POTENTIAL ROLE OF TREE INTRODUCTION IN AGRICULTURAL LAND TO REDUCE GREENHOUSE GAS EMISSIONS

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Abstract. The European Union (EU) has proposed legislative revisions to achieve climate neutrality in EU by 2050. The Land Use, Land-Use Change and Forestry (LULUCF) Regulation, adopted in 2018, is being revised to ensure that accounted greenhouse gas (GHG) emissions from LULUCF are balanced by equivalent accounted removals of carbon dioxide (CO_2) from the atmosphere. This study focuses on the impact of targeted tree introduction in agricultural land in Latvia, specifically afforestation of drained organic soil and implementation of agroforestry systems (riparian buffer strips), on national GHG reduction targets for the LULUCF sector. The potential contributions of selected measures were evaluated using evaluation methods including GHG emissions factors based on the Intergovernmental Panel on Climate Change (IPCC) guidelines and recent scientific studies. The study differentiated between different land use categories by GHG emissions from soil and CO_2 removals in living biomass, dead wood, litter, mineral soil, and organic soil. Basic scenarios were compared with additional scenarios that included afforestation of drained organic soils and implementation of agroforestry systems. The study analysed the possibilities of achieving LULUCF sector goals for 2030, 2035, and 2050 with the selected scenarios. According to the basic scenarios, the LULUCF sector has been a continuous source of GHG emissions since 2019, partly compensated by forest management by 2040, but after 2040 forest management becomes a source of GHG emissions as well. The study shows that afforestation of organic soils currently used for agricultural production can reduce GHG emissions and ensure the achievement of national LULUCF targets for 2021-2025, with a significant decrease in GHG emissions by 3.9 million t CO_2 eq. during the 2021-2025 period if compared to the basic scenario. However, the study finds that national target of net GHG removals is not achieved for 2026-2030 according to both basic and afforestation scenarios if no additional measures, e.g., establishment of the shelter belts, are implemented.

Keywords: agricultural land, agroforestry, climate change, greenhouse gas, tree introduction.

Introduction

Within the framework of the EU climate targets under the European Green Deal [1] which supports the United Nations Framework Convention of Climate Change (UNFCCC) and its Paris Agreement [2], the European Commission (EC) adopted a series of legislative proposals in 2021 setting out how it intends to achieve climate neutrality in EU by 2050, including the intermediate target of net reduction in GHG emissions by 2030 [3]. The package proposed includes revision of the LULUCF Regulation (EU) 2018/841 (adopted in 2018) which stated that EU Member States have to ensure that accounted GHG emissions from LULUCF are balanced by at least an equivalent accounted removal of CO_2 from the atmosphere in the period 2021 to 2030 [4]. New proposal for the Regulation (EU) 2018/841 states that LULUCF commitments for the period 2021-2025 are based on the so-called no-debit rule, which means that accounted GHG emissions and removals must be in balance in particular accounting categories [5]. For the period from 2026 to 2030, the specific national CO_2 removal target will be set for each member state (the proposed value of the net GHG emissions reduction for Latvia is -644 kt CO_2 eq.), but for the period 2030 to 2035, there is an objective to reach EU-level climate neutrality in the combined sector of LULUCF and agriculture (AFOLU) [5]. No particular national targets are proposed now for the post-2030 period for the LULUCF sector.

In general, sustainable land use practices in the LULUCF sector involving increse of woody vegetation cover on agricultural land can significantly contribute to climate change mitigation through additional CO_2 sequestration in tree and shrub biomass and soil, reduction of GHG emissions (especially from drained organic soils), and maintaining and enhancing carbon (C) sinks and stocks [4; 6]. This study focuses on impact of targeted tree planting in agricultural land in Latvia (afforestation of drained organic soil, agroforestry) on national GHG reduction targets. Afforestation of agricultural land with drained organic soils is a promising mitigation strategy to reduce GHG emission from organic soils [7; 8] and provides a substantial net C uptake over the forest cycles [9]. In general, afforestation of agricultural land with drained organic soils lowers heterotrophic soil CO_2 emissions due to the cessation of cultivation practices including ploughing and, at the same time, significantly increases C stock in living biomass because annual agricultural crops are replaced by forest trees with a perennial rotation and larger biomass [8]. As a result, CO_2 uptake by the wooden vegetation (trees), and its subsequent transfer and storage into the soil, is greater than losses from decomposition of soil organic matter [9]. Agroforestry systems on agricultural land such as riparian buffer strips have been shown to provide a wide range of ecosystem services including production of woody biomass in an efficient and environmentally friendly way [10] to meet the growing demand for raw materials within the context of bioeconomy [11]. Study of Christen and Dalgaard (2013) showed that an annual biomass DM yield in buffer strips can reach 5-8 t ha^{-1} for short rotation forestry (SRF) and up to 16 t ha^{-1} for willow/poplar short rotation coppice (SRC) depending on species combination and growing conditions [12]. A study in Sweden showed that strategically planted willow in riparian buffer strips can achieve CO_2 removals of up to 11.9 Mg CO_2 ha^{-1} $year^{-1}$ [13].

