

Chapter 15

The Role of Forests in Climate Change Mitigation: The EU Context



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Abstract The European Union (EU) aims at reaching carbon neutrality by 2050. Within the land use, land-use change, and forestry (LULUCF) sector, forestry will contribute to this target with CO₂ sink, harvested wood products (HWP), and use of wood for material or energy substitution. Despite the fact that the forest sink currently offsets about 9% of the total EU GHG emissions, evaluating its future mitigation potential is challenging because of the complex interactions between human and natural impacts on forest growth and carbon accumulation. The Regulation (EU) 2018/841 has improved robustness, accuracy, and credibility of the accounting of GHG emissions and removals in the LULUCF sector. For the forest sector, the accounting is based on the Forest Reference Level (FRL), i.e., a projected country-specific value of GHG emissions and removals against which the actual GHG emissions and removals will be compared. The resulting difference will count toward the EU GHG target for the period 2021–2030. Here, we provide an overview of the contribution of forests and HWP to the EU carbon sink for the period 2021–2025 (proposed FRLs) and focus on the contribution of mountain forests to the EU carbon sink, through exploring co-benefits and adverse side effects between climate regulation and other ecosystem services.

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15.1 Mitigation from EU Forests: Policy Context

The EU is at the forefront in implementing climate policies aiming at mitigation over the medium and long term. In order to contribute to maintaining the global temperature rise well below 2 °C above preindustrial levels (Paris Agreement¹), in 2015, the EU committed to reduce GHG emissions by at least 40% by 2030 compared to 1990.² Since then, the EU has set out several climate policies and strategies to meet this target and is now preparing to increase its climate ambition, i.e., through further reducing emissions in 2030 (by –50%/–55% compared to 1990³) and moving toward reaching climate neutrality (i.e., a net balance between GHG emissions and removals) by the middle of this century. In particular, the European Green Deal (COM(2019) 640⁴) and the proposal for an EU Climate Law (COM(2020) 80⁵) are setting the basis for a comprehensive new climate legislative framework.

The LULUCF sector⁶ – including mainly GHG fluxes from forests and wetlands and CO₂ fluxes from cropland and grasslands – plays a key role in mitigation. In particular, EU forests and harvested wood products (HWP) contribute to climate change mitigation by removing about 9% of the total GHG emissions from the atmosphere, which mainly originate from energy, transport, and agriculture sectors (EEA 2020). The mitigation potential of EU forests – which cover about 36% of European land area – refers to both their capacity to accumulate/release carbon during forest stands' development and the use of HWP for bioenergy purposes or material substitution. This not only is a result of recent mitigation actions but also derives from the legacy effects of historical management activities and external environmental changes (Grassi et al. 2019). Moreover, the effectiveness of these actions also depends on the uncertain effects from other human and natural perturbations, such as land-use changes, forest degradation, natural disturbances (Seidl et al. 2014), and climate change (Kirilenko and Sedjo 2007).

Given the difficulty in disentangling the natural and the anthropogenic contribution to the net GHG fluxes in the LULUCF sector – and especially on forests – a distinction had been applied between the *reporting* of current net emissions and the *accounting* of the impact of human activities on net emissions. The *reporting* refers to the implementation of standardized methodologies and approaches to describe all GHG exchanges between managed lands and the atmosphere (IPCC 2019). The

¹ https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

² https://ec.europa.eu/clima/policies/strategies/2030_en#tab-0-0

³ <https://www.euractiv.com/section/climate-environment/news/environment-agenda-eu-climate-talks-enter-decisive-phase/>

⁴ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019DC0640>

⁵ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020PC0080>

⁶ The LULUCF sector includes the following categories: forest land, cropland, grassland, wetlands, settlements, other lands, and HWP (IPCC 2019).

accounting concerns the implementation of specific policy-agreed rules to evaluate the impact of anthropogenic activities for the climate mitigation targets (Krug 2018).

