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Abstract

The Russian-Ukrainian war increases the stress on forests. International sanctions hit exports from Russia and Belarus, while the conflict severely affects production in Ukraine. The three countries accounted for a quarter of the worldwide timber trade in 2021, and Russia was the world's largest exporter of softwood. The war increases the European Union's (EU's) dependency on its own forest resources. This brings forward the challenge to achieve a balance between forests as carbon sink, habitat for biodiversity conservation, and functional ecosystems on the one hand, and on the other hand, the growing demand for wood-based materials harvested from forests and rising demand for renewable energy. Our study provides insights into this trade-off with regard to the climate goals, where EU's forest-based bioeconomy may play a major role.

JEL:F18, L73,H70, Q54, Q57

Keywords: Bioeconomy, biodiversity, climate-change, forest management, sustainability

1 Introduction

After the Russian invasion of Ukraine, the dependence of many European Union (EU) countries on Russia for its oil and gas supply became apparent. Similarly, Ukraine's production of grain wheat is crucial for many parts of the world, and as a consequence of the war, food prices are increasing and millions of people are threatened by food shortage and hunger. On top of that, Russia is not only a major exporter of fossil fuels and fertilizer, it is also a country very rich in forest resources. Russia has the world's largest forest cover with 20% of the global forest area (Table 1). Related to this, Russia was also world's largest exporter of coniferous sawnwood in the year 2020 (see Table 3 in the Appendix).

Although the EU-import of Russian wood and wood products has decreased over the last decade, higher energy prices and less external sourcing may have a large impact on the European forest-based sector. Rising costs of harvesting and transportation of timber and higher demand during the pandemic led to a substantial increase of prices for wood-based products in Europe, which peaked around early March 2022 (Figure 1), though the prices have declined since then. While the price peak for timber was caused by the Russian invasion of Ukraine, the direct and indirect consequences of the war and of the imposed import sanctions on Russia's timber and wood products are likely to affect the European forest sector for a long time. This implies a turning point for EU's forest-based bioeconomy and also with regard to achieving the climate goals, where forests and the bioeconomy play a major role.

The Forest Steward Ship council (FSC) suspended all wood trading certificates for Russia and Belarus shortly after the Russian invasion. As the EU legislation requires that all timber imports to the EU should have FSC certificates, which guarantee sustainable wood sourcing practices, import of timber and wood products from these two countries to the EU are blocked. In addition, the EU has decided, as part of their sanctions, to impose import bans on all Russian wood products. But not only the sanctions, but also the war itself directly affects wood supply to the EU. Ukraine's wood production was negatively affected by the war. For the European market, reduced round-wood supply and higher energy prices make production more expensive for the whole forest-based industry throughout the value chain, from forest to the end consumer. It is important to note that as long as Russia and Belarus are excluded from the FSC certification system, even if import sanctions on timber by the EU would be relieved, it may be impossible for Russian wood producers to return to the European market.

The total consumption of timber and wood products in the EU has steadily increased over the last decades. Most of the wood supply comes from forests within the EU, with Sweden

Table 1: Top ten countries for forest area, 2020

Rank	Country	Forest area (1000 ha)	% of world forest area	% cumu- lative
1	Russian Federation	815312	20	20
2	Brazil	496620	12	32
3	Canada	346928	9	41
4	United States of America	309795	8	49
5	China	219978	5	54
6	Australia	134005	3	57
7	Democratic Republic of the Congo	126155	3	60
8	Indonesia	92133	2	63
9	Peru	72330	2	64
10	India	72160	2	66

Source: FAO (2020), Table 3.

and Finland as the top sawnwood supplier, but also Germany is an important producer. In addition, about one-tenth is imported from North-America and from South-America each. However, the three countries Russia, Belarus, and Ukraine[1] together provided about a fifth of the total import of coniferous sawnwood (“softwood”) to the EU, and Russia alone had an import share of 15%. Though the share of EU’s softwood import from Ukraine is much lower, this is different for non-coniferous sawnwood (“hardwood”), since Ukraine had a share of almost a tenth of all imports to the EU before the war.[2]

Insufficient supply of timber and wood products will also have negative climate implications. Coniferous sawnwood is very important to meet the growing demand for sustainable building materials, which is particularly true for France, Germany, Netherlands, and the UK. There are consequences for other countries and other wood-based product groups too.

In summary, the Russian-Ukrainian war is likely to have a long-term impact on wood supply and makes the EU having to rely more on its own internal forest resources. Tighter markets for timber together with higher prices reinforces the need to improve the trade-offs between wood provision, biodiversity, and forests as carbon sink in order to compensate for industrial, agriculture, and transportation emissions. Although Russia has not been the main source of wood imports for the EU despite its huge forest resources, the current crisis intensifies the need for European countries to commit to a faster transition

[1]Belarus, Russia and Ukraine belong to the group of Eastern Europe, Caucasus and Central Asia (EECCA) countries, see `https://www.oecd.org/environment/outreach/the12eeccacountries.htm` for entire list of EECCA countries. Europe refers to the EU27 member states + UK.

[2]See UNECE/FAO (2021), supplementary trade flow statistics, `https://unece.org/forests/forest-products-trade-flow`.

Figure 1: Lumber future price development at Chicago Mercantile Exchange from July 2021 to June 2022

Source: TradingEconomics, `https://tradingeconomics.com/commodity/lumber`, retrieved on 20 June 2022.

to a self-sustained forest-based bioeconomy.

2 The status of EU forests and wood production

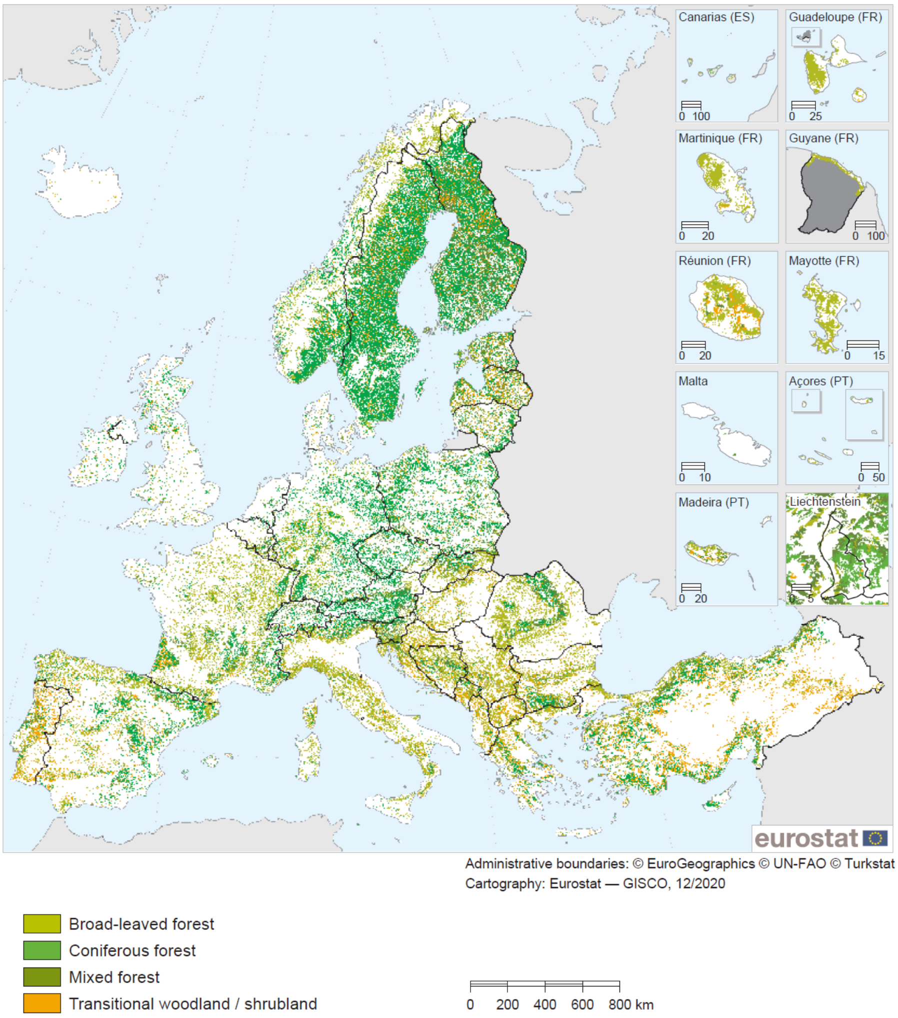
The EU-27 member states have an estimated 180 million hectares of forests and other wooded land, which corresponds to 45.1% of its land area and to 5% of global forested area. The EU member states with the largest areas of forests and other wooded land in 2020 were Sweden (30.3 million hectares), Spain (28.0 million hectares), and Finland (23.2 million hectares). France has 18.1 million hectares and Italy as well as Germany have both 11.4 million hectares covered by forests and other wooded land. Those six countries together contain two-thirds of the total forest area of the EU-27 (EuroStat 2020).

