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Methodology to evaluate the impact of the Nitrogen Footprints in the dietary transition

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Abstract

A methodology was developed to calculate nitrogen footprints: nitrogen fertilizer requirements to produce the food of a certain diet. We evaluated the average diet of Kenya, Mexico and The Netherlands which represent extremes throughout the spectrum of the dietary transition (staple to affluent diets). There are large differences of nitrogen fertilizer use throughout countries and crops. However, the type of diet plays an important role; the nitrogen footprint does not increase linearly as diets become more affluent, but it increases exponentially. In the coming years, countries with fast economic development will present changes into more affluent diets. This will have a major impact in the nitrogen fertilizer use. Nevertheless, this study shows that the options for assessing the impact are not only in the agricultural site, large improvements in the nitrogen fertilizer use can be done by changing food consumption patterns.

Keywords
[nitrogen fertilizer, dietary change, footprints, environmental impact]

1. Introduction

Nitrogen is an essential nutrient for the growth of plants. In agriculture, the amount of nitrogen is often an important limiting factor for the productivity of crops (Bouwman, et al., 2009). Availability of nitrogen in the soil determines the growth of crops, and, therefore, the output per hectare in an agricultural field. Artificial nitrogen fertilizer is applied in croplands to increase the nitrogen availability in the soil, and consequently, the crop's yield increases.

In the last 50 years, global use of artificial nitrogen fertilizer has increased 7 times (FAO, 2011a; Tilman, 1999). During the same period, global food production has doubled due to the increase in crop yields. Present global food supply depends on artificial nitrogen fertilizer. Globally, around half of the nitrogen in soils comes from artificial nitrogen fertilizer (Liu et al. 2010; Smil, 1999); and hence, 40% of the World's dietary protein derived from fertilizers (Smil, 2001).

Large environmental problems have been caused by the increase of artificial nitrogen fertilizer use. It is the largest anthropogenic source affecting the global nitrogen cycle by increasing the reactive nitrogen in the environment (Galloway et al., 2008; Liu et al., 2010; Smil, 1999). This reactive nitrogen derives mainly from the production of artificial nitrogen fertilizer, specifically the Haber-Bosch process. The production of artificial nitrogen fertilizer increased the energy use; currently it accounts for half of the total energy use in agriculture (Woods et al., 2010). Around half of the nitrogen applied in croplands is taken up by crops and the rest is accumulated in the soils or lost into the environment as leaching, soil erosion and gaseous emissions (Liu et al., 2010). This causes local environmental problems, for instance, eutrophication, loss of biodiversity, soil acidification, pollution of ground and surface water (Eickhout et al., 2006; Smil 1999).

There are large differences on the local environmental problems around the globe. Some regions, like Northern Europe, China, India and some countries in South America, use large amounts of nitrogen fertilizer (Galloway et al., 2008; Xiong et al., 2008). These regions encounter not only problems of nitrogen accumulation in the environment but also health problems for local people. However, the productivity of their croplands is higher leading to large food production. In contrast, other regions, like Africa, use not enough nitrogen fertilizer (Liu et al., 2010). These regions have different environmental problems, for example soil depletion because of nitrogen scarcity in croplands. Frequently, these countries do not produce enough food for their population so they have to import it. This often results in a deficit of food sovereignty, dependency in global food prices and nutritional problems.

For the coming decades, countries with rapid economic development will present a nutritional transition from staple to more affluent diets (Caballero et al., 2002). In general, affluent diets require more resources for food production than staple diets (Gerberns-Leenes et al., 2005). Since these countries represent a large share of global population, it means that an important part of the world will demand more luxurious food, and thus, more resources for food production. Furthermore, projections of global population growth state that, even with the most optimistic decrease of fertility rate, population will keep growing until reaching a steady state in 2040 or 2050 (UN, 2007). It is not clear whether the present food production system could sustain this increase in food demand. For this reason, it is important to evaluate ways to improve the global food production system in a more sustainable way.

