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Preliminary evidence of softwood shortage and hardwood availability in EU regions: A spatial analysis using the European Forest Industry Database

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A R T I C L E I N F O

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A B S T R A C T

As the overall demand for wood-based products continues to grow, questions arise on how local wood resources and industry characteristics can effectively meet this growing demand. In the European Union (EU) 550 million m^3 of wood is harvested annually, and is to a large extent processed by the wood industry. Little is known about the interplay between industrial capacity and the regional availability of timber resources. We compared the capacities from the European Forest Industry Facilities Database (EUFID) with the estimated wood supply from the procurement areas around processing industries, calculated using a spatially explicit resource model (EFISCEN-Space). We found that the estimated total capacity for the available European countries is 427 M m^3 roundwood equivalent (rw. Eq.) for pulp and paper (including both virgin and recycled fibres), 102 M m^3 for bioenergy (only bioenergy plants), and 153 M m^3 for sawmills. We then conducted an in-depth analysis of three case studies: Norway, the Czech Republic, and Germany. Given the current probability of trees being harvested (excluding disturbances) and the hypothetical optimal grading of the logs, the volume for each assortment type is closely aligned with the current capacity of each industry branch, indicating no overcapacity. We found undersupply of softwood of 3.4 M m^3 for the Czech Republic, 1.5 M m^3 for Norway, and 3.8 M m^3 for Germany. At the same time, in Germany, we found an oversupply of hardwood of 3.0 M m^3. Additionally, a substantial amount of biomass graded as bioenergy was found for Germany and the Czech Republic, potentially serving as fuelwood in households. Concerning wood procurement areas, we concluded that a fixed radius of 100 km from the facility limited the availability of raw material procurement, particularly for bioenergy and pulp and paper mills, suggesting that these two product chains use a broader procurement basin than sawlogs. This study provides a high-resolution, spatially explicit modelling methodology for assessing the interaction between potential wood harvest and industrial processing capacity, which can support projections of sustainable development of the forest industry.

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1. Introduction

The forest-based bioeconomy is receiving increasing attention as a potential strategy for mitigating climate change (Grassi et al., 2021). Biobased products, along with being renewable, possess a long-lasting carbon storage capacity, and offer a potential substitution for energy-intensive materials with higher carbon dioxide (CO_2) emissions, especially when used in construction materials (e.g Churkina et al., 2020). As the transition toward the European Union (EU) bioeconomy gains momentum, an increased demand for wood is likely, driven by the elevated usage of biomass for both biomaterials and bioenergy (Bell et al., 2018).

While the bioeconomy may assist in reducing fossil-based carbon emissions, the concurrent increase in harvesting driven by heightened demand for bio-based products could potentially offset these benefits by diminishing the forest carbon sink in the short to medium term (Bozzolan et al., 2023; Pilli et al., 2015; Gawel et al., 2019). To fulfil the higher expected demand of the bioeconomy, there are two options available: either increase harvesting or improve the efficiency of processing and utilization of the raw material.

The first option may have significant trade-offs between increased harvesting and the valuable ecosystem services provided by forests (Eyvindson et al., 2018; Verkerk et al., 2014). Firstly, an increase in harvesting levels would conflict with the EU environmental and climate targets (Blattert et al., 2023; Korosuo et al., 2023). Secondly, the rates of harvesting and wood mobilization in the EU are already conspicuously high, leaving limited room for further increase (Lerink and Orazio, 2023; Orazio et al., 2017).

Given the transition toward a bioeconomy and the goal of maintaining a similar level of harvest, the second option, which involves the optimization of wood resource usage, emerges as a viable strategy to enhance overall biomass availability (Vis et al., 2016; Bozzolan et al., 2023). However, such optimisation requires a detailed understanding of the availability and regional-scale utilization of wood resources, and these are currently lacking. Presently, only national-level statistics on production and trade are available (FAOSTAT, 2024), making it challenging to comprehend the local dynamics of wood production and usage. This limitation is particularly significant as different regions within a country may exhibit unique wood utilization patterns influenced by their specific industries, markets, and the availability and characteristics of resources. While commercial databases do exist, their accessibility is often limited.

The current and future availability of timber is assessed using a large variety of methods. Projection system range from the original yield tables to more evolved models such as stand-level models, individual-tree and process-based eco-physiological models (Rennolls et al., 2007). Barreiro et al. (2016) reviewed the tools and methods currently in use for reporting woody biomass availability in 21 European countries. They found that projection systems based on National Forest Inventory-oriented models prevail over stand wise forest inventory–oriented methods. However, it has been found that official estimation done using these models was sometimes producing inaccurate results.

Mantau et al. (2010), using back calculation based on the semi-finished wood products, found that volumes of timber used by the forest industries proved to be greater than those published in national felling statistics, revealing a total difference of 47 M m^3 at EU scale (Mantau et al., 2010). Wood use back calculation is currently used to compute the German national logging statistics (UNFCCC, 2021). Other researchers have analysed wood production and consumption trends using wood product statistics (e.g., FAOSTAT) (Camia et al., 2018; Cazzaniga et al., 2019). Despite the completeness of these studies, FAOSTAT relies on information reported by member states, and concerns about underestimations in the statistics on the production and trade of wood products have been raised (Buongiorno, 2018; Kallio et al., 2018; Pettenella et al., 2021). A recent study confirmed that removals and fellings in official statistics are often underestimated when compared to the wood uses (Jonsson et al., 2021). These uncertainties lead to data gaps and inaccuracies, compromising the reliability of the data.

As demand for woody biomass rises and discrepancies between reported supply and industrial consumption persist, it becomes crucial for the forest-based industries, the bioenergy sector, and policymakers to access accurate information on the availability and use of the regional woody biomass. In this research, our focus is to analyse the alignment between regionally available wood assortments and the corresponding regional industry needs.

We develop a wood distribution model that classifies the amount of harvested wood, split into assortments, based on explicit geographical data of available resources. Subsequently, these assortments are assigned to the nearest industry facilities to evaluate both potential regional procurement areas and the local resourcecomsumption. Furthermore, we developed a novel wood grading module that integrates National Forest Inventory (NFI) plot-based forest resource modelling with detailed industry facility information. We then compared our results with FAOSTAT data, encompassing the three primary sources of information. This study provides a methodology for the grading and allocation of wood resources, giving the research a focus more centred on the technical aspects while currently disregarding the purely economic aspects.

2. Methods

The methodology employed in this study involved integrating a comprehensive representation of forest resources with a detailed database of forest industry facilities. We graded the harvested wood (from felling chances per diameter class, per species and NFI plot) into different assortments and allocated them to specific nearest industry facilities to test regional procurement areas under various radius constrains. A new forest industry facilities database was established to provide information on the industrial utilization of wood (see Table 1). Subsequently, we developed a spatial explicit wood grading and allocation model. This model can integrate the resource side (derived from the output of EFISCEN-Space) with the industrial processing capacity, as obtained from the forest industry database. We selected three European countries: Czech Republic, Norway and Germany. We selected these three case studies for three reasons. Firstly, we had comprehensive NFI plot data. Secondly, through a preliminary comparison, we found that the industry capacities extracted from the database aligned with the FAOSTAT values for the corresponding class, suggesting a relatively complete set of industry-related information. Finally, we have a complete list of both location and production capacity for each mill.