Figure 2 shows the distribution and diversity of tree species of European forests. Northern Europe is mainly covered with coniferous (boreal) forest while in middle and southern Europe broad-leaved forests dominate. Large parts of EU area are also covered by mixed forests of both tree families.

It is a well know fact that climate change exerts a serious threat to European forests.[3] Climate change makes extreme weather events more likely. Not only powerful storms that can cause huge forest damages, as the cyclone Gudrun did in the year 2005 (Seidl and

[3]See, for instance `https://efi.int/forestquestions/q4`, retrieved on 1 July 2022, and the given reference list.

Figure 2: Europe's Forest Cover, 2018



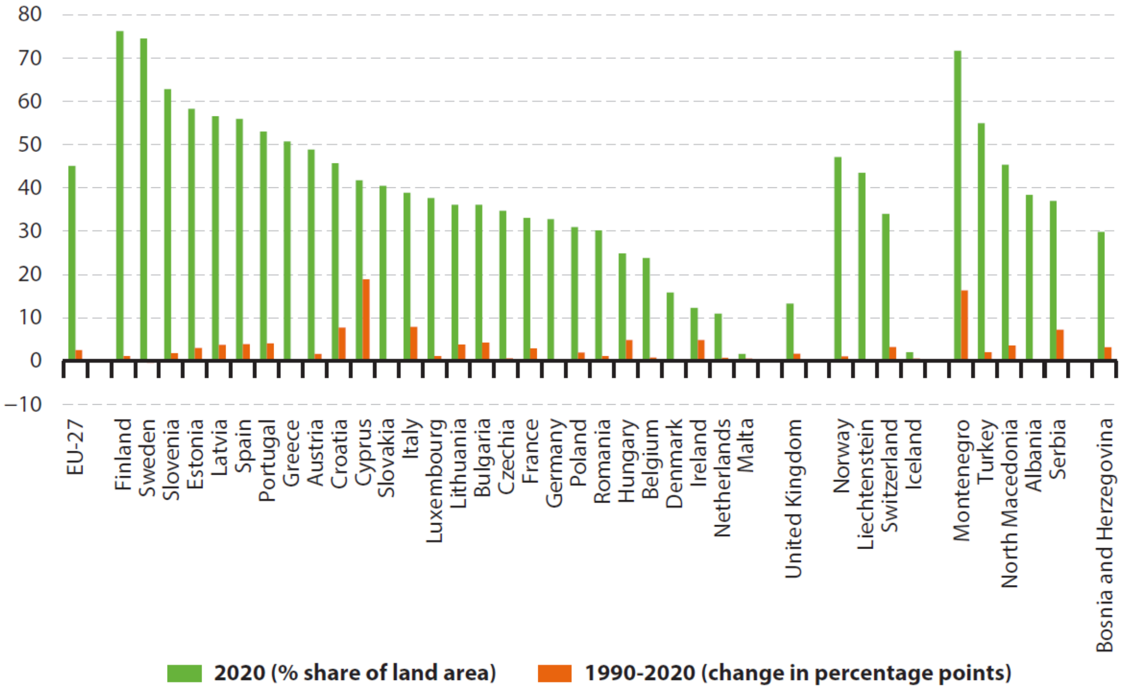
Source: (EuroStat 2020)

Blennow 2012), but also long drought periods are expected to happen more often in the future. Droughts make forests more vulnerable against damaging insects like the spruce bark beetle, and also increase the likelihood of forest fires. Every year, around 0.5 million hectares of EU forest are destroyed by forest fires.[4] In the longer term, higher average temperatures will also increase the risk that invasive species and pathogen diseases enter new areas and will cause serious damage to trees (Finch et al. 2021).

Figure 3 shows that EU-27 member states' forests and other wooded lands have increased by 2.66% between 1990 and 2020. With the exception of Sweden, where forest areas moderately decreased by 0.4% over the period of 1990–2020, in all other EU countries forest areas have increased. The largest increases took place in Cyprus (18.9%), Italy

[4]European Environmental Protection Agency, `https://www.eea.europa.eu/highlights/forest-fires-in-southern-europe-destroy-much-more-than-trees`, retrieved on 1 July 2022

Figure 3: Forest and other wooded land in 2020 and change 1990-2020



Source: EuroStat (2020)

(7.8%) and Croatia (7.7%) [5].

The highest forest land share among the EU-27 countries have Finland and Sweden (both over 70%), Slovenia (over 60%), followed by Estonia, Latvia, Spain, and Portugal (with over 50% shares) (Figure 3).

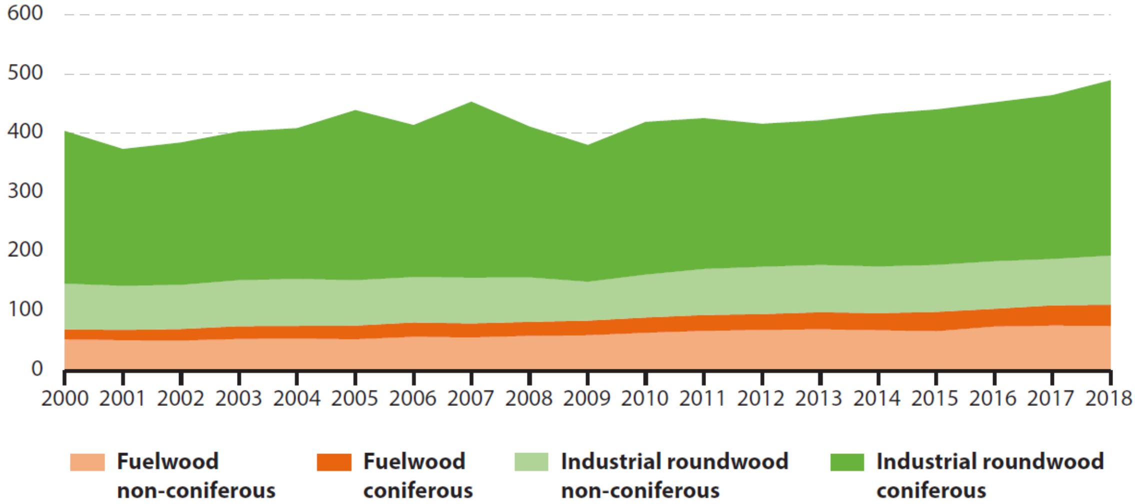
The EU forest-based industry provides significant employment and value added. These industries need primary raw materials from forestry and logging, like industrial roundwood. Industrial roundwood is an important resource and raw material for wood-based industries, being the basis for sawnwood and veneers but also for pulp and paper production. Another primary product from forests is fuelwood. Fuelwood is used a renewable energy source.

