Taking into account the emissions from the production and use of mineral fertilizers by imposing a ‘carbon tax’

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Abstract

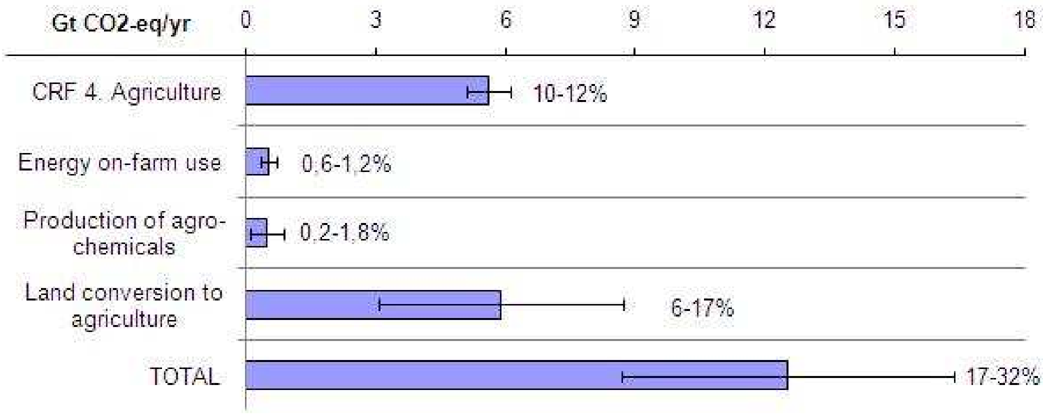
Production and application of mineral fertilizers are associated with GHG emissions. The EU pursues an active policy of GHG emissions mitigation. One of the instruments of this policy is the EU ETS. Due to the inclusion of ammonia and nitric acid production into the list of activities covered by the EU ETS, the production of mineral fertilizers would be burdened with a “carbon tax”. If the emissions from the application of fertilizers to agricultural soils would be considered, the rate of a “carbon tax” would double. In this paper the impact of a “carbon tax” on the production and use of mineral fertilizers in the EU is analysed with the GTAP model. The analysis requires a separate treatment of the fertilizer industry. Therefore, the “Chemical, Rubber and Plastic products” sector (“crp”) of the GTAP database was split and a new sector representing the fertilizer industry (“FERT”) was introduced. Further, the production structure was modified to introduce the substitution possibility between the land and the fertilizers by crop production. This is done with regard to the fact that a reduced fertilization in the EU due to a “carbon taxation” on fertilizers could only be compensated by either an agricultural land extension or an intensification of crop production abroad. The preliminary results show, that a “carbon tax” on fertilizers in the EU can slightly reduce the GHG emissions of the EU. However, due to an increase in the imports of fertilizers / decrease in the exports of fertilizers and an increase in the imports of grains / decrease in the exports of grains the “carbon leakage” effect takes place. To answer whether a reduction of GHG emissions on the global level takes place, the indirectly induced GHG emissions abroad have to be considered.

1. GHG emissions from agriculture and the contribution of fertilizers

1.1 Overview of the main sources of GHG emissions from agriculture

If all direct and indirect emissions, including emissions from land use and land use change (LULUC) are taken into account, agricultural activities are responsible for 17-32% of the global human-induced GHG emissions (see Figure 1).

Figure 1 – Global contribution of agriculture to GHG emissions



Source: IPCC (2007), Bellarby et al. (2008)

Agriculture contributes to the emissions of greenhouse gases through a variety of ways. Emissions may occur directly during exercise of agricultural activities or indirectly during the production and transport of the required inputs or as the result of land use change. In this respect, following GHG emission source categories related to the agricultural activities can be identified (see Table 1):

