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ORGANIC SOILS ON THE WAY TO CLIMATE NEUTRAL EUROPEAN UNION: THE EXAMPLE OF ESTONIAN AGRICULTURAL LAND

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Abstract. European Union climate policy envisages climate-neutrality by 2050 and fosters Member States to find opportunities to reduce GHG emissions. Land use is a key sector to achieve net-zero emissions. To understand how each Member State can contribute to achieving climate goals, the impact of land use change on GHG emissions should be studied at the national level. The use of organic soils for crop production has a detrimental climate impact due to the large carbon stock decrease. In Estonia, approximately a quarter of GHG emissions from agricultural soils results from cultivation of organic soils. This study aims to show the impact of a scenario that assumes part of agricultural land (AL) will be converted into forest land (FL) and green focus areas; and that AL on organic soils will be converted into grassland (GL). Furthermore, 20% of this area will be rewetted. The future scenario of AL use was created using the Shared Socio-economic Pathways methodology. IPCC Guidelines were used in assessing GHG emissions. AL use changes following this scenario would help reduce GHG emissions by 90% by 2050 compared to 2020. In case of rewetting 20% of converted organic soils, the reduction would be 82% under assumptions about Estonian conditions. It is important to convert cropland on organic soils to GL and FL in order to reduce GHG emissions. However, before designing policy measures for changing AL use, it is important to analyse the actual status of organic soils in Estonia and determine emission factors at the national level.

Key words: organic soils, GHG, agricultural land use change, future scenarios.
JEL code: Q54, Q58

Introduction

The European Union's (EU) climate policy envisages achieving climate-neutrality by 2050 through significant reduction of greenhouse gas (GHG) emissions and finding ways to achieve a net-zero emissions balance (Climate change: what …, 2023; Fit for 55, 2023). The land use, land use change and forestry (LULUCF) sector in combination with agricultural non-CO_2 GHG emissions, the so-called land sector, has the potential to become climate-neutral already by 2035. In addition to that, improved forest management, afforestation, avoided deforestation for forest lands (FL), stopping agricultural land use on organic soils and improved cropland (CL) management strategies on agricultural land (AL) have potential to cost-efficient GHG emission reductions and carbon sequestration. Additionally, the land sector can promote synergies between land-based mitigation measures and make possible more integrated policy-making and policy implementation at national and the EU level (Commission proposal on…, 2021; General approach on…, 2022). Considering this, the agricultural land (AL) and its use will play an important role in reducing GHG emissions and removing CO_2 from the atmosphere. In this case, the potential of the land sector needs more research and analysis, especially on the impact of agricultural land use (ALU) and agricultural land use change (ALUC) on GHG emissions. According to EU 2022 National Inventory Submissions (National Inventory Report and Common Reporting Format Table), crop production on organic soils has the most negative climate impact due the carbon stock decrease (European Union (Convention), 2022) and the first action on these areas should be conversion of CL to grassland (GL) or FL. Some studies showed that rewetting organic soils might also have a positive effect on reducing GHG emissions or help organic soils to become even a carbon sink (Wilson D. et al., 2016; Bianchi A. et al., 2021). In Estonia, approximately a quarter of GHG emissions from agricultural soils results from the cultivation of organic soils. In addition, the CL on organic soils causes significant carbon loss in the soil, and as a result, CL emits about 2.7 times more CO_2 than it sequestrates (in the LULUCF sector) (Estonia.

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2022 Common …, 2022). While the area of CL with organic soils has remained relatively stable since 1990, in Estonia, there conversion of GL to CL on the areas of organic soils is still taking place (Estonia. 2022 National …, 2022). In order to better understand how each Member State of the EU can contribute to the achievement of EU climate goals, it is important to study the impact of land use change (LUC) on GHG emissions at the national level. The aim of the study is to show the impact of one possible ALU scenario on the climate footprint of agriculture in Estonia. Our study addresses two main research questions, first, what could be the climate impact of CL conversion to GL on organic soils by 2050. Second, whether rewetting of GLs with drained organic soil could have a positive effect on the climate change mitigation under Estonian conditions. This paper draws on the results of the research project "Analysis of changes in agricultural land use depending on future scenarios", financed by the Estonian Environmental Research Centre.

