Forest Policy and Economics 92 (2018) 193–201

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Economic impacts of setting reference levels for the forest carbon sinks in the EU on the European forest sector

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ARTICLE INFO

Keywords:
Forest sector
Harvest leakage
Carbon sink
Climate policy
Modelling

ABSTRACT

In order to meet the requirements of the Paris climate agreement, the EU plans to set new goals for forest carbon sinks. This may affect the future development potential in the wood using sectors in Europe and their contribution in the new circular bio-economy. We explore the potential consequences mainly on the forest sector in the region consisting of EU and Norway (EU + N), but also globally, that would arise if the countries in the EU + N constrained economic utilization of their forest resources. For the analysis, we use the global forest sector model EFI-GTM, which also incorporates the trade in wood and wood products.

Due to the globally growing demand for forest products and available forest resources in the rest of the world (RoW) outside of the EU + N, the leakages of harvests, forest industry production and employment opportunities from EU + N to RoW would be considerable. Decreased wood harvests and forest industry production in the EU + N would raise the wood and forest industry product prices globally, and increase production and employment in the forest sector in RoW. Due to the harvest leakage, climate mitigation benefits of the policy in the form of forest carbon sinks in the EU + N would be considerably reduced. Also, there would be inter-sectoral carbon leakage, as part of the wood consumption would shift to more energy-demanding competing materials.

1. Introduction

During 1990–2015, the average net removal of greenhouse gas from the atmosphere by forest land in the EU28 has been 419 Mt-$CO_{2\text{-eq}}$/yr. Thus the EU forests have been an important carbon sink, without which the annual greenhouse gas emissions in the EU would have been on average 9% higher (Eurostat, 2017a). The Paris agreement (UNFCC, 2015) for climate change mitigation requires that the parties should take action to enhance the carbon sinks, but it does not define which baseline to use for verification (Valade et al., 2017). For its 2030 climate and energy framework, the EU Commission proposed setting "forest reference levels" (FRLs) for carbon sequestration in forests for 2021–2030. They would define the country baselines to which the future carbon sinks or emissions would be compared for accounting purposes. The draft text for a legal proposal (COM(2016) 479 final, article 8.3) stated that the national forestry accounting should include FRLs based on the continuation of current forest management practice and intensity, as documented between 1990 and 2009 per forest type and age class in national forests, expressed in tonnes of CO_2 equivalent per year (European Commission, 2016). After the commission's proposal, the rapporteur Lins (European Parliament, 2017) suggested using instead the period 2000–2012 for calculating the FRLs. In both cases, the new FRLs would have been based on the past intensity of the use of forests and tightened the forest carbon sink goals compared to the FMRLs. The impact of EU climate policies to the harvests in the member countries remains still open: The EU Parliament's (2018) decision in April 2018 leaves some flexibility for the countries to decide on their FRLs.

The new FRL approach will replace the Forest Management Reference Levels (FMRL) of the second commitment period of the Kyoto Protocol (KP) for 2013–2020. The FMRLs account for market prospects and the national policies adopted before the end of 2009. At the same time, the credit of exceeding the forest management sink is capped to a maximum of 3.5% of a country's total emissions in 1990. In some cases, this may have reduced the countries' incentive to increase their forest sinks (Laturi et al., 2016).

In this study, we aim to examine the socio-economic impacts that could result if the EU member countries have to meet tighter goals for forest carbon sinks and if they therefore have to limit the utilization of their forest resources. Due to confidentiality, the planned country level

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https://doi.org/10.1016/j.forpol.2018.04.010
Received 21 December 2017; Received in revised form 26 April 2018; Accepted 27 April 2018
1389-9341/

FRLs were not available from the EU commission for research purposes despite their importance and need for evaluating the impacts of the policy proposal. Lacking the figures that have been under consideration at any stage, we apply the average harvest levels in FAOSTAT (2017a) in the period 2000–2012 in the EU and Norway for the constraint on utilization of the forest resources. For a sensitivity analysis, we consider three other cases of harvest constraints and one case where the baseline is also changed. The policy impacts are analysed by comparing scenarios with and without the assumed harvest limitations. The EFI-GTM global forest sector model is used to quantify the forest sector developments in the scenarios. The time period considered is up to year 2030.

We examine how and how much an introduction of the assumed constraints on forest utilization would influence, mainly in the region consisting of the EU and Norway (EU + N), but in some degree also in the rest of the world (RoW):

- roundwood harvests
- production of forest-based products
- turnover and employment in the forest sector.

The impacts caused by the harvest constraints in the EU + N will be summarized using the concept of leakage of harvests and forest industry production from the EU + N to RoW. By leakage we mean the ratio $-A_t/B_t$, where B_t is the difference in annual harvests or production in the EU + N in year t between a baseline scenario and a scenario where the harvests are constrained in the EU + N, and A_t is the respective difference in harvest or production in RoW.

Few studies have examined the market level impacts of recent climate policies on the forest sector in the EU. Laturi et al. (2016) investigated the timber market impacts and the effectiveness of setting FMRLs in the EU27 in the second Kyoto period. They showed that in the countries where non-LULUCF sector emissions are high relative to the sink potential of the forests, the market impacts of the FMRLs in the form of reduced harvests and increased timber prices could be substantial. In the smaller forested countries, the cap could be reached more easily. That would limit the incentive to forego harvests in order to increase forest sinks and thus affect the wood market less.

Ellison et al. (2011) examined the treatment of forest related carbon sinks in the KP and identified, in addition to the caps set on crediting the sinks, several other sources of disincentives for using these sinks in climate change mitigation. Ellison et al. (2014) pointed out that also the lacking possibilities for trading forest carbon hinder the EU from achieving the full potential of climate mitigation by forest based resources. Based on examining the literature on the role of forest sector in climate change mitigation in Europe, Nabuurs et al. (2017) concluded that by revising the earlier policies and by introducing new measures to improve synergies between climate policy and other societal forest-related goals, mitigation impact of the forest sector could be considerably increased in the EU by 2050.