The Regulation (EU) 2018/841⁷ (hereafter “LULUCF Regulation”), adopted in May 2018, aims to make the accounting in the LULUCF sector more credible and comparable to other sectors. To this aim, any change in policy/management compared to a base period (e.g., for cropland and grassland) or to an agreed benchmark (for forests) will be reflected in the accounting of future GHG emissions and removals (Grassi et al. 2018). For managed forest land, the LULUCF Regulation requires EU Member States (MS) to define national Forest Reference Levels (FRLs), i.e., the benchmark against which future forest emissions and removals will be compared to for accounting purposes. The FRL represents the projected average net GHG emissions in the periods 2021–2025 and 2026–2030 (i.e., first and second compliance period, respectively) based on the impact of management practices as documented in the period 2000–2009 (i.e., reference period, RP) on the evolution of age-related forest characteristics. This approach is based on (i) a transparent documentation of historical country-specific forest management practices (e.g., harvest intensity), (ii) the simulation of forest stands’ development based on continued management practices and future evolution of age structure, and (iii) the exclusion of assumed policies and other influences from the market (Grassi et al. 2018). Based on this, MS will generate credits – if net emissions are lower than the proposed FRL – or debits, if net emissions are higher than the proposed FRL. The credits generated by the LULUCF sector can then contribute to reaching the targets in other sectors, up to a limit of 280 Mt CO_{2e} at EU scale for the period 2021–2030, while any LULUCF debits shall be compensated by extra emission reductions in other sectors. Credits generated on managed forest land (without considering dead wood and HWP) are capped at 3.5% of the total GHG emissions in the base year from all sectors excluding LULUCF. The LULUCF Regulation also introduces an internal flexibility mechanism, through which any removals exceeding this threshold in the first compliance period (2021–2025) can be transferred to the second compliance period (2026–2030) or to other MS that report debits, without affecting the overall target set at EU level.

In the next sections, we discuss the contribution of forests and HWP to the EU carbon sink in the period 2021–2025, with a particular focus on the mitigation potential of mountain forests.

15.2 Forest Reference Levels in EU

Article 8 of the LULUCF Regulation (and its Annex IV) lays down the accounting rules for managed forest land and includes principles and criteria to be followed in the determination of the FRL as well as the elements to be included in the National

⁷https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.156.01.0001.01.ENG

Forestry Accounting Plans (NFAPs). The NFAP is a report submitted to the European Commission (EC) and made public by individual MS, which contains the FRL value including the considered pools and gases, a description of the approaches and methods used for its determination, qualitative and quantitative information on forest management practices and intensity, adopted national policies, and historical and future harvesting rates.

MS submitted the draft NFAPs including the FRLs to the EC in December 2018. Based on the proposed FRLs as in the draft NFAPs and the feedbacks from an expert group,⁸ the EC issued technical recommendations to MS (SWD (2019) 213⁹). Based on recommendations, as well as on the outcomes of several bilateral meetings and an additional expert group meeting, MS submitted the revised NFAPs including the FRLs to the EC between the end of 2019 and the beginning of 2020. The EC performed an in-depth assessment of the revised NFAPs and proposed FRLs between February and June 2020. In October 2020, the EC adopted the delegated act (C(2020) 7316¹⁰) reporting the FRLs to be applied by MS in the period 2021–2025 (see Table 15.1).

The projected EU forest sink (sum of individual MS' FRLs) in the period 2021–2025 is about 337 million tons CO₂e year⁻¹ including the contribution from HWP, which corresponds to about 13% of the total.

MS made a considerable effort to implement robust and in some cases complex modelling approaches to simulate the evolution of the forest sink with regard to age-related dynamics, especially considering the living biomass pool (Korosuo et al. 2021; Vizzarri et al. 2021). This means that MS incorporated the dynamics of age-related forest characteristics (area, standing volume, increment) in the FRL simulation, excluding any additional influence from policy or market mechanisms. This is the main difference with respect to the Forest Management Reference Level developed under the Kyoto Protocol.¹¹ To prove that the FRLs have been built on data and information that accurately reflect the national circumstances, MS also provided additional documentation of their management practices – including harvest intensity – as implemented in the period 2000–2009, as well as a demonstration of their continuation within the compliance period. According to the

⁸The LULUCF Expert Group was established on 30 October 2018 and consisted of individuals appointed in their personal capacity, members from research institutions and non-governmental organizations, MS representatives, members from other public entities and third countries' authorities, and observers. Activities and other information about the LULUCF Expert Group are available at <https://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=3638>.