Total roundwood production in the EU-27 in the year 2018 was estimated to be 490 million cubic metres under bark, which was 21.2% higher than in 2000 (Figure 4). Coniferous tree species account for about 60% of the total roundwood production, while non-coniferous tree species account for about 15% of the total. About 25% of roundwood is used as fuelwood.

The major producers of industrial roundwood in the EU-27 are Sweden, Germany, and Finland (Figure 5). Together with France and Poland, these five countries produce up to

[5] EuroStat (2020).

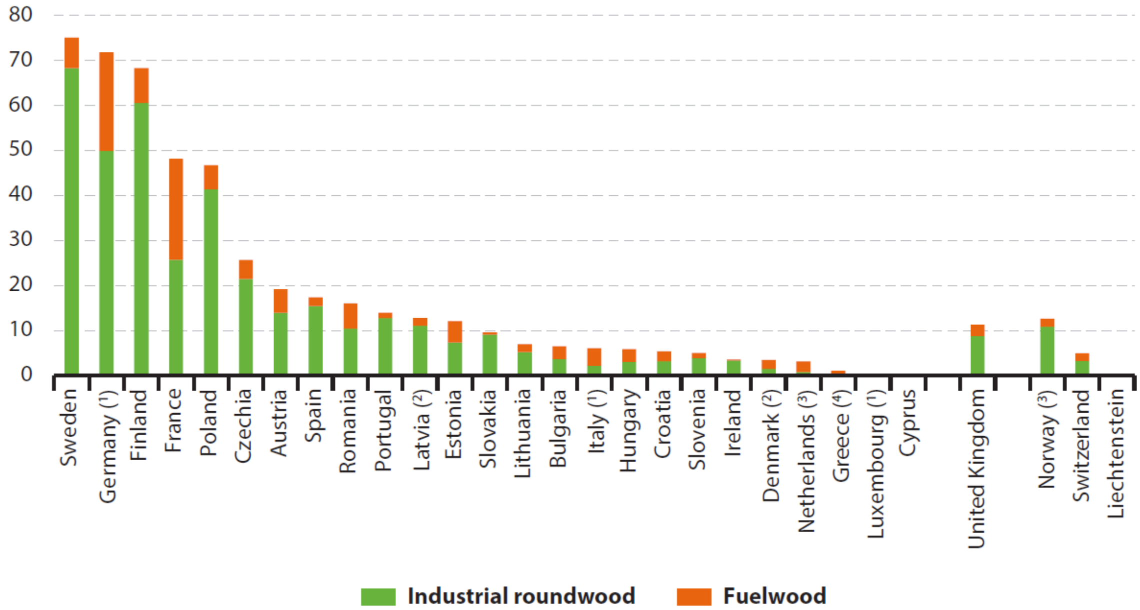
Figure 4: Development of roundwood production, EU-27, 2000-2018 (million m3 under bark)



Source: EuroStat 2020

two-thirds of total roundwood in the EU.

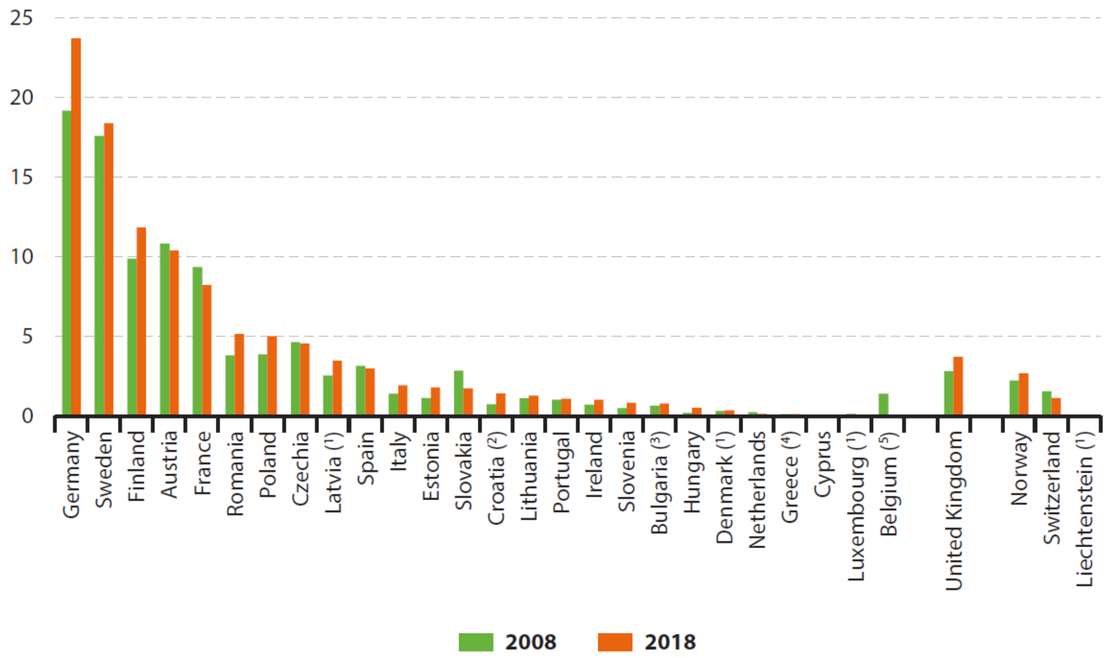
Figure 5: Round and fuel wood production in 2018 (million m3 under bark), by country



Source: EuroStat 2020

Sawnwood is an important input for the construction sector and the total output across the EU-27 was estimated to be 109 million cubic metres in 2018, which was also 11.7% higher than in 2008. The leading sawnwood producers of the EU-27 were Sweden and Germany, followed by Finland, France, and Poland (Figure 6). Germany and France experienced the largest increases of sawnwood production between 2008 and 2018.

Figure 6: Sawnwood production, 2008 and 2018, by country



Source: EuroStat (2020)

Wood production within the EU constantly increased over the last decades, but recently, other aspects of forests gained in importance, such as their role as carbon sinks and as important pools for biodiversity. The EU Biodiversity Strategy formulates the target that by 2030 more than 30% of EU land and sea should be legally protected to prevent further species and biodiversity losses. Forests play an important role in this. The EU common bird indicator[6] shows an overall decline of wild bird species, though forest-dwelling bird species appear to have even slightly increased in recent years.

Another important focus of biodiversity conservation are primary or old-growth forests. Those are particularly rich in terms of biodiversity and in providing eco-system services. Estimates suggest that less than 3% of EU's total forests are primary forests and with a declining trend. Consequently, the EU Biodiversity Strategy for 2030 also aims to strictly protect all remaining EU primary and old-growth forests (Muys et al. 2022).