The market impacts and carbon leakage of the EU policies related to reducing emissions in the energy sector have been examined more frequently. Parossous et al. (2015) estimated such leakage to be 28%, while the median of leakage estimates in the studies they reviewed was 20%. The energy sector differs from the forest sector in many aspects. In the energy sector, various alternative options exist for fuel feedstock, energy carriers and production methods which can be taken into use for emission reduction purposes. Furthermore, energy is an input for a heterogeneous set of applications and products, not all of which are easily transferable to the other countries. Also, the level of product differentiation between the markets and products can be considerable. In the forest industry instead, wood used as a raw material is not easily replaced by other materials or inputs. Forest products tend to be rather homogenous and widely traded in the international markets without important barriers of trade. That makes products coming from one country rather easily substitutable with those produced in another country. The policies affecting the forest sector can thus be anticipated to be more vulnerable to carbon, harvests, and production leakage than those tackling the emissions from the energy production.

Former studies confirm the intuition that the leakage effect caused by policies on wood harvests and forest industry production can be considerable. Wear and Murray (2004) found harvest leakage rate of reduced public harvests in the US to be 84%, whereas Gan and McCarl (2007) report rates from 42% to 95%. Nepal et al. (2013) found that the carbon leakage related to the programs incentivizing the U.S. landowners to sequester carbon into forests and forego timber harvests would lead to the carbon leakage of 70–85% as timber removals would shift to other areas. Hu et al. (2014) examined a set of restricting forestry policies in China and found that their implementation would cause an 80–90% carbon leakage to Russia, Southeast Asia and the EU.

Our study differs from those above particularly in two important aspects. First, we analyse the impacts of potential harvest limitations in Europe, but look also at the wider market impacts. Secondly, we apply a global forest sector model which is rather detailed regarding the European forest sector and includes trade between all regions and products involved.

In the next section, we introduce the model and the main assumptions. The results are presented in Section 3. Section 4 provides discussion. Main conclusions are drawn in Section 5.

2. Material and methods

2.1. Model used

The EFI-GTM model is a multi-regional and multi-periodic partial equilibrium model of the global forest sector. It depicts the system consisting of wood supply, forest industries and production of wood-based energy and biofuels, demand for forest industry products and wood biomass for energy, and international trade in wood and forest products. The model version used includes 57 regions covering the entire world, the regional disaggregation being most detailed in Europe. The model includes about 30 forest industry and energy sector products, five roundwood categories, three categories for forest chips, four recycled paper grades, and the main by-products of the forest industries, such as sawmill chips and sawdust. The model is continuously updated and developed and it has been used in various applications (e.g. Solberg et al., 2003; Moiseyev et al., 2013; Kallio et al., 2018). The documentation in Kallio et al. (2004) still provides a valid description of its basic operational principles.

2.2. Scenarios and sensitivity analyses

In the main analysis, we compare a scenario “Baseline” with a scenario “Limited” where the harvests in the EU + N are constrained.

In the Baseline, the global forest product markets are allowed to develop rather freely. Yet, we imposed a sustainability condition requiring that no more than 5% of the regional growing stocks can be harvested annually. We also included some trade inertia conditions for wood as discussed in Section 2.3.2.

In scenario “Limited”, the EU + N roundwood harvests after 2020 are not allowed to exceed the average harvest levels of the period 2000–2012 in these countries, a period proposed by the Environment Committee of the European Parliament (European Parliament, 2017). All other assumptions are the same as in the Baseline.

In addition to the scenario “Limited” where the EU + N harvests are constrained to

(i) average harvests during 2000–2012,

we calculate the leakage rates for harvests and forest industry production in three other cases for sensitivity analysis. In these cases, the maximum harvests allowed in the EU + N in 2021–2030 are

(ii) average harvests during 1990–2009,
(iii) average harvests during 2006–2015 or
(iv) 531 Mm^3 in 2021–25 and 552 Mm^3 in 2026–30.

While tackling with the problems of using different statistical source (FAOSTAT, 2017a) and lacking country level figures, alternative (iiii) aims to mimic at the aggregated EU level the scenario "Continuation forest management" with a reference period 2000–2009 in Grassi and Pilli (2017). Nevertheless, our figures include also Norway.

Furthermore, we provide one additional sensitivity analysis which uses an alternative baseline where we assume lower demand for forest products than in the main Baseline. We examine the leakage impact of harvest constraint (iiii) under that baseline.

Because the policy period for FRLs (2021 – 2030) is much shorter than the optimal rotation periods in the EU forests, limiting the harvests is practically the only way to adapt to the proposed sink requirements (Laturi et al., 2016). We are aware of the fact that it is unclear how the limitations could be accomplished in practice by policy governance. The forests in the region are mostly privately owned and so are the businesses using wood and forest products. Rather than trying to respond to the question of "how", we focus on responding only to the question of "what if", by examining what would be the consequences if harvests were limited.

2.3. Main background assumptions common to the baseline and policy scenarios

2.3.1. Forest product demands

The assumptions on the demand development for final forest products are quite essential for projecting the global forest sector development (Kallio, 2010). In the EFI-GTM, regional periodic inverse demand functions are defined for all final products (e.g. newsprint, and sawnwood). These functions are parameterized using price elasticity estimates found in the literature so that the observed base year market price (reference price) equals the observed demand in the base year (reference demand). The demand functions are then shifted according to the assumed future annual market changes, as briefly outlined below for the main forest products.