Taking into account ambitious climate targets for the LULUCF sector, different climate change mitigation approaches have been considered and evaluated across different LULUCF categories in order to reduce GHG emissions. Within this study we evaluated the potential impact of targeted tree introduction in agricultural land on national GHG reduction targets for the LULUCF sector in Latvia (at national level). Contribution of two measures in agricultural land was evaluated: i) afforestation of drained organic soils currently used for agricultural production; ii) implementation of agroforestry systems (riparian buffer strips) around drainage ditches in agricultural land with mineral soil.

Materials and methods

Within the study, potential contribution of two climate change mitigation measures in agricultural land to total reduction of net GHG emissions from the LULUCF sector was evaluated: i) afforestation of drained organic soils currently used for agricultural production; ii) implementation of agroforestry systems (riparian buffer strips) around drainage ditches in agricultural land with mineral soil. The used evaluation methods including GHG emission factors (EFs) were based on the IPCC guidelines (for instance: CH_4 and N_2O EFs for drained organic soils in forest land; CO_2, CH_4 and N_2O EFs for rewetted organic soils in forest land; EF for direct N_2O emissions from nitrogen mineralization/immobilization in land concerted to cropland and settlements; CO_2 EF for organic soils in land converted to wetlands; other factors [14; 15] and results of the latest scientific studies (for instance: CO_2, CH_4 and N_2O EFs for drained organic soils in wetlands drained for peat extraction [16]; CO_2 and CH_4 EFs for drained organic soils in cropland and grassland [17]; tree biomass expansion factors [18]; other factors). Detailed description of calculation methodology of GHG emissions and CO_2 removals and sources of activity data under the LULUCF sector is provided in Latvia's National Inventory Report (NIR) under the UNFCCC and Article 26 of Regulation (EU) 2018/1999 of the European Parliament and of the Council, submitted in 2022 [19]. In order to establish interconnection between this study and national reporting under different EU regulations, potential impact of implementation of selected measures was calculated using activity data used also for: i) NIR under the UNFCCC and Article 26 of Regulation (EU) 2018/1999 of the European Parliament and of the Council, submitted in 2022 [19]; and ii) Reporting on policies and measures and on projections under Article 18 of Regulation (EU) No 2018/1999 of the European Parliament and of the Council [20]. Calculations were conducted using AGM model [21] and modified 'Emissions projection & inventory model (EPIM)' spreadsheet tool developed at LSFRI Silava [19]. Within the study, following land use categories of LULUCF sector are distinguished according to the IPCC guidelines [14]: i) forest land; ii) cropland; iii) grassland; iv) settlements; v) wetlands; and vi) other land. GHG emissions and CO_2 removals were calculated for following sources/pools: i) living biomass; ii) dead wood; iii) litter; iv) mineral soil; and v) organic soil [14]. The main data source for the area of all land use categories (Fig. 1), dynamics of living biomass and dead wood is the National Forest Inventory (NFI).

Firstly, GHG emissions and CO_2 removals from the LULUCF sector were estimated for two basic scenarios (continuation of current practices in forestry): i) preservation of the area of current managed forests (IKD); ii) cessation or limitation of forest management in 30% of the current forest area (IKD_ZV). For IKD_ZV scenario it was assumed that the area where forest management does not take place increases to 10% of the total forest area and limitation of forest management (clearcuts replaced with selection cutting) increases to 20% of the total forest area. In general, for the basic scenario it was assumed that forest management, land use changes, peat extraction and other assumptions continues according to the previous 5-year average values.