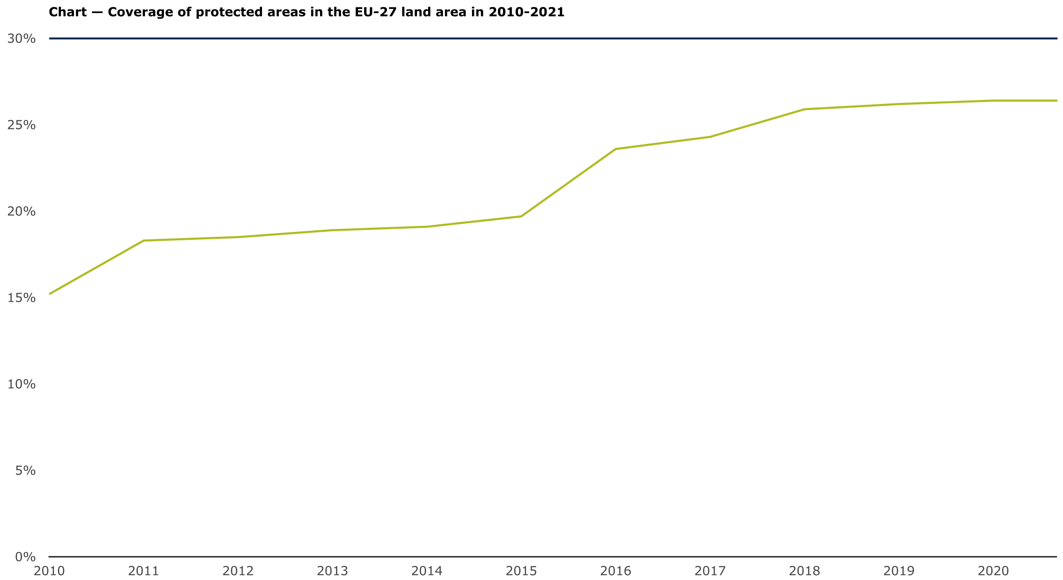
Figure 7 shows that in 2021 26.4% of all EU land was already protected, implying an increase of about 10 percentage points since 2010. Natura 2000[7] sites are an important

[6] European Commission, Eurostat, Common bird index (EU aggregate) (t2020_rn130), 2022, accessed 2022-06-25, http://data.europa.eu/88u/dataset/nw629tCTrBN5aIptk2H5A.

[7] Natura 2000 is a network of protected areas covering Europe's most valuable and threatened species and habitats, which are designated under the 'Nature Directives', i.e. the Birds and the Habitats Directives, https://www.eea.europa.eu/themes/biodiversity/natura-2000.

pillar of protected land. About 18.5% of EU land area is designated as Natura 2000 areas, while 7.9% are protected by national designations in the member states. Figure 8 displays a great heterogeneity of protected land shares among EU member states, ranging from more than 50% in Luxembourg, around 40% in Bulgaria and Slovenia to less than 15% in Sweden, Ireland, and Finland.

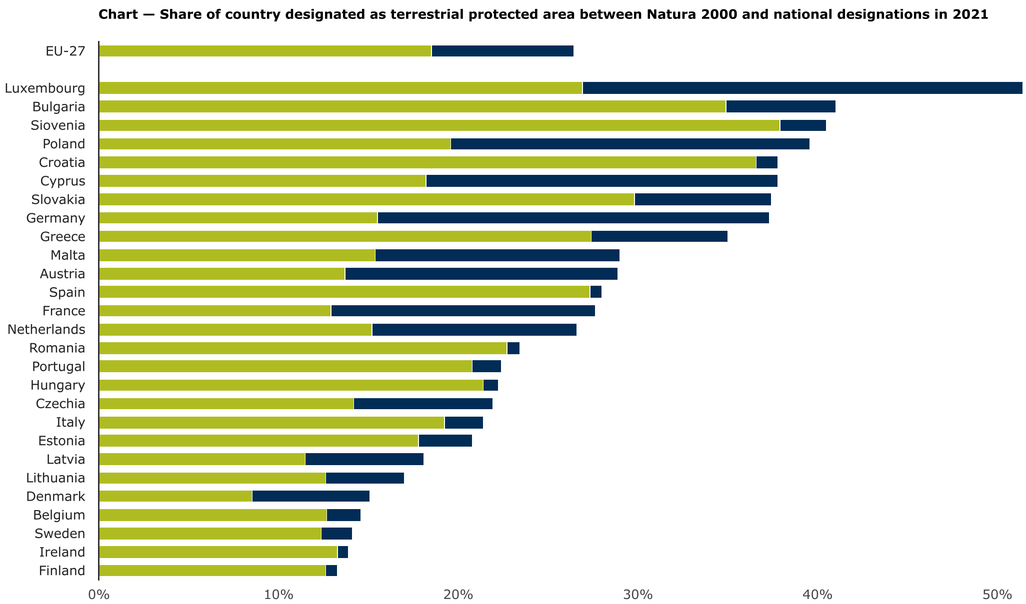
Figure 7: Development of coverage of protected areas in the EU-27 land area 2010-2021



Source: European Environmental Protection Agency, `https://www.eea.europa.eu/data-and-maps/`

In sum, while the EU has a significant forest-based industry and major parts of wood resources can be provided from its own forests, there is some dependency on timber imports from abroad. In addition, there exist apparent trade-off and target conflicts between increasing wood removal, on the one hand, and climate goals and the conservation of biodiversity, on the other hand.

Figure 8: Share of country designated as terrestrial protected area between Natura 2000 and national designations in 2021



Source: European Environmental Protection Agency, `https://www.eea.europa.eu/data-and-maps/`

3 Russia's timber and wood exports and the impact of the war-related sanctions on the EU's bioeconomy sector

The forest-based bioeconomy can be defined as the substitution of fossil-based materials and energy with bio-based and renewable solutions. It links the whole forest value chain–from the management and use of natural resources to the delivery of outputs. Bioeconomy implies producing and transforming biomass for products, materials, energy, and related services. A recent study by Ronzon et al. (2020) estimated that in the year 2017 EU bioeconomy contributed almost 9% of the EU-27 labour force and 4.7% of the EU-27 GDP. Forestry employs about 517,500 people, the manufacture of wood products and furniture about 1,4 million, and the manufacture of paper has about 590,500 employees (Ronzon et al. 2020, Table 1). In addition, forestry provides important raw materials to other sectors in the EU with significant employment shares, such as bio-based chemicals, bio-based textiles, and manufacture of liquid biofuels.

Russia is the world's third largest exporter of industrial roundwood (UNECE/FAO 2021). However, the trade relationship with the EU has been troubled in the past by the high export tariffs on unprocessed roundwood imposed by Russia around 2008. Volumes sharply decreased and have never recovered to earlier levels. Before the Russian-Ukrainian war, Russian exports accounted for 8.5% of all imported roundwood to Europe in the years 2018 and 2019.[8]

More than half of Russian exports of wood and wood products go to China[9], which does not participate in trade sanctions against Russia. As a consequence of cancelled contracts, lost FSC certificates, and the imposed import bans on Russian wood products, Russia is likely to be dismissed as a supplier of wood to the EU even in the longer term. It is also very likely that the Russian-Ukrainian war will influence EU policies in regard to the contribution of the forest-based bioeconomy to the EU goal of climate neutrality by 2050.

Strategies for reaching the most efficient use of forest resources with respect to partly conflicting interests–such as climate change mitigation, environmental protection, well-being, employment, and economic growth–are formulated and partly launched by various international bodies, including the following: Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), UN Environment Programme (UNEP), FSC, and the EU, as well as agencies and orga-

[8]UNECE/FAO (2021), Forest Product Trade flows, https://unece.org/sites/default/files/2021-05/trade-flow-fpamr2021.pdf.

[9](UNECE/FAO 2021), Forest Products Trade Flow Annex 2020-21.

nizations at the national, regional, and industrial level. The effect of these strategies are reflected in the national greenhouse gas (GHG) inventories, which follow standardised formats recommended by the IPCC and agreed upon by the Parties to the UNFCCC.

