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SELECTION OF GREENHOUSE GAS EMISSION-REDUCING MEASURES WITH ANALYTICAL HIERARCHY PROCESS APPROACH: A CASE STUDY FROM LATVIAN CROP PRODUCTION SECTOR

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Abstract. The Latvian agriculture has achieved remarkable progress with regard to crop production over the past decade, which has resulted in constantly growing greenhouse gas (GHG) emissions from agriculture. Currently, the agricultural sector is the second largest source of GHG emissions, accounting for 21.5% of the total GHG emissions in the country, and the key source of GHG emissions is direct nitrous oxide emissions from soil, which are largely the result of nitrogen applied. Such trends indicate that without additional measures Latvia cannot reach its GHG emission targets set internationally. In this paper, authors aim to select measures that have potential to reduce the GHG emissions from the Latvia's crop production sector by using Analytical Hierarchy Process (AHP) approach. Within the hierarchical structure of decision-making process, four factor groups affecting implementation of measures were evaluated: economic, social, environmental and technological factors. The study results indicated that the potential to reduce emissions from crop production sector is limited by technology as technological factors play the most important role in the process of implementation of GHG emission-reducing measures. Study results showed that reduction of direct N_2O emissions can be achieved through several alternatives from which, according to experts' rating, the most important is such GHG emission reducing measures that promote accurate management of nitrogen circulation and introduction of an organic management system.

Key words: GHG, emissions, measures, AHP, crop, sector.
JEL code: Q01, Q54

Introduction

Climate change is one of the defining challenges of the 21st century, along with the global population, poverty alleviation, environmental degradation and global security (Maslin, 2013). There is strong scientific evidence which shows that the current climate change is caused largely by the increased concentration of carbon dioxide (CO_2) in the atmosphere emitted through human activities (The National Academy of Science, 2010; EPA, 2014). It has been estimated that agricultural activities are one of the major greenhouse gas (GHG) emitters behind such sectors as transport and industrial processes (UNEMG, UNEP/GRID-Arendal, 2008). After regaining its independence, Latvia has been actively involved in reducing global climate change. However, since 2006, along with an increase in economic activity, GHG emissions from Latvia's agricultural sector have tended to increase; besides, the agricultural sector is the second largest source of GHG emissions, in 2014 accounting for 21.5% of the total GHG emissions in the country (Latvia's National Inventory Submission, 2015). Such changes in GHG emissions from agriculture in Latvia indicate that without additional measures Latvia cannot reach its GHG emission targets set internationally as one of the EU strategic goals is to introduce low carbon farming in practice.

In order to identify appropriate GHG emission-reducing measures to be introduced in Latvia's agriculture, it is important to determine the key sources of GHG emissions from agriculture in Latvia. According to Latvia's National GHG emissions Inventory Report (Latvia's National Inventory Submission, 2015), one of the main sources of GHG emissions from the agricultural sector are nitrous oxide (N_2O) emissions from soil - in 2014, it comprised 53.6% of the total agricultural emissions. One of the key sources of N_2O emissions are application of nitrogen (N) fertilisers that in 2014 comprised 24% of the total N_2O emissions. The use of N is essential in the production of crops, however during the period 2005-2014 the direct N_2O emissions from

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N fertilisers has risen by 8%, and agricultural production trends in Latvia allow forecasting that the use of N fertilisers is going to increase in the future too, which unfortunately creates negative external effects, i.e. N_2O emissions.