⁹<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52019SC0213>

¹⁰EC (European Commission). Commission Delegated Regulation (EU) ... of 28.10.2020 amending Annex IV to Regulation (EU) 2018/841 of the European Parliament and of the Council as regards the forest reference levels to be applied by the Member States for the period 2021–2025. [C(2020)7316] [Internet]. Available from: https://ec.europa.eu/clima/sites/clima/files/forests/docs/c_2020_7316_delegated_regulation_en.pdf

¹¹<https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf/forest-management-reference-levels>

Table 15.1 Forest Reference Levels including HWP for the period 2021–2025

Member State	Forest Reference Levels including HWP (2021–2025) [t CO ₂ e yr ⁻¹]
Belgium	–1,369,009
Bulgaria	–5,105,986
Czech Republic	–6,137,189
Denmark	354,000
Germany	–34,366,906
Estonia	–1,750,000
Ireland	112,670
Greece	–2,337,640
Spain	–32,833,000
France	–55,399,290
Croatia	–4,368,000
Italy	–19,656,100
Cyprus	–155,779
Latvia	–1,709,000
Lithuania	–5,164,640
Luxembourg	–426,000
Hungary	–48,000
Malta	–38
Netherlands	–1,531,397
Austria	–4,533,000
Poland	–28,400,000
Portugal	–11,165,000
Romania	–24,068,200
Slovenia	–3,270,200
Slovakia	–4,827,630
Finland	–29,386,695
Sweden	–38,721,000
United Kingdom	–20,701,550
EU-28	–336,964,579

Source: Annex to C(2020) 7316

https://ec.europa.eu/clima/sites/clima/files/forests/docs/c_2020_7316_annex_en.pdf

LULUCF Regulation, MS should also ensure the consistency between modelled estimates and estimates reported in their GHG inventories or other historical information (e.g., from National Forest Inventories or statistics). In some cases, however, ensuring the consistency between the model outcomes and the GHG inventory for the period 2000–2009 was challenging. Indeed, this exercise required an additional model run that shows that the model can reproduce GHG inventory data for the period 2000–2009.

The overall forest sink at EU level (including HWP) as set within the FRL offers an overview of the mitigation potential of EU forests in the near future (Fig. 15.1).

If compared to GHG inventory estimates for the period 2000–2009 (submission 2020), the FRL estimates a 22% reduction of the forest C sink. The reduction of the

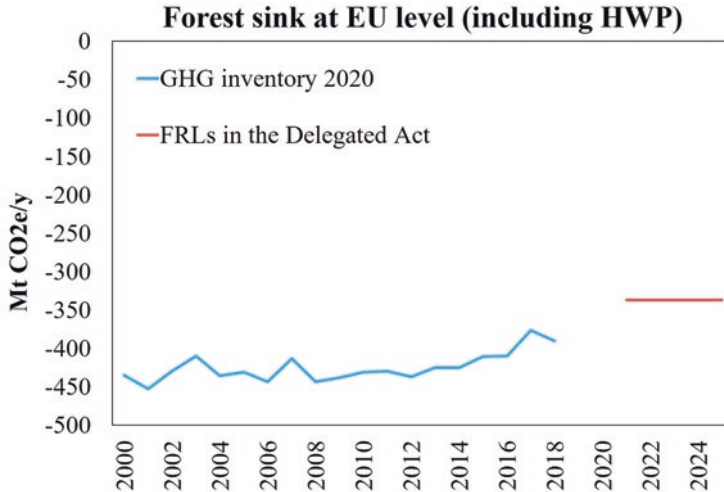


Fig. 15.1 Evolution of the EU forest sink (including HWP) in the period 2000–2025 based on different data sources and projections: EU GHG inventory (submission 2020) for the period 2000–2018 (solid blue line); FRLs in the Delegated Act (C(2020) 7316) (see Table 15.1) (solid red line). Values are in million tons CO₂e yr⁻¹

C sink largely depends on the effects of age-related dynamics and forest management (see also Grassi et al. 2018). The robustness of the FRLs is supported by independent analysis by Forsell et al. (2019), who, using similar assumptions as those underlying the MS FRLs, reached an estimate of similar magnitude.

