

IMPACT OF LULUCF ACCOUNTING RULES FOR CLIMATE CHANGE MITIGATION GOALS: WINNING OR LOSING?

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Highlights

- ▶ LULUCF sector contributes to GHG removals needed to reach climate neutral economy target.
- ▶ LULUCF just recently was included in EU climate change mitigation goal for 2030.
- ▶ EU LULUCF accounting rules seem to create a potential winners-losers situation.

Abstract. Land use, land-use change, and forestry (LULUCF) sector plays an important role in climate change mitigation as long-term goal of carbon neutral economy depends on sector's ability to sequester carbon in biomass and soil. With reference to the Paris Agreement, accounting rules for LULUCF sector have been heavily discussed in European Union (EU), seeking of trustworthy inclusion of the sector in the assessment of Union's greenhouse gas (GHG) emission reduction target. Therefore, the paper aims to analyze LULUCF sector's contribution to climate change mitigation with different accounting rules applied in EU countries and particularly in Lithuania. On EU level LULUCF sector's absorption in 2019 has equaled around –234 million t CO₂ eq. (6% of total EU GHG emissions), in some countries reaching more than a half of national emissions. However, different accounting rules applied may provide significantly different number of potential credits for separate EU countries, creating some “winners” and “losers” situation. Though inclusion of LULUCF sector into GHG's emissions reduction targets remains discussible, some stability in rules is one of the main preconditions for proper LULUCF sector management decisions.

Keywords: land-use change and forestry, GHG accounting, emissions, removals, climate change mitigation, environmental policy.

Introduction

The land use, land-use change and forestry (LULUCF) sector is an important contributor for climate change mitigation and greenhouse gas (GHG) reduction. Because of the atmospheric GHG removals, i.e., its ability to sequester carbon in biomass and soil, LULUCF sector can become an important actor for GHG offsetting in some countries while on the other hand can become an additional source of emissions if forest sink declines. For example, LULUCF sector is estimated to be able to offset 4% of global emissions (Tubiello et al., 2015), whereas in the European Union (EU) it may store up to 10% of total GHG emissions (Eurostat, 2017).

However, some complexities inherent to LULUCF sector are identified, such as not defining one specific

accounting procedure for all LULUCF categories and voluntary reporting of forest management in 1st Kyoto Protocol commitment period (Schlamadinger et al., 2007; Macintosh, 2011; Grassi, 2012). In addition, high uncertainties in reporting, very different pre-1990 national circumstances of the countries and a threat to create opportunity to earn credits without any action performed are highlighted (Krug, 2018). Criticism of inclusion of credits from LULUCF sector in climate change mitigation target accounting is also expressed due to the nature of biological sinks (mostly biomass) and fossil fuels and their difference in reversibility (Dooley, 2014). On the other hand, the opportunity to account for carbon stock changes in biological sinks provide incentive for substitution effects, however, it does not provide sufficient incentives for forest sector since the limitations (forest management cap) are

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much smaller than the current sink (Krug, 2018; Ellison et al., 2014).

EU LULUCF sector policy framework after 2020 (European Parliament and Council, 2018a, 2018b) is also widely discussed. According to Aho (2018), regulations provide incentives to avoid deforestation, but are still lacking strict target to limit global warming to not more than 1.5 °C. In addition, LULUCF inclusion into overall target accounting would mean lower efforts from other sectors: after the removals from LULUCF are accounted, 40% emission reduction target would actually mean 35% reduction in 2030 (Böttcher & Graichen, 2015). Bioenergy and climate change mitigation targets also raise questions about their compatibility. Some scholars (Frank et al., 2016) state that turnover to renewable energy sources (biomass exceptionally) would negatively affect LULUCF climate change mitigation potential. However, some studies (Gundersen et al., 2021) on old stands' carbon sequestration potential highlight this potential to be overestimated, implying potential for bioeconomy. Even more, it is argued that proper management of forests can create sinks (Diao et al., 2022; Këniņa et al., 2022). Nevertheless, considering different management schemes, old forests have to be regarded, as they still provide carbon sink (Luyssaert et al., 2021), act as carbon pools (Këniņa et al., 2022) and play important role in biodiversity (Berglund & Kuuluvainen, 2021). Hence, LULUCF sector inclusion in climate change mitigation target is multifaceted and strongly linked to the other sectors.

Therefore, proper accounting of LULUCF contribution to overall GHG target achievement is one of the important questions both on national and international level due to sector's ability to remove significant amount of GHG and thus offset other sectors' emissions. Nevertheless, impact of different accounting rules for LULUCF sector's potential credits to offset GHG emissions is rarely addressed in the research (Liu et al., 2011; Ellison et al., 2014). Liu et al. (2011) discuss the influence of accounting rules on potential net emissions and removals in EU 27 and other countries. On the EU level the implication of EU accounting rules on climate change policy is analysed by Ellison et al. (2014). Therefore, study aims to analyse LULUCF accounting rules, particularly EU accounting rules as of 2018 (LULUCF Regulation (EU 2018/841), Effort Sharing Regulation (EU 2018/842)), and their impact on potential credits in the EU countries, with focus on Lithuania.

First, the paper provides LULUCF policy changes under United Nations Framework Convention on Climate Change (UNFCCC), its Kyoto Protocol (KP) and EU regulations. Second, it introduces methods and data issues, followed by LULUCF role in national GHG emissions, influence of different accounting rules for LULUCF credits and analysis on GHG projections and removal goals. The paper ends with sections on discussion and conclusions.