The perhaps most extensive and far-reaching international forest strategy was established in the European Green Deal announced in January 2020. The strategy aims to contribute to the achievement of the EU's biodiversity objectives and the GHG-emission-reduction target of at least 55% by 2030 and of climate neutrality by 2050. This framework strives to create resilient and multifunctional forest ecosystems and to include the entire forest cycle, also considering biodiversity. Another main objective is to support a growing circular bioeconomy. The EU plans to re- and afforest 3 billion additional trees by 2030 and to establish biodiverse forests. The strategy also includes to protect EU's last remaining primary old-growth forests.[10]

Noteworthy is the emphasize on a forest-based bioeconomy in the Green Deal. Traditionally, the role of forests for sustainable economic development has been largely focused on the potential of forests to capture and store atmospheric carbon dioxide (carbon sequestration). The broader bioeconomy perspective, however, facilitates forest management practices to achieve a balance between the different possible uses of the forest in accordance with internationally agreed climate and environmental goals.

4 Importance of forest-based sectors for EU's climate goals

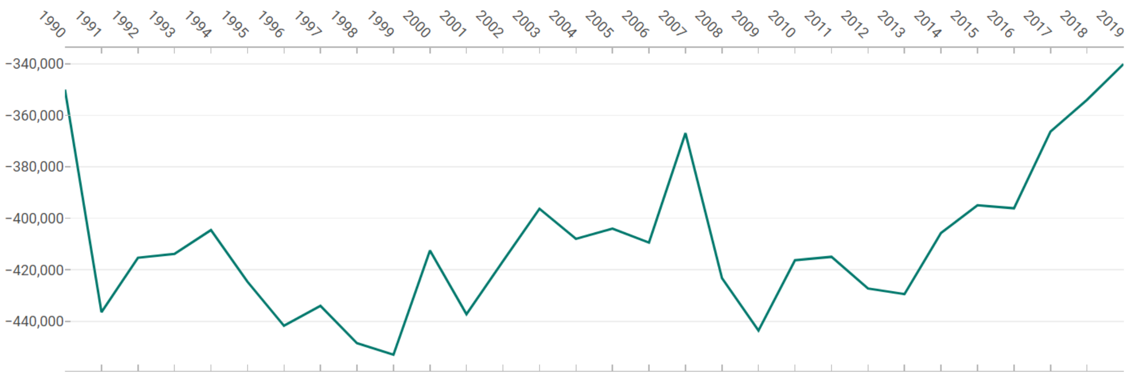
Forests and the forest-based sector play a key role in the climate policy agendas with regard to reducing carbon dioxide concentration in the atmosphere. According to the United Nations Environment Programme (2019) report, there is an urgent need of an annual 7.6% decrease of global GHG emissions between 2020 and 2030 to be in accordance with the course towards the 1.5°C goal of the Paris Agreement. Presently the land use, land-use change and forestry (LULUCF) sector is assumed to contribute with about a quarter of the pledged global emission reductions in Nationally Determined Contributions (NDCs) (Grassi et al. 2017). Moreover, so called 'natural climate solutions' (conservation, restoration, and improved land management actions that increase carbon storage or avoid greenhouse gas emissions in landscapes and wetlands across the globe) have been suggested as important means to mitigate climate change, and they can contribute up to 37% of the required global emissions reduction by 2030 (Griscom et al. 2017). It is suggested that two-thirds of the total mitigation potential from natural climate solutions could be achieved by storing carbon in forest ecosystems and the rest with the help of material

[10] https://environment.ec.europa.eu/strategy/forest-strategy_en

substitution (Roe et al. 2019).

The forest-based bioeconomy contributes to climate change mitigation by increasing carbon stocks (creating a 'net sink') in the Harvested Wood Products (HWP) pool, and by replacing cement, steel and other greenhouse gas (GHG)-intensive building materials with wood (see for instance Gustavsson et al. 2021; IPCC 2018). There are also positive effects from using residual wood waste to replace fossil fuels for energy production. Both the academic literature and policy stakeholders discuss potential trade-offs and synergies among these two categories of options (Jonsson et al. 2021). There is also a trade-off between domestic and imported wood harvest. Increasing harvest in the EU and reducing harvest outside the EU, for instance in Russia, Belarus and Ukraine, might affect the total global amount of GHG-emissions.

Figure 9: EU-27 net emission



Notes: EU27 net emission and removals from total forest land, million tonnes CO2 1990-2019 Source: European Environment Agency, EEA .

In 2019, the total GHG-emission by EU-27 was 3610 million tonnes (Mt) CO2 equivalent (CO2-equivalent is a metric measure used to compare the emissions from various greenhouse gases by converting amounts of other gases to the equivalent amount of carbon dioxide), while the removal by forest amounted to 328 Mt CO2. Figure 9 shows a trendwise declining net sink from 440 Mt in 2009. In order to meet the EU climate objectives in the medium term (2050), the current net forest sink should increase substantially. Reversing the trend requires a combination of different forest management policies. In the short-term, these include increases in the net annual forest increment (wood produced in forests annually minus the natural mortality including natural disturbances) and reduced harvest levels together with the associated logging residues (leaves, stumps, roots, tops, bark, and other woody debris from final felling etc.). The plan to increase forest increment by planting at least three billion trees in the EU by 2030 would increase the sink, however only to the order of 15 Mt CO2e/yr in the medium term. Apparently, tight wood supply after Russia's invasion of Ukraine has created incentives to increase rather then reduce the rate of felling, thereby creating a dilemma.

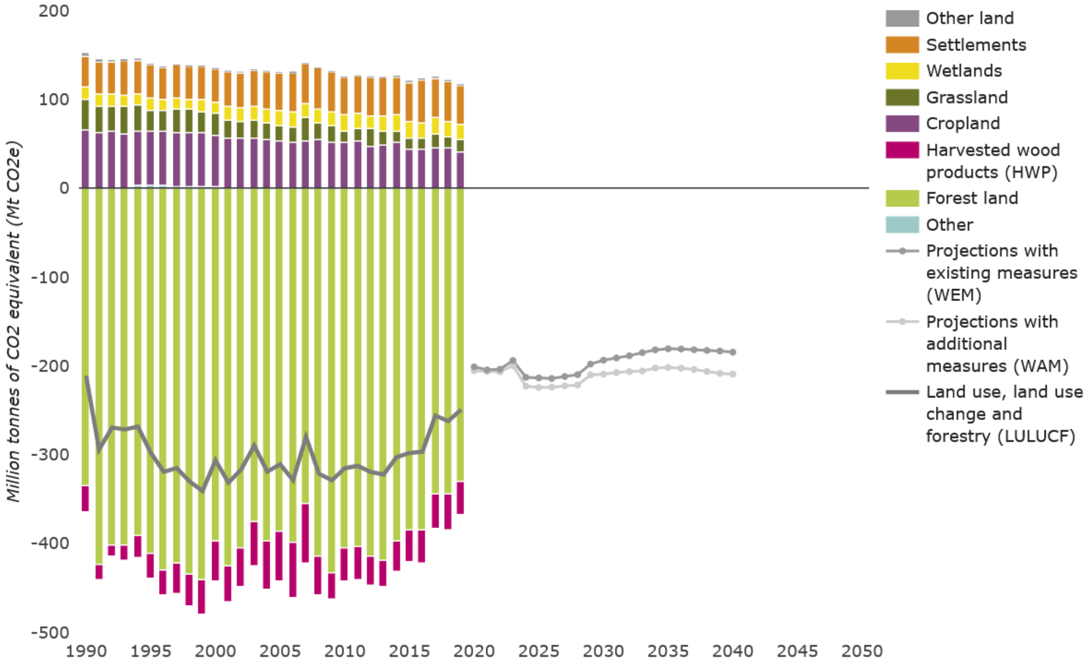
Increasing the net forest sink in the short to medium term by reducing the harvest may slow down forest growth in the long term, since younger forests typically grow faster than older forests (Smyth et al. 2020; Valade et al. 2017). Younger forests sequester more carbon and the net rate of carbon sequestration declines as forests get older. Therefore it might be preferable from a mitigation perspective to harvest growth and produce forest products that provide mitigation through product substitution and carbon storage in harvested wood products (HWPs) (Petersson et al. 2022). However, it might take up between 5–20 years after harvest and following regeneration of forest until forests again become a carbon sink, which might be considered as too late given the urgency to mitigate climate change in the coming 15 to 20 years.[11]

