, which is necessary for the formation of the plant biomass or the achievement of the expected yield, respectively. This nutrient demand is calculated as a function of the crop yield (nutrient withdrawal that is harvested from the field). However, normally there is no total utilization (uptake) of the applied N by the plants, instead a certain amount is not exploited [Eq. 2]. In other words, the supply of the nutrient has to exceed the demand by a certain fraction. This situation is taken into consideration by using a 'coefficient of increased demand' which expresses the additional requirement for the unutilized portion of nutrient.

$$\text{N supply} = \text{total N demand} = \text{N harvest withdrawal} * \text{coefficient of increased demand} \quad [2]$$
$$(= \text{harvested N yield} / \text{degree of N utilization})$$

The total nutrient demand can be covered by various nutrient carriers: mineral fertilizers (chemical fertilizers), on-farm-produced organic fertilizers (liquid manure, dung), fertilization by organic secondary raw material (sewage sludge, compost), and the N fixation of legumes.

$$\text{Total N demand} = \text{mineral N fertilizers} + \text{organic N fertilization} * \text{apportionment factor} \quad [3]$$
$$+ \text{organic secondary raw material} + \text{legume N fixation}$$

To simplify the calculation we assume that farmers account for full (100 %) nitrogen availability of the N supply on the nutrient demand, with the exception of organic fertilizers. Reproducing the farmer's usual attitude, that nitrogen supply with manure only take into account a certain fraction in their fertilization management which expresses the 'apportionment factor' of equation 3. In regard to the calculation of nitrogen surface balances on a municipality level, the input terms of on-farm-produced organic fertilizers, organic secondary raw material, and legume N fixation (each one aggregated for the municipality) are calculated according to the above-mentioned approaches; the same applies to harvest withdrawal. After the transformation and introduction in equation 3 the mineral N fertilizer quantity may finally be calculated as a resultant according to equation 4.

Mineral N fertilization
= harvest withdrawal * coeff. of increased demand – organic fertilization * apportionment factor – organic secondary raw material – legume N fixation [4]

with

Harvest withdrawal :	N quantity in harvest withdrawal.
Coeff. of increased demand:	Takes into account the incomplete utilization of the supplied nutrients (estimation see below).
Organic fertilization:	N input from livestock manure production, whereby: N input = livestock N excretion * N availability (after subtraction of gaseous nitrogen losses during storage and application, see Table 1).
Apportionment factor:	Consideration of N in manure calculated by farmers in their fertilization planning (estimation see below).
Organic secondary raw material:	N input from sewage sludge and compost.
Legume N fixation:	N input by legume N fixation.

The resulting quantity is the estimated chemical N fertilization amount of a municipality, and is equivalent to the remaining N demand that farmers have to apply with commercial N fertilizers after the total crop nutrient demand has been covered in part by organic fertilization, organic secondary raw material fertilization, and through legume N fixation (atmospheric N deposition is not taken into account by farmers). The intention of this approach is to reflect, in a simplified manner (and aggregated for a regional unit), the usual conduct of farmers when they project the fertilization figures.

For the estimation of the two coefficients, the 'coefficient of increased demand' and the 'apportionment factor', the following approach is used. The coefficient of increased demand can be determined from fertilization recommendations tables (e.g. KTBL, 1999) expressing the recommended total N demand for a given field crop proportionally to the N quantity in the harvest withdrawal. In this way crop-specific coefficients of increased demand are obtained. However, these crop-specific factors have been summarized into an average coefficient of increased N demand of 1.2 (uniform for all crops and municipalities in Germany) in order to maintain simplicity of calculation.

