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Estimation of nitrous oxide and methane emission from Polish agriculture**

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A b s t r a c t. Estimation results of nitrous oxide and methane emission from Polish agriculture in 2006 are presented for voivodeship territorial units. The data for the estimation were taken from the Central Statistical Office's Regional Data Bank. The methodology used complies with the tier-1 approach in the 1996 IPCC Methodology Guidelines for National Greenhouse Gas Inventories with the changes introduced in 2006. Emission estimation results, broken into categories in accordance with the methodology and additionally into animal and plant production, are presented in Gg and in Gg mln ha^{-1}. The main part of methane emission originated from enteric fermentation, with the minimum of 68% in the Greater Poland voivodeship to the maximum of 89% in the Podlachian voivodeship. The smallest total methane emission was in the Lubusz voivodeship (7 Gg) and the biggest in the Masovian (90 Gg). Expressed in Gg mln ha^{-1}, the total methane emission was the smallest in the West Pomeranian voivodeship (11 Gg mln ha^{-1}) and the biggest in the Podlachian (61 Gg mln ha^{-1}). The lowest total nitrous oxide emission of 1.4 Gg was in the Lubusz voivodeship and the highest of 8.2 Gg in the Greater Poland voivodeship. The differences are due to dissimilar agricultural land area and to different animal production intensity in the voivodeships.

K e y w o r d s: emission estimation, methane, nitrous oxide

INTRODUCTION

The first important scientific contribution to the issue of anthropogenic nature of climate change was made at the First World Climate Conference in 1979 (Depledge and Lamb, 2005). In 1988 the Intergovernmental Panel on Climate Change (IPCC) was created, which presented in its First Assessment Report scientific evidence on anthropogenic causes of climate change, leading to growing public interest in the issue. One of the important international agreements on climate change was the Convention on Climate Change adopted at the Rio de Janeiro United Nations Conference on Environment and Development in 1992. The Kioto Protocol, which outlined legally binding commitments to emission cuts, was adopted in 1997 by 160 governments and entered into force in 2005 (Depledge and Lamb, 2005). The Kioto Protocol (Anonymous, 1998) focuses on carbon dioxide, methane, nitrous oxide and so called industrial gases as basic greenhouse gases. The commitment of Poland is, among others, to conduct research and monitoring in the scope of climate change and to submit to the Climate Change Secretariat in Bonn annual inventories of its greenhouse gas emissions and removals, prepared in compliance with the approved IPCC methodology.

The current work focuses on the distribution of methane and nitrous oxide emission over territorial units of the country in 2006.

MATERIAL AND METHODS

Calculations of methane and nitrous oxide emission were conducted for 16 voivodeships in Poland using the Central Statistical Office's data (Anonymous, 2006) on livestock population, consumption of mineral nitrogenous fertilizers and the data on the yields of main crops (cereals, potato and sugar beet). The calculations were performed using solely publicly available data.

The methodology used complies with the tire-1 IPCC 1996 methodology (Gibbs *et al.*, 2002; IPCC, 1997; Jun *et al.*, 2002; Nevison, 2002; Oenema *et al.*, 2002; Smith *et al.*, 2002;

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Zeeman and Gerbens, 2002) and takes into account the changes to the methodology introduced in 2006 (Dong *et al*., 2006; De Klein *et al.*, 2006). These changes regard emission factor for enteric fermentation for dairy cows and other cattle (Dong *et al*., 2006), EF1 emission factor for N_2O direct emissions from N inputs, EF2 emission factor for N_2O direct emissions from organic soils, introduction of a new source of N_2O emission on pastures and paddocks (from urine) and removal of nitrogen fixing crops as the source of N_2O in the soil.

The emission estimation results are given in gigagrams (Gg). Another unit is also used, namely gigagrams per one million hectares of agricultural land (Gg mln ha^{-1}). This somewhat atypical unit seems to have the advantage of better demonstrativeness as the unitary values *ie* those expressed in Gg mln ha^{-1}, can have then much the same dimension as the absolute ones *ie* the ones expressed in Gg. The emission estimation results were broken into categories in agreement with the IPCC methodology (Table 1) as well as into the emission originating from animal and plant production.

RESULTS AND DISCUSSION

The total emission for Poland in 2006, broken into the main sources, is presented in Table 1. The main part of methane emission originated from enteric fer mentation (cca. 79%). According to an estimation made by the Institute of Environmental Protection (IEP), the emission from enteric fermentation in 2003 was ca. 90% (Olendrzyński *et al*., 2005). These values depend, above all, on cattle stock and pig stock.