Improved carbon balance requires a set of complementary forest management strategies to help preserving and enhancing the multi-functionality of forests. One such measure is to strengthen protection against increased natural disturbances caused by climate change, such as drought, storm winds, forest fires, and insect infestations (Lindner et al. 2014). Another way to improve the balance while maintaining a stable harvest over time, is to increase the net carbon stored and life length in harvested wood products (HPW) through circular economy, research, and innovation. However, given the need for immediate action to slow down global warming, it might be necessary to significantly increase the net annual forest increment. This serves to both reverse the European trend of declining carbon sinks and to substitute GHG-intensive products with wood materials–especially in the construction sector but also in some other areas, for instance bioenergy production using pellets and recycled wood products.

[11] According to current scientific knowledge, the achievement of the particular target would require deep cuts in global greenhouse gas (GHG) emissions and an increase in carbon sinks over the next few decades in order to have GHG emissions and sinks in balance, i.e. to achieve net GHG emissions zero by 2050 (Rockström et al. 2017; Soimakallio et al. 2021). This implies that even if the global GHG emissions are reduced close to zero within a few decades, the carbon sinks must remain at least at the current level.

5 Discussion and Policy Insights

Figure 10: EU LULUCF GHG emission 1990-2050



Source: European Environment Agency, EEA .

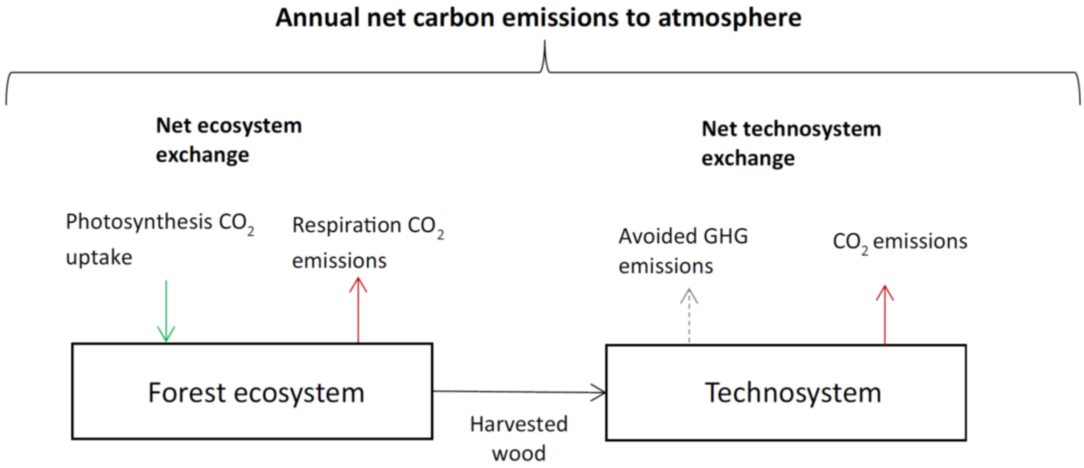
Figure 10 shows how EU LULUCF affects the exchange of GHG emissions between the terrestrial biosphere system and the atmosphere over the period 1990-2020 with net projection until 2050. Forest land is a significant contributor to the terrestrial sinks; harvested wood products as well but to a lesser extent. Cropland and settlements are the main LULUCF drivers of increased emission. The projection is that the current trend with less LULUCF compensation for emissions in other sectors will continue. The war in Ukraine causes concern over the potential of EU-forest to further increase its important role as carbon sink.

Table 2: Strategies for reducing GHG-emissions

Increasing carbon stocks	A. In living biomass, dead wood and litter, and soils	B. In the harvested wood pool (HWP)
Substitution	C. Using wood to replace GHG-intensive materials	D. Using wood to replace fossil fuels for energy

Table 2 illustrates two main bioeconomic strategies for the forest sector's contribution to mitigating climate change. The first is (A) increased biomass through larger growth than extraction of timber, more dead wood and litter, and improved soil quality for forest

Figure 11: Causes of carbon flows from the forest ecosystem and the technosystem



Source: Hurmekoski et al. (2020)

growth, and (B) increased carbon stocks in the harvested pool. The second is (C) substitution effects by using wood to replace GHG-intensive materials such as cement and steel, and (D) by using wood to replace fossil fuel for energy. Figure 11 illustrates the two parts, which are the net carbon emissions of the forest ecosystem and the net carbon emissions for the Technosystem.

The trade-off between the partly overlapping strategies may be expressed as the equation below (see Hurmekoski et al. 2020):

$$NCE_t = (TC_{t-1} - TC_t] + (SC_{t-1} - SC_t) + (PC_{t-1} - PC_t) - SUBP_t - SUBEOL_t, \quad (1)$$

where NCE_t is net carbon emissions in year t, TC is the total carbon sink in European forests, SC denotes the soil carbon stock, PC is the stock of carbon in harvested wood products (HWP), $SUBP_t$ is the reduction of carbon emissions at production stage due to substituting GHG-intensive building materials by HWP, and $SUBEOL_t$ is the avoidance of fossil fuel emissions from energy production at the HWP's end-of-life stage.

As a consequence of the international sanctions imposed over Moscow's invasion of Ukraine, several EU countries are increasing their logging to compensate for the shortfall in their own wood import, or to take advantage of improved export opportunities. Together with supply chain disruptions during the Covid-19 pandemic, an outbreak of spruce bark beetles damaging central European and Alaskan forest, and extensive wildfires in Europe and North-America, the war has caused raised timber prices globally and a boom for European wood producers. This implies reduced carbon stock in living biomass, corresponding to decreased TC term in the equation above, while the carbon of HWP will increase. On a global scale, the impact on GHG-emissions of replacing timber from Russia, Belarus, and Ukraine with EU production has to be taken into account. Several issues are relevant, for instance whether the total amount of living biomass will be affected, how the felling is conducted, the age of the felled trees, soil preparation after felling, new planting, the treatment of by-products etc (Swedish Forest Agency 2021).

As European countries use more sustainable forestry practices than Russia[12] which imply climate benefits (Swedish Forest Agency 2021), the sanctions may nevertheless have positive climate and environmental effects overall, provided that Russia does not increase its exports to other regions. It is well known that Russia has problems with both forest management and control, and there is illegal logging in the country. Extensive exploitation of forest resources have led to over-harvesting and impoverishment of forests in several regions, and massive and largely uncontrolled wildfires in Siberia have destroyed millions of hectares of forests. For a recent discussion, see Leskinen, Lindner, et al. (2020).

The war is posing a threat also to Ukraine's forests and wood production, with uncontrolled wildfires spreading across woodlands mainly in the eastern part of the country. Moreover, since the sanctions offer Ukraine the chance to increase its share in the European timber market in place of Russia and Belarus, the risk of increased indiscriminate and illegal logging is obvious.

Concerning the substitution effect (C and D in Figure 2 and the two last terms in equation (1), there are several issue to take into account. Research emphasizes the importance of wood as a building material, and the EU has developed guidelines for the recognition of biomass as a sustainable renewable energy source.[13] However, this use of the forest's resources for climate mitigation can only be effective if the net effect of carbon emission reduction[14]is greater than the alternative of increasing the carbon stock of forests.