2.3.1.1. Forest product demands in the main "baseline". We defined the future reference demands for *the mechanical forest industry products* by assuming that the demand per capita of these products will increase 50% by 2050 from 2015. The per capita demands for softwood sawnwood were however constrained to increase at most up to 1 m^3, which is roughly the current consumption level in the countries with highest per capita consumption. The population growth assumption was based on FAO's projection (FAOSTAT, 2017b).

For *dissolving pulp and other pulp grades* for applications other than making paper and paperboard, we assumed that as the world's growing population gets wealthier, growing amounts of textiles, diapers and other absorbent materials and fibre products made of wood pulps are needed and affordable for more and more people. We assumed the demand growth for these pulps to be 6%/yr from the year 2020 onwards.

Linerboard and fluting are together referred to as containerboard. Li and Luo (2008) estimate income elasticity for total industrial production in the US of 0.4 for these products. We assumed that the containerboard demand in a country follows its assumed total GDP growth and that the GDP increase in low income countries is more strongly connected to increased production, consumption and shipping of manufactured goods needing packaging, whereas in the high income countries the GDP growth is more connected with the growth of services. We applied the GDP elasticity 0.4 for low income countries, and 0.3 for high income countries.

Cartonboard includes grades like folding boxboard, white lined chipboard, liquid packaging board and other boards. For cartonboard, we also let the reference demand follow the assumed GDP growths. Lacking recent income elasticity estimates for these products, we chose to apply the same GDP elasticities for cartonboard as for containerboard, 0.3 for high income countries and 0.4 for low income countries. Also, the consumption of *household and sanitary papers* was tied to the GDP growth.

The demand for *newsprint and other printing and writing papers* has declined in high income OECD-countries since the start of this century. There is no reason to believe that this tendency connected to the consumers' shift to use electronic media will change course. Based on examining the demand trends, we assumed the demand for these papers to decline by 36% in the EU + N and 25% globally from 2010 to 2020, and then remain at the 2020 level thereafter.

Other papers and paperboards form a mixed group of products for which the grades, production technologies and the respective demand and supply functions are complex to specify. Often, these are niche grades produced in limited quantities and with old machinery. We assumed that the demand for these papers remains constant over time.

For the demand for *wood for production of heat and power and liquid biofuels*, we used a scenario created in an earlier study reported in Kallio et al. (2015). In that scenario, the long run global climatic warming is assumed to be limited to 2 °C and the EU is assumed to implement the energy and climate policies decided before 2015 (including the goal to decrease greenhouse gases by 80% or more by 2050). The consumption and production for wood based bioenergy in the scenario were projected by Lehtilä and Koljonen with a global energy system model as described in Kallio et al. (2015).

The GDP growth was assumed to follow the forecasts in IMF (2015) until 2020. Thereafter, it was assumed to converge to the OECD's (2013) long run forecast by 2030. For the few regions missing a forecast the choice was made by the authors.

The assumed reference demands aggregated to larger product categories and larger regional levels are shown in Table A1 in Appendix.

2.3.1.2. Lower forest product demands in an alternative baseline used in sensitivity analysis. We examined the changes in harvest and forest industry production and leakage rates also in an alternative baseline where the economic activities in the forest sector develop more slowly. The assumed demand prospects for the forest products differ from those in the main baseline above as follows: (i) no liquid biofuels will be produced of woody feedstock, (ii) wood-based heat and power production is not allowed to increase after 2020, (iii) demand growth for dissolving pulp and novel pulp grades is lower, 3%/yr, (iv) in order to define modest future demand prospects for mechanical forest products, we took the income elasticities estimates of Jonsson (2012) as a starting point, but first limited the highest values of those to be at most 0.9, and then halved all the figures. It follows e.g., that the sawnwood demand is assumed to be stagnant in China.

2.3.2. Trade inertia

International trade is an important part of forest product markets. Due to for instance trading habits and transaction costs, the quantities of bilateral trade may not necessarily change dramatically from one year to the next. This is why we imposed some inertia conditions to trade in wood between the countries in the EU + N and RoW. The data (FAOSTAT, 2017a) supports the intuition that the relative year-to-year changes tend to be smaller in the larger quantities and vice versa. Based on the data for 2010–2015, we chose to allow the region's net export or net import that are below 50,000 m^3 in a certain year to increase up to 50,000 m^3 in the next year. For the quantities between 50,000 m^3 to 5,000,000 m^3, we allowed the respective change to range from 20% (at the point of 50,000 m^3) to 6% (at 5000000 m^3). The known historic quantities were taken as initial values for trade.

2.3.3. Treating of household fuelwood and industrial wood other than sawlogs and pulpwood

Because wood collected for household fuelwood is the least valuable roundwood grade, it would be economically optimal to reduce its consumption first, if the total harvest volumes were constrained. Yet, an important part of the fuelwood harvests is related to forest owners collecting wood from their own forest properties for their private or local use and such collection of fuelwood might at least partly take place in the forest sites where harvesting wood for other purposes is not technically or economically viable. Also, this wood may include dead or damaged wood. Partly due to these reasons, the statistics related to fuelwood may be somewhat unreliable. Nevertheless, fuelwood harvests reported to the statistics are counted as a factor reducing the forest carbon stock. We chose to fix the harvests of fuelwood at their present level and let the harvest limitations in the EU + N to involve only pulpwood and sawlogs used in the forest industry or in modern heat, power and biofuels production. Also harvests of “other industrial roundwood” were kept constant, because the further processing related to this wood category is not included in the EFI-GTM. These harvests are low or non-existent in most EU + N countries.

3. Results

3.1. Forest sector in the baseline scenario

In the Baseline, no new climate policies affect the roundwood harvest possibilities. The globally increasing demand for forest products drives the harvests in the EU + N up by 17% from 518 Mm^3 (millions cubic meters, over bark) in 2015 to 605 Mm^3 in 2030 (Fig. 1) and the use of forest chips for energy increases by 70%. The supply of both pulpwood (+18%) and sawlogs (+29%) increase. The harvests also include the supply of wood for household fuelwood and other industrial uses that were assumed to remain constant as discussed in Section 2.3.3.

