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Assessment of possible leakage effects of implementing EU COM proposals for the EU Biodiversity Strategy on forestry and forests in non-EU countries

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List of abbreviations

BWI	Federal Forest Inventory
EFISCEN	European Forest Information SCENario Model
EU BioDiv Strategy	EU Biodiversity Strategy 2030
FRA	Global Forest Resources Assessment
FTE	Full-time equivalent
GFPM	Global Forest Products Model
ISIC	International Standard Industrial Classification of All Economic Activities
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
NACE	Statistical Classification of European Activities
NBS	National Biodiversity Strategy
NWE	Natural forest development
PCA	Principal Component Analysis
PPP	Purchasing Power Parity
SFM	Sustainable Forest Management
SSP	Shared Socioeconomic Pathways
UNCCD	United Nations Convention to Combat Desertification
WEHAM	Forest development and timber volume modeling
WGI	World Governance Indicators

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Summary

Overarching objective of the EU biodiversity strategy for 2030 is recovering biodiversity by strengthening the protection and restoration of nature. Key elements are the creation of protected areas on at least 30% of Europe's land and sea area, including stronger protective measures for forests. However, any implementation of dedicated measures will reduce roundwood production in EU member states. It is to be expected that parts of this reduced roundwood production will be compensated by increasing roundwood production in non-EU countries. There is a fundamental risk of biodiversity losses in non-EU countries accompanying such leakage of roundwood production. From a global perspective, such biodiversity losses must be opposed to biodiversity gains in EU countries. The presented study provides a first assessment of possible leakage effects and represents the state of work as of September 2020.

At first, the presented study provides an estimate of the decline in roundwood production in EU member states as a result of implementing partial or full production restrictions in forests. In a second step, implications of reduced roundwood production within EU-27 on global wood markets are assessed. Finally, leakage of roundwood production to non-EU countries is evaluated using indicators related to governance, sustainable forest management, biodiversity, forest condition, deforestation pressure and socio-economic aspects.

In order to estimate the reduction in roundwood production in EU countries firstly three single implementation measures are assessed and then consolidated for Germany: (i) 10 % share of forest area set-aside, (ii) non-utilization of "old-growth forests" and (iii) 30 % share of protected forest areas under Habitats Directive management requirements. As a result, the potential roundwood production in Germany declines on average within the period examined (2018 – 2052) by 23.96 million m³/a to 52.77 million m³/a or to 69 %. In the following calculations, this reduction share is assigned to all EU-27 countries.

Modelling international roundwood production leakage using the Global Forests Products Model GFPM projects an overall roundwood production decrease of 42 % in the EU-27 for the year 2050. Increased roundwood production in non-EU countries would compensate for 73 % of the decreased roundwood production in the EU. The remaining 27 % can be understood as price-induced reduction of wood products consumption. Until 2050 EU-27's decreased roundwood production would mainly be offset by increased production in the USA. According to the modelling results, 26 % of decreased roundwood production are leaked to the USA. Further leakage occurs to Russia (12 %), Canada (9 %) und Brazil (8 %). Differentiating non-consumption into soft- and hardwood, non-consumption of hardwood is more pronounced (39 %) than non-consumption of softwood (11 %). Consumption of fuelwood declines by 67 % but its production does not shift to non-EU countries. Basically, fuelwood is consumed to a much smaller share, due to increasing prices and the following assumed transition to other energy sources. Only small leakages are calculated for pulp and paper products. Leakages for sawn wood and wood-based panels show comparable relative changes to those modelled for roundwood production.

Implementation of the EU biodiversity strategy causes decreasing roundwood production in EU member states and increasing roundwood production in non-EU countries. The expected additional production would be shifted to countries that have a significantly higher proportion of intact forest areas compared to the EU, but already have lost significant amounts of these areas in recent years. The described leakage poses a threat to the remaining intact forest areas in non-EU-countries. Non-EU countries with a modelled roundwood production increase often show smaller biomass stocks and higher shares of already degraded area than EU-27 member states. Either this could indicate a further threat or a potential for promoting afforestation measures to buffer pressure on natural forests.

Further protection measures in the EU would further increase the discrepancy to protection measures of other countries. In non-EU countries, net deforestation is higher, significantly lower proportions of forest areas are placed under protection and less money is spent on the conservation of biodiversity than in EU countries. The average Red List Index indicates an increased threat of extinction of species for non-EU countries. Also, income disparities are higher in non-EU countries than in EU member states. For particularly poor countries, the shift of roundwood production could mean an opportunity to benefit from potential job creation, but on the other hand there is also the risk of displacement effects for often subsistence-based income groups.

Countries with high additional roundwood production and high vulnerability should be primarily focused on in the risk assessment. Immediate risks are further endangerment of already endangered species, reduction of intact forest area, increase of degraded land area and increased net deforestation. At a global scale it is expected that positive biodiversity effects in the EU due to additional protection are counteracted by negative effects in non-EU countries. Thus, European policy measures should focus particularly on these countries in order to buffer potential leakage effects by strengthening sustainable forest management and respective governance.

The presented report constitutes a pre-study on leakage effect of the EU biodiversity strategy. It uses information and data that is available at this point. However, for a more detailed analysis further data from EU member states and further development of the applied methods are necessary.

Key words: leakage, biodiversity, EU, forestry, forests

1 Background

In May 2020, the European Commission adopted the EU biodiversity strategy for 2030 with the overarching objective of recovering biodiversity by strengthening the protection and restoration of nature. Key elements are the creation of protected areas on at least 30 % of Europe's land and sea areas. The activities will include legally binding targets and stronger protection of European forests, restoration of damaged land and marine ecosystems, investment in biodiversity and global leadership by the EU (COM 2020). Against this background, this publication examines possible leakage effects on forestry and forests in non-EU countries that may arise from implementing European Commission (COM) proposals on the EU biodiversity strategy 2030 (EU BioDiv strategy). There is a fundamental risk of biodiversity loss in non-EU countries. From a global perspective such biodiversity losses must be compared/opposed to biodiversity gains in EU countries. This study provides a first assessment of possible leakage effects and represents the state of work as of September 2020.

Leakage can be understood as a subset of the broader term spillover. A spillover can be any form of collateral effect that takes place across ('over') established governance boundaries, be they geographical, temporal, jurisdictional, sectoral, or political (Liu et al. 2018; Meyfroidt et al. 2018). In contrast to the broad meaning of spillovers, however, leakage is usually understood in a narrower sense. It refers to a specific type of spillover in which an environmental policy indirectly triggers impacts that go against its aims, thus reducing the overall benefit of the intervention (Meyfroidt et al. 2018). This definition allows for the identification of three key elements that characterize leakage in its strictest sense (Bastos Lima et al. 2019):

- Impacts occur as a causal effect from an environmental policy intervention
- The variable affected is the one targeted by the intervention
- The leakage has a negative effect on the targeted variable

Significant examples are deforestation caused by measures to reduce deforestation or CO_2 emissions increased by climate adaptation strategies. In the environmental sector, spatial displacement effects often occur, i.e., the desired effect occurs in places not initially focused on by the original measure (Bastos Lima et al. 2019).

In the given context of the EU BioDiv strategy, the major objective is to protect biodiversity in the EU member states. The loss of biodiversity in non-EU countries caused by the implementation of the EU Biodiversity strategy qualifies as leakage in this case.

Leakage effects are primarily examined for the EU as a whole, individual EU member states are not considered separately. The present study has the character of a preliminary study. The quantitative and qualitative assessments are mainly based on the information available to the authors at short notice. In the following chapters underlying assumptions are explained. Related limitations or their effects on the results are discussed. Due to limited availability of data, the ecological assessment of identified leakage effects can only be carried out on a national level and not further regionally disaggregated. The period 2020 to 2050 has been defined as the projection period for this assessment. The decision for this somewhat longer period is based on the fact that forestry is based on long-term processes and that special tree species and age class composition of forests sometimes have a strong impact on target values such as logging volume or net yield. The choice of a particular year can therefore have a greater influence on the result. By choosing a longer observation period, the effects of specific single characteristics are not overestimated in the leakage assessment.

In detail, the following objectives of the EU BioDiv strategy (COM 2020, p.5) are the basis of the investigation:

- “Legally protect a minimum of 30 % of the EU's land area and 30 % of the EU’s sea area and integrate ecological corridors, as part of a true Trans-European Nature Network”
- “Strictly protect at least a third of the EU's protected areas, including all remaining EU primary and old-growth forests”
- “Effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring appropriately"

As further elaborated in the EU Biodiversity strategy, "as part of this focus on strict protection, it will be crucial to define, map, monitor and strictly protect all the EU’s remaining primary and old-growth forests". Footnote 24 of the Strategy further states that "strict protection does not necessarily mean the area is not accessible to humans, but leaves natural processes essentially undisturbed to respect the areas’ ecological requirements" (COM 2020, p.4).

Chapter 2 first provides an estimate of the decline in roundwood production in the EU. It is expected that an implementation of the EU BioDiv strategy will have an impact on the roundwood supply in the EU. In concrete terms, the effects on roundwood production of i.) the set-aside (i.e., no roundwood production) of 10 % of the forest area, ii.) the abandonment of roundwood use at all sites with "old-growth forest"[1] and iii.) the designation of protected areas following management requirements of the fauna flora habitat directive (i.e. the Habitat Directive) on 30 % of forest area are examined. Chapter 3 quantifies leakage effects from a market perspective. For this purpose, the effect of reduced roundwood production on global timber markets is examined. This is done using a global model of the forest products market, the Global Forest Products Model (GFPM). Global timber flows are calculated in two scenarios, the reference scenario without and the EU BioDiv scenario with implementation of the EU BioDiv strategy. The leakage effects in the individual countries are derived from the difference in roundwood production in the two scenario calculations. Chapter 4 provides the assessment of environmental leakage effects in non-EU countries using indicators. Possible issues to be covered are (i) governance, (ii) sustainable forest management, (iii) biodiversity, (iv) forest condition, (v) deforestation pressure and (vi) socio-economic aspects. Chapter 5 concludes with a discussion of the outcomes of the analysis. In the/an annex, additional information is provided.

1 Since there is no EU agreed definition of "old-growth forests", an age limit of over 120 years was proposed.

2 Estimation of the decrease in roundwood production in the EU

In order to assess the impact of an implementation of the EU BioDiv strategy on the roundwood supply in the EU, the effect of the following measures were investigated:

i. 10 % share of forest area set-aside,
ii. non-utilization of "old-growth forest" and
iii. 30 % share of protected forest areas with Habitats Directive (COM 1992) management requirements.

Comprehensive information on forest structure, future development of potential roundwood supply, and existing and future implementation of nature conservation measures in EU member states was not available on short notice. Thus, the reduction of EU's roundwood production as direct effect of implementing nature conservation measures on in forests was estimated in an impact assessment for Germany. The relative rates of change in domestic roundwood production in Germany were transferred to the other EU member states. Alternatively, the effects could only have been estimated by means of country-specific data from the EU-27 member states, which would have been very costly and time-consuming to collect and model.

Main data sources for the estimations of the development of roundwood production according to the current forest nature conservation level (reference), and after an implementation of described nature conservation measures for the EU Biodiversity strategy, were the results of the German Federal Forest Inventory (BWI) 2012 on the forest condition as well as the Forest Development and Timber Volume Modelling (WEHAM) in the baseline scenario 2012. The WEHAM baseline scenario 2012 was developed by the federal and state governments in cooperation with forest-based associations based on BWI 2012 data. It reflects the expected forest management and economic and legislative framework of forest management at that time (Rock et al. 2016).[2] [3]

In accordance with the modelling assumptions of the WEHAM baseline scenario 2012 forest areas specified as gaps or as temporarily unstocked were assumed to be constant over time. The resulting area of 10,627,513 ha accessible and stocked forest area was used as the reference area for further calculations (BWI 2012; Rock et al. 2016; Johann Heinrich von Thünen-Institut 2012).

The results of the BWI 2012 and the WEHAM baseline scenario 2012 were directly adopted as a reference for forest management according to the current forest nature conservation level. In a first step, individual scenarios were developed for three single nature conservation. In a second step, these were combined into an overall scenario for Germany, which formed the basis for the transfer of the German decrease in roundwood production to the EU-27. In detail, for each scenario a separate analysis was conducted for the affected areas on the basis of BWI 2012. Based on this,

[2] The current forest damage caused by extreme weather conditions since 2018 is not taken into account (see, e.g., Bundesministerium für Ernährung und Landwirtschaft (BMEL) 2/26/2020).

[3] For time reasons, an independent simulation of forest development and fellings with the Strugholtz-Englert model Rosenkranz and Seintsch 2015 was not conducted.

combined reduction percentages for the potential roundwood production of the WEHAM baseline scenario 2012 until 2052 were calculated.[4] These percentages of the overall scenario were applied on FAO data on roundwood production of EU-27 member states in order to estimate reductions of roundwood production in those countries.

Thus, in this chapter the first step of the analysis intends to roughly estimate the effects on the EU roundwood supply if the German implementation scenarios of nature conservation measures were to be transferred to the other EU member states with the same impact intensity. It should be stressed that this rough estimate is subject to uncertainties and limitations. However, there is no indication of a one-sided distortion of the extrapolation.

2.1 10 % forest area set-aside scenario for Germany

According to the German "National Strategy on Biological Diversity" (NBS), forests with "natural forest development" (NWE) should account for 5 % of Germany's forest area (or 10 % of public forests) by 2020 (BMUB 2007, p. 31).[5] Due to the lack of a harmonised definition, criteria for forests with natural forest development and of an opening balance sheet, the project "Natural Forest Development as an objective of the National Biodiversity Strategy (NWE5)" was carried out.[6] In addition to the permanent exclusion of direct forest operations or nature conservation measures, an essential criterion for declaring NWE areas was a permanent protection status through legally binding safeguarding measures like sovereign protection or contractual or material safeguarding (Engel et al. 2016, S. 46).

If this NWE criterion is applied to the BWI 2012 results, the BWI identifies 149,657 ha for nature conservation and 28,046 ha as protected forests. On these areas, forest utilization is not permitted or expected due to external conditions.[7] If it is assumed that these 177,703 ha of forest area are located, according to NWE criteria, exclusively on the accessible and stocked forest area of 10,627,513 ha (reference area), non-utilized forests amount to 1.67 % when referring to BWI cut-off date 01.10.2012. Accordingly, in order to achieve a share of 10 % of the German forest area, a further 885,048 ha or 8.33 % would have to be set aside from forest utilization. In the 10$ forest area set aside scenario for Germany (set-aside scenario) existing and additional NWE areas are equally distributed across all species groups and age groups. This balanced distribution across all

4 The last 5-year period of the projection of the WEHAM baseline scenario 2012 covers the years 2048 to 2052.

5 In close connection with the 5 % target for natural forest development, the NBS target of 2 % wilderness areas on the territory of Germany was also discussed (BMUB 2007, S. 28). Depending on the (undefined) minimum size for wilderness area, there are smaller or larger intersections with the NWE area backdrop.

6 see https://www.nw-fva.de/index.php?id=454 as well as ongoing follow-up project "Natural forest development in Germany - operational and systematic supplementation of the existing area scenery (NWeos)" under https://www.nw-fva.de/index.php?id=712

7 Related to the 10,887,990 ha of accessible forest area.

forest habitat types and forest development phases is considered appropriate for natural forest development from a nature conservation point of view. [8]

Based on this assumption, the potential roundwood volume of the WEHAM baseline scenario 2012 was generally reduced by 8.33 %. On average for the period 2018 to 2052, the potential roundwood volume is reduced by a total of 6.39 million m³/a, of which 2.29 million m³/a are hardwood and 4.09 million m³/a softwood.

2.2 Non-utilization of old-growth forests scenario for Germany

Although the EU Biodiversity strategy sets the protection of all remaining primary and primeval forests in the EU as an objective, there is no uniform EU definition for forests which are referred to as "old-growth forests" (Wirth 2009). Thus, in the scenario for non-utilization of old-growth forests in Germany (old-growth forests scenario) age classes ranging above the usual productive age of the respective tree species groups as classified by the BWI 2012, were defined as “old-growth forests”. The control parameters of the WEHAM baseline scenario 2012 were used as orientation for the determination of the usual production periods (Rock et al. 2016). The term "old-growth forest" was assigned to age classes of over 160 years for tree species group oak, over 140 years for tree species group beech, over 100 years for tree species group spruce and over 120 years for tree species group pine. According to these assumptions, 1,292,384 ha or 12 % of the reference forest area would have to be classified as "old-growth forest" and would no longer be available for roundwood production. This area consists of 463,506 ha of deciduous forests (or 10 % of the total deciduous tree area) and 828,878 ha of coniferous forests (or 14 % of the total coniferous tree area)

Since the WEHAM baseline scenario 2012 also includes evaluations of the potential roundwood volume of the tree species groups differentiated by age classes, the share of the age classes assigned to the "old-growth forest" in the roundwood supply could be determined. For the WEHAM period 2013 to 2018, this share amounts to 17.36 % for deciduous trees and 26.88 % for coniferous trees. If these proportions are transferred to the following WEHAM periods, the potential roundwood supply of the WEHAM baseline scenario 2012 is reduced on average for the period 2018 to 2052 by a total of 18.08 million m³/a, of which 4.79 million m³/a are hardwood and 13.28 million m³/a are softwood.[9] The comparison of the decrease in roundwood production in the old-growth forest scenario with the 10 % set-aside scenario shows that the protection of old stands creates particularly high opportunity costs for roundwood supply.

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8 If, for example, only old stands were to be placed against the "natural forest development (NWE)" area backdrop, natural forest development at later points in time would mean that large-scale forest development phases with a low nature conservation value could be expected, which would make an insufficient contribution to biodiversity protection.

9 Double counting of the areas in the 10 % set-aside scenario is not yet taken into account in this isolated consideration of the "old-growth forest" scenario.

2.3 30 % natural habitats scenario for Germany

A central goal of the EU Biodiversity strategy is to place at least 30 % of the EU's land area under legal protection (COM 2020). As stated by Polley (2009), 67 % of the German forest area is already subject to one or more protected area categories, with categories substantially overlapping each other. The German Natura 2000 area includes protected areas under the Habitats and the Birds Directives; it accounts for about 24 % of the total forest area (Polley 2009, p.76).

In 2019, in Germany 3,327,708 ha (9.3 % of terrestrial area) are classified as terrestrial natural habitat types according to Art 4 § 1 of the Habitats Directive (COM 1992, (92/42/EEC)). Together with protected areas under the Birds Directive (COM 2009, (2009/147/EC)) the Natura 2000 network of protected areas, which covers 15.5 % of the terrestrial area of Germany. EU-wide, the Natura 2000 areas account for approx. 18 % of the land area of all member states (BfN 2019).

Wippel et al. (2013) surveyed the implementation status of the Habitats Directive in forests in Germany and Rosenkranz et al. (2014) determined the natural and economic effects of measures according to the Habitats Directive on forest management by means of case study analyses. At that time about 1.8 million ha of forest were registered in these areas. Of these, 817,000 ha (or 46 %) had forest habitat types as objects of protection. The remaining forest areas were used for species protection or as filling and buffer zones. Of the forest habitat types, beech forests had the largest share with 585,967 ha, followed by oak forests with 100,276 ha. In order to maintain or restore a good conservation status of the forest habitat types, the following measures in particular were found to have an influence on the roundwood supply: i.) minimum area share of habitat-typical tree species (possible restriction of the selection of tree species), ii.) minimum area share of old timber stands (possible extension of the production period / deferment of use), iii.) preservation of old trees and biotope trees (non-utilization) as well as iv.) preservation of dead wood (non-utilization).

Based on this knowledge, Rosenkranz and Seintsch (2015) modelled the natural and economic effects of the management requirements under the Habitats Directive for nature conservation priority areas in German forests. As a result, 69 % of the natural forest habitat type area was assigned to the tree species group beech. The remaining area was assigned to tree species groups oak (21 %), spruce (6 %) and pine (5 %), respectively.

In the habitats scenario, these tree species group shares were applied to the 30 % of protected area targeted by the EU Biodiversity strategy. Since the forest habitat types are to be actively preserved or restored as objects of protection (forestry or nature conservation measures), the habitats scenario includes only forest areas that are not already covered by the set-aside or old-growth forests scenario and thus aim at process conservation. With regard to the overall scenario, the habitats scenario covers only age groups that were not already occupied by old-growth forests.

As management requirements in forest habitat types, the limited choice of tree species, selective renunciations of use for permanent habitat trees, the preservation of a defined dead wood stock as well as an increase in production times were modelled by Rosenkranz and Seintsch (2015). A 200-years spanning felling average in forests with nature conservation priority function of 6.3 $m^3/(ha*a)$ and in commercial forests with nature conservation minimum standard of

7.8 $m^3/(ha*a)$ was calculated (in the status quo). Based on these calculations, a decline of 19 % in the roundwood potential of the WEHAM baseline scenario 2012 for forest management according to the requirements by the Habitats Directive was assumed.

Based on these assumptions, the "30 % natural habitats scenario for Germany" (habitats scenario) projects a protected area with management requirements by the Habitats Directive of 3,188,254 ha (30 % of the total forest area), of which 2,859,482 ha are deciduous forests (60 % of the deciduous tree area) and 328,772 ha are coniferous forests (6 % of the coniferous tree area). Under the management conditions of the Habitats Directive, the potential roundwood volume in the WEHAM baseline scenario 2012 is reduced by an average of 0.99 million m^3/a for the period 2018 to 2052, of which 0.19 million m^3/a are hardwood and 0.80 million m^3/a softwood. This corresponds to a decrease in roundwood production of 0.31 $m^3/(ha*a)$ across all tree species groups. These results are comparable to those of Wippel et al. (2013) who described a 200-year average felling losses of 0.4 $m^3/(ha*a)$ (arithmetic mean) and 0.33 $m^3/(ha*a)$ (median) for beech habitat type. Rosenkranz and Seintsch (2015) calculated a long-term average decrease in felling due to management requirements of 1.5 $m^3/(ha*a)$.

2.4 EU biodiversity strategy overall scenario for Germany

The individual scenarios presented were combined in the "EU Biodiversity Strategy Overall Scenario for Germany" (German BioDiv scenario). This required adjustments of double counting of areas in the set-aside and old-growth forest scenario. This correction resulted in a total protected forest area of 5,414,151 ha in the German BioDiv scenario, of which 3,749,363 ha are stocked with deciduous trees and 1,664,788 ha are stocked with coniferous trees. Furthermore, 2,225,897 ha are completely set-aside from roundwood production (889,881 ha of the deciduous tree area and 1,336,015 ha of the coniferous tree area). On 3,188,254 ha (2,859,482 ha of the deciduous tree area and 328,772 ha of the coniferous tree area) roundwood production is determined by management requirements under the Habitats Directive. Due to the application of fixed percentages in the set-aside and habitats scenario, the overall scenario for forest areas without protection area requirements results in a negative area balance for the tree species group oak in the age classes 1 to 40 years and for the tree species group beech in the age classes 101 to 140 years. However, this is balanced in total by other age classes.

According to the scenario assumptions the implementation of the three nature conservation measures would reduce the volume of potential roundwood supply estimated by WEHAM baseline scenario 2012 by a total of 23.96 million m^3/a, of which 6.88 million m^3/a are hardwood and 17.07 million m^3/a softwood, on average for the period 2018 to 2052. The total volume of potential roundwood supply estimated by WEHAM baseline scenario 2012 of 76.73 million m^3/a would be reduced to 52.77 million m^3/a or to 69 % of the average WEHAM-based roundwood supply for the period 2018 to 2052.

2.5 EU biodiversity strategy overall scenario

The roundwood reduction described above was then applied to the historical roundwood supply of the individual EU member states. For this purpose, the FAOSTAT database on the domestic roundwood supply of the EU member states for the years 2015 to 2018 was used as data source. Data for the United Kingdom were excluded from the assessment due to its recent EU withdrawal (Brexit). Furthermore, for the modelling of global timber markets, the divided island of Cyprus is attributed to the Asian continent, so that data for Cyprus also were not considered in this analysis. Malta also is not part of the analysis, as cannot explicitly be modelled by the "Global Forest Products Model (GFPM)" (compare chapter 3). The FAO data were available in the following categories of roundwood: i.) Wood fuel, coniferous, ii) Wood fuel, non-coniferous, iii) Industrial roundwood, coniferous and iv.) Industrial roundwood, non-coniferous.[10] For the purpose of projection, the potential volume of roundwood supply for the other EU member states was aggregated and an average for 2015 to 2018 of total domestic roundwood supply was derived. On this multi-year average, the reduction factors for the years 2020 (69.1 % compared to the potential supply calculated by WEHAM), 2030 (68.8 %), 2040 (68.6 %) and 2050 (68.5 %) calculated in the previous section were applied and distributed to the individual assortments in the projection with the country-specific shares of the historical multi-year average.

Summarizing, in the EU BioDiv scenario, the multi-year average 2015 – 2018 of total roundwood supply of 473.40 million m^3, would be reduced by 149.18 million m^3/a to 324.22 million m^3/a in 2050. In 2050, the total roundwood supply would then be distributed as follows: 24.14 million m^3/a (7 %) wood fuel, coniferous, 56.50 million m^3/a (17 %) wood fuel, non-coniferous, 189.95 million m^3/a (59 %) industrial roundwood, coniferous and 53.62 million m^3/a (17 %) industrial roundwood, non-coniferous.

3 Quantification of leakage effects

Based on the results on reduced roundwood production from the implementation of the EU BioDiv strategy as calculated in Chapter 2, the following section shows possible impacts on the forest-based economy both in the EU and in non-EU countries. The implementation of the COM proposals may lead to shifts in global production and trade of roundwood and wood-based products. Thus, the protection of forests in one country could influence forest conservation and the use of forest resources in other countries, as the markets for wood and wood-based products are highly interlinked via international trade (Dieter and Englert 2007; Gan and McCarl 2007).

Therefore, the aim of the following analysis is the quantitative estimation of possible leakage effects and their impact on roundwood production outside the EU. The measurement of leakage effects by means of general equilibrium modelling (Gan and McCarl 2007) or partial timber market modeling is a proven methodological approach for this type of analysis (Kallio et al. 2006). With

[10] It should be noted that according to the international definition, industrial roundwood is all raw wood used for material purposes and not the German "Industrieholz".

