A new framework of measuring national nutrients balance for international and global comparison

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Abstract

Nutrients balance such as nitrogen and phosphorus balance are increasingly used as an indicator of the environmental performance of agricultural sector in international and global context. However there still is a lack of harmony in the use of methods for estimating the nutrients balance among countries. This is because of the disagreement regarding the accuracy and uncertainty of different accounting methods. The lack of harmony in the methods used in different countries further increases the uncertainty in the context of the international comparisons. This paper provides a new framework for nutrients balance calculation using the farm-gate accounting method. The calculation under this new framework takes advantage of availability of data from FAO and other reliable national and international sources. Due to this, the proposed framework is highly adaptable in many countries, making the global comparison feasible. The paper also proposes three criteria including adaptability, accuracy and interpretability to assess the appropriateness of nutrients accounting method. Based on these criteria, the paper provides a comprehensive comparison of the farm-gate and soil-surface methods in accounting country-level nutrients balance of agricultural production. The paper identifies some shortcomings of the soil-surface balance and shows that the farm-gate method has a greater potential of providing a more accurate and meaningful estimation of national nutrients balance.

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A NEW FRAMEWORK OF MEASURING NATIONAL NUTRIENTS BALANCE FOR INTERNATIONAL AND GLOBAL COMPARISON

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Abstract

Nutrients balance such as nitrogen and phosphorus balance are increasingly used as an indicator of the environmental performance of agricultural sector in international and global context. However there still is a lack of harmony in the use of methods for estimating the nutrients balance among countries. This is because of the disagreement regarding the accuracy and uncertainty of different accounting methods. The lack of harmony in the methods used in different countries further increases the uncertainty in the context of the international comparisons. This paper provides a new framework for nutrients balance calculation using the farm-gate accounting method. The calculation under this new framework takes advantage of availability of data from FAO and other reliable national and international sources. Due to this, the proposed framework is highly adaptable in many countries, making the global comparison feasible. The paper also proposes three criteria including adaptability, accuracy and interpretability to assess the appropriateness of nutrients accounting method. Based on these criteria, the paper provides a comprehensive comparison of the farm-gate and soil-surface methods in accounting country-level nutrients balance of agricultural production. The paper identifies some shortcomings of the soil-surface balance and shows that the farm-gate method has a greater potential of providing a more accurate and meaningful estimation of national nutrients balance.

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1 INTRODUCTION

Nutrient budgets have been a valuable tool for scientists to summarize and facilitate the understanding of nutrient cycling in agro-ecosystems for more than a century (Oenema et al. 2003). Nutrients balance, based on the difference between nutrients imported to and exported from a defined system, is increasingly being used by farmers and policy makers alike at farm, regional and country scales to assess both the environmental impact and potential sustainability of agricultural systems (Gourley et al. 2007; Janssen 1999; OECD 2001b; Sveinsson et al. 1998; Watson et al. 2003). Nutrient budgets are also used as regulatory policy instruments (De Walle and Sevenster 1998).

There are many different methods of accounting the balance at farm, regional and national levels (see, for example, Goodlass et al. 2003; Gourley et al. 2007; Oenema et al. 2003; Smaling and Oenema 1997; Watson et al. 2003). These methods have also been practiced either compulsorily or voluntarily in many countries (Goodlass et al. 2001). Recently OECD has reported a nitrogen and phosphorus balance of OECD countries for the period from 1985 to 2004 (OECD 2001b, 2008). This report probably provides the first and most comprehensive international comparison of environmental performance of agricultural sectors in terms of the nitrogen and phosphorus balance.

However, among different countries there is a lack of agreement regarding which accounting method should be used especially at the national level. This makes international and global comparison difficult. Even within the most developed countries in OECD, the methods have not been fully harmonized. This results in uncertainty in nutrient budgets (OECD 2001a).

Two methods that have received most attention from researchers and policy designers: soil-surface and farm-gate balance. OECD used the soil-surface method in their report and has documented a very detailed framework for the estimation of nutrients balance (OECD 2008). The farm-gate method was used to monitor nitrogen and phosphorus balances released to the North Sea and the Baltic Sea from the surrounding countries (OSPARCOM 1994). There are also some efforts in comparing the two methods such as Hansen (2000), Oenema and Heine (1999), Oenema et al. (2003), Sveinsson et al. (1998), and van Eerdt and Fong (1998). Their research motivation was to identify the more appropriate method to estimate national materials balance condition. A review of the relevant literature undertaken in Section 2 on these works shows that the conclusion on the appropriateness is mixed. The reason for this is because their comparison lacks clear assessment criteria.

