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Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Exploratory Analysis of an EU Sink and Restoration Target

Berlin, 18.03.2021

Commissioned by Greenpeace Germany

Authors

Dr. Hannes Böttcher
Judith Reise
Dr. Klaus Hennenberg
Oeko-Institut e.V.

Contact
info@oeko.de
www.oeko.de

Head Office Freiburg
P. O. Box 17 71
79017 Freiburg

Street address
Merzhauser Straße 173
79100 Freiburg
Phone +49 761 45295-0

Office Berlin
Borkumstraße 2
13189 Berlin
Phone +49 30 405085-0

Office Darmstadt
Rheinstraße 95
64295 Darmstadt
Phone +49 6151 8191-0

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1 Motivation and aim of the report

In September 2020 the European Commission (EC) proposed to increase the 2030 greenhouse gas (GHG) emission reduction target to at least -55 % compared to 1990 levels. While the EU policy framework originally excluded the land use sector, the proposal includes now the full scope of GHG emissions and carbon removals. According to the European Commission, the target forms an interim goal **towards a climate-neutral EU** and updates its Nationally Determined Contribution (NDC) under the Paris Agreement. However, the European Parliament demanded a more ambitious target of 60 % emission reduction [1], while scientific evidence also indicates that the current EU target does not meet the commitments required under the Paris Agreement. According to projections by CAN (2020) a 65 % emission reduction target would be required to close the gap, together with an additional increase in voluntary climate funding to address the historic responsibility.

Carbon sinks have become more relevant with the Paris Agreement that sets the target of "*holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*" by rapid reductions in GHG emissions and finally achieving "*a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of this century*". **The only sector providing options for natural carbon sinks is the sector on Land Use, Land Use Change and Forestry** (LULUCF). Carbon sinks are created by biomass growth and the long-term storage of carbon in vegetation, soils and products. However, the sector accounts also for carbon emissions from biomass use, land conversion and vegetation removal. Moreover, the sector suffers from drastic climate and environmental change, potentially leading to reduced rates of carbon uptake and increased emissions. **A contribution to the balance of emissions and removals as anticipated by the Paris Agreement can only be achieved through a long-term overall net negative carbon balance of the land sector.** The inclusion of the full scope of anthropogenic emissions and removals into the -55 % GHG reduction target implies the need for a net carbon sink target for this sector. If left undefined, it would be determined by the degree of GHG emission reductions to be achieved in other sectors and remaining emissions in 2030.

In 1990 the net sink in EU27 amounted to 275 Mt CO_2/year (EU 2020). In 2006 the net removals of carbon by the sector peaked at 355 Mt CO_2/year and have since then been declining to again 280 Mt CO_2/year in 2018. In the scope of the -55 % target, the sector has been included into the base year 1990. Since the net sink is still of similar size compared to 1990, this implies that emission reductions by other sectors need to be even less than -55 % to achieve the overall target. Instead, if all sectors achieved a -55 % emission reduction compared to 1990, the sink could even be reduced to 124 Mt CO_2/year, still meeting the EU target and counteracting the necessary enhancement of the sink towards 2050 for meeting a global 1.5°C target. The risk for environmental integrity by integrating LULUCF into the overall target calls for an even more ambitious overall target (far beyond -55 %) to compensate for a decreased ambition level due to this integration. Moreover, the LULUCF sector needs to have a separate target for ensuring that land-based emissions are reduced, sinks are maintained or enhanced where possible.

In the Impact Assessment accompanying the 2030 Climate Target Plan, the EC discussed options for changes to the treatment of LULUCF emissions and removals that are currently handled by the LULUCF Regulation (EU) 2018/841 and opportunities for increasing the sink. **The rules for accounting emissions and removals of the sector is crucial for providing incentives to**

[1] Press release: EU climate law: MEP want to increase 2030 emissions reduction target to 60 %

Member States (MS) to implement management changes but also for ensuring environmental integrity of the overall emission reduction target.

If these rules are designed wisely and transparently and interchangeability of fossil and biogenic carbon is prohibited to the degree necessary to ensure environmental integrity, there is the scope and the opportunity for defining a net sink target for managed land that supports adaptation needs in the sector and addresses requirements for the protection and restoration of biodiversity. Hence, realizing the net sink target is directly linked to the implementation of restoration and protection of carbon rich ecosystems and should therefore be defined as a combined net sink and restoration target.

In a public consultation[2] in early 2021, the EC looked for stakeholder input on the revision of the LULUCF Regulation. **This paper presents a short exploratory analysis that discusses important elements for a separate EU land net sink and restoration target that defines a realistic net sequestration potential within the EU and rules that incentivise the achievement of such a target. This should be aligned with adaptation needs and existing EU biodiversity and ecosystem restoration targets and regulations - including the EU Biodiversity Strategy.**

2 Scientific background

2.1 What is the role of natural sinks in the global carbon cycle?

Carbon is constantly exchanged among the main global carbon pools, the atmosphere, the oceans and terrestrial systems which is known as carbon fluxes comprising the global carbon cycle. The carbon circulation appears on very different timescales from sub-daily to millennia and even much longer considering exchanges with geologic reservoirs (Archer et al. 2009). The burning of fossil fuels, deforestation and other land-use change activities release CO_2 emissions in a very short time compared to the rather long time of carbon sequestration in stable pools. Natural carbon sinks are essential for decreasing the CO_2 concentration in the atmosphere by storing carbon in chemical compounds by photosynthesis or absorption through pressure differences for an indefinite time (IPCC 2013). Today terrestrial and marine ecosystems remove half of all anthropogenic emissions globally (Friedlingstein et al. 2019) by biomass growth and storage and mineral compounds as well as geological formations.

The aim of the Paris Agreement of balancing emissions and removals by 2050 can only be achieved if emissions are cut drastically and natural sinks are restored on a large scale. **A net sink to compensate for remaining emissions that cannot be avoided needs to be long-term, of high permanence and contributing to overall environmental integrity.** Long-term carbon storage is the main challenge to maintain and increase the net sink potential in forests, wetlands and soils and includes both: **promoting long-term carbon sequestration and thereby enhancing the duration of carbon storage in biomass and soil pools as well as reducing emissions from those in the short-term.**

[2] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12657-Land-use-land-use-change-and-forestry-review-of-EU-rules/public-consultation

2.2 What types of carbon pools exist and what is their current state to act as natural sinks?

The main physical pools of the terrestrial system in Europe are **above- and below-ground living biomass, litter** and **dead wood** as well as **soil organic carbon (SOC)** in organic and mineral soils in different land use categories, such as forests, agricultural land or settlements.

Forests store carbon in their living biomass that can have a long lifetime depending on the tree species, biogeographic region and occurrences of disturbances like fire or insect calamities. The EU27+UK forests cover 167 Mha (EU 2020) with a carbon stock of 9.8 Gt C in living biomass, which is 36 % of the total forest carbon pool in 2020 (FOREST EUROPE 2020). The decomposition of litter and deadwood can take decades forming a share of 10 % in the carbon pool of EU forests (FOREST EUROPE 2020). Not all carbon from litter and deadwood decomposition is completely released to the atmosphere. It is also stored in the forest soil as SOC, which in its stable fraction is also known as humus. The forest soil has the highest share in the EU forest carbon pool of 54 % (FOREST EUROPE 2020).

Harvested wood products (HWP) can also store carbon but cannot sequester it. Therefore, they are not considered as carbon sinks. However, they form a carbon pool that is closely connected to the pool in living forest biomass. Harvest of biomass reduces the living biomass pool but moves carbon partly to the HWP pool. The amount of carbon stored in HWPs depends on the allocation pattern of the harvested wood to wood product types. In 2018, the EU27+UK net storage through HWP was 12 Mt C (-44.6 Mt CO_2), i.e. the stock of carbon in HWP increased in most MS (FOREST EUROPE 2020; European Union 2020).

Globally, **soils** store more carbon than all the vegetation and the atmosphere combined (Friedlingstein et al. 2019). A total storage of organic carbon for the EU27+UK topsoil (0-30 cm) is estimated to be 73 Gt C. About 50 % is located in peatlands and under forests and 22 % under agricultural soil, of which around 13 Gt C can be found in cropland and 8 Gt C in grassland (pasture) (Jones et al. 2005). In the EU27+UK, mineral soils mainly occur under forests (154 Mha), cropland (123 Mha) and grasslands (89 Mha). Soil carbon stocks are mainly influenced by the type of management. A study by Hiederer (2018) showed that SOC under permanent crops is lowest (16 g/kg) compared to long-term cultivated land (17 g/kg) and permanent grassland (44 g/kg). Under natural vegetation SOC is more than doubled (90 g/kg) compared to agricultural management.

Organic soils mainly occur in wetlands (EU27+UK: 16.3 Mha) and can store carbon very efficiently because under water saturation the production of biomass (e.g. peat) exceeds its decomposition. Organic soils are often also referred to as peatlands (Joosten 2009). In Europe organic soils store four to five times more carbon than forests and about half of Europe's total SOC (Swindles et al. 2019). However, under cultivation, organic soils are often drained which causes high GHG emissions from these areas. About 4.1 Mha of organic soils are under agriculture or grassland management in the EU27+UK (EU 2020) which can be considered as drained (Schils et al. 2008). Therefore, after Indonesia the EU is the second largest emitter of GHG emissions from drained peatlands (van Akker et al. 2016).

Important **marine carbon pools** in Europe are coastal ecosystems like saltmarshes and seagrass meadows that store carbon in plant biomass and especially in their sediments along the European coastline. Globally coastal ecosystems cover approximately 2 % of the ocean area, but account for about 50 % of the carbon that is sequestered in ocean sediments (IUCN 2017). Coral reefs, kelp and

marine fauna are important parts of the marine carbon pool but are most likely not involved in the long-term carbon sequestration (Howard et al. 2017).

2.3 What are risks associated with carbon pools?

The **main pressures** to Europe's carbon pools are **intensive land management practices** and the **conversion of carbon-rich ecosystems**, mainly by drainage of organic soils, deforestation as well as an **increasing expansion of settlements and infrastructure**.

Climate change and natural disturbances also affect plant growth and decomposition processes and therefore influence the ability of ecosystems to store carbon in the long-term. Natural disturbances such as storms, fires, droughts, snow (abiotic disturbances), insects and pathogens (biotic disturbances) are an integral part of most ecosystems. However, due to climate change, especially abiotic disturbances are more likely to increase in frequency and intensity (Seidl et al. 2017; IPCC 2019). In European **forests**, wind and drought are major drivers of natural disturbances that facilitate additional biotic disturbances like bark beetle outbreaks (Seidl und Rammer 2017). Seidl et al. (2014) estimated that the carbon storage potential of Europe's forests could be reduced by 180 Mt CO_2 annually in 2021 to 2030 due to disturbances and thus reduce the expected net forest sink by more than 50 %. In 2018 to 2020, mainly spruce trees suffered from storms and droughts followed by bark beetle outbreaks in Germany. The actual extent of the calamities has not been officially documented yet, but estimates show that the disturbances covered an area of approximately 285.000 ha [3]. Hence, emissions of 113 Mt CO_2 from affected spruce forests could occur. Reported data for Portugal and Italy showed a drastic reduction of carbon storage by forests in 2017 when severe wildfires affected both countries (EU 2020). While the net sink in Italy was reduced by 40 % compared to previous years, the sink switched into a source of similar magnitude for Portugal. The net sink reduction in both countries was in total 23 Mt CO_2 for that year.

Climate change can also have long-term effects on the productivity of ecosystems in Europe. Especially changing precipitation patterns have strong influence particularly in the steppe region of South-eastern Europe [4]. In the long-term, it is expected that increased microbial activity leading to faster decomposition (Davidson und Janssens 2006) and increased disturbances reduce the overall ability of long-term carbon storage in EU ecosystems (Reyer et al. 2017; Seidl und Rammer 2017). In **wetlands,** fluctuations of carbon sequestration can occur during dry summers and when water levels decrease. A change in vegetation cover after the drying of natural peatlands, e.g. towards sedges, can increase methane emissions and further change the hydrology leading to peat decomposition (Swindles et al. 2019).