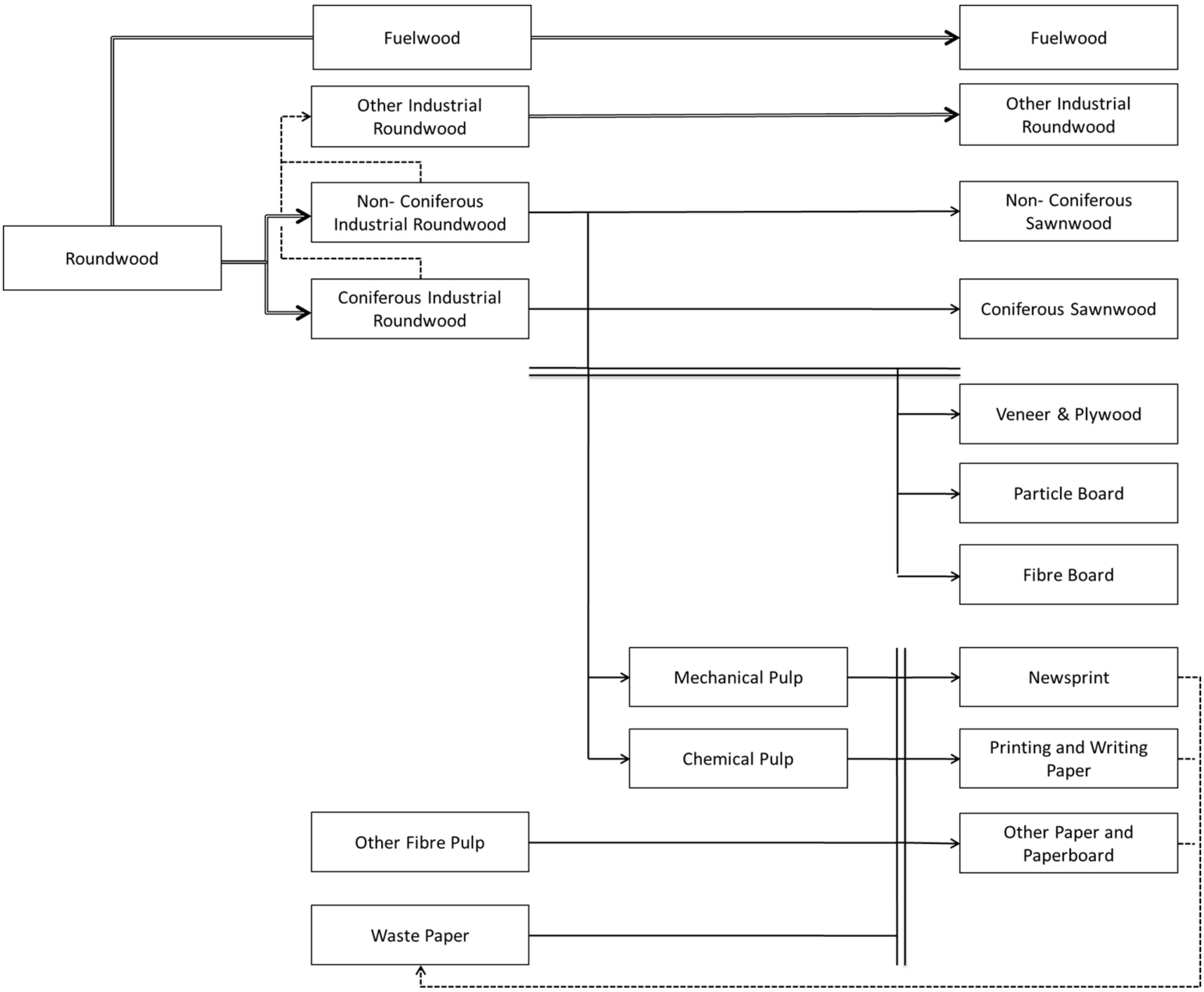
the help of dynamic mathematical simulation models, it is possible to simultaneously evaluate country and product-specific market developments over time which are otherwise difficult to grasp in their complexity. The Global Forest Products Model (GFPM, Buongiorno 2003) has proven itself to be such an instrument for policy impact or scenario assessment in the past (Buongiorno 2015; Nepal et al. 2012; van Kooten and Johnston 2014; Schier et al. 2018). The GFPM is a partial and dynamic equilibrium model that simulates production, consumption, and trade of wood and wood-based products of different processing steps in 180 countries. The model structure distinguishes between raw, intermediate and end products. By simulating different scenarios, the influence of different exogenous market impacts on the production and consumption of wood and wood products can be analyzed. The GFPM has also been widely used as a methodological approach to analyze the possible effects of trade barriers (Johnston and Buongiorno 2017; Turner et al. 2008), payments for the compensation of greenhouse gas emissions (Buongiorno and Zhu 2013; Johnston and Buongiorno 2017) or possible benefits and losses from international trade in the forest-based sector (Buongiorno et al. 2017).

3.1 Methods

To assess possible leakage effects of the implementation of the EU Biodiversity strategy, the GFPM was used to simulate two alternative scenarios. In the first scenario, the forest sector development is framed by general socio-economic parameters but a restriction on the production of roundwood as proposed by the EU Biodiversity strategy was not implemented in the simulation. This scenario serves as a reference scenario. The second scenario adopts the results calculated in Chapter 2. The restrictions on the availability and production of roundwood due to the implementation of the EU Biodiversity strategy, exogenously limits the production potential of roundwood in the EU 27 countries for the scenario simulation. The comparison of the two scenarios is then used to quantify possible leakage effects.

For the purpose of the present working paper, an extended version of GFPM is used. In this model version, industrial roundwood and sawnwood are differentiated into coniferous and non-coniferous industrial roundwood and sawnwood (Schier and Weimar 2018; Schier et al. 2018). This version of the GFPM thus simulates production and trade of 16 products (Figure 1).

Figure 1: Product structure in GFPM



Source: Schier et al. (2018)

This modification already has been successfully implemented, tested and applied in the course of the WEHAM Scenario project (Schier and Weimar 2018). The changes in the model structure and calibration allow for differentiation of coniferous and non-coniferous roundwood products. Furthermore, based on the modifications, wood-based materials and wood pulp can be produced from a mix of coniferous and non-coniferous roundwood. This provides a more differentiated representation of the wood market development in the scenarios.

The input data for the GFPM are obtained from three global databases: The forestry statistics of the Food and Agriculture Organization of the United Nations (FAO 2020a), the database of the Global Forest Resources Assessment 2010 (FRA, FAO 2010) and the database of the World Bank (World Bank 2020). The simulations of the reference scenario and the EU BioDiv scenario are based on the model and the settings created for the WEHAM Scenarios project. The base and start year of the simulations is 2012.

For the simulation in the modified GFPM model, behavioral parameters and control variables are adjusted as follows:

- The price and income elasticities of coniferous and non-coniferous sawnwood are taken from Morland et al. (2018)
- For Germany, the share of coniferous and non-coniferous industrial roundwood in raw material input mix is calculated based on the studies on the development of production capacities and wood use in the wood-based panel industry and the wood pulp industry (Döring et al. 2017a, 2017b).

One of the most important exogenous development parameters in the GFPM is the GDP (gross domestic product), as variable for economic income. As demand for wood-based products is positively correlated to income, an increase in income basically leads to an increase in demand. Demand, on the other hand, is part of equilibrium processes which balance product supply, demand and price formation for each simulation period. The assumptions about future GDP developments and population growth for the calculation of per capita income are based on the IPCC-A1 scenario (Nakicenovic et al. 2000)). This scenario describes a world of dynamic economic growth, efficient technology development and diminishing differences in the global distribution of per capita income. Further global exogenous model parameters were derived from the basic version of the GFPM (Buongiorno 2003), including the development of forest areas and forest stock (which was originally based on FAO 2010) and the development of technological change.

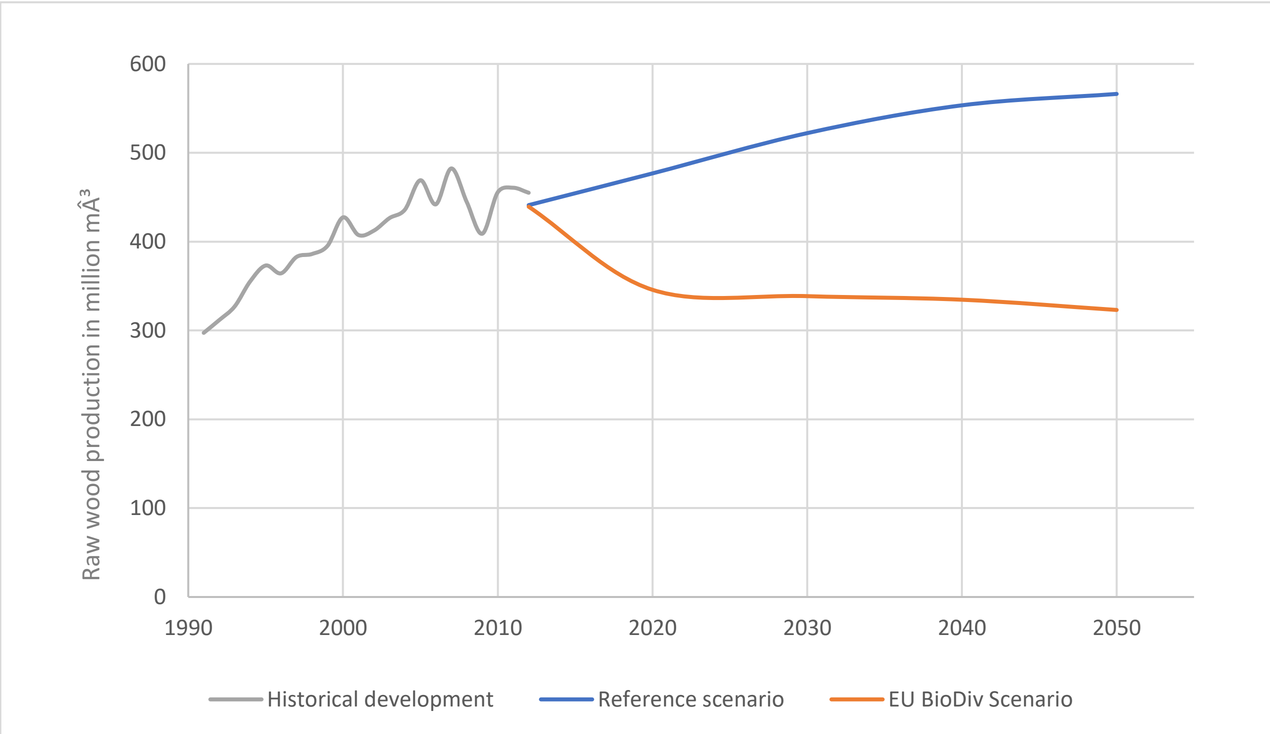
In the EU BioDiv scenario, the reduction in EU roundwood production as described in chapter 2 is implemented as maximum potential roundwood supply until 2020. As of the year 2020, the roundwood quantities available under the EU BioDiv scenario are set as exogenous maximal production potentials for the simulation until 2050. For the reference scenario, no specific restrictions regarding roundwood production are assumed for Germany or the EU.

In the following, the results from the two scenarios are compared and the differences in the roundwood production of individual countries are presented for the year 2050. Based on these results, it can be deduced where the production of roundwood can increase if the roundwood production in the EU 27 countries is limited, and thus leakage occurs. Leakage effects for further processed wood-based products are only shown to a limited extent.

3.2 Results of the wood products market modelling

In the base period, the roundwood production in the EU-27 in the BioDiv scenario is approximately 31 % lower than reported by FAOSTAT. In 2050, the wood products market modeling simulation for the reference scenario results in a projected total roundwood production of 576 million m³ for the EU-27 countries. In the EU BioDiv scenario, the amount of available roundwood volumes is held constant (see Chapter 2) and results in a total roundwood production of 332 million m³ for the EU-27 countries in 2050. Therefrom, 80 million m³ are used as fuelwood for energy production. Another 190 million m³ are used as coniferous industrial roundwood and 53 million m³ as non-coniferous industrial roundwood for material production. Thus, total annual roundwood production in the EU-27 in 2050 is 42 % (-244 million m³) lower in the EU BioDiv scenario than in the reference scenario. The lower roundwood production in the EU BioDiv scenario can be understood as a projected production deficit compared to the reference scenario in 2050. In addition, a few countries outside the EU also produce around three million cubic meter less roundwood compared to the reference scenario. Thus, in sum, the total production deficit in the EU BioDiv scenario accumulates to 247 million m³ globally. The comparison of the two scenarios also shows that 73 % (or 181 million m³) of this production deficit is compensated by increasing production volumes in non-EU countries. The remaining 66 million m³ are neither produced nor demanded and thus, potentially substituted by other, non-wood-based products. Figure 2 shows the effects from the limited roundwood production in the EU BioDiv scenario in comparison to the results of the reference scenario for the EU.

Figure 2: Simulation of roundwood production in the EU in the Reference Scenario and the EU BioDiv Scenario



Source: Own calculations

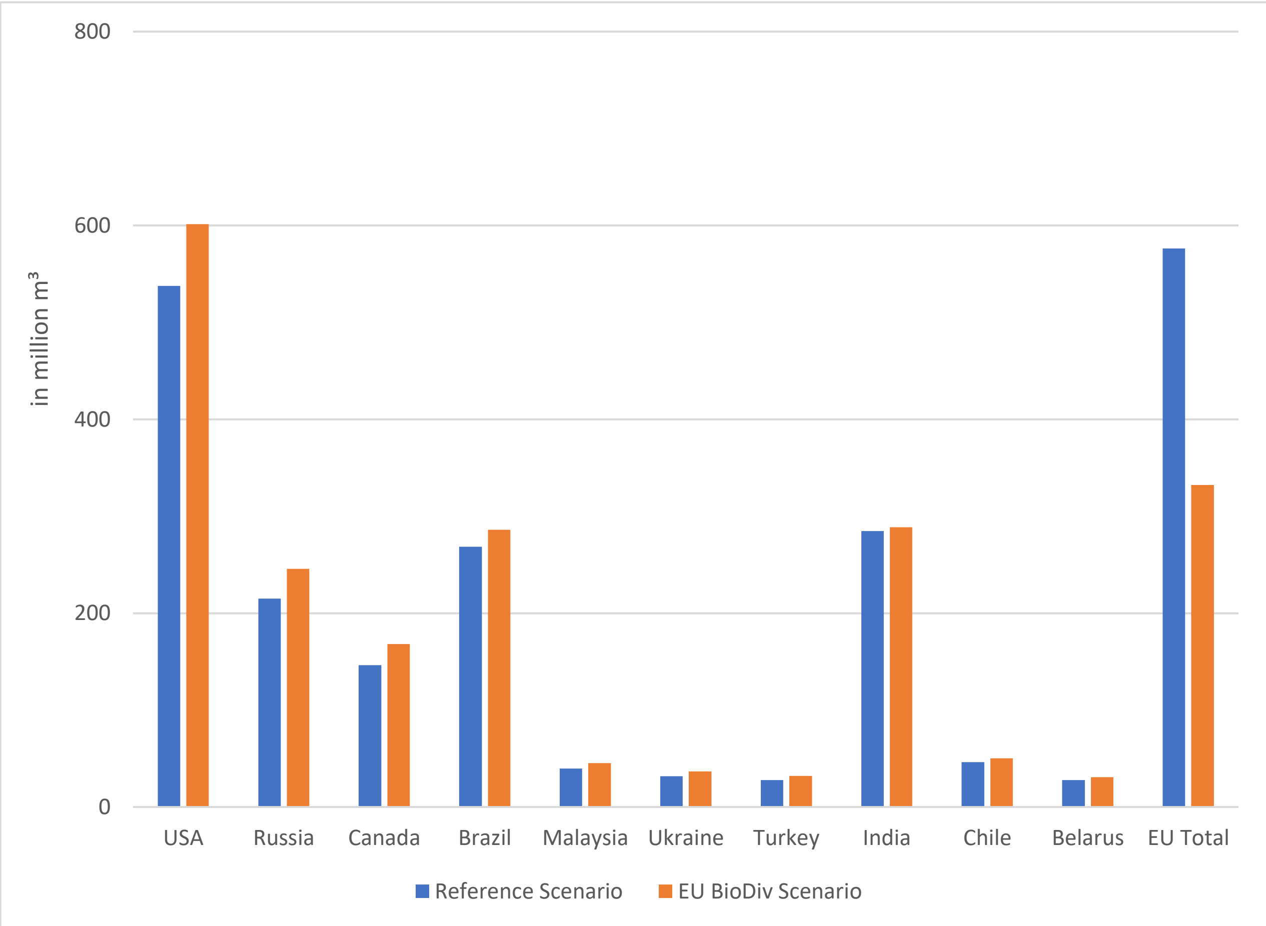
However, in 2050 the production deficit in the EU-27 is mainly offset by increased production of roundwood in the USA (where 26 % of the production deficit is shifted to), Russia (12 % of the production deficit), Canada (9 % of the production deficit) and Brazil (8 % of the production deficit). The results show that in terms of volume, a large part (61 % or 151 million m³) of the change in roundwood production takes place in non-EU countries of the northern hemisphere.

The production of coniferous roundwood for material use is shifting mainly to the USA (39 % of the reduced coniferous industrial roundwood production of the EU is shifting to this country), Russia

(16 %) and Canada (14 %), while the change in production of non-coniferous roundwood for material use is shifting mainly to Brazil (19 %), Russia (10 %) and Malaysia (8 %). However, it can be seen that in the segment of non-coniferous industrial roundwood, about 39 % of the production deficit is no longer consumed and may be substituted by products from other raw materials. This proportion is thus significantly higher than in the coniferous industrial roundwood segment (11 %).

The decline in the consumption of fuelwood has an even stronger impact. Here, about 67 % of the fuelwood that is no longer produced in the EU in comparison to the reference scenario is not compensated by shifting production of fuelwood to non-EU countries, but by a reduction of consumption. One reason for this effect could be that the price of fuelwood in the EU BioDiv scenario is 38 % higher than in the reference scenario. If the price of fuelwood is comparatively high, it may be possible that consumers will switch to other energy sources (Glasenapp et al. 2019).

Figure 3: Raw wood production of the countries with the greatest changes and the EU: Reference scenario (blue), EU BioDiv scenario (orange) in 2050

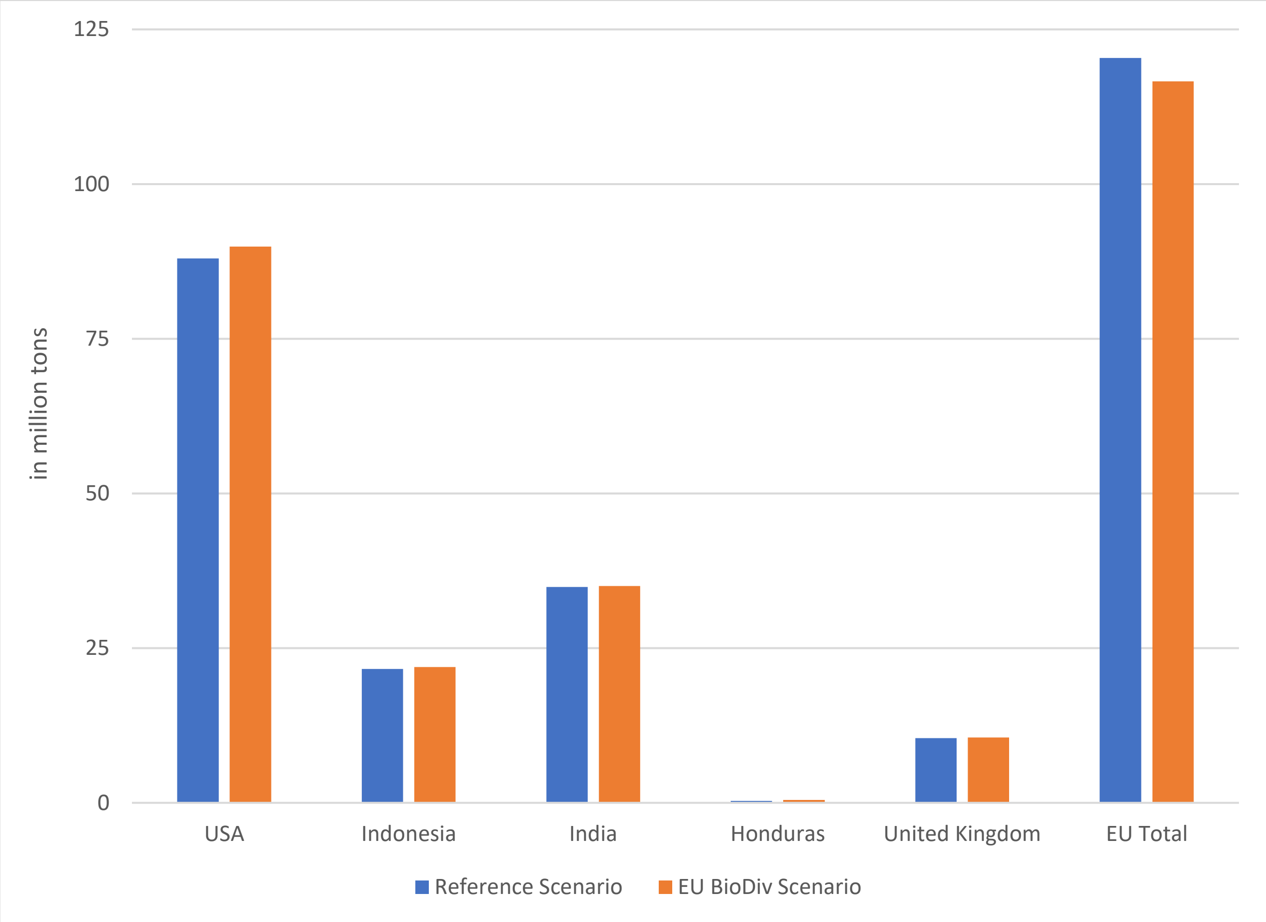


Source: Own calculations

When looking at processed wood-based products, it can be seen that the production of paper and paperboard is hardly influenced by a possible implementation of the EU biodiversity strategy. The production of the paper sector within the EU is only reduced by 3 % from 120 million tons to 117 million tons, while consumption only decreases by 1 % to 97 million tons. This is possible due to a decline in exports of paper products from the EU to non-EU countries. Globally, the production volume of the paper sector in the EU BioDiv scenario is 1 % below the reference scenario in 2050. However, shifts in the production volumes of other non-EU countries are becoming apparent. In addition to the EU countries, non-EU countries such as Russia (-21 %), Japan (-4 %), Canada (-16 %), Thailand (-4 %) and Brazil (-3 %) also produce fewer paper products under the EU BioDiv scenario. However, this decrease in production is compensated by other non-EU countries (see Figure 4), so that in sum, there are only minor leakage effects for paper products.

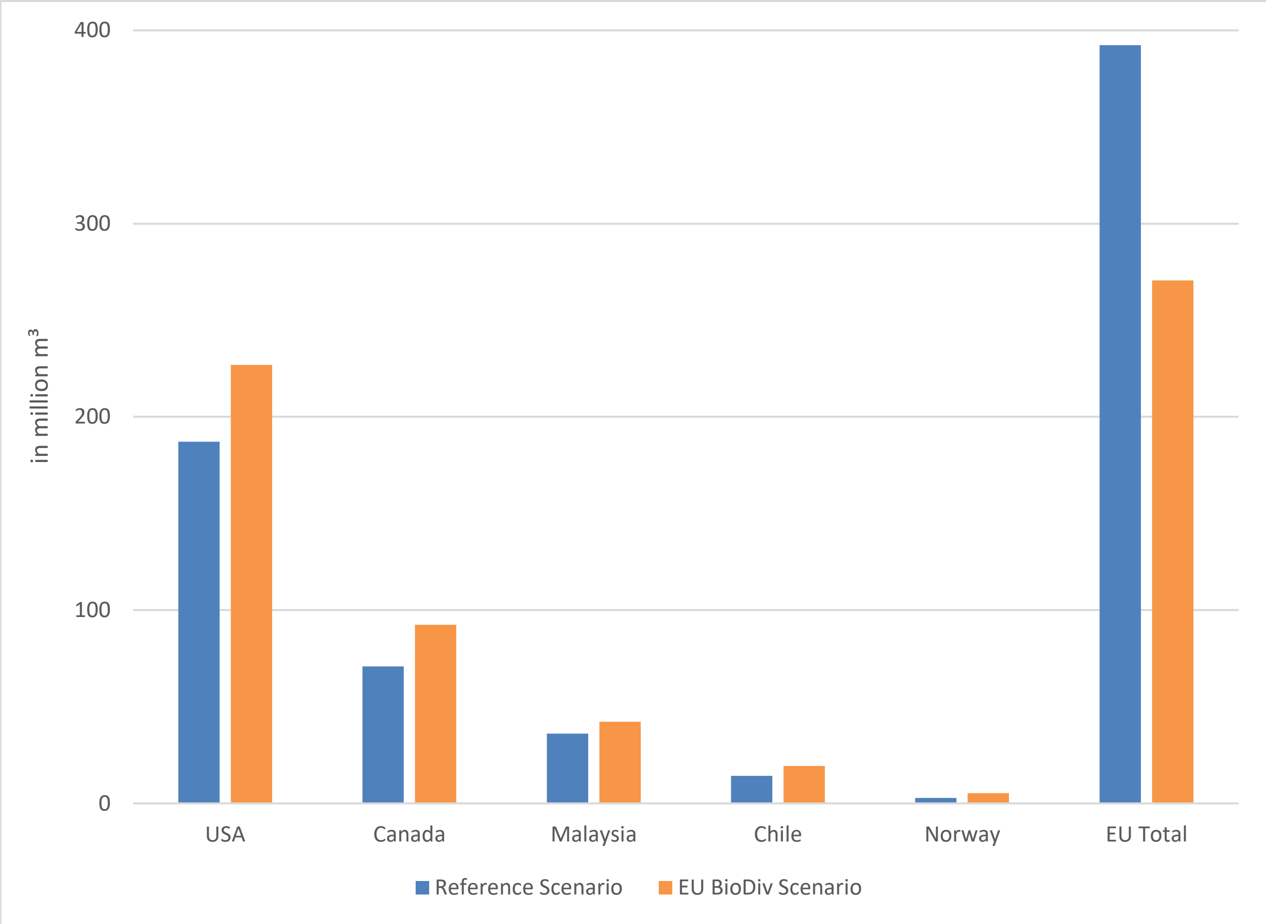
However, the situation is different for the production of sawnwood and wood-based panels. In the EU BioDiv scenario, EU production (270 million m^3) is 31 % lower than in the projected reference scenario (392 million m^3). At the same time, consumption of these two product groups decreases by only 4 % to 317 million m^3. This is mainly due to the sharp drop in exports, while imports increase. Globally, the production of sawnwood and wood-based panels is 8 % lower, which means that the discrepancy between a significantly reduced production with only slightly lower consumption of sawnwood and wood-based panels in the EU leads to a shift of production to non-EU countries. Figure 5 shows that this shift is mainly distributed to the USA (where 32 % of the production deficit is shifted), Canada (17 %) and Malaysia (5 %).

