NITROGEN FERTILIZER USE EFFICIENCY AND GHG EMISSIONS IN THE LATVIAN GRAIN SECTOR

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Abstract. The agricultural sector has shown a stable and steady growth in Latvia, and the year 2015 was the most successful for Latvian grain growers. The largest grain harvest was collected that year. Nitrogen (N), phosphorous (P) and potassium (K) fertilizers are an essential factor that determines the quantity and quality of the crops harvested. However, over-fertilization can lead to negative economic and environmental consequences such as high production costs, depletion of energy resources and increased greenhouse gas (GHG) emissions. Emissions from agricultural soils contributed to the major share of the total emissions from the sector – 53.7 %. N (pure nitrogen content) fertilizer application management is essential in improving the mentioned indicators. Traditionally, N fertilizers have been applied uniformly across the entire field while ignoring inherent spatial variation in the crop N needs within the crop fields. This results in either too little or too much application of N in various parts of the fields. Too little N reduces the yields, while too much N reduces the nitrogen use efficiency (NUE). The aim of the research study is to examine the opportunities to reduce direct N_2O emissions from N (nitrogen content) fertiliser application in crop farming using the constant and variable N fertiliser spreading technologies. In the present research study, the authors have carried out an N fertilizer efficiency assessment to understand the evolution of cereal production in Latvia by using precision farming experimental data. Suitable qualitative and quantitative research methods were applied in the research. The research found that the use of the variable N fertiliser spreading technology led to a decrease in the consumption of N (pure nitrogen) fertilisers, as the average fertiliser application rate in the case of variable fertiliser spreading decreased by 10 $kg \cdot ha^{-1}$, which, in its turn, reduced CO_2 emissions by 46.8 $kg \cdot ha^{-1}$.

Keywords: fertilisers, emissions, precision farming, Latvia.

Introduction

To foster the economic development of rural areas in Latvia, increasing the utilised agricultural area (UAA) up to 2 million ha has been set as one of the key targets in the Rural Development Programme of Latvia 2020. According to the Rural Support Service, in the period 2010-2015 the area declared for the support payment scheme increased by 6 %, reaching an area of 1.67 million ha UAA. It indicates that the UAA in which agricultural activity is performed increases. However, Latvia has joined the countries that made commitments to reduce the effect of agricultural intensification on climate change. Every year a national inventory report (NIR) on total greenhouse gas (GHG) emissions is produced and submitted to the Intergovernmental Panel on Climate Change (IPCC) to follow the reaching of the targets [1]. At present, it is forecasted that an increase in agricultural production will contribute to GHG emissions from agriculture [2]. *Direct and indirect* N_2O emissions from soils exploited by the crop sector are calculated based on the IPCC guidelines. The key direct emission sources are as follows: synthetic N fertilisers (nitrogen content), organic N fertiliser (for example, manure, compost, sewage sludge), N excreted by animals at pasture, N accumulated in crop residues and integrated into soil in the field (green manure, crop residues etc.) and used organic soils. According to Latvia's NIR, the UAA contributed to 85.4 % of the total N_2O emissions in 2013. Organic soils and N fertilisers contributed to 44.7 % and 30.9 %, respectively, of the total direct N_2O emissions. Direct N_2O emissions from application of N fertilisers rose by 25 % to 1.1 $Gg \cdot year^{-1}$ in the period 2009-2013. Application of N fertilisers is essential to provide high crop yields. Trends in agricultural output in Latvia allow forecasting that the application of N fertilisers will increase in the future, too, which unfortunately makes negative external effects. These are emissions in the form of N_2O that is produced in the nitrification process releasing NO_2. The present research analyses the opportunities to reduce direct N_2O emissions from application of N fertilisers in agriculture, as the impact of N_2O emissions on the greenhouse effect are 298 times greater than that of CO_2. The effectiveness of N absorption by crops is associated with significant additional factors than can be controlled. According to research studies, crops absorb 30-50 % of the amount of N fertilisers spread in the field [3]. In Latvia too, under the guidance of A. Ruza, experiments have been conducted on N application rates for cereals. The findings allow concluding that higher N application rates reduce the effectiveness of N absorption by crops [4]. The amount of nitrogen unabsorbed by crops is a direct economic loss for farmers and a significant source of direct emissions. The research calculated nitrogen use efficiency (NUE) based on an approbated methodology [5]. The research *aim* is to examine the opportunities to reduce direct N_2O emissions from N fertiliser application in crop farming using the constant and variable N fertiliser spreading technologies. The research employed experimental precision farming field data on the application of N fertilisers for winter wheat, data of the Central Statistical Bureau of Latvia on N-fertilised areas under field crops and Latvia's national inventory reports on GHG emissions.