A recent study by Leskinen, Cardellini, et al. (2018) suggests that the use of wood and wood-based products in most cases are associated with lower fossil and process-based emissions when compared to non-wood products.[15] For each kilogram of carbon in wood products that substitute non-wood products, there occurs an average emission reduction of approximately 1.2 kg carbon. However, as the study points out, the fundamental aim for mitigating climate change should not only consider substitution factors but total emissions, which requires a broader and dynamic analysis of the overall effect of forest and forest soil sinks, harvested wood products carbon storage, permanence of forest sinks and

[12]Such as immediate, active regeneration after harvest.

[13]https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biofuels_en, retrieved on 2 July 2022.

[14]This is also known as wood's displacement factor, see Hurmekoski et al. (2020).

[15]This finding is based on reviewing 51 studies on 433 separate substitution factors.

forest disturbances, and potential carbon leakage effects, captured by the terms SUBP and SUBEOL in equation (1).

Thus, the trade-off between the objective of using forests as a natural carbon sink, or to harvest wood to substitute fossil fuel intensive materials is complex. Increasing harvest volumes without decreasing forests' potential being natural carbon sinks might be a difficult goal to achieve in the short-term of 5 to 20 years.[16] This also highlights that the forestry industry will have to develop better technologies and innovative climate-smart products to mitigate this trade-off.

6 Conclusion

This paper analyzes the impact of the Russian-Ukrainian war on EU's forest-based bioeconomy. Russia is globally the largest producer of sawnwood, but has not been the main source of industrial roundwood for the EU-27 in the past despite its huge forest resources. As a consequence of cancelled contracts, lost FSC certificates and the imposed import bans, Russia is likely to be dismissed as a supplier of wood to the EU even in the longer term. It is also most likely that the Russian-Ukrainian war will influence EU policies on the contribution of the forest-based bioeconomy to the EU goal of climate neutrality by 2050. The current crisis exacerbate the need for European countries to commit to a faster transition to a self-sustained forest-based bioeconomy. While the role of forests for sustainable economic development traditionally has been largely focused on carbon sequestration, in a broader perspective bioeconomy facilitates forest-management practices to achieve a balance between the different possible uses of the forest in accordance with internationally agreed climate and environmental goals.

[16]For a discussion on short-and long-term consequences for GHG concentrations of forest management strategies and forest products, see Petersson et al. (2022).

Appendix

Table 3: Global forest products trade in 2020

Major exporters of forest products — Percentage of global exports	
Wood fuel	Eswatini (9%); Bosnia and Herzegovina (9%); France (9%); Croatia (8%); Latvia (8%); Spain (7%); Netherlands (5%); Lithuania (5%); South Africa (5%).
Industrial roundwood	New Zealand (16%); Czechia (14%); Russian Federation (12%); Germany (9%); United States of America (5%); Canada (4%); Australia (4%); Poland (3%); Norway (3%).
Wood charcoal	Indonesia (16%); Myanmar (9%); Namibia (7%); Poland (6%); Ukraine (5%); Mexico (4%); Nigeria (4%); Viet Nam (4%); India (4%); Cuba (4%); Paraguay (3%); Philippines (3%); Belgium (3%).
Wood pellets and other agglomerates	United States of America (23%); Viet Nam (11%); Canada (10%); Russian Federation (8%); Latvia (8%); Denmark (3%); Estonia (3%); Austria (3%); Germany (3%).
Sawnwood	Russian Federation (21%); Canada (17%); Sweden (9%); Germany (7%); Finland (5%); Austria (4%); United States of America (4%); Belarus (3%).
Veneer sheets	Viet Nam (19%); Russian Federation (12%); Canada (11%); China (9%); Gabon (5%); United States of America (4%); Brazil (4%); Ukraine (3%); Thailand (3%).
Wood-based panels	China (14%); Canada (8%); Russian Federation (7%); Germany (7%); Thailand (7%); Brazil (4%); Belarus (4%); Poland (4%); Indonesia (4%); Austria (3%); France (3%); Romania (3%); Belgium (3%); Turkey (3%).
Pulp for paper	Brazil (25%); Canada (14%); United States of America (11%); Indonesia (8%); Chile (7%); Finland (6%); Sweden (6%); Uruguay (4%); Russian Federation (4%).
Recovered paper	United States of America (32%); United Kingdom (9%); Japan (7%); France (5%); Netherlands (5%); Germany (5%); Italy (4%); Canada (3%); Belgium (3%).

Paper and paperboard	Germany (12%); United States of America (9%); Sweden (8%); Finland (7%); Canada (5%); Indonesia (5%); China (4%); Austria (3%); Russian Federation (3%); Belgium (3%); France (3%); Italy (3%).
Major importers of forest products — Percentage of global imports	
Wood fuel	South Africa (15%); Italy (15%); Eswatini (7%); United Kingdom (6%); Germany (6%); France (5%); Austria (5%); Finland (4%).
Industrial roundwood	China (44%); Austria (9%); Sweden (5%); Finland (5%); Germany (4%); Belgium (4%); Canada (3%); Republic of Korea (3%).
Wood charcoal	China (10%); Germany (6%); United States of America (6%); Poland (5%); Japan (5%); Saudi Arabia (4%); France (4%); Republic of Korea (4%); South Africa (4%); United Kingdom (4%).
Wood pellets and other agglomerates	United Kingdom (33%); Republic of Korea (13%); Denmark (12%); Netherlands (8%); Japan (7%); Italy (7%); Belgium (5%).
Sawnwood	China (23%); United States of America (18%); United Kingdom (5%); Germany (4%); Japan (3%); Egypt (3%); Italy (3%); Belgium (3%).
Veneer sheets	China (24%); United States of America (12%); India (5%).
Wood-based panels	United States of America (17%); Germany (7%); United Kingdom (4%); Japan (3%); Republic of Korea (3%); Canada (3%); Italy (3%); Poland (3%); Belgium (3%).
Pulp for paper	China (40%); United States of America (9%); Germany (6%); Italy (5%); Republic of Korea (3%); Netherlands (3%); France (3%).
Recovered paper	China (15%); India (13%); Germany (10%); Viet Nam (8%); Indonesia (7%); Netherlands (5%); Mexico (4%); Thailand (4%).
Paper and paperboard	China (11%); Germany (9%); United States of America (7%); Italy (4%); United Kingdom (4%); Poland (4%); France (4%); Belgium (4%); Mexico (3%).

Source: FAOSTAT — Forestry database, Forest product statistics

References

EuroStat (2020). "Agriculture, forestry and fishery statistics - 2020 Edition". In: Luxembourg. Chap. 5: Forestry activities. DOI: 10.2785/143455.

FAO (2020). *Global Forest Resources Assessment 2020: Main report.* Report. Rome, FAO. DOI: 10.4060/ca9825en.

Finch, Deborah M., Jack L. Butler, Justin B. Runyon, Christopher J. Fettig, Francis F. Kilkenny, Shibu Jose, Susan J. Frankel, Samuel A. Cushman, Richard C. Cobb, Jeffrey S. Dukes, Jeffrey A. Hicke, and Sybill K. Amelon (2021). "Effects of Climate Change on Invasive Species". In: *Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector*. Ed. by Therese M. Poland, Toral Patel-Weynand, Deborah M. Finch, Chelcy Ford Miniat, Deborah C. Hayes, and Vanessa M. Lopez. Cham: Springer International Publishing, pp. 57–83. DOI: 10.1007/978-3-030-45367-1_4.