1. Review of the key LULUCF policy and accounting rules

In general accounting means calculation of annual (or at the end of commitment period) GHG emissions and removals under certain conditions. Accounting might differ depending on included accounting categories, reference levels and accounting approaches. For example, for LULUCF categories it is either net-net accounting, gross-net accounting or business as usual (BAU) accounting (Krug, 2018). Net-net accounting means total reported GHG emissions/removals in reporting year minus the value of the reference year/period. On the contrary, gross-net accounting is the total of GHG emissions or removals reported in the accounting period without comparison to the reference year/period value. BAU accounting – use of forest (management) reference level – is the most complex way to account GHG emissions and removals in the accounting category – reported GHG emissions/removals are compared to the projected GHG emissions or removals in that category for that certain year or period, taking into account management practices in the past. Application of forest reference levels (FRLs) makes the emission accounting comparable between other sectors and countries, and enable accounting for country-specific forestry dynamics (Grassi et al., 2018b). However, reference period set for estimation of the reference level might have a significant impact on the potential climate change mitigation due to limitations for forest management practices in the future, i.e. some countries may need to reduce their harvest intensity in order to maintain FRLs (Vizzarri et al., 2021; Päivinen et al., 2022).

LULUCF sector accounting rules under international and EU level legislation have varied in different policy periods.

1.1. Accounting rules during 1st and 2nd Kyoto commitment period

First LULUCF accounting rules have been proposed for the 1st Kyoto Protocol (KP) commitment period by the Subsidiary body for Scientific and Technical Advice (SBSTA) under the United Nations Framework Convention on Climate Change. Under the rules set in the decisions of Conference of the Parties of the UNFCCC (15/CMP.1, 17/CMP.1, 2005) mandatory reporting of afforestation/reforestation and deforestation (KP Article 3.3 activities) and optional reporting on forest management, grazing land management, cropland management, wetland drainage and rewetting and revegetation have been established (KP article 3.4 activities) (Table 1). The aim behind this was to increase GHG removals in forestry related activities through the possibility to use removal units (RMU's). However, European Union has decided to not include LULUCF (as KP LULUCF activities) sector in its domestic collective target for the 1st commitment period.

Table 1. GHG emissions reduction targets and LULUCF accounting in 1st and 2nd Kyoto protocol commitment periods

	Kyoto Protocol 1 st commitment period	Kyoto Protocol 2 nd commitment period
	<i>Not included in EU target accounting – no commitment, no credits accounted</i>	
Accounting categories	1. Afforestation/reforestation, deforestation Mandatory, gross-net accounting 2. Forest management Optional, gross-net accounting 3. Cropland management, grazing land management, wetlands drainage and rewetting, revegetation Optional, gross – net accounting	1. Afforestation/reforestation, deforestation Mandatory, gross-net accounting 2. Forest management Mandatory, net-net or BAU accounting 3. Cropland management, grazing land management, wetlands drainage and rewetting, revegetation Optional, gross – net accounting
Credit limitations	Forest management credits cap'd – 3.5% from total country's base year emissions (excl. LULUCF)	Forest management credits cap'd – 3.5% from total country's base year emissions (excl. LULUCF)
“No debit” rule	–	+

For the 2nd commitment period KP LULUCF accounting rules have been slightly changed – forest management reference level has been introduced for the first time, however, the European Union has not yet included LULUCF sector (as KP LULUCF activities) in accounting of target achievement and accounted LULUCF GHG removals have not been added to countries' emission allowances (Table 1).

The European Union provided some reasoning for not including LULUCF in the framework of climate change policy until 2020. Reasoning covers “problems of uncertainty in the estimates of sequestered carbon, the lack of annually based LULUCF reporting cycles, and uncertainty over whether LULUCF should be incorporated into the EU's ETS [emission trading system-authors expl.] or into the commitment mechanism” (Ellison, 2014, p. 5). However, after consultations with stakeholders on possibilities to include LULUCF into EU 2030 climate and energy framework, in 2016 European Commission presented a proposal (European Commission [EC], 2016) adopted in 2018 (European Parliament and Council, 2018a).

1.2. Post-Kyoto and EU accounting rules

The LULUCF Regulation (841/2018) sets rules for accounting of GHG emissions and removals from LULUCF categories for EU 2030 climate and energy target achievement (European Parliament and Council, 2018a) (Table 2). Core accounting pillars are “no debit” rule, application of reference levels and cap – limitation for accounting

of credits from managed forest land. “No debit” rule and cap have been applied in the 2nd KP commitment period (United Nations Framework Convention on Climate Change, 2012) and maintained for post-Kyoto EU legislation (European Parliament and Council, 2018a). “Cap” limits accounted GHG removals from managed forest land to 3.5% of total country's GHG emissions in base year (1990 for most of the EU countries, including Lithuania). Reference levels are introduced for managed forest land (since the start of 2nd Kyoto Protocol commitment period) and agricultural lands (in the EU Regulation for Post Kyoto – 2021–2030 period) (Table 2). There are several revisions proposed in 2021 for the LULUCF accounting for post-2025 period, including net GHG removals target for each country for 2030 (Figure 5), creation of joint agriculture and LULUCF sector (AFOLU) from 2031, with emission neutrality target in 2035 and net GHG removals starting from 2035.

The main change in LULUCF accounting after Kyoto Protocol is a shift from activity-based KP accounting to land-use based Convention accounting categories (Krug, 2018). Change from activity-based to land-based accounting simplifies GHG reporting and incentivises accurate coverage of the whole country creating the need for integrated land-use planning.

Effort Sharing Regulation (European Parliament and Council, 2018b) also plays an important role for the LULUCF inclusion in the EU climate and energy framework: it creates the possibility for the EU Member States

Table 2. EU accounting rules of LULUCF inclusion in 2030 climate and energy target, according to the Regulation 2018/841

Accounting categories	Accounting	References	Commitment	Credits
Managed forest land (FM)	BAU, forest reference level	Forest reference level	“No debit” rule	Cap – 3.5% of total country's base year emissions, excl. LULUCF
Afforested land (AR)	Gross-net accounting	–		+
Deforested land (D)	Gross-net accounting	–		+
Managed cropland (CM)	Net-net accounting	2005–2009		+, against reference level
Managed grassland (GM)	Net-net accounting	2005–2009		+, against reference level
Managed wetland (WM)	Net-net accounting	2005–2009	“No debit” rule as from 2026	+, against reference level

to benefit from sustainable land-use planning with option to offset other sectors' GHG emissions with credits from LULUCF sector. Nevertheless, credits from LULUCF sector have several restrictions: LULUCF credits basically are an overachievement of removals or underachievement of emissions, as compared with forest reference level or base period (2005–2009) for managed cropland, grassland, and wetlands (as of 2026), while credits and debits from afforested and deforested areas are included without the reference levels. In addition to the forest impact on climate change mitigation, forest products – harvested wood products (HWP) – may have a significant impact reducing GHG emissions through substitution effect and long-term carbon storage, therefore credits from HWP sawn wood and wood-based panels categories are not limited by the cap under LULUCF regulation.