In previous studies, it was shown that affluent diets require more resources for the food production than staple diets (Gerberns-Leenes, et al. 2005; Kastner et al., 2009). In this project, we assess the role of dietary changes in the requirements of nitrogen fertilizer. We evaluate the nitrogen fertilizer requirements to feed a person, the so-called Nitrogen Footprint, for diets in different development and nutritional stage. In this way, we assess the impact of the dietary transition, staple to affluent diets, and at the same time of changing agricultural technology, from extensive to intensive production systems with large use of nitrogen fertilizer.

2. Materials and Methodology

For the assessment of the Nitrogen Footprint, we chose 3 countries, The Netherlands, Mexico and Kenya, which have different diets and agricultural systems. From these countries, The Netherlands has the richest diet, then Mexico and Kenya has the poorest diet. According to FAO (2011b), in 2000 the total daily caloric intake in the Netherlands was 3,210 kcal/cap/day, in Mexico was 3,170 kcal/cap/day and in Kenya was 2,020 kcal/cap/day. The Netherlands has the most affluent diet in which 35% of the calories are from animal origin, in Mexico 18%, and in Kenya only 11% (FAO, 2011b). By evaluating the Nitrogen Footprint of these diets, we assessed the impact of diets in different stages of the dietary transition.

The agricultural production systems also divert from each other. In respect to the amount of nitrogen fertilizer consumption, The Netherlands has the most intensive agricultural system, then Mexico, and then Kenya. FertiStat (FAO, 2011c) reports Nitrogen Rates for several crops for these countries in a specific year. The data for The Netherlands is for the year 2000, for Mexico is for the year 1998, and for Kenya is for the year 1998. FertiStat calls Nitrogen Rates to the amount of nitrogen fertilizer use per hectare and it is expressed in kilograms of nitrogen fertilizer per hectare. In this project, we use this same term. According to FertiStat, The Netherlands has the largest nitrogen rates, then Mexico, and Kenya has the lowest. For example, in the Netherlands the nitrogen rate of wheat was 190 kg N/ha; in Mexico the nitrogen rate of maize was 60 kg N/ha; and in Kenya the nitrogen rate of maize was only 12 kg N/ha. These cereals represent the main cereal crops consumed in each country. The nitrogen rates of other crops have similar values, see table 3.

2.1. Data

We used data of diets, crop yields and nitrogen fertilizer rates in order to calculate the Nitrogen Footprints per person of the three countries. We used different online databases from the Food and Agricultural Organization of the United Nations, FAO. We used average national data for The Netherlands, Mexico and Kenya.

For dietary values, we used the Food Balance Sheets database, FBS (FAO, 2011b). The FBS gives average values of food supply per capita of several countries in kilograms per person per year for 92 food items and 20 food categories, e.g. total cereals. These values indicate the amount of available food per person in a household level. It is not the actual food intake because it includes retail wastes. However, it is a good indication for country comparison.

For crop yield values, we used the FAOSTAT database (FAO, 2011a) which gives yield values for 154 crops and 13 crop categories, e.g. total cereals. For the nitrogen fertilizer rates, we used the FertiStat database (FAO, 2011c) which gives data on the amount of nitrogen fertilizer consumption per crop. This database provides values of nitrogen rates for a small selection of crops for different countries.

2.2. Methodology

2.2.1. Nitrogen Footprint

To calculate the Nitrogen Footprint, we used a similar approach as Kastner et al. (2009) in which they calculate land requirements for food. The starting point is the diet of a person. We used the food supply data from FAO (2011b). We split up the diet into eight food categories: cereals, roots, sugar, pulses, vegetable oils, vegetables and fruits, alcoholic beverages and animal products, see the first column of table 1. These categories include all the food items in the diet given by the FBS except honey, stimulants, spices and tree nuts. These last food items represent a very small share of the diet and for these reason we did not included them in our calculations. Column two of Table 1 shows the categories of the food supply given by the FBS that were included in the eight food categories used in this project. For each food category, we traced back to the agricultural production to calculate the amount of artificial nitrogen fertilizer that was required to produce that amount of food. A different methodology was used for vegetal and animal products.