Materials and methods

The calculation of nitrogen use efficiency for winter wheat employed data of a field experiment carried out in Zemgale, and the field location coordinates were as follows: latitude 56.42278147 and longitude 23.61160522. The experiment involved precision farming technologies using the GPS and the GIS. An N-tester was used to monitor the content of nitrogen. The total field area was 93.7 ha. For the purpose of spreading N fertilisers in maintenance fertilisation operations for winter wheat, the field was divided into nine zones, and permanent wheel tracks were created for constant and variable N fertilise spreading. In the previous years, based on soil agrochemical tests, an adequate P and K background was created to provide optimum N absorption by crops during the vegetation period. Basic data on crop fertilisation and harvest were processed using the software EXAgT GbR "Büro für präzise Agronomie". Direct N_2O emissions from application of synthetic N fertilisers in crop farming were calculated based on the 2006 IPCC Guidelines, using the Tier 1 method, by the equation:

$$N_2O_{SNDirect} - N = [N_2O - N_{Ninput}] = F_{SN} * EF \tag{1}$$

where $N_2O_{SN\ Direct}–N$ – direct emissions from the application of N fertilisers in crop farming, kg N_2O–N·year^{-1}
F_{SN} – amount of N fertilisers (nitrogen content) applied in crop farming, kg per year;
EF – N_2O emission factor for N fertilisers applied, kg N_2O–N·(kg N·applied)$^{-1}$.

The estimated N_2O–N emissions from application of N fertilisers, according to the 2006 IPCC Guidelines, have to be converted into N_2O emissions by the following equation:

$$N_2O = N_2O - N \cdot 44/28. \tag{2}$$

The index NUE gives the ratio of output N to input N indicating how well the given N-management strategy performs in recovering the applied N. The national and regional NUE values may reflect the particular mix of farming systems within those areas. NUE is calculated using equation 3 [6].

$$NUE = \frac{N_o}{Ni} \cdot 100, \tag{3}$$

where N_o – total N removed in crops, kg;
N_i – fertilizer N applied to crops, kg.

Results and discussion

N, P and K fertilisers are the most essential factor that determines the yield and quality of crops [7]. Particularly N application rates contribute to adequate level yields. The application of N fertilisers is regulated in Latvia by the Cabinet Regulation No.834 (Annex 3) [8], which stipulates maximum nitrogen rates for crops, depending on the planned yield level. The research employed the data of the Central Statistical Bureau of Latvia on the UAA and applied N fertilisers in Latvia. The data on application of N fertilisers for selected crops are summarised in Table 1.

In the period 2009-2014, the application of N fertilisers for cereals increased the fastest, reaching 57.9 thou. t a year. In the same period, the area cropped with cereals, in the production of which N fertilisers are used, increased from 394.3 thou. ha to 511.7 thou. ha. The distribution of the fertilised area under crops for 2014 is presented in Fig. 1.

Table 1

Amount of applied N fertilisers in Latvia by crop in 2009-2014 (thou. t, converted into 100 % crop nutrients)

Crop	2009	2010	2011	2012	2013	2014	Change from base year, %
Cereals	37.9	41.5	41.7	46.6	49.1	57.9	+53
Potatoes	0.9	0.7	0.9	0.8	0.8	0.8	-
Industrial crops (rapeseed)	8.2	12.4	12.4	12.7	15.1	10.5	+28
Open field vegetables	0.4	0.3	0.4	0.3	0.3	0.3	-
Feed and green forage crops	4.5	3.9	4.0	4.5	4.0	3.1	-32
Total	51.9	58.8	59.4	64.9	69.3	72.6	+40