2. Materials and methods

GHG inventory of national total and LULUCF emissions

National total emissions and removals from LULUCF sector for EU countries are analysed referring to the National inventories data for 2010–2019, with particular focus on 2019 situation. The LULUCF potential for offsetting of national GHG emissions from the other sectors is calculated by the authors, applying EU LULUCF accounting rules under Regulation EU 2018/841.

Analysis of the different accounting rules impact for LULUCF climate change mitigation

Credits from LULUCF sector to be accounted for Lithuania are estimated using 3 different accounting rule sets: Kyoto Protocol 1st commitment period, Kyoto Protocol 2nd commitment period and post-Kyoto EU LULUCF accounting rules (as of 2018). Credits are calculated using activity data as reported under UNFCCC and its Kyoto Protocol by Lithuania for 2010–2019 (submitted to UNFCCC on 15th April 2021), taking into account specific accounting categories for those 3 different rule sets and limitations for credits set in each of the period. Potential credits are calculated for the years 2010–2019. Credits limit for Lithuania is adopted from EU Effort sharing regulation (2018/842).

For the other EU countries only EU LULUCF accounting rules as of 2018 are applied, and potential credits/debits are compared to the LULUCF inventory for the year 2019. Accounting of the LULUCF credits for the EU countries (Austria, Belgium, Bulgaria, Cyprus, Croatia, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, UK) is carried out using data from National GHG Inventory reports (NIR) of 2021 (obtained from official UNFCCC website). The preliminary analysis of potential credits/debits generation in countries is done for the year 2019, including all accounting categories as set in LULUCF Regulation (2018/841). Countries'

credit limitations are adopted from the EU Effort sharing regulation (2018/842). Additionally, based on NIR data, LULUCF emissions/removals on 2010–2019 average are plotted against set goals and projections for LULUCF sector for 2030. Increasing goals from 2026 to 2030 for each EU member state, taking into account 2021, 2022 and 2023 National GHG inventories are foreseen in the proposal of revised accounting rules by the EU (2021/0201 (COD), Annex II). Projections refer to the Policies and Measures Reports under the requirement of Article 18 of Regulation (EU) No. 2018/1999. LULUCF GHG projections for 2030 are based on scenario with already adopted policies and measures for land use management.

3. Results

3.1. National GHG emissions and LULUCF input

In total, EU is responsible for some 4.2 billion GHG emissions as of 2019. Depending on the area and population size, economic activities, geographical locations and natural conditions, and energy mix used countries contribute differently to the total GHG emissions of EU (Figure 1). The LULUCF sector is less dependent on economic factors, except for harvested wood products category, which relates to economic factors via harvest, but sectors' removal potential varies according to the natural conditions and land use changes. Hence, countries circumstance very big variety of LULUCF input to the total GHG emissions, too (Figure 1). Countries like Czechia, Denmark, Malta, United Kingdom and Netherlands contrary to the rest of the EU countries experience net addition to the total GHG emissions from LULUCF sector in 2019. Other countries could cover significant part of their national emissions if no limiting LULUCF accounting rules are applied. For ex. Croatia, Lithuania, Finland could cover some 26%, and Sweden even 66% of their national GHG emissions. In total LULUCF could offset some 6% of EU GHG emissions as of 2019 (Figure 1).

In the case of Lithuania, total land-use related sector in Lithuania could absorb nearly 26% (5.4 million tonnes of CO₂ eq.) of net country's emissions as of 2019 without application of the specific accounting rules (Figure 1). The maximum LULUCF credit allowance for Lithuania equals to 6.5 million tonnes CO₂ eq. for the 2021–2030 period (European Parliament and Council, 2018b) or 0.65 million tonnes annually. According to the unpublished data of the Ministry of Environment of Lithuania, approximately 6 million t CO₂ eq. shortage of annual emission allocations (AEA's) is expected during 2021–2030 if no additional measures for GHG emission reduction in non-ETS sectors are applied (Ministry of Environment, 2018). Hence, LULUCF might play a crucial role in climate change mitigation commitments implementation in the case of Lithuania as well as in some of before-mentioned countries.

In most of the cases, GHG removals from LULUCF sector display the significance of forest land category. Usually, GHG removals in forest land category covers