The main factors behind the increase in roundwood felling in the EU + N are the rise in the production of sawnwood and plywood (27%, 30 Mm^3), chemical pulp (26%, 7 Mt), wood based heat and power (47%, +90 TWh measured in feedstock volume) and liquid biofuels (+18 TWh). This development shown in Figs. 2 and 3 is supported by the growing forest resources making it possible to increase harvests in the EU + N.

The paper and paperboard production in the EU + N is decreasing by about 5 Mt (million tonnes) during the period 2015–2030 mainly due to the decline in the demand for the printing and writing papers. The markets for other paper and paperboard grades are rather mature in the EU + N as well which reduces the incentives for new investments.

3.2. Forest sector in the scenario limited with constrained utilization of the EU + N forest resources

3.2.1. Roundwood markets

When the average harvests of the period 2000–2012 are chosen for the level of allowed economic utilization of forest resources after 2021, roundwood harvests in EU + N need to go down from circa 518 Mm^3 in 2015 to 486 Mm^3 in 2030. Compared to the Baseline, the decline is about 119 Mm^3 (20%) in 2030 (Fig. 1, Table 1). Sawlog harvest gets a slightly smaller share of this decrease than pulpwood. Also, softwood roundwood is more represented in the decline than hardwood roundwood. The decrease in the domestic wood supply in the EU + N forces the wood using sectors to cover part of the raw material deficit with increased imports of wood from the RoW. Compared to the Baseline, 34 Mm^3 more roundwood is imported to the EU + N from the RoW in 2030 due to the assumed harvest constraints. This increase in roundwood imports replaces less than 30% of the decline in the domestic roundwood supply. This means forest industry production must adjust downwards too.

In the RoW, the roundwood harvests increase by 93 Mm^3 which is clearly more than the amount produced for the additional exports (+34 Mm^3) to the EU + N. The forest industry in the RoW is expanding and consuming more wood in order to meet the global demand for forest products and it is able to do so thanks to its improved competitiveness with respect to the producers in the EU + N. Altogether, 79% of the reduction in roundwood harvests in the EU + N is shifted (=leaked) elsewhere by 2030. In a shorter run, the leakage-percentage is slightly smaller, because time is needed for the trade and forest

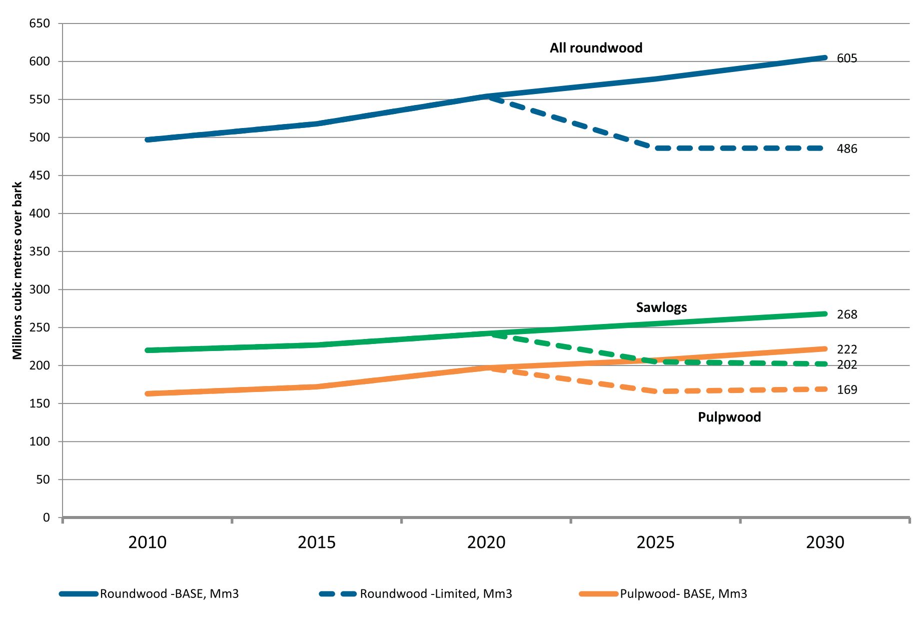

Fig. 1. Production of all industrial roundwood, pulpwood and sawlogs in the EU + N in the baseline case (Base) and when the harvests are constrained due to assumed forest carbon sink policy (Limited).