Figure 4: Paper and paperboard production in the countries with the greatest positive changes and the EU: Reference scenario (blue), EU BioDiv scenario (orange) in 2050



Source: Own calculations

Figure 5: Sawnwood and wood-based panels production in the countries with the greatest changes and the EU: Reference scenario (blue), EU BioDiv scenario (orange) in 2050



Source: Own calculations

4 Leakage effects in non-EU countries

4.1 Introduction

In Chapter 3 it was shown that reduced roundwood production in the EU leads to an increased roundwood production in non-EU countries. Increased roundwood harvesting in countries outside the EU poses the risk of ecological and socio-economic "leakage" to non-EU countries. This can have an impact on biological diversity in areas with globally important biodiversity hotspots. It is therefore necessary to assess the risks that may be associated with increased roundwood production in countries outside the EU. These risks can be compared with the corresponding conditions within the EU. In this context, risks are defined as negative impacts. Increased roundwood production in other countries may also involve opportunities. These are also described below.

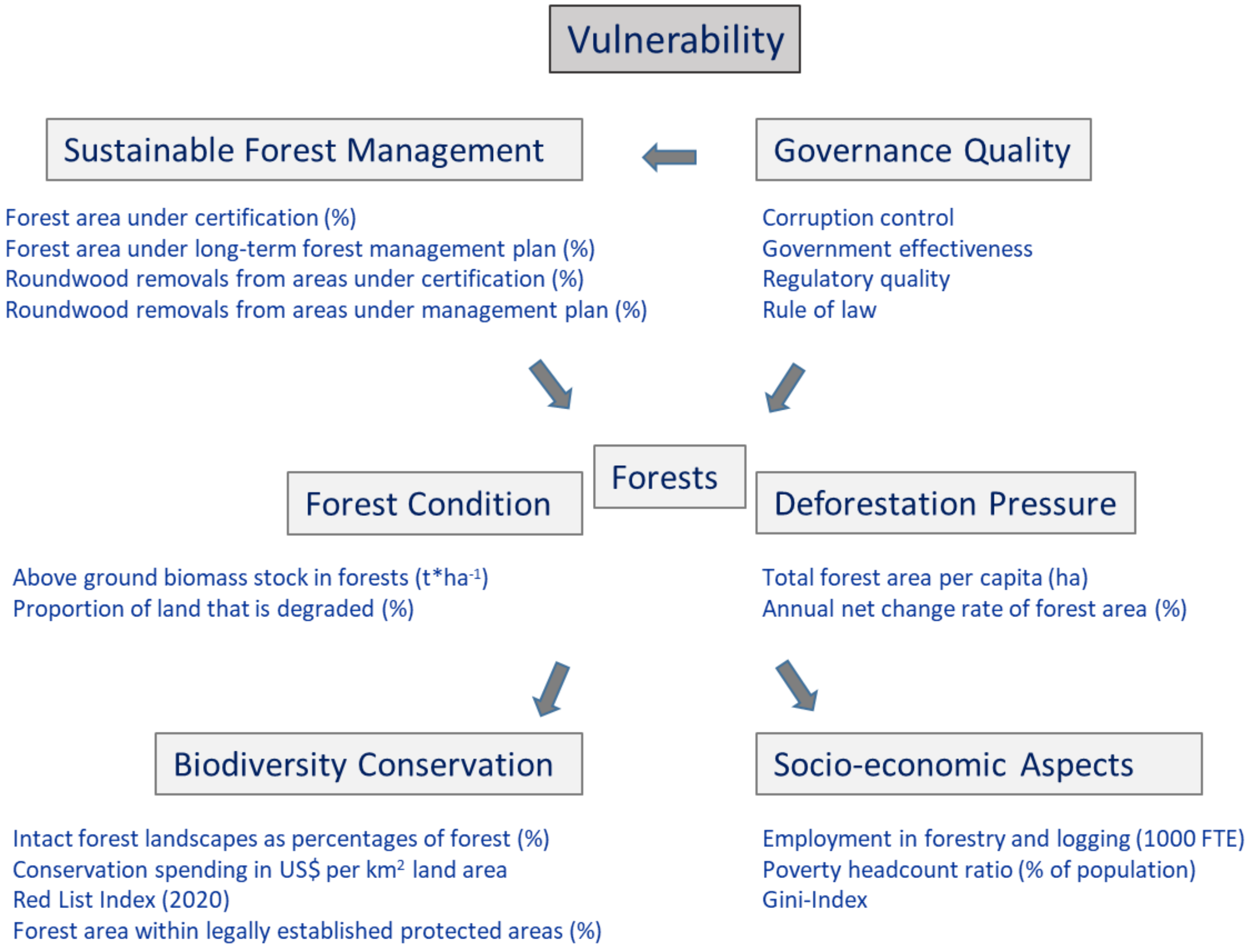
The aim of this chapter is to assess vulnerability in relation to biological diversity and socio-economy in those countries outside the EU where increased logging activities can be expected due to increased forest conservation within the EU.

4.2 Mechanisms of action

A risk assessment (R) per country must take into account both the potential hazard (G) as well as the vulnerability (V). The term "vulnerability" describes the conditions of an endangered society, in this case a leakage country, which also determines the impact of the potential hazard in terms of losses and disruptions (Birkmann 2011). Since risk is generally defined as the product of the probability of a hazard and its consequences, risk can be considered as a function of the hazard event and the vulnerability of the elements exposed to the hazard (Birkmann 2011).

The potential hazard of leakage effects is all the greater the more wood has to be produced in another country to compensate for lower wood production in the EU. It is therefore quantified by the additional felling volumes. Vulnerability can be illustrated by different indicators per country for different sectors (see Figure 6). Vulnerability is assessed using indicators on sustainable forest management (SFM), governance quality, forest condition and deforestation pressure, biodiversity and socio-economy. It is assumed that SFM and governance represent framework conditions that have an impact on forests, namely on forest condition on the one hand and on deforestation in some regions of the world on the other. Forest condition and forest area change have an impact on biodiversity and socio-economics. In order to make a final risk assessment (R), the values of individual or aggregated vulnerability indicators (V) are weighted with the additional volumes of produced roundwood in countries (G) outside the EU (R=V*G).

Figure 6: Illustration of the underlying mechanisms as a basis for the selection of relevant thematic areas (grey) and individual indicators (blue) to illustrate vulnerability



Source: Own presentation, description of the indicators, see Table 1 and Appendix.

4.3 Method

Figures on individual indicators are available primarily through the FAO's Forest Resources Assessment (FRA) and the UN's Sustainable Development Indicators (Table 1, Appendix). The indicators are presented for those 37 countries outside the EU, which compensate at least 0.1 % of the impact reduction within the EU through additional roundwood production (Annex 3). The indicators of these non-EU countries were compared with the mean values of the indicators for the 27 EU countries. The indicators were grouped into thematic areas. A detailed description and interpretation of the individual indicators is given in Annex 4.

Table 1: Individual indicators used

Governance quality	Source	Impact on governance	Use
Corruption control (2018)	(Kaufmann et al. 2010)	positive	aggregated (Gov.)
Government effectiveness (2018)	(Kaufmann et al. 2010)	positive	aggregated (Gov.)
Regulatory quality (2018)	(Kaufmann et al. 2010)	positive	aggregated (Gov.)
Rule of law (2018)	(Kaufmann et al. 2010)	positive	aggregated (Gov.)
Sustainable forest management (SFM)		**Effect on SFM**	
Proportion of forest area under certification (%)	(FAO 2020b)	positive	aggregated (SFM)
Proportion of forest area under a long-term forest management plan (%)	(FAO 2020b)	positive	aggregated (SFM)
Share of total roundwood removals coming from areas under certification (%)	(FAO 2020b)	positive	aggregated (SFM)
Share of total roundwood removals coming from areas under a long-term management plan (%)	(FAO 2020b)	positive	aggregated (SFM)
Forest condition		**Effect on forest condition**	
Above ground biomass stock in forest ($t*ha^{-1}$) (2016)	(FAO 2020b)	positive	single indicator
Proportion of land that is degraded over total land area (%)	(United Nations Statistics Division 2020)	negative	single indicator
Deforestation pressure		**Effect on deforestation pressure**	
Total forest area per capita (ha)	(FAO 2020b; United Nations Statistics Division 2020)	negative	single indicator
Annual net change rate in forest area (%) (2015-2020)	(FAO 2020b)	negative	single indicator
Biodiversity conservation		**Effect on biodiversity**	
Intact forest landscapes as percentage of forest (%)	(World Resources Institute 2020; Potapov et al. 2017)	positive	single indicator
Red List Index (2020)	(United Nations Statistics Division 2020)	positive	single indicator
Conservation spending in US$ per km^2 land area	(Waldron et al. 2013)	positive	aggregated (conservation measures)
Proportion of forest area within legally established protected areas (%)	(FAO 2020b)	positive	aggregated (conservation measures)
Socio-economic aspects		**Impact on socio-economics**	
Employment in forestry and logging (1000 FTE) 2015	(FAO 2020a)	positive	single indicator
Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population) latest available year	(World Bank 2020)	negative	aggregated (poverty and inequality)
Gini index (World Bank estimate) last available year (mainly 2016/17)	(World Bank 2020)	negative	aggregated (poverty and inequality)

Source: own compilation

The original data of the individual indicators are recorded on different scales. In order to make them comparable, the individual indicators were standardized by means of so-called z-score transformation. The mean value for all EU and non-EU countries for the respective indicator was subtracted from the individual values. Thus the mean value for each individual indicator was initially set to zero. Then, the difference between the respective individual value and the mean value was divided by the standard deviation. This results in a standard deviation of 1 for each individual indicator.

To calculate a standardized value x* for an output value x, the following applies:

$x^* = (x-m)/sd$

with

m - average value of the indicator

sd - standard deviation

A standardized value of 1 means that the original value exceeds the mean value by the amount of the standard deviation. A value of -1 means that the original value is below the mean value by the amount of the standard deviation. A value of 0 means that the original value of a country is equal to the mean value of all countries. The standardized values do not lie in a specific interval and can theoretically assume any value. All individual indicators were first standardized in order to compare them with each other and to be able to aggregate them in principal component analyses (PCA). PCA is used to check which indicators of a thematic area show a similar direction of impact and therefore indicate an underlying common cause. Related indicators can then be aggregated into a common underlying component.

Principal component analyses calculate factors based on linear combinations for multiple variables, minimizing the variance of these individual variables. Such analyses were conducted for all thematic areas. However, for only four areas there was a meaningful underlying component, i.e., in these thematic areas there were indicators that could be aggregated. In the following, these components are called aggregated indicators. For thematic areas, in which no aggregated component could be identified, non-transformed single indicators were used. Also, within the thematic areas those individual indicators which could not be aggregated on a component were used separately. Principal component analysis resulted in aggregated indicators for the following four thematic areas: (i) governance quality, (ii) SFM, (iii) conservation of biodiversity, and (iv) socio-economic aspects (see Table 1). For the first three of the aggregated indicators, higher values indicate an improvement, while for the aggregated indicator “poverty and inequality,” higher values indicate a deterioration of the socio-economic situation.

The differences of the indicator mean values between the EU countries and the countries with expected leakage effects were tested for significance using t-tests (Stata Statistical Software 2019). A significance level of 0.1 was used for the tests.

4.4 Results

4.4.1 Statistical comparison of the mean values

The mean values of the aggregated indicators and the individual indicators were compared for the 37 non-EU countries and the 27 EU countries. Vulnerability was assessed using the unweighted averages (Table 2, Columns (1) and (2)). For a risk assessment, these averages were weighted with the additional roundwood production in non-EU countries and with the reduced roundwood production in EU countries (Columns (3) and (4)), because the vulnerability of countries with more additional logging must be given more weight in a risk assessment. Significance tests are statistically only possible for the unweighted mean values (Table 2, Columns (1)-(2)).

The comparisons show clear and significant differences in vulnerability between the EU and non-EU countries across almost all indicators. The EU countries show higher mean indicator values for SFM, governance, Red List Index and conservation measures in all cases. Biomass stock and the proportion of forests in intact forest landscapes is higher in the 37 non-EU countries. However, if the countries are weighted by the roundwood production, the EU countries have higher biomass stock, i.e., wood production would increase on average in countries with lower biomass stock. The non-EU countries also have a significantly higher share of degraded land area. The non-EU countries are characterized by significantly more forest area per capita, which could indicate lower deforestation pressure (Ferrer Velasco et al. 2020). However, the mean value comparison shows a significantly higher increase in forest cover in the EU countries. The deforestation pressure is therefore lower in the EU, even though less forest is available per capita. The comparison of the socio-economic aspects shows that the reduction of roundwood production within the EU would increase roundwood production especially in countries with more people employed in the forest sector and in countries with poorer populations and higher imbalances in the distribution of income and wealth.

Table 2: Comparison of vulnerability and risk for aggregated and individual indicators between EU countries and 37 non-EU countries with expected increased roundwood production

	Vulnerability indicators			Basis risk assessment	
Indicators	**Mean value EU-27**	**Average 37 non-EU countries**	**t-test for mean value comparison**	**Weighted average EU-27**	**Weighted average 37 non-EU countries**
	(1)	(2)	(1)-(2)	(3)	(4)
Governance					
Governance quality, aggregated	1.15	-0.84	1.99***	1.50	0.30
Sustainable forest management (SFM)					
Sustainable forest management, aggregated	0.64	-0.47	1.11***	1.20	-0.17
Forest condition					
Above ground biomass stock in forest (t/ha)	128.6	143.6	-14.9ns	145.46	111.97
Proportion of land that is degraded over total land area (%)	6.5	19.9	-13.3***	9.23	17.75
Deforestation pressure					
Total forest area per head (ha)	0.67	1.66	-0.99**	0.81	2.87
Annual net rate of change in forest area (%)	0.30	-0.02	0.32*	0.12	0.04
Biodiversity conservation					
Intact forest landscapes as percentage of forest (%)	0.25	13.87	-13.6***	0	21
Red List Index (2020)	0.94	0.84	0.1***	0.95	0.87
Conservation measures, aggregated	0.28	-0.22	0.50**	0.02	-0.53
Socio-economic aspects					
Employment in forestry and logging (1000 FTE)	18.4	271.2	-252.8ns	30.9	225.9
Poverty and inequality, aggregated	-0.66	0.48	-1.13***	-0.67	0.23

Source: Own calculations

*, **, *** p values for error probabilities of 0.1, 0.05, 0.01, ^{ns} not significant. Weighted average: average values weighted according to the share of the respective country in the total wood production shifted out of the EU (for the 37 leakage countries), or weighted according to the share in the logging reduction (for EU countries).

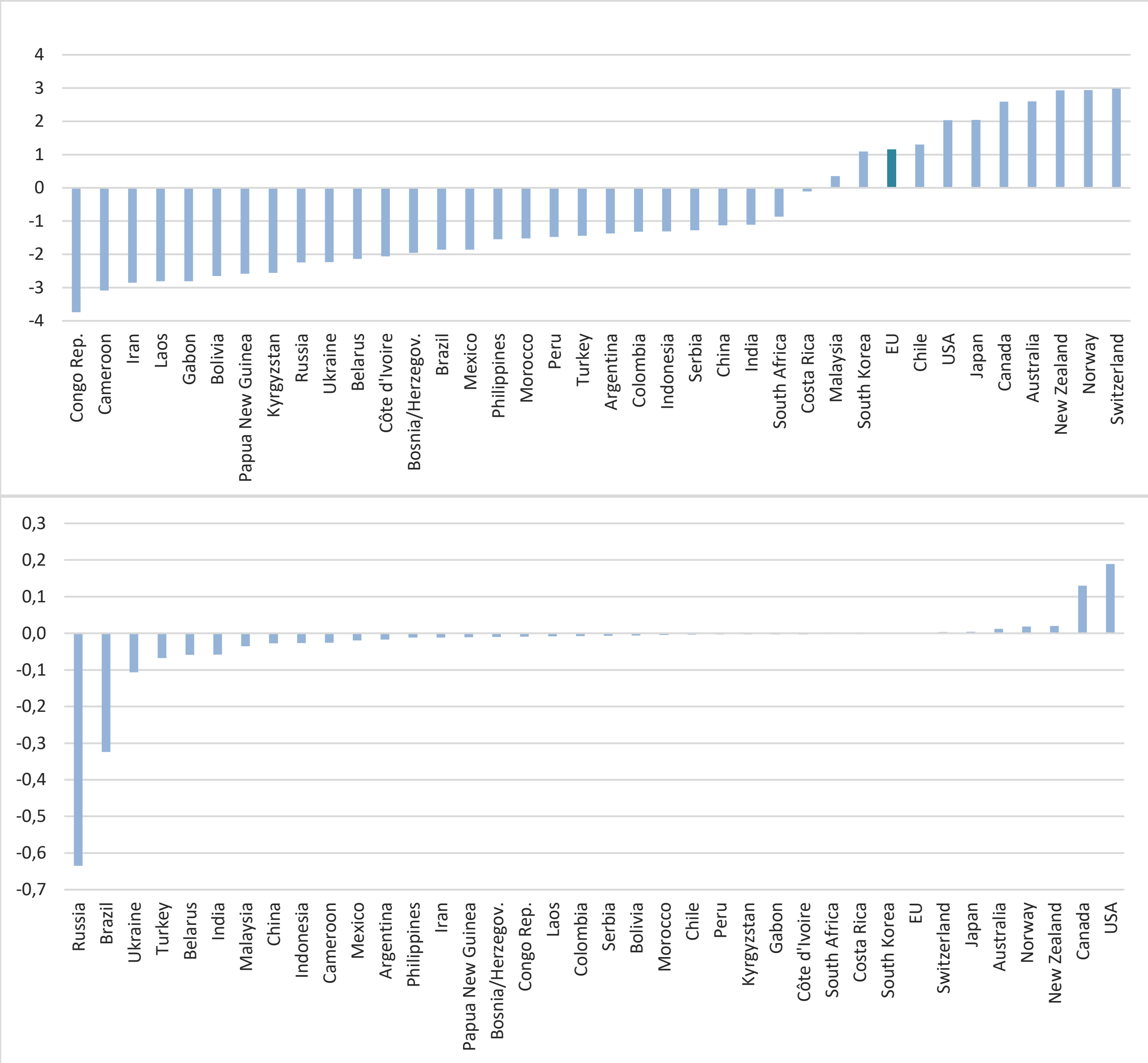
4.4.2 Individual indicators

Figures 7 to 17 show the values of the vulnerability indicators for the 37 non-EU countries compared to the average value of the same indicator for the EU countries. For each indicator, the risk assessment is also shown in a separate chart. For this purpose, the indicator mean value of the EU for each country is subtracted from the individual country value and the result is weighted with the additional roundwood production quantities. For countries with a lower indicator value than the EU, there is a risk that the additional roundwood production will have negative impacts on forest condition, biodiversity and socio-economic development. The extent of the risk depends on the amount of additional logging. The additional logging does not necessarily have to be associated with risks (negative effects). For example, increased roundwood production can also have positive socio-economic effects. Chapter 0 contains an interpretation of the risk assessments.

4.4.2.1 Governance quality

The governance vulnerability indicator (Figure 7, top) is lower for most non-EU countries than for the EU. The USA and Canada are the two countries with a higher governance score compared to the EU and comparatively high additional roundwood production. For these two countries, the risk that low governance has negative impacts on SFM, biodiversity and socio-economy is low. This risk is highest in Russia, Brazil and Ukraine (Figure 7, bottom).

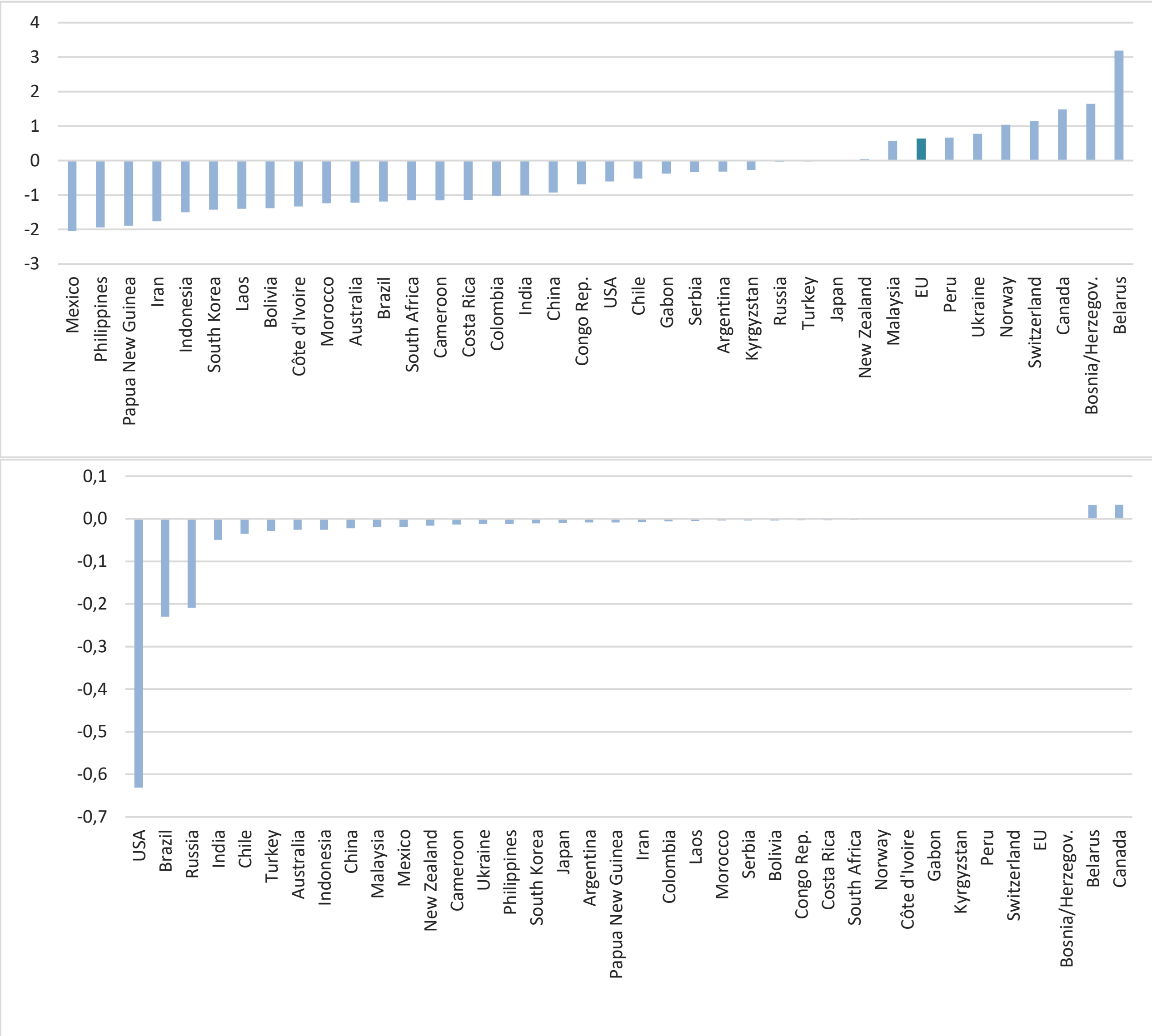
Figure 7: Country wise vulnerability indicator values for governance compared to the mean for EU countries (top) and resulting risks (bottom)



Source: Own calculations. The values for the aggregated governance indicator are derived from principal component analysis. They cannot be interpreted in the units of the original indicators and are only used for comparison between countries. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes

4.4.2.2 Sustainable forest management

Figure 8: Country wise vulnerability indicator values for SFM compared to the mean value for EU countries (top) and resulting risks (bottom)

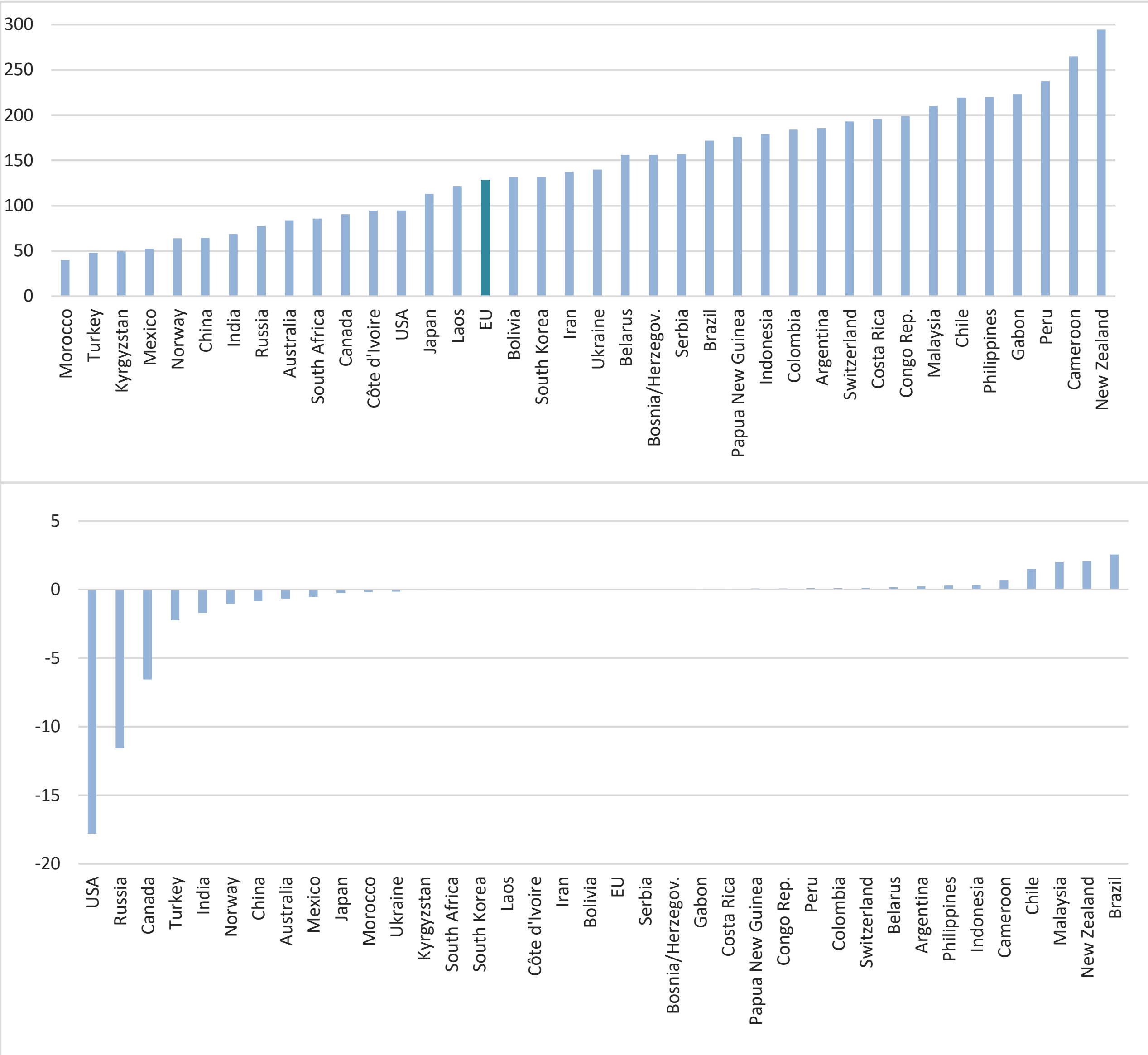


Source: Own calculations. The values for the aggregated SFM indicator are derived from principal component analysis. They cannot be interpreted in the units of the original indicators and are only used for comparison between countries. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes.

