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THE TRANSITION PERIOD TO THE MARKET ECONOMY AND THE DECREASE OF N_2O EMISSIONS FROM THE ROMANIAN AGRICULTURAL SOILS

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Abstract

An inventory of nitrous oxide (N_2O) emissions from Romanian agricultural soils was carried out in 2012 for a period of 22 years (1989-2010) using the IPCC (2000) approach. Activity data comes from the Romanian Institute for Statistics and IPCC default emissions factors were used as any country-specific emissions factors were developed since Romania ratified the Kyoto Protocol in 2001. Direct emissions of N_2O, resulted from anthropogenic activities (i.e. from the soils to which the N is added) and indirect emissions (through volatilization as NH3 and NOx and subsequent redeposition, and through leaching and runoff) were calculated using the IPCC (2000) Guidelines equations (Tier 1a and Tier 1b). The total soil emissions decreased from 46.29 Gg N-N_2O in 1989 to 20.18 Gg N-N_2O in 2000. Between 2001 and 2010, only in 2004 there was an important growth of N_2O emissions, but not more than 24.42 Gg N-N_2O respectively. This decrease of total soil emissions of N-N_2O is mainly due to the dissolution of state agricultural entreprises and agricultural cooperatives and to the reforms of this economical sector. In order to improve the quality of the estimations and to reduce uncertainty, for further inventories, national data will be necessary.

Key words: *emissions, soil, nitrous oxide.*

INTRODUCTION

Land Law No. 18/1991 changed the structure of the agricultural holdings in Romania. This law abolished the agricultural cooperatives, which were economic structures resulting from the nationalization before 1962 and allowed the rural population, mostly farmers to recover their own land. Thus, compared with the situation prior to the law, when every rural community had only one agricultural holding of 1500 ha (in case of small villages) and up to 4000 ha (in case of large communes), the number of parcels, as well as the number of farmers, increased after this law was enforced. In Romania, in 2010, there were more than 2 million farms with an area greater than 1 ha. This split land ratio was still higher in the 1990s. Small farmers had no means and some of them lacked also the required knowledge to apply technology previously used in agricultural production cooperatives. Under these conditions, crop production gradually decreased. These changes have completely unintentionally influenced the amount of greenhouse gas emissions produced by agriculture.

In 2001, Romania ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Parties that ratified the Convention, "shall develop, periodically update, publish and make available…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies…". An emissions inventory that identifies and quantifies a country's primary anthropogenic sources and sinks of greenhouse gases is essential for addressing climate change (EPA, 2011). The term "anthropogenic", in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC / UNEP / OECD / IEA 1997).

As it was already reported, agriculture is a major source of gaseous emissions contributing to air pollution and climate change (Gac et al., 2007; Wang et al., 2011) through a variety of different processes: domestic livestock, which refer to enteric fermentation and manure management; rice cultivation, which refer to flooded rice fields; prescribed burning of savannas; field burning of agricultural residues and agricultural soils (IPCC, 1996 a). Agricultural soils may emit or remove nitrous oxide (N_2O), carbon dioxide (CO_2), and/or methane (CH_4) (IPCC, 1996 b). Soils are the dominant source of N_2O worldwide, releasing an estimated 9.5 Tg N_2O-N year-1 to the atmosphere (65% of global N_2O emissions), of which 3.5 Tg N_2O-N year-1 originate in soils and 1 Tg N_2O-N year-1 in temperate grasslands (IPCC 2001a).

Nitrous oxide (N_2O) is produced naturally in soils through the microbial processes of nitrification (the oxidation of ammonia (NH_3) to nitrite (NO^{2-}) and nitrate, NO^{3-}) and denitrification (the reduction of NO^{3-} to NO^{2-}, nitric oxide (NO), N_2O and ultimately N_2 – where facultative anaerobe bacteria use NO_3- as an electron acceptor in the respiration of organic material when molecular oxygen (O_2) is in short supply). A number of agricultural activities add nitrogen to soils, increasing the amount of nitrogen (N) available for nitrification and denitrification, and ultimately the amount of N_2O emitted. The emissions of N_2O that result from anthropogenic N inputs occur through both a direct pathway (i.e. directly from the soils to which the N is added), and through two indirect pathways (i.e. through volatilisation as NH_3 and NOx and subsequent redeposition, and through leaching and runoff). Direct and indirect emissions of N_2O from agricultural soils are estimated separately (IPCC, 2001b). Anthropogenic input into agricultural systems include synthetic fertiliser, nitrogen from animal wastes, nitrogen from increased biological N-fixation, and nitrogen derived from cultivation of mineral and organic soils through enhanced organic matter mineralisation (IPCC, 1996 a).

