ASSESSMENT OF THE DIRECT N_2O EMISSIONS FROM APPLIED SYNTHETIC NITROGEN FERTILISERS IN THE REPUBLIC OF MOLDOVA WITHIN 1990-2005 TIME SERIES

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INTRODUCTION

Agriculture soils may emit or remove nitrous oxide (N_2O), carbon dioxide (CO_2) and/or methane (CH_4). The article presents the result of an assessment undertaken to calculate the national emissions of direct N_2O from applied synthetic nitrogen fertilisers to the managed soils in the agriculture sector of the Republic of Moldova within the 1990-2005 time series. The performed study has been realised within the Project "Republic of Moldova: Enabling Activities for the Preparation of the Second National Communication (SNC) under the United Nations Framework Climate Change Convention (UNFCCC)" implemented within the 2005-2009 period by the Ministry of Environment and Natural Resources of the Republic of Moldova and the United Nations Environment Programme, with financial support of the Global Environment Facility.

To be noted, that anthropogenic sources of N_2O can be biogenic (e.g., enhanced N_2O production by bacteria in fertilised fields) or abiogenic (e.g., formation during burning processes). Several studies indicate that anthropogenic sources are largely biogenic, with agriculture as a major contributor (Bouwman et.al., 1995; Mosier, Kroeze, 1999).

Biogenic production of N_2O in the soils results primarily from the nitrification and denitrification processes. Simply defined, nitrification is the aerobic microbial oxidation of ammonium to nitrate and denitrification is the anaerobic microbial reduction of nitrate to dinitrogen gas. Nitrous oxide is a gaseous intermediate in the reaction sequences of both processes which leaks from microbial cells into soil atmosphere. Most regulators of these processes are temperature, pH and soil moisture content.

In most agriculture soils, biogenic formation of N_2O is enhanced by an increase in available mineral nitrogen, which in turn increases nitrification and denitrification rates. Addition of fertiliser N, therefore, directly results in extra N_2O formation. Most studies on N_2O emissions from agriculture soils investigate the difference in N_2O production between fertilised and unfertilised fields. Emissions from unfertilised fields are considered background emissions. However, actual background emissions from agriculture soils may be higher than historic natural emissions as a result of enhanced mineralization of soil organic matter. That is particularly observed in organic soils in both cold and warm climates over the world (Bouwman and van der Hoek, 1991; Kroeze, 1994). Background emissions may also be lower than historic emissions due to depletion of soil organic matter (Groffman et al., 1993).

METHODOLOGICAL ISSUES

Direct N_2O emissions from applied synthetic fertiliser were estimated by using a Tier 1 methodology (IPCC, 2006). The following equation was used to calculate N_2O emissions:

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$$N_2O_{SN} = F_{SN} \bullet EF_1 \bullet 44/28$$

Where:

N_2O_{SN} = N_2O emissions from applied synthetic fertilizer (Gg/yr);

F_{SN} = annual amount of synthetic fertilizer N applied to soils (kg N/yr);

EF_1 = emission factor for N_2O emissions from N inputs; default: 0.01 kg N_2O-N/kg N applied; range: 0.003-0.03 kg N_2O-N/kg N;

[44/28] = stoichiometric ratio of nitrogen content in N_2O-N and N_2O.

RESULTS AND ANALYSIS

Data Sources Used

Table 1 provides a short overview of synthetic N fertilizers, including complex fertilizers most commonly used in the Republic of Moldova (Gumovschi, 2004).

Table 1: Overview of Synthetic N Fertilizers Most Commonly Used in the Republic of Moldova

Type of fertilizer	Chemical formula	Active substance, %	Form	Features
Ammonium nitrate	NH_4NO_3	34.5	White macro crystals or pellets	Physiologically it is faintly acid, may be applied to all crops and all soils. Highly hygroscopic.
Urea (carbamide)	$CO(NH_2)_2$	46	White crystals or pellets	Has a physiologically faintly acid/neutral, low hygroscopic. Highly volatile. Applied to soils, may be used in solutions for foliar fertilization.
Ammophos	$NH_4H_2PO_4$	N: 11-12, P_2O_5: 42-50	Grey pellets	Efficient on chernozems, brown soils, and phosphor deficient soils.
Diammophos	$(NH_4)_2HPO_4$	N: 21, P_2O_5: 53	Grey pellets	Efficient on chernozems, brown soils, and phosphor deficient soils.
Nitroammophos (nitrophoska)	Complex formula	N:P:K 13-19 each	Pellets of different colours	Efficient on all soils and used for all crops.
Diammophos (diammophoska)	Complex formula	N:P:K 10:26:26	Pellets of different colours	Efficient on all soils and used for all crops.