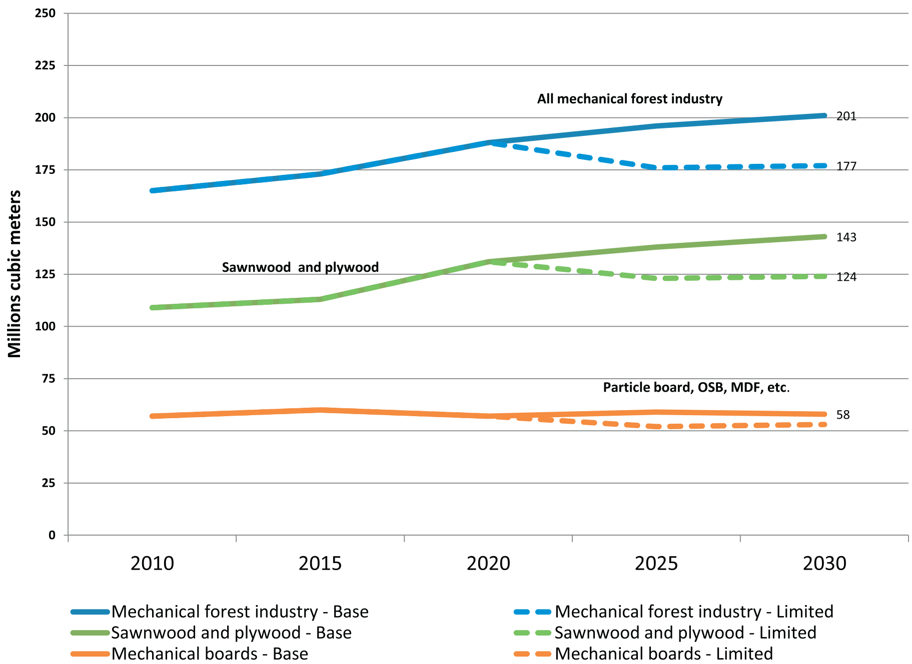

Fig. 2. Production of mechanical forest industry products in the EU + N in the baseline case (Base) and when the harvests are constrained due to assumed forest carbon sink policy (Limited).

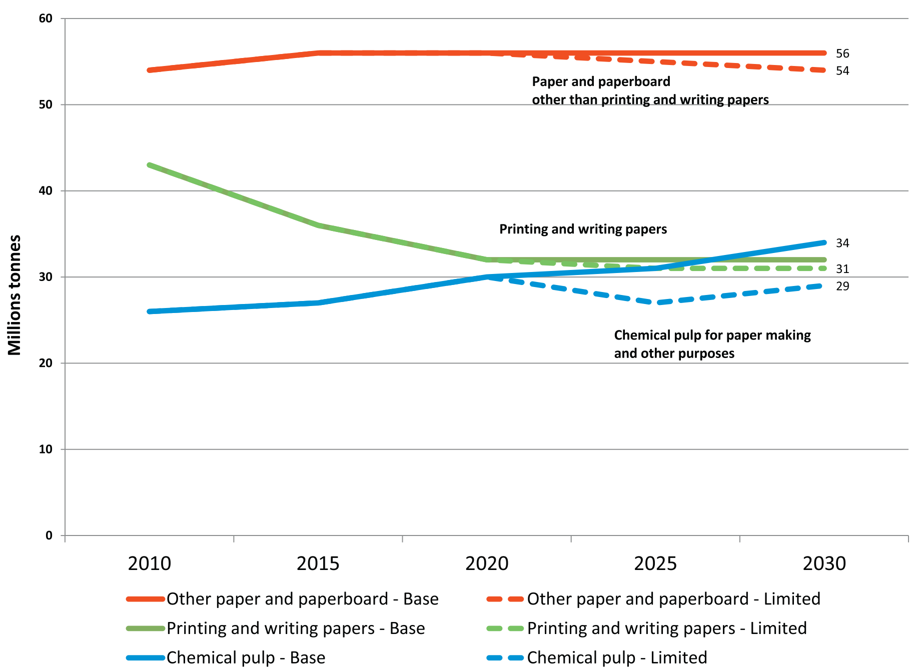

Fig. 3. Production of pulp and paper in the EU + N in the baseline case (Base) and when the harvests are constrained due to assumed forest carbon sink policy (Limited).

industry capacity in RoW to adjust to the new situation.

3.2.2. *The forest industries*

The development of the forest industry production in the EU + N in the Baseline and after applying the assumed harvest constraints are displayed in Figs. 2 and 3. The producers of chemical pulp (−5 Mt or 16%), sawnwood and plywood (−19 Mm^3, −13%) and various panels and boards that are mechanically processed from woody materials (−5 Mm^3, −9%) have to adjust down their production or future investments most. Figures in the parentheses refer to the change in production in 2030 in comparison with the Baseline. Paper production is less sensitive (−3 Mt −3%) to the constraints set to roundwood harvests. It is already decreasing in the baseline and the remaining industry can largely be supported with recycled fibre and having domestic pulp supply directed more to local use, or increasing imports of pulp. The net pulp imports increase by about 4 Mt compared to the Baseline. Printing and writing papers continue to form an important part of the paper production in the EU + N despite the decline in demand. In that branch, the new investments that would be easiest to move from a country to another are rare. The fact that the declining market demand makes new investments economically unattractive almost regardless of the location gives some advantage to the existing producers.

Table 1
Changes in forest sector production and leakage rates. Scenario with harvest limitations compared to the Baseline in 2030.

	Roundwood	Paper	Pulp	Sawnwood and plywood	Mechanical board
	Mm^3	Mt	Mt	Mm^3	Mm^3
The EU + N	−118.5	−2.6	−5.4	−19.1	−5.5
RoW	93.1	1.7	4.0	15.0	4.8
The World	−25.4	−0.9	−1.4	−4	−0.7
Leakage-%	79%	65%	74%	79%	87%

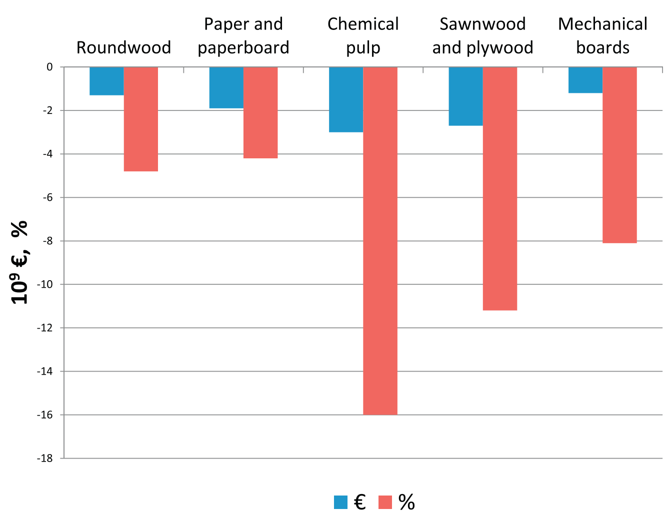

Fig. 4. Decrease in turnover for selected product groups in the EU + N in scenario Limited compared to the Baseline in 2030, billions (10^9) euros and %.