The 'apportionment factor' can be determined as the average value for the country as a whole by solving equation 4 in the reverse direction (backwards), where the quantity 'mineral N fertilization supply' for agriculture as well as all other terms are known in the whole of Germany (Statistisches Jahrbuch). Subsequently, an apportionment factor of 0.4 for the farmer's guestimate to N in organic fertilizers has been calculated for the entire agriculture in Germany (average for the years 1998 to 2000). This means that on average around 60 % of N input from on-farm produced organic fertilizers is at the present not considered by farmers to be efficient for crop N supply according to their fertilization planning. Consequently, for the assessment of nitrogen mineral fertilizer quantities at the municipality level the values cited – 1.2 for the 'coefficient of increased demand' and 0.4 for the 'N apportionment factor' – are inserted into equation 4, and with these values the nitrogen mineral fertilizer quantity is calculated as the resultant for every municipality and is taken in the nitrogen balance [Eq. 1].

4. DATABASES AND COMPLETION OF UNPUBLISHED DATA

The physical quantities for the calculation of nitrogen surface balance surpluses are based on data from the Agricultural Census of the State Office for Statistics (Statistisches Landesamt Baden-Wuerttemberg, 2001) for field crop acreages, livestock stocking and crop yields for the municipalities in Baden-Wuerttemberg from 1999 (crop yields available only at district level). In the databases of the Agricultural Census there are a certain number of table-elements at the *municipality level* (EU LAU 2 level) that, for reasons of data secrecy, are regularly incomplete with data: Table 3 shows the frequency of municipalities without data. At the *district level* (EU NUTS 3 level) no unpublished data appears with these attributes. The crop acreage areas, respectively the livestock numbers, for municipalities that have *not* been published are nevertheless included in the sum for an entire district; i.e. the sum for the district represents the actual total quantity. The difference between the 'crop acreages/livestock numbers summed up for all municipalities with published data in a district' and the 'total sum for the district' thus corresponds with the missing statistical data at the municipal level for crop acreages, respectively livestock numbers (column 4 in Table 3).

In order to (extensively) harmonize those calculated nitrogen balance elements in the sum of all municipalities with the sums of the district-level as well as the national sum, the unpublished table elements for crop acreages and livestock stocking are completed by inserting estimated values in place of the unavailable data. Therefore, the difference between the sum of all of the 'crop acreages/livestock numbers for the municipalities of a district', and the 'total district sum' for every district and crop/livestock category was determined. This difference is then distributed to those municipalities of the district without available data. In regard to the missing data for crop acreages, distribution is carried out proportionally to the agricultural area in the relevant municipalities. 'Cattle', 'dairy cows', and 'sheep' are completed proportionally to the ratio of pasture areas in the municipalities. Finally, the missing numbers of 'fattened pigs' and 'breeding sows' are distributed proportionally to the number of farms with stock livestock in the relevant category. After the replenishment of this data, the difference between the municipality sum and the regional sum for all crop acreages and livestock categories was under 1 % (with the exception of poultry: 3 %).

Table 3: Number of municipalities in Baden-Wuerttemberg with unpublished data and missing quantities in the Agricultural Census (Regional Office for Statistics Baden-Wuerttemberg, 2001).

Livestock category		Municipalities with unpublished data		
		Number	%[a]	Missing quantity[b]
Livestock total (livestock units/ha AA)		0	0 %	0 %
Bovines total	(head)	29	6,7 %	0,4 %
- Dairy cows	(head)	90	20,9 %	5,2 %
Pigs total	(head)	39	9,1 %	1,1 %
- Fattened pigs	(head)	114	26,5 %	11,7 %
- Breeding sows	(head)	157	36,5 %	11,3 %
Sheep (all ages)	(head)	122	28,4 %	15,1 %
Poultry – laying hens	(head)	167	38,8 %	45,2 %

[a]) Data base: n = 1109 municipalities in Baden-Wuerttemberg
[b]) Difference between the quantity for Baden-Wuerttemberg total and the sum of all municipalities with published quantities.

5. RESULTS

In 1999 the total N surplus of the federal state Baden-Wuerttemberg was about 60.000 tons N, corresponding to an average N surplus for municipalities in Baden-Wuerttemberg of 75 kg N/ha of agricultural area (without weighting with the agricultural area), whereas the span is from 36 to 124 kg N/ha of agricultural area (Table 4). Organic fertilization at the level of 41 kg N/ha is relatively low compared to the average for Germany. Even in the municipality with the highest livestock density (in figures) this value is still only 89 kg N/ha of agricultural area. The corresponding average values for Germany have been included in Table 4 for purpose of comparison. Therefore, the surface balance surplus in Baden-Württemberg, is about 14 % under the national average of 88 kg N/ha. This outcome results, above all, from the low livestock numbers and the moderate N input from commercial fertilizers in Baden-Wuerttemberg.