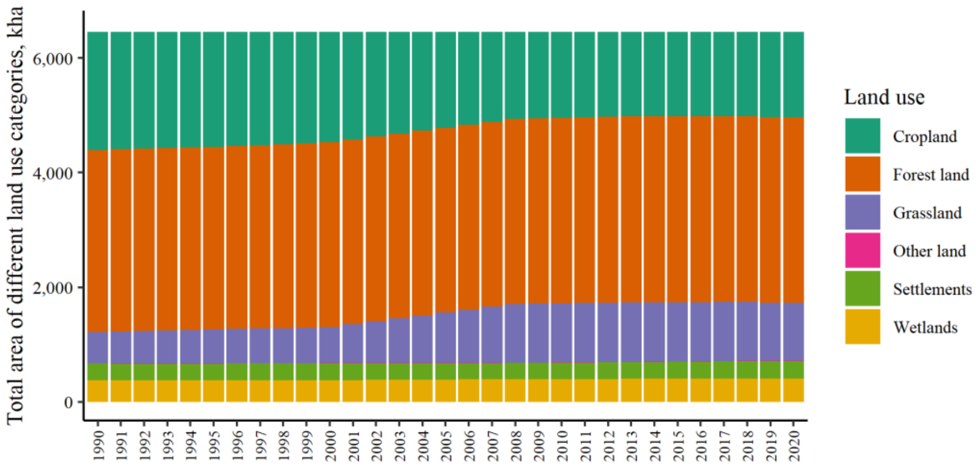

Fig. 1. **Area of land use categories of LULUCF sector in Latvia in 1990-2020 [19]**

To evaluate the impact of selected climate change measures, GHG emissions and CO_2 removals from the LULUCF sector estimated for additional scenarios include: i) afforestation of drained organic soils currently used for agricultural production (A); ii) implementation of agroforestry systems (riparian buffer strips) around drainage ditches in agricultural land with mineral soil (Buff). For A scenario it was assumed that afforestation of drained organic soils currently used for agricultural production (160 kha) will be done by 2030 restoring the natural ecosystem characteristic of these areas in the current climatic conditions. The peat extraction prognosis was maintained at the current level in accordance with the Guidelines For the Sustainable Use of Peat 2020-2030 [22]. For Buff scenario it was assumed that riparian buffer strips or "biomass factories" (10-20 m wide) will be established around each drainage ditch where there are no restrictions for establishment of buffer strips. The total length of drainage ditches in agricultural land in Latvia is 43000 km [23], potential total area of riparian buffer strips is 63 kha. For riparian buffer strips 20-year rotation cycle was assumed. The calculation includes removals in living biomass, not taking into account potential removals in harvested wood products (HWP) and substitution effect.

For all scenarios GHG emissions and CO_2 removals from the LULUCF sector were calculated for the period from 1990 to 2050. Within the study the possibilities of achieve the LULUCF sector goals for 2030, 2035 and 2050 with selected scenarios were analysed.

Results and discussion

According to the basic scenarios (IKD and IKD_ZV) LULUCF sector since 2019 is a continuous source of GHG emissions (means release of GHG into the atmosphere) partly compensated by forest management by 2040, but after 2040 forest management becomes a source of GHG emissions as well (Fig. 2). Nevertheless, both basic scenarios ensure target achieving for 2021-2025 according to the Regulation (EU) 2018/841 [4]. For 2021-2025, the LULUCF sector ensures 3.1 million t CO_2 units available for flexibility mechanisms and 4.5 and 4.2 million t CO_2 units according to the IKD and IKD_ZV scenarios, respectively, available for the voluntary carbon trading systems or for transfer to the next reporting period (2026-2030), if it will be in accordance with the new revised LULUCF Regulation. IKD_ZV scenario shows a slight increse in GHG emissions from the LULUCF sector for 2021-2025 (by 0.3 million t CO_2 eq.) due to the introduction of nature protection requirements. For 2026-2030, the national target of net GHG removals is not achieved according to both basic scenarios, and 15.5 and 17.0 million t CO_2 units removals gap (shortage) is created according to the IKD and IKD_ZV scenarios, respectively. This estimation is based on the assumption that Latvia's national target (value of the net GHG emissions reduction) to be achieved in 2030 is -644 Gg CO_2 eq. according to the Proposal for a new Regulations (EU) 2018/841 [5]. For 2026-2030, IKD_ZV scenario shows that introduction of nature protection requirements increases GHG emissions in the LULUCF sector by 1.5 million t CO_2 eq. if compared to the IKD scenario. If the estimation also includes forest land with organic soils converted to settlements, GHG removal shortage in 2030 reaches 15.8 and 17.2 million t CO_2 eq. according to the IKD and IKD_ZV scenarios, respectively. According to the IKD scenario net

