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«BAD EMISSIONS» OF NITROUS OXIDE FROM AGRICULTURAL FIELDS IN PERSPECTIVE OF CLIMATE CHANGE

Keywords: agriculture, greenhouse gases, modeling

Nitrous oxide (N_2O) is a potent greenhouse gas (GHG). Nitrous oxide affects the radiation balance of the earth and contributes to ozone depletion in stratosphere.

Nitrous oxide, together with some more unstable oxides of nitrogen, is producing mostly in the soils under agricultural use. The production of nitrous oxide in the soil is influenced by microbiological, chemical and physical soil processes. These processes are connected to the soil carbon (C) and nitrogen (N) cycles. Nitrification and denitrification are generally believed to be microbiological sources for nitrous oxide production in the soil; in neutral and acidic soils chemo-denitrification could be additional source. After a physical redistribution of produced nitrous oxide between water and air phases within the soil pore space, gaseous nitrous oxide is emitted into the atmosphere or transported as dissolved nitrous oxide via groundwater.

The emitted from the agricultural fields nitrous oxide contributes to «bad emissions» in perspective of climate change.

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The «bad emissions» of GHG

Climate change caused by anthropogenic (man-made) emissions of GHG is one on the greatest global environmental threats. Agriculture in Russian Federation as well contributes to the emissions of GHG, in particular carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

Greenhouse gases (GHG) are gaseous components of the atmosphere that contribute to the greenhouse effect. According to the global warming hypothesis, GHG from industry and agriculture are partly or wholly to blame for recent global warming.

Warming capability of the different greenhouse gases can be compared with so called global warming potential (GWP), defined as 1 for carbon dioxide. Nitrous oxide is the most important greenhouse gas from agriculture; it has a global warming potential (GWP), which is 310 greater than that of carbon dioxide. For methane GWP is 21 greater than that of carbon dioxide.

Carbon dioxide is the subject of the proposed Kyoto Protocol. Methane and nitrous oxide are also taken into account in the international agreements.

The international agreements

The emissions of GHG are regulated by the Kyoto Protocol under UNFCCC (United Nations Framework Convention for Climate Change). Russian Federation has ratified the Kyoto Protocol on global climate change in October 2004 clearing the way for the treaty to become international law in early 2005. It is happened after ratification of the Kyoto Protocol of European Union in May 2002. As the international response to climate change the Convention's ultimate objective is to prevent «dangerous anthropogenic (man-made) interference with the climate system». The developed countries commit themselves to reducing their collective emissions of GHG by at least 5% (Russian Federation has only to stabilize the own emissions). The GHG gases are to be combined in a «basket», with reductions in individual gases translated into «carbon dioxide equivalents» (GWP) that are then added up to produce a single figure. Each country's emissions target must be achieved by the period 2008–2012. It will be calculated against a base year of 1990. Actual emission reductions will be much larger than 5%.

Countries will have a certain degree of flexibility in how they make and measure their emissions reductions. In particular, an international «emissions trading» regime will be established allowing industrialized countries to buy and sell emissions credits amongst themselves. They will also be able to acquire «emission reduction units» by financing certain kinds of projects in other developed countries through a mechanism known as Joint Implementation. In addition, a «Clean Development Mechanism» for promoting sustainable development will enable industrialized countries to finance emissions-reduction projects in developing countries and receive credit for doing so. They will pursue emissions cuts in a wide range of economic sectors. The Protocol encourages governments to cooperate with one another, improve energy efficiency, reform the energy and transportation sectors, promote renewable forms of energy, phase out inappropriate fiscal measures and market imperfections, limit methane emissions from waste management and energy systems, and protect forests and other carbon «sinks».

The Protocol will advance the implementation of existing commitments by all countries. Under the Convention, both developed and developing countries agree to take measures to limit emissions and promote adaptation to future climate change impacts; submit information on their national climate change programmes and inventories; promote technology transfer; cooperate on scientific and technical research; and promote public awareness, education, and training. The Protocol also reiterates the need to provide «new and additional» financial resources to meet the «agreed full costs» incurred by developing countries in carrying out these commitments. The new agreement will be periodically reviewed.

The calculations

Nations under UNFCCC have to perform inventories of GHG, including nitrous oxide, using the Intergovernmental Panel on Climate Change (IPCC) methodology. Based on experimental data from UK and USA, a N_2O emission factor of 1.25% of nitrogen input was estimated, and this emission factor is presently recommended by IPCC. Nevertheless, nations under UNFCCC are allowed to use locally adapted emission factors, provided sufficient documentation exists.