Table 1. Linking food and crop categories from FBS (FAO, 2011b), FAOSTAT (FAO,2011a) and FertiStat (FAO, 2011c) to the food categories used in this project

Food Categories used in this project	**Food categories used for food supply values (FBS)**	**Crops used for crop yield values (FAOSTAT)**	**Crops used for nitrogen rate value (FertiStat)**
Cereals	Cereals - Excluding Beer	Wheat (The Netherlands Maize (Mexico & Kenya)	Wheat (The Netherlands Maize (Mexico & Kenya)
Roots	Starchy Roots	Potatoes	Potato
Sugar	Sugarcrops Sugar & Sweeteners	Sugar cane (Mexico & Kenya) Sugar Beet (The Netherlands)	Cane (Mexico & Kenya) Beet (The Netherlands)
Pulses	Pulses	Beans, dry (Mexico & Kenya) Peas, dry (The Netherlands)	Pulses
Vegetable oils	Oilcrops Vegetable Oils	Groundnut (Mexico & Kenya) Rapeseed (The Netherlands)	Groundnut (Mexico & Kenya) Oilcrops misc. (The Netherlands)
Vegetables and Fruits	Vegetables Fruits - Excluding Wine	Vegetables&Melons	Vegetables
Alcoholic Beverages	Alcoholic Beverages	Barley	Barley
Animal Products	Eggs Milk - Excluding Butter Meat	----	----

For the vegetal products, we linked each food category with the average crop yield and nitrogen fertilizer rate of the country. We assigned a specific crop to each food category. For instance, for cereals we used wheat for the Netherlands and maize for Mexico and Kenya. Column three and four of table 1 shows the crop that was used to assign a crop yield value and a nitrogen rate value to each food category. The choice of the crop was based on the importance of that crop in the food supply. For instance, according to FAO (2011b), wheat represents 84% of Dutch cereals consumption, and maize represents 73% of the Mexican cereals consumption and 72% of the Kenyan cereals consumption. We used crop yields data from FAOSTAT (FAO, 2011a) and nitrogen fertilizer rate from FertiStat (FAO, 2011c).

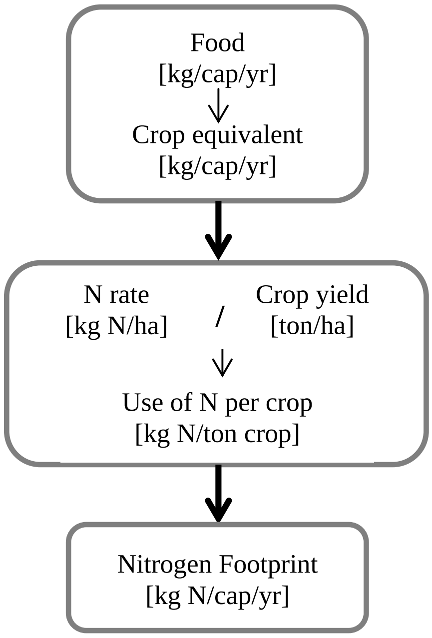

Figure 1. Methodology to calculate Nitrogen Footprint of vegetal products

In order to link the food data with the production data, the food was converted into its crop equivalent, for instance, sugar into sugar cane. We used the conversion factors given by Kastner et al. (2009). Then, for each crop category, we calculated the amount of nitrogen fertilizer used to produce a tonne of crop. To do so, the nitrogen rate is divided by the crop yield. Finally, this value is divided by the crop equivalent to obtain the nitrogen footprint of the vegetable products (figure 1).

To calculate the nitrogen requirements for the animal products, first we calculated the amount of feed needed to produce a kilogram of animal product; then, we traced the amount of nitrogen fertilizer required to produce the feed. We used a similar approach as Elferink (2009) in which he calculates the land requirements to produce three types of meat in the Netherlands: pork, beef and chicken.