2.1. EFISCEN-space model

EFISCEN-space is a forest resource model that provides spatially explicit information on tree species composition, diameter and timber resources across Europe. The model incorporates data on forest structure and dynamics such as tree growth, mortality, ingrowth, and management activities like harvesting and planting. The model accounts for the distribution of trees over diameter classes and includes transitions between classes based on diameter increment. EFISCEN-Space uses aggregated NFI data as a main source of input to describe the current structure and composition of European forest resources. Based on this information, the model can project the development of forest resources, based on different scenarios (Schelhaas et al., 2022). According to the NFI characteristics of each country, the number and the shape of plots may vary, but collectively, they constitute a relatively small portion of the total forest area; often around 0.01 %. To infer our calculations to the country level, we employed a multiplier called “representative area”. For this simulation we used static mortality (see Schelhaas et al., 2022) and continuation of current management as observed from the NFI plot data (Schelhaas et al., 2018). 95 % of the total stem volume is removed from the forest and considered as harvest, while non-stem wood is left in the forest.

The model output provides for each plot the reference year, the representative area of the plot, and the expected harvested volume per hectare for each species (20 in total) divided into 40 diameter classes. Each diameter class corresponds to 2.5 cm, which means that class_1 contains trees with a DBH between 0 and 2.5 cm. The expected harvest is based on the probability of a specific tree and diameter to be harvested (for more information Schelhaas et al., 2018). In this case, we calculated the harvest by running the model and averaging the yearly output of the first five years, starting from the reference year of the NFI inventory.

2.2. European Forest Industry Dataset

We compiled a new and detailed EUFID, collecting information from several data sources. The data holds the location and processing capacities of about 4000 facilities across 29 European countries (Table 1). The database is subdivided into three main industry branches: pulp and paper, bioenergy and sawmills. For pulp and paper and bioenergy, the information has been obtained from a third party (https://www.fastmarkets.com/). The database for pulp and paper encompasses facilities utilizing both raw fibres and recycled paper in their production processes. For the analysis of the three case studies, we considered only the share of the capacity constituted by raw fibres. For bioenergy, the database includes only the industrial plants that generate heat and power using wood. The capacity data for pulp and bioenergy likely include a mixture of residues and roundwood; however, the data at our disposal does not allow us to distinguish between the types of wood fiber inputs. However, fuelwood used at the household level, is not recorded. It is important to note that certain facilities may also import feedstock from neighbouring countries. The sawmill industry information has been collected from local correspondents, country associations, online material and grey literature (Annex C). Since the data are collected from many different sources and not on a yearly basis, the database does not have a unique reference year for the capacities of each facility but rather represents the average processing capacities over recent years. The panel industry was excluded for two reasons. Firstly, the information regarding the location and capacities of panel industry facilities was deemed insufficient to conduct the analysis. Secondly, the panel industry primarily utilizes a limited amount of raw material (e.g., sawlogs), prioritizing residues and post-consumer wood. To determine locations, a geocoding script, implemented in Python, has been utilized to generate coordinates based on provided addresses. However, the accuracy of the results has been variable. In instances where the exact location of the mills could not be determined, we opted to record the coordinates of the nearest village or town to overcome the issue with the low accuracy (Fig. 1).

2.3. Wood grading and allocation module

The module consists of two parts: the grading module and the allocation module.

The grading module categorizes harvested wood into various potential assortments, including sawlogs, pulpwood, and bioenergy wood, based on diameter at breast height (DBH) classes and tree species. This classification utilizes a grading matrix (Annex A) applied to the EFISCEN-space output. The matrix is grounded in literature (Giurgiu et al., 2004; Giurgiu et al., 1972) and developed through collaboration with a panel of specialists (see Wood grading and allocation modelling in discussions). Following that, it has been validated by sector expert during a dedicated EU project workshop. The logs grading involved two main steps. Initially, each tree was divided into shares of total biomass in the stem and bark. Subsequently, each stem was further categorized into shares of thick, medium, and small logs. This categorization considered the tree tapering effect, which is the gradual reduction in the tree trunk's diameter as you move from the base to the top. For example, for a log with a diameter at breast height (DBH) of 30 cm, only the lower part (bottom 30 %) of the tree can be considered as sawlogs. Finally, based on

Table 1
Capacities (cubic meters of roundwood) and number of facilities per country. For pulp and paper, the list does not distinguish between raw and recycled materials. For bioenergy, the list reports the capacities of industrial bioenergy plants using woody biomass as feedstock. The capacity of sawmills is not available for Switzerland and France. (See Annex C for further details and data sources).

Country	Capacity m^3 P&P	Number of P&P facilities	Capacity m^3 Bioenergy	Number of Bioenergy facilities	Capacity m^3 Sawmill	Number of Sawmill facilities
Austria	19,107,234	33	1,404,499	20	19,394,000	43
Belgium	7,520,458	7	311,524	8	2,730,000	94
Bulgaria	1,113,070	12	974,174	5	–	–
Croatia	1,548,680	3	168,962	6	–	–
Czech Republic	3,939,505	29	2,460,516	7	12,420,200	216
Denmark	553,100	2	2,608,359	22	1,610,000	16
Estonia	277,200	3	649,449	10	2,334,000	15
Finland	39,196,602	46	15,993,356	109	21,196,028	72
France	37,135,199	118	18,150,258	160	–	659
Germany	110,606,666	228	3693,000	50	29,460,600	112
Greece	1,713,564	16	–	–	–	–
Hungary	3,224,880	7	580,809	6	–	–
Ireland	–	–	739,212	6	3,100,001	11
Italy	49,340,941	227	2,478,996	24	114,000	6
Latvia	–	–	211,203	6	6,214,900	25
Lithuania	1,105,175	4	15,322,786	4	1,110,000	11
Netherlands	18,277,758	32	290,403	9	259,001	69
Norway	4,481,269	13	6790,179	26	5,524,894	52
Poland	19,628,053	63	2,040,746	32	4,614,000	366
Portugal	9,993,877	33	467,286	5	–	–
Romania	2,936,074	15	2,238,753	5	–	–
Slovak Republic	3,967,200	8	4,767,908	27	1,250,000	5
Slovenia	2,876,940	9	5280	1	–	–
Spain	29,315,354	90	1,254,021	24	580,000	52
Sweden	38,210,400	56	10,108,696	149	37,727,964	138
Switzerland	4,747,122	13	36,960	2	–	172
United Kingdom	16,042,266	60	8,001,954	66	3,638,000	18
Grand Total	**426,858,588**	**1127**	**101,749,289**	**789**	**153,272,588**	**2152**