GHG emissions from the LULUCF sector reach 5.4 million t CO_2 eq. in 2050 and remain approximately at the same level in the second half of the 21st century, while according to the IKD_ZV scenario net GHG emissions from the LULUCF sector reach 5.9 million t CO_2 eq. in 2050 and 6.1 million t CO_2 eq. in the second half of the 21st century. Thus, in case of IKD and IKD_ZV scenarios Latvia cannot achieve the goal of climate neutrality. For the second half of the 21st century, introduction of nature protection requirements increases GHG emissions from the LULUCF sector by an average of 0.7 million t CO_2 eq.

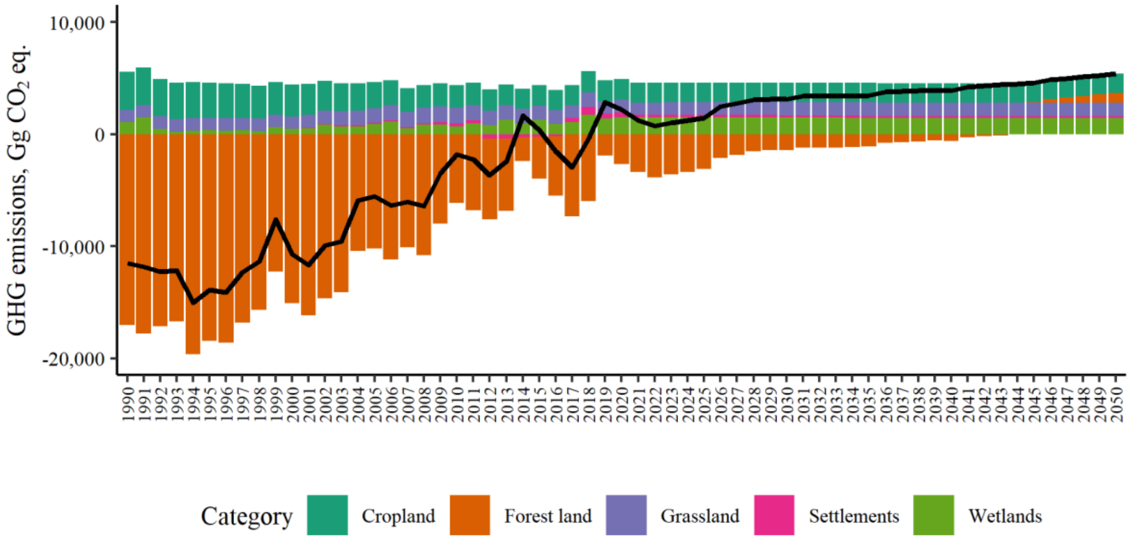

Fig. 2. **GHG emissions (positive values) and removals (negative values) from LULUCF sector in Latvia according to the basic scenario (IKD). Black line shows total net GHG emissions or removals from LULUCF sector**