15.3 Trade-Offs Between Climate and Other Forest Services: The Case of EU Mountain Forests

The mountain forests cover about 40% of the total forest area in the EU+27 UK (see Fig. 15.2 and detailed calculation in Box 15.1). The mountain forests in EU 27+UK provide a number of benefits to people, which encompass the provision of wood and non-wood products, regulation of climate, mediation of extreme events, conservation of biodiversity and habitats, and preservation of cultural features and aesthetics (Egan and Price 2017). Despite their multifunctional role, productivity and resilience of mountain forests are increasingly undermined by several ecological and socioeconomic factors, ranging from susceptibility to extreme climate events (e.g., avalanches, floods, landslides, windstorms, drought) to social segregation and low attractiveness for economic investments (Vizzarri et al. 2017). It is, therefore, extremely important to explore the relationships between mountain forests' services in terms of synergies and trade-offs (e.g., Rodríguez et al. 2006), as well as to understand the main drivers altering the ecosystem services' bundle, especially in mountain environments (e.g., Briner et al. 2013).

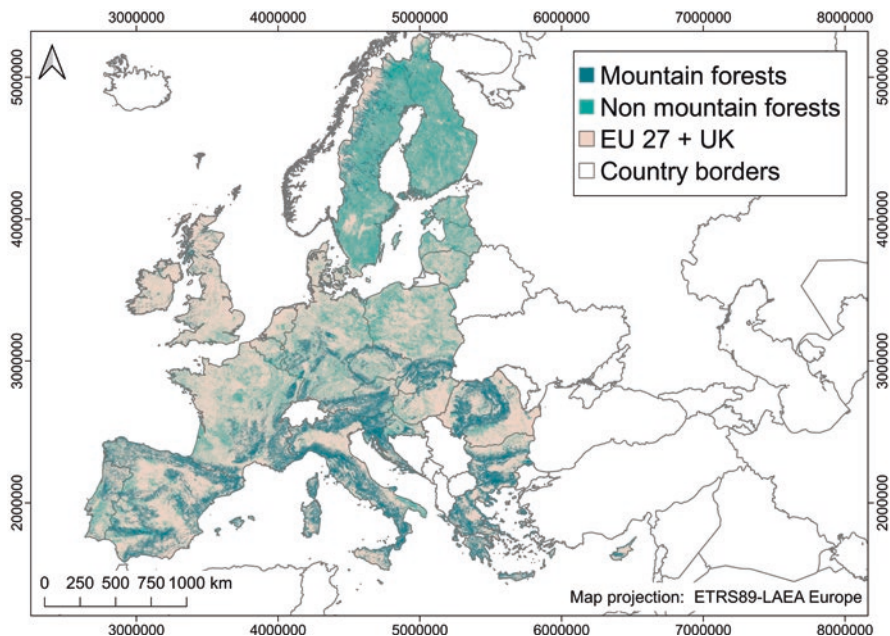


Fig. 15.2 Mountain/non-mountain forests in EU 27 + UK. See Box 15.1 for detailed explanation of mountain forests mapping

The mountain forests in the EU 27+UK contribute to remove about 127 million tons CO₂ from the atmosphere – forming about 35% of the total forest carbon sink (2015 value) (see Table 15.2 and detailed calculation in Box 15.1). If only forests located in high and scattered high mountains were considered (37% of the total mountain coverage; Sayre et al. 2018), CO₂ removals would be slightly more than 47 million tons (or about 13% of the total carbon sink; 2015 value). Hence, the major contribution to the total C sink comes from forests located in low and scattered low mountains, i.e., between 300 and 900 m a.s.l. with a slope > 50% (Sayre et al. 2018). The elevation range combined with a relatively ample forest extent at national scale may explain a larger contribution to the total C sink from mountain forests located in countries overlapping the most important massifs in Europe, such as the Alps and Apennines (more than 37% of the sink from Italy, Germany, and France), Pyrenees (15% of the sink from Spain), and Balkans (8% of the sink from Romania).