Table 4: The terms of nitrogen soil surface balances of municipalities in Baden-Wuerttemberg in 1999 and averages for Germany.

Balance terms	Municipalities of Baden-Wuerttemberg[a]				Mean Germany[c]	Baden-Wuerttemberg
	Mean	Standard deviation	Minimum	Maximum		Sum
	---------- kg N/(ha AA*a) ----------					1000 kg N
Inputs						
- Chemical fertilizer	116	14	77	156	118	89 100
- Organic fertilizer	41	18	0	89	53	31 700
- Biological fixation	12	6	0	26	11	9 400
- Atmospheric deposition	19	4	10	25	23	14 100
Total inputs	192 [b]	28	115	282	210	147 500
Output (withdrawal)	117	16	31	158	121	89 800
Surplus	75	16	36	124	88	57 600

[a]) n = 1109
[b]) incl. 4 kg N/ha AA supply with organic secondary raw material (compost, sewage sludge)
[c]) ref. Behrendt et al. (2002).

The regions with higher N surpluses, as compared to the level of the national average, seem to be those with greater cattle stocking numbers, while the regions with mainly market crop farms are characterized by lower surpluses (Figure 1). The frequency distribution of the N surpluses is almost distributed normally (Figure 2).

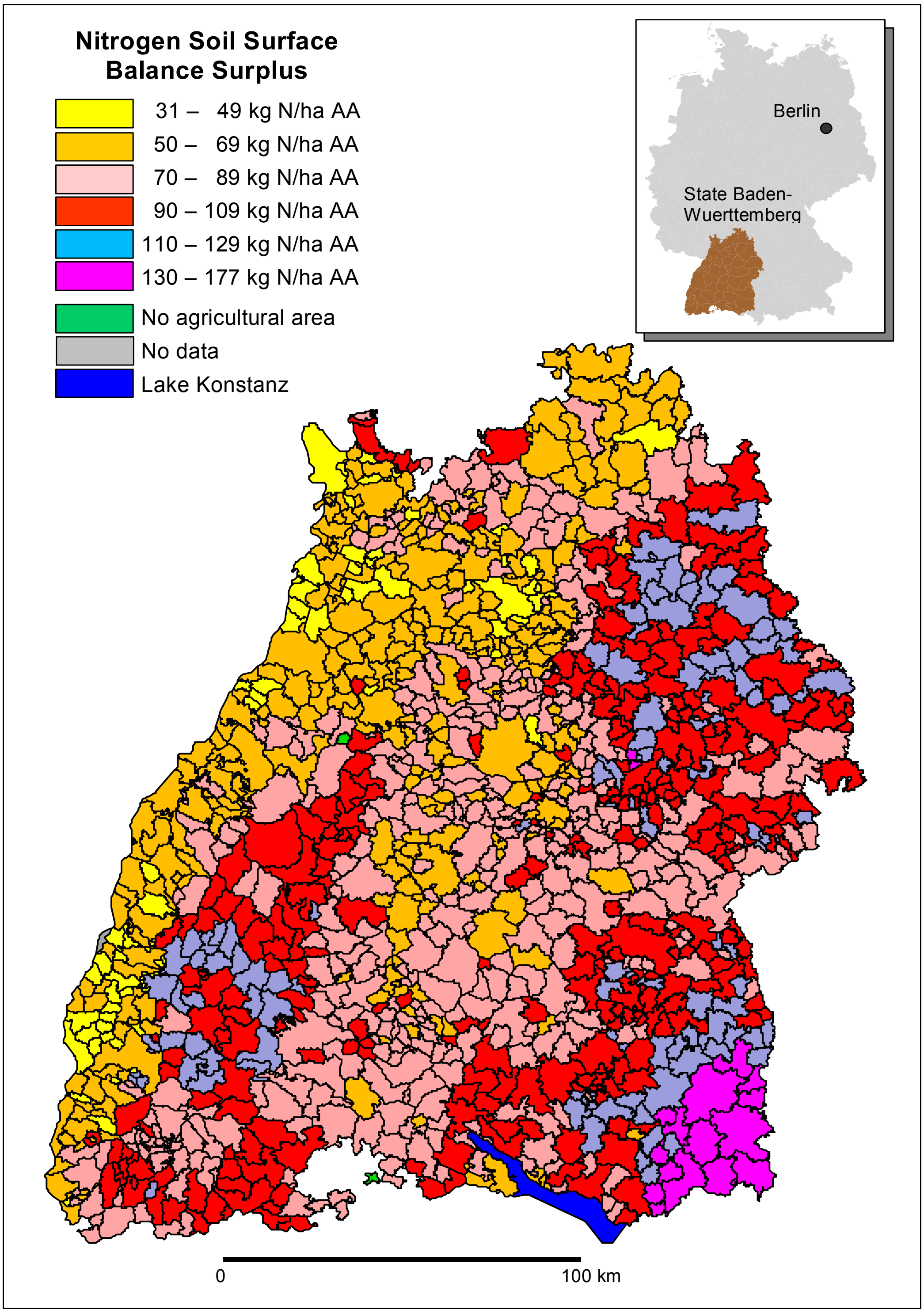

Figure 1: Surplus of nitrogen soil surface balances for municipalities in Baden-Wuerttemberg 1999.

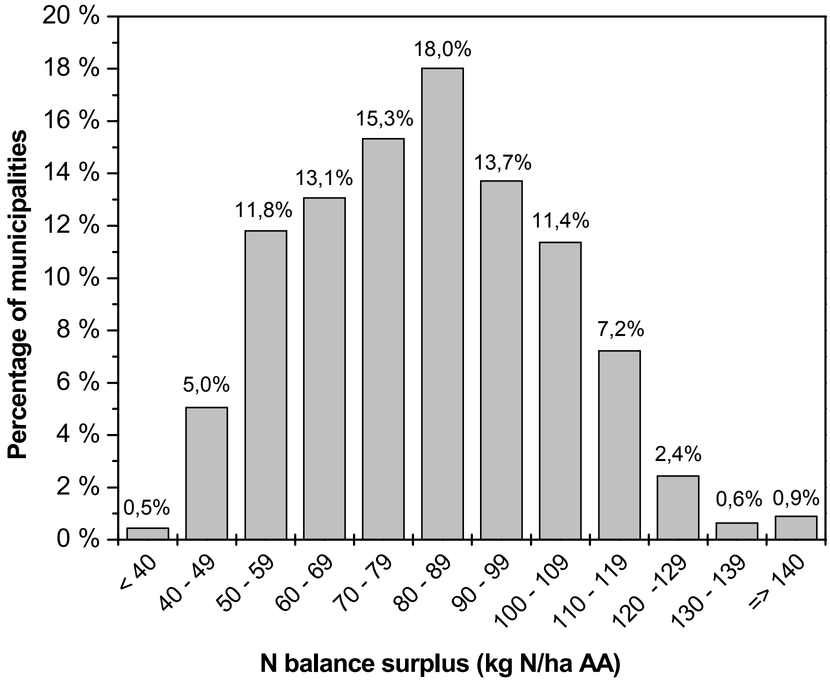

Figure 2: Frequencies of nitrogen soil surface balance surpluses (kg N per hectare agricultural area) for municipalities in Baden-Wuerttemberg 1999 (n = 1109).