Table 1 – Sources of GHG emissions related to the agricultural activities

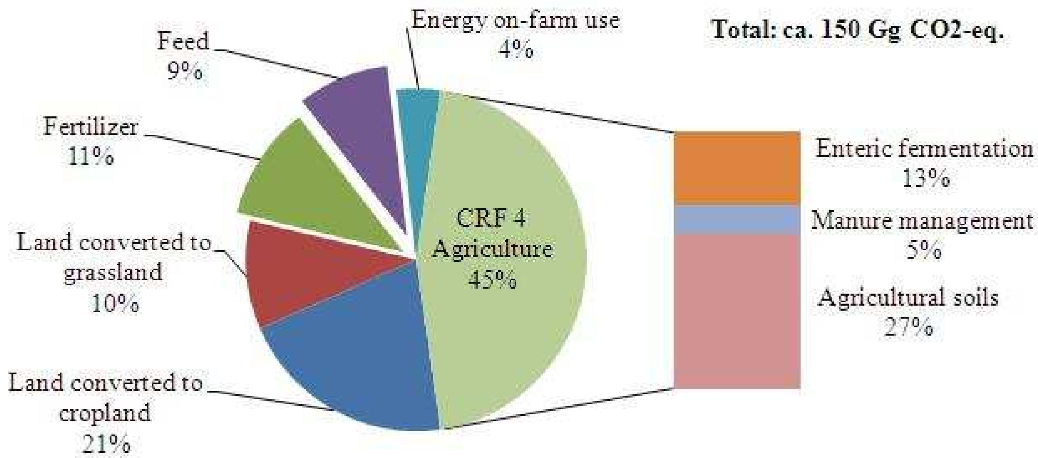
Identified source category	**CRF* sector**
Enteric fermentation in livestock	CRF 4. Agriculture
Livestock manure management	
Rice cultivation	
Management of agricultural soils	
Burning of savannas and agricultural residues	
Electricity and fuel on-farm use	included in CRF 1. Energy
Land use and land use change	included in CRF 5. LULUC
Production of agrochemicals (fertilizers)	included in CRF 2. Industrial Processes
Imported agricultural inputs**	---

* *CRF = Common Reporting Form used for reporting national GHG inventories to the UNFCCC*
** *Only by accounting of GHG emissions from agricultural activities in one separate region*

Emissions occurred from the production of investment goods (machines, building etc.) could be also included in the total GHG emissions from agricultural activities. However, on this place the total emissions are delimited to the sum of emissions from categories defined in the Table 1.

The relative shares of the source categories in the overall GHG emissions from agriculture vary from region to region. Figure 2 shows the estimated shares of emissions related to agricultural activities in Germany in 2008.

Figure 2 – Sources of GHG emission from agricultural activities in Germany, 2008*



Source: EEA (2010), NIR (2010), Ostenburger B. et al. (2009)

* *GHG emissions from fertiliser production and feed estimated for 2005 (domestic and imported)*

The emissions reported in sector CRF 4 Agriculture make only 45% of the GHG emissions associated with agricultural activities. Main emissions in this category are related to the nitrous oxide (N_2O) emissions from fertilised soils, methane (CH_4) emissions from enteric fermentation of cattle and CH_4 / N_2O emission from manure management of cattle and pigs.

On-farm use of electricity and fuel contribute to the total GHG emissions with about 4%.

Emissions from the land converted to cropland and grassland (included in LULUC) in the form of carbon dioxide (CO_2) are responsible for further 31% of the total emissions. These emissions occur not only from cropland/grassland remaining cropland/grassland, but also from further converting of land to cropland / grassland.

Emissions from production of mineral fertilizers (both domestic and imported from abroad) contribute 11% to the total GHG emissions.

Emissions from feed (9%) are mainly related to the emissions that occur by production of feed abroad and imported to Germany for domestic livestock. Such emissions are not included in national emissions, but domestic agricultural activities are the indirect cause of them.

1.2 Contribution of fertilizers

1.2.1 Emissions from the production of mineral fertilizers

The production of mineral fertilizers gives a rise to the GHG emission, mainly CO_2 and N_2O. Carbon dioxide emissions are associated with energy use, while nitrous oxide emissions are released by production of nitric acid.

Since the manufacture of all nitrogen (N) fertilizers accounts for 94% of the sector's energy use and nitric acid is used for production of nitrate fertilizers (IFA, 2009), N – fertilizers are responsible for a large majority of industry's GHG emissions. Therefore, to make it easier for further analysis, the production of N – fertilizers assumed to be the only source of THG emissions in this sector.

The total GHG emissions from production and transport of N-fertilizers used in Germany were estimated by Kaltschmitt and Reinhardt (1997). Their results are summarized in Table 2 and were used for accounting of GHG emissions from production of fertilizers.

Table 2 –GHG emissions from production of N-fertilizers

	CO_2 (g)	CH_4 (g)	N_2O (g)	CO_2 – eq. (g)
N-fertilizer (1 kg N)	2,468.00	0.54	9.63	5,351.00

Source: Kaltschmitt, Reinhardt (1997) in Flessa et al. (2001)

1.2.2 N_2O-Emissions from soils

The application of fertilizers is the main driving force of N_2O emissions from agricultural soils. These emissions occur because the fertilizers applied to the soils are not fully untaken by crops. The recovery of fertilizer N in a global crop production is about 50% (Eickhout et al., 2006). Consequently, its surplus is accumulated in soils and is either lost directly as N_2O, or leached to water courses, enhancing downstream indirect N_2O emissions (Bellarby et al., 2008).