3.2.3. Turnover in the EU + N forest sector

The decreased supply of wood and other forest products causes price increases which make the demand adjust to the scarcer supply.

The total sales value of wood produced (price at the mill gate) in the EU + N is about 5% lower in the scenario Limited than in the Baseline in 2030 (Fig. 4). In some member countries, the reduced availability of domestic wood makes wood prices increase so much that the total costs resulting from buying, now smaller quantities, of local wood is the same or even higher than in the Baseline. On the average, prices for softwood sawlogs and pulpwood at the mill gate in the EU + N in 2030 are 27% higher with the policy assumed in the scenario Limited than without it. The relative price increase of hardwood grades is slightly smaller. In the RoW, the value of wood sales is projected to be 10% higher in 2030 than in the Baseline. The rise in turnover from wood sales is due to both increased prices and increased harvests.

In 2030, the turnover in the mechanical forest industries (sawnwood, plywood, panels and boards) in the EU + N is projected to be some 10% lower in the Limited scenario than in the Baseline. The industry becomes more oriented to supply the local customers, while it supplies less to the export markets. In the paper and paperboard production, the respective reduction in turnover is 4%, and in chemical pulp production it is 16% (Fig. 4).

3.2.4. Employment in the EU + N forest sector

The decline in the harvests and forest industry production would also reduce employment in the EU + N. Forestry and mechanical forest industry are labour intensive branches, whose activities typically locate in rural areas and provide an important basis for economic diversification for rural communities (Eurostat, 2017b). In 2016, roughly 530,000 persons worked in "forestry and logging" operations, 1.38 million persons worked in "woodworking industries", and 623,000 persons worked in the branch "manufacture of paper and paper products" in the EU + N (Eurostat, 2017c).

The average employment in the section "forestry and logging" in the EU + N declined by 6000 persons during 2008–2016 (Eurostat, 2017c), while roundwood production (FAOSTAT, 2017a) increased 38 Mm^3 (over bark). Making conclusions upon the productivity growth in roundwood harvests in this rather short period is difficult. The figures are aggregated and refer to the broader set of activities than just roundwood removals. Also, the employment did not necessarily adjust immediately to the reduction in the harvests in the recession occurring in the beginning of the period. Considering that productivity tends to increase over time, the output of roundwood per person employed in the sector is likely to be at least 1000 m^3/person in the future. Hence, the projected difference of 119 Mm^3 (20%) in roundwood fellings in 2030 between the scenarios Limited and the Baseline means that the employment in the forestry activities would then be at most 119,000 persons lower in Limited than in the Baseline.

Similar simple calculations can be made for the wood working industries and paper and paperboard industries, noting again that due to productivity increase these figures might only give the upper bound for the employment decrease and that the employment data used cover broader product categories than considered here. Decline in the mechanical forest industry production (12%) and the paper industry (3%) from the Baseline to scenario Limited would thereby give the decrease in employment of at most 184,000 persons.

In addition to these direct impacts, there are indirect employment impacts related to sectors providing materials and services to forestry and forest industries and to the declined economic activity in the EU + N.

3.2.5. Leakage of roundwood harvests and forest industry production from EU + N to RoW

About 79% of the roundwood harvests in the EU + N are offset by a corresponding harvest increase in the RoW. This harvest leakage from EU + N to the RoW takes place mostly towards Russia (14%), North America (34%) and Latin America (39%) (Fig. 5, Table 2).

Expectedly, South America increases its production of pulpwood more than sawlogs, as the region can increase its production of fast

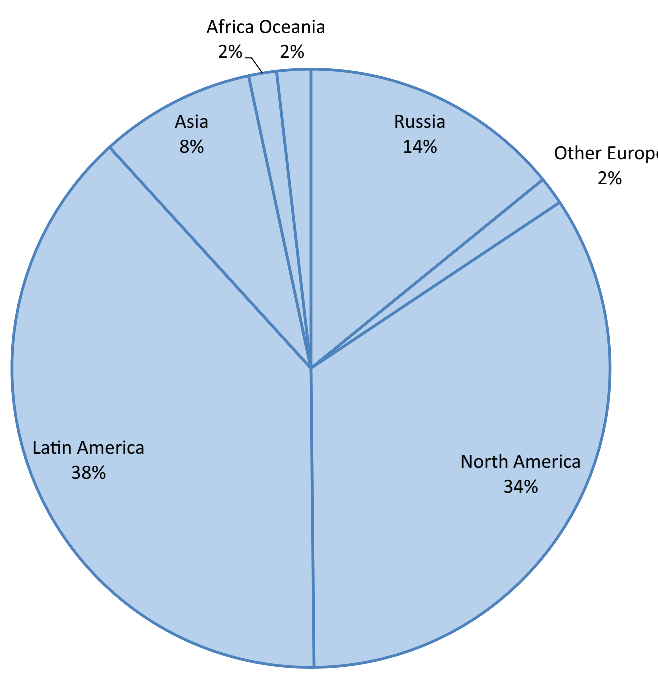

Fig. 5. Geographic distribution of the roundwood harvest leakage of 93 Mm^3 in 2030.

Table 2
Assumed allowed harvests in the EU + N, and leakage rates compared to the Baseline in 2030 when the EU + N harvests were constrained by their average levels of 2000–2012, 2006–2015 or 1990–2009 or when they were constrained to be at most 530 Mm^3 in 2021–2025 and 550 Mm^3 thereafter.