6. DISCUSSION AND REMARKS

The calculation of nitrogen surface balances for municipalities, e.g. for the compilation of WFD river basin management plans, is characterized by two critical items. Firstly, the entities of the Agricultural Census at the municipality level feature to a greater or less extent (for reasons of data secrecy) unpublished data for the acreage of field crops and the stocking of livestock. In addition to the above analysis, an approach is introduced for dealing with the problem of completing the missing data. However, the extent of estimation bias (over- or underestimation) which can be caused by this completion cannot be predicted for the individual municipalities involved.

In the nitrogen balance calculations for the municipalities of another German federal state (Hessian), it was possible to examine the deviation. For the 430 municipalities in Hessian, N balances surpluses had, on the one hand, been calculated simultaneously based on the independent database of the EU controlling system for the German agriculture (so-called InVeKoS database, without data gaps; Bach et al., 2003), and on the other hand, analogously to the methodology described in this paper by replacing the missing data. From this comparison we can draw the conclusion that balance surpluses can be calculated in most cases with insignificant or justifiable deviation, and only in few cases do larger errors occur. There was a tendency for larger municipalities and those with higher N surpluses to have smaller deviations.

This tendency implies that high *relative* estimation error mainly appeared in those municipalities with *low absolute* quantities of N surplus. According to the authors' opinion, the approach interpreted here presents a convincing method for 'closing' the existing database gaps in the Agricultural Census. It should also be considered here that the calculation of N balances, whereby the missing data is not completed, would contain even more distortion.

The second critical point is related to the estimation method for nitrogen mineral fertilization. The plausibility of the nitrogen commercial fertilizer quantities, which are calculated for the administrative units (counties, municipalities) using these means, cannot be explicitly examined for the individual regional units of Germany. Only the quantities of nitrogen mineral fertilizers, which are calculated by summing up the values of all units throughout the whole country, can be used as the test figures for this procedure for comparison with the real quantities of nitrogen commercial fertilizer input in Germany. Deviations in the data for the 1990s only amount to a few per cent. As far as is known, the chosen method provides the best possible approach for reasonably plausible estimation of nitrogen mineral fertilization.

Instructions from the agricultural administration or extension service, regarding the fertilization according to Best Management Practice (BMP) as mentioned by some authors, are not normally applicable for these purposes, because this kind of instruction usually issues the *recommended* fertilization quantities but they are not taken from (representative) farm bookkeeping or agricultural surveys. This means that these instructions do not apply to empirical data; instead they use normative values which express the target value or the "ideal performance" of agricultural extension services. It is known, however, that over-fertilization frequently occurs in agricultural practices, especially on livestock farms.

In an earlier investigation (Bach and Frede, 1996) the calculated N balances at the municipality level were examined on the basis of comparison with empirically recorded balances, mainly taken from farm documentation. Among the 31 municipalities that were surveyed (mainly in Lower Saxony) the mean difference between the calculated and the empirical nitrogen surpluses was less than 1 kg N/ha (Figure 3), and the absolute deviation was less than ± 20 kg N/ha in 60 % of the cases; no systematical bias was observed. The 'N apportionment factor' (Eq. 4) was only 0.25 in the empirical N balances, indicating the lack of importance of the farmer's contribution to an efficient utilization of nitrogen from organic fertilizers in the beginning of the nineties.