However, most carbon pools and their related ecosystems in the EU are currently destroyed, degraded or under threat due to **unsustainable land management** (IPBES 2019; IPCC 2019; EEA 2020). According to the latest report of the European Environmental Agency (EEA 2020), only 15 % of the habitat assessments show a good conservation status, while about 45 % show a poor and 36 % a bad conservation status. Especially coastal habitats are in a bad state as well as peatlands (more than 50 %) and grasslands (49 %). Forests also show mainly poor to bad (total 80 %) conservation conditions in 2018 (EEA 2020). Ceccherini et al. (2020) recently reported an **increase in the forest harvest rate** for Europe, which is an important driver of decreasing carbon stocks in forest biomass. The negative impact on the climate is additionally increased when forest biomass is

[3] https://www.bmel.de/DE/themen/wald/wald-in-deutschland/wald-trockenheit-klimawandel.html
[4] https://www.eea.europa.eu/data-and-maps/indicators/land-productivity-dynamics/assessment

mainly used for bioenergy purposes, instead of long-lived products like construction wood (Rüter et al. 2016).

Also, about 45 % of **mineral soils** in Europe have a low or very low organic carbon content (0 – 2 %) due to unsustainable agriculture practice that leads to erosion and loss of soil carbon stocks (JRC 2012). Additionally, about half of the **peatlands** in Europe are degraded by drainage and agricultural management (Tanneberger et al. 2021), which causes about 100 Mt CO_2 emissions representing 74 % of the emissions in the total EU LULUCF sector (European Union 2020).

Therefore, an increasing effort has to be put into the sustainable management, protection and restoration of ecosystems as important adaptation and mitigation response options (IPCC 2019). Globally, the potential of these measures is assumed to provide over one third of climate mitigation needed until 2030 to stabilise warming to below 2 °C in the long-term (Griscom et al. 2017).

2.4 How are these natural sinks covered by current policy and legislation?

The **EU LULUCF Regulation** provides the legislative framework for emissions and removals of the land use sector for the period 2021 to 2030. For the first time a specific target was set for this sector which requires MS to **keep the land use sector as a net sink** after accounting ("no debit" rule obligation). The Regulation defines accounting rules against which progress towards this target is measured (Böttcher et al. 2019). There will be two accounting periods where reported emissions and removals will be assessed, the first from 2021 to 2025 and the second from 2026 to 2030. The accounted pools covered by the Regulation are on **managed land** and are defined as six land use categories: **Afforested land, deforested land, managed forest land, managed cropland and managed grassland.** For the second accounting period it is also obligatory to account for **managed wetlands**. Harvested wood products can be from afforested land or managed forests and form a separate accounting category.

The Regulation includes all relevant carbon pools discussed in section 2.2: above- and below-ground biomass, litter, dead wood and SOC. For afforested land and managed forest land it also accounts for HWP. It is important to notice that natural carbon sequestration and emissions are only covered by the Regulation when they occur on managed land. Carbon and other GHG emissions and removals originating from **unmanaged land** are not officially monitored in a standardised manner. The Regulation does **not consider pools from marine ecosystems** like saltmarshes and seagrass meadows.

Emissions from **agriculture** originating from livestock management, fertiliser usage and machineries form their own emission sector and are regulated under the Effort Sharing Regulation (ESR), they are therefore separated from the agricultural soil management emissions accounted under LULUCF.

Natural disturbances occurring on managed land are included in reported data by MS and therefore also under the LULUCF Regulation. A special provision on natural disturbances allows MS to exclude emissions from single natural disturbance events from accounting if they exceed a certain margin of historic disturbance emissions. Natural disturbances can affect carbon pools differently. While windstorms and insect outbreaks lead to reduction of living biomass but increases in dead wood and through salvage logging to HWP, fires cause direct emissions of carbon. Therefore, emission peaks are not always visible in single inventory years (fire being an exception) but reflected in the long-term through the national forest inventories.

2.5 What are existing restoration and conservation targets?

The UN General Assembly declared 2021 to 2030 the UN Decade on Ecosystem Restoration, and the **EU Biodiversity Strategy for 2030** aims to **protect 30 % of the EU land area** (of which one third to be strictly protected including all primary and old-growth forests of the EU) and **restore carbon-rich ecosystems**. The strategy also includes planting of 3 billion trees across all MS in urban and rural areas. Additionally, the European Commission will bring forward a proposal for legally binding EU nature restoration targets in 2021 to restore degraded ecosystems and carbon-rich ecosystems.

The EU 2020 Biodiversity Strategy already defined a voluntary target to restore at least 15 % of degraded ecosystems by 2020. But the target was not met, mainly due to its non-binding character and lack of understanding of definitions and criteria for restoration and the sustainable use of ecosystems in the EU. In current EU legislation like the Birds and Habitats Directives, the Marine Strategy Framework Directive and the Water Framework Directive ecosystem restoration activities are only partly required. Also, not all ecosystems relevant for restoration are covered by actual legislation. This mainly affects cropland and intensively used grasslands, forests not covered by the Habitats Directive, forest plantations and urban ecosystems as well as soil health. More recently, the One Planet Summit in Paris in early 2021 featured several initiatives targeting restoration, e.g. the Great Green Wall [5], but no prominent initiatives have targeted restoration in the EU on a broad scale so far.

Globally, restoration has been addressed by a variety of different concepts (e.g. Nature-based solutions, Natural climate solutions, etc.). Nature-based Solutions (NBS) are defined by IUCN as "*actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits*". Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services. The IUCN has developed the Global Standard for Nature-based Solutions and the European network BiodivERsA has proposed a typology characterising NBS opportunities. Such approaches form an important basis for introducing the concept into other land-related policies. However, the concept needs further development to formulate clear criteria for complex ecosystems and develop specific adaptive management strategies to incorporate the principles. Eventually, also the concept of NBS needs to overcome the incoherence of policies related to land in the EU to become effective (Cohen-Shacham et al. 2019).

3 Net land sink and restoration targets: potentials and constraints

3.1 What is the EU net sink potential for the land use sector?

3.1.1 Current sinks and emission sources of the land use sector

Forests and agricultural land cover about 75 % of the EU land area. The majority is under intensive or less intensive management, which also applies to many protected areas which cover about 26 % of the EU's land area as part of Natura 2000 (18 %) and national protection schemes (8 %). Only 3 % of the EU land territory is under strict protection without major interventions in natural processes

[5] https://www.greatgreenwall.org/about-great-green-wall

(European Commission 2020). The LULUCF sector inventory reports show GHG emissions and CO_2 removals resulting from land management practices. Currently, the EU27+UK GHG inventory submission under the UNFCCC for 2020 shows **GHG emissions of 136 Mt CO_2e** for the LULUCF sector which also **removes emissions** from the atmosphere amounting to **-410 Mt CO_2e in 2018** (European Union 2020). Hence, the sector is a reported **net sink of -274 Mt CO_2e**, which is about 63 % of the non-CO_2 emissions from agriculture or 7 % of the total emissions from industry, energy production, cement and waste (Figure 3-1a).

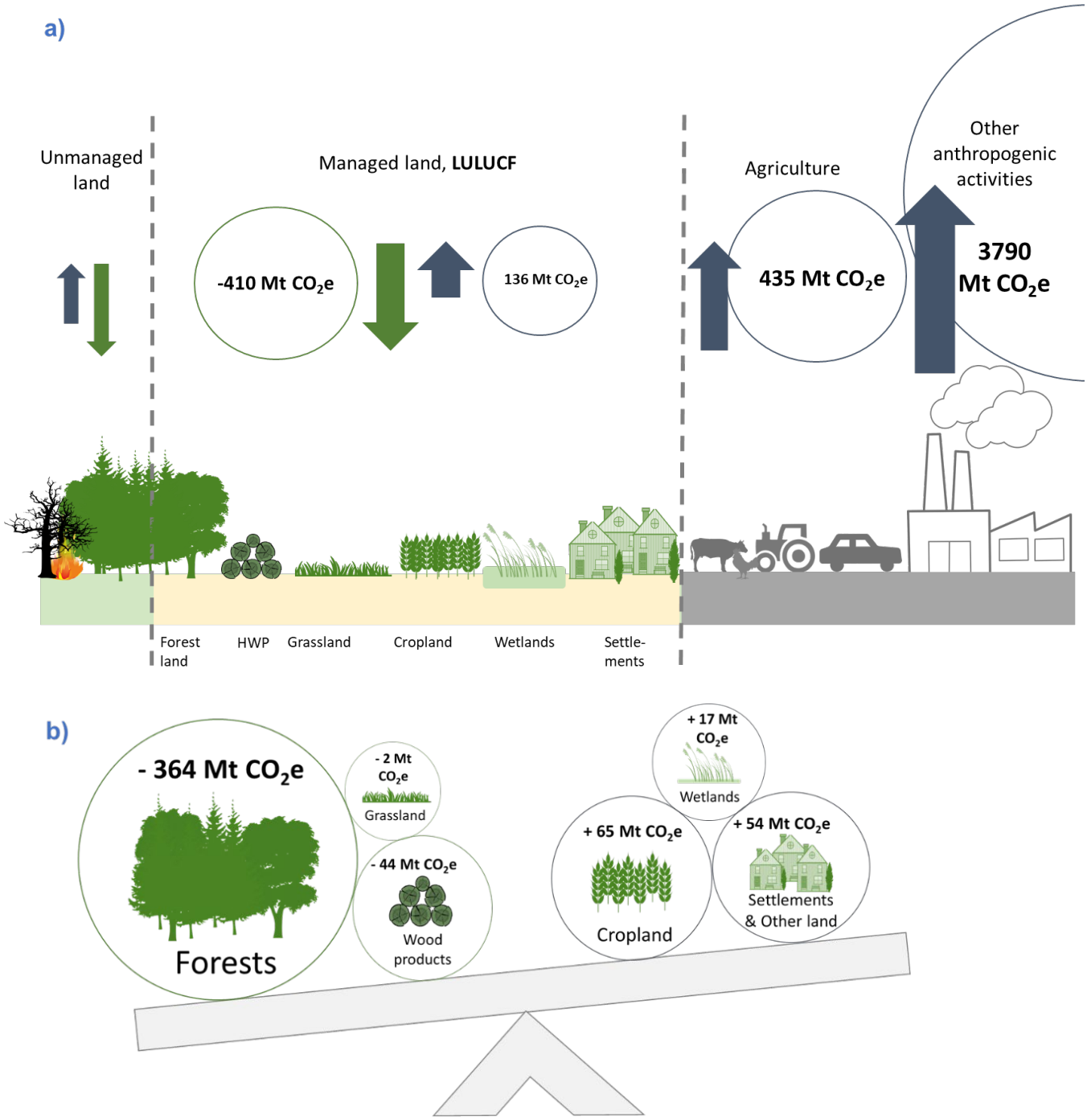
The main GHG emission source in the LULUCF sector is **cropland** with about 65 Mt CO_2e (Figure 3-1b). About 50 % (30 Mt CO_2, European Union 2020) of the emissions from cropland are caused by **organic soils**, which only represent 1.2 % (1.5 Mha) of the total cropland area (European Union 2020) . The emissions from organic soils originate from constant drainage of peatlands for agricultural use. About 5.8 Mha of EU27+UK peatland area is drained, of which the majority can be found under grassland (2.7 Mha) and cropland (1 Mha, (Schils et al. 2008)). Germany, Finland, the United Kingdom, Poland, Ireland, Romania and Sweden are among the main contributors to GHG emissions from drained peatlands, with a share of up to 25 % of their total emissions from agriculture and agricultural land use (O'Brolchain 2020). Besides emissions from drained organic soils, there are also substantial emissions from the **loss of SOC in mineral soils**. According to Rusco et al. (2001) about 45 % of the mineral soils in Europe have a low to very low organic carbon content (0-2 %) due to management practice. High risks for the loss of SOC in mineral soils are high nitrogen content from soil fertilisation which cause an increase in mineralisation of SOC and soil erosion by water and wind (JRC 2012).

The second highest emissions in the LULUCF sector originate from the **conversion of land to settlements** which causes about 91 % of the emissions from settlements (52 Mt CO_2e, Figure 3-1 b). Significant emissions result from the loss of carbon in soils, forests and other woody lands. In total, settlements showed the highest area increase (26 %) compared to all other land use categories since 1990. About 47 % (3 Mha) of the land converted to settlements used to be classified as cropland, 34 % (2.2 Mha) as grassland and 16 % (1 Mha) as forests (European Union 2020).

GHG emissions from **wetlands** account for 13 % (13 Mt CO_2e) of the total GHG emissions from the LULUCF sector (Figure 3-1 a). **Peat extraction** is the main source of GHG emissions, contributing **9.2 Mt CO_2 emissions** corresponding to only 292.000 ha of peatland area in the EU27+UK, mainly in Poland, Germany, Estonia, Ireland and Finland (European Union 2020).