The methane and nitrous oxide emission calculated for Poland in 2006, broken into voivodeships and the categories described above, are presented in Figs 1-7.

Figures 1-3 show methane emissions in different schemes. In Fig. 1 methane emission (Gg) broken into enteric fermentation and manure is presented. The main part of the emission (on average 79%) originated from enteric fermentation. There are differences among the voivodeships in this regard, from the minimum of 68% in the Greater Poland voivodeship to the maximum of 89% in the Podlachian voivodeship. The differences result mainly from dissimilar proportions of the pig stock to

T a b l e 1. Estimation of methane and nitrous oxide emission from agriculture for Poland in 2006

CH_4		N_2O	
Emission source	Emission (Gg)	Emission source	Emission (Gg)
Enteric fermentation	425.1	Soils	30
Animal manure	111.7	Animal manure	34
Crop residue burning	0.0	Crop residue burning	0
Total from agriculture	536.8	Total from agriculture	64

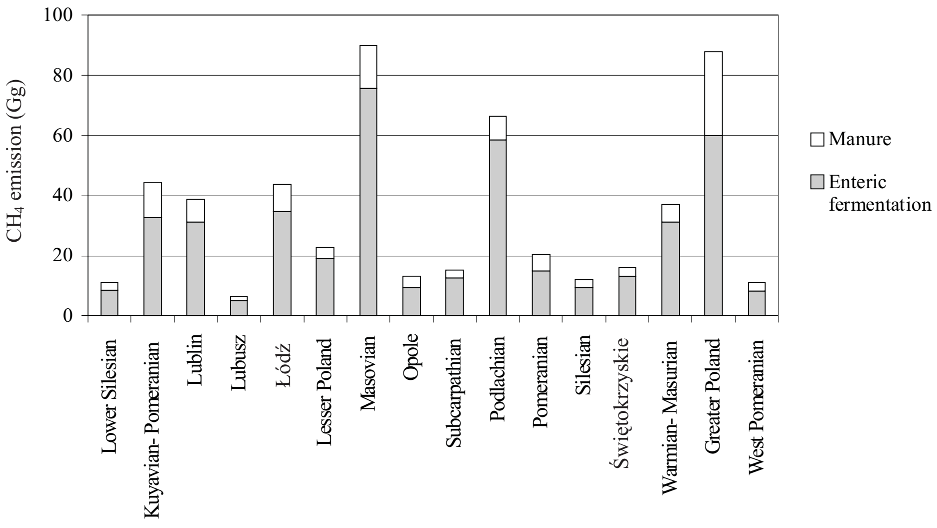

Fig. 1. Methane emission from agriculture in 2006 broken into manure and enteric fermentation.

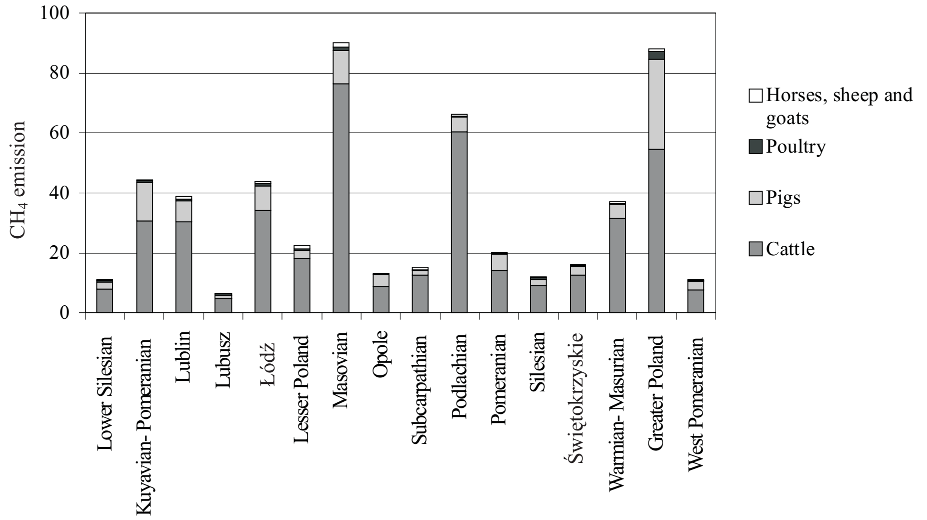

Fig. 2. Methane emission (Gg) from agriculture in 2006 broken into animal species.