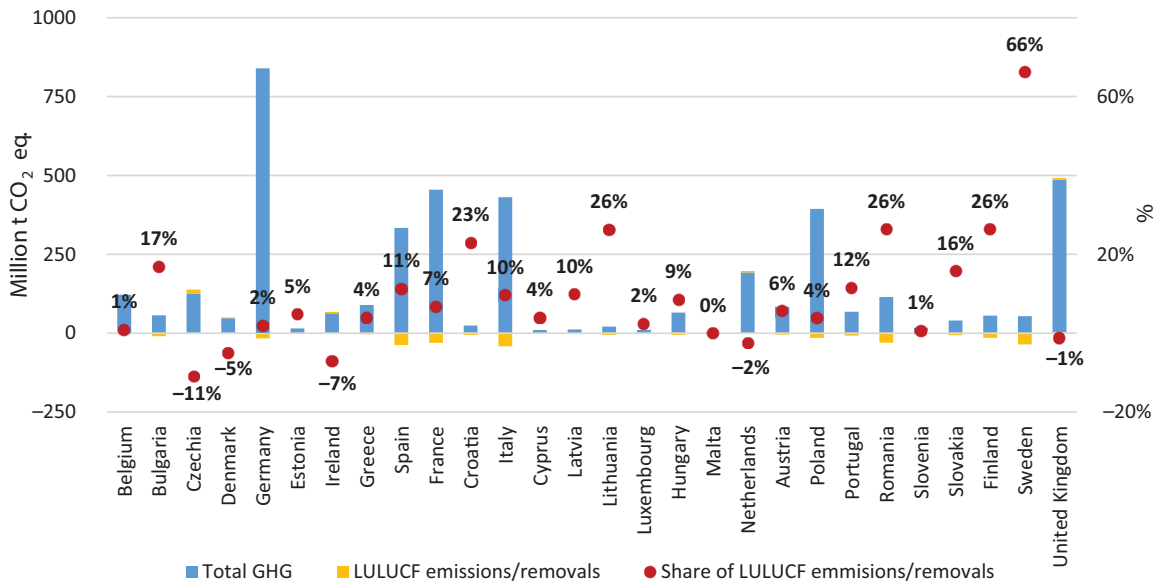


Figure 1. National GHG emissions (excluding LULUCF, CO₂ eq.), LULUCF GHG removals/emissions (CO₂ eq.) and the potential of LULUCF sector to offset national emissions (% of national emissions without applying accounting limits, “-” indicates GHG emissions from the sector) in EU countries in 2019

emissions occurring in cropland, wetlands and settlements categories and provide potential to cover other sectors’ emissions altogether with harvested wood products (HWP) and grasslands. For many of the EU countries, except Slovenia, Czechia and Malta, forest category provides the highest share in overall sector’s removals. In Ireland, Netherlands and Denmark despite forest being the biggest sink, other LULUCF categories outweigh GHG removals of this category. On the EU level, forests absorbed some 357 million tons of GHG (CO₂ eq.) in 2019.

3.2. Influence of different accounting rules on LULUCF credits

Analysis of GHG emissions and removals under different accounting rules show that they have a significant impact in estimation of potential LULUCF credits. Despite significant GHG removal potential, under application of Kyoto Protocol 1st commitment accounting rules Lithuania could report only a small part of GHG credits and even resulted in debit in year 2018, due to significant increase in emissions from deforestation (large forest land areas were deforested for governmental needs) (Figure 2). If 2nd Kyoto Protocol commitment period rules and estimated forest management reference level (FMRL) (estimated in 2011, recalculated in 2013 and 2015, included under EU decision 529/2013/EU; FMRL for Lithuania is -5474 kt CO₂ eq.) are applied, potential GHG removals increase more than 6 times in the certain years (e.g., in 2014). This has become possible due to the larger number of credits allowed to be included from forest management category. Nevertheless, LULUCF credits and debits in Lithuania varies greatly from -0.17 to -1.92 million t CO₂ eq. if 2nd KP commitment period accounting rules are applied (Figure 2) and could cover some 7.5–9.5% (in

2010–2017), but only 0.8% in 2018 and 3.1% in 2019 of total national emissions.

If EU LULUCF accounting rules (as of 2018, including -5.165 mill. t CO₂ eq. forest reference level for Lithuania under Annex C to the Regulation EU 2018/841) are applied for the 2010–2019 period, potential credits could vary from - 4.86 mill. t CO₂ eq. in 2010 to -2.31 mill. t CO₂ eq. in 2019 (Figure 2). This means Lithuania could cover some 11.3–23.4% of its national emissions, which is much more to compare to the 2nd Kyoto commitment rules applied for 2019. Much higher credits in 2019 with EU post-Kyoto rules applied can be explained with removals from cropland and grassland categories included in the credit accounting for the first time, contrary to the Kyoto Protocol commitment periods where cropland and grazing land management reporting was optional. 2nd Kyoto commitment period accounting rules applied resulted in significantly larger GHG removals compared to 1st Kyoto commitment rules applied due to the inclusion of forest management category (against forest management reference level: -5.474 mill. t CO₂ eq.). In addition, GHG emissions from deforested areas were included under both 1st and 2nd Kyoto commitment rules applied, as it was obligatory requirement (Table 1). Nevertheless, it must be noted that those potential credits with EU LULUCF accounting rules applied for the 2021–2030 period are additionally limited to 6.5 million t CO₂ eq. or 0.65 million t CO₂ eq. annually by the Effort Sharing Regulation (2018/842/EU). Hence, more efforts will be needed for Lithuania to reach foreseen climate change mitigation goals, even if LULUCF credits for offsetting part of total GHG emissions will be used. Great fluctuation in potential credits from LULUCF sector using EU accounting rules is related to the fluctuations in GHG emissions and removals in agricultural

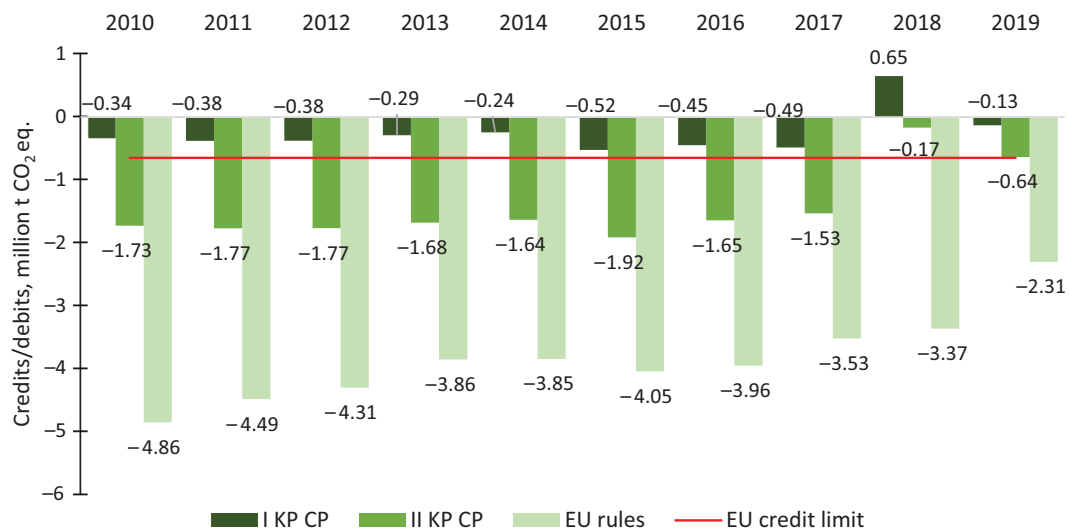


Figure 2. LULUCF credits and debits in Lithuania applying different accounting rules (million t CO₂ eq.). I KP CP – 1st Kyoto Protocol commitment period (2008–2012), II KP CP – 2nd Kyoto Protocol commitment period (2013–2020), EU rules – LULUCF accounting rules according to EU Regulation 2018/841 (2021–2030), without revisions proposed in 2021, EU credit limits – annual national LULUCF credit limit for 2021–2030 according to EU Regulation 2018/842