Method of modelling is widely used for data upscaling procedure during local adaptation of IPCC methodology. Firstly, expensive and seldom usually hourly measurements of nitrous oxide emission in the field have to be upscaled on the daily, periodical and even annual basis. Secondly, the data from a few fields have to be upscaled to the whole region or even for the state. For that purpose static models are commonly in use, often using statistics. At higher levels of upscaling the data from Geographical Information Systems (GIS) are in use. It is also known a number of simulation studies of nitrous oxide production and transport through the soil profile. Most usefull are the HIP (Holes-In-the-Pipe) conception and the DNDC model for upscaling. In HIP conception emissions are looses through the «holes» from the permanent flux of nitrogen through the «pipe» (formalized nitrification/denitrification); the size of the «hole» is determined by the functions of soil-ecological factors (soil temperature, water content etc.).

An exercise for GHG field emissions modelling

Grasslands may constitute an important source for nitrous oxide emissions. This is a result of both the high rates of fertiliser applied in grasslands and because the animals during grazing deposit urine and faeces that adds to the available nitrogen. The objective of an exercise was to extend the FASSET model with an algorithm for estimating N_2O emissions from agricultural field, and to evaluate the effects of variation in management, soils and climate for N_2O emissions from grasslands.

The FASSET whole-farm model includes all major N-flows at the farm level including a detailed dynamic simulation of the soil-plant-climate system at the field level. This makes the model suitable for evaluating environmental consequences of changes in farm management.

The models estimates of nitrous oxide emissions have been compared with measurements from grasslands in Denmark, Finland and England. The model explained up to 89 percent of the variation in measured annual nitrous oxide emissions.

The emissions of nitrous oxide increase after each fertilisation event. The increase is greatest in mid-summer, where the soil temperature is high and the grass growth may be limited by water shortages. The large recycling of nitrogen in the grazed system leads to a considerably higher level of nitrous oxide emissions. This higher level of nitrous oxide emissions is evident even during spring before the grazing starts, which is a residual effect from the grazing during the previous year.

The model estimates showed considerably higher nitrous oxide emissions from loamy soils compared with a sandy soil. The soil aeration is generally better on the sandy soils and this reduces the risk of nitrous oxide emissions, because conditions for denitrification are more rarely present. The nitrous oxide emissions increased with increasing nitrogen fertilisation. The rate of increase was greater at higher fertilisation rates. This was primarily an effect of a larger addition of mineral nitrogen to the soil at higher nitrogen fertilisation. The increase in nitrous oxide emissions at higher fertiliser rates was particularly large for the loamy soils and under grazing. The large effect of grazing on nitrous oxide emissions shows the importance of ensuring a proper regulation of the protein intake by the grazing animals. A high protein intake will increase the nitrogen excretion in urine and faeces and thus increase not only the emissions of nitrous oxide, but also the losses through ammonia volatilisation and nitrate leaching.

National aspect

Ratification of the Kyoto Protocol by Russian Federation supposes to help transfer just a paper works into reality. Decision of the ratification was made taking into account national interests: this is an indication that the decision makes good sense for business, environment and for the people. It is important now to present and discuss specific projects aimed to decrease greenhouse gas emissions, which could be implemented soon to have long time term effect. The business should not beware the Kyoto Protocol, on the contrary it is ready to share the benefits using the mechanisms established by the treaty. The «carbon investment» projects and business ideas that should help to mitigate the industrial activity impact on the world climate could perfectly illustrate both economic and environmental interests of Russian Federation. The Kyoto Protocol provides ground for GHG emissions trade and realization of joint implementation projects. Now it is time to discuss emissions market and additional investments.

Ratification of the Kyoto Protocol by Russian Federation commits now only to stabilization and latter to reduction in the national emissions of GHG in the future. The focus on emission reduction measures in agriculture has so far been on the reduction of nitrogen fertiliser use. In the national emissions inventory, nitrous oxide emissions from fertiliser use are estimated as const. (1.25) percent of the applied amount of nitrogen. The model results presented here for North European countries show that this is a much too simple approach for estimation of the actual emissions. There are large differences between soil types in the emissions, and the proportion of fertiliser nitrogen emitted as nitrous oxide is smaller at lower nitrogen rates. The non- linear response of nitrous oxide emissions to nitrogen input may make, for example, organic farming an interesting option for reducing greenhouse gas emissions, because the nitrogen input is lower in organic farming. Agricultural management such as reduction of soil tillage operations intensity and increasing of N use efficiency by crops in crop rotations, which are able to synchronized C and N cycles, could also bring some benefits for reduction of GHG from agricultural fields. There is, however, need for further studies to document this. Additionally, there is an expectation of domestic specifics connected to adaptation of IPCC methodology in a range of socio- environmental conditions in different regions of Russian Federation.