Information on the amounts of applied synthetic N fertilizers (active substance) on managed soils in the Republic of Moldova is available in the Statistical Yearbooks of the Republic of Moldova (for the period until 1992 for the whole territory of the country, and for the period after 1993 - only for the right bank of the Dniester river), and in the Statistical Yearbooks of Administrative Territorial Units on the left bank of Dniester (ATULBD) (for the 1993-2005 time series).

Table 2: Applied Synthetic Fertilizers in the Republic of Moldova within 1988-2005 time series, thousand tones active substance

Indicator	1988	1990	1991	1992	1993	1994
Applied Synthetic N Fertilizer, kt	180.0	87.8	82.7	61.8	28.7	16.2
Total Applied Synthetic Fertilizer, kt	423.0	217.2	191.4	127.6	44.9	20.0
Total Fertilizers Applied, kg/ha	205.9	136.0	124.0	86.0	37.7	27.0
Indicator	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Applied Synthetic N Fertilizer, kt	10.5	13.2	11.4	10.2	5.9	10.2
Total Applied Synthetic Fertilizer, kt	12.5	14.3	12.1	20.3	6.1	10.3
Total Fertilizers Applied, kg/ha	7.8	7.6	9.9	12.3	10.3	12.6
Indicator	**2001**	**2002**	**2003**	**2004**	**2005**	**1990-2005, %**
Applied Synthetic N Fertilizer, kt	12.7	18.0	14.6	16.1	16.1	-83.1
Total Applied Synthetic Fertilizer, kt	12.8	18.4	15.4	17.5	18.1	-92.4
Total Fertilizers Applied, kg/ha	12.3	19.4	16.5	18.6	19.7	-84.6

Source: Statistical Yearbooks of the Republic of Moldova for 1988 (page 280), 1994 (page 239), 1999 (page 330), 2003 (page 442), 2004 (page 493), 2005 (page 360) and 2006 (page 352); Statistical Yearbooks of the ATULBD for 1998 (page 230), 2000 (page 107), 2002 (page 111) and 2006 (page 108).

Table 2 indicates, that in the period from 1988 through 2005 there was a significant decrease (by circa 23 times) of the amounts of synthetic fertilizers used in the agriculture sector of the Republic of Moldova: from about 206 kg active substance per 1 sown hectare in 1988 to circa 20 kg active substance per 1 sown hectare in 2005, while the average consumption of nutrients, in kg of nitrogen per 1 tone of basic yield in most crops is 30-35 kg, and the yield capacity of crops grown in the Republic of Moldova, according to the National Complex Soil Fertility Enhancing Program for 2001-2020, vary between 35-48 quintals/ha in winter wheat, 45-64 quintals/ha in grain maize, 21-35 quintals/ha in sunflower, 268-370 quintals/ha in sugar beets, etc.

A sharp reduction in fertilizer consumption occurred due to a number of reasons, such as: a drop in import of synthetic fertilizer in the country, lack of financial resources by farmers in certain times of the year, in particular in the context of the breakdown of agriculture during transition to market economy. To be noted that in conformity with the National Complex Soil Fertility Enhancing Program for 2001-2020, it is planned to increase the annual amount of synthetic N fertilizer up to 70-80 thousand tones of nitrogen by 2010, and up to circa 120-130 thousand tones of fertilizer by 2020.

Uncertainties and Time-Series Consistency

Uncertainties related to activity data on applied synthetic N fertilizer in the RM are considered to be low (±10 percent). Uncertainties associated with the default emission factor (EF_1 for F_{SN}) may reach up to ±6 percent. So, combined uncertainties associated with direct N_2O emissions from applied synthetic N fertilizer are considered to be low (±11.66 percent).

In view of ensuring time-series consistency of the obtained results, the same approach was used for the entire period under review, in conformity with the recommendations included in the Good Practice Guidance and Uncertainty Management in National GHG Inventories (IPCC, 2000).