The aim of this paper is to present the results of an inventory of estimated N_2O emissions from the Romanian agricultural soils, for 1989-2010 period. This period was one of transition to the market economy, which was characterised by different kind of reforms regarding the agriculture and the market. In order to estimate the N_2O emissions, the IPCC 2000 Guidance methodologies were used. Also, as in Romania, until present, there are not available national values for the emission factors, there were used the default values from the IPCC (1996) Good Practice Guideline. Even some uncertainties were calculated, both for activity data and for the emission factors, the goal of this work is to reveal the important decrease of the greenhouse gases emissions due to the changes in the structure of the soil property, to the agricultural holdings and farms structure, and also due to the decrease of the synthetic fertilisers quantities used in agriculture, the decrease of the cultivated area or to the application of a wrong thechnology.

MATERIALS AND METHODS

General approach

Direct emissions of N_2O, resulted from anthropogenic activities (i.e. from the soils to which the N is added) and indirect emissions (through volatilization as NH_3 and NO_x and subsequent redeposition, and through leaching and runoff) were calculates using the IPCC (2000) Guidelines equations (Tier 1a and Tier 1b). The Tier 1b equations represent increased precision due to expansion of the terms in the equations. Tier 1a equations were considered appropriate when the activity data needed to use Tier 1b equations were not available.

Direct emissions of N_2O from agricultural soils due to applications of N and other cropping practices accounts for anthropogenic nitrogen (N) inputs from the application of: synthetic fertilisers (FSN) and animal manure (FAM); the cultivation of N-fixing crops (FBN); incorporation of crop residues into soils (FCR); and soil nitrogen mineralisation due to cultivation of organic soils (i.e. histosols) (FOS). Indirect emissions refers to the leaching and runoff of applied N in aquatic systems, and the volatilisation of applied N as ammonia (NH_3) and oxides of nitrogen (NO_x) followed by deposition as ammonium (NH_4) and NO_x on soils and water (IPCC 2000).

In this inventory, soil nitrogen mineralisation due to cultivation of organic soils (i.e. histosols) (FOS), as part of direct emissions, were not take in account because the lake of statistical data, as well as the nitrogen resulted from sewage sludge, as part of indirect emissions.

Activity data

Activity data comes from the Romanian Institute for Statistics: annual amount of synthetic fertiliser nitrogen applied to soils; number of each livestock category; surfaces cultivated annualy with different crop categories; crop productions. The animal categories and sub-categories were grouped according to the main production system, and follow international inventory formats. The main categories were: cattle, buffaloes, pigs, sheep, goats, mules and donkeys, horses and poultry. The classes of crops were defined based on Romanian crop production within the main production system, and follow international inventory formats and comprise: cereals, legumes, textil plants, oil plants, industrial plants, medicinal and aromatic plants, vegetables, forrage plants. Nitrogen excretion rates were calculated for each sub-category.

Emissions factors were used as IPCC (1996a) default values as any country-specific emissions factors were developed since Romania ratified the Kyoto Protocol in 2001 (EF1 = 0.0125 kg N-N_2O/kg N; EF4 = 0.01 kg N_2O per kg NH_3 and NO_x; EF5 = 0.025 kg N_2O per kg N).

For different parameters used for emissions estimation, default values (IPCC 1996a) or assumed values by the experts were used (FracGASF = 0.1 kg NH_3-N + NO_x-N/kg; FracGASM = 0.2 kg NH_3-N + NO_x-N/kg). For the parameters FracFUEL-AM, FracFEED-AM, and FracCNST-AM experts assumed the value “0” as no available source of national official data. For ResBF/CropBF, FracDMi and FracNCRBFi default values (IPCC 1996a) were used as is presented below:

Parameter	Peas	Beans	Soy bean	Other grain legumes	Alfalfa for green grass	Clover for green grass	Other perennial legumes
$Res_{BF}/Crop_{BF}$	1.5	2.1	2.1	1.8	0	0	0
$Frac_{DMi}$	0.87	0.82-0.89 average 0.85	0.84-0.89 average: 0.865	0.85	0.85	0.85	0.85
$Frac_{NCRBFi}$	0.0142	0.03	0.0230	0.03	0.03	0.03	0.03

For ResOi/CropOi the IPCC default values were used as for FracNCROi and FracNCRBFj. For FracBURNi/j, Frac FUEL-Cri/j, FracCNST-Cri/j and FracFODi/j experts assumed different values in relation with the different type of crops and with the habits of the rural population in particular.

The manure quantity is calculated using the prototype parameters for different types of animals in the Eastern Europe region, given in the IPCC Guidelines (2000).