IKD_A and IKD_ZV_A scenarios which include afforestation of organic soils currently used for agricultural production show additional CO_2 removals in living biomass and reduction of total GHG emissions in the LULUCF sector. Both IKD_A (Fig. 3) and IKD_ZV_A scenarios ensure achievement of national LULUCF targets for 2021-2025, furthermore, the LULUCF sector provides 3.1 million t CO_2 units for flexibility mechanisms and 8.4 and 8.9 million t CO_2 units according to the IKD_A and IKD_ZV_A scenarios, respectively, for the voluntary carbon trading systems. Estimated impact of afforestation by 2026 (IKD_A scenario) is significant – GHG emissions decrease by 3.9 million t CO_2 eq. during this period if compared to the IKD scenario. Impact of implementation of nature protection requirements (IKD_ZV_A scenario) on GHG emissions is negligible during this period. For 2026-2030 the national target of net GHG removals is not achieved and 1.3 and 2.6 million t CO_2 units removals shortage is created according to the IKD_A and IKD_ZV_A scenarios, respectively. However, IKD_A scenario shows a positive impact of afforestation – GHG emissions decrease by 14.8 million t CO_2 eq. during 2026-2030 if compared to the IKD scenario. Implementation of nature protection requirements (IKD_ZV_A scenario) increases GHG emissions from the LULUCF sector by 1.3 million t CO_2 eq. during this period (if compared to the IKD_A scenario). If the estimation also includes forest land with organic soils converted to settlements, GHG removals shortage in 2030 reaches 1.4 and 2.8 million t CO_2 eq. according to the IKD_A and IKD_ZV_A scenarios, respectively. In case of the IKD_A scenario, GHG removals shortage in 2030 can be fully compensated with the GHG removals accumulated in the previous period (2021-2025). In 2050, net GHG emissions from the LULUCF sector reach 0.3 and 1.2 million t CO_2 eq., while in the second half of the 21st century – 1.7 and 2.6 million t CO_2 eq. according to the IKD_A and IKD_ZV_A scenarios, respectively. Implementation of nature protection requirements increases GHG emissions from the LULUCF sector by 0.9 million t CO_2 eq. in the second half of the 21st century (if compared to IKD_A and IKD_ZV_A scenarios). In 2050, in case of both IKD_A and IKD_ZV_A scenario, additional CO_2 removals in living biomass and reduction of GHG emissions do not compensate GHG emissions mostly due to peat extraction and deforestation and, thus, Latvia cannot achieve the goal of climate neutrality.

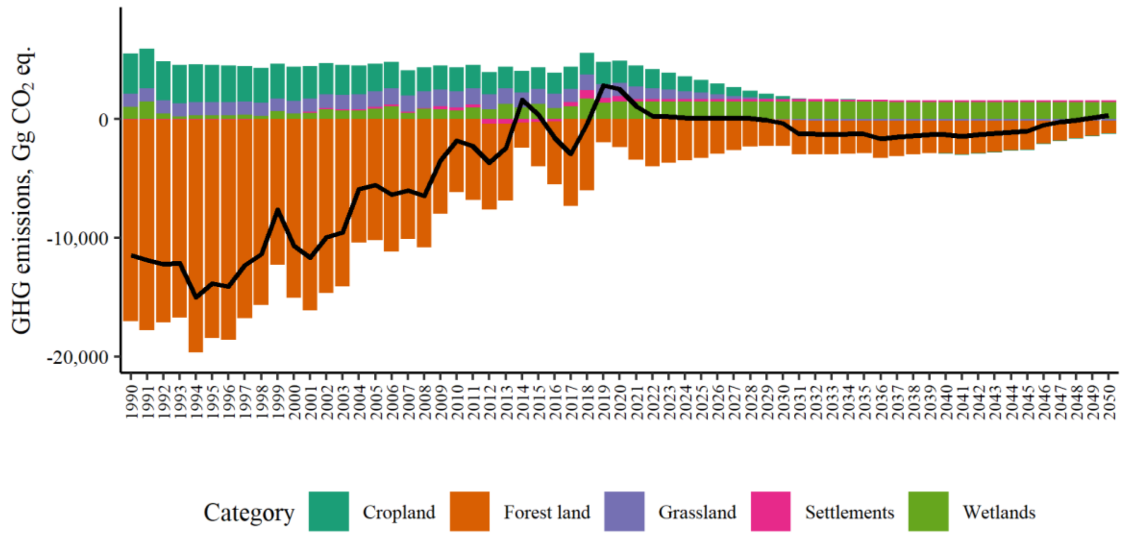

Fig. 3. **GHG emissions (positive values) and removals (negative values) from LULUCF sector in Latvia according to IKD_A scenario. Black line shows total net GHG emissions or removals from LULUCF sector**

One of the most effective climate change mitigation measures in the LULUCF sector is establishment of riparian buffer strips around drainage ditches; impact on GHG reduction appears in a relatively short period of time and at the same time it reduces the negative impact of agriculture on the environment (such as nutrient leaching [24]) as well as it provides even greater reductions in GHG emissions in the energy sector, which are not included in this assessment. We estimated that reduction of GHG emissions (cumulative removals) due to implementation of riparian buffer strips in 63 kha area during 10 years (starting from 2023) is 6.5 million t CO_2 eq. in 2030 and 25.3 million t CO_2 eq. in 2050 (Fig. 4) excluding the substitution effect in the energy sector.