One of the ways to study possible development trends is the creation of scenarios, which became popular as a method since the beginning of the 2000s in the design of climate and sustainability policies, and can be used to study climate and environmental problems at the global, regional and national levels, considering complex causal relationships, limited knowledge and high uncertainty (van Vuuren D. P. et al., 2012; Vervoort J. & Gupta A., 2018; Lee S. H. & Hamelin L., 2023). The future scenario of ALU was created using the methodology of Global Shared Socio-economic Pathways and European agriculture socio-economic scenarios (Shared Socio-economic Pathways for European agriculture and food system) (Riahi K. et al., 2017; Frame B. et al., 2018; Mitter H. et al., 2019) and involving Estonian experts from various fields. The modelling of the future scenario of ALU was based on the data characterizing the land parcels and the land use (LU) conditions specified by the future scenario. Each field parcel was assigned a complex evaluation score characterizing its potential for agricultural use (so called 'goodness measure'). The modelling of changes in agricultural land use was based on the following principles. First, AL with lower 'goodness measure' goes out of use or is afforested. Second, green focus areas (landscape elements) are created or land is afforested on those land parcels which have low or medium cohesion of natural landscape (Helm A. et al., 2021). Finally, ALUC does not happen in semi-natural habitats (alvars). The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines …, 2020), the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (2013 Supplement to …, 2014), the Estonian 2022 National Inventory Submissions (Estonia. 2022 Common …, 2022; Estonia. 2022 National …, 2022) were used in the assessment of GHG emission. GHG emissions were converted to CO_2 equivalent (CO_2-eq) according to the IPCC Fifth Assessment Report (Climate Change 2014: …, 2015). Given the high uncertainty of the scenarios and the partial lack of detailed data necessary for projection, only direct GHG emissions were estimated. In general, the cultivation of soils with high organic content and the related GHG emissions are considered under the agricultural sector according to the IPCC guidelines. Within the scope of this study, this emission has been taken into account in the LULUCF sector, as the logic of the calculations are better suited to the sector. In the scenario, due to the lack of specific emission factors in Estonia, it was assumed that green focus areas, semi-natural habitats, and unused agricultural land belong to the category of GL. In addition, it was considered that 100% of the GL and 18% of the semi-natural habitats located on the organic soils have been drained. Specific GHG emission factors related to ALU and ALUC were taken from the 2022 Estonian National Inventory Report as averages for the period 2016-2020, to take into account the dynamics of changes in the last five years.

Research results and discussion

1. Scenario 'Less is more'

The scenario 'Less is more', which is one of the five scenarios developed in the above-mentioned project, assumes the orientation of Estonian agriculture on the domestic market and the agricultural policy on the environmental protection. The preservation of the natural and living environment will be considered more important than the growth in agricultural output and food exports, and agricultural production becomes more extensive. A significant structural change of farmers will take place by 2050. Two-thirds of large-scale farmers will stop farming, half of their agricultural land will be converted into green focus areas, and the remaining half will be used by new small-scale farmers. In the scenario, the use of fertilizers will decrease, but at the same time yield of arable crops will remain the same. The number of pigs and dairy cows, and milk yield per cow will decrease. The number of beef cattle, sheep, and goats will increase, the number of poultry will be stable.

In addition to high-quality livestock production, society will value the maintenance of permanent GLs and semi-natural habitats, and the preservation of biodiversity. In the scenario, 57,971 ha (8%) of the former agricultural land were converted to green focus areas by 2050 (Table 1).

Table 1

Agricultural land use change 2050 vs 2020

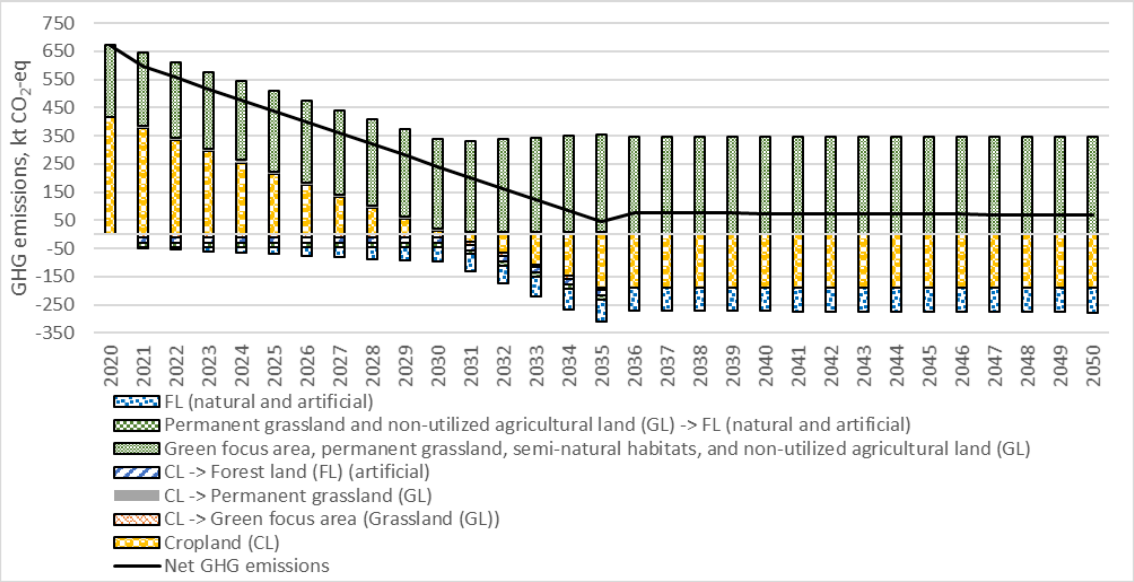
ALU	Situation in 2020, ha	Changes compared to the current situation, % or ha
Arable land	724 670	-17%
Permanent grassland	238 323	6%
Semi-natural habitats	130 307	0%
Non-utilized agricultural land	188 420	-19%
Green focus areas	0	57 971
Afforested agricultural land (natural and artificial)	0	88 603