This paper presents a more systematic investigation on the appropriateness of these two methods. The motivation is to validate the best method to measure the nutrients balance which will be used for international and global comparisons. Given this, the paper first documents the calculation framework under the farm-gate method. Under this calculation framework, data from FAO, national statistics, and national and international projects related to food composition tables can be compiled to calculate the nutrients balance in a simple and more accurate way. We proposed three assessment criteria: adaptability of the method, accuracy of the estimation, and economic and environmental interpretation of the balance. Based on these criteria, the proposed farm-gate method appears to be better than the soil-surface method.

The paper is structured as follows. Section 2 provides a critical review on two existing methods of calculating nutrients balance: soil-surface and farm-gate. Section 3 details the new calculation framework under the farm-gate method for international or global comparison purposes. Section 4 discusses the three criteria to validate the appropriateness of an accounting method. Section 5 presents an assessment of the two methods based upon the three criteria. Section 6 provides conclusion.

2. EXISTING METHODS OF ACCOUNTING NUTRIENTS BALANCE IN AGRICULTURAL PRODUCTION

Nutrient budgeting of agro-ecosystems summarises the flows of nutrients inputs and outputs from a defined system (Oenema et al. 2003). The most important information from nutrient budgets is the balance of nutrients of the defined system. The basic concept regulating the nutrient budgeting is the law of mass conservation of nutrients which is a simple version of the first law of thermodynamics in agricultural production (Legg and Meisinger 1982; Watson and Atkinson 1999).

The use of the laws of thermodynamics to explain the relationship between economic activities and the environment in general and in agricultural production has been becoming more and more popular since the late 1960s and early 1970s (Boulding and Jarrett 1966; Coelli et al. 2007; Georgescu-Roegen 1971; Hoang and Coelli 2009; Kneese et al. 1970). The first law, also named the materials balance condition, says that nutrients in an agricultural system are not lost and that nutrients inputs end up in either stock accumulation or material output flows. In other words, the nutrient inputs are transformed into desirable goods (i.e. food) and undesirable outputs (i.e. pollution).

The mathematical presentation of this law is as follow:

$$\mathbf{z} = \mathbf{a'x} - \mathbf{b'y} \tag{1}$$

Where $\mathbf{z}$ is the balance of nutrients, and equals to the nutrients amount entering the system less the nutrients leaving the system. $\mathbf{x}$ and $\mathbf{y}$ are input and output vectors of a production process while $\mathbf{a'}$ and $\mathbf{b'}$ are vectors of coefficients presenting nutrient contents in inputs and outputs. In this paper, these coefficients are named nutrient conversion coefficients.

The oversupply of nutrients makes the balance positive and puts the environment at risk and in the medium and long term this negatively affects the production output. The undersupply of nutrients makes the balance negative and there is a risk of nutrient depletion which affects agricultural production. In-between, a balanced situation indicates that there is a potential equilibrium in the nutrient fluxes of considered agricultural system.

There are various ways of budgeting nutrients balance for agro-ecosystems (Goodlass et al. 2001; Oenema and Heine 1999; Oenema et al. 2003; Watson and Atkinson 1999)[1]. Oenema et al. (2003) argue that the scale of the defined system of which the nutrients balance is recorded and the purpose of using the information of the balance are important factors determining which budgeting methods should be used.

[1] Goodlass et al. 2003; Goodlass et al. 2001; Halberg et al. 2005) provide good discussions on the results of the survey of 55 input-output accounting systems used in OECD countries at farm-level of which 45 systems focus on on-farm balance of different nutrients.

The use of the information on the nutrients balance of regional and national agricultural systems as environmental performance indicators for policy analysis is increasingly common (OECD 2008; Oenema et al. 2003; Watson and Atkinson 1999). Given this, there are two main methods of budgeting the nutrients balance of regional and national agricultural systems: soil-surface and farm-gate (OECD and EuroStat 2007; Oenema et al. 2003).