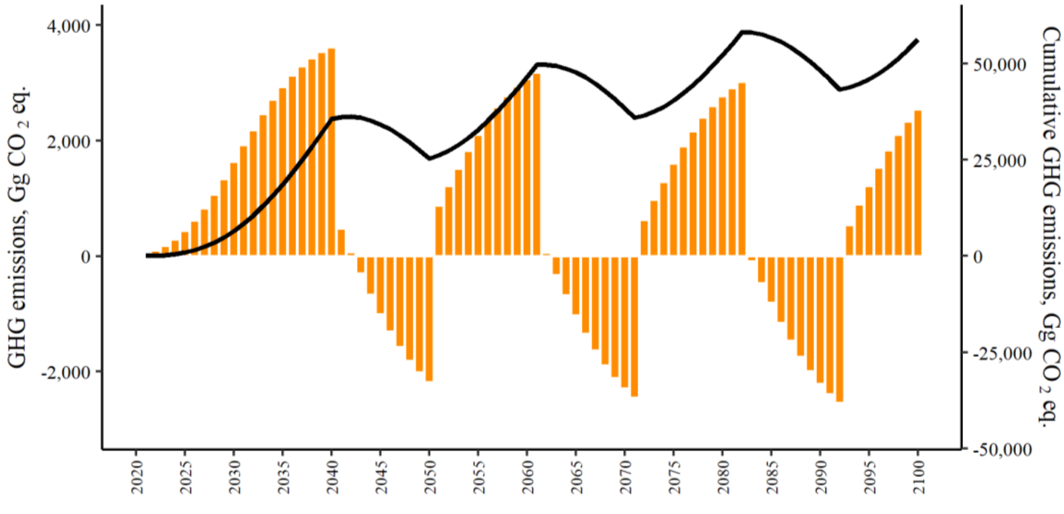

Fig. 4. **Potential impact on implementation of riparian buffer strips on reduction on GHG emissions in Latvia. Positive values show CO_2 removals, negative values – emissions. Cumulative reduction of GHG emissions (black line) is shown on secondary y axis**

IKD_A_Buff scenario (Fig. 5) which includes afforestation of organic soils currently used for agricultural production and establishment of riparian buffer strips around drainage ditches in agricultural land with mineral soil ensures achievement of the national LULUCF targets for 2021-2025, furthermore, the LULUCF sector provides 3.1 million t CO_2 units for flexibility mechanisms and 10.2 million t CO_2 units for voluntary carbon trading systems. Estimated impact of afforestation and establishment of riparian buffer strips by 2026 (IKD_A_Buff scenario) is significant – GHG emissions decrease by 5.7 million t CO_2 eq. during 2021-2025 if compared to the IKD scenario. Also for 2026-2030 IKD_A_Buff scenario achieves the national LULUCF target, furthermore, the LULUCF sector provides

5.1 million t CO_2 units for voluntary carbon trading systems. Estimated impact of afforestation and establishment of riparian buffer strips for 2026-2030 is 21.5 million t CO_2 eq. if compared to the IKD scenario. In 2050, net GHG emissions from the LULUCF sector reach 2.8 million t CO_2 eq., while in the second half of the 21st century – 1.4 million t CO_2 eq. according to the IKD_A_Buff scenario. Thus, Latvia cannot achieve the goal of climate neutrality in 2050 according to the IKD_A_Buff scenario.