Forest land is the **main net carbon sink** of all land use categories with **– 364 Mt CO_2e** (Figure 3-1 b). Forests in Germany (-63 Mt CO_2), Sweden (-44 Mt CO_2) and France (-42 Mt CO_2) are mainly contributing to the total net sink (EU 2020). Important changes in the subcategory forest land remaining forest land are increasing harvests as occurring in the Czech Republic, Bulgaria, Latvia and Germany. In the Czech Republic increased harvest rates even caused net carbon emissions from forest land remaining forest land. The forest area slightly increased by 7 Mha in the EU27+UK resulting into carbon sequestration of -41 Mt CO_2 in 2018.

Figure 3-1: Net emissions and removals for the EU27+UK in 2018 a) for the entire economy and b) within the LULUCF sector shown in CO_2e, including emissions from carbon dioxide (CO_2) and non-CO_2 gases.



Source: own compilation based on UNFCCC data for EU reported in 2020. Other anthropogenic activities include energy, industrial processes and product use, and waste.

In 2018 the carbon inflow from forest biomass into the **HWP** carbon pool and the carbon outflow from the pool resulted in a net carbon stock in HWP of -44 Mt CO_2e. (Figure 3-1b). Poland, Romania, Sweden, Finland and Germany mainly contributed to the HWP carbon stock.

Grassland was a net sink of -2 Mt CO_2e in 2018 mainly due to net CO_2 emission removals by cropland converted to grassland (-29 Mt CO_2). Especially France, Italy and the UK reported a significant carbon sink on mineral soils resulting from the conversion of cropland. However, the subcategory "grasslands remaining grasslands" showed substantial emissions of 23 Mt CO_2. Carbon emissions from grassland mainly occurred in Germany (21 Mt CO_2) and Ireland (6 Mt CO_2). The main factor impacting carbon emissions from managed grasslands is drainage of organic soils which accounted for about 3 % (3 Mha) of the total grassland area (89 Mha) in 2018 (EU 2020). In contrast, the UK reported a substantial net sink from mineral soils (-5 Mt CO_2) and Romania showed a carbon sink (-1 Mt CO_2) from woody vegetation on grassland (EU 2020).

LULUCF includes emissions and removals occurring on **managed land**, i.e. both anthropogenic and natural emissions and removals from this land are considered, excluding natural processes on unmanaged land, e.g. those caused by wildfires in primary forests (Figure 3-1a).

Non-GHG emissions from **agriculture** in EU27+UK are not included in the land use sector but form a separate sector. It includes, among others, emissions of methane (CH_4) from livestock management and nitrous oxide (N_2O) from fertiliser application. In 2018, emissions from that sector amounted to 435 Mt CO_2 and were thus of a similar size as the gross sink of the LULUCF sector (Figure 3-1a).

3.1.2 Options for emission reduction and enhancement of carbon storage and their potential

Maintaining and enhancing net sinks requires land management options that reduce emissions and support the carbon storage capacity. In this study, options have been selected to represent different land use categories and according to their mitigation potential.

Seven different options will be presented for the land use sector of the EU:

a) Increase EU forest area

b) Restore carbon stocks in forests

c) Enhance carbon storage in HWP

d) Maintain and enhance SOC in mineral soils under grassland and cropland

e) Expand agroforestry on cropland

f) Conserve carbon in organic soils and restore wetlands

As mentioned earlier, maintaining and enhancing marine blue carbon ecosystems offer great mitigation potentials (Gacia et al. 2002; Marbà et al. 2014; Lovelock und Duarte 2019). However, they are currently not considered within the LULUCF framework and the distribution and sink potential of blue carbon ecosystems in the EU is still under research, but we will provide first estimations for:

g) Protection and restoration of saltmarshes and seagrass meadows

For the assessment we analysed EU and National Inventory Reports (NIRs) and Common Reporting Framework (CRF) tables submitted to UNFCCC as well as national and international scientific literature. For some cases, we also carried out expert interviews. The potential for emission reduction and enhancement of carbon storage can be expressed as specific potential (per area unit, e.g. per

ha) and as absolute potential. The first indicates the intensity and effectiveness of a land management option regarding emission reduction and carbon storage, the latter describes the potential at landscape level if implemented at a larger scale.

Increase forest area

Increasing the forest area by afforestation and reforestation means converting non-forested land to forests, whereby afforestation is the conversion of areas without tree cover for the last 50 years. Reforestation describes the conversion of previously forested areas into forests and constitutes bringing back trees into areas that no longer meet the national definitions of forests due to reduced tree cover (e.g. less than 10-25 %). These land use options provide carbon storage in the forest related pools of tree biomass, dead wood, litter and soil. Historically, the highest afforestation rates in the EU were found in Spain, France and Italy, mainly on grasslands (European Union 2019). Afforestation can have several co-benefits like increased water infiltration, drought mitigation, flood control and habitat for wildlife (IPCC 2019). However, depending on the local situation, afforestation may have trade-offs for biodiversity on e.g. grasslands. Also, afforestation measures are less effective for mitigation in boreal regions of Scandinavia due to the albedo effect (Griscom et al. 2017; IPCC 2019). In cold regions with slower tree growth, dark coniferous trees absorb more solar radiation compared to open habitats leading to local warming which reduces the net climate change mitigation effect of sequestered CO_2.

How different estimates of the potential for future afforestation in the EU are covered in the literature can be shown by two scenarios, the EU reference scenario (European Commission (EC) 2016) and CTI 2050 roadmap (ECF 2010). Their proposed net increase in forest area ranges between 6 and 59 % (10 to 95 Mha). This would result in EU mitigation potentials of 77-210 Mt CO_2 per year or 2.2 to 7.7 t CO_2/ha/year.

Restore carbon stocks in forests

Restoring forest carbon stocks through forest management needs to focus on increasing carbon sequestration in biomass and soil. Biomass growth depends on on-site conditions (climate and soil), tree species mortality and wood harvest. Therefore, the rate of harvest intensity plays an important role to manage carbon stocks (Pilli et al. 2016). Forest biomass will increase and therefore gain carbon when harvest rates are well below the average increment and natural mortality. Also, intensive wood harvest can have negative implications for the stand structure and forest resilience towards disturbances and climate change (Drever et al. 2006). Hence, long-term productivity and carbon sequestration of forests can be negatively affected as well (Ceccherini et al. 2020).

Sweden, Finland, France, Poland and Germany have the highest area potential to restore carbon stocks, together they have more than 100 Mha of managed forests. Historically, the largest carbon sinks per unit area were reported for Germany (5.6 tCO2/ha/year), Netherlands (4.8 tCO2/ha/year) and Slovenia (4.7 tCO2/ha/year, average over period 1990-2015 based on reported CRF data).

A recent study by Welle et al. (2020) showed that sustainably managed EU forests could sequester 309 to 488 Mt CO_2 annually until 2050 compared to 245 Mt in 2010, only in biomass pools, and a short-term annual carbon sink potential of 309 to 456 Mt CO_2 until 2030. The study assumed natural growing conditions in EU forests and alternative use of wood products like abandoning fuel wood use and reducing use of hardwood for short-lived wood products. Other studies with different ambition levels estimate the development of the forest carbon sink to range between 150 and 400 Mt

CO_2 per year in 2050 (Nabuurs et al. 2017; EC 2016; European Commission 2020, see also Table 3-2). An important assumption is the future harvest level assumed by studies estimating the forest sink potential. Recently, wood harvest intensity has been reported to be increasing (Ceccherini et al. 2020), with likely implications for the net storage of carbon in EU forests. There is also a scientific debate about the saturation of the sink and the role of forest age for the sink potential (Nabuurs et al. 2013; Luyssaert et al. 2008).

Carbon storage in harvested wood products

The carbon pools for forest biomass and HWP are very closely connected. Reducing harvest rates usually leads to an increase in forest biomass carbon stocks. Moreover, the trees that were not harvested continue to grow and sequester carbon. With reduced harvest rates, the flow of carbon into the HWP pool is decreased, potentially leading to decreases in HWP carbon stocks with products reaching their end of life. If harvest rates are increased and the carbon stock in forests is reduced, typically only a fraction of the removed carbon is stored in HWP. If the wood is used for energy, it counts as an emission. Wood left to decompose in the forest still contributes to the forest's deadwood, litter and soil carbon pools. Wood products thus only contribute to mitigation when they are long-lasting. Carbon can also be retained longer in HWP pools through re-use and recycling.

Additionally, HWP can help reduce emissions in other sectors (substitution) through replacing products and uses with higher energy input of fossil fuel emissions compared to those of HWP. But substitution effects depend on assumptions of future energy and fossil fuel use. Substitution effects are thus expected to decrease with progressing decarbonisation of energy systems. Moreover, they are not accounted for under the LULUCF sector but in the sector where the emission reduction is achieved.

Assuming a reduction of primary use of wood for energy and increased wood product could double the expected storage of CO_2 by HWP from 17 to 40 Mt CO_2 annually until 2030 (Rüter et al. 2016). As the option does not affect harvest levels but simply the allocation of harvested wood to energy and material use, impacts on the forest are negligible. Another study by Pilli et al. (2015) estimated HWP storage capacities for 2030 to amount to 43.8 Mt CO_2/year through increased harvest rates. However, the study of Pilli et al. ignores the forest carbon stock and implications of increased harvest for the forest sink.

Maintain and enhance carbon in mineral agricultural soil

The choice of management practices that have the most significant potential for maintenance and sequestration of soil carbon varies according to climate and biophysical conditions (e.g. soil type), as well as the production system involved.

Generally, the largest potentials can be achieved with cover cropping; improved crop rotations (e.g. through inclusion of legumes and other nitrogen fixing crops), reduced or zero tillage as well as agroforestry established on cropland or grassland. Also, preventing conversion of grassland to arable land and additional conversion from arable to grassland and organic farming practices can help restore SOC levels. The potential for increasing SOC in agricultural soils is highly variable and ranges between 0.5 and 7 t CO_2 /ha/year (Smith 2016; Roe et al. 2019; Poeplau und Don 2015). Scenario estimates of the potential for cropland SOC enhancement in the EU until 2050 range from 9 Mt (Frank et al. 2015) to 23 to 58 Mt CO_2e per year (Lugato et al. 2014a). The "4 per mill" initiative launched at the 2015 United Nations Climate Change Conference in Paris aims at increasing global

SOC stocks in 0–40 cm depth by annually 4‰. With an estimated SOC stock of 17.6 Gt C, corresponding to 64.5 Gt CO_2 (Lugato et al. 2014b), an annual increase by 4‰ would be 260 Mt CO_2 annually. However, scenarios mixing different management options in Bavaria (Germany) including cover cropping, improved crop rotation, organic farming, agroforestry and conversion of arable land to grassland revealed that the potential for Bavaria would at maximum rather be around 1‰ of present stocks (Wiesmeier et al. 2020). Hence, the scope for accumulating SOC in mineral soils is expected to be limited, also because e.g. the availability of additional carbon sources originating from extra primary production is limited and practices that enhance SOC may cause N_2O emissions (Berge et al. 2017; Lugato et al. 2018). Moreover, carbon gains in SOC are quickly reverted if management practices change. But the area potentially involved can be large and the option thus results in a significant contribution to the net sink. The option is especially suitable for countries with large arable lands on mineral soils such as France, Germany, Hungary, Romania and Poland.

The increase of organic farming practices on arable land in the EU can also contribute to higher SOC content. According to Gattinger et al. (2012) organic farming shows a mean difference in annual carbon sequestration ranging from 0.9 to 2.4 t CO_2/ha in the top soil compared to non-organic agricultural practices. Therefore, converting all available cropland on mineral soil in the EU27+UK (123 Mha) could lead to a potential sequestration of 110 Mt CO_2 per year to 295 Mt CO_2 per year (Gattinger et al. 2012; European Union 2020). The main difference in changes of SOC between both management practices results from extended crop rotation, improved crop varieties and applying organic fertilisers in organic farming.