land use categories – managed cropland and grassland. Decrease in potential credits is attributed to the zero net and even increasing GHG emissions in grassland category in Lithuania. Increased GHG emissions from deforested areas in certain years also significantly reduce total credits. It must be mentioned that GHG emissions and removals in agricultural land use categories are mainly a result of carbon stock changes in soils, with higher carbon stock in grassland soils than in cropland. GHG balance therefore is strongly related to land-use changes between those two categories. Potential credits or debits from managed agricultural land use categories are not only dependent on land-use changes between cropland and grassland in recent years but on changes in those land uses during the reference period from 2005 to 2009 in the Lithuanian case.

Coming back to the accounting rules, it is evident, that EU accounting rules are more beneficial for Lithuania even in the case of credit limitation applied. This limit would have not been reached in the case of the 1st KP commitment period rules applied, and in the years of 2018 and 2019 in the case of 2nd KP commitment period rules applied (Figure 2).

Application of the EU LULUCF accounting rules (as of 2018, for 2021–2030 accounting period) for the other EU countries indicate that some countries under analysis might face a challenge to use assigned limit to cover some national GHG emissions and even must cover LULUCF emissions by more significant emission reductions in the other sectors (Figure 3). Belgium, Cyprus, Luxemburg, Czechia, France, Poland, Portugal, Slovenia, and Finland are those “losing” because of the EU accounting rules. Only Ireland, Netherlands and Denmark could be called “winners” in this situation, as from GHG emitter LULUCF sector becomes a GHG sink in those countries when EU accounting rules are applied for the year 2019. For all other countries (except Germany), lower potential credits

are being estimated than the total sectors potential according to GHG inventory balance. This group of countries (Germany, Bulgaria, Greece, Spain, Croatia, Italy, Latvia, Lithuania, Hungary, Malta, Austria, Romania, and Sweden) could be called as “relatively losing ones”, as they can cover some national emissions up to the set limits, but their potential of the LULUCF sector in most cases is much higher. The only “relatively winning” country from the set limitations could be UK, as the set limit is higher than current potential annual credits. Hence, focus on LULUCF activities with higher GHG removals (afforestation/reforestation) over whole 2021–2030 period for UK could help to offset bigger share of national emissions, especially having in mind that the credit limit is set for the whole period. On the EU level, the credit limit for the period of 2021–2030 is 280 million t CO₂ eq. This total 10-year allowance is relatively very small; on the yearly basis (28 million t CO₂ eq.), this corresponds to some 0.7% of annual EU emissions (as of 2019).

Analysing in more detail situations of “losing” countries when LULUCF accounting rules as of EU Regulation 2018/841 are applied, no removals in any of the accounting categories, like for e.g., in Finland (Figure 4), is observed. This is a result of possibly unfavourable base years and reduced GHG removals in forest land, compared to the forest reference level. Therefore, the reference year emissions from managed cropland and managed grassland have also a significant impact on credit and debit accounting. Since Finland has a significantly large forest coverage, deforestation events are inevitable and contribute to the sectors debits. Aging forests also contribute to lower forest land GHG removals.

The example of “relatively losing” countries, Germany, shows, that despite large emissions from deforestation and managed cropland, there could be a larger potential for credits from forest land with significant supplement from

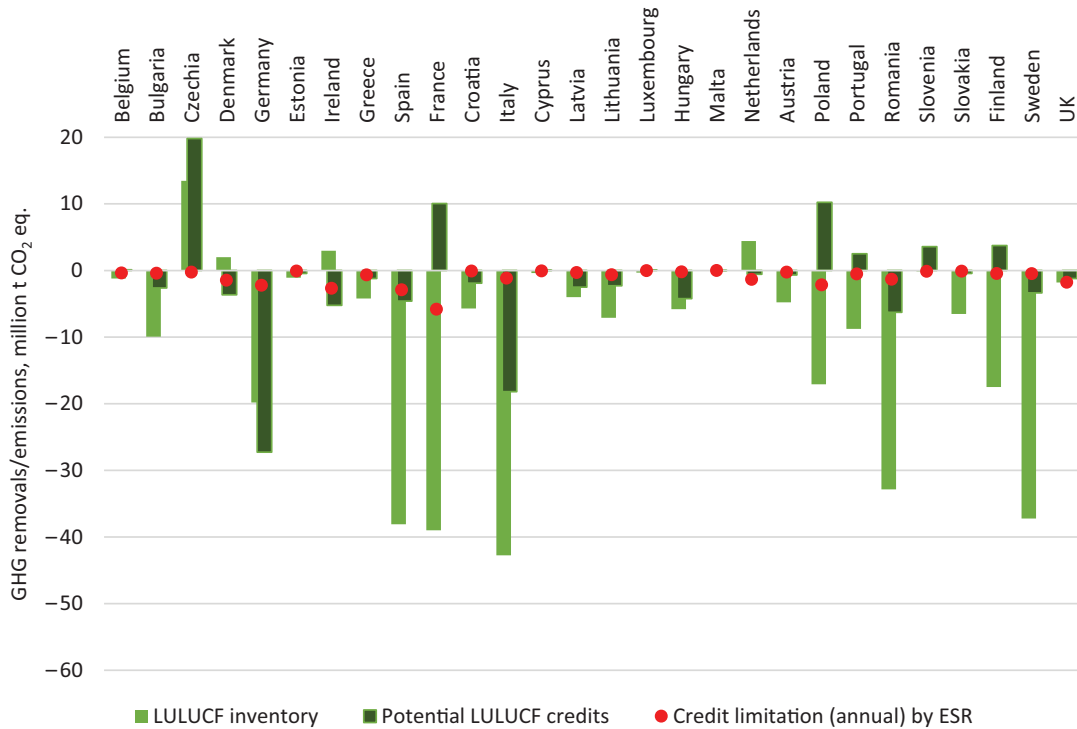


Figure 3. Credits and debits from LULUCF in 2019 according to LULUCF inventory, EU accounting rules for 2021–2030 (EU Regulation 2018/841, revisions of 2021 not included), and national credit limitation (EU Regulation 2018/842) distributed annually (million t CO₂ eq.)