Fertiliser-induced N_2O emissions from agricultural soils are included in the emissions of category CRF Agriculture. They incorporate the emissions from application of mineral fertilizers and animal manure. The N_2O emissions related to the application of fertilizers in Germany in 2008 are summarised in Table 3.

Table 3 - N_2O emissions from application of fertilizer in Germany in 2008

Source category	**N_2O emissions ($GgCO_2$-eq/yr)**
Soils, mineral fertilizers	11 004
Soils, application of manure	6 111
Soils, indirect emissions (deposition)	2 280
Soils, indirect emissions (leaching, run-off)	4 211

Source: NIR (2010)

1.2.3 Diminishing of LUC

The primary objective of agriculture is to provide the world with the food. It has been estimated, that in 2008 almost half of people on the Earth (ca. 48%) were fed due to the use of N-fertilizers (Erisman et al., 2008) and the connected with it rise of yields. Without use of fertilizers by far more additional arable area would be required to produce the same amount of agricultural output. Thereby, by preventing the conversion of new land to agriculture, which is the great source of GHG emissions, fertilizers help to reduce the global GHG emissions (IFA, 2009). Regarding the growing global demand for food, feed, fibre and bioenergy, the effect of indirect mitigation of GHG emissions from use of fertilizer is very important.

From the point of view of one separate region, the reduced production and application of fertilizers can diminish the national GHG emissions from agriculture in this region. However, this can induce higher import of agricultural inputs (e. g., fertilizers, feed) or high import of agricultural outputs (reduced export of agricultural outputs) for this region. On the global level, it results in either intensification of agriculture elsewhere abroad (therefore higher production/use of fertilizers) or further land use change. Both options are attended by additional GHG emissions.

2. Agriculture and fertilizer sector in the context of the EU / German climate policy

2.1 Emission reduction target: ETS and non-ETS sectors

In June 2009 the European “climate and energy package”[1] became a law, according to which, the EU-wide GHG emissions are to diminish by 10% by 2020 in relation to the 2005 levels (contribution to the EU’s goal of at least 20% reduction compared to 1990). This Decision lays down a minimum contribution of Member States (e. g., Germany has to reduce its GHG emission by 14% compared to 2005) and declares that all sectors of the economy should contribute to achieving the reduction targets.

The key tool for cutting emissions is the EU Emissions Trading System (ETS). From 2013 a single EU-wide cap will be applied and will be cut annually, reducing the number of allowances available to businesses to 21% below the 2005 level in 2020. The free allocation of allowances will be progressively replaced by auctioning, and the sectors and gases covered by the EU ETS will be somewhat expanded.

The “effort sharing” Decision regulates the reduction of GHG emissions from sectors not covered by the EU ETS, such as transport, agriculture, housing and waste. The overall EU GHG emissions from non-ETS sectors have to be cut by 10% by 2020 compared with 2005.

Thus, agriculture is now directly requested to reduce its GHG emissions, and it has to occur besides the achievement of another goal – the share of biofuels in transport sector has to reach the 10%- target by all Member States by 2020.

2.2 Fertilizer production under the EU ETS

In 2013 the third trading period of the EU ETS will start. The scope of the EU ETS will be extended to include new activities and GHG. Among the new activities are production of ammonia (relevant GHG: CO_2) and the production of nitric acid (relevant GHGs: CO_2, N_2O).

Since both ammonia and nitric acid are important inputs for N-fertilizer production, this will have an indirect impact on agriculture.

[1] COD/2008/0014

3. Disaggregation of the chemical sector in GTAP with separate treatment of fertilizers in Germany, rest of EU and the ROW

3.1 Composition of the CRP sector in GTAP and relevance of national statistics

For the analyses the separate treatment of fertilizers is necessary. Fertilizers are the part of the “crp” sector in GTAP Database. The concordance between the “crp” GTAP sector and sectors in the EU classification (NACE Rev. 1.1) for **S**tructural **B**usiness **S**tatistics (SBS) in Eurostat, is depicted in Table 4.