RESULTS AND DISCUSSIONS

The values of the total, direct and indirect estimated emissions are presented in the Table 1a, Table 1b and Figure 1. The total soil emissions decreased from 46.29 Gg N-N_2O in 1989 to 20.18 Gg N-N_2O in 2000. Between 2001 and 2010, only in 2004 there was an important growth of N_2O emissions, but not more than 24.42 Gg N-N_2O respectively. This decrease of total soil emissions of N-N_2O is due especialy to the dissolution of state agricultural entreprises and agricultural cooperatives but also to the inability of small farmers to manage their own crops and farms. In the same time, the decrease of N_2O soil emissions it is also a consequence of the some other reasons such as: the decrease of cultivated area (Figure 2), the decrease of the quantities of mineral fertilizers used per hectare (Table 2), as it was observed by Hera (2009) and, not in the end, the small quantities of organic fertilizers that were used.

From the total soil estimated emissions, the direct one are representatives in relation with the indirect emissions (Figure 3) during all the period. So as, the direct emissions represented more than 60% from the total soil emissions with a biggest value in 1999 (68.37%) and the indirect one represented more than 30%, the biggest have been noted in 2007 (38.44 %).

Table 1a. Direct, indirect and total N-N_2O soil emissions (1989-1999)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Direct emissions (Gg N-N_2O)	30.08	26.10	19.68	15.75	17.59	16.91	17.08	16.16	16.66	15.78	15.90
Indirect emission (Gg N-N_2O)	16.21	15.52	9.78	8.73	9.69	9.03	9.00	8.47	8.03	7.89	7.36
Total soil emissions (Gg N-N_2O)	**46.29**	**41.63**	**29.46**	**24.48**	**27.29**	**25.94**	**26.08**	**24.63**	**24.68**	**23.67**	**23.25**

Table 1b. Direct, indirect and total N-N_2O soil emissions (2000-2010)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Direct emissions (Gg N-N_2O)	12.82	15.12	15.10	15.79	14.42	15.93	15.37	12.79	14.58	14.74	15.11
Indirect emission (Gg N-N_2O)	7.36	7.69	7.46	7.66	8.05	8.49	7.89	7.98	8.05	8.11	7.77
Total soil emissions (Gg N-N_2O)	**20.18**	**22.81**	**22.56**	**23.45**	**22.47**	**24.42**	**23.26**	**20.77**	**22.64**	**22.85**	**22.88**

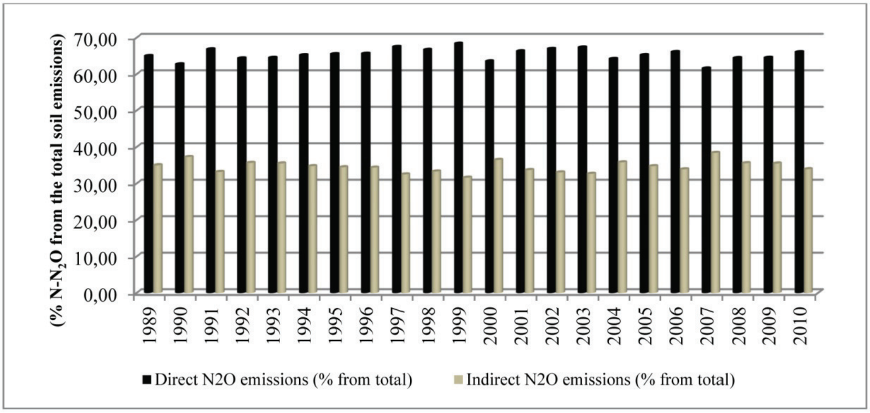

Figure 1. The trend of total (direct and indirect N_2O) soil emissions

Table 2. The quantities of mineral fertilisers used ($N+P_2O_5+K_2O$) in the Romanian agriculture (Hera, 2009, from Dumitru, 2002-ICPA)

Year	Total (t a.m.*)	Agricultural land (kg ha^{-1})	Arable land (kg ha^{-1})
1950	5.921	0.4	0.6
1970	594.347	39.8	61.0
1990	1.103.075	74.8	117.0
2000	342.174	23.0	36.4