grassland category (Figure 4). Though Germany reports emissions from grassland category, it is still possible to account potential credits (-3.2 million t CO₂ eq.) from managed grassland category due to recently decreased emissions compared to emissions during reference years. However, significantly large potential credits (-27,1 million t CO₂ eq.) from the LULUCF accounting categories

are limited to -2.23 million t CO₂ eq. annually by the Effort Sharing Regulation.

Analysis of one of the “winners” – Denmark – situation indicate that it could use nearly half (-1.46 million t CO₂ eq.) of its potential credits (-3.6 million t CO₂ eq.) (Figure 4). To compare, Lithuania could use more than 25% of its potential credits, Germany – only 8.2%.

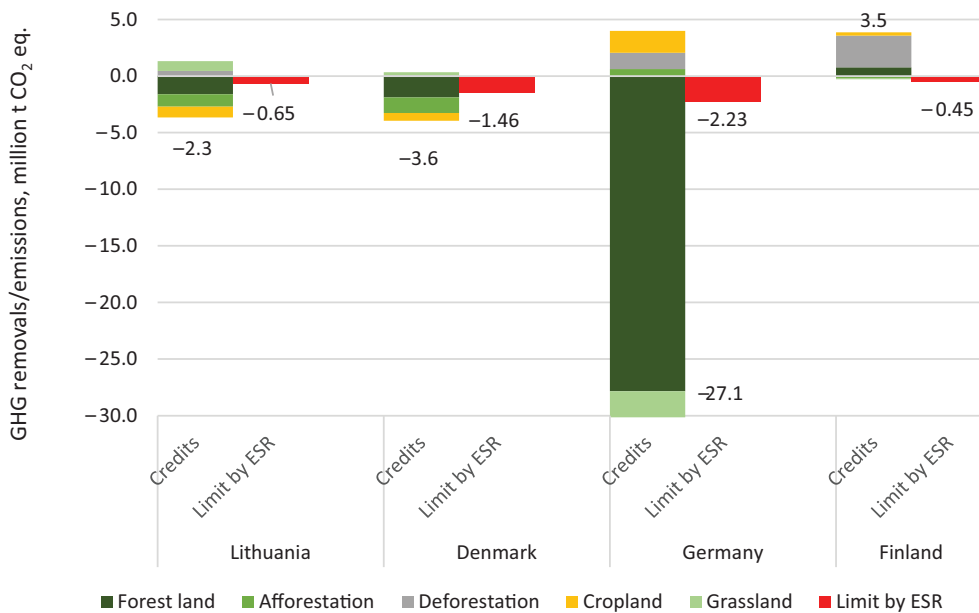


Figure 4. Credits and debits from LULUCF accounting categories according to EU LULUCF accounting rules for 2021–2030 (based on 2021 NIR data of Lithuania, Denmark, Germany and Finland, million t CO₂ eq.). Credit accounting as of EU Regulation 2018/841, limits (red columns) – EU Regulation 2018/842. Forest land includes removals from harvested wood products (HWP)

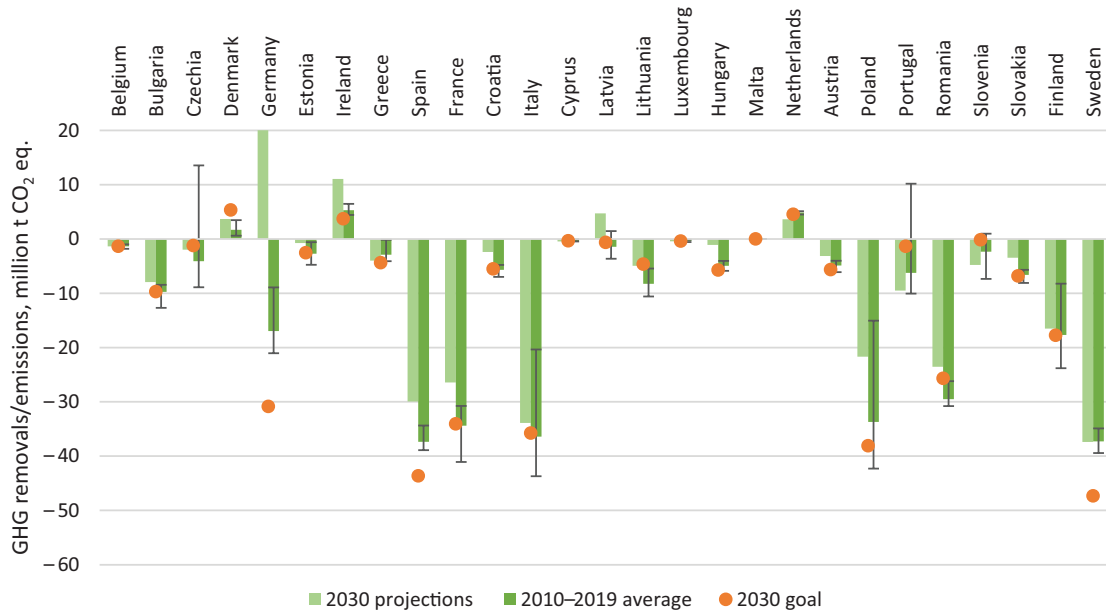


Figure 5. Credits and debits from LULUCF (LULUCF GHG inventory data, 2010–2019 average, error bars indicating min and max values), 2030 LULUCF GHG projections (Policies and Measures Reports under the requirement of Article 18 of Regulation (EU) 2018/1999) and 2030 LULUCF GHG removal goals proposed in the revision of EU LULUCF Regulation (EU 2021/0201 (COD)) (million t CO₂ eq.)