We split up the animal products into the main categories given by the FBS, excluding fish: eggs, milk, bovine meat, mutton & goat meat, pig meat, poultry meat and other meat. We assumed that all the animals are feed with the same type of feed, in the Netherlands with wheat, in Mexico with sorghum and in Kenya with maize. The choice of the feed was based on the importance of the crop in the total feed consumption of the country, and on the availability nitrogen rate data for the feed. According to the FBS, in Kenya 11% of the feed is maize, in Mexico 46% is sorghum, and in The Netherlands 14% is wheat. For each food item, we calculated the amount of feed needed to produce a kilogramme of animal product. For all meat products we used the values given by Elferink (2009), for the milk we used the production values of CVB (2003), and for the eggs we assumed the same value as for milk. Table 2 shows the "feed to food ratio" values. This ratio is the amount of feed, given in kilogrammes, required to produce a kilogram of animal products.

The feed to food ratio is multiplied by the food supply of the diet to obtain the amount of feed required to produce the total amount of animal products of the diet. Then, we used the same methodology of the vegetal products to calculate the nitrogen requirements to produce the feed. This value is the Nitrogen Footprint of the animal products. Finally, we obtained the nitrogen footprint of the total diet by adding the nitrogen footprint of the vegetal and animal products.

Table 2. Feed to food ratio values.

Food item according to FBS	**Feed to food ratio** *[kg of crop required to produce a kg of food item]*		
	Wheat	Sorghum	Maize
Eggs	0,6	0,6	0,6
Milk	0,6	0,6	0,6
Bovine meat	8,5	7,5	6,8
Mutton & goat meat*	8,5	7,5	6,8
Pigmeat	3,7	-	3,4
Poultry meat	3	2,4	2,7
Other meat**	3,7	2,4	3,4

* We assumed the same feed to food ratio as bovine meat
** We assumed the same feed to food ratio as Pigmeat

2.2.2. Comparing Nitrogen fertilizer use and Nitrogen in diets (proteins)

The nitrogen fertilizer applied in croplands is dissolved in the soil and taken up by crops to produce proteins. In our analysis, we compared the amount of nitrogen fertilizer applied in croplands to the amount of nitrogen in the diets. In this way, we evaluate the nitrogen flow from the application of nitrogen fertilizer to the actual consumption of nitrogen. The nitrogen in diets is calculated based on the protein supply of each food category given by the FBS. We used the N:P (Nitrogen to Protein) factor ratio given by Sosulski et al. (1990) for several food products. By doing this, we calculated the amount of nitrogen in the diets for each food category (figure 3).

3. Results

The nitrogen footprint of a diet depends on the type of diet and on the amount of nitrogen fertilizer required to produce a certain amount of crop. In this section, we first discuss the differences in protein supply and in nitrogen fertilizer use. Then, we discuss the differences in the nitrogen footprints of these diets.

3.1. Differences in diets

There are large differences in the daily protein supply between The Netherlands, Mexico and Kenya reported by the FAO (2011b) in the year 2000. Figure 2 can be read as a dietary transition from a staple diet to a more affluent diet. Kenya had a staple diet, Mexico had a more affluent diet, and The Netherlands had the most affluent diet. In 2000, the average protein supply in The Netherlands was 20% larger than in Mexico and 80% larger than in Kenya. The protein supply was different not only in quantity but also in quality. The animal protein supply in The Netherlands accounted for 70% of the total supply, in Mexico it accounted for 40%, and in Kenya only for 25%. In total numbers, the animal protein supply in the Netherlands was 2 times larger than in Mexico and 5 times larger than in Kenya.

There were also differences in the supply of vegetal proteins. In Kenya, the cereals consumption accounted for half of the protein supply, in Mexico it accounted for 40%, and in The Netherlands it only accounted for 15%. Furthermore, the daily supply of pulses proteins largely decreases once the diet becomes more affluent. In Kenya, the pulses supply accounted for 20% of the total supply, in Mexico for 10%, and in The Netherlands only for 1%.