*active matter/substance

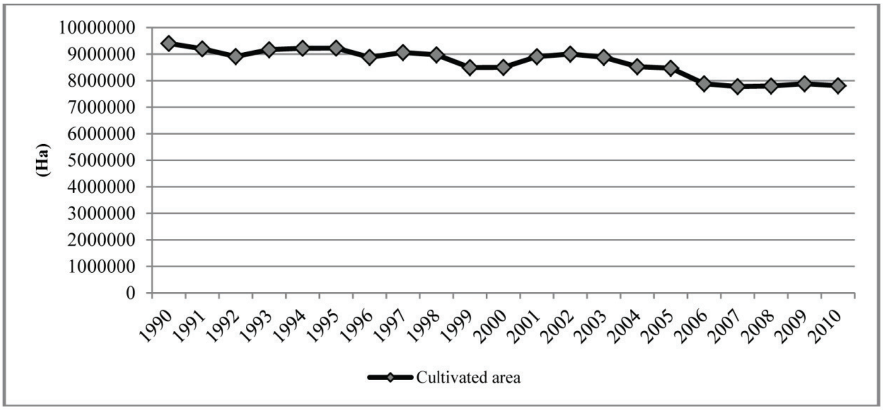

Figure 2. The decrease of cultivated area during the period 1910-2010

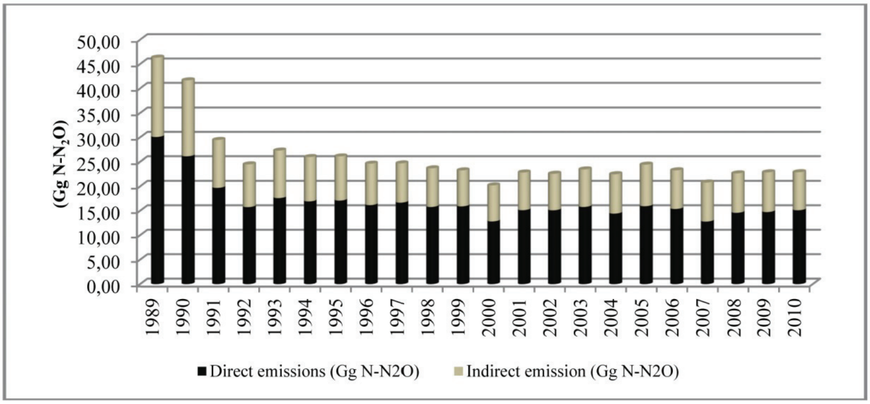

Figure 3. Contribution of each category (direct and indirect) to the total estimate of N_2O emissions

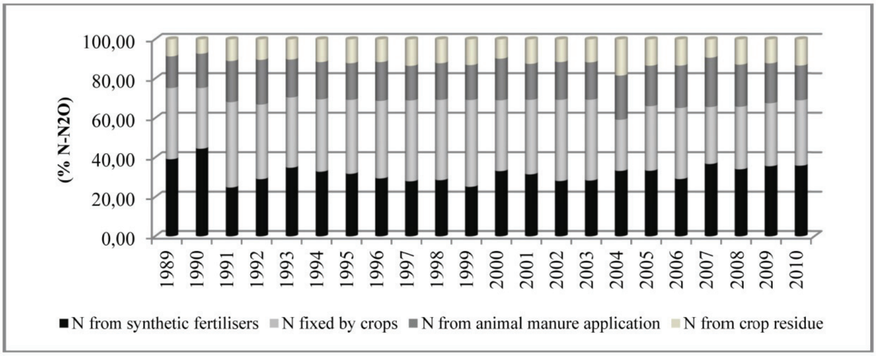

Figure 4. Contribution of each sub-category to te total of direct N_2O emissions estimate

As it can be observed in Figure 4, the values of the sub-categories "N from synthetic fertilizer" (from 24.70 % in 1991 to 44.43% in 1990) and "N fixed by crops" (from 26.03% in 2004 to 44.12% in 1999) have been the most important into the structure of the direct emissions from soil. The contribution of the "N resulted from animal manure application" (from 15.92% in 1989 to 24.94% in 2007) and "N from crop residues" (from 7.35% in 1990 to 18.52% in 2004) to the direct soil emissions were less important.

The contribution of each sub-category to the indirect soil emissions is presented in the Figure 5. The leaching nitrogen contributes with more than 80 % and the atmosphere deposition nitrogen contributes with less than 20%.