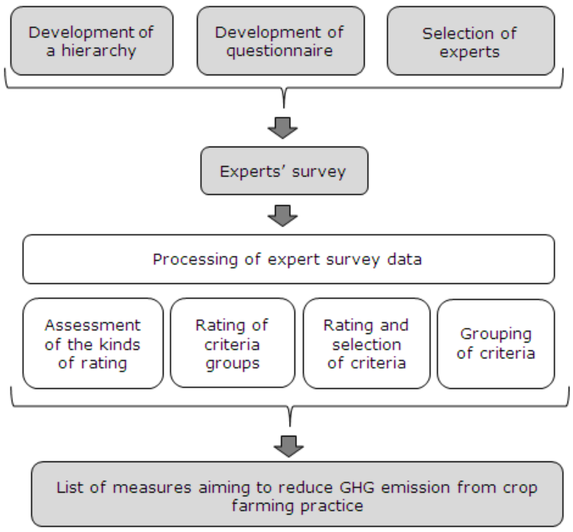
Such situation analysis sets aim for this study - to select measures that have potential to reduce the GHG emissions from the Latvia's crop production sector by using Analytical Hierarchy Process (AHP) approach. To achieve the aim, two specific research tasks were set: to develop hierarchy pyramid with appropriate levels; to assess kinds of rating regarding factors and group of GHG emission reduction measures in crop farming. There can be found several approaches used for selection of GHG emission-reducing measures; however, international research studies that employed the AHP for designing GHG emission reduction policies (Konidariand, Mavrakis, 2007) and analysing climate change adaptation measures (Choy et al., 2012; Sposito, 2006; Varela-Ortega, 2013) have proved that the AHP may be employed for similar problems researched, and it can be a useful method for academic research in selecting GHG emission reduction measures in the crop sector. To achieve the set aim of this research, the authors have used the publications and studies of foreign and Latvian scientists, legislation, reports and recommendations. The research authors widely have applied generally accepted research methods in economics, i.e. monographic descriptive method, analysis and synthesis methods, as well as multidimensional factor analysis to study the problem elements. In order to carry out multidimensional factor analysis 6 experts were involved in survey. The selection criteria for experts were as follows: 1) expertise and education (agriculture, climate change, economics, social science, technologies and natural sciences) and 2) affiliation with an institution associated with agriculture.

Research results and discussion

The main focus of this study is to employ the experience and knowledge of experts in order to comprehensively assess potential obstacles to introducing selected GHG emission reduction measures in agriculture. Data acquired in a survey of the experts were processed using AHP approach developed by American mathematician T. Saaty (1981). The AHP is a multi-criteria decision-making method for complicated problem situations and, in combination with quantitative and qualitative analyses, helps scientifically justify decisions made. The AHP is a mathematically justified method, and it allows acquiring unbiased results based on experts' subjective ratings. In view of the complicated environment, in which GHG emission reduction measures have to be introduced, by means of the AHP it is possible to:

- divide a complicated and unstructured problem into components;
- use expert knowledge and ratings to identify factors, criteria for priorities and causal associations;
- acquire scientifically justified results.

The stages of preparation and implementation of an AHP analysis in the research are shown in Figure 1



Source: author's construction

Fig. 1. **Application of the AHP to rate GHG emission reduction measures**

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The adaptation of AHP algorithms to rate GHG emission reduction measures for the crop sector in the national economy of Latvia involved the development of a hierarchy pyramid consisting of four levels:

- at Level 1 of the hierarchy, an objective was set: introduction of GHG emission reduction measures in crop farming;
- at Level 2, the experts rated economic, social, environmental and technological factors influencing the achievement of the objective;
- at Level 3, the experts determined the significance of criteria influencing each factor in relation to the objective to be achieved.

The following criteria were used to rate ***economic factors***: available support funding of the EU Common Agricultural Policy; change in the number of jobs on agricultural holdings; economic sustainability of agricultural holdings; financial possibilities of agricultural holdings and effects of GHG emission reduction measures on farm output. ***Social factors*** were rated employing the following criteria: change in the density of rural areas; cooperation among agricultural holdings; effects of social and public organisations; build-up of knowledge by owners/managers of agricultural holdings; and amounts of taxes paid by agricultural holdings to the local government. ***Environmental factors*** were rated employing the following criteria: potential reduction of GHG emissions; enhancement of soil qualitative characteristics; enhancement of water qualitative characteristics; ecological sustainability of agricultural production and the reproduction of live organisms and species. ***Technological factors*** were rated employing the following criteria: availability of new technologies; utilised agricultural area managed by the farm; professional knowledge; existing technology and the build-up of knowledge.