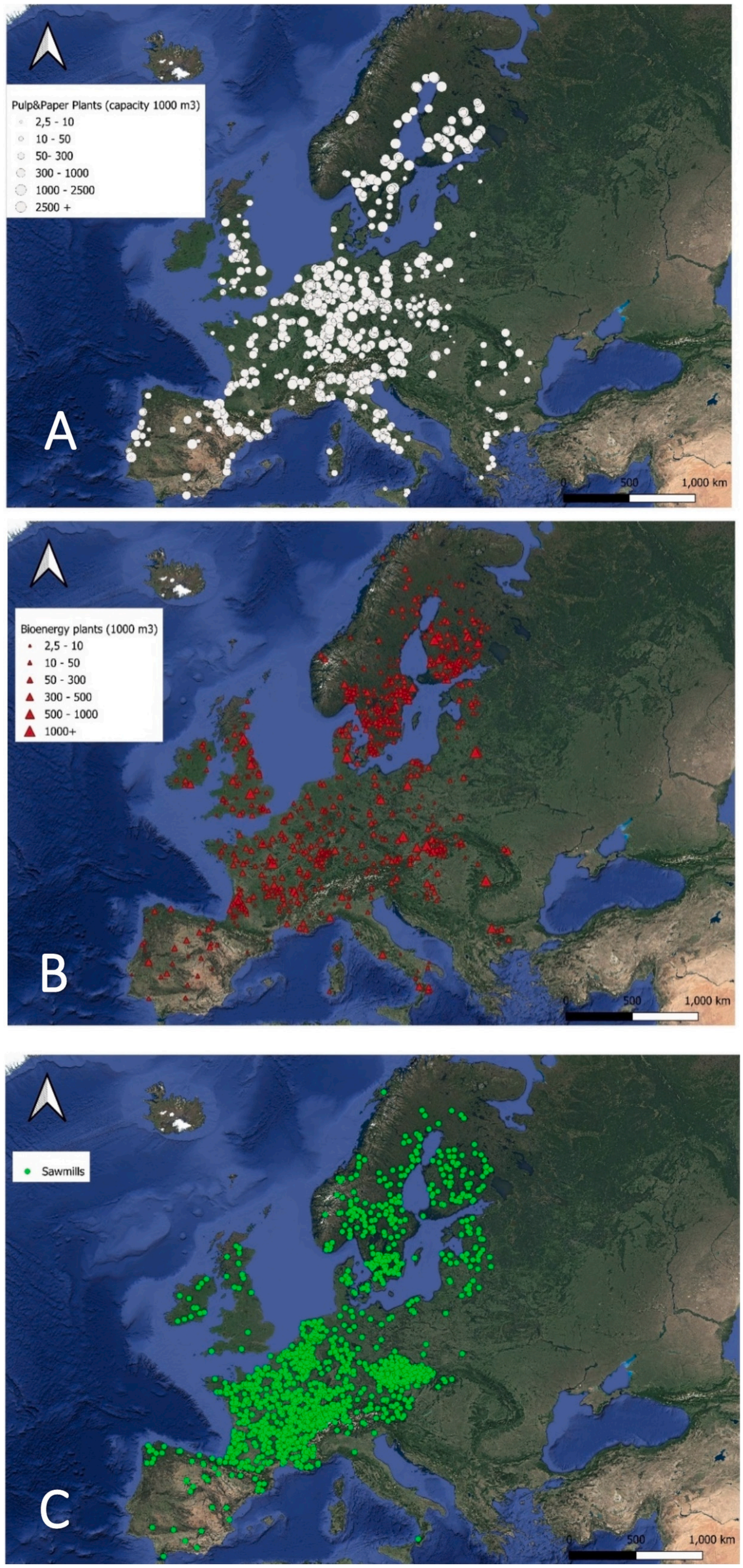

Fig. 1. Geographical Distribution and Capacities of Mills in the European Forest Industry Database (EUFID). A: pulp and paper Mills (white dots). B: Bioenergy Facilities (red triangles). C: Sawmills (green dots). Please note that sawmill capacities are not depicted in the image. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

these characteristics, the logs were sorted into assortments. For example, for conifer trees, thick logs (DBH > 20 cm) are designated as sawlogs, medium logs (20 cm < DBH > 14 cm) as pulpwood, and small logs (DBH < 14 cm) along with bark are allocated to bioenergy. Due to the distinct morphologies of trunks, there is a discrepancy between the grading of conifers and broadleaves. Broadleaves generally have more branches, reducing the volume of the trunk that can be graded as sawlogs for sawmilling. Therefore, the grading values for broadleaves were adjusted accordingly. Finally, in our analysis, we considered that some trees might be unsuitable for sawmilling due to poor quality, including defects and irregular shapes. Consequently, we systematically reallocated 10 % of the total volume of trees deemed suitable for sawlogs to the bioenergy category.

The second part, the allocation module simulates the distribution of the graded available wood resources to the nearest facilities requiring specific wood assortments (Fig. 2).

The wood allocation is determined by factors such as the allocation radius (distance plot-to-mill), the quantity and the wood type requested by the mill. Currently, distance calculation employs the Euclidean distance formula (air distance between two points), we do not consider existence of roads, or rail or ports. We assume that the road network in Europe is so dense that the Euclidean distance is a good proxy. Once the wood is allocated to a mill, it becomes locked and cannot be redirected to another mill, ensuring avoidance of double counting. This also means that e.g. sawing residues are not re-allocated.

The wood allocation module allows the setting of a "maximum allocation radius" (defaulted to 100 km). Mills of different types may have varying maximum allocation distances. We determined that setting an averaged maximum distance of 100 km for all industry types would be suitable for this specific analysis (e.g Anderson, 2008; Brown, 2015; Ranta and Korpinen, 2011). To explore the impact of allocation radius variations, we conducted some simulations using the wood grading and allocation module with the maximum radius and others using country borders as maximum radius, assessing how changes in the allocation radius influence the distribution of wood assortments to nearby facilities. Additionally, although we did not conduct specific analyses for import/export, we explored the border interaction between two neighbouring countries: the Czech Republic and Germany. We ran the model first at the country level and then treated them as one entity (see Annex B).

Additionally, the module prioritizes the allocation of wood to small sawmills. This decision is based on the assumption that small sawmills typically source logs locally, while larger mills can purchase raw wood in greater quantities, thereby amortizing transportation costs, even for wood sourced from a long distance.

Upon completion of the process, the module generates details on which wood assortment has been delivered to a specific mill from a particular plot, which plots still have available resources, whether mills meet or fall short of full capacity, and statistics on maximum, minimum, and mean allocation distances.

To enhance the visualization of our results at the regional level, we introduced a "utilization factor." EFISCEN-Space provides an average of harvested wood per plot, categorized by tree species and DBH (Schelhaas et al., 2018). After completing the grading and allocation phase, it is possible that some plots still contain wood in principle available for harvest but remains unallocated by the industry. This could occur because, during the allocation phase, the model did not find a suitable match for allocating the wood to a nearby facility. Reasons are incorrect wood type, excessive distance, or the facility's capacity already being satisfied. We calculated the percentage of wood allocated to a mill and the percentage that remains in the plot, defining this ratio as the "utilization factor." When all estimated harvest from a plot is successfully allocated to the mill, the utilization factor will be 100 %. Conversely, if all the wood remains hypothetically unallocated at the plot, the utilization factor will be 0 %. In the utilization factor map (see result section Fig. 3), red areas will show regions where harvested wood is more likely to be used by the wood industry, while blue areas will indicate regions where wood is more likely to be left in the plot.