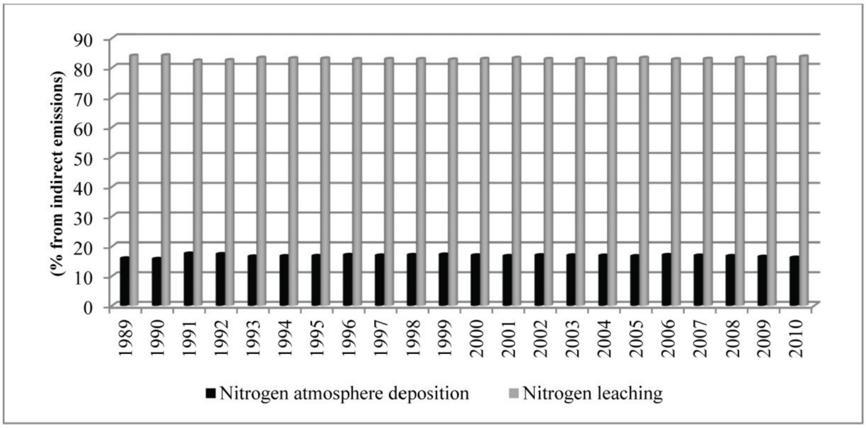

Figure 5. Contribution of each sub-category to the total of indirect N_2O emissions estimate (Gg)

Even the values of the total soil emissions were small, we cannot compare any values of estimated soil emissions with any other values reported by others. As it was already presented in the part of "Material and methods/Activity data", there is a lake of national data, especially referring to the emissions factors and parameters that are very important for the accuracy of the emissions calculation. So, for this inventory they were assumed large uncertainties. So, for further inventories, national data will be necessary to increase the quality of estimation and to reduce uncertainty.

CONCLUSIONS

The agricultural reforms made after 1990, especially those related to land ownership as well as to the size of farms and the application of production technologies have led to decreased amounts of N_2O emissions.

Romania must take advantage of this situation in terms of maintaining emissions at a low level through technological measures. Also, producing national values for the activity data and the emission factors as well as making up a national portofolio of publications in the field seems to be necessary.

As in other EU countries, Romania also needs to develop working groups of experts in estimating the GHG emissions, who run constant scientific activities in the field and international cooperation activities in the scientific research of this emission effects and who will contribute to the improvement of emission data collection, the improvement of calculation methodology and the development of computational models and some recommendations regarding the quality assurance.

In the medium and long term, the estimation of GHG emissions must be an ongoing process, a current activity that allows considering much more details in order to reduce uncertainty.

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REFERENCES

Bouwman A.F., Van Der Hoek K.W., Olivier J.G.J., 1995. Uncertainities in the global source distribution of nitrous oxide. In: Revised 1996 IPCC Guidelines for National Greengouse Gas Inventories: Reference Manual. 1996C Guidelines for National Greengouse Gas Inventories: Reference Manual.

EPA (United States Environmental Protection Agencie), 2011. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. Executive Summary.

Gac A., Béline F., Bioteau T., Maguet K., 2007. A French inventory of gaseous emissions (CH4, N_2O, NH3) from livestock manure management using a mass-flow approach. Livestock Science 112, p. 252-260.

Hera C., 2009. Solul –temelia dezvoltării durabile a agriculturii şi economiei naţionale.Academia Română, Iunie 2009. http://www.enciclopedia-economica.ro/upload/files/AT_2-2-1-power-point-prezentare-SOL-acad-Hera.pdf.

IPCC 2000. Good practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory.

IPCC 2001a. Climate Change. The Scientific Basis – Contribution of Working Group I to the Third Assessment Report of Intergovernmental Panel on Climate Change (IPCC). In Flechard et al., 2007.

IPCC 2001b. Climate change 2001, The Scientific Basis. In: Zhengqin, X. et al., Measurement of nitrous oxide emissions from vegetable production in China. Atmospheric Environment 40, p. 2225-2234.

IPCC/UNEP/OECD/IEA (1997) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency. in EPA, 2011. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. Executive Summary.

IPCC, 1996 a. Revised 1996 IPCC Guidelines for National Greengouse Gas Inventories: Reference Manual. Module 4, Agriculture, p. 333.

IPCC, 1996 b. Revised 1996 IPCC Guidelines for National Greenhouse Inventories: Workbook. Module 4, Agriculture, p. 198.

Mosier A.R., Duxbury J.M., Freney J.R., Heinemeyer O., Minami K., 1995a. Nitrous oxide emissions from agricultural fields: Assessment, measurement and mitigation. In:Revised 1996 IPCC Guidelines for National Greengouse Gas Inventories: Reference Manual.

Mosier A.R., Duxbury J.M., Freney J.R., Heinemeyer O., Minami K., 1995a. Mitigating agricultural emissions of nitrous oxide. In: Revised 1996 IPCC Guidelines for National Greengouse Gas Inventories: Reference Manual.

Statistical Yearbook of the Romanian National Institute for Statistics, 1989-2010.

Wang J., Cardenas L.M., Misselbrook T.H., Gilhespy S., 2011. Development and application of a detailed inventory framework for estimating nitrous oxide and methane emissions from agriculture. Atmospheric Environmenet 45, p. 1454-1463.