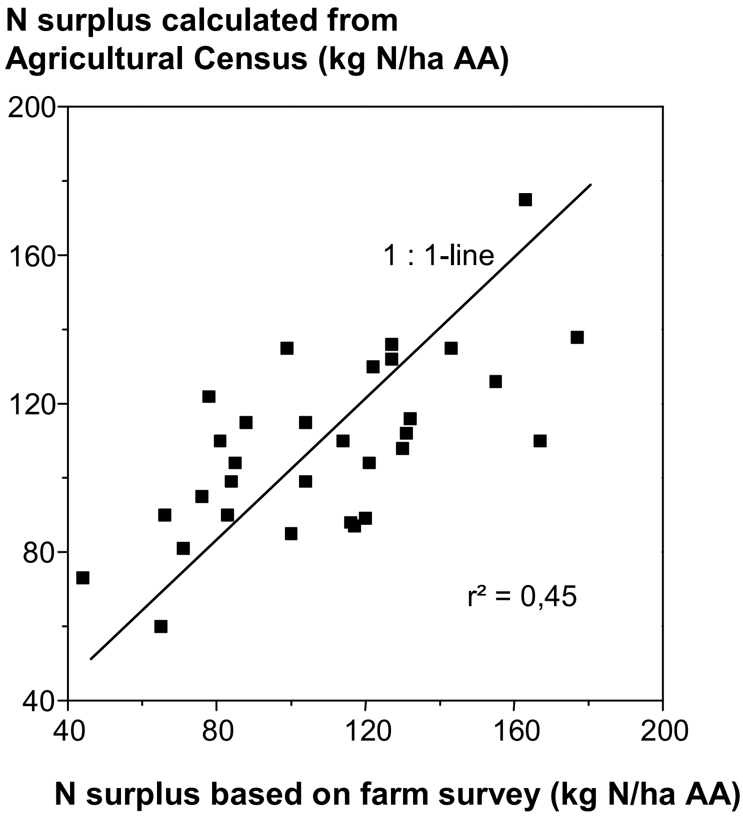

Figure 3: Comparison of nitrogen soil surface balance surpluses based on farm surveys vs. calculated from Agricultural Census for 31 German municipalities (Bach and Frede, 1996).

Altogether it is to be noted that, with certain restrictions, nitrogen soil surface balance surpluses can be calculated for the administrative units of municipalities (EU-LAU level 2, with the example of the state Baden-Wuerttemberg in Germany), using the available data of the Agricultural Census and the methodology described above. Within the context of the implementation of the WFD, the N balance surplus for municipalities forms a useful operational tool for judging the risk of nitrogen water contamination from non-point sources within river basins.

7. FUTURE SCOPE: USE OF FARM GATE BALANCES

However, experience also shows that even between the farms within one municipality or one watershed very significant differences in N surpluses may occur, mainly resulting from the varying cropping structures and livestock intensities. These variations are not indicated in calculations of the balance surplus which are based on administrative units. Nevertheless, measures to reduce nitrogen eutrophication as part of WFD river basin management plans should, above all, concentrate on the so-called “hot spots”, i.e. the areas with high N pollution potential. Yet these areas can only be characterized and identified by way of the farms that utilize the areas. Thus, the farm-specific N balance surpluses of the individual farms must be known.

In order to use the quantity "N balance surplus" as a criterion for source apportioning as an integral item of river basin management plans, it is suggested to calculate the quantity "surplus of the *farm gate* balance" in the future. The farm gate balance surplus represents, in principle, the more meaningful and, in regard to the methodological approach, the more accurate estimation value for water pollution caused by nitrogen from agriculture. Only farm gate balances are capable of also portraying the variation between the farms within a river basin. It is possible to obtain the surface balance surplus from the farm gate balance with simple approaches.

ACKNOWLEDGEMENT

We would like to thank the Ministry for Transport and the Environment of Baden-Wuerttemberg, the Environmental Agency of Baden-Wuerttemberg, and the Regional Office for Statistics of Baden-Wuerttemberg for their friendly support.

REFERENCES

Bach, M., Frede H.G., 1996. Vergleich zwischen empirisch und statistisch ermittelten Stickstoffbilanzen auf Gemeindeebene. Z. Kulturtechnik Landentwicklung 37, 269-274.

Bach, M., Frede, H.G., 1998. Agricultural nitrogen, phosphorus and potassium balances in Germany – Methodology and trends 1970 to 1995. Z. Pflanzenernaehr. Bodenkunde 161, 385-393.

Bach, M., Frede, H.G., 2001. Nährstoffbilanzierung der landwirtschaftlich genutzten Fläche – Methodik und Detailergebnisse. In: Deutscher Bericht zur EG-Nitratrichtlinie – Anhang 3. Bundesministerium f. Umwelt, Naturschutz u. Reaktorsicherheit, Berlin, 7 S. *[http://www.bmu.de/download/dateien/nitratrichtlinie_anhang_3.pdf]*.