The soil-surface method records the amount of nutrients entering the soil and leaving the soil via crop removal and defines the balance as the difference between the nutrients inflows to and outflows out of the soil-surface. OECD used this approach in their latest estimation of nitrogen and phosphorus balance of OECD countries (OECD 2001b, 2008; OECD and EuroStat 2007). There are four input items including fertilizers, livestock manure, atmospheric deposition and biological fixation. The output side has two items: market crops and fodder crops and grass. Figure 1 presents the concept of the soil-surface budgeting method. Detailed calculation framework of nutrient conversion coefficients and the acquisition of data on input and output quantity are outlined in OECD and EuroStat (2007).

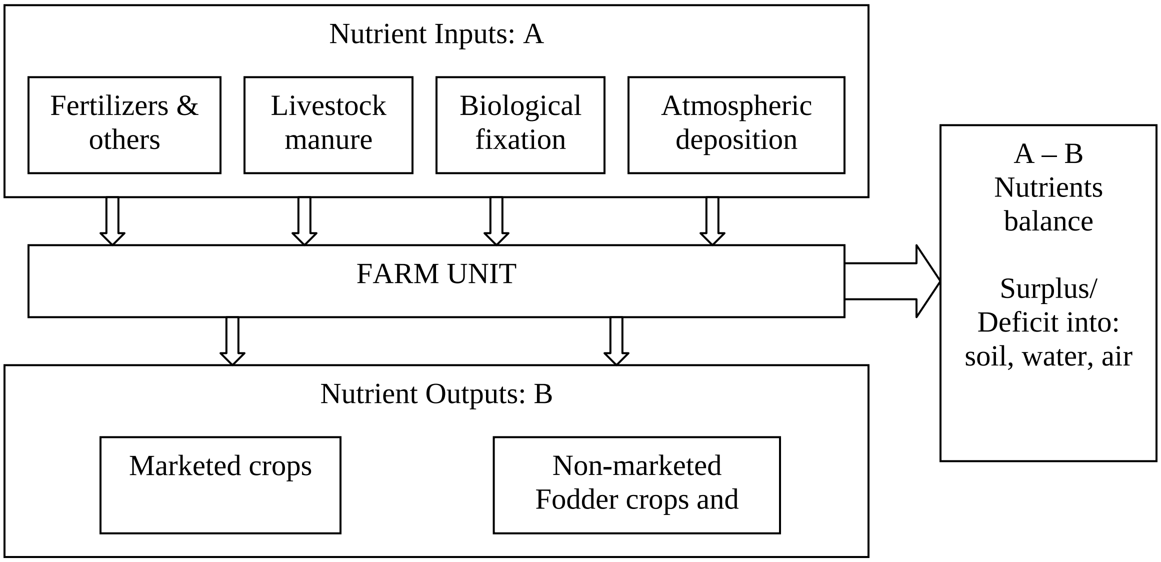

Figure 1: Soil-surface budget method (adapted from OECD and EuroStat (2007))

The farm-gate budget considers the system as a "black box" and records the quantity of nutrients contained in all kinds of products entering and leaving it. This simple approach has been used widely in farm-level, regional and national analysis. Typically the Netherlands has used this approach in its officially statistical Mineral Accounting System (MINAS) which focuses on nitrogen and phosphorus flows on individual farms since 1998 (Ondersteijn et al. 2002)[2]. The OSPARCOM (Oslo and Paris Conventions for the Prevention of Marine Pollution) has also used this method to monitor the nitrogen and phosphorus discharges into to the North Sea and Baltic Sea from the surrounding countries (OSPARCOM 1994).

For the purpose of international comparison, there are interactions of livestock and crop production activities inside the black box. Harvested fodder crops and grazed grass are

[2] Luxembourg government used the farm-gate method in its Herdbooks Systems in which farms are compulsorily required to use this accounting method in order to join the beef labeling scheme (Goodlass et al. 2001).

consumed by the livestock and the excretion of the livestock is a source of fertilizer for crops. Different from the soil-surface method, the biological nutrient fixation and atmospheric deposition under the farm-gate balance is completely internalised into the black box.

Input and output terms can vary depend on how the boundaries of systems are defined, (Gourley et al. 2007; Oenema and Heine 1999; Smaling and Oenema 1997). This paper aims to provide a more appropriate method of calculating the nutrients balance which is used for international and global comparison. Given this objective, this paper defines the input and output terms under the farm-gate method as outlined in Figure 2.