Expand Agroforestry coverage

Agroforestry is the integrated management of woody elements on managed cropland or grassland (European Commission 2013). Two types of agroforestry can be distinguished: silvo-pastoral agroforestry (animals grazing or animal fodder produced under trees), which represents the majority of agroforestry systems in the EU, and silvo-arable agroforestry (crops are grown under trees, with row spacing allowing for tractor traffic) (Burges et al. 2019). In regions suffering from multiple environmental pressures like nitrogen pollution, soil erosion and SOC loss as well as rising temperatures, agroforestry can be an effective adaptation and mitigation measure. Compared to conventional agricultural practices it can enhance carbon sequestration in soil and wood biomass and improve water availability and quality as well as protect crops and livestock from extreme climate events like heat waves. According to a study by Kay et al. (2019) on area and carbon storage potentials of agroforestry in Europe, about 8.9 % (13.7 Mha) of arable land in the EU27+UK+Switzerland (minus Cyprus and Croatia) were identified as priority areas that could benefit from agroforestry. These arable regions are mainly in the lowlands of Mediterranean countries like Greece, Spain and Italy. Annual carbon storage potentials show a wide range between biogeographical regions and different kinds of agroforestry practices mainly depending on tree species and density as well as the time span until trees are harvested. If agroforestry is applied in the priority areas proposed by Kay et al. (2019), the average minimum annual carbon storage potential estimate is about 7.7 Mt CO_2 (0.6 t CO_2/ha). This corresponds to mainly silvo-arable systems with alley cropping in the Atlantic and continental regions and silvo-pastoral systems with low tree density (about 20-100 trees/ha) in the Mediterranean. However, carbon storage is substantially increased to 235 Mt CO_2 (17 t CO_2/ha) if mainly silvo-pastoral and silvo-arable systems are applied with high tree density (> 100 trees/ha). Generally, recent studies suggest that agroforestry can have multiple benefits, when regionally adapted systems are applied considering

soil, climate and water conditions as well as which environmental pressures should be addressed, like nitrogen leakage or soil erosion (Kay et al. 2018).

Conserve carbon in organic soils and restore wetlands

Reducing GHG emissions from organic soils in arable land and wetlands will be one of the most effective measures to rapidly decrease emissions from the land use sector and achieve the EU's climate targets (Pérez Domínguez et al. 2020). Efficient emission reductions can be achieved by raising the water levels near to the surface on drained organic soils, e.g. by blocking or regulating drainage systems and restoring wetland ecosystems. Fallowing of all organic soils in the EU could mitigate about 42 Mt CO_2e in 2030 (Pérez Domínguez et al. 2020). Another study by UBA (2019) assumed that 50 % of the total organic soils area under cropland and grassland (2 Mha) could be rewetted. The resulting total annual mitigation potential for 2050 was 23.5 t CO_2/ha (48.1 Mt CO_2). Differences in estimations for emissions from degraded peatlands or mitigation effects of peatland restoration can vary substantially, depending on the peatland area assumptions and applied emission factors. For example, reported area extend of organic soils in NDCs can differ from alternative data bases due to poor data base (Barthelmes 2018).

Additionally, abandoning peat extraction could avoid substantial emissions. According to recent data reported by the EU27+UK, abandoning peat extraction could avoid emissions of about 9 Mt CO_2 annually (European Union 2020). In some cases, the introduction of paludicultures like sphagnum moss and reed can be a solution to avoid land use conflicts. The main advantage of paludicultures is that they can be cultivated under wet conditions and simultaneously the peat body can be preserved (Wichtmann et al. 2016).

The mitigation potential of natural peatlands shows high local and regional variability and depends on complex interaction of climatic, hydrologic and hydro-chemical conditions. Peatland carbon sequestration rates can show considerable year-to-year variability and peatlands can also turn into sources of GHG emissions. Especially methane emissions can occur under wet conditions if biomass is decomposed anaerobically. In the long-term (more than 100 years), the climatic effect of CO_2 and CH_4 emission fluxes of peatlands is either slightly positive or negative and depends on age and type of peatland. Generally, the sink effect of sequestered carbon in peatlands balances the emissions in the long run (Barthelmes et al. 2015). Therefore, the protection of current carbon stocks in peatlands (organic soils) should be of highest priority.

Protection and restoration of saltmarshes and seagrass meadows

Saltmarshes and seagrass meadows can be successfully restored if initial threats were eliminated prior to replanting. Main stressors are eutrophication, waste and coastal modifications. Aerial loss is one of the main disturbances of coastal ecosystems, resulting in loss of carbon storage capacity and construction activities (Luisetti et al. 2019). For example, bottom trawling affects sedimentary carbon storage through remineralisation and by impacting the seabed species involved in bioturbation and bio-irrigation (Duplisea et al. 2001). Therefore, stopping further degradation by applying sustainable fishing methods and restoration of these ecosystems could contribute to mitigating GHG emissions from coastal wetland ecosystems. The current estimated extent of saltmarshes and seagrass meadows in the EU is about 3 Mha (Luisetti et al. 2013) but information on the sequestration potentials of European blue carbon ecosystems is missing. There are only studies on single seagrass species or estimates for small regions, e.g. for saltmarshes in the UK that showed a sequestration potential of 3.4 to 4.2 tCO_2/ha/year (Adams et al. 2012).

3.1.3 Estimate of the total EU net sink potential for the land use sector

Looking at different options for emission reductions and carbon stock enhancement results in considerable ranges of potentials. This is due to underlying assumptions in studies and uncertainty in data and models. To come up with an estimate of the total EU net sink potential for the land use sector, different options cannot be simply summed up because assumptions like reference year, geographical scope or ecological constraints are not necessarily consistent between studies. Moreover, there are considerable interlinkages between options, like competition for land, that require integrated studies to model the implementation of various options in competition. Therefore, it is not adequate either to average over potential ranges.

However, there are some studies that have published **integrated scenarios** of net GHG emissions from the land use sector for the EU (see Table 3-2 below). Still, the studies consider different scopes and combinations of measures. Hence, the published data do not allow for a differentiated comparison of single measures within the scenarios. Considering the above-mentioned constraints regarding interpretation, the **potential for the EU net sink in 2050 ranges between 244 Mt CO_2** (the EU Reference scenario forming the baseline of the development of the sector) **to 787 Mt CO_2 per year** in an ambitious policy scenario. **Most estimates consider a net sink of 400 to 600 Mt CO_2 per year as feasible for 2050** while also avoiding major trade-offs with other sustainability constraints (e.g. regarding biodiversity). **A similar potential for the net land use sink can be derived from scenario studies already for the year 2030 if ambitious measures are implemented in the sector.** In the following sections we discuss main assumptions leading to these estimates.

3.2 What are conditions and pathways for realising net sink potentials?

3.2.1 A short review of scenarios of net sink potentials

The potential carbon storage on managed land cannot be achieved instantly. The uptake of carbon depends on growth rates of vegetation, limited by light, temperature, nutrients, water and other resources. Moreover, changing management practices and realising restoration of ecosystems is also limited by the implementation rate, expressed as amount of area where the change occurs.

The rate of implementation and the rate of carbon uptake depend on assumptions regarding the specific measures. For scenarios of pathways of emissions and removals in the LULUCF sector these assumptions need to be set and are partly predetermined by the type of model or extrapolation method applied for the projections. Existing studies of net sink potentials that the sector might be able to offer can be compared when these assumptions and specific settings are considered. Typical influencing assumptions are:

- The impact of environmental and climate change on plant growth and decomposition rates;
- Changes in productivity of agricultural and forestry production based on assumed fertiliser input, irrigation, plant breeding etc.;
- Changes in demand for land-based products and linkages between biomass consuming sectors and land use determining land availability.

Specific assumptions regarding the estimated emissions and removals through measures directly affect their potential contribution to net GHG emissions from managed land (see Table 3-1). For

designing effective policies to support a net sink target that is oriented towards a selected scenario, it is crucial that policies are in line with these assumptions. This could be food and health policies addressing dietary changes that are a precondition for certain pathways or energy policies that set adequate incentives (or disincentives) for the use of biomass consistent with respective scenario assumptions. However, policy scenarios are not meant to be direct blueprints for policy implementation. They are instead explorative studies of pathways determined by set pre-conditions (what-if situations) and can be useful for increasing the understanding of system behaviour.

Table 3-1: Overview of potential mitigation options and assumptions relevant for potential

Pools	Mitigation option	Examples of measures	Assumptions relevant for potential
Forest biomass and soils	Increase forest area	Afforestation of cropland/ grassland	Assumption on availability of land and previous carbon stocks on the land to be afforested.
	Conserve carbon stocks in forests	Reduction of deforestation emissions	The maximum potential that can be avoided are current emissions from deforestation. Assumption on the time horizon and effectiveness of deforestation reduction.
	Restore carbon stocks in forests	Reduce harvest intensity/increase target diameters Increase dead wood	Potential depends on how close countries are already to the maximum level of wood harvest. The theoretical potential can be very high. However, trade-offs regarding reduced wood harvest need to be considered.
Wood products	Increase carbon storage in wood products	Increase lifetime of wood products/ share of long-lived products Increase cascade use of wood	Increased wood production has impacts on the forest sink that are often not considered. Options should therefore target more efficient use of wood and increasing lifetime of products. The additional storage potential in wood products is rather medium- to long-term. Net effects of increased cascade use of wood can be limited if temporarily reduced availability of biomass for energy needs to be compensated by increased biomass production or imports.
Mineral soils	Maintain and enhance carbon in mineral agricultural soils	Increase humus content of soils Reduce soil management intensity	The maximum potential that can be avoided are current emissions from grassland conversion. Assumption on land use dynamics and competition with alternative land uses to grassland.
	Expand agroforestry coverage	Introducing trees and hedges into agricultural land	Maximum potential includes cropland and grassland area where such measures have not yet been implemented Specific mitigation potential per unit area is relatively low, but measures can improve biodiversity and increase landscape resilience
Organic soils	Conserve carbon in organic soils and restore wetlands	Rewetting of cropland/grassland on organic soils Abandoning peat extraction	The maximum potential that can be avoided are current emissions from organic soils. Assumption on land availability for rewetting and water level that can be achieved.

Source: own compilation

Table 3-2: Comparison of selected studies assessing net sink potentials of managed land in EU

No.	Study author and name	Main mitigation categories	Time horizon	Potential Mt CO_2/ year	Main assumptions
1	EC (2016) EU Reference scenario [6]	LULUCF	2030 2050	-288 -244	Business as usual management of EU lands.
2	Naturwald Akademie (2020): Forest vision scenario for the European Union (EU-25 [7])	forest restoration	2030 2050	-430 -488	Forest harvest intensity is reduced to 60 % by 2030 and to 50 % between 2030–2050.
3	Oeko-Institut: GHG-neutral EU 2050 [8]	afforestation, forest restoration, harvested wood products, peatland restoration, grassland protection	2050	-518	Increase forest area by 16 Mha; stabilising forest harvest rate at 70% of increment; increase the share of longer-living wood products; conversion of 50 % of cropland on organic soils to wetlands, forests and grasslands; reduction of grassland conversion on organic soils to zero, on mineral soils to 50 %; no net land take of infrastructure and settlements by 2050.
4	CTI 2050 Roadmap Tool (2019) [9]	afforestation, forest restoration, reduced cropland and grassland management intensity	2050	-584	Reduced land degradation; 24 % less land required to produce food (multi-cropping, etc.); 76 % of surplus land is afforested, 20 % converted to grasslands; forest harvest intensity lowered by 25 %.
5	EU CALC project (2020), Ambitious scenario [10]	afforestation, bioenergy, area protection, forest restoration	2030 2050	-570 -787	Afforestation of 114 Mha grassland and cropland, increasing bioenergy capacities, improved diets and alternative protein sources, improved forestry practices and land management, improved hierarchy for biomass end-uses, and set aside 50 % of area for protection.
6	EC 2030 Climate Target Plan Impact Assessment, LULUCF+ scenario [11]	afforestation, forest restoration, restoration of peatlands,	2030 2050	-340 -425	Optimisation of forest management, afforestation projects and improving soil management including through rewetting and restoration.
7	Nabuurs et al. (2017) [12]	afforestation, forest restoration, harvested wood products	2050	-300	Measures like enhanced thinning of stands leading to additional growth and higher quality raw material, regrowth with new species, planting of more site-adapted species, and regeneration using faster growing species would even increase harvest potential from 522 to 557 Mm^3 per year.

Source: own compilation based on cited literature

[6] https://ec.europa.eu/energy/data-analysis/energy-modelling/eu-reference-scenario-2016_en
[7] excluding Luxembourg, Cyprus and Malta, including UK
[8] https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-11-26_cc_40-2019_ghg_neutral_eu2050-technical-annex.pdf

3.2.2 Enabling conditions and constraints for realising net sink potentials

Despite the wide range of assumptions made by the reviewed studies, some general conclusions can be drawn regarding the enabling conditions for the realisation of net sink potentials at the scale of the EU.