Source: author's calculations based on the scenario narrative

To support the achievement of climate policy goals, 24,740 ha of agricultural land on deep organic soils were converted to permanent GL, and 43,605 ha of agricultural land on mineral soils were afforested (Table 1). As well as 9,999 ha of current permanent grassland and 19,999 ha of currently non-utilized agricultural land were afforested. Additionally, 15,000 ha of currently non-utilized agricultural land were converted to FL due naturally afforestation.

2. The climate impact of cropland conversion to grassland on organic soils

As of 2020, there were 24,740 ha of arable land on organic soils in Estonia. In the scenario, these were converted to permanent GL by 2035, i.e., 1,649 ha each year in the period of 2021-2035, and after that the land use remained without changes. The natural afforestation will continue until 2050 with pace of 500 ha per year. In the scenario, the impact of ALUC on the GHG net mission was mainly assessed in 2035 and 2050 compared to 2020 (Figure 1).



Source: author's calculations based on the scenario narrative

Fig. 1. **GHG emissions of ALU and ALUC in the period 2020-2050**

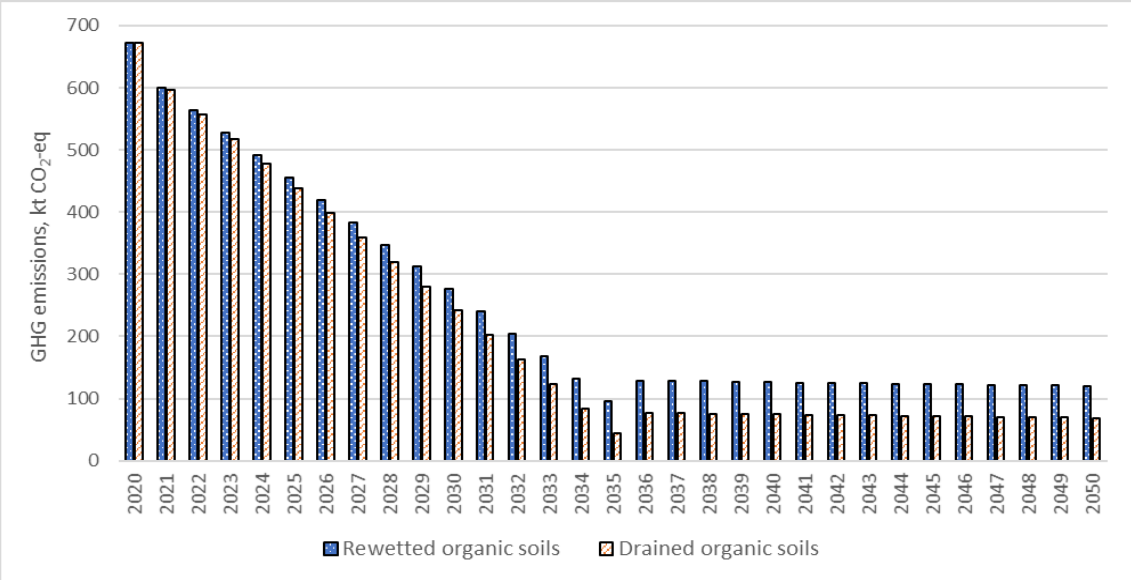
By 2035, agriculture related GHG emission in the LULUCF sector will decrease by 93.4% compared to 2020, but by 2050, with stabilized land use, the emissions will increase by 24.26 kt CO_2-eq. So, the final reduction of GHG emissions will be 90% by 2050 compared to 2020. CO_2 sequestration is particularly supported by the conversion of arable land to GL and FL and the conversion of GL to FL on mineral soils. The increase in GHG emission from 2036 is explained by the fact that the positive climate effect of ALUC will disappear. Some GHG emission reductions are supported by natural afforestation throughout the whole scenario period. According to the ALU and ALUC GHG emission estimates, it is clear that the greater positive climate effect of afforestation (land converted to FL) is manifested in Estonian conditions precisely on mineral soils. But if we compare the climate effects of GL and FL on organic soils, it is obvious that it is worth to convert CL and GL on organic soils into FL because the GHG emissions of FL per hectare on organic soils are about 2.6 times lower than in case of GL. So, the results of the study show that in order to reduce GHG emissions, it is important to convert CL on organic soils to GL, and if the growing conditions are suitable, it would be reasonable to convert GL on organic soils to FL.