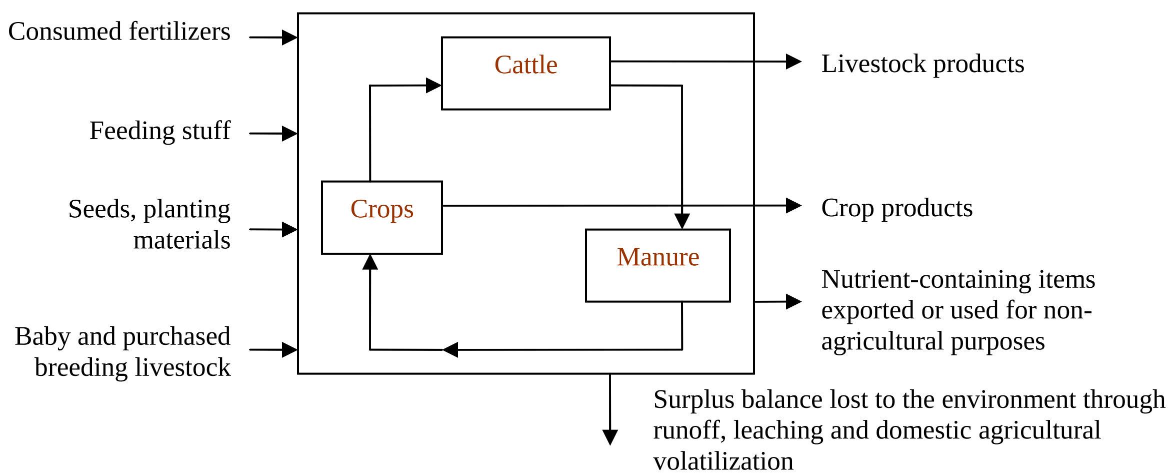

Figure 2: Farm-gate method

The input side of the box includes fertilizer (i.e. inorganic and organic but not manure), feeding stuff, seeds and planting material and purchased breeding and baby livestock. The output side has three main groups: marketed livestock products, marketed crop products, and all nitrogen and phosphorus-containing items (e.g. fodder crops, grass, manure) exported to other countries or used for non-agricultural purposes. The next section provides detailed discussion of the framework of using this method to calculate national nutrients balance for international comparison.

3 PROPOSED CALCULATION FRAMEWORK USING FARM-GATE METHOD FOR INTERNATIONAL AND GLOBAL COMPARISON

Fertilizers in the input side include both inorganic and organic fertilizers. Inorganic fertilizers are chemical mixtures such as simple mineral fertilizers (e.g. urea, ammonium, nitrate and sulphate etc.), complex mineral fertilizers (e.g. NP, NK and NPK mixtures) and mineral-organic fertilizers (e.g. calcium cyanamid) which are applied to agricultural land. Data on sales or consumption of inorganic fertilizers in terms of nitrogen and phosphorus content are generally readily available. Organic fertilizers includes urban compost and sewage sludge disposed of by spreading on agricultural land and imports of organic fertilizer (e.g. manure imported from overseas) but excludes manure from domestic livestock. According to OECD and EuroStat (2007), data on organic fertilizers are not readily available and if its contribution to the balance is considered to be small, it can be left out of the calculation.

The feeding stuff in the input side ideally should include all the feedstuff and forage entering the system either from domestic supply (i.e. domestic feedstuff manufacturers) or overseas supply via imports. FAO reports statistics on feed in Supply Utilization Account (SUA) which is generally available on its website. The data have to be converted to nitrogen and phosphorus content. Ideally, nitrogen and phosphorus conversion coefficients should be collected from domestic manufacturers or from importers. However if Nitrogen and phosphorus content is not readily available, they can be approximated equal to content of the similar food items.

Seed and planting materials in the input side covers all the seed and plants required for crop planting. OECD and EuroStat (2007) also acknowledge that little data are generally available for planting materials and if its contribution is considered to be small then it can be ignored. FAO also reports statistics on seed in SUA. Most of nitrogen and phosphorus conversion coefficients can be derived from using the information from the food composition tables. OECD (2008) also provides another good source of data on this component for OECD countries.

Baby and purchased breeding livestock in the input side cover two types of animals: (1) the live animal at the beginning of the year (2) the live animals that a country imports from overseas during a year for breeding and milking purposes. In general the data on the first type of animal stock is readily available, which is the recorded number of live animal on a given census day. Data on the imported live animal can be derived from FAO's TradeSTAT. The uncertainty involved in this component is potentially high due to the fact that statistics on both types of live animals do not give exact weight of the stock making the estimation of nutrient content deviate from the actual values. The best available option is to use the readily available information on average yield to convert the number of animal stock to tonnes quantity.