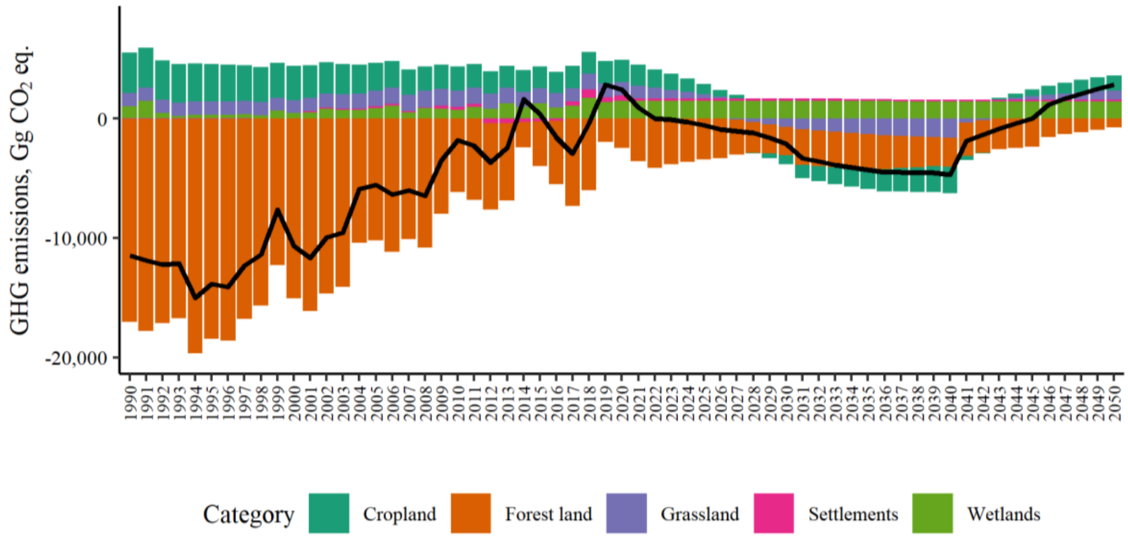

Fig. 5. **GHG emissions (positive values) and removals (negative values) from LULUCF sector in Latvia according to IKD_A_Buff scenario. Black line shows total net GHG emissions or removals from LULUCF sector**

In the EU-27, Norway, Switzerland and the UK, forest restoration (peatlands) and afforestation/reforestation have the potential to mitigate on average additional 115 and 54 Mt CO_2 eq yr^{-1}, respectively, by 2050 [25]. In general, tree introduction in agricultural land is a recognized, implemented and subsidized climate change mitigation measure in the Baltic Sea region, for instance, afforestation of agricultural land in Denmark [26], afforestation of organic soil (former peat production areas) in Finland [27]. However, in some cases, afforestation of agricultural lands used for cultivation as well as afforestation of meadows, pastures and clearings that are important in terms of their environmental and nature value is not intended and eligible [28]. In recent study in Latvia, it was estimated that the total area of agricultural land in Latvia where land quality is low and agroforestry could provide a solution for more effective land management (excluding agricultural land around watercourses and roads) is 351.5 kha (14.1% of the total agricultural land in Latvia) including 306.6 kha of area without underground drainage systems [29]. In addition, it was concluded that establishment of agroforestry systems in less fertile agricultural land could contribute significantly to achieving not only climate change mitigation but also biodiversity and environmental goals, while simultaneously ensuring multiple agricultural productions avoiding reduction of the area of high-value agricultural parcels [29].

Conclusions

1. We concluded that tree introduction in agricultural land can contribute significantly to reach climate change mitigation aims set for the LULUCF sector both for 2030 and 2050, as well as for the second half of the 21st century. Nevertheless, Latvia cannot achieve the goal of climate neutrality in 2050 by only implementation of the measures evaluated within this study (afforestation of organic soils and establishment of riparian buffer strips).
2. To reach long-term climate change mitigation aims set for the LULUCF sector in Latvia, additional climate change mitigation measures in must be evaluated and implemented.

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Author contributions

Conceptualization, A.L. and An.B.; methodology, A.L. and Ar.B.; validation, D.P. and Ar.B.; formal analysis, An.B. and D.P.; writing – original draft preparation, An.B. and D.P.; writing – review and editing, Ar.B. and A.L.; visualization, An.B., Ar.B.; project administration, An.B.; funding acquisition, A.B. and A.L. All authors have read and agreed to the published version of the manuscript.

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