Within the European context, mountain forests are probably the best example of the complex, and sometimes competitive, interactions between different forest functions, spatial scales, and human activities (Fig. 15.3).

The economic revenues from forest resources are in most cases the key function attributed to forest land, above all in mountain areas. Here, this function is clearly “scaled” at local level, since forest management is based on activities and planning strategies which have a small scale and direct impact on local communities, through

Table 15.2 CO₂ emissions and removals in mountain forests in the EU 27+UK

Member State	Share of mountain forest cover [percentage of total forest cover]	CO ₂ emissions (+)/removals (-) in mountain forests (t CO ₂)
Belgium	0.09	-80,711
Bulgaria	0.83	-4,293,943
Czech Republic	0.51	-2,152,393
Denmark	0.00	
Germany	0.31	-17,557,365
Estonia	0.00	
Ireland	0.48	-504,541
Greece	0.97	-1,385,956
Spain	0.76	-22,055,007
France	0.42	-16,716,235
Croatia	0.65	-2,370,456
Italy	0.89	-20,565,547
Cyprus	0.91	-126,578
Latvia	0.00	
Lithuania	0.00	
Luxembourg	0.10	-34,079
Hungary	0.28	-1,137,033
Malta	0.00	
Netherlands	0.00	
Austria	0.86	-2,209,965
Poland	0.10	-2,283,392
Portugal	0.50	-4,323,900
Romania	0.79	-12,222,014
Slovenia	0.93	+823,697
Slovakia	0.91	-3,356,676
Finland	0.01	-434,988
Sweden	0.14	-6,480,554
United Kingdom	0.40	-7,290,015
EU 27+UK	0.40	-126,757,652

See Box 15.1 for methodology, data, and limitations

the economic and social benefits (i.e., on employment) provided by forest products (Pilli and Pase 2018). Within this context, carbon sequestration and timber provision have both synergies and trade-offs, depending on the management strategies (Gusti et al. 2020).

An increase in timber provision (i.e., harvesting rates) induces a temporary reduction of the standing volume at least at local level and in turn a relative reduction of the carbon stock and sink in aboveground living biomass. For this reason, several authors found that carbon sequestration rates in the short term (e.g., few decades) are higher under unmanaged scenarios (e.g., Mina et al. 2017). At the same

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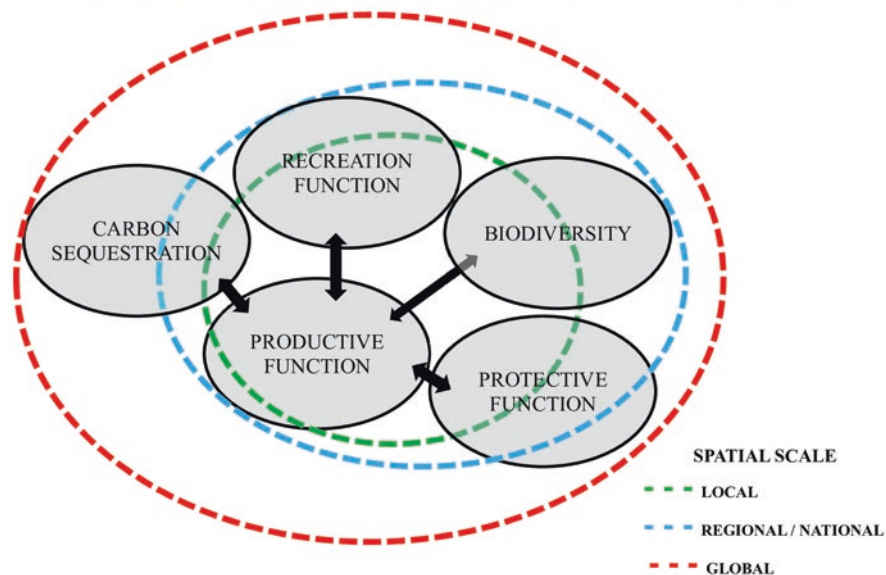