In the output side, standard agricultural statistics can provide data on livestock products, i.e. meat, milks, eggs etc. plus non-commercial parts of animals such as head, skin, bones and intestines. These data on livestock products are generally available as well as the data for crops products. Nitrogen and phosphorus conversion coefficients are generally readily available from different national food composition tables.

Many countries have published food composition tables which report micronutrient values (i.e. nitrogen content or protein content and phosphorus content) in 100 g of a particular commodity of editable food. There are a number of international projects which aims at constructing international food composition tables. These include the international food composition tables directory of FAO (Infoods 2009), European food information resource network (EUROFIR 2009) and International Framework for Food Description (LANGUAL 2009). These resources provide a good reliable source of nitrogen and phosphorus conversion coefficients[3]. For any country that data is not readily available, data on neighborhood countries can also be used instead[4].

The last component in the output side covers all nutrient-containing items such as live animal, forage and manure which are exported aboard or are for domestic non-agricultural use. Statistics on export are generally available from FAO's TradeSTAT. Data for domestic non-agricultural use are not readily available and can be ignored if it is considered as a small contribution to the balance. Regarding the export of live animal, in order to reduce the uncertainty, positive net export (export – import) should be credited to the output side while negative net export (or positive net import = import – export) should be credited to the input side.

[3] Some national food composition tables also exchange their information. This practice however makes food information more internationally comparative.

[4] Hoang and Coelli (2009) also estimated the nitrogen and phosphorus content of the inputs and outputs for 28 OECD countries using the information from food composition tables of thirteen OECD countries. These countries are Australia, Belgium, Canada, Denmark, Finland, Italy, Japan, New Zealand, Norway, Spain, Sweden, Switzerland and USA. There were some missing data in the nutrient content due to unavailable access to food composition tables in English. To fill in missing values, the authors argue that nutrient contents in food commodities in countries of similar biological and weather conditions did not vary. Based on this assumption, they applied nutrient contents of Korea to Japan, Mexico to USA and Canada. Nutrient content in Austria, France, Greece, Hungary, Iceland, Ireland, Netherlands, Poland, Portugal, and Turkey are estimated using the average of Belgium, Denmark, Finland, Italy, Norway, Spain, Sweden, Switzerland, and UK.

4 ASSESSMENT CRITERIA

The purpose of using the information on the nutrients balance determines the choice of different methods (Goodlass et al. 2003; Hansen 2000; OECD and EuroStat 2007; Sveinsson et al. 1998). Given that country-level nutrients balance can be used as an environmental performance indicator in agriculture, this paper aims to identify criteria used to assess the properties of a good method to be used for international and global comparison. This paper proposes three critical criteria: (1) the adaptability of the proposed method; (2) the accuracy of the balance estimated from the proposed method and (3) the interpretation of the estimated balance.

The adaptability of the proposed method refers to ability that a country can adapt the method to measure nutrients balance in that country. There are two relevant issues: simplicity of the method and availability of data. The simplicity of the method is not only about the formula of calculating the balance but also about data acquisition and handling. The availability of data determines the level of costs involved in the whole process of estimation. In this regard, the method which utilizes the most readily available data would be preferred since it greatly reduces the uncertainty and cost, making the method more adaptable. Obviously the method which utilizes a better data quality and lower uncertainty are preferred to use.

The accuracy of the method implies that the calculated balance must be of high accuracy so that the information of the balance provides useful interpretation. There are two critical aspects that determine the level of accuracy: the quality of data used and estimation uncertainty (Oenema and Heine 1999; van Eerdt and Fong 1998).

At the country level, the nutrient budget records aggregate amount of nutrients in the inputs and outputs of the system. For any input (or output) item, these aggregate nutrient amounts are normally equal to the quantity of that input (output) item timed with a coefficient which converts input (output) quantity to nutrient amount. This paper attributes data quality and uncertainty with both the quantity of input and output and the values of conversion coefficients. Input and output quantity data at the country level mostly is from national or international statistical reports. Particularly in agriculture, as widely accepted, the quality of aggregate country-level input or output data from FAO is reliable. Under the proposed farm-gate calculation framework, data on nutrient conversion coefficients are from food composition tables which is part of international cooperation projects which involves the construction of comparable international food composition tables.