The aggregated indicator for SFM (Figure 8, top) is lower in most non-EU countries than in the EU. Sustainability is measured by the existence of management plans and forest certification. The indicator does not necessarily indicate the quality of the management plans. If the vulnerability indicators are weighted with the roundwood production, the relatively high proportion of expected additional roundwood production in the USA, Brazil and Russia means that there is a comparatively high risk that the additional roundwood volumes will be provided by uncertified forests and to a lesser extent from forests managed on the basis of long-term management plans as compared to the EU.

4.4.2.3 Forest condition

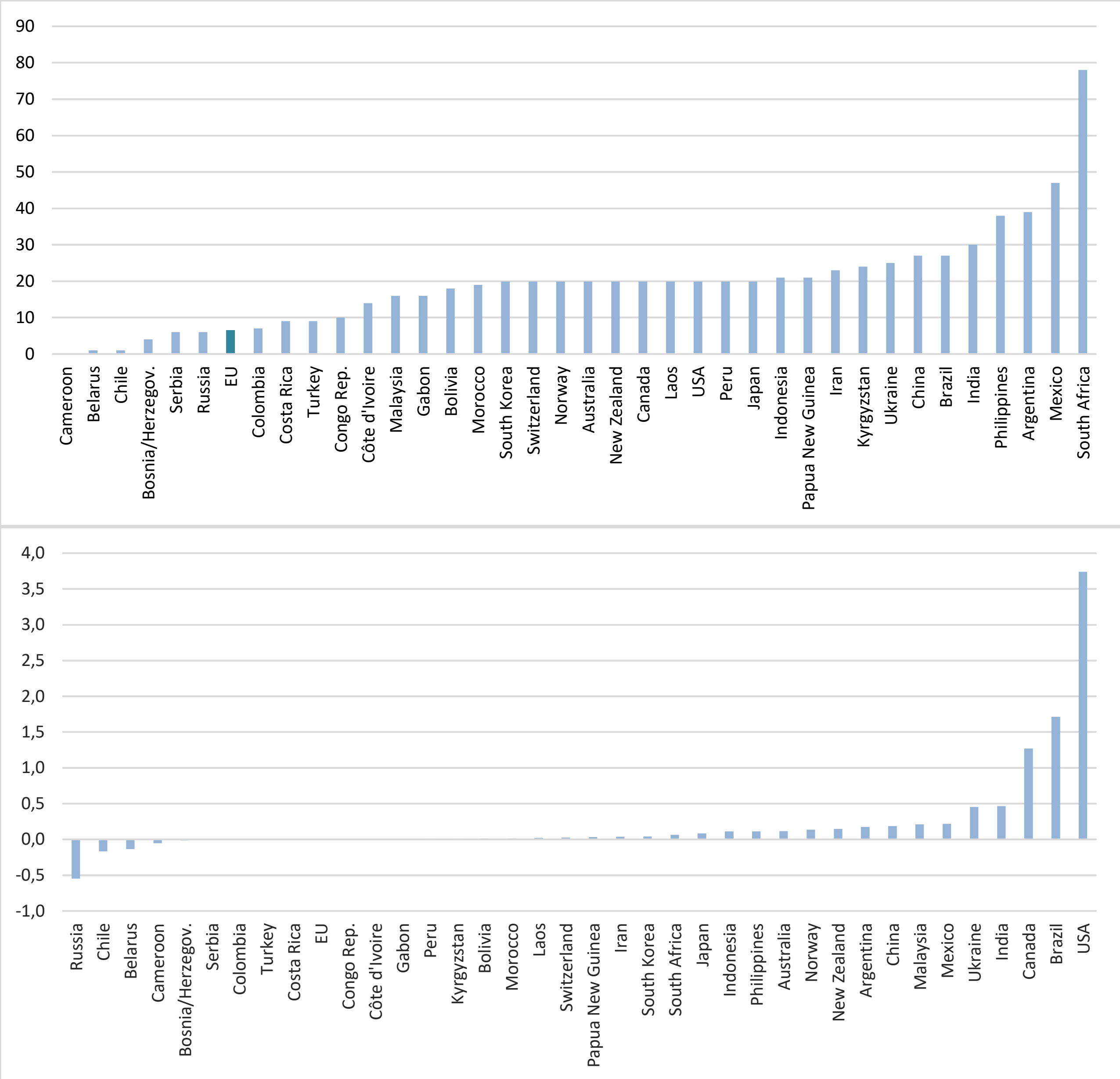
Figure 9: Country wise biomass stocks in t*ha^{-1} compared to the mean value for EU countries (top) and resulting risks (bottom)



Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

The vast majority of the countries compared show higher above-ground biomass stocks per hectare than the EU (Figure 9, top). Biomass stocks depend, on the one hand, on the predominant natural forest types. They are naturally lower in boreal forests of the north than in the tropics. On the other hand, they are influenced by forest management. Most countries with higher biomass stocks would only supply very small additional quantities of roundwood, whereas the forests of most potential main suppliers have lower stocks. The risk of further decreasing biomass stocks through increased roundwood production is highest in the United States, Russia and Canada (Figure 9, bottom).

Figure 10: Country wise proportions of degraded land area in % compared to the average for the EU countries (top) and resulting risks (bottom)



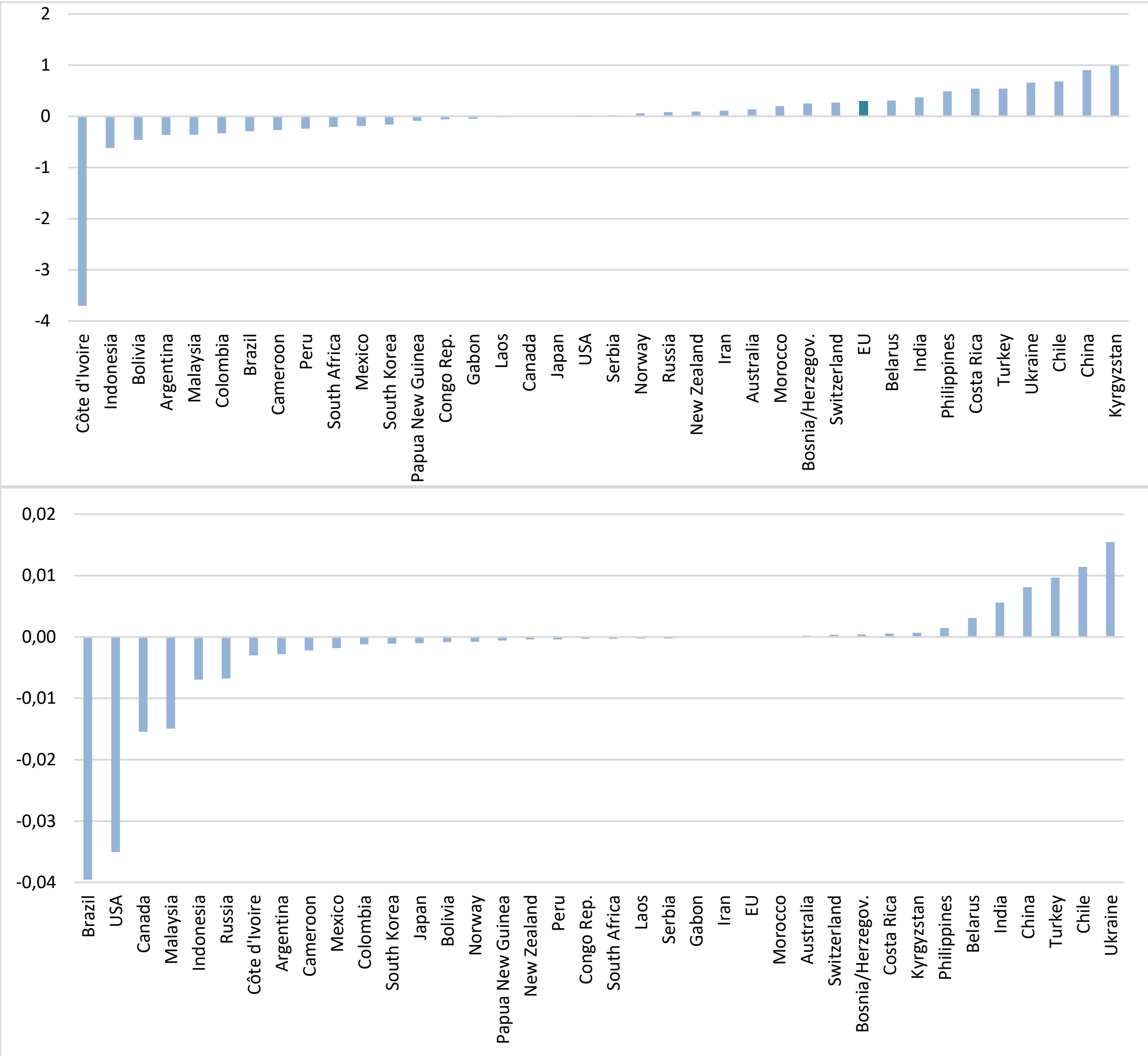
Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

Most of the countries with expected higher roundwood production show a significantly higher proportion of degraded land (Figure 10, top). The percentages refer to the respective total country area and not only to forests. Degradation can result from unsustainable land use and overuse. (Figure 10, bottom). Since the majority of the additional logging occurs in the USA, Canada and

Russia, the risk of this additional roundwood production coming from degraded land may also be higher than in the EU.

4.4.2.4 Deforestation pressure

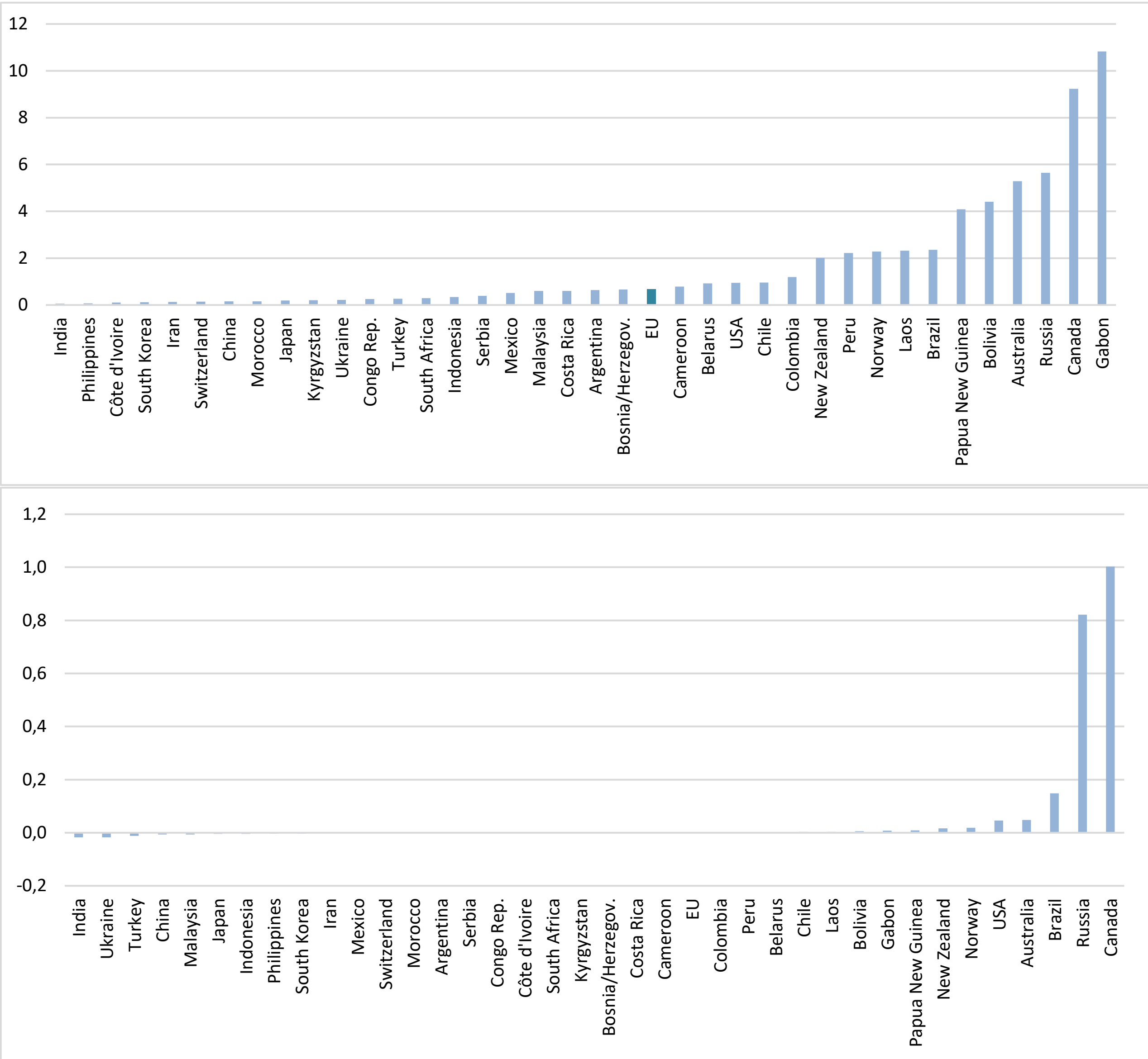
Figure 11: Country wise deforestation rates in % compared to the average for EU countries (top) and resulting risks (bottom)



Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

Half of the non-EU countries show net deforestation, while the other half of the non-EU countries and the EU show an average increase in forest cover (Figure 11, top). Statistically, the non-EU countries show on average a higher deforestation rate than the EU (Table 2). The risk of contributing to deforestation through additional logging is highest for Brazil, the USA and Canada. For other countries, such as Turkey, Chile and Ukraine, there are no calculated risks but rather opportunities, since the forest area in these countries is currently increasing (Figure 11, bottom). Due to the higher additional roundwood production in countries with net deforestation, the risk of contributing to deforestation is high. This would not be compensated by the additional felling from countries with increasing forest area, such as Ukraine, Chile or Turkey.

Figure 12: Country wise forest areas per inhabitant in ha per capita compared to the mean value for the EU countries (top) and resulting risks (bottom)

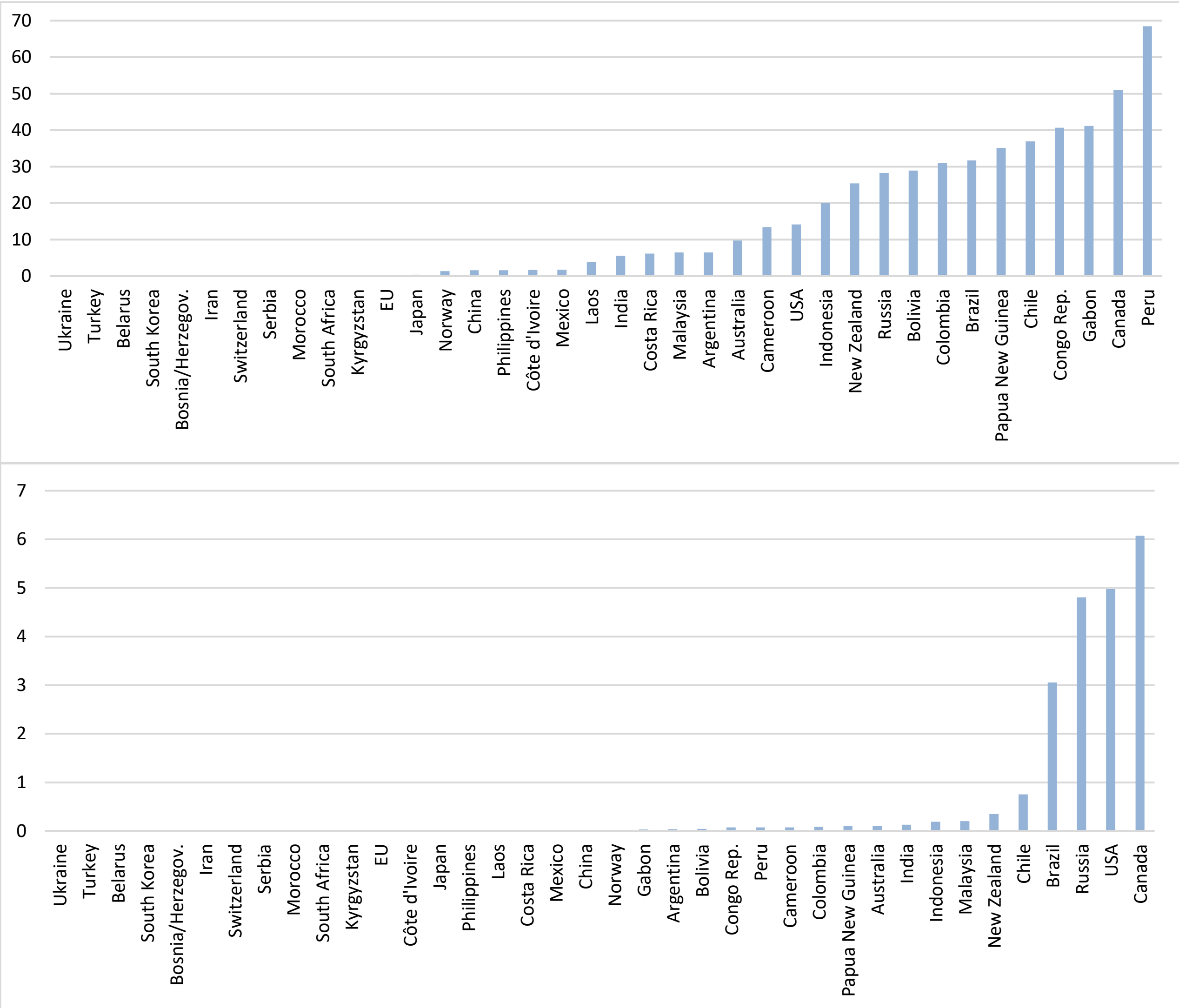


Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

Almost half of the non-EU countries have more forest area per capita than the EU (Figure 12, top). The indicator provides an indication of population pressure, but provides no information on the extent to which the population actually uses the forest. Accordingly, the forest area is decreasing in countries like Brazil and not increasing as in the EU (Figure 11, top), although Brazil has much more forest per capita (Figure 12, top). The total forest area per capita is lowest in India, the Philippines and Côte d'Ivoire with less than 0.11 hectares per capita. Since potential main suppliers such as the USA, Brazil, Russia and Canada have more forest per capita than the EU, there is no risk for these countries based on the pure consideration of this indicator (Figure 12, bottom).

4.4.2.5 Biodiversity conservation

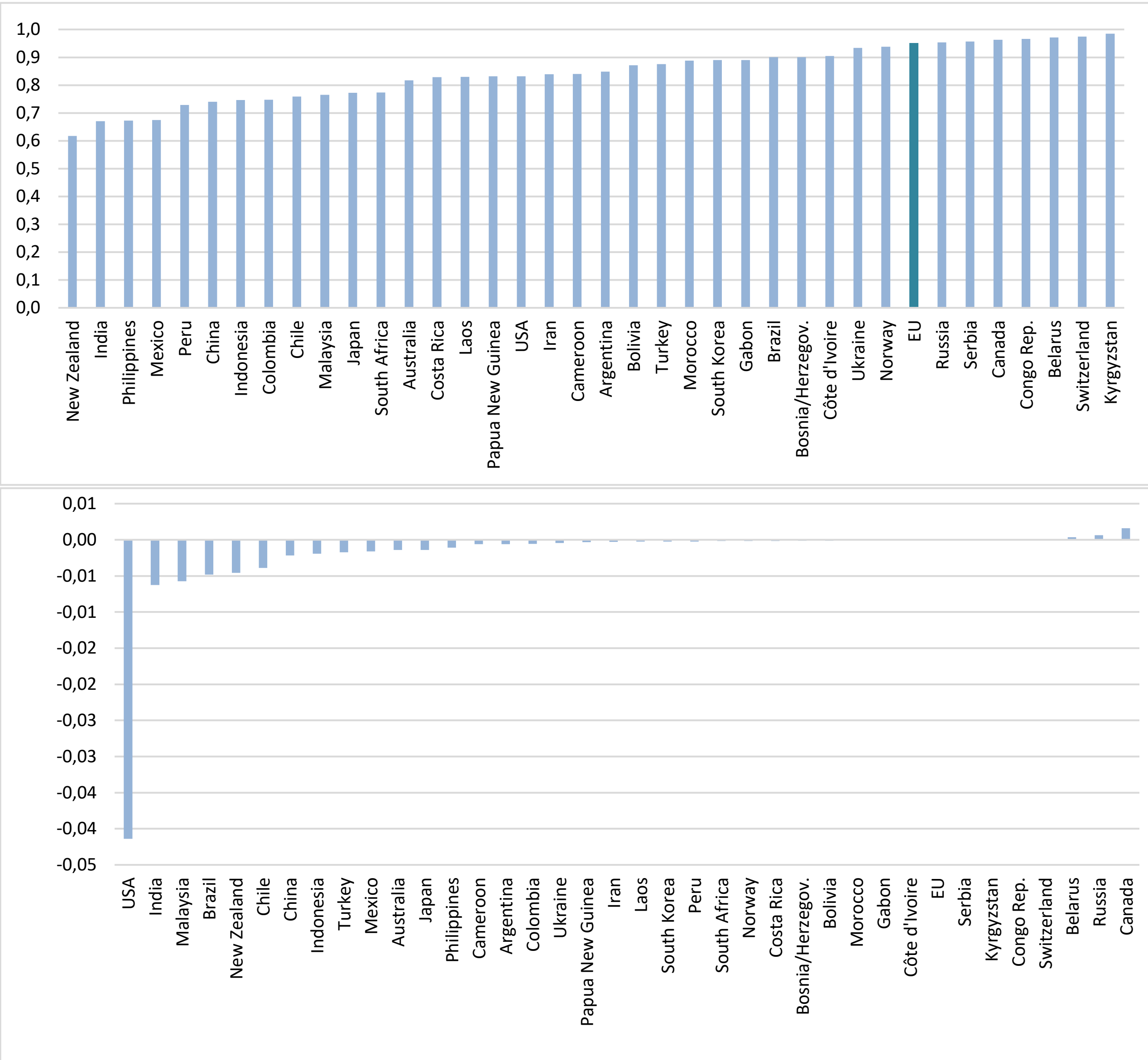
Figure 13: Country wise shares of intact forest landscapes in % as a proportion of forest compared to the mean value for the EU countries (top) and resulting risks (bottom).



Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

A total of 25 out of the 37 non-EU countries still have intact forest landscapes. (Figure 13, top). Intact forest landscapes are defined as seamlessly connected forests of at least 500 km^2 with natural biodiversity (Potapov et al. 2017). On average, 14 % of the forests in the 37 non-EU countries are still located in intact forest landscapes. The 25 non-EU countries with intact forest landscapes lost on average 11 % of these forest areas in the years 2000 – 2013 (not depicted). In the EU in 2000, only Finland, Sweden and Romania had comparatively small intact forest landscapes. In 2013, these areas had already disappeared in Romania. Since the additional logging would take place mainly in Canada, the USA, Russia and Brazil, where intact forest areas still exist, the risk of reducing the proportion of intact forest areas is higher than in the EU. It would therefore be necessary to ensure that this does not happen (Figure 13, bottom).