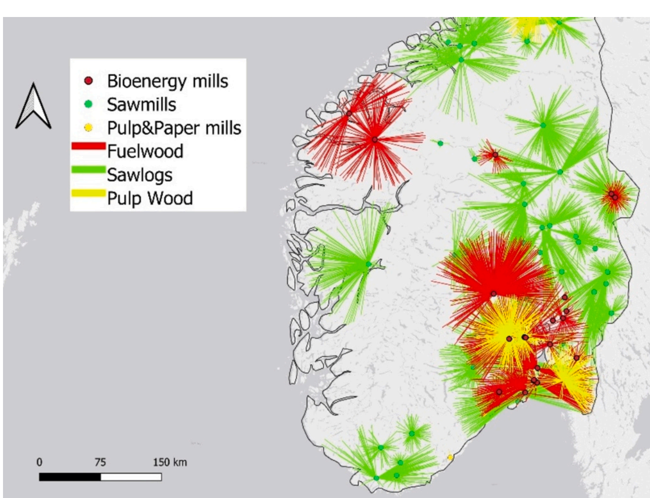

Fig. 2. Wood grading and allocation Module Example: Plot-to-Mill Allocation for the South of Norway. Dots represent mills, and lines depict the connections between plots and mills.

3. Results

The EUFID encompasses data on 1127 pulp and paper mills across 25 countries, 789 Bioenergy mills in 26 countries, and 2152 sawmills in 20 countries (see Table 1). The estimated total capacity for the available EUropean countries is 427 M m^3 roundwood equivalent (rw eq) for pulp and paper, 102 M m^3 for Bioenergy, and 153 M m^3 for sawmills. The value reported in this table for pulp and paper includes the production capacity for both virgin and recycled raw materials converted to roundwood equivalent. Henceforth, we will refer only to m^3 of wood. In the EU, there is a paper recycling rate of 73.9 % (CEPI, 2020), indicating that only one-fourth of the total consumption (~ 110 M m^3) of raw wood is utilized in the production of pulp and paper. Additionally, it is important to note that the capacity values in the table represent nominal capacity which can differ from operational capacity. While some mills (such as pulp mills) may operate at or near full capacity, others may not, depending on various factors such as economic conditions or seasonal fluctuations (e.g climate conditions, energy price, etc.).

For the case studies the results are summarized in Table 2. In the Czech Republic, the total industry capacity, based on EUFID, is 18.1 M m^3 of roundwood, while the wood grading indicates that 20.8 M m^3 could potentially be used. This aligns well with the FAOSTAT-reported figure of 20.8 M m^3, which represents the sum of the volume of the corresponding FAOSTAT classes. In the Sawlogs Conifers category, the industry capacity is 12.4 M m^3, while the graded wood is 9.0 M m^3. For Bioenergy, the industry capacity is 2.5 M m^3, and the graded wood is 8.0 M m^3. In the pulpwood category, the industry capacity is 3.3 M m^3, but only 2.9 M m^3 are graded. Notably, the fixed radius wood allocation approach shows an effective utilization of 12.2 M m^3, compared to the 14.4 M m^3 of the country border maximum radius approach.

In Norway, the total industry capacity amounts to 16.0 M m^3, with graded wood amounting to 12.1 M m^3, comparable to FAOSTAT figure of 10.4 M m^3. Specifically, in the Sawlogs Conifers category, the industry capacity is 5.5 M m^3, yet only 4.1 M m^3 are graded. There is a notable disparity in the Bioenergy sector, where the industry capacity stands at 6.8 M m^3, but the graded wood is 5 M m^3. Similarly, for the pulpwood category, the industry capacity is 3.7 M m^3, but only 3.0 M m^3 are graded. Examining wood allocation, the model shows a potential utilization of 12.1 M m^3 when utilizing country borders as the maximum radius, twice the amount delivered with a fixed radius (6.0 M m^3).

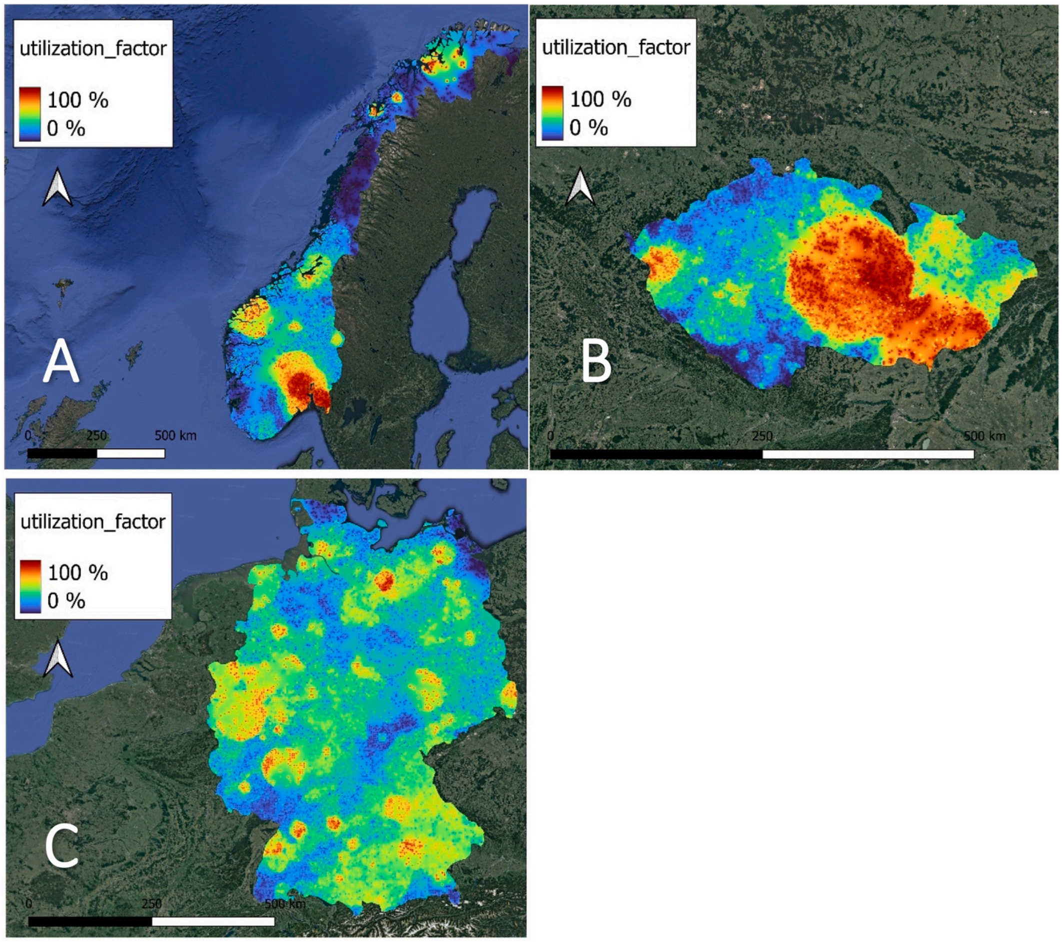

Fig. 3. Utilization Factor Map: When all the probable harvested wood is successfully allocated to the mill, the utilization factor will show 100 %. Conversely, if all the wood remains hypothetically unallocated at the plot, the utilization factor will be 0 %. In the utilization factor map, red areas signify regions where harvested wood is more likely to be used by the wood industry, while blue areas indicate regions where wood is more likely to be left in the plot. A: Norway; B: Czech Republic; C: Germany. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

For Germany, the total industry capacity, according to EUFID, is 42.1 M m^3, with graded wood amounting to 65.2 M m^3. FAOSTAT reports a total figure for all the industry of 69.6 M m^3. For Sawlogs Conifers, the industry capacity is 27.9 M m^3, while the graded wood is 24.1 M m^3. Sawlogs Broadleaves have an industry capacity of 1.6 M m^3, with 4.6 M m^3 graded. The Bioenergy sector shows an industry capacity of 3.7 M m^3, and the graded wood is 28.1 M m^3. For pulpwood, the industry capacity is 9.0 M m^3, and the graded wood is 8.4 M m^3. Wood allocation indicates a potential utilization of 37.7 M m^3 with country borders as the maximum radius, compared to the 30.5 M m^3 allocated with a fixed radius.