Oenema and Heine (1999) and Oenema et al. (2003) provide good discussions on the classification and main sources of calculation uncertainty. Uncertainty can be classified into biases and errors. Biases refer to misrepresentation of data, making the estimated data systematically deviates from the true mean values while errors are random variation around the true mean. They argue that biases caused by sampling techniques can be a large in quantifying nutrient losses such as leaching, volatilization, erosion and runoff. Methods which have these components therefore are not highly recommended.

Another way of classifying of uncertainty is to differentiate two types of uncertainty: fundamental uncertainty and operational uncertainty (Oenema et al. 2003). Fundamental uncertainty refers to those related to the structure of defined system and the presentation of the method of measuring nutrients in inputs and outputs. Operational uncertainty is related to uncertainty in the data and parameters used in estimating the balance. The operational uncertainty arises from lack of data or knowledge, variability in space and time or changes in items and parameters with time. This classification of uncertainty is helpful in comparing the appropriateness of different nutrient budget methods but fails to take into account the difficulties in data interpretation (Oenema et al. 2003).

The third criterion is important because it ensures that the information of calculated balance is useful for policy design purposes. In order to capture the multi-dimensional nature of agricultural sustainability, the information of nutrients balance must deliver meaningful economic and environmental interpretation.

Economic interpretation implies that information on nutrients balance should be used in connection with other economic information to deliver further information for policy design. Economic information is information about the structure of economic activities, economic or market conditions, economic behavior of market entities or economic performance of the sector. For example, when a country having intensive livestock farming is compared with another country having intensive crop farming, the nutrient surplus of the former country might appear larger than that of the latter. Policy makers in the former country if wanting to compare their performance with the latter country can use this information together with the economic value of their production to incorporate environmental performance with economic performance.

Environmental interpretation on the other hand links the information on nutrients balance with farming practice to address the issue of environmental management of the players (i.e. farmers). For example, when we compare two countries which both have mixed livestock and crop farming structure, a country which internalizes more manure for crop production (i.e. use less inorganic fertilizer) should have better environmental performance. The nutrients balance should capture this mixed farming practice.

5 ASSESSMENT OF FARM-GATE AND SOIL-SURFACE METHODS

This section uses the three assessment criteria to assess the appropriateness of the two methods: soil-surface and farm-gate. The evaluation of the soil-surface method is drawn mainly upon the framework discussed in OECD and EuroStat (2007) while the assessment of the farm-gate method is based on the proposed calculation framework which was detailed in Section 3. The summary of this comparison is presented in Table 1.

Adaptability

Data required in the farm-gate method include data on input and output quantity and data on nutrient conversion coefficients. FAO is a reliable and rich source for input and output data. Conversion coefficients of most output and input commodities can be derived from food composition tables. This implies that any country can easily apply this method to calculate their nutrients balance without huge extra costs on acquiring data. The savings in the cost of doing the estimation is also due to taking advantage of available information from other projects related to food composition tables.

The soil-surface method, on the other hand, requires more work to estimate nutrient coefficients. For example, regarding the estimation of nutrients of biological fixation or atmospheric deposition, OECD and EuroStat (2007) noted that statistics on cultivated areas of leguminous crops may not be readily available since those planted specially for nitrogen fixation are often grown as secondary crops between main crops.

Accuracy

Oenema and Heine (1999) classifies items in the input and output sides of the systems in three classes according to the relative uncertainty. Class 1 items are those with less than 5% relative uncertainty. Examples of Class 1 items are marketed fertilizer and market livestock output. Class 2 items with 5-20% relative uncertainty include animal manure, atmospheric deposition and harvested crops. Class 3 items with more than 20% relative uncertainty are nutrients loss via leaching, runoff, volatilization and denetrification. Yli-Viikari et al. (2007) also pointed out that accurate values are difficult to obtain for the amount of biological N fixation. The authors concluded that the calculation from the soil-surface balance is still not completely reliable.

Based on these considerations, the farm-gate method has lower level of uncertainty than the soil-surface method since more Class 2 items (i.e. animal manure and atmospheric deposition) are in the latter method. Oenema et al. (2003) also came to the same conclusion that the farm-gate method is more accurate and easier to construct than the soil-surface method. van Eerdt and Fong (1998) provided a simple check on the difference between the two methods by using the national statistical data on the Netherlands' agriculture. They found out that the accuracy of the farm-gate method is generally greater than the accuracy of the soil-surface balance.