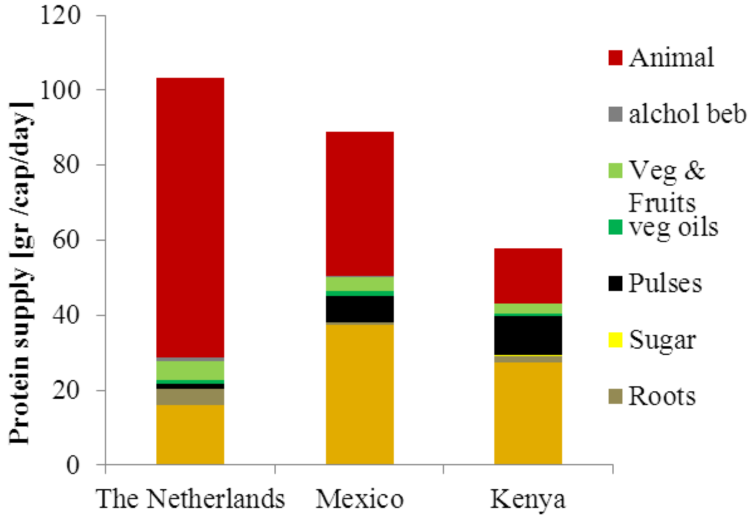

Figure 2. Average protein supply per food category in 2000. Source: FAO (2011b)

3.2. Differences in nitrogen fertilizer use

There are differences in the use of nitrogen fertilizer throughout crops and the three countries. In general, The Netherlands have the largest nitrogen fertilizer rates, then Mexico, and Kenya have the lowest (table 3). This table shows, next to the nitrogen rate, the crop yield value given by FAOSTAT. There is a clear relationship of high crop yields with high nitrogen rates, and low crop yields with low nitrogen rate. The amount of nitrogen fertilizer required to produce a tonne of crop is calculated by dividing the nitrogen rate with the crop yield value. This value shows the nitrogen efficiency of the agricultural production system. The nitrogen efficiency refers to the amount of nitrogen required to produce a tonne of crop, with low requirements of nitrogen fertilizer the efficiency is higher.

The production of cereals in The Netherlands, for example, has a very large nitrogen fertilizer rate of 190 kg N/ha and also a large crop yield of 8,4 ton/ha; this leads to a requirement of 22,7 kg of nitrogen fertilizer to produce a tonne of cereal. Mexico has a lower nitrogen rate of 60 kg N/ha and a yield of 2,3 ton/ha. In this case, the nitrogen efficiency is lower, 25,6 kg N/ton, because of the low value of the crop yield. This shows that higher nitrogen rates do not always result in higher nitrogen requirements to produce a tonne of crop. Roots, pulses, barley and vegetables show a similar situation in which The Netherlands, with very large nitrogen rate, reaches large crop yields and ends up with higher nitrogen efficiency than Kenya and Mexico. In contrast, for the production of oilcrops and sugar crops, the nitrogen efficiency of the Netherlands is lower than in Mexico and Kenya, even though The Netherlands uses large nitrogen rates.

However, Kenya with a very low nitrogen rate for cereals, is high nitrogen efficient, and ends up with less than half of the amount of nitrogen fertilizer to produce a tonne of cereal than Mexico and The Netherlands, only 8,2 kg N/ton.

Table 3. Requirements of nitrogen fertilizer to produce a tonne of crop for each vegetal food category

Sources: N rate: FAO (2011c); Crop yield: FAO (2011a);
N efficiency: calculations from the authors

Food category	The Netherlands				Mexico			
	Crop	**N rate [kg N/ha]**	**Crop yield [ton/ha]**	**N efficiency [kg N fert / ton crop]**	**Crop**	**N rate [kg N/ha]**	**Crop yield [ton/ha]**	**N efficiency [kg N fert / ton crop]**
Cereals	Wheat	190	8,4	22,7	Maize	60	2,3	25,6
Roots	Potato	168	46	3,7	Potato	108	20	5,3
Sugar	Sugar beet	108	61	1,8	Sugar cane	90	77	1,2
Pulses	Peas, dry	20	5	4	Beans, dry	16,5	0,6	28
Vegetable oils	Rapeseed	180	3,6	50	Groundnuts	20	1,4	14
Vegetables and Fruits	Vegetables	125	49	2,6	Vegetables	42	16	2,7
Alcoholic Beverages	Barley	85	6	14	Barley	32	1,5	21