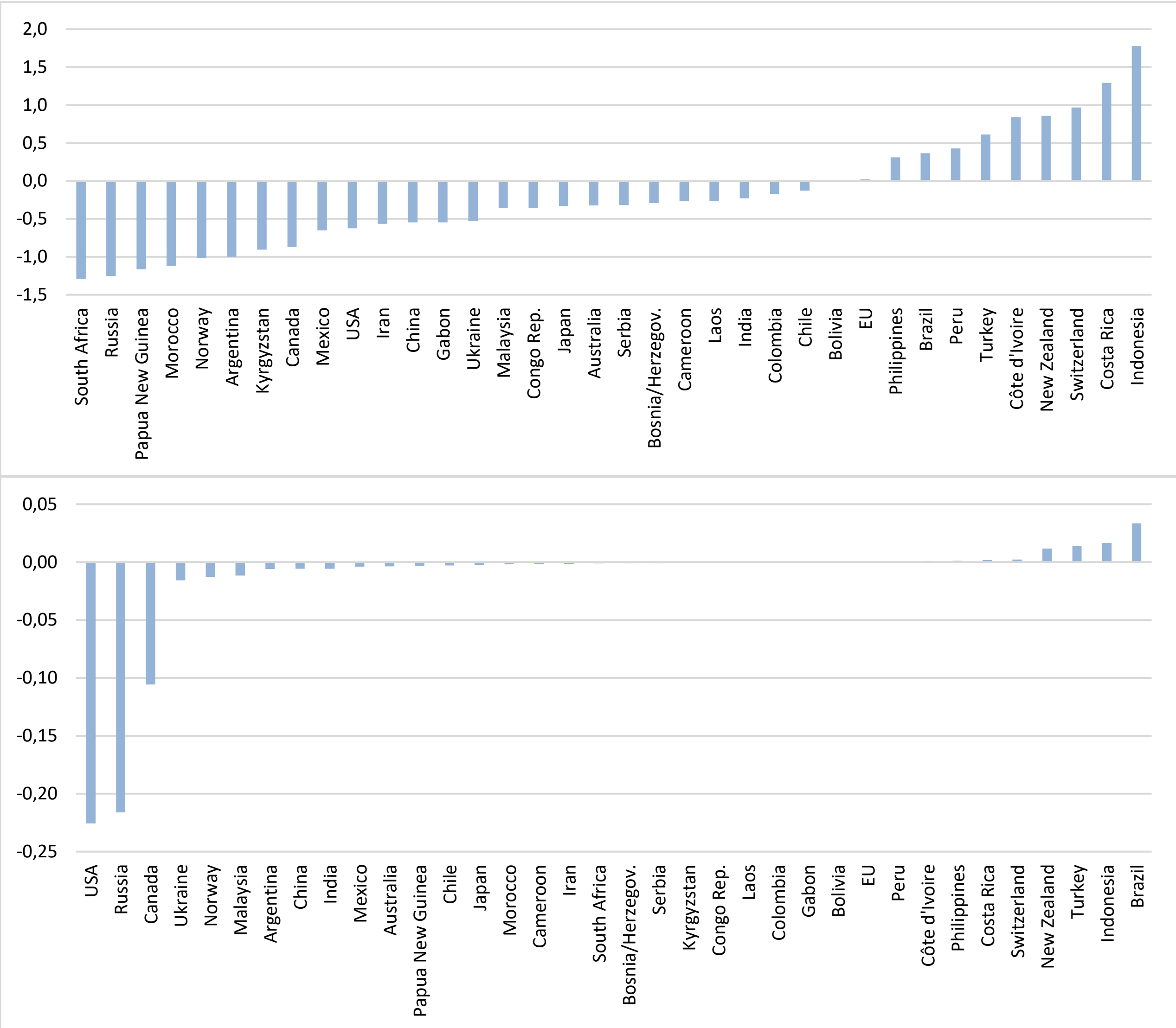
Figure 14: Country wise Red List Index compared to the mean value for the EU countries (top) and resulting risks (bottom)



Source: Own calculations. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator and are only used for comparison between countries.

The Red List Index shows the threat of extinction of species. Based on the Red Lists, the risk of extinction as an aggregated value is calculated for different species groups. A theoretical value of 1 means that there is no risk of extinction. This risk is higher in 30 of the 37 non-EU countries than in the EU (Figure 14, top). Since a large proportion of the increased roundwood production would take place in the US, where the risk of extinction is higher than in the EU, it would need to be ensured that the increased roundwood production does not increase the risk of extinction (Figure 14, bottom). When interpreting the data, however, it must be kept in mind that the underlying data quality is estimated to be lower in many tropical countries (Collen et al. 2008). The risk could therefore be underestimated, especially for tropical countries with relatively high additional logging, such as Brazil and Malaysia.

Figure 15: Country wise protective measures compared to the mean value for the EU countries (top) and resulting risks (bottom)

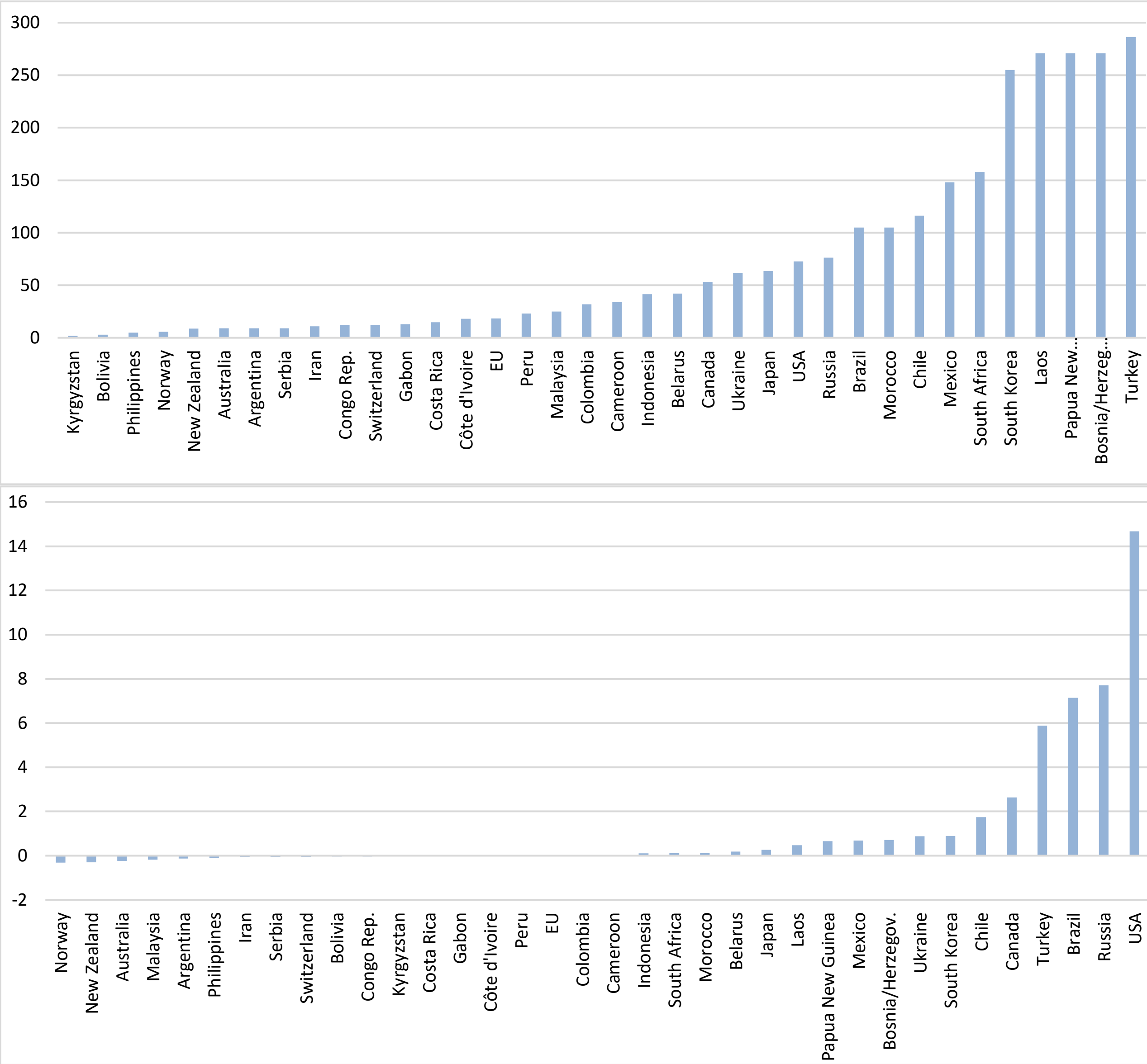


Source: Own calculations. The values for the aggregated protective measures indicator are derived from the principal component analysis. They cannot be interpreted in the units of the original indicators and are only used for comparison between countries. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes.

The aggregated indicator for conservation measures contains information on the proportion of forest areas in protected areas and on the expenditures of the countries for the conservation of biodiversity. For most non-EU countries, the indicator value is below that of the EU (Figure 15, top). While the EU countries spend on average USD 1,750 per km^2 on biodiversity conservation and 22 % of forest areas have protected area status, non-EU countries spend on average USD 290 and have protected 19 % of forest areas (not depicted). Of the countries with comparatively high additional roundwood production, Brazil and Indonesia have higher values than the EU. Brazil has reported 30 % and Indonesia 54 % of the forest area as protected to the FAO. However, spending on biodiversity conservation is lower in both countries than in the EU. If the indicator values are weighted with the additional roundwood production, the overall risks clearly outweigh potential benefits, because countries with the highest additional felling volumes - the USA, Russia and Canada - have both protected significantly lower proportions of forest areas and at the same time spend less money per km^2 of land area on biodiversity conservation (Figure 15, bottom).

4.4.2.6 Socio-economic aspects

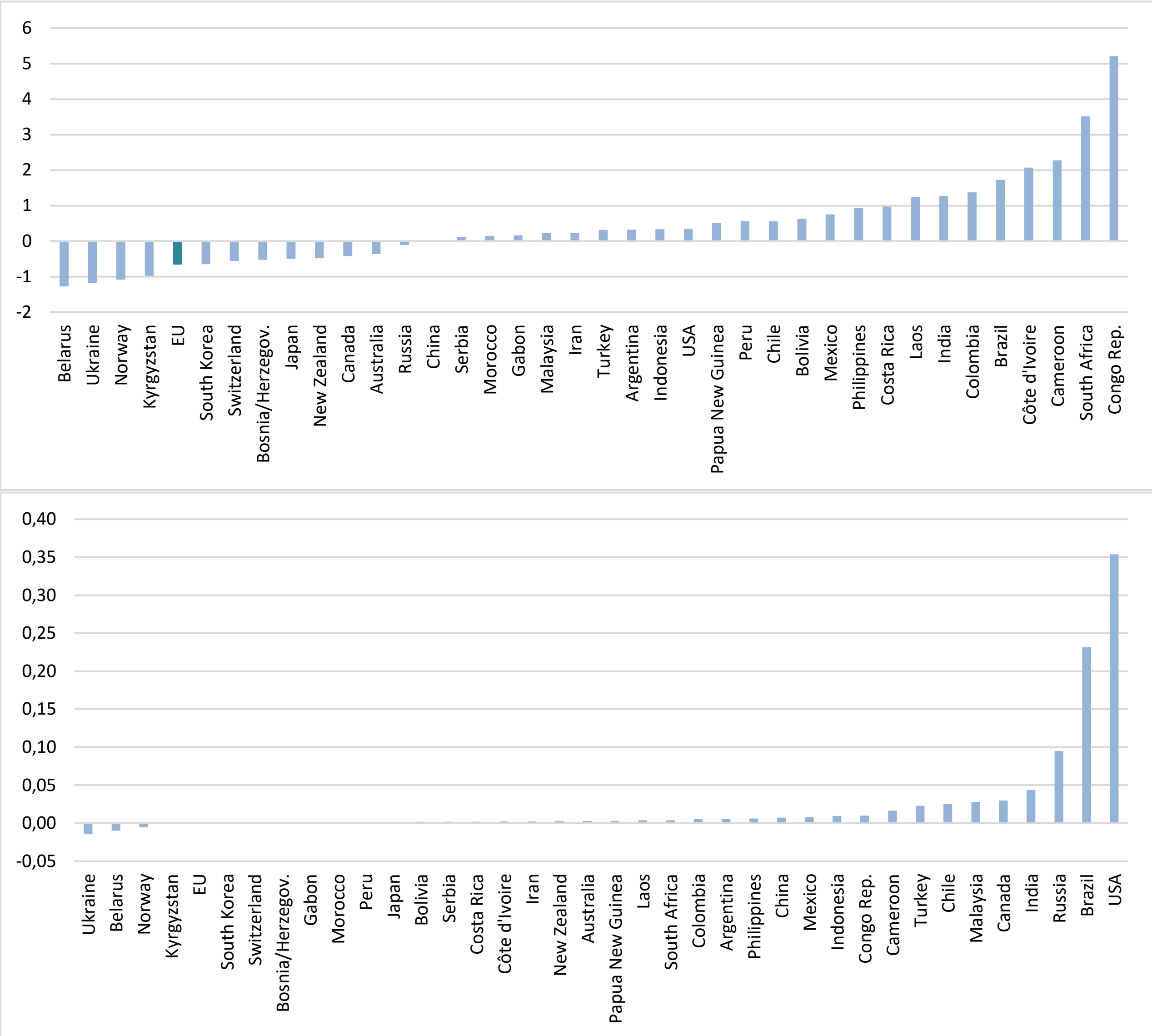
Figure 16: Country wise number of people employed in forestry and logging in 1.000 FTE compared to the average for the EU countries (top) and resulting risks (bottom)



Source: Own calculations. **Extreme values** for China (1147) and India (6242) are not shown. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes. They cannot be interpreted in the units of the original indicator are only used for comparison between countries.

In most countries, more people are employed in forestry and logging than in the EU (Figure 16, top). However, this indicator only relates to formally reported employment. It does not reflect the importance of informal employment in the forestry sector of developing countries. Further analyses based on secondary literature could provide further insight here. In any case, increased roundwood production would not pose a risk but rather an opportunity for increasing employment in forestry and logging activities in the countries concerned at the expense of decreased employment in the EU.

Figure 17: Country wise indicator values for poverty and inequality compared to the mean value for the EU countries (top) and resulting risks (bottom)



Source: Own calculations. The values for the aggregated poverty and inequality indicator are derived from the principal component analysis. They cannot be interpreted in the units of the original indicators and are only used for comparison between countries. The values for the risk assessment are derived from the vulnerability indicator weighted by the additional roundwood production volumes.

Increased export-oriented logging can lead to increased poverty and unequal living conditions if it deprives the local population of livelihoods in countries with high subsistence agriculture. However, it can also promote prosperity if it is implemented sustainably and the population benefits through economic development. Only four of the countries compared have lower poverty and/or inequality in income and wealth than the EU (Figure 17, top). The risk assessment shows the highest values for the USA, Brazil and Russia (Figure 17, bottom). In these countries, special care would need to be taken to ensure that higher logging does not promote poverty and/or inequality.

4.5 Summary and evaluation of leakage effects in non-EU countries

Vulnerability

- On average, the EU has significantly higher values for almost all indicators and thus lower vulnerability than the non-EU countries that would compensate further protection in the EU by more roundwood production.
- Protection of biodiversity hotspots and endangered species is a core concern of the EU BioDiv strategy. The expected additional production would be shifted to countries that have a significantly higher proportion of intact forest areas compared to the EU, but already have lost significant amounts of these areas in recent years. Moreover, the risk of species extinction is significantly higher in non-EU countries than in the EU. The non-EU countries have placed significantly lower proportions of forest areas under protection and spend less money on the conservation of biodiversity than the EU countries. Further protection measures in the EU would further increase the discrepancy to the protection measures of other countries.
- Non-EU countries also have lower SFM and governance indicators than the EU and are characterized by higher deforestation rates. However, a few countries also have higher values.
- Many of the countries concerned have higher biomass stocks per hectare and thus possibly greater buffer capacities than the EU. However, the most affected countries have lower stocks. Most of the countries show higher shares of already degraded land area. Either this could indicate a further threat or a potential for promoting afforestation measures to buffer pressure on natural forests.
- In most non-EU countries, more people are employed in the forest sector than in the EU. The figure is reported to the FAO in absolute employment figures and is therefore higher for large and forest-rich countries, on the one hand. On the other hand, it can also indicate higher mechanization in the EU. Beyond that, however, a possible shift of potential for bio-economic development from the EU to non-EU countries needs to be taken into account. Most of the countries are characterized by higher inequality indicators than the EU. For particularly poor countries, this could mean an opportunity to benefit from potential job creation, but on the other hand also the risk of displacement effects for often subsistence-based income groups.

Risk Assessment

- Further protection of forest areas in the EU, with the associated shift of roundwood production to other countries, bears the risk of transferring negative effects to other countries, most of which are already characterized by higher vulnerability. This applies in particular to aspects of biodiversity. The positive biodiversity effects in the EU due to additional protection are counteracted by negative effects in non-EU countries.
- Countries with high additional roundwood production and high vulnerability are in the focus of the risk assessment. European policy measures should focus particularly on these countries in order to buffer potential leakage effects.

- In most countries, there is a risk that endangered species and intact forest areas will become more endangered. Due to the higher roundwood production on the one hand, and higher vulnerability compared to the EU on the other hand, intact forest areas in Canada, the USA, Russia, but also Brazil and Chile could be affected.
- Due to the already lower forest biomass, higher fellings, especially in the USA, Russia and Canada, can be buffered less effectively. In the USA, Brazil, Canada and India, there is a risk that compared to the EU a higher proportion of additional logging will occur on degraded land. In Brazil and Russia, two countries with a large share of additional logging, the governance indicators are significantly lower than in Europe. A comparatively large amount of additional logging would occur in forest areas without certification and a long-term management plan. Specifically in Brazil, the USA and Russia there are lower proportions of forests under management plans or certification schemes. In order to avoid leakage effects, improved governance and SFM should be promoted before new areas are afforested or existing forests are more intensively managed, especially in these countries.
- Particularly in Brazil, USA, Canada, Malaysia, and to a lesser extent in Indonesia and Russia, there is a risk that the already higher net deforestation compared to the EU could be exacerbated by increased roundwood production. Potential risks of forest area losses in these countries are only partially offset by possible increases in reforestation in Ukraine, Chile, Turkey, China and India.
- The USA, Russia, Brazil, Turkey, Canada and Chile are the main countries that can benefit from changes in employment in the forestry sector. This is a consequence of the higher expected roundwood production in these countries. In Europe, jobs in the forest management sector would be lost as a result of reduced roundwood production.
- Specifically in the USA, Brazil, Russia, India, Canada and Malaysia it has to be ensured that negative social effects and unequal distribution of income are not exacerbated through the implementation of EU policy.

5 Discussion and conclusions

The aim of the present study is, on the one hand, to quantitatively assess possible leakage effects and, on the other hand, to qualitatively evaluate possible negative impacts on forestry in the affected non-EU countries as a consequence of an implementation of the EU BioDiv strategy in Europe. In a first step, a scenario for the implementation of the EU BioDiv strategy is used to estimate the extent to which a reduction in the EU's roundwood production could occur. Based on this, a global timber market model is used to calculate how global markets for roundwood and wood products could change and to which non-EU countries the production of roundwood could shift. Finally, the vulnerability and risk of these non-EU countries for a resulting less sustainable forest management is assessed.

5.1 Estimation of the decrease in roundwood production in the EU

In order to assess the impact of an implementation of the EU BioDiv strategy on the roundwood supply in the EU, the following measures were examined:

i. 10 % share of forest area set-aside,
ii. non-utilization of "old-growth forest",
iii. 30 % share of protected forest areas with Habitats Directive (COM 1992) management requirements.

Since the authors were not able to obtain information on forest condition, forest development, future roundwood supply and implementation of nature conservation measures in the EU member states in the short term, an assessment of the effect of the measures on roundwood supply in the EU was made on the basis of an impact assessment for Germany. In a first step, three different national implementation scenarios (set-aside, old-growth forest and habitat scenario) were developed based on the main nature conservation measures defined and proposed by the EU biodiversity strategy. In a second step, these isolated scenarios were integrated into an overall scenario. To estimate possible impacts of the implementation of these measures on the roundwood supply of the EU as a whole, reduction factors for the potential roundwood production were calculated for Germany. These factors were then transferred to the actual roundwood production of the other EU member states, which was then extrapolated into the future. Central data sources for these calculations were the BWI 2012, the WEHAM baseline scenario 2012 and FAO data on the roundwood production of the EU-27.

Development of implementation scenarios for the EU BioDiv strategy

The target definitions in the EU BioDiv strategy (COM 2020, p.5) leave room for interpretation. The first objective of legally protecting at least 30 % land and sea area does not specify the degree or type of protection status these areas must formally be subjected to. According to Polley, p. 75 (2009), already in 2002, 67 % of Germany's forest area was subject to one or more nature conservation law categories, if national parks, biosphere reserves, nature reserves, Natura 2000 areas, nature parks and landscape protection areas are taken into account. The nature conservation requirements of the different categories range from the preservation of the (forest) cultural landscape with marginal effects on roundwood production to the protection of natural processes resulting in a complete end to roundwood production. For a successful implementation of the EU biodiversity strategy, minimum requirements for the legal protection status should be defined and communicated. In the habitats scenario, nature conservation requirements for the preservation of forest habitat types were assumed, which continue to allow forestry management and significantly, but not seriously, restrict roundwood production. The assumption that 30 % of the forest area is covered by management requirements under the Habitats Directive seems moderate, since the EU biodiversity strategy requires at least 3 % of the land area of the EU. In reality, forest areas are likely to account for a comparatively high share of protected terrestrial area, as settlement and infrastructure areas (as part of the EU's land area) cannot be designated as protected.

The second objective of strictly protecting "all remaining primary and primeval forests", i.e. so-called "old-growth forests", also leaves room for interpretation. The EU biodiversity strategy explains that "[...] strict protection [...] does not necessarily mean that the area is closed to humans, but leaves natural processes essentially undisturbed to respect the areas' ecological requirements (COM 2020p. 4). Thus, in the set-aside scenario, forest areas were designated in the sense of the "National Strategy on Biological Diversity (NBS)" according to the criteria of a "natural forest development (NWE)". The set-aside scenario aims at the protection of natural processes and includes all tree species and age classes. According to the EU biodiversity strategy process conservation is to take place in the strictly protected areas. This will also lead to the designation of comparatively large shares of forest area as compared to other land use types (conservation of natural processes in Germany's agricultural landscape is also likely to lead to forest development and thus to an increase in forest area, mainly as a result of natural succession (Elsasser 2008)). This specification implies an end to roundwood production and other forestry measures, but also of active nature conservation and landscape management measures to preserve protected goods. Accordingly, these strictly protected areas cannot be designated in forests under the Habitats Directive, since numerous forest habitat types (e.g., secondary oak habitat types[11]) can only be preserved through active measures. In addition, climate change is likely to make active measures to preserve forest habitats increasingly necessary. Due to the long development cycles of forest ecosystems, it can be further deduced that with a strict protection status all forest development phases must be involved in balanced proportions to protect undisturbed natural processes. An exclusive focus on the later stages of forest ecosystem development, which are particularly valuable from a nature conservation perspective, would only represent partial aspects of the natural processes of forest ecosystems.

Furthermore, primary forests are largely absent in the cultural landscape of Germany and many other EU member states (Sabatini et al. 2018). The EU BioDiv strategy gives the impression that "old-growth forests" are to be regarded as "replacement biotopes" for the non-existent primary forests in many EU member states. Since there is no uniform EU definition for "old-growth forests" and a large number of related terms are used at EU level, an understanding of "old-growth forests"

[11] Secondary forests are forests in which the main tree species, although adapted to the sites, is not competitive and can only be maintained by special constant forestry management.

as forests in later stages of stand development has been followed here. In the "old-growth forest scenario for Germany" all age groups above the usual production periods of the tree species groups were therefore assigned to "old-growth forests". Due to our own assumptions on the average production times of the tree species groups, a higher proportion is allocated to the coniferous forest area. From a nature conservation point of view, a higher proportion of deciduous trees in Germany would be desirable. According to this assumption for the total protection of "old-growth forests", 12 % of the forest area, would no longer be available for the production of roundwood.

Moreover, the second objective of the EU Biodiversity strategy of strictly protecting one third of all of EU's protected area does not specify if strict protection refers to the targeted 30 % overall protected area or the actual protected area (one third of the 30 % or more protected area would mean, for example, 10 % strictly protected area, while one third of the 67 % of the actually protected forest areas in Germany (Polley 2009) would result in 20 % strictly protected area).

In the habitats scenario, only age classes within the usual production times are designated as protected areas in order to avoid overlapping with "old-growth forests". This may lead to underestimating the reduction of roundwood production in forests managed under the Habitats Directive, as the proportion of old-growth forests is likely to be underrepresented.

In the German BioDiv scenario, area double counting of the upper age classes in the old-growth forest scenario and in the set-aside scenario were adjusted. Thereby old-growth forests are underrepresented in the German BioDiv scenario, causing an underestimation of the negative effects on roundwood production. In the scenario 20.9 % of the total forest area is designated as set-aside and old-growth forests area.

Federal Forest Inventory 2012 and WEHAM baseline scenario 2012

The current level of forest nature conservation was calculated based on BWI 2012 and WEHAM baseline scenario 2012 data. It was assumed that conservation measures derived from the strategic EU biodiversity objectives would be implemented only on accessible and stocked forest area covering 10,627,513 ha. However, conservation measures can potentially be implemented on the total German forest area that includes non-accessible and unstocked forest areas and amounts to 11,419,124 ha. In the latter case, the presented reduction in roundwood production would be overestimated as the implementation of conservation measures would then affect a smaller area under forest management and roundwood production.

Furthermore, used data sources reference on the year 2012. Since then, forest area under "natural forest development" has increased (Engel et al. 2016: 46)[12], and some forest enterprises may also have integrated additional biodiversity conservation measures into their management concepts. Therefore, the actual initial level of forest conservation may have been underestimated and the

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[12] According to the definition of "natural forest development (NWE)" of the NWE5 research project, a NWE area of 213,145 ha or 1.9 % of the total forest area was determined for the year 2013 (according to the company's own area basis, this would correspond to 2.01 %). A NWE share of 2.3 % was expected by 2020 and 3 % for the period immediately thereafter (Engel et al. 2016: 46).

additional measures required to implement the EU Biodiversity strategy may have been overestimated. As a result, the decline in potential roundwood production is also likely to be overestimated.

In the previous WEHAM baseline scenario 2002, the actual fellings of coniferous trees were underestimated, while the actual fellings of deciduous trees were overestimated (Schmitz et al. 2005; BWI 2012). Since the WEHAM baseline scenarios represent in particular a forest treatment according to the forest policy objectives of the federal states, this over- and underestimation also apply to the WEHAM Baseline Scenario 2012. Thus, roundwood supply reduction caused by the implementation of the EU Biodiversity strategy may be underestimated for coniferous species and overestimated for deciduous species.

It should also be noted that the WEHAM baseline scenario 2012 is not sensitive to climatic changes and does not take into account forest conversion. In addition, forest damages caused by extreme weather and bark beetle infestations since 2018 in Germany are not considered in the forest condition and potential roundwood supply. In particular, spruce is strongly affected and roundwood supply is likely to decrease in the future.

The EU Biodiversity strategy aims to increase the percentage of protected areas and the level of protection for forest biodiversity in those areas. The associated decline in roundwood supply could theoretically be compensated by intensifying roundwood production at the remaining areas (within certain limits). This option was not considered in the presented study and is also likely to result in ecological leakage effects within the EU.

Transfer to the EU-27

The reduction factors calculated for Germany on the potential roundwood supply were transferred to the roundwood supply of the other EU member states. Whether the forest structures, forest treatment and forest nature conservation concepts in Germany can approximate the EU average value could not be examined in the short term. At least on the level of individual EU member states, a significant change in the decline in roundwood supply can be expected as a result of the chosen procedure.