Bach, M., Grimm, M., Frede, H.-G., 2003. Berechnung von Stickstoff-Flächenbilanzen für Gemeinden – Beispiel Hessen. Wasser & Boden, 55/7+8, 120-126.

Behrendt, H., Bach, M., Kunkel, R., Opitz, D., Pagenkopf, W.G., Scholz, G., Wendland, F., 2003. Nutrient Emissions into River Basins of Germany on the Basis of a Harmonized Procedure. Umweltbundesamt (German Environmental Agency), UBA-texte 82/03, 191 p., Berlin.

Bundesregierung, 2002. Perspektiven für Deutschland: Unsere Strategie für eine nachhaltige Entwicklung. Deutsche Bundesregierung, Rat für Nahhaltige Entwicklung, Berlin, 343 S. *[http://www.dialog-nachhaltigkeit.de/html/infos.htm]*

Crouzet, P., 2001. Calculation of nutrient surpluses from agricultural sources - Statistics spatialisation by means of CORINE land cover - Application to the case of nitrogen. European Environment Agency, Technical report No. 51, 62 p., Copenhagen

EMEP, 2002. Executive Body for the Convention on Long-Range Transboundary Air Pollution – Draft guidelines for estimating and reporting emissions data. UNITED NATIONS, Economic and Social Council, Economic Commissions for Europe, EB.AIR/GE.1/2002/7 *[http://www.emep.int/]*.

Hansen, J., 2000. Nitrogen balances in agriculture. Statistics in Focus - Theme 8, 16/2000. EUROSTAT.

KTBL, 1999: Betriebsplanung 1999/2000 (Datensammlung, 16. Auflg.). KTBL Kuratorium Technik u. Bauen in d. Landwirtschaft, Darmstadt, 1999.

MusterVwV, 1996. Muster-Verwaltungsvorschrift für den Vollzug der Verordnung über die Grundsätze der guten fachlichen Praxis beim Düngen (Düngeverordnung) vom 26.01.1996 (BGBl. I S. 118) [*Administrative Instruction for the Execution of the Fertilizer Ordinance*].

OECD, 2001a. Extract from OECD publication: Environmental Indicators for Agriculture. Volume 3: Methods and Results, 32p (Doc AGRI-ENV/FEB01/2.1A-EN).

OECD, 2001b. OECD National Soil Surface Nitrogen Balances – Explanatory notes. OECD, 20 p., Paris *[http://www.oecd.org/dataoecd/0/11/1916652.pdf]*.

Schoumans, O.F., Silgram, M. (eds.), 2003. Review and literature evaluation of quantification tools for the assessment of nutrient losses at catchment scale. EUROHARP report 1-2003. NIVA report SNO 4739-2003, Oslo, Norway, 120 p. *[http://euroharp.org/diss/store/rep/eh-report1-WEB.pdf]*.

Statistisches Jahrbuch (var. vol.). Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten [*Statistical Yearbook for Food, Agriculture and Forestry*]. Hrsg. vom Bundesministerium für Ernährung, Landwirtschaft und Forsten, Berlin, various volumes.

Statistisches Landesamt Baden-Wuerttemberg, 2001. Landwirtschaftszählung 1999 (zugl. Agricultural Census 1999). Landesamt, Stuttgart *[http://www.statistik.baden-wuerttemberg.de/SRDB/]*.

Terres, J.M., Campling, P., Vandewall, S., VanOrshoven, J., 2002. Calculation of agricultural nitrogen quantity for EU river basins. European Commission, Joint Research Centre – ISPRA, Report EUR No. 20256 EN, 85 p. *[http://agrienv.jrc.it/publications/pdfs/NsurplusFinalJRC.pdf]*.

de Wit, M., Behrendt, H., Bendoricchio, G., Bleuten, W., van Gaans, P., 2002. The Contribution of Agriculture to Nutrient Pollution in Three European Rivers, with Reference to the European Nitrates Directive. European Water Management Online, 19 p. *[http://www.ewaonline.de/journal/2002_02.pdf]*.