Food category	Kenya			
	Crop	**N rate [kg N/ha]**	**Crop yield [ton/ha]**	**N efficiency [kg N fert / ton crop]**
Cereals	Maize	12	1,5	8,2
Roots	Potato	60	7	8,5
Sugar	Sugar cane	30	80	0,4
Pulses	Beans, dry	10	0,3	32
Vegetable oils	Groundnut	16	0,6	25
Vegetables and Fruits	Vegetables	60	10	5,9
Alcoholic Beverages	Barley	20	1,6	12

For animal products, the amount of nitrogen fertilizer required to produce a tonne of animal product depends on the nitrogen rate and crop yield of the feed, and on the feed to food ratio; see table 2 for the latter. Table 4 shows the nitrogen rates and crop yields of the feeds that were used in the calculations of this study. In contrast to the vegetal products, The Netherlands is the less nitrogen efficient, then Mexico and Kenya is the most nitrogen efficient. The amount of nitrogen fertilizer to produce a tonne of feed in the Netherlands is 60% larger than in Mexico and almost 3 times larger than in Kenya.

Table 3 and 4 show that the nitrogen efficiency largely diverts throughout crops and countries. The agricultural production system in a country could be nitrogen efficient for some crops but low efficient for other crops. The Netherlands is more nitrogen efficient for the production of potatoes, pulses and vegetables than Mexico and Kenya; but for the production of animal products Kenya is the most nitrogen efficiency, then Mexico, and The Netherlands is the less nitrogen efficient.

Table 4. Requirements of nitrogen fertilizer to produce a tonne of feed
Sources: N rate: FAO (2011c); Crop yield: FAO (2011a);
N efficiency: calculations from the authors

Feed	N rate [kg N/ha]	Crop yield [ton/ha]	N efficiency [kg N fert / ton crop]
Wheat in The Netherlands	190	8,4	22,7
Sorghum in Mexico	48	3,3	14,5
Maize in Kenya	12	1,4	8,2

3.3. Nitrogen footprint VS nitrogen in diet

There are large differences of the nitrogen footprints in the 3 countries (figure 3). The Dutch nitrogen footprint is almost two times larger than the Mexican, and four times larger than the Kenyan. Next to the nitrogen footprint, figure 3 shows the nitrogen content of the protein supply, the nitrogen consumption of the diet (in the methodology we describe how we calculated it). By comparing these two columns, it shows the differences between the nitrogen that is required to produce the food, as nitrogen fertilizer, with the actual nitrogen consumed in the diet, as proteins. It shows that, in order to produce the food for the average diet in the Netherlands, the nitrogen fertilizer required is three times larger than the nitrogen that is actually consumed. In Mexico, it is two times larger, and in Kenya it is only one third larger than the diet. This shows that, the requirements of nitrogen fertilizer for the diet is not linear throughout the whole spectrum of the dietary transition.

The production of animal products in the Netherlands has the largest impact in the nitrogen footprint, and it accounts for 70% of the total nitrogen footprint, in Mexico it account for 40%, and in Kenya only for 20%. The differences in the share of the total footprint are related to the share of animal proteins in the diet and to the nitrogen efficiency of the feed (table 4). For the production of animal products, the Netherlands requires 3 times more nitrogen than the nitrogen consumed as animal proteins, Mexico requires 2 times more nitrogen, and Kenya requires only 10% more nitrogen. This shows that, with our assumptions of feeding in each country, the production of animal products in the Netherlands is the less nitrogen efficient and Kenya is the most nitrogen efficient.

The production of cereals is more nitrogen efficient than the production of animal products. In the Netherlands, cereals require 50% more nitrogen than the nitrogen in the diet; in Mexico, cereals require almost twice, and in Kenya cereals require even less than what it is consumed. This last issue could have implications of nitrogen stress in the soil and should be evaluated in more detail in further research. For pulses, the nitrogen efficiency is the highest. In the 3 countries, the nitrogen required to produce pulses is lower than the nitrogen consumption of pulses. This is further discusses in the next section.