Fig. 15.3 Spatial scale (local, regional (or national), and global) and overall interactions between the main functions provided by forests (see the text for further information)

time, a shift in developmental stage toward younger forests (<140 years) due to changes in management regimes or land use may increase the carbon sink in living biomass in the medium to long term (Pugh et al. 2019). If properly balanced at regional or national level, however, an appropriate mixture of adaptive forest management strategies can be a means to both ensure sustainable timber provision and maintain or even enhance the forest carbon sink (Gusti et al. 2020). The positive effects of timber provision on carbon sequestration (in the medium term) are amplified if all pools (including their interactions) are considered. Indeed, timber also contributes to store carbon through the HWP pool, especially if in long-lived products. This adds to the mitigation impact arising from using wood products for substituting energy-intensive materials (e.g., steel, cement) and fossil fuel energy (Jonsson et al. 2021). For example, the management of coppice forests in mountain regions ensures on the one hand economic and social benefits, including the use of wood for energy purposes, and on the other hand is an alternative and partially in competition with carbon sequestration in HWP and the subsequent benefits for material substitution (Pilli and Pase 2018). Despite all these activities being carried out at local level, their effect on the carbon balance is generally accounted at national level, and, through the atmosphere, they have a direct impact on the overall carbon balance at global level.

Carbon sequestration and other services, such as biodiversity, progressively reduce while increasing the management intensity, i.e., from non-intervention to

business as usual (Mina et al. 2017). Indeed, carbon sequestration positively correlates with biodiversity in mountain areas with low accessibility and less-intense management regimes (e.g., Lecina-Diaz et al. 2018). Isolated forests, often mountainous, are characterized by high density and diverse structures, and large amounts of deadwood, and in turn by higher carbon stocks and more species and habitats (Burrascano et al. 2013). The carbon-biodiversity relationship may be weak and vary across spatial scales and taxonomic groups, e.g., higher plant competition for light in denser forest stands (e.g., Sabatini et al. 2019). A change in the landscape pattern, for example, through clearcuts and other harvesting activities, may also affect the forest benefits for recreation, especially in mountain sites with a touristic vocation or in biodiversity-rich sites. In the latter case, the direct effect of management activities at landscape scale may add up to a broader interaction, for example, with the home range of big mammals, such as wolves, lynxes, and bears, mostly living in mountain territories, at least in Europe. The harvesting activities can reduce tree cover, limit soil protection, and in turn negatively influence the protective functions from forests, especially in mountain regions (Thees and Olschewski 2017). Such negative impact is exacerbated at a larger spatial scale, where management activities interact with the hydrological cycle (Sun and Vose 2016). Natural disturbances heavily impact carbon sequestration in forests (e.g., Thom and Seidl 2016). Storms, avalanches, insect outbreaks, and fires (in terms of their frequency, severity, and unpredictability) threaten the resilience and stability of mountain forest landscapes and inherently affect their carbon sequestration potential (e.g., Kulakowski et al. 2017). In particular, natural disturbances have negative effects on carbon uptake through reducing forest cover and subsequently living biomass, changing species composition, altering the carbon flows among pools and between the pools and the atmosphere (Pilli et al. 2016). Nevertheless, the effects of climate on ecosystem services (in particular carbon storage and biodiversity) in European mountain forests fluctuate over time and largely depend on site-specific characteristics, such as species composition and susceptibility to climate-related extreme events (e.g., drought), elevation, and topography (Mina et al. 2017).

15.4 Final Remarks

The EU is committed to reach climate neutrality by the middle of this century. Beyond expected contributions from the energy and transport sectors, the forest sector can also contribute to this target through carbon uptake in living biomass, dead organic matter, forest soils, and harvested wood products. However, the forest mitigation potential is driven by coupling age-related dynamics (growth rates, competition, and developmental stage) with management intensity, land-use change (land abandonment and forest regrowth), and severity and frequency of natural disturbances, whose effect may be exacerbated by climate in the long run. Therefore, the mitigation actions need to incorporate the expected response of forest carbon sink to external perturbations. On the policy side, the LULUCF Regulation poses the

Box 15.1: Calculation of CO₂ Emissions and Removals in EU Mountain Forests

Determination of the mountain forest area. The coverage of mountain forests in EU 27 was determined in QGIS 3.14™ by clipping the Copernicus High Resolution Layer (HRL) “Forest Type” (year 2015)^(a) with the high resolution map of mountain areas (year 2010) by Karagulle et al. (2017)^(b). The outcome of this process is a raster layer with 20 m spatial resolution of mountain forests for EU 27 + UK (MFA). The area of mountain forests [ha] was determined for each of the EU 27 MS + UK (hereafter country) by dividing the number of pixels by 10,000 [m²]/400 [m²] = 25.