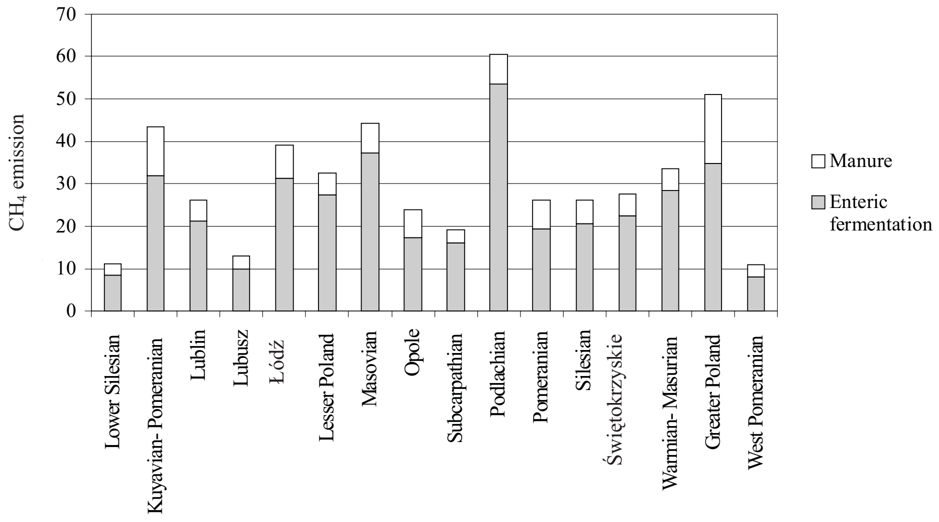

Fig. 3. Methane emission (Gg mln ha^{-1}) from agriculture in 2006 broken into manure and enteric fermentation.

the cattle stock in the territorial units, since pigs produce methane primarily in manure (compare Fig. 2). In Fig. 2 the methane emission results (Gg) broken into animal species are presented. It follows that the principal source of the emission is the cattle stock (enteric fermentation), the pig stock being the next one (manure). In Fig. 3 the unitary methane emission (Gg mln ha^{-1}) broken into enteric fermentation and manure is presented. The unitary emission distribution in the voivodeships differs from the distribution as shown in Fig. 1 due to the fact that the correlation between the agricultural area and the intensity of animal production is relatively weak (more intensive animal production may occur in voivodeships with smaller area). As shown in Fig. 1, the smallest methane emission is in the Lubusz voivodeship (7 Gg) and the biggest in the Masovian (90 Gg), but when expressed in Gg mln ha^{-1}, as in Fig. 3, the smallest emission is in the West Pomeranian voivodeship (11 Gg mln ha^{-1}) and the biggest in the Podlachian (61 Gg mln ha^{-1}).

Figures 4-7 show nitrous oxide emissions in different schemes. From Figs 4 and 5 it follows that the distribution of the total nitrous oxide emission in the voivodeships in Gg differs significantly from the unitary emission, expressed in Gg (mln ha)$^{-1}$. The biggest variation, when these figures are compared, can be observed in the Silesian voivodeship (the absolute value of emission is two times bigger) and the Masovian voivodeship (the absolute value of emission, conversely, is two times smaller). These differences result of

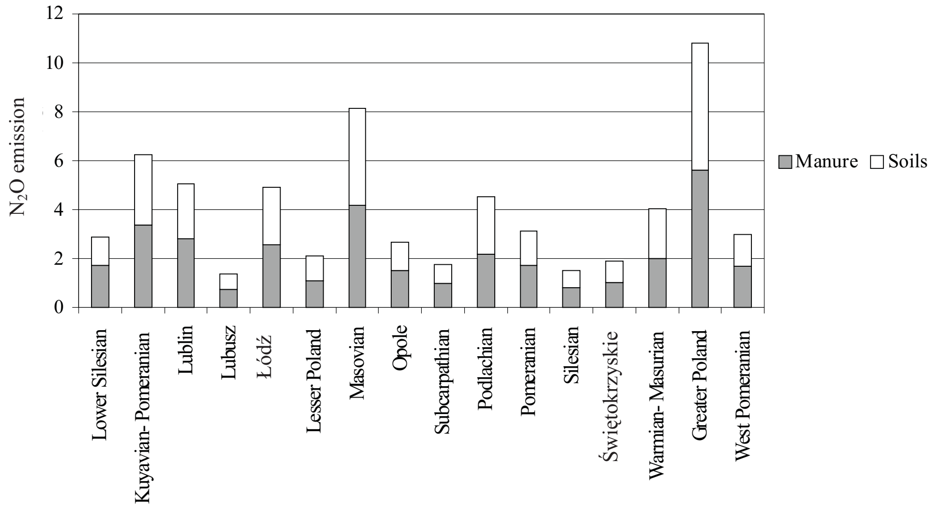

Fig. 4. Nitrous oxide emission (Gg) from agriculture in 2006 broken into manure and soils.