Grassi, Giacomo, Jo House, Frank Dentener, Sandro Federici, Michel den Elzen, and Jim Penman (2017). "The key role of forests in meeting climate targets requires science for credible mitigation". In: *Nature Climate Change* 7.3, pp. 220–226.

Griscom, Bronson, Justin Adams, Peter W. Ellis, Richard A. Houghton, Guy Lomax, Daniela A. Miteva, William H. Schlesinger, David Shoch, Juha V. Siikamäki, Pete Smith, Peter Woodbury, Chris Zganjar, Allen Blackman, João Campari, Richard T. Conant, Christopher Delgado, Patricia Elias, Trisha Gopalakrishna, Marisa R. Hamsik, Mario Herrero, Joseph Kiesecker, Emily Landis, Lars Laestadius, Sara M. Leavitt, Susan Minnemeyer, Stephen Polasky, Peter Potapov, Francis E. Putz, Jonathan Sanderman, Marcel Silvius, Eva Wollenberg, and Joseph Fargione (2017). "Natural climate solutions". In: *Proceedings of the National Academy of Sciences* 114.44, pp. 11645–11650. DOI: 10.1073/pnas.1710465114. eprint: https://www.pnas.org/doi/pdf/10.1073/pnas.1710465114. URL: https://www.pnas.org/doi/abs/10.1073/pnas.1710465114.

Gustavsson, L., T. Nguyen, R. Sathre, and U.Y.A. Tettey (2021). "Climate effects of forestry and substitution of concrete buildings and fossil energy". In: *Renewable and Sustainable Energy Reviews* 136, p. 110435. DOI: 10.1016/j.rser.2020.110435.

Hurmekoski, Elias, Tanja Myllyviita, Jyri Seppälä, Tero Heinonen, Antti Kilpeläinen, Timo Pukkala, Tuomas Mattila, Lauri Hetemäki, Antti Asikainen, and Heli Peltola (2020). "Impact of structural changes in wood-using industries on net carbon emissions in Finland". In: *Journal of Industrial Ecology* 24.4, pp. 899–912. DOI: https://doi.org/10.1111/jiec.12981. eprint: https://onlinelibrary.wi ley.com/doi/pdf/10.1111/jiec.12981. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12981.

IPCC (2018). *Global Warming of 1.5°: An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Ed. by V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, J. Skea D. Roberts, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Pean, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield. Cambridge University Press. DOI: 10.1017/9781009157940.

Jonsson, Ragnar, Francesca Rinaldi, Roberto Pilli, Giulia Fiorese, Elias Hurmekoski, Noemi Cazzaniga, Nicolas Robert, and Andrea Camia (2021). "Boosting the EU forest-based bioeconomy: Market, climate, and employment impacts". In: *Technological Forecasting and Social Change* 163, p. 120478. ISSN: 0040-1625. DOI: https://doi.org/10.1016/j.techfore.2020.120478. URL: https://www.sciencedirect.com/science/article/pii/S0040162520313044.

Leskinen, Pekka, Giuseppe Cardellini, Sara Gonzalez-Garcia, Elias Hurmekoski, Roger Sathre, Jyri Seppälä, Carolyn Smyth, Tobias Stern, and Pieter Johannes Verkerk (2018). *SSubstitution effects of wood-based products in climate change mitigation.* From Science to Policy 7. European Forest Institute. DOI: 10.36333/fs07.

Leskinen, Pekka, Marcus Lindner, Pieter Johannes Verkerk, Gert-Jan Nabuurs, Jo Van Brusselen, Elena Kulikova, Mariana Hassegawa, and BJW Lerink (2020). *Russian forests and climate change*. European Forest Institute.

Lindner, Marcus, Joanne B Fitzgerald, Niklaus E Zimmermann, Christopher Reyer, Sylvain Delzon, Ernst van Der Maaten, Mart-Jan Schelhaas, Petra Lasch, Jeannette Eggers, Marieke van Der Maaten-Theunissen, et al. (2014). "Climate change and European forests: what do we know, what are the uncertainties, and what are the implications for forest management?" In: *Journal of environmental management* 146, pp. 69–83.

Muys, B., P. Angelstam, J. Bauhus, L. Bouriaud, H. Jactel, H. Kraigher, J. Müller, N. Pettorelli, E. Pötzelsberger, E. Primmer, M. Svoboda, B.J. Thorsen, and K. Van Meerbeek (2022). *Forest Biodiversity in Europe*. From Science to Policy 13. European Forest Institute. DOI: 10.36333/fs13.

Petersson, Hans, David Ellison, Alex Appiah Mensah, Göran Berndes, Gustaf Egnell, Mattias Lundblad, Tomas Lundmark, Anders Lundström, Johan Stendahl, and Per-Erik Wikberg (2022). "On the role of forests and the forest sector for climate change mitigation in Sweden". In: *GCB Bioenergy* 14.7, pp. 793–813. DOI: 10.1038/s41558-019-0591-9.

Rockström, Johan, Owen Gaffney, Joeri Rogelj, Malte Meinshausen, Nebojsa Nakicenovic, and Hans Joachim Schellnhuber (2017). “A roadmap for rapid decarbonization”. In: *Science* 355.6331, pp. 1269–1271.

Roe, Stephanie, Charlotte Streck, Michael Obersteiner, Stefan Frank, Bronson Griscom, Laurent Drouet, Oliver Fricko, Mykola Gusti, Nancy Harris, Tomoko Hasegawa, et al. (2019). “Contribution of the land sector to a 1.5 C world”. In: *Nature Climate Change* 9.11, pp. 817–828.

Ronzon, Tevecia, Stephan Piotrowski, Saulius Tamosiunas, Lara Dammer, Michael Carus, and Robert M’barek (2020). “Developments of Economic Growth and Employment in Bioeconomy Sectors across the EU”. In: *Sustainability* 12.11. ISSN: 2071-1050. DOI: 10.3390/su12114507. URL: https://www.mdpi.com/2071-1050/12/11/4507.

Seidl, Rupert and Kristina Blennow (Mar. 2012). “Pervasive Growth Reduction in Norway Spruce Forests following Wind Disturbance”. In: *PLOS ONE* 7.3, pp. 1–8. DOI: 10.1371/journal.pone.0033301.

Smyth, CE, Z Xu, TC Lemprière, and WA Kurz (2020). “Climate change mitigation in British Columbia’s forest sector: GHG reductions, costs, and environmental impacts”. In: *Carbon balance and management* 15.1, pp. 1–22.

Soimakallio, Sampo, Tuomo Kalliokoski, Aleksi Lehtonen, and Olli Salminen (2021). “On the trade-offs and synergies between forest carbon sequestration and substitution”. In: *Mitigation and Adaptation Strategies for Global Change* 26.1, pp. 1–17.

Swedish Forest Agency (2021). *Sustainable boreal forest management – challenges and opportunities for climate change mitigation*. REPORT 2021/11. Jönköping. URL: https://www.skogsstyrelsen.se/globalassets/om-oss/rapporter/rapporter-20212020192018/rapport-2021-11-sustainable-boreal-forest-management-challenges-and-opportunities-for-climate-change-mitigation-002.pdf.

UNECE/FAO (2021). *Forest Products Annual Market Review 2020-2021*. Report ECE/TIM/SP/52. URL: https://unece.org/sites/default/files/2021-11/2114516E_Inside_Final_web.pdf.

United Nations Environment Programme (2019). *Emissions gap report 2019*. United Nations Environment Programme.

Valade, Aude, Valentin Bellassen, Claire Magand, and Sebastiaan Luyssaert (2017). “Sustaining the sequestration efficiency of the European forest sector”. In: *Forest Ecology and Management* 405, pp. 44–55.