Table 4 – Concordance between the “crp” and sectoral classification NACE Rev. 1.1

“crp” =	+ **DG** – Manufacture of chemicals, chemical products and man-made fibres - *DG247 – Manufacture of man-made fibres*	-> **DG241**5 – Manufacture of fertilizers and nitrogen compounds (part of **DG**)
	+ **DH** – Manufacture of rubber and plastic products	

The objective of the disaggregation procedure is to break down the sector “crp” in two sectors: fertilizers (“FERT”), associated with the activity DG2415, and rest of the “crp” (“r_crp”). For some intermediate steps the sector “crp” is treated as the sum of two sectors: manufacture of chemicals (“Ch”) and manufacture of rubber and plastic products (“RP”).

The production and trade values of the sectors “FERT”and “r_crp” for Germany and the rest of the EU are taken from the Eurostat Statistics (SBS[2], External Trade Statistics[3])

For the Rest of the World (ROW) the production and trade values for sector “FERT” and “r_crp” were estimated on the basis of published data. At first the sector “crp” was broken down into “Ch” and “RP” due to estimated global values of these markets (COMM/ESTAT 2006 and 2009). Then, the values for the sector “FERT” were estimated from the available data about the share of this sector (“FERT”) in sector chemicals production (“Ch”) and the estimated data about the global manufactured and consumed in agriculture values of fertilizers and agricultural chemicals (Datamonitor, 2006 and 2010).

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[2] EUROSTAT -> Statistics -> Industry, trade and services -> Structural business statistics -> SBS - industry and construction -> Annual detailed enterprise statistics - industry and construction (sbs_na_ind) -> Annual detailed enterprise statistics on manufacturing subsections DF-DN and total manufacturing (NACE Rev.1.1 D) (sbs_na_2a_dfdn)

[3] EUROSTAT -> Statistics -> External Trade -> External Trade -> EU27 Trade since 1995 by HS2-HS4 (DS_016894)

3.2 Production cost structure of mineral fertilizers

In case of Germany and the EU the shares of labor costs and capital costs in production of “FERT” were obtained from the SBS of Eurostat. While the share of total intermediates in production costs is known, there are no available data about the distribution of these costs between different sectors. That is why by specification of the production technology the relevant data from the US Input-Output Table (IOT) were involved.

Data from the US IOT and the SBS accounts were also used to specify the avarage production technlogy of sector “FERT” for the ROW region. Taxation and tariff rates for the sector “FERT” are assumed to be the same as for the sector “crp”.

3.3 Disaggregation procedure

Information about production and trade values as well as information about production technology of sector “FERT” were used to split the “crp” sector into “FERT” and “r_crp”. Since the sector “FERT” is only a small part of the sector “crp” (ca. 3% of the global production value), by exclusion of “FERT” from sector “crp”, the production structure of “r_crp” does not differ much from the production structure of the sector “crp”.

It is assumed that fertilizers are used only as an intermediate input in the crop production and in the production of fertilizers. The value of fertilizers used as intermediate in own production depends on the output value of sector “FERT” and is defined by the production technology of sector “FERT”. The disaggregation of “crp” into “FERT” and “r_crp” was made by SplitCom.

4. Specification of the model

4.1 Organic fertilizers as by-products of animal production

The values of inputs from animal production to crop production are assumed to be the values of manure applied as fertilizers and should be treated as by-products of animal production.

4.2 Specification of crop production function

Considering the GHG emissions related to the agricultural activities, two main sources of emissions (i.e., fertilized soils and LULUC (land use and land use change)) were identified. Therefore, the strategy of mitigation of GHG emissions would incorporate two objectives. Objective 1: Mitigation of GHG emissions from fertilized soils. Objective 2: Mitigation of GHG emissions from LULUC.