Only few studies have assessed the full land use sector, including all land categories and almost none has assessed potential implications for emissions outside the EU (an exception in this list is the EC 2030 Climate Target Plan Impact Assessment). Leakage effects leading to increased emissions from land use change and biomass production outside the EU can be significant but are difficult to assess. General equilibrium models that simulate changes to markets and trade flows are highly uncertain and can only be interpreted within the modelling assumptions. Those studies ignoring market effects outside the EU assume flanking measures on the demand side that address expected changes in production levels and land availability (e.g. study 3 in Table 3-2).

Competition for land primarily determines the net sink potential. This is especially true for measures involving land use change, such as the increase of forest area and restoration of wetlands. At the same time the specific CO_2 removal or emission reduction potentials per unit area can be very different. Despite expected negative effects of rewetting organic soils on agricultural production, such measures can be more effective than afforestation of marginal lands, especially in high latitudes.

The potential related to measures that do not involve land use change seem to be rather limited per hectare, however there is a large scaling effect due to the potentially large area where measures could be implemented. An example is the expansion of agroforestry coverage. While the specific potential per unit area is comparatively small compared to forest area increase, the area where such measures can be implemented without drastically affecting other land uses is rather large (basically the entire EU cropland and grassland area where such measures have not yet been implemented). Similarly, forest restoration options yield high absolute potentials due to the relatively large extent of existing forests compared to area available for new forests.

All scenarios have in common that the potential net sink enhancement can only be achieved with changes in current management practices and significant investments, be it into boosting land productivity (e.g. study 7) or into alternative consumption patterns (e.g. study 3), increases in resource efficiency (e.g. study 2) or sustainable energy technologies (e.g. study 4).

Typically, large scale assessments of mitigation potentials assume perfect policy implementation. Important details that might constrain the potential in the realisation phase such as ownership structure, capacities of technologies, training of land managers and landowners, efficiency of funding instruments, effectiveness of carbon markets, change in consumption patterns etc. are ignored. This reveals all selected studies as highly biased towards an overestimation of the effectiveness of measures. This is especially true for potentials estimated for the short-term perspective of 2030.

Similarly, potentials are likely to be overestimated regarding damage to ecosystems due to climate and environmental change, including natural disturbances. For the sake of complexity reduction, none of the studies provides uncertainty ranges associated with such effects. It is often assumed that the measures enhancing the net sink simultaneously lead to higher resilience of ecosystems

[9] https://www.buildup.eu/en/learn/tools/cti-2050-roadmap-tool
[10] https://www.european-calculator.eu/transition-pathways-explorer/
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020SC0176
[12] https://edepot.wur.nl/430072

and climate change adapted conditions. This is an assumption that can be considered overly positive given the potentially large areas where climate change and disturbance impacts can be expected (Seidl et al. 2017; IPCC 2019).

3.2.3 Specific accounting challenges for assessing the net sink

Accounting, in contrast to reporting, relates to the definition and tracking of the achievement of a GHG mitigation target and sets the reported emissions and removals into perspective to the target. An important element of accounting is the **reference**, baseline or base year against which a target for GHG emissions and removals is compared to. These can be historic or projected data. Accounting against a reference level of emissions or removals in the LULUCF sector aims to factor out historic drivers of emissions and removals and thus allows to assess the most recent progress of countries but also to compare the level of ambition of targets between countries with different starting conditions.

Establishing **credible baselines** for accounting is a challenge. Baselines aim to serve as a fixed or dynamic reference to calculate projected anthropogenic changes in carbon stocks or emissions and removals occurring in the absence of a measure or policy within a certain area. They can be based on projections using models or on historic data (i.e. assuming no change in the future). It is also a method for assessing **additionality** of measures, i.e. answering the question whether the measures or policies have caused the changes in emissions and removals observed (a question relevant for mitigation finance and carbon markets). Baselines involve considerable uncertainty regarding the question what scenario is likely to occur in the future but also regarding the underlying data, be it projected or historic. It is therefore important that baselines are built on transparent and consistent data sources for emissions and removals. There is typically a trade-off between baseline complexity and transparency as can be observed with the reference level accounting for forests in the LULUCF regulation.

As in all sectors there is also a certain risk of **leakage** with measures for enhancing the net natural sinks in countries. Leakage occurs when a targeted land use activity in a certain place at a certain time has an indirect impact on carbon storage at another place or time (IPCC 2000). An example are emissions from forest management intensification abroad as a result of market shifts in timber production caused by mitigation policies affecting wood production in one country. Leakage leads to increased overall net emissions of the sector **undermining environmental integrity** and reducing cost effectiveness of mitigation policies and measures. The risk for leakage depends on how strongly mitigation measures affect the production level and how much the goods are traded and substitutable. Leakage risks can be mitigated by increasing the coverage of land uses in national targets, increasing the coverage of countries participating in the regime, implementing effective monitoring and robust accounting systems. However, there is also the need to design mitigation measures cautiously, anticipate potential market shifts and flank mitigation measures with measures targeting the demand side of agricultural and forestry production.

4 Towards a proposal for a land net sink and restoration target

4.1 What are key challenges regarding the role of the net sink for achieving climate neutrality?

The aim of climate neutrality puts forward explicit or implicit "expectations" of EU climate policy regarding the role of a future net sink for achieving climate neutrality in 2050. This role includes the following three perspectives.

The net sink is expected to provide a **counterbalance for remaining unavoidable emissions** from other sectors after 2050. In order to counterbalance remaining emissions and thus being in line with aspirations for a climate-neutral EU in 2050, net removals would have to almost double from their current level to 500 Mt CO_2 annually (EC 2020 Inception Impact Assessment [13]). It is important to understand the different gross components (emissions and removals) of such projections. Especially emissions from the agricultural sector are not expected to be eliminated by 2050 because they are considered difficult to be avoided with existing technology and practices (EC 2020 Communication on stepping up the EU's 2030 climate ambition [14]). However, focusing solely on the net sink potential for counterbalancing emissions most likely increases the focus on ecosystem management practices to exclusively enhance the carbon sequestration potential. This might put pressure on biodiversity and ecosystem services not directly related to carbon. For example, afforestation can also have negative side effects when it leads to an increase in surface albedo in snow covered boreal regions. Also, exchanging deciduous trees by coniferous trees in temperate regions results in changes of albedo, canopy roughness and evapotranspiration contributing to warming of the climate (Naudts et al. 2016). Moreover, the prospect of a future counterbalance by carbon removals takes pressure off other sectors to push for the needed emissions reductions. This applies to any integration of natural or technical sinks into an emissions reduction target.

The integration of the separate net sink target into a full scope emissions reduction target should **set incentives for land management** change towards overall more sustainable practices and increased resource efficiency. Currently, measures for enhancing carbon storage and biological diversity are not sufficiently rewarded. It takes clear incentives for farmers and foresters to change management practices. However, the integration of the net sink into an emissions reduction target without additional safeguards bears the risk of setting wrong incentives that do not promote more sustainable but rather more intensive land use. Moreover, MS struggle with setting up incentive schemes for individual land managers that form clear linkages to binding national emission reduction targets and the EU climate policy framework. There is still a lack of standardised approaches to ensure that mitigation contributions also meet high sustainability requirements. Change of management practices could be achieved by rewarding sustainable land management practices through favourable tax schemes or subsidies at the producer and consumer level, thus by introducing incentive schemes that are outside the emissions reduction target.

Flexibility between sectors must allow for cost-efficiency to meet the overall mitigation target without lowering the ambition of drastically cutting emissions from all sectors. The EU LULUCF and Effort Sharing Regulations currently limit EU-internal trading of carbon emissions and removals between the land use and other sectors and constrain it to the MS level. Such flexibility is expected

[13] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12657-Land-use-land-use-change-and-forestry-review-of-EU-rules
[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562

to make the LULUCF sector more relevant for other sectors, reduce costs of mitigation but also to disincentivise emission reductions and transformation of sectors with reduction obligations that are needed to meet the temperature target of 1.5 degrees. The Paris Agreement accounting framework aims at striking a balance of emissions and removals by 2050. This implies full flexibility between emitting and removing sectors. However, there is the need to balance between flexibility and ambition level to ensure that mitigation focuses on emissions reductions first by keeping the pressure high on fossil fuel sectors to transform. It remains entirely unclear how flexibility should be allocated to the emitting sectors.

There are also proposals for an AFOLU sector that would grant full flexibility to agriculture while cutting other sectors off such opportunities, even though there might exist cost-efficient mitigation options also in the agriculture sector. **There is no evidence that GHG emissions from agriculture cannot be reduced cost-efficiently under a coherent and stringent climate policy regime, taking into account that an overall societal transition towards more sustainable land use, healthier diets, more animal welfare and less waste production is urgently needed.** An exclusive emission balancing option for agriculture would clearly reduce pressure from the agriculture sector and undermine transformation efforts that are widely accepted to be without alternative.

4.2 What are key principles for a net sink and restoration target?

Based on the observations in sections 2 and 3 and the challenges regarding its role for achieving climate neutrality, there are some key principles needed to ensure that a sink and restoration target is ambitious and ensures overall environmental integrity.

Meyer-Ohlendorf (2020) set out some legal principles of a net sink target arguing that it needs to be a **legally binding, enforceable, quantitative target** to be most effective.

Moreover, **a separate target for net sinks** is needed. Considering the full scope of emissions and removals in the EU 2030 emissions reduction target implies basically full flexibility between all sectors included. Only with a separate target can restriction of flexibility between sectors be guaranteed. The current LULUCF no-debit target is a separate target. It ensures that there is no “run to the sink bottom” in case the ambition level for other sectors is not high enough and the overall target can easily be achieved without contributions from the land use sector’s net sink. However, it does not prevent ambition reduction in other sectors caused by including a sink that can be achieved without much extra efforts. To address this risk, Meyer-Ohlendorf (2020) opts for a strictly separate target for net sinks. However, having two targets (one full scope target, one net sink and restoration target) increases visibility of the land use sector as its performance matters for achieving the overall emission reduction and it reflects best the general accounting approach agreed for the Paris Agreement.

To avoid a deterioration of the ambition level, it is important to **first decide on the scope of the target and then set its level.** Otherwise there is the risk that the ambition level will be watered down by changing the rules for achieving it. Only with accounting and flexibility rules in place a target can be set whose ambition level can be assessed adequately.

There is the need that the target addresses an immanent challenge of the land use sector, that is non-permanence (see 2.3). **Dealing with non-permanence risks** requires accurate reporting but also accounting rules. An accounting framework as planned by the EU that potentially involves

carbon markets, needs to discriminate between units of carbon from land use and those from fossil fuels and provide a trading exchange rate that accounts for the risk of non-permanence.

A high level of flexibility might also cause the land use sector to be strongly driven by mitigation if other sectors fail to bring down emissions rapidly enough. Such pathways can be a threat for other ecosystem services provided by land. Carbon storage is only one among many important services provided by ecosystems. An effective target for sink enhancement creates a level playing field for carbon storage with already commercially traded goods but not necessarily with other provisioning, regulating and supporting services. In order to **avoid trade-offs**, social and environmental sustainability safeguards are needed.

There is an inertia in the processes forming the net sink. Principles for a net sink and restoration target need to allow for adequate **short-term** (e.g. 2030 and 2040) and **long-term milestones** (beyond 2050) for assessing effectiveness of measures and policies, identifying potential ambition gaps and ensuring consistency with required mitigation pathways towards the Paris Agreement long-term temperature goal.

4.3 What are important technical elements for the architecture of the net sink and restoration target?

Besides basic principles of the net sink and restoration target as discussed above, there is the need for concrete technical elements that transfer principles into rules and metrics.

4.3.1 National targets

A net sink target at EU level alone would be meaningless as MS have to contribute to achieving it to be effective (Meyer-Ohlendorf 2020). **Having national net sink and restoration targets for each EU MS ensures that countries are committed to the target.** There are different options and criteria that can be applied for breaking down an EU-wide target to specific country targets. These can involve economic criteria, like GDP per capita. However, economic criteria alone do not relate to a country's potential for sink enhancement. Member states' actual potential to increase the net sink in a cost-efficient way would have to be estimated in a consistent approach to produce comparable numbers. The EU Impact Assessments typically involve economic land use models (e.g. GLOBIOM) for such analyses. However, uncertainties of such estimates are high and very strongly depend on model assumptions and underlying data.