4. Discussion

Based on the model data, the overall potential harvest from the national wood resources is sufficient to meet the industry nominal capacity in Germany and the Czech Republic, but it falls short in Norway. However, a closer examination of the disaggregated figures in Table 2 for each country reveals shortages in some assortments, even with an overall surplus of raw wood.

For the Czech Republic, the industrial sawmill capacity in the EUFID database amounts to 12.4 M m^3, while for the resource side (through grading) we estimate only 9 M m^3. In our modelling approach, we used the harvest probability as calculated in Schelhaas et al., 2018, which represent the likelihood of a specific tree being harvested based on field records prior to 2017. While forest management practices and harvesting routines can be considered relative stable at the national level, the impact of forest disturbances may significantly alter harvesting patterns. The real volume of harvesting in the Czech Republic exceeds our estimate, because of an increase in salvage logging due to bark beetle outbreak (Hlásny et al., 2021). The harvesting routines for the Czech Republic were derived from the 2012 NFI, and as such, the substantial volume of salvage logging conducted in recent years is not represented in our simulations. According to FAOSTAT, Czech production of coniferous sawlogs increased from 8.5 M m^3 in 2015 to 18.7 M m^3 in 2019. This peak is only partially reflected in industry records, which indicate a processing capacity of 12.4 M m^3 for sawlogs, closely aligning with the FAOSTAT average value (2015–2020) of 13.4 M m^3. Regarding the pulpwood category in Czech Republic, the findings indicate that the volume of graded wood (3.0 M m^3) falls below the sector's capacity (3.3 M m^3).

In Norway, the harvested volume appears insufficient to meet the regional industry capacity for all the branches. This apparent shortfall can be attributed to the conservative harvesting regimes employed in the simulation, aligning with observed plot data. This indicates that the current harvesting pressure may result in a shortage of raw material for the wood industry.

In Germany, we observe a harvested volume (65.2 M m^3) notably surpassing wood industry's capacity (42.1 M m^3). An evident discrepancy is observed in the availability of graded coniferous sawlogs, falling short by 3.8 M m^3 to meet the total capacity of the sawmills. At the same time, there is an excess of approximately 3 M m^3 of hardwood, which

Table 2
Summary wood allocation per country. Values reported are in 1000 m^3. Industry capacity: nominal capacity of the mills as based on our own industry database EUFID; Wood grading: amount of wood graded per assortment as based on EFISCEN-space forest resource data; Wood allocation fixed radius: amount of wood delivered to the facility using a fixed radius of 100 km; Wood allocation c. b: amount of wood delivered to the facility using country borders as maximum radius; FAOSTAT: averaged production values from 2015 to 2020.

Assortment type	Industry Capacity as based on EUFID	Wood Grading	Wood allocation fixed radius	Wood allocation up to country border	FAOSTAT (avg 2020–2015)
Czech Republic					
Sawlogs Conifers	12,420	9002	8077	9002	13,411
Sawlogs Broadleaves	0	763	0	0	452
Bioenergy	2461	8020	2461	2461	3992
Pulpwood	3256	2972	1678	2972	2978
TOT	18,137	20,757	12,216	14,435	20,833
Norway					
Sawlogs Conifers	5519	4051	3247	4051	5718
Sawlogs broadleaves	0	82	–	–	3
Bioenergy	6790	4969	1852	4969	1645
Pulpwood	3673	2944	887	2944	3043
TOT	15,982	12,046	5985	11,965	10,409
Germany					
Sawlogs Conifers	27,884	24,087	20,440	24,087	35,278
Sawlogs broadleaves	1577	4584	1577	1577	3107
Bioenergy	3693	28,140	3561	3693	22,365
Pulpwood	8984	8362	4877	8362	8834
TOT	42,138	65,173	30,455	37,719	69,584

represents the difference between the supply of graded logs and the wood industry capacity. In this situation, we suspect that hardwood, suitable for sawlogs, is potentially being exported for the production of high added value product such as wood flooring (Mračková et al., 2021). This suggests that there is potential for the regional industry to benefit from the surplus of hardwood by expanding their operations to accommodate more hardwood processing. Concerning bioenergy, we recorded a volume of 28 M m^3, in line with FAOSTAT value for wood fuel (22.4 M m^3) whereas the industry's recorded capacity stands at only 3.6 M m^3. This difference could be attributed to the fact that the bioenergy capacity in the industry database only accounts the volume used by industrial plants, while the results of wood grading and FAOSTAT class include all wood meant for burning, including fuelwood intended for household use.

During the study, we also investigated the impact of varying the length of the allocation radius. We primarily explored two scenarios: a fixed allocation radius of 100 km for all the assortments, indicating the maximum distance wood could be recruited from a nearby plot was limited to 100 km, and a country borders radius, permitting wood procurement from the entire national area within the borders. In general, we observe that a fixed allocation radius of 100 km imposes constraints on wood procurement for the industry in all three case studies. The pulp and paper, and bioenergy industries appear to be most affected by the radius limitation. For example, in Norway, applying a maximum radius of 100 km only 0.9 M m^3 of pulpwood is adequately allocated to the industry, which represent roughly one third the available resources (2.9 M m^3 of pulpwood). Similarly, in Germany and the Czech Republic, the pulp and paper sector faces the most significant limitations. It can be deduced that pulp and paper sector needs a larger basin for gathering raw material compared to the sawmills industry. This is likely attributed to the greater size of pulp mills, as they tend to be larger on average than sawmills, resulting in a significantly wider radius for raw material sourcing.

According to our modelling exercise using a fixed radius, we observed that in Norway, most wood resources are utilized in the south-east (Fig. 3), coinciding with the location of most mills. As mentioned earlier, this pattern is likely influenced by the country's geography and its proximity to significant economic centres, such as the city of Oslo, where ports are also situated. In more remote areas, like the north and south-west, it appears that a substantial portion of resources remains unused. In Germany, we found a more homogeneous use across the country. Conversely, in the Czech Republic, there was a concentration of use in the central part of the country (Prague, Brno, and Hradec Kralove). This method can be utilized to identify areas where prioritizing the establishment of set-aside forests is advisable, characterized by a lower presence of industry and, consequently, lower pressure on forest resources. Conversely, it could also be employed to pinpoint locations suitable for specific industries based on the potential availability of resources. Finally, although we did not conduct specific analyses for import/export, we explored the border interaction between two neighbouring countries: the Czech Republic and Germany. We ran the model first at the country level and then treated them as one entity (see Annex B.). The overall sum of the realized amount of raw material allocated to the mills did not show significant gaps when compared with the outcome of the simulation when the model was run at the country level. This suggests that the main limiting factors for wood procurement are the availability of wood resources and the length of the allocation radius.

When evaluating the results, it is crucial to acknowledge several limitations. Three primary uncertainties can be identified: the output of forest resource modelling (EFISCEN-Space), the output of harvested wood products modelling and the consistency of the database.