The FAO data on the roundwood production of the EU-27 were constantly extrapolated into the future with the (historical) multi-year mean values 2015 – 2018 and reduced by the factors calculated for Germany. This reduced roundwood supply of the EU-27 served as a limit in the following market modeling of the EU BioDiv scenario, which is an exogenous limitation that influences the market equilibrium. In the GFPM, roundwood demand is met in accordance with these settings, depending on the respective prices from both national and international supplies.

While the extrapolated, actual roundwood production of the EU-27 in the multi-year average 2015 to 2018 is 473 million m³/a according to FAO data, the EFSOS II reference scenario shows a potential roundwood supply for the EU-27 ("Fellings on FAWS" - forests available for wood supply) of 509 million m³/a (2020) and 526 million m³/a (2030) (UNECE and FAO 2011). This deviation can be explained by the fact that the EFSOS II scenario shows a potential, whereas the FAO data express the actual roundwood production of the past. The magnitude of the deviations shows that the assumed roundwood production in the EU BioDiv scenario are already close to the potential wood roundwood production in the EU. Nevertheless, the biological production limit could be underestimated by extrapolating the historical FAO data on the actual roundwood supply.

For Germany, too, the potential roundwood supply is higher than the actual roundwood supply of the past. While the FAO data for Germany show an actual roundwood supply of 68 million m^3/a on average for the years 2015 to 2018, the potential roundwood supply of the WEHAM baseline scenario 2012 amounts to 77 million m^3/a for the simulation period 2018 to 2032. The EFSOS II reference scenario for Germany is again slightly higher with 80 million m^3/a for the simulation period 2020 to 2030.

Likewise, the historical distribution of the total roundwood production in the EU-27 between the roundwood assortments of industrially used roundwood and firewood was assumed to remain unchanged in the future. In the event of a significant shortage of roundwood due to the implementation of the EU Biodiversity strategy, these proportions could shift towards material use.

5.2 Reduction of the roundwood volume in the EU through nature conservation scenarios

Based on a projected future roundwood production of about 77 million m^3/a in Germany in the WEHAM baseline scenario 2012, an increase in the set-aside area from 1.67 % to 10 % of the productive forest area results in a reduction of the total roundwood production of 6 million m^3/a for the period 2018 to 2052. In the old-growth scenario, roundwood supply is reduced by 18 million m^3/a. The comparison of both scenarios allows the conclusion that if old-growth forests are not used, particularly high opportunity costs for raw wood production arise in the medium term. It should also be taken into account that the protection of old-growth forests places a disproportionate burden on the forestry operations, since the economic value is often not evenly distributed across the age classes, but accumulates in old forest stands.

In the habitats scenario, the potential roundwood supply is reduced by a total of 1 million m^3/a. The integrated implementation of the three nature conservation measures reduces the potential roundwood supply by a total of 24 million m^3/a, of which 7 million m^3/a are hardwood and 17 million m^3/a softwood. Based on the roundwood potential of the WEHAM baseline scenario 2012 of 77 million m^3/a ,the domestic roundwood supply would be reduced to 53 million m^3/a or 69 % of the average for the period 2018 to 2052.

For an impact assessment of the implementation of the EU Biodiversity strategy, reduction factors derived from these results for Germany were transferred to the other EU member states. Based on a total roundwood supply of 473 million m^3 in the EU-27 in the multi-year average 2015 – 2018, the roundwood supply would be reduced by 149 million m^3 to 324 million m^3 in 2050 after implementation of the EU Biodiversity strategy.

Summarizing, there are both reasons to consider the calculated reduction of the roundwood supply within the EU as overestimation and to consider it as underestimation. For example, although doublecounted areas in the set-aside and the old-growth forests scenarios have been adjusted, in the habitats scenario protected areas are distributed exclusively over the remaining forest area. Including the already protected areas (old-growth and set-aside) in the 30 % requirement would have mitigated the decline in roundwood production. However, the decision on the "right" allocation of protected areas has not yet been made, and the result thus shows policymakers options for implementing the EU biodiversity strategy as efficiently as possible, i.e., with as little reductions of roundwood production as possible.

On the other hand, the present results are not a maximum scenario, since the exact definition of "old-growth forests" determines to a large extent how high the decline in roundwood production will be. The threshold value set here by main tree species groups can be set even lower in the further discussion by the protagonists of the EU BioDiv strategy, with a correspondingly higher decrease in roundwood production.

5.3 Quantification of leakage effects outside the EU

The scenario developed in Chapter 0for a possible reduction of the roundwood volume when implementing the EU biodiversity strategy, was compared with a reference scenario in the market modeling (Chapter 3). Since 1991 the actual roundwood production has been characterized by a continuous growth. In the reference scenario calculated here, this dynamic is continued over the simulation period. Developments in demand, but also in supply in non-EU countries and international trade developments are simulated simultaneously. Accordingly, withdrawals in the reference scenario until 2019 develop very similar to the data actually reported by the FAO (FAO 2020a). Furthermore, the reference scenario describes the development of the market for the next decades without any restriction of the roundwood production in the EU by the EU biodiversity strategy.

The goal of the market modeling was to show possible shifts in the international supply situation due to a reduction of roundwood extraction in the EU-27 with the help of a partial global equilibrium model. For this purpose, the quantities calculated in Chapter 0for the roundwood supply of the EU-27 for the years 2020 to 2050 were transferred into the global timber market model as exogenous production potential. The estimation of the roundwood potential in Chapter 0based on the multi-year average (2015 – 2018) of roundwood production reported by the FAO (FAO 2020a). For the base year, the estimates in Chapter 2 show a 31 % reduction in roundwood production for Germany. In the EU biodiversity strategy, this reduced quantity for roundwood is constantly extrapolated to the year 2050 by the wood volume estimate. Since the available roundwood quantities estimated in Chapter 0were naturally lower than the current roundwood production reported by the FAO, this production potential from the beginning of the simulation period in the model functioned as an exogenous production cap in the EU BioDiv scenario.

At the beginning of the simulation period, the measured leakage (31 % reduction in roundwood removals) is lower than the leakage measured in the reference scenario at the end of the simulation period (about 40 % reduction in roundwood removals). This percentage is to be understood as a projected deficit in roundwood production. The growing gap between the scenarios also results from the fact that the dynamic reference scenario in the EU BioDiv scenario is contrasted with an almost constant roundwood production, and thus no development of forest production will take place on the managed areas. The assumption of constant roundwood production in the EU BioDiv scenario is mainly the result of the fact that the estimation of the roundwood supply for Germany does not show a growth path for roundwood production. This result was transferred to the other EU member states in Chapter 2. Due to the assumed stagnation of the area production in the EU BioDiv scenario, compared to the dynamic development in the reference scenario, an overestimation of the leakage in the present study could have occurred, depending on the strictness of the future version of the Habitats Directive’s forest management regulations.

By comparing the EU BioDiv scenario with the reference scenario, possible market shifts caused by the European supply shortage are highlighted. It becomes clear that the components of the leakage effects shift over the different decades of the simulation. Particularly at the beginning of the simulation period, when the effects of the reduced roundwood supply in the EU-27 will become apparent for the first time, an increased abandonment of the use of the raw material wood can be observed. In the further course of the simulation, the renunciation of consumption of wood in the EU-27 decreases as production in non-EU countries becomes more and more competitive, thus meeting the demand for wood products in the EU-27. The fact that the competitiveness of non-EU countries in the EU BioDiv scenario is constantly increasing is due, among other things, to the strong and persistent roundwood shortage in the EU-27 countries. This creates a gap between roundwood demand and supply, which continuously increases roundwood prices in the EU-27 and thus makes products from overseas (despite high costs due to transport) more attractive for the EU market. A similar effect can be observed currently in North America. Here, the prices for sawn softwood are rising very strongly, because the demand for building houses clearly exceeds the currently possible production (EUWID 2020). If this situation persisted, exports to North America would become increasingly attractive due to the high prices.

Since the estimation of the roundwood quantities resulting from Chapter 2 means a very strong reduction of the roundwood production in the EU-27, which could not be observed in its history so far (FAO 2020a), a further investigation of alternative scenarios and the performance of a sensitivity analysis seems to be useful. In addition to various, lower reduction rates of roundwood production, a dynamic, country-specific investigation of forest development and the associated potential roundwood supply, in which the implementation of the EU biodiversity strategy is determined individually for each member country, would be a desirable extension. It is probable that the implementation of the EU biodiversity strategy would have different effects on the timber market due to the different forest resources of the individual EU member states. Also the intensity of the roundwood extraction on the productive areas would probably be different. Consequently, the roundwood production as well as the production, trade and consumption of wood products would develop different dynamics in the countries. In such alternative scenarios, for example, smaller volume effects could arise, which would then have a direct influence on the price development. For example, a lower roundwood shortage in the EU-27 could lead to a lower price increase for roundwood compared to the scenario used here. This in turn could make transport from more distant non-EU countries less economical, so that the shift effects could focus more on closer non-EU countries with lower transport costs. These market changes do not necessarily have to be linear, as they depend on the interaction of prices and costs. If, for example, the production of roundwood in an alternative scenario were to be only 15 % below the reference level throughout the EU, this would not necessarily lead to proportional effects in the same order of magnitude in the non-EU countries identified so far; rather, structural changes in market activity could also occur. Such structural changes could then not only shift the level of leakage and the country ranking, but presumably also change the country composition.

No bilateral trade flows are simulated in the version of GFPM used here. Thus, no direct trade shifts or leakage effects between individual countries can be shown, but only as aggregates. The calculation of bilateral trade flows to quantify direct leakage effects would provide a good basis for assessing political options for action to reduce leakage.

When interpreting the results from the partial equilibrium model, it must also be borne in mind that production and demand developments in particular, both for the entire reference scenario and for the EU BioDiv scenario, are influenced by exogenous projections of global income and population trends. The model version used here is based on the dynamic economic growth rates of IPCC scenario A1 (Nakicenovic et al. 2000). An adjustment of these developments has been made in the recently published SSP scenarios (The Shared Socioeconomic Pathways, O'Neill et al. 2014). The results on the leakage effects resulting from the implementation of the EU BioDiv strategy would probably be different when using a current SSP scenario. It is not possible to make a concrete a priori assessment of what form this would be. However, the composition of the non-EU countries in which increased roundwood production is evident could change depending on new income projections.

5.4 Vulnerability and risk assessment

The interdependencies (Figure 6) were illustrated by means of a concept developed for the study, which places individual thematic areas in a logical context. The list of vulnerability indicators characterizing these thematic areas is based on publicly available data sets. The concept can be extended for further questions and would then have to consider additional indicators. The selection of the compared indicators is also determined by data availability. Only indicators that are globally available could be used. For example, the thematic area of biodiversity conservation contains only two forest-specific indicators. There is further information on endangered forest species (Bubb et al. 2009) or the "biological intactness" of forests (UNEP-WCMC and Natural History Museum 2016). However, respective indicators would first have to be evaluated and aggregated in additional studies at country level. An updated list of threatened tree species is currently being compiled (https://globaltrees.org/threatened-trees/red-list/). There is no globally comparable indicator for the socio-economic impacts of wood use. Furthermore, there is no comparable data on formal and informal employment in the forest sector. Further data could be compiled and could possibly influence the results. However within this study, several indicators per thematic area have already been tested to provide a consolidated and consistent basis, especially for comparison between the EU and non-EU countries.

All calculations are based on country wise data. A sub-national view, which takes into account the vulnerability and risks of the actually affected areas, is not possible with globally available data. While it would be possible to spatially determine the theoretically new protected areas in the EU, there is no information on which areas and under which conditions the additional roundwood would be produced in the non-EU countries. Moreover, even if the relevant areas were known, there would be no comparable indicator values on the sub-national level.

In order to include as many countries as possible, countries with at least 0.1 % of the total additional impact in non-EU countries were selected as countries for comparison. The relative change in roundwood production within the individual countries was not taken into account. In countries with high relative change, however, the additional pressure on forests would be particularly high. Of all non-EU countries not considered, only Saudi Arabia shows a calculated relative change in roundwood production of more than 20 %. However, absolute roundwood production is extremely low here. In addition, the selected countries realize 99 % of the additional roundwood production.

The results presented do not include any prediction of how the implementation of the EU biodiversity strategy will affect biodiversity conservation in non-EU countries. The current evaluation merely indicates which countries, based on the selected indicators, are likely to be exposed to a higher risk of biodiversity loss compared to the EU. Furthermore, the socio-economic aspects in the countries are analyzed in order to gain first clues about further side effects of the implementation of the EU biodiversity strategy. A more detailed analysis of the individual countries with the highest potential risk would be necessary to better understand the underlying mechanisms. This would allow policy approaches to be adapted to the specific country context, but would require additional data from individual sectors and regions within the countries.

Individual PCAs were calculated for the indicators of individual thematic areas. However, alternative analytical approaches are also possible. For example, a PCA could be calculated with all indicators without prior definition of thematic areas, with the goal of classifying new categories based on the resulting main components.

The future forecasts are based on projections of the timber market. In contrast, the future vulnerability indicators could not be predicted, because it is not possible to model the indicator values for future years without specific extensive research. Therefore current indicator values were compared with additional logging in the future.

Risk estimates are based on the multiplication of vulnerability indicators and additional timber volume. For the risk estimation it was assumed that the risk increases linearly with the additional roundwood volume. In reality, the function could also be non-linear and thus lead to higher or lower risk values. However, this would not affect the comparability between countries and regions.

The results show a relative comparison between countries. An absolute quantification of the risk is not possible.

The current risk assessment has been based on the leakage of roundwood production (as a difference of reference scenario and EU BioDiv scenario). A separate calculation of risk indicators separately for the reference scenario and the EU BioDiv scenario at different times in 2020/2050 would also be possible.

Vulnerability and risk assessments with more comprehensive sets of indicators supplemented by statistical methods might improve the robustness of the results, but require more time.

References

BASTOS LIMA, MAIRON G.; PERSSON, U. MARTIN; MEYFROIDT, PATRICK (2019): Leakage and boosting effects in environmental governance: a framework for analysis. In *Environ. Res. Lett.* 14 (10), p. 105006. DOI: 10.1088/1748-9326/ab4551.

BFN (2019): Aktueller Meldestand der FFH-Gebiete in Deutschland. Edited by Bundesamt für Naturschutz, Abteilung Biotopschutz und Landschaftsökologie, FG II 2.2. Bonn. Available online at https://www.bfn.de/fileadmin/BfN/natura2000/Dokumente/Meldeueb_FFH_20191213_bf.pdf, updated on 12/13/2019, checked on 8/10/2020.

BIRKMANN, JOERN (2011): Risk and vulnerability indicators at different scales: Applicability, usefulness and policy implications. In *Environmental Hazards* 7 (1), pp. 20–31. Available online at https://www.tandfonline.com/doi/pdf/10.1016/j.envhaz.2007.04.002?needAccess=true, checked on 10/1/2020.

BUBB, PHILIP; BUTCHART, STUART; COLLEN, BEN; DUBLIN, HOLLY; KAPOS, VAL; POLLOCK, CAROLINE ET AL. (2009): IUCN Red List Index. Guidance for national and regional use. Version 1.1. Edited by IUCN. Gland, Switzerland. Available online at https://portals.iucn.org/library/sites/library/files/documents/2009-001.pdf, checked on 9/9/2020.

BUONGIORNO, JOSEPH (2003): The Global Forest Products Model. [S.l.]: Academic Press.

BUONGIORNO, JOSEPH (2015): Global modelling to predict timber production and prices: the GFPM approach. In *Forestry* 88 (3), pp. 291–303. DOI: 10.1093/forestry/cpu047.

BUONGIORNO, JOSEPH; JOHNSTON, CRAIG; ZHU, SHUSHUAI (2017): An assessment of gains and losses from international trade in the forest sector. In *Forest Policy and Economics* 80, pp. 209–217. DOI: 10.1016/j.forpol.2017.04.004.

BUONGIORNO, JOSEPH; ZHU, SHUSHUAI (2013): Consequences of carbon offset payments for the global forest sector. In *JFE* 19 (4), pp. 384–401. DOI: 10.1016/j.jfe.2013.06.005.

BWI (2012): Dritte Bundeswaldinventur-Ergebnisdatenbank. Edited by Johann Heinrich von Thünen-Institut. Available online at https://bwi.info/start.aspx, checked on 8/7/2020.

COLLEN, BEN; RAM, MALA; ZAMIN, TARA; MCRAE, LOUISE (2008): The Tropical Biodiversity Data Gap: Addressing Disparity in Global Monitoring. In *Tropical Conservation Science* 1 (2), pp. 75–88. DOI: 10.1177/194008290800100202.

COM (1992): Council Directive on the conservation of natural habitats and of wild fauna and flora (Council Directive, 92/43/EEC). Available online at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0043&from=EN, updated on 7/22/1992.

COM (2009): The Birds Directive. On the conservation of wild birds. Edited by European Parliament and the Council (2009/147/EC). Available online at https://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm, updated on 9/14/2020, checked on 10/26/2020.

COM (2020): EU Biodiversity Strategy for 2030 - Bringing nature back into our lives. Edited by COM. Brussels (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions der Komission an das Europäische Parlament, den Europäischen Rat, den RAT, den Europäischen Wirtschafts- und Sozialausschuss und den Ausschuss der Regionen, COM (2020) 380 final), checked on 10/26/2020.

DIETER, MATTHIAS; ENGLERT, HERMANN (2007): Competitiveness in the global forest industry sector: an empirical study with special emphasis on Germany. In *European Journal of Forest Research* 126 (3), pp. 401–412. DOI: 10.1007/s10342-006-0159-x.

DÖRING, PRZEMKO; GLASENAPP, SEBASTIAN; MANTAU, UDO (2017a): Rohstoffmonitoring Holz: Holz- und Zellstoffindustrie 2015. Entwicklung der Produktionskapazität und Holzrohstoffnutzung. Zwischenbericht. Available online at https://literatur.thuenen.de/digbib_extern/dn058689.pdf, checked on 5/27/2019.

DÖRING, PRZEMKO; GLASENAPP, SEBASTIAN; MANTAU, UDO (2017b): Rohstoffmonitoring Holz: Holzwerkstoffindustrie 2015. Entwicklung der Produktionskkapazität und Holzrohstoffnutzung. Abschlussbericht. Available online at https://literatur.thuenen.de/digbib_extern/dn058690.pdf, checked on 5/27/2019.

ELSASSER, PETER (2008): Neuwaldbildung durch Sukzession: Flächenpotentiale, Hindernisse, Realisierungschancen. Edited by Johann Heinrich von Thünen-Institut, Institut für Ökonomie der Forst- und Holzwirtschaft (Arbeitsbericht des Instituts für Forstökonomie, 5). Available online at https://literatur.thuenen.de/digbib_extern/bitv/dk041111.pdf, checked on 9/30/2020.

EUWID (2020): USA: 2x4 prices jump well above 900 US$ mark. EUWID Europäischer Wirtschaftsdienst (EUWID Wood Products and Panels). Available online at https://www.euwid-wood-products.com/news/roundwoodsawnwood/single/Artikel/usa-2x4-prices-jump-well-above-900-us-mark.html, updated on 9/17/2020, checked on 9/30/2020.

FAO (2010): Global Forest Resources Assessment 2010 (FRA 2010). Available online at http://www.fao.org/forest-resources-assessment/past-assessments/fra-2010/en/.

FAO (2020a): Forestry Production and Trade. Available online at http://www.fao.org/faostat/en/#data/FO.

FAO (2020b): Global Forest Resources Assessment. Terms and Definitions (Forest Resources Assessment Working Paper 188). Available online at http://www.fao.org/3/I8661EN/i8661en.pdf, checked on 9/7/2020.

FERRER VELASCO, RUBEN; KÖTHKE, MARGRET; LIPPE, MELVIN; GÜNTER, SVEN (2020): Scale and context dependency of deforestation drivers: Insights from spatial econometrics in the tropics. In *PLOS ONE* 15 (1), e0226830. DOI: 10.1371/journal.pone.0226830.

GAN, JIANBANG; MCCARL, BRUCE A. (2007): Measuring transnational leakage of forest conservation. In *Ecological Economics* 64 (2), pp. 423–432. DOI: 10.1016/j.ecolecon.2007.02.032.

GLASENAPP, SEBASTIAN; AGUILAR, FRANCISCO X.; WEIMAR, HOLGER; MANTAU, UDO (2019): Assessment of residential wood energy consumption using German household-level data. In *Biomass and Bioenergy* 126, pp. 117–129. DOI: 10.1016/j.biombioe.2019.04.020.

JOHANN HEINRICH VON THÜNEN-INSTITUT (Ed.) (2012): Waldentwicklungs- und Holzaufkommensmodellierung Ergebnisdatenbank. Available online at https://bwi.info/start.aspx, checked on 8/7/2020.

JOHNSTON, CRAIG M. T.; BUONGIORNO, JOSEPH (2017): Impact of Brexit on the forest products industry of the United Kingdom and the rest of the world. In *Forestry* 90 (1), pp. 47–57. DOI: 10.1093/forestry/cpw062.

KALLIO, A. MAARIT I.; MOISEYEV, ALEXANDER; SOLBERG, BIRGER (2006): Economic impacts of increased forest conservation in Europe: a forest sector model analysis. In *Environmental Science & Policy* 9 (5), pp. 457–465. DOI: 10.1016/j.envsci.2006.03.002.

KAUFMANN, DANIEL; KRAAY, AART; MASTRUZZI, MASSIMO (2010): The Worldwide Governance Indicators: Methodology and Analytical Issues (World Bank Policy Research Working Paper, 5430). Available online at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1682130, checked on 9/4/2020.

LIU, JIANGUO; DOU, YUE; BATISTELLA, MATEUS; CHALLIES, EDWARD; CONNOR, THOMAS; FRIIS, CECILIE ET AL. (2018): Spillover systems in a telecoupled Anthropocene: typology, methods, and governance for global sustainability. In *Current Opinion in Environmental Sustainability* 33, pp. 58–69. DOI: 10.1016/j.cosust.2018.04.009.

MEYFROIDT, P.; ROY CHOWDHURY, R.; BREMOND, A. DE; ELLIS, E. C.; ERB, K.-H.; FILATOVA, T. ET AL. (2018): Middle-range theories of land system change. In *Global Environmental Change* 53, pp. 52–67. DOI: 10.1016/j.gloenvcha.2018.08.006.

MORLAND, CHRISTIAN; SCHIER, FRANZISKA; JANZEN, NIELS; WEIMAR, HOLGER (2018): Supply and demand functions for global wood markets: Specification and plausibility testing of econometric models within the global forest sector. In *Forest Policy and Economics* 92, pp. 92–105. DOI: 10.1016/j.forpol.2018.04.003.

NAKICENOVIC, NEBOJSA; ALCAMO, JOSEPH; DAVIS, GERALD; VRIES, BERT DE; FENHANN, JOERGEN; GAFFIN, STUART ET AL. (2000): Special report on emissions scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. Edited by Nebojsa Nakicenovic, Robert Swart. IPCC. Cambridge. Available online at https://www.ipcc.ch/site/assets/uploads/2018/03/emissions_scenarios-1.pdf, checked on 9/8/2020.

NEPAL, PRAKASH; INCE, PETER J.; SKOG, KENNETH E.; CHANG, SUN J. (2012): Projection of U.S. forest sector carbon sequestration under U.S. and global timber market and wood energy consumption scenarios, 2010–2060. In *Biomass and Bioenergy* 45, pp. 251–264. DOI: 10.1016/j.biombioe.2012.06.011.

O'NEILL, BRIAN C.; KRIEGLER, ELMAR; RIAHI, KEYWAN; EBI, KRISTIE L.; HALLEGATTE, STEPHANE; CARTER, TIMOTHY R. ET AL. (2014): A new scenario framework for climate change research: the concept of shared socioeconomic pathways. In *Climatic Change* 122 (3), pp. 387–400. DOI: 10.1007/s10584-013-0905-2.

POLLEY, HEINO (2009): Wald in Schutzgebieten - ein Überblick Sonderheft (327), pp. 75–82. Available online at https://literatur.thuenen.de/digbib_extern/dk041611.pdf, checked on 8/11/2020.

POTAPOV, PETER; HANSEN, MATTHEW C.; LAESTADIUS, LARS; TURUBANOVA, SVETLANA; YAROSHENKO, ALEXEY; THIES, CHRISTOPH ET AL. (2017): The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. In *Science Advances* 3 (1), e1600821, checked on 9/30/2020.

ROCK, JOACHIM; DUNGER, KARSTEN; MARKS, ALEXANDER; SCHMIDT, URSULA (2016): Wald und Rohholzpotenzial der nächsten 40 Jahre: Ausgewählte Ergebnisse der Waldentwicklungs- und Holzaufkommensmodellierung 2013 bis 2052. Edited by Bundesministerium für Ernährung und Landwirtschaft (BMEL). Berlin. Available online at https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/Wald-Rohholzpotential-40Jahre.pdf;jsessionid=ED7D78C8F7B6DFD567C2D6475DD49EAA.internet2841?__blob=publicationFile&v=3, checked on 8/19/2020.

ROSENKRANZ, LYDIA; SEINTSCH, BJÖRN (2015): Opportunitätskostenanalyse zur Implementierung des naturschutzorientierten Waldbehandlungskonzepts "Neue Multifunktionalität". In *Landbauforschung - Applied Agricultural and Forestry Research* 65 (3/4), pp. 145–160. DOI: 10.3220/LBF1452524672000.

ROSENKRANZ, LYDIA; SEINTSCH, BJÖRN; WIPPEL, BERND; DIETER, MATTHIAS (2014): Income losses due to the implementation of the Habitats Directive in forests — Conclusions from a case study in Germany. In *Forest Policy and Economics* 38, pp. 207–218. DOI: 10.1016/j.forpol.2013.10.005.

SABATINI, FRANCESCO MARIA; BURRASCANO, SABINA; KEETON, WILLIAM S.; LEVERS, CHRISTIAN; LINDNER, MARCUS; PÖTZSCHNER, FLORIAN ET AL. (2018): Where are Europe's last primary forests? In *Divers Distrib* 24 (10), pp. 1426–1439. DOI: 10.1111/ddi.12778.

SCHIER, FRANZISKA; MORLAND, CHRISTIAN; JANZEN, NIELS; WEIMAR, HOLGER (2018): Impacts of changing coniferous and non-coniferous wood supply on forest product markets: a German scenario case study. In *European Journal of Forest Research* 137 (3), pp. 279–300. DOI: 10.1007/s10342-018-1111-6.