More possibilities to employ LULUCF sector for climate mitigation goals will be addressed with the accounting rules applicable for the period 2026–2030. The European Commission proposed an update to the LULUCF Regulation taking into account ambitious goal set in Green Deal to reach the “no net” GHG emissions target in 2050 and 55% GHG emission reduction in 2030. Proposal amending Regulations (EU) 2018/841 (LULUCF Regulation) and (EU) 2018/1999 (Governance Regulation and Climate Action), provide new national goals for LULUCF sector in 2030 (Figure 5), in total 310 million t CO₂ eq. net GHG removals for EU. It is evident that for half of EU countries (13 of 27, UK not included anymore) goals set are rather achievable, compared to the projections for 2030. However, some countries will need to develop and apply additional policies and measures to reach ambitious goals (for ex. Germany, Poland, Sweden, Spain, France, Slovakia, Austria, Croatia or Hungary) (Figure 5).

Extremely alarming situation is observed in Germany and Latvia; here, according to 2030 GHG projections, LULUCF sector shifts from sink to the source. In addition, a shift from national goals and increase of GHG emissions from LULUCF sector is projected in Ireland. Hence, some countries will benefit more from changes in accounting rules because of high current credit potential (for ex. Italy or Romania), others – because of set higher allowable debits (Netherlands, Denmark) compared to inventory data and projections (Figure 5). Some countries (for ex. Germany) might be losing because of the influence of the high historical GHG removals and correspondingly high goals set, while significantly large areas of mature and old forest stands could be the reason of shifting from sink to source.

4. Discussion and implications

Total GHG emissions and removals balance shows that the LULUCF sector might be very important for climate change mitigation in Lithuania and other EU countries, with potential GHG removals covering significant share of national GHG emissions in some countries. Forest land category have proved to be the major GHG sink in most of the EU countries as of 2019. However, the study shows that LULUCF accounting rules and their changes (e.g., from 1st to 2nd KP commitment period) result in significant differences of the LULUCF potential for climate change mitigation. In the case of Lithuania, because of the rules applied, the potential LULUCF credits in the 1st KP commitment period are estimated to be 4 to 5 times lower than in the 2nd KP commitment period, though land use changes are not so significant. However, to compare to the EU rules as of 2018 applied, the 2nd commitment period has been less favourable in Lithuania because of optional accounting of managed cropland and grassland. Application of EU accounting rules (according to the EU Regulation 2018/841) for the EU countries also show variety of situations. It suggests that past national land use changes (during the reference period of 2005–2009), credit limits and forest reference level applied have a significant impact for the total LULUCF credit accounting, therefore it may lead to more favourable conditions for some countries and unfavourable for the others. Hence, acknowledging the EU efforts to find the balance between possible heavy emitters and forest rich countries in the accounting rules (as of 2018), hypothesis of potential “winners” and “losers” on the national level due to the LULUCF accounting rules applied can be proved (Figures 3 and 4). This

supports the previous idea of Liu et al. (2011) and Grassi et al. (2012) that LULUCF contribution to climate change mitigation depends on accounting rules. Though EU accounting rules as of 2018 cover more mandatory land use categories to account than Kyoto Protocol requirements and allow some optional accounting, estimation of forest reference level is more strictly described (Nabuurs et al., 2018). However, specifically forest management cap creates “winners” and “losers” situation according to Ellison et al. (2014). Authors argue that countries with low forest cover will benefit from the caps. Our results, the case of Lithuania and particularly example of Finland, also support this opinion. In general, countries with higher forest cover (and LULUCF potential) like Lithuania or Finland would favour more if no FRL or credits limits were applied. Scientists (Vizzarri et al., 2021; Päivinen et al., 2022) also argue, that reference period set for estimation of the reference level also might have a significant impact on the climate change mitigation potential due to limitations for forest management practices in the future, i.e. some countries may need to reduce their harvest intensity in order to maintain FRLs. The latter might influence the potential of carbon removal in the future, especially in the old forest rich countries. Hence, some countries might be losing to reach foreseen goals because of before mentioned rules’ peculiarities. Ellison et al. (2014) state that forest potential is not fully employed in LULUCF framework, suggesting incorporating all carbon pools and activities without limitations into LULUCF accounting. Nevertheless, projections on LULUCF GHG balance indicate that some countries will experience significant difficulties reaching foreseen targets for LULUCF sector in general. For e.g. Germany, based on historical data for 2010–2019, having rather significant removals in LULUCF and corresponding goals for the future, is projected to experience debits from LULUCF sector in 2030.

Though the whole picture of “winners” and “losers” cannot be captured on the single year basis, study results have several implications and rise additional issues to be pondered. Next to the abovementioned factors, one more issue that is important is methodological level (Tier) used to report GHG emission/removals. Depending on availability of country specific emissions factors or even detailed datasets for the highest accounting level (Tier 3), the accuracy of the inventory and accounting results might be quite different, i.e., level of GHG emissions/removals can differ even several times (Grassi et al., 2018a; McGlynn et al., 2022). In addition, inconsistency within accounting categories (activity based vs. land use based) and their inclusion (see Tables 1 and 2) might contribute to the results of LULUCF credit balance. For ex., emissions from drainage and use of peatlands are covered by UNFCCC reporting, but are not included into EU accounting. However, peatlands can be now optionally accounted under EU rules until 2026, afterwards accounting of this category becomes mandatory (EU 2018/841). Furthermore, recent study in Scotland (Hermans et al., 2022) shows that afforestation of previously drained peatlands and further

forest management activities can even increase soil carbon stocks due to litter input which exceed heterotrophic peat decomposition, while default reporting guidelines (Tier 1 level, IPCC 2006) still request reporting of GHG emissions due to drainage of organic soils. Hence, increasing reporting accuracy by setting reliable emission factors on the national levels and moving to higher Tier level, as well as aligning reporting and accounting rules under different mechanisms would be beneficial.