4.1. Modelling out-put (EFISCEN-space)

Regarding the supply-side simulation, it is important to highlight that our harvesting and mortality scheme is based on a probabilistic formula derived from observed and remeasured trees in a data analysis conducted prior to 2018 (Schelhaas et al., 2018). It is crucial to acknowledge that harvesting and mortality probabilities may have evolved over time, which could lead to potential discrepancies between the EFISCEN-Space output and actual circumstances. This is particularly relevant for disturbances, which are not currently included in the model. Additionally, NFIs are based on sampled plots, and to generalize these samples, we employ a multiplier called "representative area," aiming to capture the total forested area. While at the national level the total harvest closely matches country statistics, this approach might be inaccurate at smaller scale leading to a potential misrepresentation of the available wood at plot level.

4.2. Consistency of EUFID

Regarding the consistency of EUFID, there are a few points that need to be mentioned. Specifically, for the pulp and paper sector, the database provides information on both pulp and paper from raw material and recycled sources, while our in-depth analysis for the three case studies focused exclusively on virgin pulp. It is crucial to note that at the EU level, a substantial portion of pulp used in paper manufacturing comes from recycled paper (CEPI, 2020). However, the industry still relies on a minor proportion of virgin fibres, approximately 20 % of the total, to sustain its operations.

Sawmills data from each country were gathered from diverse sources, resulting in a disparity in the reference year. For example, information for the Czech Republic was sourced from a technical report published in 2006 and revised by the country correspondent. This raises the potential concern that the presented data may not accurately reflect the more recent figures in wood processing. Moreover, it is important to acknowledge that, for some countries, we only have a list of sawmill facilities along with their relative locations, but corresponding capacity information is missing. Fortunately, in the instance of the case studies, the information is complete. Another limitation is associated with location accuracy. In certain cases, when the address could not be precisely matched, the script assigned coordinates of the nearest city. Consequently, there might be instances where the recorded facility locations do not perfectly align with their actual, physical locations. Finally, we assumed that all the mills work at full capacity; however, mills typically do not operate at maximum capacity. For instance, pulp mills have an operating rate ranging from 84 % to 93 % (CEPI, 2020).

4.3. Wood grading and allocation modelling

It is crucial to consider that the grading system developed in this research is based on literature and refined by sector experts to provide the best average outcome at the EU level. Wood grading can be influenced by factors such as origin, quality, and the capabilities of the local wood industry. Therefore, the model presented here is regarded as a simplification of reality. For example, for one hardwood species, there may be large regional differences in properties which command the price and favour a specific application. Oak wood from the Allier region (FR), Rheinland Pfalz (DE) or Toka region (HU) is appreciated for barrel making and in general oak from Spessart (DE), Slavonia (CR) and Poland is especially used for veneer and furniture production (Teischinger, 2017). The various regional differences in wood properties with respect to specific uses in wood products are well-known by experienced traders and wood procurement managers but a thorough documentation on specific regional properties of woods is lacking (Teischinger, 2017).

Another factor that may profoundly change wood grading is forest disturbance. Bark beetles outbreaks and windstorm can drastically change the patterns of wood use in the industry. Salvaged or damaged wood can occasionally be utilized as pulpwood or bioenergy when there is an abundance on the market, invoked by such disturbances (Cremer and Velazquez-Marti, 2007; Hlásny et al., 2019). Large-scale forest disturbances can also have a long-term impact on the timber sector. In Czech Republic, large-scale bark beetle calamity has led to a significant change in tree species composition during regeneration. The proportion of spruce regeneration is significantly decreasing in the calamity areas in favour of broadleaved species (beech and oak), but also pioneer species like birch (Dudík et al., 2021). This fact will in future force a change in the existing timber processing technologies, which are currently focused mainly on coniferous timber (spruce and pine). Moreover, subsidies and policies may influence wood consumption (Johnston and van Kooten, 2016; Lundmark and Mansikkasalo, 2009; Stordal, 2004). For example, import/export taxation can play an important role in the feedstock characteristic for each industry.

It is important to acknowledge that our model primarily focuses on primary sources of raw wood, specifically roundwood provisioning, and does not currently account for secondary sources such as the waste stream from the sawmill industry. It is worth noting that for sawmills, we account for 100 % roundwood which is processed to produce sawn wood with varying levels of efficiency, typically ranging from 44 % to 64 % in highly efficient mills (FAO et al., 2020). Portions of the generated residues, including chips, sawdust, and shavings, are often utilized within the mills themselves, for purposes such as wood drying, while the remainder is purchased by panel, pulp and paper, and bioenergy industries. In the case of pulp and paper production, only a minor portion (20 %) of the total virgin fibres used in the industry is derived from residues, while the rest originate from roundwood (CEPI, 2020). In this case, we have reported only the capacity of industries that use raw wood fibres, excluding recycled paper. This raw wood input likely consists of a mixture, with a minor portion being residues and a major portion being pulpwood. Bioenergy feedstock probably includes bark, small-diameter trees mixed with low-quality broadleaves, and sawmill residues. However, the data at our disposal regarding capacity do not allow for differentiation between these types of wood fiber inputs.

Another aspect of the model that requires clarification is the method used for allocating wood resources. The model employs Euclidean distance, ranging from the closest to the farthest facilities, without considering terrestrial obstacles like rivers and mountains. An improvement would involve using routable distance, considering all roads suitable for log trucks (e.g., those with slopes below 6–7 %). Additionally, the current model excludes alternative transportation modes like trains and boats, whose inclusion could alter wood resource distribution. The selection of transportation methods is based on factors such as distance, terrain, infrastructure, and economics, with many logging operations utilizing a combination.

Dynamic components, such as variations in the volume requested by the industry over time and the import/export of raw wood, were not included in this study. Typically, these factors are examined by incorporating equations into the model, including macroeconomic indicators such as Gross Domestic Product and housing starts. These indicators are valuable for conducting long-term macroeconomic scenario simulations, as demonstrated by Latta et al. (2018). However, our primary focus in this manuscript was to assess whether the locally extracted wood resources from the procurement area around the mills was sufficient to meet the regional industry capacity under normal circumstances. Therefore, we excluded considerations related to exchanges with third countries and dynamic demand fluctuations.

This approach is applicable for modelling future management strategies and offers a reliable prediction of future wood assortments based on available wood resource typology. EFISCEN-Space can be utilized to anticipate the evolution of wood resources under various conditions such as climate change and increased harvesting, assessing subsequent impacts on the wood industry. Moreover, the wood grading and allocation module enables the analysis of introducing new mills with specific capacity in specific areas, allowing an examination of their effects on the redistribution of wood resources across different branches. Finally, the grading matrix can be easily adjusted to be country specific and can be used to explore possible changes in the total volume of the assortments.

5. Conclusions

In the context of the forest-based bioeconomy and the growing utilization of wood, assessing the actual presence of wood resources and their related usage is fundamental. This research used ground-based data to determine whether regional wood supply aligns with the needs of the local wood industry. We established a novel European Forest Industry Database (EUFID), containing information on 4000 forest industry facilities. These facilities are categorized into three product chains: sawmills, pulp and paper, and bioenergy. Utilizing this database, we obtained detailed insights into the industry's specific requirements, including potential spatialized wood consumption per assortment type.