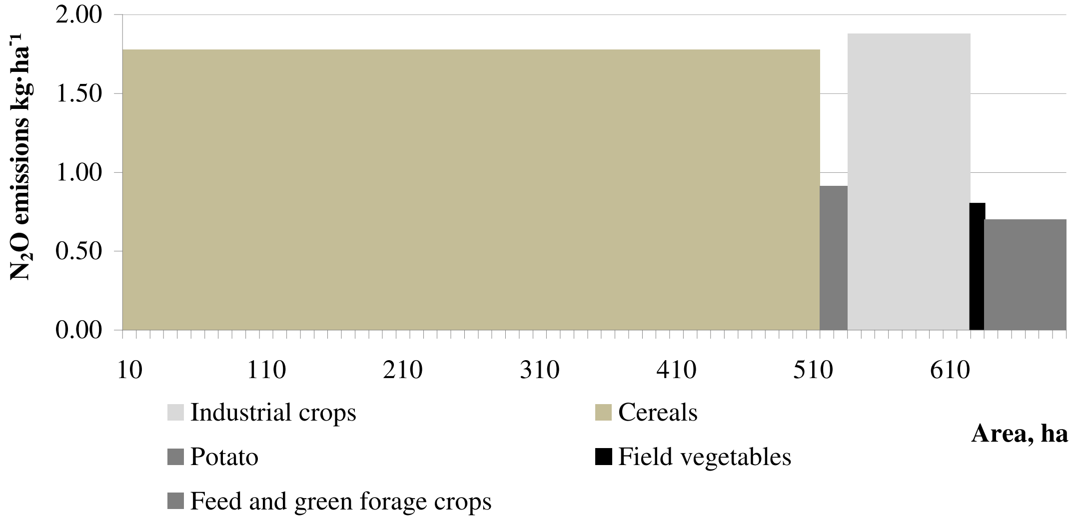

Fig. 1. **N-fertilised area under field crops (thou. ha) and direct N_2O emissions (t CO_2 eq) per ha in Latvia in 2014**

The crop industry develops through intensifying the exploitation of the UAA for cereals in particular. Greater direct N_2O emissions per ha are specific to industrial crops; yet, cereals make the greatest effect on total emissions, as the cereals account for 74 % of the total cropped area. Precision fertiliser application is important for improving the indicators of cereal production intensification. It may be defined as “a set of concerted activities related to N application in agriculture to reach economic, agronomic and environmental/ecological targets” [9]. The basic idea of precision N fertiliser application is to identify the necessary fertiliser rate for every part of the field as much objectively as possible. It means that average soil fertility qualitative characteristics for a field are not used; in contrast, the characteristics are identified for as small part of the field as possible. The key advantages are as follows: 1) increase in crop output is provided through variable fertiliser application rates; 2) financial savings due to less application of fertilisers in field parts with sufficient crop nutrients and due to no application of fertilisers during the period when no photosynthesis process takes place in crops; 3) economic gains – higher profit margins; 4) environmental/ecological gains – field parts with sufficient crop nutrients are not over-fertilised and no N_2O emissions are produced from the amount of fertiliser that the crops are not able to absorb. The variable rate fertiliser application technology involves two stages. At Stage 1, basic agrochemical characteristics of a soil are acquired, which provide insight into the soil fertility. In Latvia, soil agrochemical research or soil analysis (Table 2) is voluntary (except for those agricultural lands that are in nitrate vulnerable zones) and farmers do not receive any financial support. However, the dynamics of the agricultural land area, in which soil agrochemical research has been carried out over the years, has been increased.

Table 2

Dynamics of the soil agrochemical research in Latvia

Year	2010	2011	2012	2013	2014	2015	Change from base year %
Area, ha	8394	15397	27499	36630	26117	30715	+365
Farm, numbers	131	243	222	238	277	389	+296

The key characteristics are as follows: soil reaction (pH), amounts of organic substances, contents of movable phosphorous (P_2O_5) and potassium (K_2O). In addition, to decide whether a soil is appropriate for particular crops, it is advised to identify the content of secondary microelements in the soil: exchangeable magnesium (Mg) and calcium (Ca), movable sulphur (S-SO_4), boron (B), copper (CU), manganese (Mn), zinc (Zn), etc. The tests conducted showed that at a very low content of phosphorous, winter wheat yields decreased by 14 % and maize yields were 43 % lower. At a very low pH (4.5), crop losses for wheat and maize exceeded 18 %, while crop losses for rapeseed could reach 46 % [10]. According to the information provided by the State Plant Protection Service, Latvian agricultural land has a tendency to acidification of soil; agricultural land is generally poorly served by phosphorus, where one of the most important reasons for the low phosphorus content could be unbalanced fertilizer use; potassium available for plants in soils tends to get worse. It meant that nitrogen was not used efficiently. The key soil characteristics, which would provide optimum N application, were equalised for the selected field parts to carry out the experiment in the field. Stage 2 entailed crop growth monitoring to assess the need of N fertiliser for the crop. It was performed using an N-tester, and a farmer could make a decision on the timing of maintenance fertilisation and fertiliser rates based on the tester readings. During the experiment, the whole field area of 93.7 ha was divided into nine zones. Based on the N monitoring results, the farmer applied constant N fertiliser rates to five zones. The N sensor, which analysed the need of plants for N fertiliser and varied the selected rate, was exploited for the remaining four zones.

The data obtained in the field experiment are summarised in Fig. 2.