One more weak point is that the LULUCF accounting rules (2018) does not set a particular target to increase sequestration to mitigate climate change from the beginning, but only asked to maintain balance of emissions and removals from the sector. Thus, according some scientist (Nabuurs et al., 2018) sector’s importance to reach Paris agreement target might be underestimated. Though this limitation is partially eliminated in the proposed revision of the LULUCF Regulation (European Parliament and Council, 2021) setting net LULUCF GHG removal targets for all EU countries for 2030, overall losing to achieve global climate change mitigation goals should be also considered. Some scientists (Böttcher & Graichen, 2015) highlight that inclusion of the LULUCF sector as such in climate change mitigation might even lower efforts for GHG emission reduction to some extent in general. It should be also mentioned that reported national GHG emissions do not take into account consumption related emissions, and many of the impacts of imported products remain behind the EU borders (Liobikienė & Dagiliūtė, 2016). Therefore, climate change mitigation including LULUCF sector might look promising only on the national level. On the other hand, the LULUCF is given an important and challenging role. For example, Lithuania in the National Climate Change Management Agenda (2021) foresees to reduce national GHG emissions by 80%, to compare to 1990, and the remaining 20% are to be offset by LULUCF, which, from the current view of accounting rules, seems hardly achievable. 20% of GHG emissions in 1990 comprise 9.558 million t CO₂ eq. Nevertheless, introducing joint zero net emission approach in agriculture and LULUCF sectors combined after 2030 and combined AFOLU sector becoming a sink after 2035 might also rise additional challenges and should be taken into account while making corresponding decisions.

Study also provides some insights for the sector, especially forest land category, management. As a result, in countries with forests playing a significant role in GHG balance, important management issue is not only to maintain GHG sink in forest land, which is projected (EC, 2021) to decline by 11% and 14% in 2030 and 2050 respectively, but also ensure stable land-use pattern among agricultural land use categories to prevent carbon stock loss. For some countries increase of forest area coverage is essential to not only offset emissions from other sectors (e.g., agriculture), but also to comply with “no debit” rule within the LULUCF sector, especially considering increasing wood demand. Also, forest species composition, length of forest management period, etc. (Luyssaert

et al., 2008; Gurmessa et al., 2013; Galka et al., 2013; Jonard et al., 2017) may have an impact on carbon sequestration in LULUCF sector and therefore should be considered in management decisions.

One more issue to be concerned while considering LULUCF climate change mitigation potential, is to reconcile climate change and bioeconomy objectives. It is projected (EC, 2021) that wood removals from forests could increase 12.3% and 13.8% until 2030 and 2050 respectively. In addition, increasing wood demand for bioenergy purposes cannot be included under new forest reference levels (Grassi et al., 2018b; Nabuurs et al., 2018). This could contribute to the decrease of forest sink potential, though some scientist (Nabuurs et al., 2018) show increasing trend in harvest without creating debits from the sector. Jasinevičius et al. (2017) also highlight that negative impact of forest harvest could be offset, and harvested wood products carbon stock could increase in the future if there would be focus on long-life products and a decrease in export of raw wood material. The latter study notes that exported raw material is not included in reporting and thus exporting countries might be significantly underestimating carbon sinks in harvested wood products. In general, reported increase in forest harvest due to the bioeconomy needs (Ceccherini et al., 2020) is considered to be overestimated (Palahí et al., 2021), implying that managed forests are aimed at harvest cycles to increase regeneration and forest biomass (Wernick et al., 2021).

In addition, next to land use changes and policies, climate conditions and extremities (droughts, floods, pests, changes in precipitation) should be considered as significant factors. Climate change itself might challenge forest productivity, species structure and hence, sequestration potential (Walker et al., 2021; Yu et al., 2021). Therefore, there are still some additional uncertainties to be considered before relying fully on the LULUCF sector's potential for climate change mitigation, as it might change due to various factors. However, while overcoming shortcomings and uncertainties, some stability in rules would give at least some continuity and better monitoring of accountability of LULUCF credits and national GHG balances in general. Furthermore, this would be beneficial for managerial decisions for increasing mitigation potential in a long run.

Conclusions

The study indicates that there is a big difference ranging from debits to credits between countries regarding overall LULUCF impact into climate change. Forest rich countries show higher LULUCF potential to offset national emissions. However, this does not necessary turns into possibility to use this potential when accounting rules are applied. In the case of Lithuania all three types of accounting rules applied indicated different number of potential credits to be reported with the most favourable option of EU accounting rules (according to Regulation 2018/841,

revisions not included), still being much higher than the set accounting limit. Though in 2019 LULUCF sector creates 2.3 million t CO₂ eq. potential credits in Lithuania, only slightly more than one fourth of it can be accounted for climate change mitigation. Preliminary application of LULUCF accounting rules (according to Regulation 2018/841, revisions not included) for all EU member states also shows a potential of “winners” and “losers” situation due to the limits set in accounting rules itself or credit limitation set in the ESR regulation. For example, countries like Finland, with relatively big area of forested land and overall LULUCF sector as a sink might result in GHG debits from LULUCF sector. Other forest rich countries also are not benefiting, as decreasing LULUCF GHG sink in 2030 is projected for them. Germany, in reference to the GHG inventory results, might be losing also due to accounting rules peculiarities. Even more, LULUCF GHG projections for Germany as well as Latvia show that in 2030 LULUCF sector can become a source of emissions, shifting countries away from ambitious removal goals set in revised LULUCF Regulation and rising additional challenge to offset those emissions with other sectors' emission allowances. Hence, considering that there are already new revisions of accounting rules proposed after 2025 and other factors influencing LULUCF sector's carbon removal potential, at least some stability of the accounting rules should be kept, allowing countries to take proper management decisions to maintain sector as a GHG sink or at least ensure compliance with “no debit” concept.

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Authors' contributions

All authors have made substantial contributions to the conception and design of the work as well as interpretation of results provided. All authors have approved the submitted version of the manuscript.

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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