National forest accounting plan of the Czech Republic, including the proposed forest reference level

Submission pursuant to Article 8 of Regulation (EU) 2018/841

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MINISTRY OF AGRICULTURE
OF THE CZECH REPUBLIC

Ministry of the Environment
of the Czech Republic

With the contribution of Forest Management Institute
and IFER – Institute of Forest Ecosystem Research, Ltd.

Contents

List of abbreviations

CBM	*Carbon Budget Model of the Canadian Forest Sector (also abbreviated as CBM-CFS3)*
CMA	*Czech Ministry of Agriculture*
CME	*Czech Ministry of the Environment*
CP	*Compliance Period (2021-2030)*
COSMC	*Czech Office for Surveying, Mapping and Cadastre*
CP 1	*First part of the Compliance period (2021-2025)*
CP 2	*Second part of the Compliance period (2026-2030)*
CzechTerra	*Landscape Inventory CzechTerra (also abbreviated as CZT)*
CZT 1	*CzechTerra measurement cycle 1 (2008-2009)*
CZT 2	*CzechTerra measurement cycle 2 (2014-2015)*
DW DOM	*Deadwood – carbon pool including standing dead trees and stem parts lying on the ground*
CzSO	*Czech Statistical Office*
EFISCEN	*European Forest Information Scenario Model*
FLrFL	*Forest land remaining Forest land (category 4A1 in the LULUCF GHG emission inventory)*
FMI	*Forest Management Institute, Brandýs n. Labem*
FMP	*Forest Management Plan*
FRL	*Forest Reference Level*
FRL 1	*Forest Reference Level, part 1 applicable for 2021-2025*
FRL 2	*Forest Reference Level, part 2 applicable for 2026-2030*
GHG	*Greenhouse gases*
HWP	*Harvested Wood Products*
IFER	*IFER – Institute of Forest Ecosystem Research, Ltd.*
KP	*Kyoto Protocol*
LB	*Living Biomass - carbon pool including below- and above-ground components of living trees*
LULUCF	*Land Use, Land-Use Change and Forestry*
NDFMP	*National Database of Forest Management Plans*
ND	*Natural Disturbance*
NFAP	*National Forest Accounting Plan*
NFI	*National Forest Inventory*
NFI 1	*NFI measurement cycle 1 (2001-2004)*
NFI 2	*NFI measurement cycle 2 (2011-2015)*
NIL	*National Forest Inventory*
NIR	*National Inventory Report (on greenhouse-gas emissions) under UNFCCC*
P_Av	*Proportion of harvest to biomass available for wood supply*
PA	*Paris Agreement*
PP	*Projection Period (2018-2030)*
RP	*Reference Period (2000-2009)*
UNFCCC	*United Nations Framework Convention on Climate Change*

CZECH NATIONAL FOREST ACCOUNTING PLAN

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FOREST REFERENCE LEVEL

1. General introduction

1.1 General description forest reference level (FRL) for the Czech Republic

The estimation of the forest reference level (FRL) in the Czech Republic is based on i) activity data as used in the National greenhouse gas emission inventory reporting for the Land Use, Land-Use Change and Forestry (LULUCF) sector, and ii) adoption of the specifically calibrated Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3, further denoted as CBM; Kull et al., 2016). CBM is calibrated on activity data as of 2004, which represent state of the forest and management practices of the Reference period (RP; 2000-2009). CBM estimates for RP are based on the actual (reported) activity data on wood harvest. These CBM runs represent so called consistency estimates to demonstrate the match with the GHG inventory as reported in NIR 2019 submission. The consistency estimates use the actual land area of forest land remaining forest land as of 2000, identical as used in the Czech national greenhouse gas emission inventory. Since 2010, the CBM projection estimates (2010 to 2025, i.e., including the first part of the Compliance period – CP 1) are determined using the harvest data given by the ratio of biomass removals to biomass available for wood supply (P_Av, Grassi and Pilli, 2017), which is derived from the harvest quantities observed in RP. The projection estimates are initiated on the data on forest resources for forest land remaining forest land as of 2010 (first simulation year of the projection). The Czech FRL includes changes in above- and below-ground biomass, standing and lying deadwood, as well as the contribution of harvested wood products (HWP). Apart from the known extent of forest wildfires, no other natural disturbance (ND) is explicitly included. ND is, however, included implicitly within the harvest rates, that do include a part that is attributed to commonly disturbances affecting forest management in the country, such as bark-beetle and fungal infestation, local windstorms and others. Czech Republic does not intend to use the ND provision and hence no background level is estimated and/or included in FRL (ref. to Annex VI of the LULUCF Regulation).