	Maximum harvests in EU + N		Leakage rate				
			Round wood	Paper	Pulp	Sawnwood and plywood	Mechanical board
Case	2021–2025	2026–2030	%	%	%	%	%
1990–2009	443	443	76	46	57	81	84
2000–2012	491	491	79	65	74	79	87
2006–2015	506	506	78	67	72	79	87
530/550	531	552	79	64	80	84	89
530/550 under alternative baseline	531	552	84	85	77	83	96

growing plantation wood, hardwood in particular. North America plays an important role in covering the deficit caused by the European wood supply cut both in sawlog and pulpwood markets. Nevertheless, its importance is higher in the sawlog markets, particularly in softwoods. Russia assumes its role in offsetting the deficit in global timber supply in both sawlogs and pulpwood and in both softwoods and hardwoods.

In the scenario projections in this study, we had imposed a sustainability condition requiring that no more than 5% of the growing stock can be harvested annually. In most countries this figure is somewhat higher than the respective forest growth. This assumption constrains harvesting in some parts of Asia and Africa.

Because the harvests increase in the RoW, the forest carbon sinks are doomed to be smaller there compared to the Baseline. This considerably weakens the effectiveness of the climate policy actions proposed by the EU.

The leakages are considerable also in the forest industry production (Table 1). For instance, 79% of the decline in sawnwood and plywood production in the EU + N is replaced by production in RoW.

3.2.6. Other impacts

Because the prices of wood and forest industry products increase, the global consumption for forest products decreases (Table 1). Evidently, wood and products made of wood would then be partly replaced by other materials, like metal, concrete and plastics. These materials are typically more carbon intensive than wood products (Gustavsson et al., 2006; Eriksson et al., 2012; Sinha and Kutnar, 2012). Hence, also intersectoral carbon leakage would take place.

It has been considered favourable to increase the use of long-lived harvested wood products (HWP) such as sawnwood and plywood in building construction, and these views have also been adopted in the policies of some EU + N countries (Mahapatra et al., 2012, Finnish Bioeconomy Srategy 2014). This could have an impact on the future forest management regimes by shifting them to favour forests with longer rotations and the harvests would increasingly take place in mature forests with lower carbon sequestration rates. After industrial processing, the carbon stored in the trees would be transferred to stock of carbon in the HWPs.

3.2.7. Sensitivity analyses: leakage rates under other harvest constraint levels and under an alternative baseline

3.2.7.1. Alternative constraints for harvest levels. Table 2 displays the harvests constraints and leakage rates in the scenario Limited and in the three sensitivity analyses presented in Section 2.2. In all the cases, the direction of the impact of harvest constraints on the forest sector in EU + N is similar to those reported in Sections 3.2.1-3.2.6. So, here we only discuss the leakage rates.

Table 2 shows that the leakage rates with the four alternative harvest constraints do not differ much, except for the paper and pulp, for which the absolute impact of the policies on the produced quantities is smaller than for the other product categories. It can be observed that the leakage rates tend to increase when the harvest constraint is loosened, which is intuitively plausible. The smaller the cut in production or harvests is in one region, the easier it is to replace it by the production increase elsewhere. The results suggest that considerable leakage would take place, if the EU unilaterally imposed policies that limit the roundwood harvests regardless of the magnitude of the limitation.

3.2.7.2. Alternative baseline with weaker demand for forest products. The demand assumptions behind this alternative baseline are described in the end of Section 2.3.1. The new EU + N baseline roundwood production is 562 Mm^3 in 2030, whereas the production of mechanical forest industry products reaches the level of 191 Mm^3 by 2030.

Applying harvest constraint of roughly 552 Mm^3 by 2030 (constraint iiii in Section 2.2), the roundwood production is projected to be 5% lower, paper production 2% lower, chemical pulp production 4% lower, and mechanical forest industry production 4% lower in 2030 than in the new baseline. Table 2 shows the leakage rates for this case. There is now more room to increase wood use globally in order to response to the decline in the harvests and production in the EU + N. Thus the leakage rates tend to be higher than under the main baseline, above 80% for roundwood and mechanical forest industry products.

4. Discussion

The results show that the leakage of harvests, forest industry production and employment opportunities from the EU + N to the RoW would be considerable if the EU + N unilaterally constrained the utilization of its growing forest resources. The allocation of the economic benefits and losses caused by the policy depends on how it is implemented. We assumed harvests to be constrained. Then the decrease in wood supply increases competition among wood buyers and raises wood prices. If the forest owners were compensated for placing less timber on the markets, they would benefit both from the increased wood prices and subsidies. The costs of the policy would then be paid by industries, consumers of forest industry products, and by the citizens in the EU + N in the form of reduced employment and economic wellbeing. The RoW countries would gain in the form of increased production possibilities and improved sectoral employment, and in the form of higher prices for the forest products they would increasingly supply.

If the growth of the roundwood harvests is curbed now in the EU + N, the forest carbon sinks might still be lower in the long run due to forests coming to a more mature age with lower growth. The forest sinks are showing signs of saturation in Europe (Nabuurs et al., 2013). Forest left without management might also become more vulnerable to damages caused by windfalls, fire, fungi and insect attacks, all expected to increase in changing climate (Gardiner et al., 2013; Seidl et al., 2014). When planting new forest after final harvests, it is possible to introduce seedlings and species that have higher growth and are more adapted to the changing climate than the previous tree generation. This option (see e.g. Aitken and Bemmels, 2016; Costa et al., 2017; Nabuurs et al., 2017) is not available for the forests that are not regenerated.

These factors weaken the benefits of foregoing harvests in order to increase the forest carbon sink, which is the most realistic option to maintain carbon sinks in the ten year term of the policy. Yet, it can be anticipated that the globally increasing wood prices would create some incentives to spur the forest growth, increase the managed forest area, and also to move some forests from the non-timber use to plantations.