SCHIER, FRANZISKA; WEIMAR, HOLGER (2018): Holzmarktmodellierung - Szenarienbasierte Folgenabschätzung verschiedener Rohholzangebotssituationen für den Sektor Forst und Holz. In *Thünen Working Paper* (91). DOI: 10.3220/WP1523005251000.

SCHMITZ, FRIEDRICH; POLLEY, HEINO; HENNIG, PETRA; DUNGER, CARSTEN; ENGLERT, HERMANN (2005): Das potenzielle Rohholzaufkommen 2003 bis 2042 - Das Wichtigste in Kürze. Zu den Bundeswaldinventur-Erhebungen 2001 bis 2002 und 1986 bis 1988. Edited by BMELV.

STATA STATISTICAL SOFTWARE. Version 16 (2019). College Station, Texas, USA: StataCorp LLC.

TURNER, JAMES A.; BUONGIORNO, JOSEPH; KATZ, ANDRES; ZHU, SHUSHUAI (2008): Implications of the Russian roundwood export tax for the Russian and global wood products sectors. In *Scandinavian Journal of Forest Research* 23 (2), pp. 154–166. DOI: 10.1080/02827580801995307.

UNECE; FAO (2011): The European Forest Sector Outlook Study II: 2010 - 2030. Edited by United Nations (UN). United Nations Economic Commission for Europe. Geneva (United Nations publication). Available online at https://www.unece.org/fileadmin/DAM/timber/publications/sp-28.pdf, checked on 8/7/2020.

UNEP-WCMC; NATURAL HISTORY MUSEUM (2016): Biodiversity Intactness. Available online at www.globalforestwatch.org, checked on 9/9/2020.

UNITED NATIONS STATISTICS DIVISION (Ed.) (2020): SDG Indicators Database. Available online at https://unstats.un.org/sdgs/indicators/database/, checked on 9/4/2020.

VAN KOOTEN, G. CORNELIS; JOHNSTON, CRAIG (2014): Global impacts of Russian log export restrictions and the Canada–U.S. lumber dispute: Modeling trade in logs and lumber. In *Forest Policy and Economics* 39, pp. 54–66. DOI: 10.1016/j.forpol.2013.11.003.

WALDRON, ANTHONY; MOOERS, ARNE O.; MILLER, DANIEL C.; NIBBELINK, NATE; REDDING, DAVID; KUHN, TYLER S. ET AL. (2013): Targeting global conservation funding to limit immediate biodiversity declines. In *PNAS* 110 (29), pp. 12144–12148, checked on 9/30/2020.

WIPPEL, BERND; BECKER, GERO; SEINTSCH, BJÖRN; ROSENKRANZ, LYDIA; ENGLERT, HERMANN; DIETER, MATTHIAS ET AL. (2013): Project FFH-Impact: Implementing the Habitats Directive in German Forests. Executive Summary of a case study on the economic and natural impacts on forest enterprises. Edited by Johann Heinrich von Thünen-Institut, Institut für Forstökonomie, Zentrum Holzwirtschaft Universität Hamburg, Becker, Borchers and Wippel consultancy, Juristische Fakultät Universität Göttingen. Hamburg (Arbeitsbericht des Instituts für Forstökonomie, 01/2013). Available online at https://literatur.thuenen.de/digbib_extern/dn052208.pdf, checked on 8/7/2020.

WIRTH, CHRISTIAN (2009): Old-Growth Forests: Function, Fate and Value - a Synthesis. In Christian Wirth, Gerd Gleixner, Martin Heimann (Eds.): Old-Growth Forests. Function, Fate and Value. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg (Ecological Studies, Analysis and Synthesis, 207), pp. 465–491.

WORLD BANK (2020): World Development Indicators | DataBank. Available online at https://databank.worldbank.org/source/world-development-indicators, updated on 9/4/2020, checked on 9/4/2020.

WORLD RESOURCES INSTITUTE (Ed.) (2020): Global Forest Watch. Forest Monitoring, Land Use & Deforestation Trends. Available online at http://www.globalforestwatch.org/, updated on 9/30/2020, checked on 9/30/2020.

Annex

1 Impact decrease

Table 3: DE BioDiv Scenario: area balance

1.) Total forest area											
Tree species groups	**Measure**	**1 - 20 years**	**21 - 40 years**	**41 - 60 years**	**61 - 80 years**	**81 - 100 years**	**101 - 120 years**	**121 - 140 years**	**141 - 160 years**	**> 160 years**	**all tree age classes**
Oak	[ha]	68.735	93.501	122.590	163.810	139.047	155.607	144.663	122.725	119.029	1.129.706
Beech	[ha]	547.422	580.208	632.208	556.572	393.484	304.711	238.472	193.351	151.125	3.597.554
All deciduous trees	**[ha]**	**616.157**	**673.709**	**754.798**	**720.382**	**532.531**	**460.319**	**383.136**	**316.076**	**270.155**	**4.727.260**
Spruce	[ha]	359.362	583.734	806.360	460.358	422.241	285.870	129.038	68.926	47.690	3.163.580
Pine	[ha]	91.314	373.549	667.000	529.923	434.421	343.112	181.045	83.984	32.324	2.736.673
All coniferous trees	**[ha]**	**450.677**	**957.284**	**1.473.360**	**990.281**	**856.662**	**628.982**	**310.083**	**152.910**	**80.014**	**5.900.253**
All tree species	**[ha]**	**1.066.834**	**1.630.992**	**2.228.158**	**1.710.663**	**1.389.192**	**1.089.301**	**693.219**	**468.986**	**350.169**	**10.627.513**

2.) Protection forest area											
Tree species groups	**Measure**	**1 - 20 years**	**21 - 40 years**	**41 - 60 years**	**61 - 80 years**	**81 - 100 years**	**101 - 120 years**	**121 - 140 years**	**141 - 160 years**	**> 160 years**	**all tree age classes**
Oak	[ha]	91.232	93.709	96.617	100.739	98.263	99.919	98.825	96.631	119.029	894.965
Beech	[ha]	366.830	370.109	375.309	367.745	351.436	342.559	335.935	193.351	151.125	2.854.399
All deciduous trees	**[ha]**	**458.062**	**463.817**	**471.926**	**468.484**	**449.699**	**442.478**	**434.760**	**289.982**	**270.155**	**3.749.363**
Spruce	[ha]	71.267	93.704	115.967	81.367	77.555	285.870	129.038	68.926	47.690	971.385
Pine	[ha]	34.484	62.708	92.053	78.345	68.795	59.664	181.045	83.984	32.324	693.402
All coniferous trees	**[ha]**	**105.752**	**156.412**	**208.020**	**159.712**	**146.350**	**345.534**	**310.083**	**152.910**	**80.014**	**1.664.788**
All tree species	**[ha]**	**563.813**	**620.229**	**679.946**	**628.196**	**596.049**	**788.013**	**744.843**	**442.892**	**350.169**	**5.414.151**

3.) Remaining forest area											
Tree species groups	**Measure**	**1 - 20 years**	**21 - 40 years**	**41 - 60 years**	**61 - 80 years**	**81 - 100 years**	**101 - 120 years**	**121 - 140 years**	**141 - 160 years**	**> 160 years**	**all tree age classes**
Oak	[ha]	-22.497	-208	25.973	63.070	40.783	55.688	45.838	26.094	0	234.742
Beech	[ha]	180.592	210.099	256.899	188.827	42.048	-37.848	-97.463	0	0	743.155
All deciduous trees	**[ha]**	**158.095**	**209.892**	**282.872**	**251.897**	**82.831**	**17.841**	**-51.624**	**26.094**	**0**	**977.897**
Spruce	[ha]	288.095	490.030	690.393	378.991	344.686	0	0	0	0	2.192.195
Pine	[ha]	56.830	310.842	574.947	451.578	365.626	283.448	0	0	0	2.043.270
All coniferous trees	**[ha]**	**344.925**	**800.872**	**1.265.340**	**830.569**	**710.312**	**283.448**	**0**	**0**	**0**	**4.235.465**
All tree species	**[ha]**	**503.021**	**1.010.763**	**1.548.212**	**1.082.466**	**793.143**	**301.288**	**-51.624**	**26.094**	**0**	**5.213.363**

Source: Own calculations

Table 4 DE BioDiv Scenario: roundwood balance

1.) Total forest area										
Tree species groups	**Measure**	**2013-2017**	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**	**2038-2042**	**2043-2047**	**2048-2052**	**2013-2052**
Oak	[1000 m^3/a]	6.302	6.675	5.598	5.900	5.355	5.930	5.544	5.852	5.895
Beech	[1000 m^3/a]	27.619	24.635	20.646	21.692	21.319	20.786	21.312	20.919	22.366
All deciduous trees	**[1000 m^3/a]**	**33.921**	**31.310**	**26.244**	**27.592**	**26.674**	**26.716**	**26.856**	**26.771**	**28.261**
Spruce	[1000 m^3/a]	35.493	34.900	31.828	33.353	33.691	34.395	34.121	36.530	34.289
Pine	[1000 m^3/a]	16.341	16.596	14.976	14.702	14.663	14.411	14.660	15.133	15.185
All coniferous trees	**[1000 m^3/a]**	**51.834**	**51.496**	**46.804**	**48.055**	**48.354**	**48.806**	**48.780**	**51.663**	**49.474**
All tree species	**[1000 m^3/a]**	**85.755**	**82.806**	**73.048**	**75.647**	**75.028**	**75.522**	**75.636**	**78.434**	**77.735**

2.) Protection forest area										
Tree species groups	**Measure**	**2013-2017**	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**	**2038-2042**	**2043-2047**	**2048-2052**	**2013-2052**
Oak	[1000 m^3/a]	2.003	2.016	1.691	1.782	1.617	1.791	1.674	1.768	1.780
Beech	[1000 m^3/a]	6.902	5.808	4.867	5.114	5.026	4.900	5.024	4.932	5.273
All deciduous trees	**[1000 m^3/a]**	**8.905**	**7.824**	**6.558**	**6.896**	**6.643**	**6.691**	**6.699**	**6.699**	**7.053**
Spruce	[1000 m^3/a]	14.499	13.345	12.170	12.753	12.883	13.152	13.047	13.968	13.111
Pine	[1000 m^3/a]	4.606	4.441	4.007	3.934	3.923	3.856	3.923	4.049	4.063
All coniferous trees	**[1000 m^3/a]**	**19.105**	**17.786**	**16.177**	**16.687**	**16.806**	**17.008**	**16.970**	**18.017**	**17.174**
All tree species	**[1000 m^3/a]**	**28.010**	**25.609**	**22.736**	**23.583**	**23.450**	**23.699**	**23.668**	**24.717**	**24.228**

3.) Remaining forest area										
Tree species groups	**Measure**	**2013-2017**	**2018-2022**	**2023-2027**	**2028-2032**	**2033-2037**	**2038-2042**	**2043-2047**	**2048-2052**	**2013-2052**
Oak	[1000 m^3/a]	4.299	4.659	3.907	4.118	3.738	4.139	3.870	4.085	4.114
Beech	[1000 m^3/a]	20.717	18.827	15.779	16.578	16.293	15.886	16.288	15.987	17.093
All deciduous trees	**[1000 m^3/a]**	**25.016**	**23.486**	**19.686**	**20.696**	**20.031**	**20.025**	**20.157**	**20.072**	**21.207**
Spruce	[1000 m^3/a]	20.995	21.555	19.657	20.599	20.808	21.243	21.074	22.562	21.178
Pine	[1000 m^3/a]	11.735	12.155	10.969	10.768	10.739	10.555	10.737	11.084	11.122
All coniferous trees	**[1000 m^3/a]**	**32.729**	**33.710**	**30.626**	**31.368**	**31.548**	**31.798**	**31.811**	**33.646**	**32.300**
All tree species	**[1000 m^3/a]**	**57.745**	**57.196**	**50.313**	**52.064**	**51.579**	**51.823**	**51.968**	**53.717**	**53.507**

Source: Own calculations

2 Quantification of leakage

Table 5: Total scenario for Europe: Total roundwood

Item	Item Code	Element	Area	Unit	FAO Historisch				Mittelwert 2015-2018		Projektion WaldD			
					2015	2016	2017	2018	[m³]	[%]	2020	2030	2040	2050
Total rawwood	1864	Production	Austria	m3	17.549.526	16.763.033	17.647.118	19.192.060	17.787.934	100%	12.286.650	12.242.491	12.205.979	12.182.480
			Belgium	m3	5.412.140	5.412.140	5.412.140	5.212.140	5.362.140	100%	3.703.788	3.690.476	3.679.470	3.672.386
			Bulgaria	m3	6.372.102	6.409.662	6.405.268	6.529.115	6.429.037	100%	4.440.725	4.424.765	4.411.568	4.403.075
			Croatia	m3	5.178.471	5.165.279	5.307.125	5.619.722	5.317.649	100%	3.673.057	3.659.856	3.648.941	3.641.916
			~~Cyprus~~	~~m3~~										
			Czechia	m3	16.163.000	17.617.000	19.387.000	25.689.000	19.714.000	100%	13.617.041	13.568.099	13.527.635	13.501.591
			Denmark	m3	4.311.300	3.842.100	3.842.100	3.842.100	3.959.400	100%	2.734.874	2.725.045	2.716.918	2.711.687
			Estonia	m3	9.515.031	10.218.940	9.947.728	11.452.000	10.283.425	100%	7.103.064	7.077.535	7.056.428	7.042.843
			Finland	m3	59.410.884	61.433.874	63.279.358	68.289.165	63.103.320	100%	43.587.323	43.430.665	43.301.140	43.217.777
			France	m3	51.005.348	51.228.506	49.769.664	49.381.975	50.346.373	100%	34.775.724	34.650.735	34.547.395	34.480.885
			Germany	m3	68.999.000	66.179.000	65.717.000	71.802.000	68.174.250	100%	47.089.963	46.920.716	46.780.783	46.690.721
			Greece	m3	1.432.000	1.432.000	1.432.000	1.432.000	1.432.000	100%	989.125	985.570	982.630	980.739
			Hungary	m3	5.743.969	5.586.169	5.586.169	5.673.180	5.647.372	100%	3.900.806	3.886.786	3.875.194	3.867.734
			Ireland	m3	2.907.990	3.050.423	2.944.332	3.540.623	3.110.842	100%	2.148.750	2.141.027	2.134.642	2.130.532
			Italy	m3	12.887.464	12.928.000	12.928.000	12.908.020	12.912.871	100%	8.919.301	8.887.243	8.860.739	8.843.680
			Latvia	m3	12.294.416	13.051.406	12.896.149	12.942.170	12.796.035	100%	8.838.599	8.806.832	8.780.567	8.763.662
			Lithuania	m3	6.414.000	6.747.000	6.795.000	6.982.000	6.734.500	100%	4.651.718	4.634.999	4.621.176	4.612.279
			Luxembourg	m3	372.389	324.712	367.760	447.900	378.190	100%	261.227	260.288	259.512	259.012
			~~Malta~~	~~m3~~										
			Netherlands	m3	2.245.700	3.253.305	3.150.886	3.113.422	2.940.828	100%	2.031.317	2.024.016	2.017.980	2.014.095
			Poland	m3	41.375.282	42.401.232	45.312.633	46.586.000	43.918.787	100%	30.336.000	30.226.969	30.136.822	30.078.803
			Portugal	m3	11.399.677	13.103.429	13.555.016	13.957.100	13.003.806	100%	8.982.112	8.949.829	8.923.137	8.905.959
			Romania	m3	15.314.700	15.116.714	14.491.635	14.975.408	14.974.614	100%	10.343.407	10.306.232	10.275.495	10.255.713
			Slovakia	m3	8.994.604	9.266.868	9.361.492	9.602.854	9.306.455	100%	6.428.242	6.405.138	6.386.036	6.373.742
			Slovenia	m3	5.054.443	5.381.391	4.509.048	5.093.701	5.009.646	100%	3.460.310	3.447.873	3.437.590	3.430.972
			Spain	m3	17.427.490	16.248.295	16.910.937	17.457.119	17.010.960	100%	11.749.972	11.707.741	11.672.824	11.650.352
			Sweden	m3	74.300.000	74.800.000	72.880.000	73.028.000	73.752.000	100%	50.942.680	50.759.585	50.608.203	50.510.773
			EU 27	**m3**	**462.080.926**	**466.960.478**	**469.835.558**	**494.748.774**	**473.406.434**	**100%**	**326.995.774**	**325.820.511**	**324.848.804**	**324.223.407**

Source: FAOSTAT: Production and Trade, own calculations

Table 6: Overall scenario for Europe: Wood fuel, coniferous

Item	Item Code	Element	Area	Unit	FAO Historisch				Mittelwert 2015-2018		Projektion WaldD			
					2015	2016	2017	2018	[m³]	[%]	2020	2030	2040	2050
Wood fuel, coniferous	1627	Production	Austria	m3	2.999.342	2.709.688	2.872.955	3.217.600	2.949.896	17%	2.037.580	2.030.257	2.024.202	2.020.305
			Belgium	m3	61.570	61.570	61.570	61.570	61.570	1%	42.528	42.375	42.249	42.168
			Bulgaria	m3	603.627	792.901	875.117	850.358	780.501	12%	539.115	537.177	535.575	534.544
			Croatia	m3	62.546	58.050	62.165	62.165	61.232	1%	42.294	42.142	42.017	41.936
			~~Cyprus~~	~~m3~~										
			Czechia	m3	1.514.000	1.550.000	1.647.000	3.600.000	2.077.750	11%	1.435.163	1.430.005	1.425.740	1.422.995
			Denmark	m3	1.532.400	1.357.500	1.357.500	1.357.500	1.401.225	35%	967.867	964.389	961.513	959.662
			Estonia	m3	1.200.000	1.100.000	1.072.727	1.200.000	1.143.182	11%	789.629	786.791	784.445	782.935
			Finland	m3	3.946.391	3.389.162	3.677.519	3.547.190	3.640.066	6%	2.514.301	2.505.264	2.497.792	2.492.984
			France	m3	2.596.209	2.594.000	2.440.901	2.366.181	2.499.323	5%	1.726.356	1.720.151	1.715.021	1.711.719
			Germany	m3	9.045.000	8.498.000	8.432.000	8.135.000	8.527.500	13%	5.890.196	5.869.025	5.851.522	5.840.257
			Greece	m3	97.000	97.000	97.000	97.000	97.000	7%	67.001	66.760	66.561	66.433
			Hungary	m3	140.358	148.757	148.757	133.690	142.891	3%	98.699	98.344	98.051	97.862
			Ireland	m3	105.126	255.435	149.344	109.304	154.802	5%	106.926	106.542	106.224	106.020
			Italy	m3	1.180.000	1.180.000	1.180.000	1.180.000	1.180.000	9%	815.061	812.131	809.709	808.150
			Latvia	m3	200.000	200.000	200.000	200.000	200.000	2%	138.146	137.649	137.239	136.975
			Lithuania	m3	739.000	754.000	721.000	441.000	663.750	10%	458.472	456.824	455.461	454.585
			Luxembourg	m3	27.721	28.034	36.230	45.900	34.471	9%	23.810	23.725	23.654	23.608
			~~Malta~~	~~m3~~										
			Netherlands	m3	140.000	411.000	420.000	420.000	347.750	12%	240.201	239.338	238.624	238.165
			Poland	m3	2.694.000	2.570.698	2.607.537	2.595.500	2.616.934	6%	1.807.593	1.801.097	1.795.725	1.792.268
			Portugal	m3	200.000	207.266	169.437	234.600	202.826	2%	140.098	139.594	139.178	138.910
			Romania	m3	1.017.574	869.986	858.392	741.416	871.842	6%	602.207	600.043	598.253	597.101
			Slovakia	m3	237.744	251.094	317.812	262.126	267.194	3%	184.559	183.895	183.347	182.994
			Slovenia	m3	202.520	180.018	153.015	198.020	183.393	4%	126.675	126.220	125.843	125.601
			Spain	m3	2.895.890	1.418.927	1.036.385	1.036.385	1.596.897	9%	1.103.024	1.099.059	1.095.781	1.093.672
			Sweden	m3	3.500.000	3.450.000	3.750.000	3.500.000	3.550.000	5%	2.452.090	2.443.276	2.435.990	2.431.300
			EU 27	**m3**	**36.938.018**	**34.133.086**	**34.344.363**	**35.592.505**	**35.251.993**	**7%**	**24.349.590**	**24.262.075**	**24.189.717**	**24.143.147**

Source: FAOSTAT: Production and Trade, own calculations

Table 7: Overall scenario for Europe: Wood fuel, non-coniferous

Item	Item Code	Element	Area	Unit	FAO Historisch 2015	2016	2017	2018	Mittelwert 2015-2018 [m³]	[%]	Projektion WaldD 2020	2030	2040	2050
Wood fuel, non-coniferous	1628	Production	Austria	m3	1.979.722	1.880.264	2.035.758	2.025.620	1.980.341	11%	1.367.880	1.362.964	1.358.899	1.356.283
			Belgium	m3	831.180	831.180	831.180	831.180	831.180	16%	574.121	572.057	570.351	569.253
			Bulgaria	m3	2.244.572	2.135.311	2.114.138	1.998.856	2.123.219	33%	1.466.570	1.461.299	1.456.941	1.454.136
			Croatia	m3	1.706.195	1.710.404	1.795.877	2.108.474	1.830.238	34%	1.264.199	1.259.655	1.255.899	1.253.481
			~~Cyprus~~	~~m3~~										
			Czechia	m3	822.000	794.000	729.000	646.000	747.750	4%	516.493	514.637	513.102	512.114
			Denmark	m3	745.800	703.600	703.600	703.600	714.150	18%	493.284	491.512	490.046	489.102
			Estonia	m3	1.875.000	2.091.667	2.033.333	2.300.000	2.075.000	20%	1.433.264	1.428.112	1.423.853	1.421.112
			Finland	m3	4.018.054	3.717.976	4.271.572	4.211.541	4.054.786	6%	2.800.760	2.790.694	2.782.371	2.777.014
			France	m3	23.365.884	23.320.416	21.968.107	21.295.629	22.487.509	45%	15.532.785	15.476.958	15.430.801	15.401.094
			Germany	m3	14.300.000	13.664.000	13.956.000	13.739.000	13.914.750	20%	9.611.328	9.576.784	9.548.222	9.529.840
			Greece	m3	968.000	968.000	968.000	968.000	968.000	68%	668.626	666.223	664.236	662.957
			Hungary	m3	2.538.813	2.487.393	2.487.393	2.580.390	2.523.497	45%	1.743.054	1.736.789	1.731.609	1.728.276
			Ireland	m3	97.669	60.929	60.929	101.518	80.261	3%	55.439	55.240	55.075	54.969
			Italy	m3	9.659.000	9.659.000	9.659.000	9.659.000	9.659.000	75%	6.671.756	6.647.777	6.627.951	6.615.191
			Latvia	m3	1.000.000	1.500.000	2.000.000	2.000.000	1.625.000	13%	1.122.435	1.118.401	1.115.066	1.112.919
			Lithuania	m3	1.371.000	1.331.000	1.294.000	1.308.000	1.326.000	20%	915.907	912.615	909.894	908.142
			Luxembourg	m3	40.258	36.697	33.600	38.620	37.294	10%	25.760	25.667	25.591	25.541
			~~Malta~~	~~m3~~										
			Netherlands	m3	1.257.000	1.890.000	1.912.000	1.921.000	1.745.000	59%	1.205.323	1.200.991	1.197.409	1.195.104
			Poland	m3	2.803.000	2.724.445	2.640.676	2.665.000	2.708.280	6%	1.870.689	1.863.965	1.858.407	1.854.829
			Portugal	m3	400.000	884.763	878.213	943.600	776.644	6%	536.451	534.523	532.929	531.903
			Romania	m3	4.061.727	4.293.795	4.055.491	3.908.352	4.079.841	27%	2.818.067	2.807.938	2.799.564	2.794.174
			Slovakia	m3	322.050	264.079	273.297	261.494	280.230	3%	193.563	192.867	192.292	191.922
			Slovenia	m3	1.039.709	1.091.694	885.828	944.113	990.336	20%	684.054	681.596	679.563	678.255
			Spain	m3	1.626.981	1.504.379	1.232.209	1.232.209	1.398.945	8%	966.292	962.819	959.948	958.100
			Sweden	m3	3.500.000	3.450.000	3.750.000	3.500.000	3.550.000	5%	2.452.090	2.443.276	2.435.990	2.431.300
			EU 27	**m3**	**82.573.614**	**82.994.992**	**82.569.201**	**81.891.196**	**82.507.251**	**17%**	**56.990.189**	**56.785.360**	**56.616.007**	**56.507.010**