- At Level 4, the experts were suggested five alternatives to solve the problem. The alternatives were developed by grouping the GHG emission reduction measures by way of achieving the reduction effect.

The ***1st potential alternative*** – accurate management of nitrogen circulation, which may be achieved by: precision fertiliser application; introduction of integrated farming; direct incorporation of fertilisers into soil; application of nitrification inhibitors; fertilisation planning and soil liming. The ***2nd potential alternative*** – fixation of nitrogen, which may achieved by: increasing the area under papilionaceous plants; papilionaceous intercrops (nitrogen fixation); green manure crops sown in black fallow land; increasing the productivity of biomass crops. The ***3rd potential alternative*** – storage of carbon in soil, which may achieved by: enhancing physical and chemical properties of soil; removing a limited amount of crop residues from the field; conservation tillage and the maintenance of amelioration systems. The ***4th potential alternative*** – intensive development of organic farming. The ***5th potential alternative*** – production intensity reduction, which may achieved by: introducing permanent grasses in organic soils; establishing plantations of fast-growing tree species in agricultural areas.

Priority vectors and criteria significance coefficients were calculated by means of a calculation model developed in the MS Excel program using the Web-HIPRE (Mustajoki, Hamalainen, 2000) methodology. The application of the AHP involved the following sequential steps:

- defining the general objective to solve the problem and identifying factors influencing the achievement of the objective;
- simulating potential alternatives for the achievement of the objective and performing a pairwise analysis of the factors, criteria and

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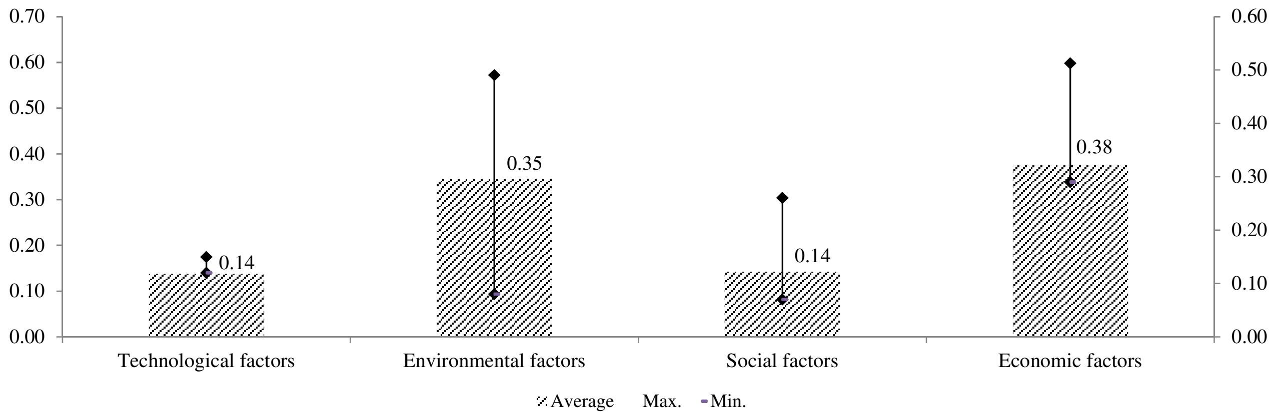
sub-criteria in relation to each criterion at the previous level of the hierarchy. The experts' judgements are expressed numerically on a 9-point scale;

- identifying priorities to acquire an overall priority for each alternative.

A relative significance coefficient was calculated for every element of the hierarchy; the coefficient shows the degree of significance or importance relative to every higher-level element (Saaty, 2006).