In addition, as noted in OECD (2008), there is a double-counting error in their calculation regarding atmospheric deposition of nitrogen into the soil. In the farm-gate method, all of non-agricultural domestic nitrogen deposition consisting of all nitrogen in the air or in the water are internalized into the black box. The calculation of these items are not present, therefore there is no similar error.

On the output side, the soil-surface method indirectly estimated nutrients in non-marketed fodder crops and grass by subtracting from feedstuff from total recommended animal feed requirements. This calculation is restricted to the assumption that farmers have perfect knowledge of recommended animal feed requirements. This assumption appears unrealistic especially in developing countries.

Interpretation

On the ground of data interpretation, the farm-gate method is also preferred since it delivers more valuable economic and environmental implications. For example, under the soil-surface method, in order to reduce the nutrient surplus, a country can choose to reduce fertilizer supply and livestock manure. Theoretically, an easy way of reducing livestock manure is to scale down the size of livestock production[5]. However, scaling down the livestock production is not always economically feasible, especially in those countries where livestock production is a main agricultural production activity of their agricultural sector (i.e. where livestock production is more profitable than crop production).

When used together with other economic information, the nutrients balance calculated from the farm-gate method also delivers more a meaningful interpretation. For example one can take the ratio of total nutrients balance over total economic value of outputs to define a new environmental performance indicator. Under the farm-gate method, total economic value of output equals to total economic value of crop and livestock products

[5] One can also reduce the livestock manure deposition into the soil by exporting the livestock manure from agriculture to other commercial activities. However, this is not always economically feasible.

while under the soil gate method the value only covers crop products. The soil-surface method then fails to capture the integrative nature of agricultural systems.

Under the soil-surface method, the use of manure for crops production as a way of abatement is implicitly ignored. This fails the interpretation of the balance in connection with on-farm nutrient management best practice. On the other hand, under the modified farm-gate method, one can think of maximizing the recycling of manure from the livestock production for crop production activities to reduce the nutrients balance.