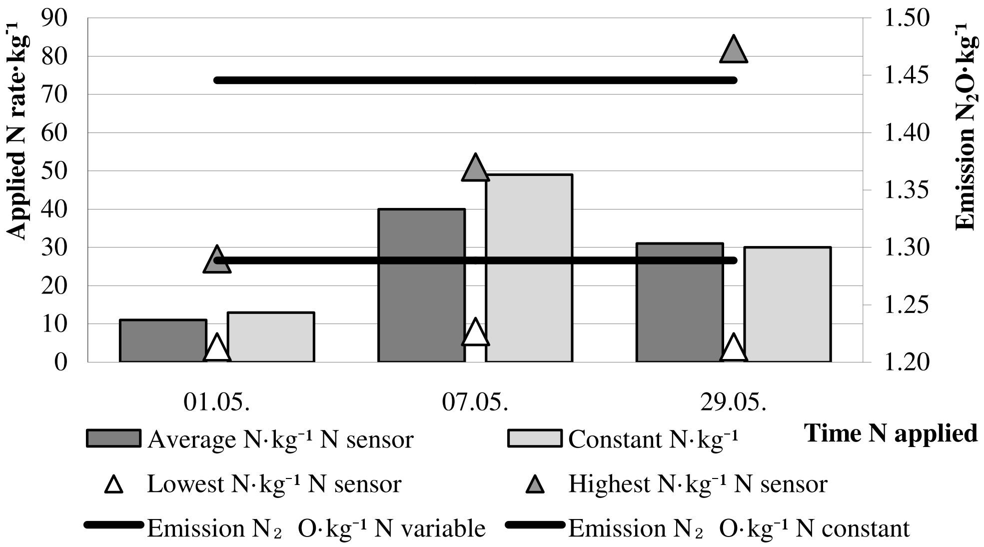

Fig. 2. **Constant and variable N fertiliser spreading (kg) and N_2O emissions from it in Latvia in 2014**

The research studies available in literature do not always specify that the variable rate N fertiliser application technology reduces the consumption of nitrogen. The key gain is an increase in the crop yield [11]. The main experimental results are summarised in Table 3.

Table 3

Comparison of N application indicators between constant and variable fertiliser spreading in Latvia in 2014

N application indicator	Constant N spreading	Variable N spreading	Change c/v (+/-) %
Winter wheat yield, $t \cdot ha^{-1}$	6.16	6.23	+1
N fertiliser application rate (nitrogen content), $kg \cdot ha^{-1} . yr^{-1}$	154.3	144.3	-8
CO_2 emissions from N application (N_2O eq.), $kg \cdot ha^{-1} \cdot yr^{-1}$	722.56	675.73	-6
NUE rate, %	95	103	+8
CO_2 emissions per agricultural output unit, $kg \cdot t^{-1}$	117.30	108.46	-7

The findings of the research studies conducted in Latvia show that a very significant improvement in N application indicators can be achieved by a farmer if applying the N monitoring method, and, based on the data, the farmer can choose the necessary N application rate and the timing of fertilisation. The research results show that variable N fertiliser spreading leads to N fertiliser savings as well. However, the situation analysis in Latvia shows that over the past six years only for 10 % of agricultural land soil agrochemical research has been made. It is an essential requirement for N fertiliser precision technology implementation. In the case of variable N fertiliser spreading, the average N fertiliser application rate decreased by 10 $kg \cdot ha^{-1}$. The N fertiliser application rates were calculated to achieve the research aim. The calculations took into account the corrective N fertiliser rate of 62.3 $kg \cdot ha^{-1}$ applied when sowing winter wheat. The overall results of the field experiment indicate that farmers make direct economic gains from savings on N fertilisers and from higher yield per ha UAA. Indirect gains from applying such a technology are considerable, as the technology reduced emissions from agricultural production. The field experiment was repeated in 2015 to verify the accuracy of the data.

Conclusions

1. In the period 2009-2014, the consumption of N fertilisers in grain production increased from 37.9 to 57.9 thou. t per year.
2. Over the period of analysis, the area under cereals, in the production of which N fertilisers are used, raised from 394.3 to 511.7 thou. ha.
3. Large part of Latvian farmers grows crops without knowing the soil agrochemical properties. Only for 10 % of agricultural land soil agrochemical research has been made. Thus, the variable rate fertiliser application technology has to be included in the list of national agricultural activities eligible for support, which would motivate farmers and contribute to maintaining the fertilization practice and nutrient balance.
4. By applying the variable rate N fertiliser application technology in the field during the experiment, the consumption of fertilisers per ha UAA decreased by 8 %.
5. In the field experiment, the fertiliser use efficiency NUE reached 103 % owing to the variable rate N fertiliser application technology.

Applying the variable rate N fertiliser application technology, the CO_2 emissions from N fertiliser application per unit of products produced $kg \cdot t^{-1}$, decreased by 7 %, compared with the constant rate N fertiliser application technology.

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