Calculation of CO₂ emissions and removals. To determine the CO₂ emissions and removals in mountain forest areas for each MS, Eq. [15.1] was used:

$$ER_{(\text{mountain},i)} = w_i ER_{(FL-FL,i)} \quad (15.1)$$

where: $ER(\text{mountain}, i)$ is the value of net CO₂ emissions and removals in mountain forest areas in the i -th country (tons CO₂), w_i is the ratio between the mountain forest area in the i -th country (derived from MFA) and the total forest area in the i -th country (derived from HRL) (dimensionless), and $ER(FL-FL,i)$ is the value of net CO₂ emissions and removals related to forest land remaining forest land (FL-FL) as reported for i -th country in the Common Reporting Format (CRF) Table 4 submitted to UNFCCC in 2020 for the inventory year 2015 (tons CO₂)^(c).

The CO₂ emissions and removals in mountain forest areas for each country were then corrected [range between -0.31 and 0.11] to reflect the area consistency with FAOSTAT^(d).

Limitations. This calculation of CO₂ emissions and removals is proportional to the total area of forest land in each country, and therefore does not take into account forest stands (age structure, species composition) and site characteristics (soil moisture, temperature, precipitation), land use (forest management and land-use change) and other drivers (e.g. natural disturbances) that may determine a spatial differentiation of the forest carbon sink at a finer scale than national.

- (a) Available online at <https://land.copernicus.eu/pan-european/high-resolution-layers/forests/forest-type-1/status-maps/2015>. Conifers and broadleaves classes were combined.
- (b) Available online at <https://rmgsc.cr.usgs.gov/outgoing/ecosystems/Global/>. High and scattered high (>900 m a.s.l.), and low and scattered low (301–900 m a.s.l.) mountains classes were merged to obtain a unique thematic class.
- (c) Available online at <https://unfccc.int/ghg-inventories-annex-i-parties/2020>.
- (d) Available online at <http://www.fao.org/faostat/en/#data/GF>.

basis for a credible and robust accounting system to ensure that the mitigation efforts in the forest sector are comparable to those in other sectors. Within this framework, the FRLs for the EU 27+UK already ensure that mitigation efforts will be compared against a robust benchmark that is based on the projected evolution of the forest sink, resulting from the impact of historical management on the future development of age-related forest characteristics. Such approach allows to not penalize countries, which will have a reduced sink purely due to age-related effects but will instead account for any additional impact from changes in policies (Grassi et al. 2018). On the management side, the forest mitigation potential in the EU can be enhanced by fostering resilience and adaptation, especially in fragile mountain environments, which increasingly suffer from land abandonment and susceptibility to extreme climate events, and properly balancing alternative management strategies (Gusti et al. 2020). For example, improved forest management, reforestation and forest restoration, and climate-smart forestry have large positive potentials for both mitigation and adaptation from forest ecosystems (Nabuurs et al. 2017; Bowditch et al. 2020; Smith et al. 2020). However, it is important to consider that the forest mitigation potential strongly varies across spatial and temporal scales. Forest management practices that are well-tailored to local circumstances and requirements are preferable in order to maximize the win-win combinations of forest ecosystem services, beyond carbon sequestration (e.g., Vizzarri et al. 2015). Advanced modelling tools (e.g., Shifley et al. 2017) and remote sensing techniques (e.g., Ceccherini et al. 2020) may allow policy-makers, forest managers, public administrators, and other stakeholders to provide evidence-based support to national policies and planning strategies toward mitigation targets.

Disclaimer The views expressed are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission or any other Government Agency.

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