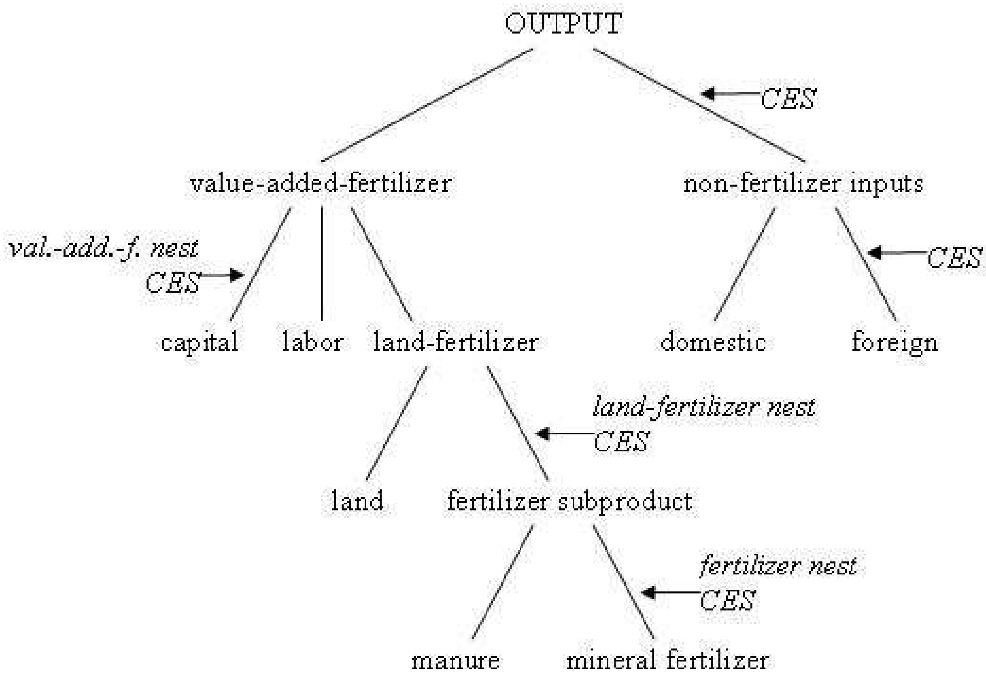
The connected with these aspects problem is, that without further progress in rise of fertilizers uptake (i.e., its efficiency), the achievement of both of these objectives is very complicated. Thus cause is the conflict of these two objectives: The decrease of applied fertilizer quantity can reduce the THG emissions from fertilized soils, but the demand for land would increase and cause a further increase of THG emissions from land use change. Vice versa: mitigation of GHG emissions from LULUC is associated with stop/decrease in land use change process. However, in this case the productivity of crop production has to rise and this is supposed to increase the application of fertilizer, and therefore, to increase the GHG emissions from fertilized soils.

The conflict of these two objectives can be incorporated in the production structure of crop production by assumption that fertilizers and land are substitutes. In this respect the standard production structure of GTAP model has to be modified. The procedure of modification applied in this study is similar to those introduced by Burniaux and Truong (2002), who modified the production structure for the E-GTAP.

On the production side, fertilizers must be taken out of the intermediate input ‘nest’ to be incorporated into the ‘value-added’ nest (see Figure 3). The incorporation of fertilzers into value-added nest is done in two steps. First, fertilizers are separated in “FERT” and “manure”. Next, the fertilizers composite is combined with land to produce a fertilizer-land composite, which is in its turn is combined with the other primary factors in a value-added-fertlizer nest through a CES structure.

At first, analysis can be simplified, when the only commodity included in the fertilizer nest are mineral fertilizers (“FERT”).

Figure 3 – GTAP – LaFe production structure



Source: own presentation

5. Consideration of the GHG emissions from fertilizers by modeling a 'carbon tax'

As already mentioned, the production of ammonia and the production of nitric acid will be among the activities covered by the EU ETS in the third trading period. Since ammonia and nitric acid are primary inputs for N-fertilizers, the costs of emission allowances will be incorporated in the production costs of N-fertilizers. This situation can be considered by imposing a "carbon tax" (price for emissions allowances) on "FERT" production in the EU. A "carbon tax" can be simulated as a rise of a production tax on "FERT".

Application of fertilizers induces the further GHG emissions from soils. A "carbon tax" that incorporates all emissions, including emissions from production and application of fertilizers, can be imposed on agricultural end-products. In this case consumers pay for all emissions occurred during the production of products.

6. Conclusions

Production and application of mineral fertilizers are associated with GHG emissions. The EU pursues an active policy of mitigation the GHG emissions. One of the instruments of this policy is the EU ETS. Due to the inclusion of ammonia and nitric acid production into the list of activities covered by the EU ETS, the production of fertilizers would be burdended with “carbon tax”. The preliminary results of such “carbon tax” on production and use of the fertilizers in the EU have showed a slight decrease of production of fertilizers in the EU. At the same time the demand for fetilizers used in crop production had a smaller decrease, because of a slight rise of demand for imported fertilizers. Therefore, the marginal decrease of crop production in the EU was replaced by imports.

To summarize, the “carbon tax” on production and use of fertilizers can slightly reduce the GHG emissions of the EU, but due to the rise of import of fertilizers (decrease of exports of in the EU produced fertilzers) and the rise of imports of grains (decrese of exports of grains) the overall effect on the global level is not definite.

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