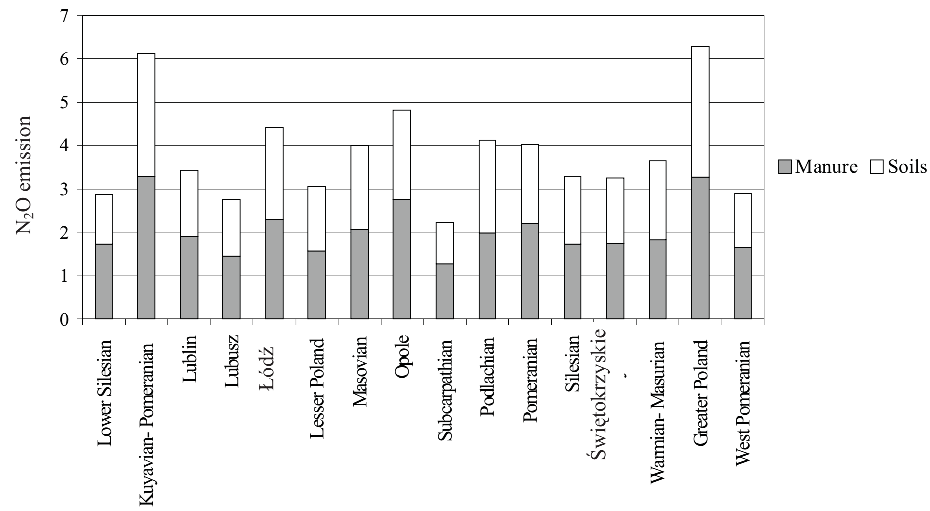

Fig. 5. Nitrous oxide emission (Gg mln ha^{-1}) from agriculture in 2006 broken into manure and soils.

course from differences in the area. In Fig. 6 the nitrous oxide emission is broken into animal and plant production. Taken as a total, the lowest emission of 1.4 Gg was in the Lubusz voivodeship and the highest – of 10.8 Gg – in the Greater Poland voivodeship. These differences can be explained by dissimilarities in the area (the area proportion Lubusz/ Greater Poland is ca. 1:3.5), but also by different animal production intensity. If expressed in Gg (mln ha)$^{-1}$, as in Fig. 7, the Lubusz/Greater Poland proportion of emission values from plant production is very close to 1:1.5. This fact can be explained by more intensive plant production in the Greater Poland voivodeship (higher consumption of nitrogenous fertilizers and higher biomass production). The respective proportion of emission values from animal production for theses two voivodeships is 1:4 (Fig. 7).

In Figs 6-7 the nitrous oxide emission is broken into animal and plant production and shown in Gg (Fig. 6) and in Gg (mln ha)$^{-1}$ (Fig. 7). The share of these two sources of emission varies in the voivodeships. The differences are caused by dissimilar total emission values and different emission levels from plant and animal production. For instance, in the Lower Silesian voivodeship the share of the emission from plant production is 61% and in the Podlachian voivodeship only 23%. The emission from animal production in the case of the Lower Silesian voivodeship is 0.7 Gg in comparison with

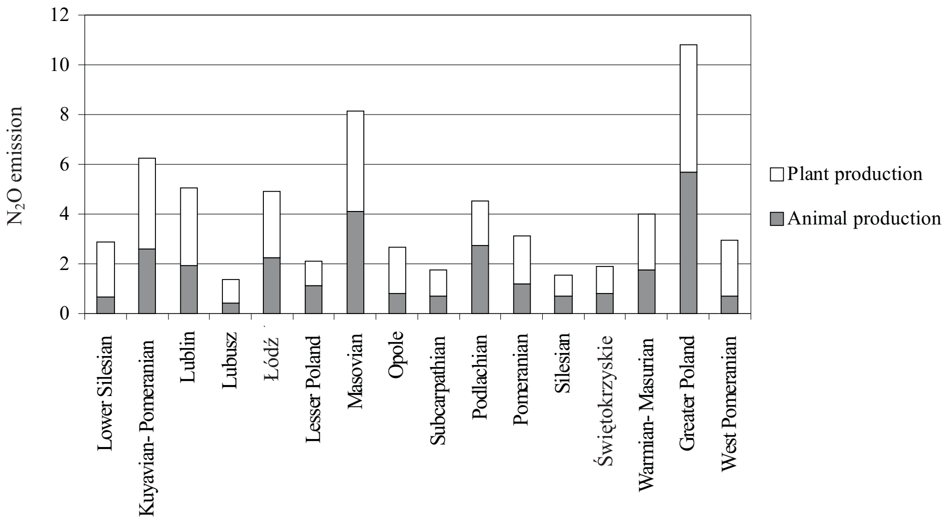

Fig. 6. Nitrous oxide emission (Gg) from agriculture in 2006 broken into plant and animal production.