More transparency could be achieved by applying the criterion of a percentage increase compared to the Member State's net sink in a baseline specific to each land use category. Such an approach would build on publicly available and reviewed reporting data on historic emissions and removals. The share of a Member State of a specific land use category like forests or wetlands does not necessarily give an indication of the future potential, however, reporting of historic emissions and removals can form a baseline against which targets can be set. It is important that such baselines are transparent and can be assessed independently. This does apply to the current accounting of cropland, grassland and wetland under the LULUCF Regulation but not to the accounting of forests, where the forest reference levels have proven to be too complex reference estimates.

There is no common generic criterion to fairly accommodate different national circumstances (e.g. reflecting historic development) that at the same time adequately reflects potentials and is cost-efficient and transparent. An alternative might thus be to additionally allow for country pledges that go beyond a minimum EU average benchmark. As the national net sink and restoration

target to be set directly corresponds to remaining emissions allowed in the target year, there are clear incentives for member states for ambitious yet reasonable targets.

4.3.2 A framework for consistent and transparent monitoring

The inclusion of GHG emissions and removals into the EU's climate target for 2030 requires more than a critical review of completeness, accuracy and consistency of LULUCF reporting and accounting. It demands that rules be designed to really set incentives for land management improvement.

The IPCC Good Practice Guidance to be applied for reporting LULUCF emissions and removals provides basic calculation methods and respective default data (IPCC 2006). The choice of the method has implications for uncertainty of the estimates. Moving to a higher tier method usually reduces uncertainties as it removes potential biases and better represents the complexity of systems. But higher tier methods may also increase uncertainty by revealing additional complexity that was not captured by the lower tier method.

Böttcher and Reise (2020) identified potential issues of completeness, consistency and accuracy in current reporting and accounting rules and procedures for EU MS and their implications for incentives to change land management within the EU looking at cropland, harvested wood products, managed forests and organic soils. Countries are more likely to increase their ambition level in LULUCF if there is a closer connection between concrete management practices, co-benefits of other policy targets (e.g. area of organic farming, hectares of ecosystems restored) and GHG inventories. In general, coarse reporting approaches tend to make the effects of land management changes on carbon stocks less visible and therefore disincentivise MS to act. Most issues of accuracy and completeness identified by Böttcher and Reise (2020) can be overcome by an increased level of detail and improved data sources applied for reporting.

A net sink and restoration target needs to consider that a higher level of accuracy is a prerequisite for a higher level of ambition. Therefore, improved estimates for GHG emissions and removals are needed. Improved estimates might also increase the ambition level indirectly by making hidden emissions visible. Eventually they are essential for an effective planning and implementation of mitigation measures that can reduce costs for MS in the long run. However, in the short-term there are no incentives for countries to improve their monitoring because it involves higher costs.

Any carbon trading of credits and debits from the LULUCF sector needs to be based on the best available monitoring systems to ensure that such market mechanisms do not threaten environmental integrity. Moreover, there is the **need for a consistent and transparent register** for exchange of credits and debits between different accounting systems (e.g. LULUCF and Effort Sharing), sectors (e.g. LULUCF and Agriculture), and countries. By applying common standards and definitions, it needs to make sure that transfers are comparable and equivalent. Restricting market access to only those countries that meet requirements of such a register could create incentives for improving monitoring and certification. Moreover, there is a need for discounting credits to be transferred to account for uncertainty.

4.3.3 Robust accounting approaches to address non-permanence and volatility

Including the LULUCF sector into the overall climate target requires accounting rules to address the non-permanence issue of the sink enhancement. Emissions and removals in forests fluctuate sharply between years and can amount to very significant shares of the total annual emissions in member

states. Moreover, countries' GHG accounts can easily change from sink to source and vice versa due to recalculations required after changes in methods or underlying data (see for example a recent analysis of German GHG inventory data by Oeko-Institut [15]).

There is a high risk for transporting the volatility and uncertainty of LULUCF into joint accounts with the emitting fossil fuel sectors. Interannual variation can be addressed by averaging GHG estimates over subsequent inventory years for accounting. Under the LULUCF Regulation only reference periods exist to avoid fluctuation of accounts. The 2030 overall EU mitigation target of -55% includes LULUCF in the single years 1990 and 2030 and can therefore be affected more easily by recalculations with implications for the ambition level and the risk of non-compliance. The LULUCF sector is subject to frequent recalculations of data that can have major implications for reported historic emissions and removals, even for the net balance reported, especially following changes in methods that are expected from member states. Recalculations in countries with large areas under LULUCF reporting can significantly affect EU total numbers.

Robust accounting rules are best based on historic reference periods. These should be set to a period of 10 to 20 years before the commitment period and cover a period of 5 to 10 years. Such a temporal distance is long enough to make management changes visible in inventories and short enough to cancel larger effects on emissions and removals from past practices. An example would be the period 2001-2010 as reference for the commitment period 2021-2030. A simple historic reference increases transparency and facilitates reconciliation of accounts by independent bodies. It also reduces efforts and potential misuse of technical corrections to be applied after recalculations of inventory data.

Moreover, **robust accounting requires complete reporting of emissions and removals from all land areas** using at least simple methodologies. This includes especially emissions from pools that are currently not fully reported by member states or with rather simple methods. Especially organic soils seem to be underrepresented compared to international data regarding their occurrence (Böttcher and Reise 2020). Accounting of all six land use categories should be mandatory from 2021 onwards as this increases efforts by countries to provide accurate inventories.

Countries are free to choose methods and tools for reporting to apply approaches that best fit the country conditions. However, there is the **need for setting up an authoritative and unbiased reference information system based on consistent international data**. The reference system that could be run by EEA or an international organisation should make use of the best available data as a combination of inventory data (forest and soil surveys by member states), remote sensing information (e.g. based on Copernicus services) and modelling. The system could serve for initial checks of member state reports, gap-filling and projections. Moreover, the reference data system could also form a quantitative scientific basis for establishing and benchmarking certification and labelling systems to promote and attest processes and products that are climate friendly and support achieving ambitious mitigation targets.

Currently, the LULUCF Regulation includes provisions for addressing natural disturbances. However, they mainly aim at allowing countries to exclude emissions from events of force majeure, i.e. emissions that exceed a certain margin of historic emissions related to disturbances. Instead, the **consideration of natural disturbances should address the risk of non-permanence of carbon stored in vegetation and soil**. Countries with proven historic records of natural

[15] Text in German: Oeko 2021: LULUCF sources and sinks in the German GHG emission-inventory. Short analysis for the DNR. https://www.dnr.de/fileadmin/Positionen/21-02-23-Memo_Inventare_LULUCF.pdf

disturbances or an estimated risk for future events should be required to incorporate buffers when accounting for net sinks. This would be equal to a mandatory banking of credits to reduce the risk of non-compliance in future periods.

4.3.4 Additional metrics as performance indicators to support compliance and environmental integrity

Emissions and removals from LULUCF are affected by climate change and natural disturbances and therefore might cause issues of non-compliance for some countries trying to achieve ambitious net sink targets. There is the opportunity to introduce additional metrics for assessing performance towards more sustainable land use in member states that go beyond carbon accounting. This could not only be an option for countries facing natural disturbances to demonstrate compliance at a different level but also for integrating non-carbon aspects into a restoration target. Additional metrics could be based on restored area or additional area not managed or protected.

Other metrics could be introduced to assess carbon storage in wood products to achieve more diversion of wood into material and away from energy use. Applying non-CO_2 metrics in this field could incentivise countries to introduce policies that support relatively more material use and cascading of wood than only GHG accounting that is often too coarse.

Additional metrics are to a large degree readily available for member states. However, they require some common definitions and methods to make them comparable and equivalent.

4.3.5 Creation of adequate funding opportunities for realising sink potentials

To a large degree, land use activities in the EU are driven by subsidies (e.g. under the Common Agricultural Policy and the Renewable Energy Directive). Additional incentive schemes that ignore the existing flows of subsidies will not be effective. Therefore, the redirection of subsidies that oppose sink and restoration targets is needed.

The same applies to carbon markets within and outside the LULUCF sector. The EU Emission Trading Scheme incentivises the use of biomass for energy production by assigning zero emissions to biomass use. If incentive schemes for restoring carbon stocks in forests need to work against such strong inducements, they will not be effective. Similarly, mechanisms for higher product prices (e.g. via labelling) operate at much smaller margins compared to existing subsidies.

To adequately provide funding opportunities for agents outside of existing subsidy schemes (e.g. forest owners) a dedicated EU land climate fund would be needed. In Germany, the *Waldklimafonds* [16] funds mitigation and research projects targeting forest-based climate mitigation and adaptation. The *Waldklimafonds* intends to support the implementation of measures that serve to adapt forests to climate change and enhance CO_2 emission reduction and carbon storage in forests and wood.

Revenues from selling land-based carbon credits are seen as a funding source for realising management changes towards climate-friendly and more sustainable practices. The integration of land use activities into carbon market mechanisms, however, is debated controversially. **There are key risks to environmental integrity associated with carbon markets, with regard to**

[16] https://www.waldklimafonds.de/

additionality, leakage, ensuring permanence or addressing non-permanence, monitoring emission reductions, and crediting issues such as avoiding double counting of reductions. Opportunities and risks of engaging the land use sector differ significantly between different measures. For crediting of afforestation and restoration there is experience with existing standards (TREES, CDM, VCS, etc.), credits for enhancing forest carbon stocks, agricultural soil carbon enhancement and avoided deforestation involve significant uncertainty regarding the above-mentioned aspects. Many existing crediting systems focus on the voluntary market and lack a clear concept for their integration into a compliance system.

5 Aligning the net sink and restoration target with land use related EU policies

For making an EU net sink policy effective, land use related policies need to be aligned with the policy objectives behind it. This includes removing barriers by amending policies that set wrong incentives but also introducing references between policies for gaining leverage towards a net sink target. Under the EU Green Deal, the European Commission has announced to review several policies in this regard in the course of 2021. Here, the following EU policies are briefly assessed regarding potential trade-offs and synergies with an EU net sink and restoration target:

- LULUCF Regulation;
- Renewable Energy Directive;
- EU Communication on forest protection;
- EU Adaptation Strategy;
- EU Biodiversity Strategy.

5.1 How does the LULUCF framework need to be adapted towards a net sink and restoration target?

5.1.1 Flexibilities between sectors

The European Commission is currently reviewing the LULUCF Regulation EU 2018/841 with the aim to ensure a consistent implementation of the Climate Target Plan. The 2030 Climate Target Plan Impact Assessment identified three options for amendments:

- Option 1: to strengthen the current LULUCF Regulation and to increase its ambition in line with the 2030 Climate Target Plan;
- Option 2: to strengthen flexibility with the Effort Sharing Regulation (ESR);
- Option 3: to combine the agriculture and LULUCF sectors into a single climate policy pillar with a separate target.

All three options constitute different positions along a gradient of flexibility between the LULUCF sector and other sectors, ranging from no flexibility (Option 1) to limited flexibility with **several** sectors (ESR, Option 2) and full flexibility with **one** sector (Agriculture, Option 3).

The inclusion of LULUCF in the new revised EU 2030 target makes sure that an important area of climate protection policy is now directly addressed in an overall and binding framework. However,

as discussed above in section 4.3.3 on robust accounting approaches to address non-permanence and volatility, the full-scope inclusion creates uncertainties for the quantitative determination of overarching and sectoral climate targets, as well as the governance of MS commitments, including flexibilities between sectors.

Changes in GHG inventories of large EU MS due to recalculations can easily change reference emissions in the range of several percentage points. This can make a timely and sanctioned climate protection regime largely ineffective or have considerable consequences for other sectors. **In view of persisting large methodological and data uncertainties of emission and removal estimates for the LULUCF sector, targets should be kept strictly separate and flexibilities between these commitments should not be allowed or at least very clearly constrained.** This applies to existing flexibilities with the EU Effort Sharing Regulation and much more to potential ones with the EU ETS.

Any flexibility granted needs to include a certain safety margin or buffer to accommodate for uncertainties related to methods, data, and trend. Alternatively, a discount rate could be applied for the exchange of carbon credits when using flexibilities. Examples for such discounting are applied by the REDD+ Environmental Excellence Standard (TREES)[17]. It uses a conservative approach allowing a maximum uncertainty level of 15 % (at the 90 % confidence level) beyond which the crediting level is reduced by the calculated percentage uncertainty, while the reported emissions are to be increased by the calculated percentage uncertainty.