At the moment, few tools are available to secure that certain reference levels for forest carbon sinks are maintained in the short run. The forests in EU + N are largely privately owned and any legislation or policies affecting the private forest owners' harvesting behaviour would take time to implement. The forest management practices with long planning horizons make it difficult to increase the forest carbon sequestration in a decade or too. Yet, a possible failure of the EU member countries to meet the FRLs could harm the image of the European forest sector, causing reputational damage among the global buyers and lead to a decrease in the demand for the products made in the EU. So it is important to consider what would be the impact if the harvests in Europe were constrained.

An interesting extension of this study would be to further analyse the developments in forest carbon sinks, as well as the overall sustainability performance of the forest sector in those areas where the harvests and production would be shifted to from Europe.

The projections by forest sector models are subject to uncertainties regarding the data and assumptions made. Here, for instance, without assuming some trade inertia, trade in roundwood would have been freer to adjust, perhaps allowing the imports to grow more rapidly from the RoW to the EU + N. In the projections, this could have helped the forest industry production in the EU + N to adjust to the tightened wood supply and maybe given less leakage of forest industry production to the RoW, but not necessarily less harvest leakage. Nevertheless, when comparing scenarios differing only regarding the policy assumption, the uncertainty in the assessment of policy impacts can be less important than the uncertainty in the projected scenario paths themselves, as shown in Kallio (2010). Our sensitivity analyses indicate that the harvest and production leakage rates are robust regarding the choice of the harvest limitation levels or the baseline. Their magnitudes are also in line with results of the studies from other regions.

5. Conclusions

The growing European forest resources would make it possible for the region's forest sector to respond to the globally increasing consumption of forest products. Both the roundwood harvests and the production of forest products in the EU + N could increase at moderate pace. Such possibilities of using wood for the needs of the new circular bio-economy could be hampered, if the EU + N countries had to limit their harvests due to the implementation of Forest Reference Levels. Due to the globally growing demand for wood and forest products and the forest resources available in RoW, a large part of the increase in harvests and in forest industry production would shift from EU + N to RoW. Jobs would disappear from the labour-intensive wood products manufacturing and from the forestry sector, both often located in rural areas. Wood and wood-based product imports to Europe would increase despite the growing European forest resources.

Because of the very high leakage rates (of the magnitude of 80%), the climate mitigation benefits of the proposed EU forest sink policy may be very modest. The sinks might be larger in the EU in the short run, but smaller elsewhere because of the leakage. In combatting climate change, it does not matter where the carbon sequestration to the growing trees takes place. Some inter-sectoral carbon leakage would also take place, because the scarcer supply of wood products would increase their prices and shift consumption to more carbon intensive competing materials, like steel and concrete.

The results of this study show what could happen if FRLs or other policy instruments lead to a need to constrain harvests in the EU + N. It was not possible to employ the FRLs figures discussed in the EU, because the EU Commission was not releasing the confidential figures. The recent EU Parliament decision in April 2018 provides certain flexibility for the member states to set FRLs, and the magnitude of FRLs remains still open. However, our results should capture the main directions of the impacts on the forest sector of potential harvest limitations, and they can be scaled to assess the magnitude of the impacts of eventual FRLs when they will come available. Concerning the leakage rates of harvests and forest industry production, the results are insensitive to the strictness of the harvest limitations that would be needed to comply with the potential policies.

Acknowledgements

The authors are grateful for the financial support for this work from the Ministry of Agriculture and Forestry in Finland and the Norwegian Research Council. We also want to thank the participants of the workshop in Brussels in September 2017 for their comments and feedback for the preliminary results of the study. The authors are fully responsible for the study design, analysis, results and interpretations presented in this article.

Declarations of interest

None.

Appendix A

Table A1
Assumed reference demands for selected years on aggregated product group level. Totals are given for the EU + N region and the world. GDP refers to GDP growth. Ela means that GDP elasticities (range of regional values given) are applied to update the reference demands. “Bioinno” refers to a scenario reported in Kallio et al. (2015).

	Basis for assumption	The EU+N				World total[a]			
Millions m^3		2010	2015	2020	2030	2010	2015	2020	2030
Sawnwood	m^3/capita growth	94	94	100	114	368	418	455	533
Plywood and veneer	m^3/capita growth	9	9	10	11	99	112	121	140
Mechanical boards	m^3/capita growth	48	50	57	65	182	225	245	283
Mechanical forest industry, total		151	152	167	189	649	755	821	956
Millions tonnes		2010	2015	2020	2030	2010	2015	2020	2030
Newsprint	Declining trend mostly	9	6	4	4	33	25	20	21
Other printing and writing	Declining trend mostly	27	23	19	19	113	103	90	94
Household and sanitary	GDP/ capita	7	8	8	8	29	32	36	38

(continued on next page)

Table A1 (*continued*)

Millions m^3	Basis for assumption	The EU + N 2010	2015	2020	2030	World total[a] 2010	2015	2020	2030
Case materials and paperboard for packaging	GDP (Ela 0.3–0.4)	36	37	39	42	185	208	228	269
Other paper and paperboard	Unchanged	7	7	7	7	32	33	33	33
Dissolving and other pulps not used in paper making	Growth of 5–6%/yr	1	1	2	6	4	7	9	31
Paper and paper board, total		87	82	77	85	395	407	416	486
Bioenergy, TWh									
Wood chips for modern heat and power production	Bioinno	150	193	235	258	530	942	1354	1336
Liquid biofuels made of wood chips	Bioinno	0	0	8	18	0	0	24	211

[a] Note that the data for sawnwood and plywood, e.g. for 2015, deviate from the figures that could be directly aggregated from the FAOSTAT data. This is because we adjusted the figures for China considerably downwards in order to get them comply better with the reported use of logs (production + net imports) there.

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