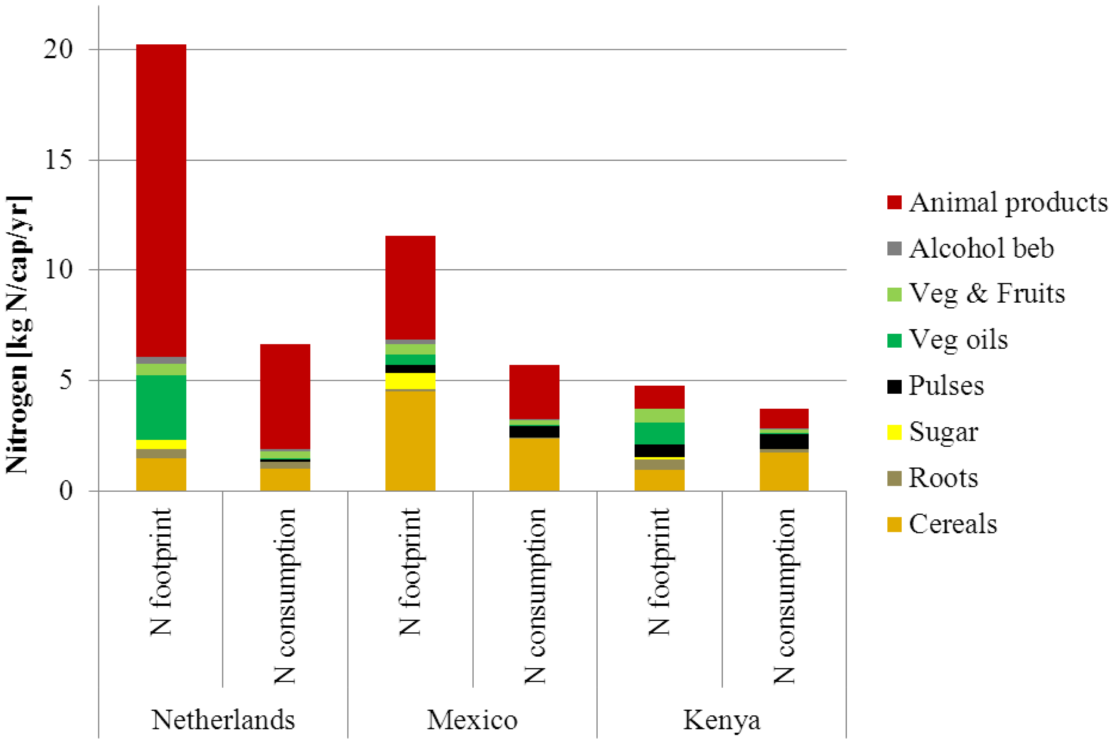

Figure 3. Nitrogen footprint and Nitrogen consumption.
The Nitrogen footprint refers to the amount of nitrogen fertilizer required to produce the food supply per capita of the average diet in the country. The Nitrogen consumption refers to the nitrogen content of proteins in the average daily protein supply reported by FAO (2011b).

The production of vegetable oils and sugars requires a significant amount of nitrogen fertilizer. However, sugars and vegetable oils do not have any proteins content, and therefore they do not represent any nitrogen consumption in the diet. Figure 3 shows that, for the Netherlands, sugars and vegetable oils account for 16% of the nitrogen footprint, in Mexico it accounts for 10%, and in Kenya it accounts for 23%.

4. Discussion

In this study, we evaluated the average diets of three countries that represent extreme stages in the spectrum of the dietary transition. Kenya has a staple diet in which staple items, like cereals, pulses and roots, represent more than three thirds of the protein intake; and affluent items, like animal products, only represent one forth. Mexico has a more affluent diet representing the phase of countries with fast economic development, in which the share of animal products, vegetable oils and sugar increases. For the Mexican diet, the share of staple proteins account for only half of the total protein intake, and the animal products for 40%. The Netherlands has the most affluent diet from these countries. The staple items only account for one fifth of the total protein intake, and the animal products account for 70%. Furthermore, the share of pulses in the diet decreases from a staple to an affluent diet. In Kenya, pulses account for one fifth of the protein supply, in Mexico for one tenth, and in the

Netherlands only for 1%. This is important for the analysis of the nitrogen footprint because pulses are nitrogen fixators, and for this reason they require less nitrogen fertilizer for its production than other crops. Therefore, the nitrogen footprint of pulses is significantly smaller than other crops.