Source: FAOSTAT: Production and Trade, own calculations

Table 8: Overall scenario for Europe: Industrial roundwood, coniferous

Item	Item Code	Element	Area	Unit	FAO Historisch				Mittelwert 2015-2018		Projektion WaldD			
					2015	2016	2017	2018	[m³]	[%]	2020	2030	2040	2050
Industrial roundwood, coniferous	1866	Production	Austria	m3	11.571.481	11.144.513	11.721.906	12.820.998	11.814.725	66%	8.160.778	8.131.448	8.107.197	8.091.589
			Belgium	m3	3.515.400	3.515.400	3.515.400	3.315.400	3.465.400	65%	2.393.654	2.385.051	2.377.938	2.373.360
			Bulgaria	m3	2.427.526	2.436.254	2.330.248	2.623.747	2.454.444	38%	1.695.357	1.689.263	1.684.225	1.680.983
			Croatia	m3	775.334	749.552	812.520	812.520	787.482	15%	543.937	541.982	540.365	539.325
			~~Cyprus~~	~~m3~~										
			Czechia	m3	12.871.000	14.374.000	16.088.000	20.613.000	15.986.500	81%	11.042.347	11.002.659	10.969.845	10.948.726
			Denmark	m3	1.768.900	1.555.600	1.555.600	1.555.600	1.608.925	41%	1.111.332	1.107.338	1.104.035	1.101.910
			Estonia	m3	4.381.364	4.827.273	4.700.001	5.427.000	4.833.910	47%	3.338.924	3.326.923	3.317.001	3.310.615
			Finland	m3	42.924.675	45.360.272	46.528.477	50.632.499	46.361.481	73%	32.023.241	31.908.145	31.812.985	31.751.738
			France	m3	16.490.702	16.519.319	16.716.683	16.988.983	16.678.922	33%	11.520.623	11.479.216	11.444.981	11.422.947
			Germany	m3	39.894.000	37.539.000	37.306.000	43.183.000	39.480.500	58%	27.270.345	27.172.332	27.091.295	27.039.139
			Greece	m3	230.000	230.000	230.000	230.000	230.000	16%	158.868	158.297	157.825	157.521
			Hungary	m3	808.385	854.073	854.073	833.970	837.625	15%	578.572	576.493	574.774	573.667
			Ireland	m3	2.702.132	2.728.560	2.728.560	3.325.155	2.871.102	92%	1.983.155	1.976.027	1.970.134	1.966.341
			Italy	m3	1.292.445	1.318.000	1.318.000	1.298.020	1.306.616	10%	902.518	899.275	896.593	894.867
			Latvia	m3	8.045.736	8.623.985	7.549.275	7.700.000	7.979.749	62%	5.511.848	5.492.038	5.475.658	5.465.117
			Lithuania	m3	2.713.000	2.993.000	3.083.000	3.248.000	3.009.250	45%	2.078.578	2.071.107	2.064.930	2.060.955
			Luxembourg	m3	156.351	133.268	177.890	238.130	176.410	47%	121.851	121.413	121.051	120.818
			~~Malta~~	~~m3~~										
			Netherlands	m3	550.000	642.651	536.558	467.913	549.281	19%	379.404	378.041	376.913	376.188
			Poland	m3	27.937.438	29.254.685	32.309.678	33.182.000	30.670.950	70%	21.185.329	21.109.186	21.046.232	21.005.714
			Portugal	m3	2.788.056	3.836.000	3.811.886	4.109.100	3.636.261	28%	2.511.672	2.502.645	2.495.181	2.490.378
			Romania	m3	5.006.838	4.550.441	4.419.524	4.631.161	4.651.991	31%	3.213.267	3.201.718	3.192.170	3.186.024
			Slovakia	m3	4.424.515	4.942.543	5.200.488	5.527.265	5.023.703	54%	3.470.020	3.457.548	3.447.236	3.440.600
			Slovenia	m3	2.860.000	3.313.000	2.752.000	3.291.279	3.054.070	61%	2.109.536	2.101.954	2.095.685	2.091.651
			Spain	m3	6.183.470	6.121.920	7.792.271	8.012.644	7.027.576	41%	4.854.154	4.836.708	4.822.283	4.812.999
			Sweden	m3	63.760.000	64.300.000	62.130.000	61.241.000	62.857.750	85%	43.417.700	43.261.652	43.132.631	43.049.592
			EU 27	**m3**	**266.078.748**	**271.863.309**	**276.168.038**	**295.308.384**	**277.354.620**	**59%**	**191.577.009**	**190.888.458**	**190.319.164**	**189.952.762**

Source: FAOSTAT: Production and Trade, own calculations

Table 9: Overall scenario for Europe: Industrial roundwood, non-coniferous

Item	Item Code	Element	Area	Unit	FAO Historisch 2015	2016	2017	2018	Mittelwert 2015-2018 [m³]	[%]	Projektion WaldD 2020	2030	2040	2050
Industrial roundwood, non-coniferous	1867	Production	Austria	m3	998.981	1.028.568	1.016.499	1.127.842	1.042.973	6%	720.412	717.823	715.682	714.304
			Belgium	m3	1.003.990	1.003.990	1.003.990	1.003.990	1.003.990	19%	693.485	690.993	688.932	687.606
			Bulgaria	m3	1.096.377	1.045.196	1.085.765	1.056.154	1.070.873	17%	739.684	737.025	734.827	733.412
			Croatia	m3	2.634.396	2.647.273	2.636.563	2.636.563	2.638.699	50%	1.822.627	1.816.076	1.810.660	1.807.174
			~~Cyprus~~	~~m3~~										
			Czechia	m3	956.000	899.000	923.000	830.000	902.000	5%	623.038	620.799	618.947	617.756
			Denmark	m3	264.200	225.400	225.400	225.400	235.100	6%	162.390	161.807	161.324	161.014
			Estonia	m3	2.058.667	2.200.000	2.141.667	2.525.000	2.231.334	22%	1.541.248	1.535.708	1.531.128	1.528.181
			Finland	m3	8.521.764	8.966.464	8.801.790	9.897.935	9.046.988	14%	6.249.021	6.226.562	6.207.992	6.196.040
			France	m3	8.552.553	8.794.771	8.643.973	8.731.182	8.680.620	17%	5.995.960	5.974.410	5.956.592	5.945.124
			Germany	m3	5.760.000	6.478.000	6.023.000	6.745.000	6.251.500	9%	4.318.095	4.302.576	4.289.744	4.281.485
			Greece	m3	137.000	137.000	137.000	137.000	137.000	10%	94.630	94.290	94.009	93.828
			Hungary	m3	2.256.413	2.095.946	2.095.946	2.125.130	2.143.359	38%	1.480.481	1.475.160	1.470.761	1.467.929
			Ireland	m3	3.063	5.499	5.499	4.646	4.677	0%	3.230	3.219	3.209	3.203
			Italy	m3	756.019	771.000	771.000	771.000	767.255	6%	529.965	528.061	526.486	525.472
			Latvia	m3	3.048.680	2.727.421	3.146.874	3.042.170	2.991.286	23%	2.066.170	2.058.743	2.052.604	2.048.652
			Lithuania	m3	1.591.000	1.669.000	1.697.000	1.985.000	1.735.500	26%	1.198.761	1.194.452	1.190.890	1.188.598
			Luxembourg	m3	148.059	126.713	120.040	125.250	130.016	34%	89.806	89.483	89.216	89.044
			~~Malta~~	~~m3~~										
			Netherlands	m3	298.700	309.654	282.328	304.509	298.798	10%	206.388	205.647	205.033	204.639
			Poland	m3	7.940.844	7.851.404	7.754.742	8.143.500	7.922.623	18%	5.472.389	5.452.720	5.436.459	5.425.992
			Portugal	m3	8.011.621	8.175.400	8.695.480	8.669.800	8.388.075	65%	5.793.891	5.773.067	5.755.850	5.744.768
			Romania	m3	5.228.561	5.402.492	5.158.228	5.694.479	5.370.940	36%	3.709.867	3.696.533	3.685.509	3.678.413
			Slovakia	m3	4.010.295	3.809.152	3.569.895	3.551.969	3.735.328	40%	2.580.101	2.570.828	2.563.161	2.558.226
			Slovenia	m3	952.214	796.679	718.205	660.289	781.847	16%	540.045	538.104	536.499	535.466
			Spain	m3	6.721.149	7.203.069	6.850.072	7.175.881	6.987.543	41%	4.826.502	4.809.155	4.794.812	4.785.581
			Sweden	m3	3.540.000	3.600.000	3.250.000	4.787.000	3.794.250	5%	2.620.800	2.611.381	2.603.593	2.598.580
			EU 27	**m3**	**76.490.546**	**77.969.091**	**76.753.956**	**81.956.689**	**78.292.571**	**17%**	**54.078.986**	**53.884.619**	**53.723.917**	**53.620.488**

Source: FAOSTAT: Production and Trade, own calculations

Table 10: Roundwood production in million m³ for Reference and EU-BioDiv-Scenarios in 2020, 2030, 2040 and 2050. Leakage is the difference between both scenarios

2020				
Rank	Country	Reference	EU BioDiv	Leakage
1	USA	421.9	441.3	19.4
2	Canada	149.6	166.4	16.8
3	Russia	194.0	207.4	13.4
4	Brazil	249.3	256.6	7.2
5	New Zealand	27.7	31.3	3.7
6	Chile	53.3	56.0	2.7
7	Australia	29.5	32.2	2.7
8	Indonesia	111.2	113.5	2.3
9	Japan	19.5	21.5	2.1
10	China	430.4	432.3	1.9
11	United Kingdom	11.4	12.9	1.5
12	Malaysia	22.8	24.4	1.5
13	Vietnam	38.0	39.4	1.4
14	Turkey	23.5	24.9	1.3
15	Ukraine	19.5	20.6	1.1
16	Thailand	36.6	37.7	1.1
17	South Africa	29.1	29.9	0.8
18	Mexico	41.9	42.7	0.8
19	Belarus	17.3	18.0	0.7
20	Norway	12.8	13.5	0.7
21	India	318.6	319.2	0.6
22	Uruguay	11.1	11.6	0.5
23	Bosnia/Herzegovina	4.2	4.7	0.5
24	South Korea	8.1	8.5	0.4
25	Switzerland	5.1	5.6	0.4

2030				
Rank	Country	Reference	EU Bio-Div	Leakage
1	USA	465.0	500.1	35.1
2	Canada	147.7	170.9	23.2
3	Russia	208.5	224.6	16.1
4	Brazil	250.9	259.2	8.3
5	New Zealand	27.6	31.3	3.7
6	Australia	30.2	33.7	3.5
7	Chile	52.0	55.1	3.1
8	Turkey	25.8	28.5	2.7
9	Malaysia	27.0	29.5	2.5
10	Ukraine	23.0	25.4	2.4
11	Japan	19.7	22.0	2.3
12	China	474.0	476.3	2.3
13	Belarus	20.4	22.4	2.0
14	Vietnam	36.7	38.5	1.9
15	Norway	14.8	16.6	1.8
16	Indonesia	111.7	113.4	1.7
17	United Kingdom	12.1	13.7	1.6
18	South Africa	31.6	33.0	1.4
19	Thailand	35.0	36.2	1.3
20	Mexico	39.7	40.8	1.1
21	India	299.6	300.4	0.8
22	Bosnia/Herzegovina	4.5	5.3	0.8
23	South Korea	11.0	11.8	0.8
24	Switzerland	5.6	6.3	0.7
25	Argentina	17.6	18.3	0.7

2040				
Rank	Country	Reference	EU Bio-Div	Leakage
1	USA	501.8	559.7	57.8
2	Russia	212.4	234.8	22.4
3	Canada	145.2	166.8	21.6
4	Brazil	258.4	269.9	11.4
5	Ukraine	27.2	31.7	4.5
6	India	288.1	292.3	4.2
7	Chile	49.3	52.8	3.4
8	Turkey	27.2	30.6	3.4
9	Malaysia	32.4	35.4	3.0
10	China	481.7	484.7	3.0
11	New Zealand	26.7	29.5	2.9
12	Australia	31.4	34.2	2.8
13	Belarus	24.2	26.4	2.2
14	Norway	17.1	18.7	1.7
15	Japan	19.3	20.7	1.5
16	Indonesia	110.1	111.4	1.3
17	Thailand	33.8	35.1	1.3
18	South Africa	34.1	35.2	1.2
19	Mexico	40.2	41.2	1.0
20	South Korea	14.0	14.9	0.9
21	Vietnam	34.9	35.7	0.8
22	Switzerland	6.2	6.9	0.7
23	Argentina	17.7	18.3	0.6
24	Papua New Guinea	8.3	8.9	0.6
25	Bosnia and Herzegovina	5.0	5.5	0.5

2050				
Rank	Country	Reference	EU BioDiv	Leakage
1	USA	537.8	601.2	63.4
2	Russia	215.2	245.9	30.7
3	Canada	146.5	168.0	21.6
4	Brazil	268.5	286.0	17.5
5	Malaysia	39.8	45.4	5.6
6	Ukraine	31.6	36.8	5.2
7	Turkey	27.9	32.1	4.2
8	India	284.7	288.7	4.1
9	Chile	46.5	50.2	3.7
10	Belarus	28.0	30.9	2.9
11	New Zealand	26.2	28.7	2.5
12	Norway	18.3	20.5	2.3
13	Australia	32.7	34.6	1.9
14	China	467.2	469.1	1.9
15	Indonesia	105.4	107.1	1.7
16	Japan	18.7	20.2	1.4
17	Argentina	17.1	18.2	1.1
18	Mexico	40.4	41.4	1.0
19	Cameroon	10.6	11.6	1.0
20	South Korea	16.9	17.7	0.7
21	Philippines	14.0	14.8	0.7
22	Bosnia/Herzegovina	5.6	6.2	0.5
23	Papua New Guinea	8.5	9.0	0.5
24	Colombia	11.3	11.8	0.5
25	Iran	2.2	2.7	0.5

Source: Own calculations

3 Country wise indicators

The values for the aggregated indicators are derived from principal component analyses. They cannot be interpreted in the units of the original indicators and are used only for comparison between countries. Non-aggregated original indicators are given in the original units.

Table 11: Country wise indicators

	Sustainable forest management (SFM), aggregated	Governance Quality, aggregated	Intact forest landscapes as percentage of forest (%)	Red List Index (2020)	Conservation measures, aggregated	Above ground biomass stock forest (t/ha), 2016	Share of degraded land area in relation to total land area (%), 2015	Total forest area per capita (ha)	Annual net rate of change in forest area (%) (2015-2020)	Employment in forestry and logging (1000 FTE) 2015	Poverty and inequality, aggregated
USA	-0,60	2,04	14,20	0,83	-0,62	94,67	19,90	0,94	0,02	72,78	0,34
Russia	-0,03	-2,24	28,30	0,95	-1,25	77,33	6,00	5,65	0,08	76,27	-0,11
Canada	1,48	2,59	51,00	0,96	-0,87	90,43	19,90	9,23	-0,01	53,05	-0,42
Brazil	-1,18	-1,86	31,70	0,90	0,37	171,92	27,00	2,35	-0,29	104,99	1,73
Malaysia	0,57	0,36	6,50	0,77	-0,36	209,87	16,00	0,60	-0,36	25,11	0,23
Ukraine	0,77	-2,23	0,00	0,93	-0,53	140,00	25,00	0,22	0,66	61,70	-1,18
Turkey	-0,02	-1,44	0,00	0,88	0,61	48,11	9,00	0,27	0,54	286,46	0,32
India	-1,01	-1,11	5,60	0,67	-0,23	68,70	30,00	0,05	0,37	6242,00	1,27
Chile	-0,52	1,31	36,90	0,76	-0,13	219,27	1,00	0,95	0,68	116,24	0,57
Belarus	3,19	-2,14	0,00	0,97	n.a.	156,10	1,00	0,93	0,31	42,01	-1,27
New Zealand	0,04	2,93	25,40	0,62	0,86	294,65	19,90	2,01	0,09	8,71	-0,47
Norway	1,04	2,94	1,40	0,94	-1,01	64,16	19,90	2,28	0,06	5,77	-1,09
Australia	-1,22	2,60	9,80	0,82	-0,32	83,98	19,90	5,28	0,14	8,98	-0,37
China	-0,93	-1,13	1,60	0,74	-0,55	64,72	27,00	0,15	0,90	1147,30	0,02
Indonesia	-1,50	-1,31	20,10	0,75	1,78	178,95	21,00	0,34	-0,62	41,58	0,33
Japan	0,00	2,05	0,40	0,77	-0,33	113,00	19,90	0,20	-0,01	63,66	-0,50
Argentina	-0,32	-1,37	6,50	0,85	-1,00	185,74	39,00	0,64	-0,36	9,00	0,33
Mexico	-2,04	-1,86	1,80	0,67	-0,65	52,44	47,00	0,51	-0,19	147,84	0,75
Cameroon	-1,15	-3,09	13,40	0,84	-0,27	265,05	0,00	0,79	-0,27	34,00	2,27
South Korea	-1,43	1,09	0,00	0,89	n.a.	131,69	19,90	0,12	-0,16	254,81	-0,65

Philippines	-1,94	-1,55	1,60	0,67	0,31	219,77	38,00	0,07	0,49	4,84	0,94
Bosnia/ Her-zegov.	1,65	-1,95	0,00	0,90	-0,29	156,37	4,00	0,66	0,25	271,00	-0,53
Papua New Guinea	-1,89	-2,59	35,10	0,83	-1,16	176,00	21,00	4,09	-0,09	271,00	0,51
Colombia	-1,02	-1,32	31,00	0,75	-0,17	184,13	7,00	1,19	-0,33	31,90	1,38
Iran	-1,76	-2,86	0,00	0,84	-0,56	137,67	23,00	0,13	0,11	10,81	0,23
Switzerland	1,15	2,98	0,00	0,97	0,97	193,06	19,90	0,15	0,27	12,10	-0,56
Serbia	-0,34	-1,28	0,00	0,96	-0,32	156,99	6,00	0,39	0,02	9,09	0,12
Laos	-1,39	-2,81	3,80	0,83	-0,27	121,50	19,90	2,31	-0,02	271,00	1,24
Congo, Rep.	-0,69	-3,74	40,70	0,97	-0,35	198,80	10,00	0,25	-0,06	12,00	5,21
Morocco	-1,23	-1,52	0,00	0,89	-1,12	39,89	19,00	0,16	0,20	105,02	0,15
Bolivia	-1,38	-2,65	28,90	0,87	0,00	131,26	18,00	4,42	-0,46	3,00	0,63
Costa Rica	-1,14	-0,11	6,20	0,83	1,29	196,00	9,00	0,60	0,54	14,81	0,98
Peru	0,67	-1,47	68,50	0,73	0,43	237,79	19,90	2,22	-0,24	23,00	0,56
South Africa	-1,16	-0,87	0,00	0,77	-1,29	85,66	78,00	0,29	-0,21	158,00	3,51
Côte d'Ivoire	-1,33	-2,06	1,70	0,91	0,84	94,45	14,00	0,11	-3,70	18,17	2,07
Kyrgyzstan	-0,27	-2,55	0,00	0,98	-0,90	49,66	24,00	0,20	0,99	1,90	-0,98
Gabon	-0,38	-2,81	41,20	0,89	-0,54	223,25	16,00	10,83	-0,05	13,00	0,16

Source: Own calculations

n.a.: Data not available.

4 Description of the indicators

Governance Quality

All governance indicators used are part of the World Governance Indicators, which are calculated and published by the World Bank. The indicator values are units of a standard normal distribution. They predominantly lie in a range between -2.5 and 2.5 (Kaufmann et al. 2010). Detailed documentation of the World Governance Indicators (WGI), interactive tools for examining the data, and full access to the underlying source data are available at www.govindicators.org.

- **Corruption Control**
  Corruption control covers the extent to which public power is exercised for private gain, including small and large scale corruption, as well as the "conquest" of the state by elites and private interests.
- **Government effectiveness**
  The effectiveness of government action measures the quality of public services, the quality of the civil service and the degree of its independence from political pressure, the quality of policy formulation and implementation, and the credibility of the government's commitment to such measures.
- **Regulatory quality**
  The quality of public administration encompasses the government's ability to formulate and implement sound policies and regulations that enable and promote private sector development.
- **Rule of law**
  The rule of law measures the extent to which members of society have confidence in and adhere to the rules of society, particularly the quality of contract enforcement, property rights, police and courts, and the likelihood of criminal offences and violence.

Sustainable Forest Management (SFM)

- **Proportion of forest area under a long-term forest management plan (%)**
  This indicator is calculated as the share of forest area with a forest management plan related to the total forest area. The existence of a documented forest management plan is considered to be the basis for long-term and sustainable management of forest resources for a variety of management objectives.
  An increasing area managed under a forest management plan is therefore an indicator of progress towards SFM (Global Forest Resources Assessment, FAO 2020b).
- **Proportion of forests under certification (%)**
  This indicator is calculated as the share of certified forest area related to the total forest area. Such certification systems apply standards that are generally higher than the legal requirements for SFM in a country. Compliance is verified by an independent and accredited certifier. The increase in certified forest area therefore provides an additional indication of a country's progress towards SFM.

However, it should be noted that sustainably managed forest land that is not certified, either because its owners have decided against it or because there is no credible or affordable certification system in place in the respective area, can be large.
Source: Forest area under independently verified forest management certification schemes according to Global Forest Resources Assessment (FAO 2020b).

The indicator expresses the proportion of the total roundwood harvested in a country from forest areas with a long-term management plan and how the proportion changes due to leakage. The data basis for the calculation of the indicator is the roundwood harvested by a country as reported by GFPM in m^3/ha, the forest area of a country with a long-term management plan in ha (FAO 2020b) and the annual average increment of the forest of a country in m^3/ha. Information on the annual average wood increment of was derived from the Global Forest Ressources Assessment 2015 (FAO 2015, Tab. 17). If information on increment was missing for a country, the value was estimated by expert knowledge on the basis of the geographical location and the predominant forest types. By multiplying the forest area with long-term management plan by the annual increment, the arithmetically available raw wood potential of the forest with long-term management plan was first calculated. This amount was then compared to the total amount of roundwood felled. This provided the percentage of the total roundwood that can be provided by forest areas with long-term management plans. As a limitation, it should be noted that the indicator does not say anything about the quality and effectiveness of the management plans in the countries studied.

- **Percentage of roundwood that can be provided by certified forest areas (%)**
  The indicator expresses how much of a country's total roundwood felling can mathematically be provided by the certified forest area of a country and how the proportion changes due to leakage. The data basis for the calculation of the indicator is the round timber felling in m3 as reported by GFPM, the FSC (FSC 2020) and PEFC (PEFC 2020). Information was provided on certified forest areas in ha and the average increment of solid wood of the forest of a country in m3/ha (FAO 2015, Tab. 17). If information on increment was missing for a country, the value was estimated by expert knowledge on the basis of the geographical location and the predominant forest types. By multiplying the certified forest area by the annual increment of raw wood, the available raw wood potential of the certified forest area was calculated. This quantity was then compared to the total amount of roundwood felled. This results in the percentage of the total roundwood that can be provided by the certified forest area of a country.

Forest condition

- **Above ground biomass stock in the forest (tons per hectare), 2016**
  Changes in the above-ground biomass stock in forests show the balance between growth of the biomass stock due to forest growth and losses due to timber extraction, natural losses, fire, wind, pests and diseases. At the country level and over a longer period of time, SFM would mean a stable or, up to a forest type specific maximum biomass stock per hectare, while a long-term reduction of the biomass stock per hectare would mean either unsustainable forest management and/or unexpected major losses due to fire, wind, pests or diseases (FAO 2020b).

- **Proportion of land that is degraded over total land area (%)**
  Land degradation is defined as the reduction or loss of biological or economic productivity and complexity of unirrigated cropland, irrigated farmland or pasture, forest and woodland areas resulting from a combination of pressures, including land use and management practices. This definition has been adopted and is used by the 196 countries that are parties to the UNCCD. The unit of measurement for this indicator is the spatial extent (hectares or km2), expressed as a proportion (percentage or %) of degraded land area in relation to the total land area (United Nations Statistics Division 2020).

Deforestation pressure

- **Total forest area per capita (ha)**
  The total forest area per capita is calculated by dividing the total forest area in hectares by the total population size of the country. Source for total forest area: Global Assessment of Forest Resources (FAO 2020b); Source for total population size: World Development Indicators (World Bank 2020b).
- **Annual net change rate of forest area (%) (2015 – 2020)**
  Trends in the forest area are crucial for SFM monitoring. The indicator focuses both on the direction of change (whether there is a loss or gain in forest area) and on how the rate of change changes over time. The latter is important to measure progress between countries that are losing forest area but have been able to reduce the annual rate of forest area loss. The average annual rate of change for 2015 to 2020 is calculated on the basis of the indicator "Annual net rate of change in forest area" from Global Forest Resources Assessment

Biodiversity conservation

- **Intact forest landscapes as percentage of forest (%)**
  An intact forest landscape (IFL) is a seamless mosaic of forest and naturally treeless ecosystems, which, by means of remote sensing, does not show any human activity and has a minimum area of 500 km^2. IFLs are large enough to conserve all original biodiversity, including viable populations of species with large-scale habitats (Potapov, p. 2008). The term "intact forest landscape" is different from "primary forest" as defined by the Food and Agriculture Organization of the United Nations (FAO) (2010). Intact forest landscapes were set in relation to the forest area. This was calculated using the global canopy cover dataset of the year 2000 (Hansen, M.C. 2013). Forest area was determined as areas with at least 20 % tree crown cover (Global Forest Watch 2014, Potapov et al., 2017).
- **Red List Index**
  The Red List Index measures the change in the aggregated risk of extinction between species groups. It is based on real changes in the number of species in each category of risk of extinction.
  The IUCN Red List of Threatened Species (Bubb et al. 2009) is expressed as a change of an index between 0 and 1. The values of the red list index range from 1 (all species are categorized as "least threatened") to 0 (all species are categorized as “extinct2), indicating how far the species

group as a whole has moved towards extinction. Thus, the Red List Index allows comparisons between species groups both in terms of their overall level of risk of extinction (i.e. how threatened they are on average) and the rate at which that risk changes over time. A downward trend in the Red List Index over time means that the expected rate of future species extinction is worsening (i. e. the rate of biodiversity loss is increasing). An upward trend means that the expected rate of species extinction is decreasing (i.e. the rate of biodiversity loss decreases) and an unchanged trend means that the expected rate of species extinction remains the same. An upward trend in the Red List Index would indicate that SDG Goal 15.5, reducing habitat degradation and protecting threatened species, is on track. A Red List index score of 1 would indicate that biodiversity loss has been halted (United Nations Statistics Division 2020).

- **Conservation spending in US$ per km2 land area**
  The data are taken from an online database with country-by-country data on biodiversity expenditure. These take into account (domestic) financial flows from national governments, contributions from donor countries, trust funds and self-financing through payments from users, e. g. entrance fees for national parks and other user fees. Annual mean values were calculated from the data for 2001 – 2008 (Waldron, A. 2013). The annual expenditures were then divided by the respective land area (CIA, 2020).
- **Proportion of forest area within legally established protected areas (%)**
  The proportion of forest area within formally established protected areas, regardless of the purpose for which the protected areas were established (FAO 2020b).

Socio-economic aspects

- **Employment in forestry and logging (1000 FTE) 2015**
  Activities related to the production of goods from forests. This category corresponds to the ISIC / NACE Rev.2 activity A02 (forestry and logging). Full-time equivalent (FTE/FTE) is a measurement corresponding to one person working full-time during a given reference period; two half-time employees also count as one FTE/FTE (Global Forest Resources Assessment, FAO 2020b; 2020a).
- **Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population) latest available year**
  The poverty rate of 1.90 USD per day is the percentage of the population living on less than 1.90 USD per day at 2011 international prices (Weltentwicklungsindikatoren, World Bank 2020b).
- **Gini index (World Bank estimate) last available year (mainly 2016/17)**
  The Gini index measures the extent to which the distribution of income (or, in some cases, of consumer spending) between individuals or households within an economy deviates from a perfectly even distribution. A Lorenz curve shows the cumulative percentages of total income against the cumulative number of recipients, starting with the poorest person or household. The Gini index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. A Gini index of 0

therefore represents perfect equality, while an index of 100 represents perfect inequality (Weltentwicklungsindikatoren, World Bank 2020b).

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