We conducted in-depth analyses for three countries: the Czech Republic, Norway, and Germany. Our results show that, given the observed probability of trees being harvested and hypothetical optimal grading of the logs, the volume for each assortment type is closely aligned with the current capacity of each industry branch. This suggests that there is no overcapacity under current harvesting regimes. For our case studies, there appears to be a shortage of coniferous logs and a slight surplus of broadleaf logs. Additionally, a substantial amount of biomass graded as bioenergy was found, potentially serving as fuelwood in households and/or as material in particle board production.

Concerning wood procurement areas, we observed that a fixed radius of 100 km from the facility limited the availability of raw material procurement, especially for bioenergy and pulp and paper mills, resulting in shortages for all case studies except the bioenergy sector in the Czech Republic. This suggests that these two industries might have a significantly broader procurement basin, indicating the necessity for sourcing wood from distances greater than 100 km. From our theoretical simulation, it appears that the pressure on wood resources, as indicated by the utilization factor, is evenly distributed throughout Germany. In contrast, the pressure is concentrated mainly in the south of Norway (Oslo area) and in the central part of Czech Republic. These country-specific differences are likely attributed to the distribution of industries across the territory, reflecting the morphology (e.g plains, cities, etc.) of each country.

The models employed in this research can be utilized to assess the evolution of wood resources under various conditions, such as climate change and increased harvesting, thereby assessing subsequent impacts on the wood industry. The combination with the forest industry database enables new analysis, such as introducing additional mills with specific wood consumption in specific areas, allowing an examination of their effects on the redistribution of wood resources across different branches. Ultimately, integrating the forest growth model with the wood grading and allocation model can aid in identifying regional pressures on forest resources and areas that could potentially be set aside, providing policymakers with valuable insights for informed decision-making.

CRediT authorship contribution statement

Nicola Bozzolan: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **Frits Mohren:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Giacomo Grassi:** Supervision, Methodology, Conceptualization. **Mart-Jan Schelhaas:** Validation, Methodology. **Igor Staritsky:** Visualization, Data curation. **Tobias Stern:** Writing – review & editing, Data curation. **Mikko Peltoniemi:** Validation, Data curation. **Vladimír Šebeň:** Validation, Data curation. **Mariana Hassegawa:** Writing – review & editing, Validation. **Pieter Johannes Verkerk:** Writing – review & editing, Validation, Data curation. **Marco Patacca:** Writing – review & editing. **Aris Jansons:** Validation, Data curation. **Martin Jankovský:** Validation, Data curation. **Petra Palátová:** Validation, Data curation. **Hanna Blauth:** Validation, Data curation. **Daniel McInerney:** Validation, Data curation. **Jan Oldenburger:** Validation, Data curation. **Eirik Ogner Jåstad:** Writing – review & editing, Validation, Data curation. **Jaroslav Kubista:** Data curation. **Clara Antón-Fernández:** Data curation. **Gert-jan Nabuurs:** Writing – review & editing, Writing – original draft, Supervision, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets used and/or analysed during the current study are available from the corresponding author (Bozzolan Nicola) on reasonable request. The data are not publicly available due to privacy restrictions, but figures, availability of the database and the model can be found at https://github.com/NicolaBozzolan/EUFID_Manuscript_Bozzolan_etal_2024.git.

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Appendix A. Annex

A.1. Grading matrix

The term 'Grade' denotes the type of assortment, where 'sw' stands for softwood, and 'hd' for hardwood. Each class corresponds to a 2.5 cm range, such that Class 1 spans from 0 to 2.5 cm, and so onward.

species	grade	cl_1	cl_2	cl_3	cl_4	cl_5	cl_6	cl_7	cl_8	cl_9	cl_10	cl_11	cl_12	cl_13	cl_14	cl_15	cl_16	cl_17	cl_18	cl_19	cl_20
Abies spp.	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Abies spp.	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Abies spp.	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Abies spp.	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Larix spp.	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Larix spp.	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Larix spp.	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Larix spp.	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Picea abies	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Picea abies	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Picea abies	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Picea abies	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Picea sitchensis	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Picea sitchensis	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Picea sitchensis	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Picea sitchensis	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pseudotsuga menziesii	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Pseudotsuga menziesii	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Pseudotsuga menziesii	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14

(*continued on next page*)

(*continued*)

species	grade	cl_1	cl_2	cl_3	cl_4	cl_5	cl_6	cl_7	cl_8	cl_9	cl_10	cl_11	cl_12	cl_13	cl_14	cl_15	cl_16	cl_17	cl_18	cl_19	cl_20
Pseudotsuga menziesii	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pinus sylvestris	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Pinus sylvestris	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Pinus sylvestris	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Pinus sylvestris	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pinus nigra+ mugo	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Pinus nigra+ mugo	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Pinus nigra+ mugo	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Pinus nigra+ mugo	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Other Pinus	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Other Pinus	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Other Pinus	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Other Pinus	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Other conifers	sawlogs_sw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.42	0.48	0.53	0.59	0.62	0.63	0.64	0.66	0.66	0.68
Other conifers	pulpwood_sw	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.75	0.76	0.34	0.26	0.20	0.16	0.10	0.07	0.06	0.05	0.04	0.04	0.02
Other conifers	bioenergy_sw	0.83	0.83	0.83	0.84	0.84	0.20	0.13	0.09	0.08	0.17	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
Other conifers	bark_sw	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

species	grade	cl_21	cl_22	cl_23	cl_24	cl_25	cl_26	cl_27	cl_28	cl_29	cl_30	cl_31	cl_32	cl_33	cl_34	cl_35	cl_36	cl_37	cl_38	cl_39	cl_40
Abies spp.	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Abies spp.	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Abies spp.	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Abies spp.	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Larix spp.	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Larix spp.	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Larix spp.	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Larix spp.	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Picea abies	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Picea abies	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea abies	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Picea abies	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Picea sitchensis	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Picea sitchensis	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Picea sitchensis	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Picea sitchensis	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pseudotsuga menziesii	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Pseudotsuga menziesii	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudotsuga menziesii	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Pseudotsuga menziesii	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pinus sylvestris	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Pinus sylvestris	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus sylvestris	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Pinus sylvestris	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Pinus nigra+ mugo	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Pinus nigra+ mugo	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pinus nigra+ mugo	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Pinus nigra+ mugo	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Other Pinus	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Other Pinus	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Pinus	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Other Pinus	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Other conifers	sawlogs_sw	0.68	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Other conifers	pulpwood_sw	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other conifers	bioenergy_sw	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Other conifers	bark_sw	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

species	grade	cl_1	cl_2	cl_3	cl_4	cl_5	cl_6	cl_7	cl_8	cl_9	cl_10	cl_11	cl_12	cl_13	cl_14	cl_15	cl_16	cl_17	cl_18	cl_19	cl_20
Betula spp.	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Betula spp.	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Betula spp.	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Betula spp.	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Castanea sativa	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Castanea sativa	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Castanea sativa	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Castanea sativa	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Eucalyptus spp.	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Eucalyptus spp.	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Eucalyptus spp.	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Eucalyptus spp.	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04