3. The impact of rewetting organic soils on GHG emissions

Considering the descriptions of characteristics of organic soils in Estonia (Astover A., 2005; Kõlli R., 2016; Aasta muld 2019 …, 2019), it was assumed that agricultural production in Estonia takes place on nutrient-rich drained lowland soils. According to the 2006 IPCC guidelines (2006 IPCC Guidelines …, 2020) and the Estonian 2022 National Inventory Submissions (Estonia. 2022 Common …, 2022; Estonia. 2022 National …, 2022), 3.33 t of CO_2-eq per hectare is annually emitted from grassland on drained organic soils. In case that CL on drained organic soils is converted to GL, it could mean that the GHG emissions increase, which, according to the literature (Wilson D. et al., 2016; Bianchi A. et al., 2021), could be avoided by rewetting these GL on drained organic soils. According to the EU 2022 National Inventory Submissions (European Union (Convention), 2022), the climate impact of rewetting of organic soils has been assessed only in the United Kingdom and Ireland. Therefore, the experience of these countries was taken into account, which means that the Tier 1 method of the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (2013 Supplement to …, 2014) was applied. In the literature, the climate zone of Estonia is both boreal and temperate (Enno, S.-E., 2012; Anger-Kraavi, A. et al., 2020; Estonia. Current climate …, 2021). The calculations were made with a

temperate climate zone in mind and only for 20% of GL on organic soils. Similar to the rationale for Ireland's National Inventory Submissions and due to the lack of national data, the study considered the following "due to non-woody vegetation/organic soils bio-geochemical reactions are assumed to not occur because organic soils are re-saturated since drainage does not occur on regenerated wetlands" (Ireland. 2022 National …, 2022). Thus, the factor CO_2-$C_{composite}$ (on-site removal) was not taken into account, as was burning of rewetted organic soils due to the high uncertainty of the scenario.

In the case of rewetting of 20% of converted organic soils, the estimation shows a reduction of GHG emissions by 85.7% by 2035 (Figure 2). The difference in GHG emissions of rewetted and drained organic soils is 52 kt CO_2-eq, which means that rewetting of drained organic soils would cause more GHG emissions in Estonian conditions. By 2050, in this scenario with rewetting of organic soils, the reduction of GHG emissions would be 82%, which is significant, but is smaller compared to the drained organic soil variant.



Source: author's calculations based on the scenario narrative

Fig. 2. **GHG emissions of rewetted organic soils in the period 2020-2050**

Rewetting of GL on organic soils can have a positive climate effect but mainly in the boreal climate zone. According to the IPCC guidelines (2013 Supplement to …, 2014), the positive climate impact of rewetting depends on the CO_2-$C_{composite}$ factor, which is important to study at the national level. Considering the results of this study, rewetting of GL with drained organic soils is not a recommended climate measure for Estonia under the conditions studied and with the available data and knowledge.

Conclusions

1) Measures intended to support the EU climate policy (e.g., the creation of green focus areas, afforestation, protection of organic soils) affect both the agricultural and LULUCF sectors mainly through ALUC due to the limitation of land as a resource.

2) The ALUC taking place in the scenario had a more positive climate impact compared to the stable ALU that followed after the changes, but it is clear that a certain ALUC (for example, afforestation) cannot take place continuously and the climate impact of ALU must be taken into account.

3) From the point of view of climate, management on mineral soils is suitable for CL as well as GL and FL, but it is important to pay attention to organic soils. The study showed that it is important to convert CL on organic soils to GL, and if is possible to convert GL on organic soils to FL. In this way, it is possible to reduce GHG emissions and avoid a greater negative climate impact of ALU.

4) Rewetting of GL on drained organic soils showed an increase in GHG emissions under Estonian conditions (temperate climate zone and rich nutrient status), which means that (according to current and limited information) this possible climate measure is not suitable for Estonia. At the same time, it is clear that the topic of rewetting organic soils needs further research and data, precisely at the level of the National Inventory Report, so that the resulting impact can be taken into account in official climate reporting.

5) In order to better achieve the goals of the EU climate policy, it is important to study the processes of LU and LUC and their impact on GHG emissions at the national level of each EU Member State.

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