In the context of GHG emission reducing measures, it has been proved that the relationship between agricultural activities and GHG emissions is complex, as the level, extent and nature of agricultural activities affect the amount of GHG emissions (Mulatu et al., 2016). It has been also stated that agricultural systems must be resilient and able to adapt to change by maintaining economic, ecological and social benefits (National Sustainable Agriculture Coalition, 2009). Thus, in this study authors tried to understand which of four factor groups - economic, social, environmental or technological factors – are the most important and determine implementation of GHG emission-reducing measures at farm level. Expert ratings of the factor groups for the introduction of GHG emission-reducing measures are summarized in Figure 2.



Source: author's calculations based on experts' survey

Fig. 2. **Expert ratings of the factor groups for the introduction of GHG emission-reducing measures**

Figure 2 shows that the ratings of the environmental and economic factor groups given by the experts were relatively similar, prioritising the economic factors (0.38). However, the dispersion was quite large in respect to the environmental factors, which indicated that the experts' opinions considerably differed in terms of their significance. The highest agreement among the experts was observed for the significance of technological factors (0.14), which was indicated by the small dispersion of their ratings. It means that implementation of GHG emission reducing-measures associates with such fundamental question: *Does introduction of measure associates with availability of new technologies? Does size of utilised agricultural area managed by the farm limits introduction of measure? Does it require professional knowledge?*

In order that the author can identify which of the alternative groups of GHG emission reduction measures, based on the experts' ratings, may be considered as suitable for Latvia's crop sector, the experts' ratings were analysed according to all the selected criteria. Figure 3 reflects the experts' ratings.

As regards the alternative groups of GHG emission reduction measures, there was no high agreement among the experts in relation to the measures whose introduction was associated with production intensity reduction, the introduction of an organic management system, nitrogen fixation

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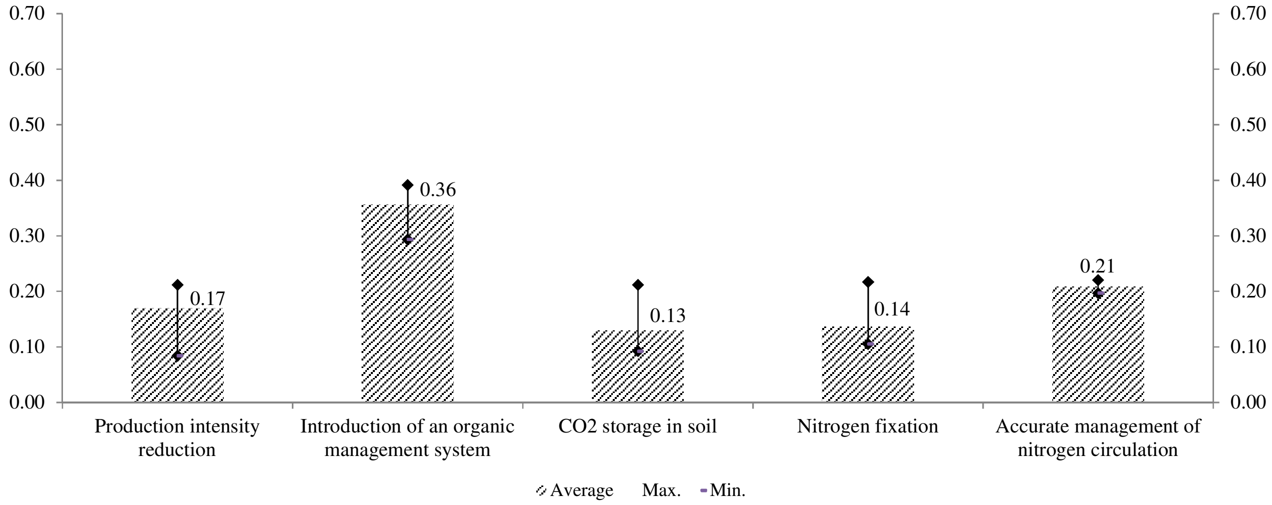
and CO_2 storage in soil. This means that the experts had diverse opinions. The lowest overall rating was given to the third group of GHG emission reduction measures – 'CO_2 storage in soil' (0.13). The second lowest overall rating was given to the measure group 'nitrogen fixation'. The experts had the highest agreement on the measure 'introduction of an organic farming system'; however, as shown by Figure 3, this measure was given the most contradictory ratings.