Calculations of Direct N_2O Emissions

Direct N_2O emissions from applied synthetic fertilisers have been calculated for the first time in the frame of the First National Communication (FNC) of the Republic of Moldova under the UNFCCC (2000).

In comparison with the results included in the FNC, the direct N_2O emissions from applied synthetic fertilisers were recalculated for the 1990-1998 time series (for the Republic of Moldova the 1990 is considered the base year under the UNFCCC, while emissions for 1988 year are presented here for comparison purposes), in particular due to becoming available new activity data on synthetic fertilizers consumption in the Republic of Moldova - data from Statistical Yearbooks of the Republic of Moldova and those of the ATULBD, as the emission factor value and the estimation methodology available in the 2006 IPCC Guidelines is identical with that from the IPCC 1995 Guidelines used within the FNC (2000).

The changes made for the period of time from 1988 to 1992 resulted in lower values of direct N_2O emissions from applied synthetic N fertilizer on managed soils in the Republic of Moldova, varying from a minimum of -4.7 percent in 1990 to a maximum of -4.9 percent in 1991 (Table 3), which is mostly explained by use of most precise activity data, which become available lately.

The changes made for the period from 1993 through 1998 resulted in increased values of direct N_2O emissions from applied synthetic N fertilizer in the RM, varying from a minimum 1.7 percent in 1996 to a maximum of 80.5 percent in 1994, the increase being explained by taking

into account for the first time of activity data available in the Statistical Yearbooks of the ATULBD.

Table 3: Comparative Results of Direct $N_2O_{(SN)}$ Emissions from Applied Synthetic N Fertiliser Included into the First and Second National Communications of the Republic of Moldova under the United Nations Framework Convention on Climate Change, Gg

	1988	**1990**	**1991**	**1992**	**1993**	**1994**
FNC	2.9700	1.4473	1.3671	1.0214	0.3143	0.1414
SNC	2.8286	1.3797	1.2996	0.9711	0.4514	0.2552
Difference, %	-4.8	-4.7	-4.9	-4.9	43.6	80.5
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
FNC	0.1509	0.2043	0.1477	0.1069		
SNC	0.1652	0.2077	0.1795	0.1600	0.0929	0.1609
Difference, %	9.5	1.7	21.5	49.8		
	2001	**2002**	**2003**	**2004**	**2005**	**1990-2005, %**
FNC						
SNC	0.1994	0.2823	0.2298	0.2524	0.2530	-81.7
Difference, %						

For the period 1999-2005, direct N_2O emissions from applied synthetic N fertilizer on managed lands in the Republic of Moldova, were estimated for the first time. The results allow assert that within the 1990-2005 time series, direct N_2O emissions from applied synthetic N fertilizer on managed lands decreased by circa 81.7 percent.

CONCLUSIONS

1. Synthetic fertiliser nitrogen applied to agriculture soils is an important source of N_2O emissions world-wide.
2. In 1990 (base year under the UNFCCC), the direct N_2O emissions from applied synthetic nitrogen fertilisers accounted for 427.7 Gg CO_2 equivalent or 1.0 percent of the total national direct greenhouse gas emissions (42886.0 Gg CO_2 equivalent) without taking into consideration the contribution of LULUCF sector, and 12.7 percent of the total national N_2O emissions (3355.6 Gg CO_2 equivalent).
3. In 2005, the direct N_2O emissions from applied synthetic nitrogen fertilisers accounted for 78.4 Gg CO_2 equivalent or 0.7 percent of the total national direct greenhouse gas emissions (11883.5 Gg CO_2 equivalent) without taking into consideration the contribution of LULUCF sector, and 5.6 percent of the total national N_2O emissions (1404.2 Gg CO_2 equivalent).
4. Between, 1990 and 2005, the direct N_2O emissions originated from applied synthetic nitrogen fertilisers have decreased by 81.7 percent: from 1.3797 Gg or 427.7 Gg CO_2 equivalent in 1990 to 0.2530 Gg or 78.4 Gg CO_2 equivalent in 2005.
5. The significant reduction of N_2O emissions originated from applied synthetic nitrogen fertilisers occurred due to the sharp reduction in fertilizer consumption, inclusive as result of a drop in import of synthetic fertilizer in the country, lack of financial resources by farmers, in particular in the context of the breakdown of agriculture sector during the transition to market economy.

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