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(*continued*)

species	grade	cl_1	cl_2	cl_3	cl_4	cl_5	cl_6	cl_7	cl_8	cl_9	cl_10	cl_11	cl_12	cl_13	cl_14	cl_15	cl_16	cl_17	cl_18	cl_19	cl_20
Fagus sylvatica	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Fagus sylvatica	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Fagus sylvatica	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Fagus sylvatica	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Robinia psedocacia	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Robinia psedocacia	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Robinia psedocacia	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Robinia psedocacia	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Populus plantations	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Populus plantations	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Populus plantations	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Populus plantations	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Quercus robur&petraea	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Quercus robur&petraea	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Quercus robur&petraea	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Quercus robur&petraea	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Quercus ilex	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Quercus ilex	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Quercus ilex	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Quercus ilex	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
Quercus suber	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
Quercus suber	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
Quercus suber	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
Quercus suber	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
long-lived broadleaves	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
long-lived broadleaves	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
long-lived broadleaves	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
long-lived broadleaves	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
short-lived broadleaves	sawlogs_hw	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.60	0.60
short-lived broadleaves	pulpwood_hw	0.00	0.00	0.00	0.00	0.00	0.44	0.64	0.73	0.77	0.81	0.82	0.83	0.84	0.85	0.85	0.85	0.85	0.07	0.04	0.04
short-lived broadleaves	bioenergy_hw	0.91	0.91	0.91	0.92	0.93	0.49	0.30	0.21	0.17	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.31	0.32	0.32
short-lived broadleaves	bark_hw	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04

species	grade	cl_21	cl_22	cl_23	cl_24	cl_25	cl_26	cl_27	cl_28	cl_29	cl_30	cl_31	cl_32	cl_33	cl_34	cl_35	cl_36	cl_37	cl_38	cl_39	cl_40
Betula spp.	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Betula spp.	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Betula spp.	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Betula spp.	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Castanea sativa	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Castanea sativa	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Castanea sativa	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Castanea sativa	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Eucalyptus spp.	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Eucalyptus spp.	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eucalyptus spp.	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Eucalyptus spp.	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Fagus sylvatica	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Fagus sylvatica	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fagus sylvatica	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Fagus sylvatica	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Robinia psedocacia	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Robinia psedocacia	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Robinia psedocacia	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Robinia psedocacia	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Populus plantations	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Populus plantations	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus plantations	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Populus plantations	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Quercus robur&petraea	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Quercus robur&petraea	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quercus robur&petraea	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Quercus robur&petraea	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Quercus ilex	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Quercus ilex	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quercus ilex	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Quercus ilex	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Quercus suber	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Quercus suber	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quercus suber	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Quercus suber	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
long-lived broadleaves	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
long-lived broadleaves	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
long-lived broadleaves	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
long-lived broadleaves	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

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(*continued*)

species	grade	cl_21	cl_22	cl_23	cl_24	cl_25	cl_26	cl_27	cl_28	cl_29	cl_30	cl_31	cl_32	cl_33	cl_34	cl_35	cl_36	cl_37	cl_38	cl_39	cl_40
short-lived broadleaves	sawlogs_hw	0.60	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
short-lived broadleaves	pulpwood_hw	0.04	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
short-lived broadleaves	bioenergy_hw	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
short-lived broadleaves	bark_hw	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Appendix B. Annex

Output simulation using grading and allocation module with County Borders Limitation and Without County Borders Limitation. Fixed Radius of 100 km.

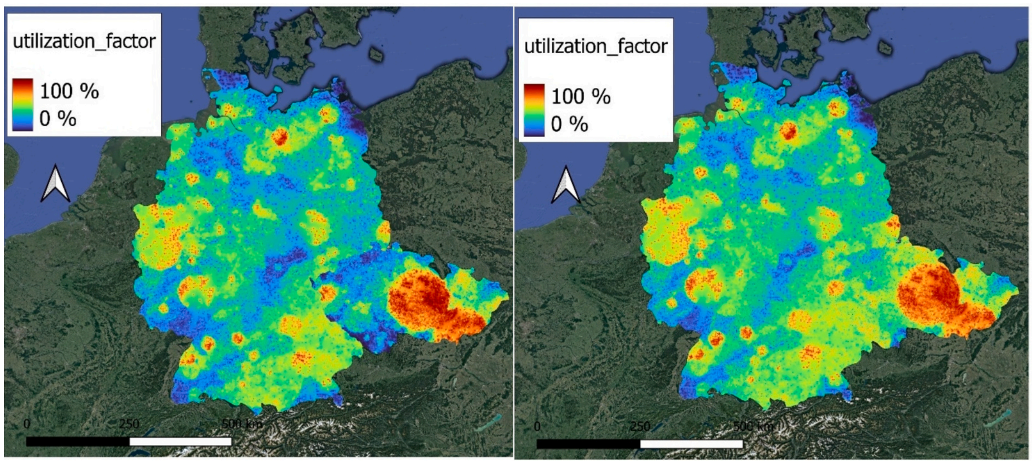

Fig. 4. Utilization Factor Map for Germany and Czech Republic. On the left side, the model was run at the country level. On the right side, the model was run without considering national borders. Fixed radius 100 km.

DE + CZ TOGETHER		
Variables	Fixed radius	Country borders radius
Wood grading TOT	85,929	85,929
Wood grading sawlogs SW	33,088	33,088
Wood grading sawlogs HW	5348	5348
Wood grading bioenergy	36,159	36,159
Wood grading pulpwood SW	11,334	11,334
EUFID sawlogs SW	40,304	40,304
EUFID sawlogs HW	1577	1577
EUFID bioenergy	6154	6154
EUFID pulpwood SW	12,240	12,240
Allocated sawlogs SW	29,041	33,088
Allocated sawlogs HW	1577	1577
Allocated bioenergy	6022	6154
Allocated pulpwood	7062	11,334

Where SW = softwood, and HW = Hardwood. Reported numbers are in 1000 m^3.

Appendix C. Annex

C.1. Data sources EUFID

Countries	Industry type	Type of data	Source
Austria	Sawmill	Country correspondent	Personal communication; https://www.timber-online.net/
Belgium	Sawmill	Country correspondent	Personal communications
Czech Republic	Sawmills	Country correspondent	Personal communication
Denmark	Sawmills	on-line data	sawmill.database.com
Estonia	Sawmills	on-line data	sawmill.database.com
EU	Bioenergy	Commercial dataset	https://www.fastmarkets.com/
EU	Pulp and Paper	Commercial dataset	https://www.fastmarkets.com/
Finland	Sawmills	Country correspondent	Personal communication
France	Sawmills	on-line data	https://www.fnbois.com/annuaire-des-adherents/
Germany	Sawmills	Country correspondent	Personal communication
Ireland	Sawmills	Country correspondent	Personal communication
Italy	Sawmills	on-line data	sawmill.database.com

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(continued)

Countries	Industry type	Type of data	Source
Latvia	Sawmills	Country correspondent	Personal communication
Lithuania	Sawmills	on-line data	sawmill.database.com
Netherlands	Sawmills	Country correspondent	Personal communication
Norway	Sawmills	Country correspondent	Personal communication
Poland	Sawmills	on-line data	panoramafirm.pl/tartaki
Slovakia	Sawmills	on-line data	sawmill.database.com
Spain	Sawmills	on-line data	sawmill.database.com
Sweden	Sawmills	on-line data	sawmill.database.com
Switzerland	Sawmills	on-line data	https://www.holz-bois-legno.ch
United Kingdom	Sawmills	on-line data	sawmill.database.com

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