Source: author's calculations based on experts' survey

Fig. 3. **Expert ratings of GHG agricultural emission reduction measures according to all the criteria**

The experts had the highest agreement on the measure group 'accurate management of nitrogen circulation'. The authors would like to stress that the experts' ratings of this measure group were very similar, and one can assert that the experts were unanimous, which indicates the need to develop an effective land resource management system, including the application of fertilisers.

Figure 3 shows that the highest agreement among the experts was observed for the necessity for the accurate management of nitrogen circulation. Taking into account the current development trends of Latvian agricultural farms, authors reveal that special focus should be drawn on the following measures.

- Precision fertilizer application - a set of concerted activities that involve the use of the newest technologies (the GPS, the GIS, sensors, software, applications, specially equipped fertiliser spreaders etc.) in planning fertiliser application rates and in fertiliser spreading. The key advantages are as follows: 1) increase in crop output is provided through variable fertiliser application rates; 2) financial savings, as field areas with sufficient crop nutrients are not over-fertilised; 3) environment-friendly practices, as the fertiliser crops are not able to absorb does not produce N_2O emissions that are released into the environment. If introducing this measure, fertiliser savings can reach 15-80%.
- Direct incorporation of fertilisers in soil - the implementation of the measure is based on the introduction of specific fertiliser direct incorporation technologies on the farm, e.g. deep incorporation (15-20 cm in depth) and direct incorporation (injections at the depth of 5-8 cm). This measure is mainly suitable for the incorporation of liquid manure in both arable land and pastures.
- Application of nitrification inhibitors - nitrification inhibitors slow down the process of nitrification of fertilisers, thus reducing the

pace at which nitrates are reduced to nitrous oxide (N_2O). This, in its turn, increases the effectiveness of N absorption, as the period during which N is in absorbable condition (NH_4-N) is longer.

- Fertilisation planning - is based on the knowledge of physical and chemical properties of soil and involves performing soil tests, designing a fertilisation plan and its practical implementation as well as calculating the balance of N, which play an important role in efficient farming. The key purpose of the measure is to ensure optimum crop fertilisation, as the lack of basic elements can reduce crop growth and yields, while the unabsorbed amount of N results in economic and environmental losses, as N_2O emissions are produced.
- Liming acidic soils - most nutrients can be better absorbed by crops if soil reaction is 6.5 pH. For this reason, liming acidic soils results in more effective use of fertilisers, which increases crop yields and reduces N_2O emissions measured per unit of produce; the liming also enhances the structure of soils and the biological activity of the soils.

Conclusions, proposals, recommendations

1) Study results showed that crop sector is important player in Latvian GHG emission reducing strategy and the key focus has to be placed on such GHG emission-reducing measures that decrease direct N2O emissions from the use of N fertilisers.
2) In this study, AHP method was applied for selection of GHG emission-reducing measures where four factor groups affecting implementation of measures were evaluated: economic, social, environmental and technological factors. According to experts' ratings, technological factors play very important role in the implementation process of GHG emission-reducing measures.
3) Reduction of direct N2O emissions can be achieved through several alternatives from which, according to experts' rating, the most important is such GHG emission reducing measures that promote accurate management of nitrogen circulation and introduction of an organic management system. Such considerations let authors to reveal that special focus should be drawn on the following measures: precision fertilizer application; direct incorporation of fertilisers in soil; application of nitrification inhibitors; fertilisation planning; liming acidic soils; and introduction of an organic farming system.

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