5.1.2 Stringency of accounting rules

The current “no-debit” target under the LULUCF Regulation is likely to leave some MS with considerable excess credits after accounting, reducing incentives to actively change management practices in the land use sector. Increasing stringency of the target would set such incentives, especially when flexibilities from the ESR are limited. The challenge is to define a target that is different from zero and considers country specific circumstances (see section 4.3.1 above). Moreover, additional safeguards for avoiding leakage would be needed to reduce displacement of land use activities to outside the EU (see section 5.3 below).

Stringency of the LULUCF target is automatically increased when a constant update of historic reference levels for each land category is required. This option should be considered for the accounting of forests as it would result in a simpler and more transparent way of establishing the reference level (see section 4.3.3 above). It also reduces efforts and potential misuse of technical corrections that need to be applied after recalculations of inventory data.

5.1.3 Linkages to Agriculture

Option 3 of the Impact Assessment suggested to form an integrated sector of LULUCF and Agriculture (e.g. the AFOLU sector), thus allowing for full flexibility between the two sectors. Such an alignment is meant to ease designing efficient and effective policies in these sectors. However, it also removes potential constraints on flexibility between two sectors being different in GHG gas characteristics, distribution of emissions and removals, and potential mitigation among MS. In its 2016 Impact Assessment (European Commission 2016) that analysed the options for inclusion of the LULUCF sector already, the European Commission came to the conclusion that there are considerable disadvantages of such an inclusion. Setting a target for the agriculture and forestry

[17] https://www.artredd.org/wp-content/uploads/2020/04/TREES-v1-February-2020-FINAL.pdf

sectors together would be a much more complex task compared to separate targets (for emissions from Agriculture and net removals from LULUCF). The report also referred to reduced environmental integrity as a result of the withdrawal of agricultural emissions from the (former) ESD as a backsliding step in the EU's commitment. This is especially true for the option that would move Building and Transport sectors into the EU ETS, getting potentially more stringent, while non-CO_2 agricultural emissions would potentially face a less stringent regime under the AFOLU sector.

5.2 What are linkages to the EU Renewable Energy Directive?

The Renewable Energy Directive of 2018 (RED II, EU 2018/2001) sets the target of achieving a 32 % share of renewable energy by 2030. Under the Green Deal, the EU Commission proposes to increase this target to 40 %. It is important to understand and consider linkages between the LULUCF Regulation and RED II regarding the implications of their interplay for a net sink and restoration target.

In principle, the use of forest biomass for energy purposes can be counted towards RED II in the heating and cooling, transport and electricity sectors. However, this use is not directly stimulated by RED II, but indirectly through specific targets, especially for cooling and heating where the energetic use of forest biomass can play a relevant role. In the transport sector, current technology development indicates that lignocellulosic fuel pathways focus more on agricultural residues such as straw. However, there are several pilot plants that already use forest-based biomass for advanced biofuels.

Biomass use for energy under RED II is assumed to cause no emissions at the point of biomass combustion, because these emissions are already counted in the LULUCF sector, as a change in carbon stocks. This approach is adopted by the IPCC guidelines for national GHG inventories (IPCC 2006, 2019) and by the UNFCCC for the accounting under the Paris Agreement. The rationale for this approach is that biomass burned in the energy sector originates from very different sources and processes (e.g. primary wood from harvested biomass, secondary harvest residues, industrial residues, waste etc.). Assessing emissions and removals reported and accounted in LULUCF based on the annual change in carbon stock, and accounting forest bioenergy under the energy sector would imply a hypothetic attribution of what is burned to the biomass harvested, requiring even ex-post adjustments to avoid double counting (Camia et al. 2021). It often leads to confusion, and the zero-rating accounting incentivises economic operators to make an increasing use of forest bioenergy, also potentially subsidised through national support schemes of MS that aim at biomass for meeting their targets, thus stimulating the demand for wood (Camia et al. 2021). For reporting, it is necessary to avoid double counting. However, for designing policy instruments, it is necessary to map causalities in order to avoid activities that lead to net higher GHG emissions, regardless of the sectors in which these emissions are to be accounted for. For example, emissions from different sectors are included in the calculation of GHG default values in RED II (see below).

Accounting of emissions of biomass use under the LULUCF Regulation is only ensured if MS go beyond an additional domestic harvest level, i.e. exceeding their FRL. Below that level emissions remain invisible, especially in MS where net removals that can be accounted for exceed the national cap. There is a need for more awareness of these linkages, especially in national policies to avoid excessive use of biomass (leading to net debits in LULUCF or not). This requires a timely and accurate monitoring of the use of forest resources that goes beyond current practice. There is especially the need to improve the information basis on the origin of biomass used for energy purposes in the National Energy and Climate Plans (NECP).

The use of forest biomass for energy under RED II must meet sustainability requirements for harvesting, process GHG emissions and LULUCF accounting. However, there are a number of shortcomings related to the applicability of criteria, especially for protecting biodiversity (Hennenberg et al. 2018). While in RED I of 2009, land-use change criteria applied to agriculture **and** forestry, their application is now removed for forestry in RED II (Art. 26). This means that forest biomass harvested in primary forests, in highly biodiverse secondary forests, and in forests on peatland - outside of protected areas - can be sold as sustainable bioenergy complying with RED II in EU markets. New rules for sustainable forest management have been added in RED II that only cover the legality of harvest, forest regeneration after harvest, maintaining or improving long-term production capacity, maintaining soil quality and biodiversity (i.e., minimising negative impacts of harvest), and respecting existing protected areas (Art. 26.5 RED II). Due to the absence of reference data as a benchmark for the biodiversity status of an area, these criteria are likely to be ineffective for mitigating biodiversity risks occurring from the energetic use of forest biomass. RED II also sets thresholds for GHG emission savings, including forestry biomass. The threshold values for heating and cooling and electricity must be applied only to new installations, and related default values in the Annex of RED II for forest biomass like stem wood do not consider changes in the forest sink. Furthermore, solid biomass plants with a total rated thermal input of less than 20 MW are exempt from the obligation to provide proof of compliance with the sustainability criteria.

There are also issues regarding the criteria on protecting highly biodiverse forests (Art. 26.2) associated with agricultural production. Protection against conversion of forests — including highly biodiverse forests — to agricultural land is already covered by the high-carbon stock criteria in Art. 26.3. Highly biodiverse forests should be protected against negative impacts arising from forestry, but this criterion is missing in Art. 26.5.

Regarding LULUCF requirements, RED II refers to Nationally Determined Contributions (NDCs) under the Paris Agreement. If the NDC includes LULUCF, imported biomass can be counted against the RED II target. However, from an analysis of submitted NDCs it is obvious that they are different regarding their ambition level on land use emissions and the approach taken for accounting. So there is the risk of imbalanced accounting of biomass in these countries. For countries without coverage of land use in their NDCs, detailed criteria ensuring maintenance of carbon stocks in the sourcing area are required.

Camia et al. (2021) estimate for the EU that currently "roughly 20 % of the total wood used for energy production is made up of stem wood, while 17 % is made up of other wood components (treetops, branches, etc.)". In addition, the use of energy wood has significantly increased over the last two decades. This is also the case for woody biomass (stem wood, treetops, branches, etc. harvested from forests) and not only for secondary woody biomass (industry, recovery). In a public consultation [18] in early 2021, the European Commission collected stakeholder views on how RED II should be revised in the light of an increased emission reduction target in the 2030 Climate Target Plan. To avoid contradictions with objectives of RED II, the LULUCF Regulation and Biodiversity Strategy for 2030 the following aspects should be considered:

- Use of stem wood directly harvested from forests should explicitly be excluded from RED II (Annex IX).

[18] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12553-Revision-of-the-Renewable-Energy-Directive-EU-2018-2001/public-consultation

- The amount of wood energy used in the heating and cooling sector should not exceed a threshold value like the cap for first generation biofuels.
- The exemption for smaller solid biomass plants should be deleted or at least rewritten towards an area related threshold (e.g. an exemption for forest smallholders).
- RED II accounting should include effects of wood harvest on the carbon storage in forests when calculating default values for GHG emission savings.
- The total amount of energetic use of sustainable biomass, especially wood directly harvested from forest, should not be increased.

5.3 What are linkages to the EU's communication on stepping up EU action to protect and restore the world's forests?

The responsibility of the EU to protect forests is not just limited to its own forest management but also has a strong global dimension. Especially the production of goods like soybeans and palm oil and cattle farming are main drivers for deforestation in the tropics and therefore loss of important global carbon pools (IPCC 2019; FAO 2020). However, the EU is the second biggest importer of Indonesian palm oil [19] and is an important trading partner for Brazil's soybeans (21 %) [20]. In 2019, the EU adopted a communication on stepping up EU action to protect and restore the world's forests. The communication by the European Commission stresses the importance to reduce the EU consumption footprint on land and to promote deforestation-free value chains in close cooperation with producing countries to reduce pressures on forests. Additionally, the EU aims to redirect finance to support more sustainable land-use practices and to support the availability and quality of information on forests and commodity supply chains (European Commission 2019).

Ambitious laws and regulations for sustainable trade and production of goods outside the EU to protect ecosystems and their carbon pools will be an essential step to accompany the restoration and sustainable land management ambitions in the EU. For example, if land is needed for restoration, there will be less land for cattle farming and crop production. This could be an incentive for increased imports from outside the EU, especially if the consumption level in the EU for e.g. meat products remains high. Hence, **it is important to address leakage effects by changing unsustainable consumption patterns and implementing effective trade and production regulations**. Leakage effects can also be problematic for wood production and trade, especially when strict forest protection laws and more extensive forestry is implemented in the EU. Therefore, implementing the EU FLEGT (Forest Law Enforcement, Governance and Trade) Work Plan 2018-2022, in particular the enforcement of the EU Timber Regulation to stop illegal wood trade will be crucial to protect non-EU forests.

5.4 What are linkages to the EU Adaptation Strategy?

In 2013, the European Commission adopted a strategy on adaptation to climate change for the EU. The EU Adaptation Strategy has three key priorities to promote climate resilience. One is to encourage all MS to adopt national adaptation strategies and to integrate adaptation considerations

[19] https://eeas.europa.eu/sites/eeas/files/fspo-01_palm_oil_20190321_en.pdf
[20] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/soya-import-dashboard_en.pdf

into EU funding programmes and investments. It also aims at providing information about climate change impacts in different sectors as well as promoting adaptation in key vulnerable sectors. In 2021, there will be an update of the current adaptation strategy in line with the "European Green Deal". A recent consultation[21] on the strategy in 2020 revealed that MS still need to improve implementation of national plans, and there are still knowledge gaps on climate impacts. According to the stakeholders, there is a need to mainstream adaptation objectives in sectoral policies and to profit from cross-MS collaboration to tackle challenges especially at a regional level. Also, adaptation concerns should be more integrated into climate mitigation policies. For example, as mentioned in chapter 2.3, carbon pools face multiple risks related to climate change and therefore need the capacity to adapt. The blueprint to the strategy further mentioned nature-based solutions to adapt towards impacts of climate change e.g. on infrastructure, and simultaneously protect carbon pools.

Figure 6-1 presents potential synergies of effective net sink and biodiversity protection strategies that can also be beneficial for climate adaptation. For example, the restoration of temperate forests towards naturally structured deciduous forests with closed canopy has positive effects on local cooling as well as water retention in the region (Norris et al. 2011). Therefore, it is important to protect and increase forests for positive regional climatic effects. This is not necessarily true for the boreal region as already mentioned in chapter 4.1 due to albedo effects. But in urban areas, the cooling effect of woody vegetation cover can be used to buffer heat waves.

Agroforestry is an effective climate adaptation strategy because it reduces water run-off and erosion in croplands. This can improve water infiltration and retention in the soil and thereby reduce drought stress for crops below the tree cover (Jose et al. 2009). The protection of infrastructure against flooding and heavy rain events can be achieved by protecting coastal and wetland ecosystems that serve as water regulating landscape systems.

The examples above stress the **importance for MS to develop strategies that consider both aspects, adaptation and mitigation to increase effectiveness of the measures.** Finally, monitoring of the measures will be needed to establish a solid data basis (e.g. by making use of earth observation data) to help inform MS about the impacts of climate change. Also, there should be a constant exchange of experiences between MS during the implementation process to improve and constantly adapt measures when necessary.