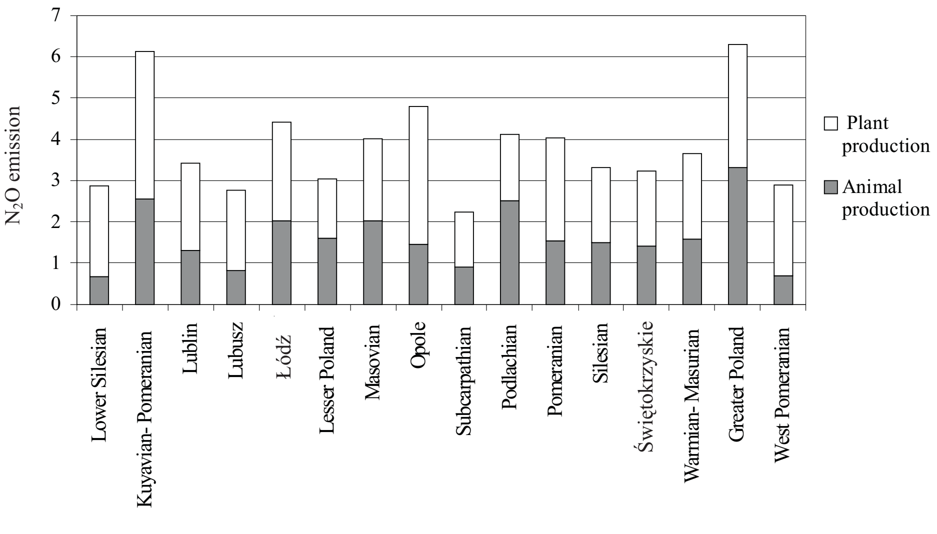

Fig. 7. Nitrous oxide emission (Gg mln ha^{-1}) from agriculture in 2006 broken into plant and animal production.

2.5 Gg for the Podlachian voivodeship, and for plant production it is 2.2 and 1.8 Gg, respectively. The species most responsible for nitrous oxide emission are cattle, swine and poultry. The emission from plant production differs in the voivodeships due to different consumption rates of mineral nitrogenous fertilizers on the one hand, and different area under crops on the other. In the case of the Lower Silesian and the Podlachian voivodeships the main reason for dissimilarities is crop area variation, as the nitrogenous fertilizer consumption rates are similar (55 and 48 kg ha^{-1}, respectively). However, the picture is different if *eg* the Kuyavian-Pomeranian and the Subcarpathian voivodeships are considered, where the nitrogenous fertilizer consumption rates differ significantly (100 and 31 kg ha^{-1}, respectively).

CONCLUSIONS

1.The main part of methane emission (on average 79%) originated from enteric fermentation. There were differences between the voivodeships in this regard, from the minimum of 68% in the Greater Poland voivodeship to the maximum of 89% in the Podlachian voivodeship. The differences result mainly from dissimilar proportions of the pig stock to the cattle stock in the voivodeships.

2. The share of nitrous oxide emission from animal production in the total nitrous oxide emission in the voivodeships varied from only 23% in the Podlachian voivodeship to as much as 61% in the Lower Silesian voivodeship. The

differences are caused by dissimilar total emission values and different emission levels from plant and animal production. The species most responsible for the nitrous oxide emission are cattle, swine and poultry.

3. The emission from plant production differs in the voivodeships due to varying consumption rates of mineral nitrogenous fertilizers on the one hand, and varying crop assortment and area on the other. The responsibility of these two causes is different in different voivodeships.

4. It should be stated that, since the tire-1 IPCC methodology does not take into account the age differences of animals and also the crops taken into consideration represent only 90% of the total arable area, most probably the results presented tend to be higher than in reality. The new methodology procedures introduced by IPCC in 2007 will perhaps yield more exact results but, because of more detailed data requirements and labour consuming calculations (a significant obstacle when estimation has to be repeated a number of times for numerous territorial units), that methodology was not considered in the present work.

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