This study shows that the nutritional transition has a large impact on the nitrogen footprint. In our analysis, the nitrogen footprint does not increase linearly in the change of a staple to an affluent diet. For the Kenyan diet, the nitrogen fertilizer required to produce the food is 30% larger than the nitrogen consumed as proteins. For the Mexican diet, the nitrogen required is two times larger than the consumed proteins; and for the Netherlands it is three times larger. This means that the nitrogen footprint increases exponentially in the change from a staple to an affluent diet.

The share of each food category in the nitrogen footprint is different in the three countries. For the Kenyan footprint, all food categories have a similar impact, cereals account for 20%, pulses and roots for 20%, vegetable oils for 20%, animal products for 20%, and the other food categories for the rest 20%. For the Mexican footprint, cereals and animal products represent four fifths of the total footprint, and the other food categories only account for one fifth. For the Netherlands, more than two third of the nitrogen footprint is caused by the animal products production; vegetable oils represent 15% of the footprint, and the rest vegetal items only represent 15% of the footprint. This overview suggests that, in order to have the largest improvement in the impact of nitrogen fertilizer, we should focus on the food items that represent the largest share of the nitrogen footprint. For instance, in the case of The Netherlands, focus on the improvement of animal products and oilcrops production.

To conclude, the type of diet plays an important role on the nitrogen footprint because luxurious items, like vegetable oils, sugars and animal products, require more nitrogen fertilizer than staple crops. In the coming years, countries with fast economic development will present changes towards more affluent diets. The impact will be large because the nitrogen fertilizer consumption will not increase linearly as diets become more affluent, but it will increase exponentially. This study shows that the options for assessing the impact of nitrogen fertilizer are not only in the agricultural site but also in the food consumption patterns. The choice of diet will play an important role on the use of nitrogen fertilizer.

5. Further research

We used a simple assumption for the calculation of the nitrogen footprint of animal products, in which all animals are feed with the same feed, wheat in The Netherlands, sorghum in Mexico, and maize in Kenya. This methodology should be improved for further research and compare the nitrogen footprints using different feeds, and mixtures of feeds. Furthermore, we should not only evaluate primary crop feeds, but also processed feeds, for example soybean cakes. In The Netherlands, according to FAO (2011b) in the year 2000, 15% of the total feed consumption was soybean cake, and in Mexico 8%.

Furthermore, more diets from different countries should be included in the analysis in order to cover a wider range of the spectrum in the dietary transition.

Finally, the issue of nitrogen stress and nitrogen accumulation should be integrated into the discussion of the nitrogen footprint. For example, the Netherlands and some countries in Latin America present large local environmental problems because of large use of nitrogen fertilizer (Galloway et al., 2008). In this case, a decrease of the nitrogen footprint could improve the local environmental problems. In contrast, some countries in Africa present large problems of nitrogen scarcity in the soil (Liu et al., 2010), these countries could show a small nitrogen footprint, and, in this case, in order to improve the local environmental problems, an increase of nitrogen fertilizer use could improve the soils quality, and therefore, the productivity of crops.

6. Glossary

Dietary Transition: Change from staple to affluent diet due to economic development (Caballero etal., 2002)

Nitrogen Efficiency: In this report, we refer to Nitrogen Efficiency to the amount of nitrogen fertilizer required to produce a tonne of crop. If the amount is smaller, then the efficiency is higher.

Nitrogen Rate: According to FertiStat, the Nitrogen rate is the amount of nitrogen fertilizer use per hectare for a certain crop in a certain year. The units are expressed in kilogrammes of nitrogen per hectare.

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