5.5 What are linkages to the EU Biodiversity Strategy?

Protecting and restoring carbon-rich ecosystems is key for an EU net sink strategy and can also substantially contribute to forest, wetland and grassland ecosystems being in good condition. This is a central target of the EU Biodiversity Strategy, and measurable results should be achieved by 2030 (see also chapter 2.5). One of the main targets is to strictly protect the last primary forests, which is of high importance to preserve biodiversity in Europe as well as save carbon pools.

In managed forests, the restoration of monocultural production forests is an important measure to support biodiversity. For example, the conversion of non-natural coniferous stands into mixed or deciduous tree stands with high growing (carbon) stocks can improve carbon storage in biomass and similarly be beneficial for forest biodiversity. This is especially true when native tree species of the natural forest habitat type are promoted to which other forest species are adapted. Additionally,

[21] Synopsis of the consultation

it is important to have all forest age classes from regeneration to decay sufficiently represented in a regional forest landscape pattern to support and enhance regional biodiversity because different species rely on different tree age classes and dead wood for survival (e.g. fungi, deadwood beetles). This can also increase resilience towards climate extremes like storms because of an uneven tree canopy structure. Also, diversity in tree ages and species decreases the sensitivity towards disastrous forest loss due to pest outbreaks. For example, deciduous trees can decrease the spread of bark beetles specialised on spruce and therefore also protect important wood resources.

Certain artificial forest habitat types like oak forests formally used for cattle farming are very important biodiversity hot spots particularly for certain insect species but need constant management and thinning to support non-competitive oak trees. These valuable habitat types and their sustainable management must be protected although their tree density and carbon storage potential might be comparatively low. This also applies to naturally sparse forest habitat types like natural pine forests in subcontinental and Mediterranean regions.

Although forests are important carbon pools and habitats, they may not always be the natural ecosystem cover. Especially when peatland ecosystems must be restored, it can be necessary to remove tree cover that further drains the peat due to transpiration. In many cases it is more effective to protect the peat cover from demineralisation compared to the carbon stored in the tree biomass. However, the main danger for peatlands is drainage due to agricultural usage and infrastructure spread which led to a substantial loss of these ecosystems and their biodiversity (see chapter 2.3). Therefore, peatland restoration and protection are major contributions towards biodiversity protection in Europe.

As shown above, carbon sink and biodiversity protection have strong synergies but, in some cases, can implicate contradicting measures like afforestation of biodiverse but sparsely vegetated landscapes. Hence, regional restoration and monitoring methodologies as well as data on biodiversity and ecosystem development is necessary to develop appropriate regionally adapted measures that target synergy effects. Profound data and an EU-wide monitoring methodology are also needed to ensure ecosystems do not deteriorate following their restoration.

6 Conclusions

1. What should be the purpose of a net sink and restoration target?

The aim of the Paris Agreement of balancing emissions and removals by 2050 can only be achieved if emissions are cut drastically. **The primary role of a net sink and restoration target should be to ensure that ecosystems maintain and regain their capacities to act as natural sinks and store carbon. This is an essential precondition to balance any remaining emissions that cannot be avoided. It further requires that natural sinks are long-term and of high permanence to contribute to overall environmental integrity.** Achieving long-term carbon storage is the main challenge to maintain and increase the net sink potential in forests, wetlands and soils and includes both: emission reductions by avoiding land conversion and unsustainable practices and protecting and restoring ecosystems and their carbon stocks.

2. What are the main risks for current carbon sinks?

The **main pressures** on Europe's carbon pools are **intensive land management practices** and the **conversion of carbon-rich ecosystems**, mainly by drainage of organic soils, deforestation as well as increasing urbanisation and infrastructure. Also, intensive forest management reduces forest

biomass carbon stocks and sink potentials. Natural disturbances accelerated by climate change like winds, fires, droughts and pests are also risks related to the persistence of natural carbon stocks.

Measures for reducing GHG emissions from land and increasing natural carbon sinks on land face the risk of **non-permanence**. Moreover, there is **natural fluctuation** and an overall **limited carbon sequestration and storage capacity** of natural carbon pools to be considered. Also, as these measures require land use and management changes, land-based mitigation activities may trigger land competition and land tenure conflicts.

3. What are the most effective areas to enhance and protect carbon stocks?

Very effective mitigation and biodiversity protection potentials lie in the **protection of forests with high carbon stocks like in primary and old-growth forests**. Also, **sustainable forest management that promotes carbon stocks in biomass and structures for biodiversity can serve both needs for adaptation and mitigation as well as sustaining biomass supply for high quality long-lived wood products** (Figure 6-1). The restoration of wetlands by rewetting organic soils mainly under cropland and grassland as well as the protection of existing wetlands are not just efficient mitigation measures but also important contributions to the targets of the EU Biodiversity Strategy (Figure 6-1). Protecting SOC by avoiding land conversion and by sustainable farming in cropland and grassland can also save substantial carbon stocks. Afforestation and reforestation measures as well as the implementation of agroforestry have the potential to contribute to carbon sequestration. Generally, all measures to enhance and protect carbon stocks have to be carried out with high sustainability standards to ensure their durability and resilience towards natural disturbances and contribution to other ecosystem services in the long run.

4. What are important principles for a net sink and restoration target?

A net sink target needs to be a **legally binding, enforceable, quantitative target** to be most effective. Moreover, **it needs to be separate from other sectors**. Having two targets (one full scope target, one net sink and restoration target) increases visibility of the land use sector as its performance matters for achieving the overall emission reduction and it reflects best the general accounting approach agreed for the Paris Agreement. To avoid a deterioration of the ambition level, it is important to **first decide on the scope of the target and then set its level. Dealing with non-permanence risks** requires accurate reporting but also accounting rules. The accounting framework that potentially involves carbon markets needs to discriminate between units of carbon from land use and fossil fuels and provide a trading exchange rate that accounts for the risk of non-permanence. In order to **avoid trade-offs**, social and environmental sustainability safeguards are needed. Principles for a net sink target need to allow for adequate **short-term** (e.g. 2030 and 2040) and **long-term milestones** (beyond 2050).

5. What are important technical elements of a net sink and restoration target?

The target needs to be brought down to the national level by criteria that relate to the mitigation potential. However, there is no common generic criterion to accommodate different national circumstances fairly (e.g. reflecting historic development) that at the same time adequately reflects potentials and is cost-efficient and transparent. Therefore, country pledges can be an option.

The net sink and restoration target needs to be built on a framework for consistent and transparent monitoring and accounting. It further needs to consider that a higher level of accuracy is a prerequisite for a higher level of ambition. Therefore, **improved estimates for GHG emissions and removals are needed**.

It further needs robust accounting approaches to address non-permanence and volatility. **Robust accounting rules are best based on historic reference periods.** Moreover, **robust accounting requires complete reporting of emissions and removals from all types of land** using at least simple methodologies.

Additional metrics as performance indicators to support compliance and environmental integrity should be considered in a net sink and restoration target. This is an opportunity for integrating non-carbon aspects of ecosystem restoration into such a target.

6. How could a net sink and restoration target be funded?

Additional incentive schemes that ignore the existing flows of subsidies will not be effective. Therefore, the redirection of subsidies that oppose sink and restoration targets is needed. There are key risks to environmental integrity associated with carbon markets, regarding additionality, leakage, ensuring permanence or addressing non-permanence, monitoring emission reductions, and crediting issues such as avoiding double counting of reductions.

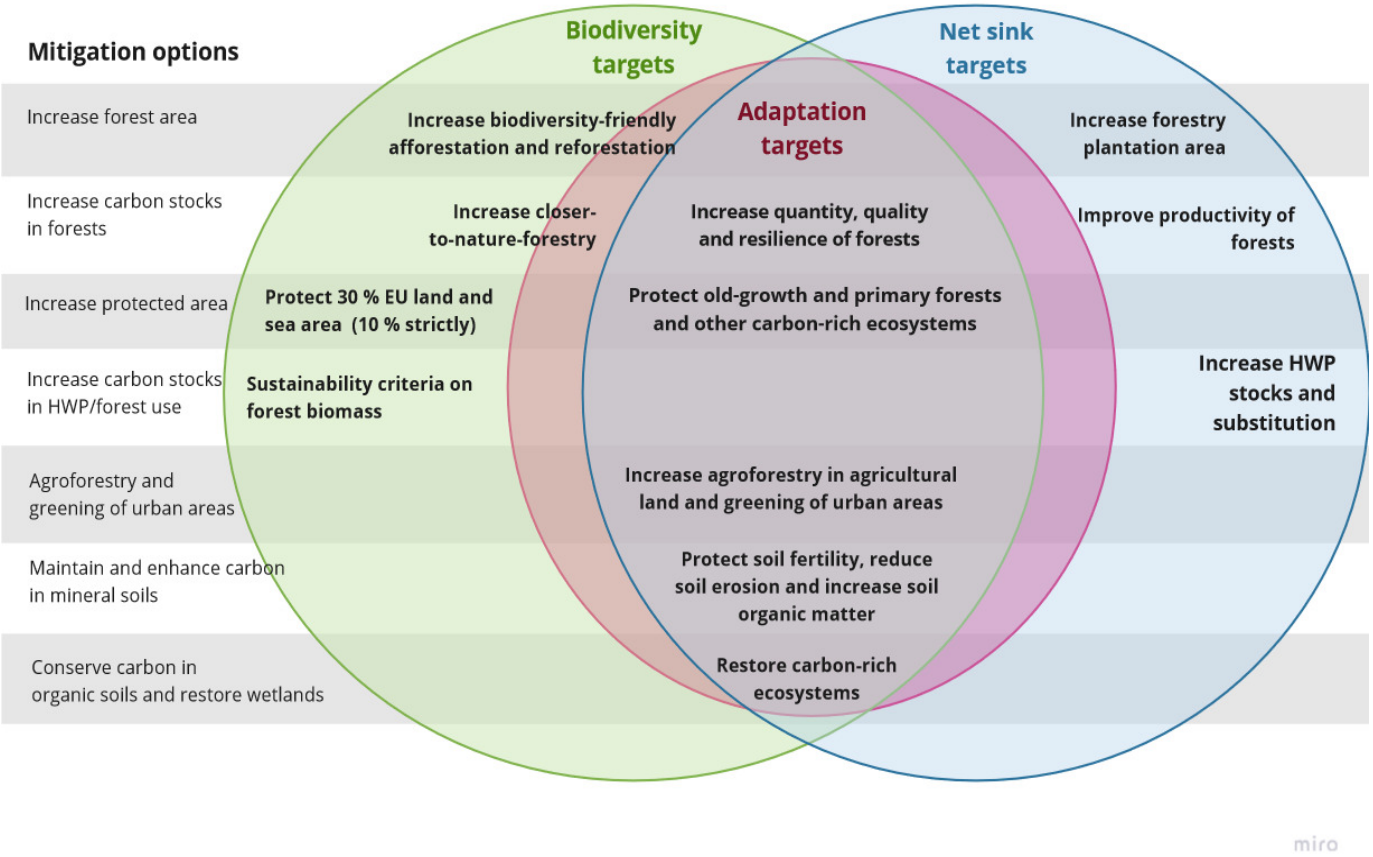
7. What changes should be made to the current EU policy framework to support a net sink and restoration target?

For making an EU net sink policy effective, there is the need to align land use related policies with the policy objectives behind them. This includes removing barriers by amending policies that set wrong incentives but also introducing references between policies for gaining leverage towards a net sink and restoration target. The study discusses potential trade-offs and synergies with an EU net sink target and implications for the LULUCF Regulation, the Renewable Energy Directive, the EU Communication on forest protection, the EU Adaptation Strategy, and the EU Biodiversity Strategy.

8. What are synergies of a well-orchestrated net sink, adaptation and restoration policy?

Measures to stop and revert the loss of biodiversity experienced over the past decades in the EU require substantial land use and management changes. These measures should also be beneficial for climate mitigation and ideally also form a response to increased adaptation needs (see Figure 6-1). The main synergies are protection and restoration of biodiversity rich ecosystems which are also important carbon pools like forests and peatlands. They additionally provide important services to protect people and infrastructure from climate change effects like increasing heat waves, drought periods and extreme weather events. Measures targeting these synergies require EU-wide guidelines on restoration and monitoring for common reporting and learning from progress.

Figure 6-1: Illustration of potential synergies of mitigation options regarding net sink, adaptation and biodiversity targets



Source: own compilation

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