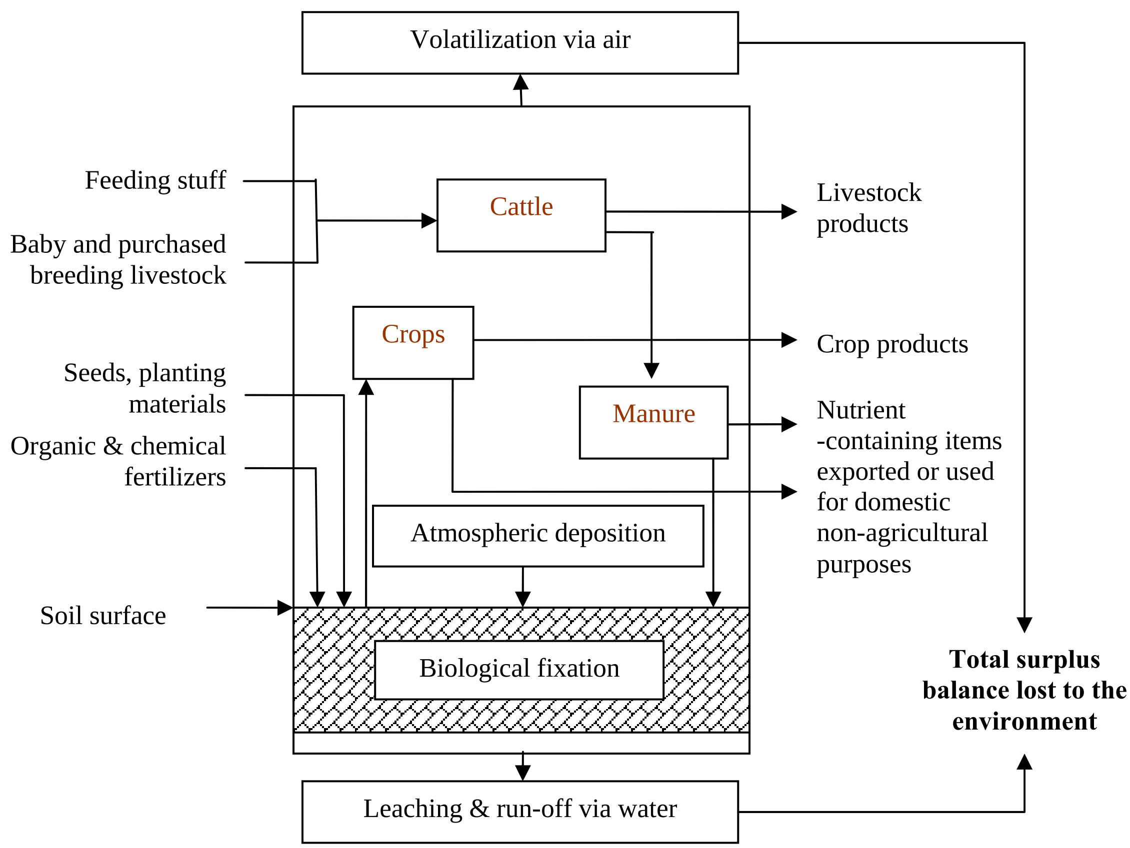

Figure 3: Combination of Farm-Gate and Soil-Surface Methods

It is important to note that the farm-gate method can also be used in conjunction with the soil-surface method to provide more detailed flows of nutrients inside the "black box" depicted in Figure 2. Figure 3 presents the proposal of combining the two methods to budget the nutrients balance of an integrative agricultural system. The total nutrients balance for the whole system is identical to the balance estimated from the proposed farm-gate method. Given high availability and quality data of internal flows of nutrients, the soil surface method gives more information about nutrient cycles of separate livestock and crop farming activities as well as the nutrient management practice.

6 CONCLUSION

The motivation of this paper is to present a reliable method of calculating the national nutrients balance for international and global comparison purposes. The paper used the approach of farm-gate method to propose a new framework of calculating the nutrients balance of national agricultural production. This new calculation framework is easy and takes advantages of high quality available data from different international and national sources. Due to this, the framework is easily adaptable and delivers cost effective and more reliable estimation of nutrients balance.

This paper also provided a more systematic comparison of the proposed farm-gate framework with the soil-surface method which was used in the latest and biggest international comparison project by OECD. The comparison was evaluated against three assessment criteria: adaptability, accuracy and economic and environmental interpretation. Based on these criteria, the proposed farm-gate framework should be preferred. However the farm-gate calculation framework can be combined with the soil-surface method to provide more information of nutrients cycles in integrative agricultural systems for policy design.

The future extension of this paper is to apply the proposed method to calculate the nitrogen and phosphorus balance of many countries to make a global report on nutrients balance of agricultural production.

Table 1: Summary of Criteria-based Assessment

Items	Farm-gate	Soil-surface	Data Availability	International Data Source	Data Reliability	Uncertainty
Input quantity						
Agricultural land (used for biological fixation atmospheric deposition)		X	High	FAO	High	Low
Cultivated area of leguminous crop (used for biological fixation)		X	Low	OECD	Moderate/Low	Moderate/High
Feeding stuff	X		High	FAO	High	Moderate
Fertilizer	X	X	High	FAO	High	Low
Live animal	X	X	High	FAO	High	Moderate
Seed & planting materials	X		Moderate	FAO	Moderate/High	Moderate
Output quantity						
Marketed crops	X	X	High	FAO	High	Low
Fodder crops & grass		X	Moderate	OECD	Moderate	High
Livestock products	X		High	FAO	High	Low
Nutrient Conversion Coefficients						
Nutrient deposition rate (used for atmospheric deposition)		X	Low	OECD	Low	High
Baby/purchased livestock	X		High	FCT*	Moderate	Moderate/High
Nutrient fixation (used for biological fixation)		X	Low	OECD	Low	High
Feeding stuff	X		High	FCT	Moderate	Low/Moderate
Fertilizer	X	X	High	FAO	High	Low
Livestock manure		X	Low	OECD	Low	High
Seed & planting materials	X		High	FCT	Moderate	Low/Moderate
Marketed crops	X	X	High	FCT	High	Low/Moderate
Fodder crops & grass		X	Low	OECD	Moderate/Low	Moderate/High
Livestock products	X		High	FCT	High	Low/Moderate

Note: (*) FCT: Food Composition Tables which are available from Infoods (2009), EUROFIR (2009) and LANGUAL (2009).

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