1.2 Consideration of the criteria from Annex IV of the LULUCF Regulation EU 2018/841

Table 1 provides the overview of the elements of the National Forest Accounting Plan according to Annex IV B of the EU LULUCF Regulation 2018/841 and the corresponding references in the document.

Table 1: Overview of the elements of the National forest accounting plan

Annex IV B paragraph item	Elements of the Czech national forestry accounting plan according to Annex IV B.	Chapter and page number(s) in the NFAP
(a)	A general description of the determination of the forest reference level	Sections 1.1, 3.1
(a)	Description of how the criteria in LULUCF Regulation were taken into account	Section 1.2
(b)	Identification of the carbon pools and greenhouse gases which have been included in the forest reference level	Sections 2.1, 3.1
(b)	Reasons for omitting a carbon pool from the forest reference level determination	Section 2.1
(b)	Demonstration of the consistency between the carbon pools included in the forest reference level	Sections 4.1, 4.3
(c)	A description of approaches, methods and models, including quantitative information, used in the determination of the forest reference level, consistent with the most recently submitted national inventory report.	Section 3
(c)	A description of documentary information on sustainable forest management practices and intensity	Section 3.2.3
(c)	A description of adopted national policies	Section 2.3.1
(d)	Information on how harvesting rates are expected to develop under different policy scenarios	Section 2.3.2
(e)	A description of how the following element was considered in the determination of the forest reference level:	-
	(i) The area under forest management	Section 3.2.1
	(ii) Emissions and removals from forests and harvested wood products as shown in greenhouse gas inventories and relevant historical data	Section 4.1
	(iii) Forest characteristics, including: - dynamic age-related forest characteristics - increments - rotation length and - other information on forest management activities under 'business as usual	Sections 3.2.1, 3.2.3
	(iv) Historical and future harvesting rates disaggregated between energy and non-energy uses	Sections 3.3.2, 3.3.4

2. Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included in FRL of the Czech Republic

The following carbon pools are included in the Czech FRL: aboveground biomass, below-ground biomass, and deadwood. Also included is the contribution of the harvested wood products (HWP).

Excluded from the FRL are the following carbon pools: litter and soil organic carbon. These two carbon pools have been excluded for two reasons. Firstly, adequate data on litter and soil organic carbon in forest land at a country level (i.e., repeated quantitative forest soil inventory sampling) do not exist to provide sufficiently robust estimates on carbon stock changes and associated emissions. Secondly, there is an evidence from a published peer-reviewed scientific study that these carbon pools are not a net source of emissions under the scenarios of sustainable forest management under the conditions of the country (Cienciala et al., 2008b). That study was based on the EFISCEN model (Schelhaas et al., 2007) that included a soil module YASSO (Liski et al., 2005) providing estimates for the two pools combined.

The following greenhouse gases are included in the Czech FRL: CO_2, N_2O and CH_4. The latter two gases originate from the prescribed biomass burning and wildfires.

2.2 Demonstration of consistency between carbon pools included in FRL

The consistency between the carbon pools included in the FRL and those in the Czech emission inventory is fully retained. The two pools not included in the FRL estimates (litter and soil organic carbon) have been identically treated in the reporting on 4.A.1 Forest land remaining Forest land, resorting to Tier 1 assumption of no change (IPCC 2006). Similarly, the reporting of Forest management (FM) under the Kyoto Protocol (NIR 2019) adopts the above reasoning of no net emissions from these two pools based on peer-reviewed modelling analysis performed for the actual circumstances of FM in the country (Cienciala et al., 2008b).

The consistency of emission and removal estimates and for the carbon pools included in the FRL and the contribution of HWP is detailed in Sections 4.1 and 4.3.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forest and forest management in the Czech Republic and the adopted national policies

The national policies influencing forest management with respect to climate change mitigation and adaptation are: National Forest Programme II, Strategy of the Ministry of Agriculture with an outlook to 2030, State Environmental Policy and National Action Plan for Adaptation to Climate Change.

Forest land covers 33.9% of the area of the Czech Republic (2 673 392 ha as of 2018) and forest stands alone 33.1% (2 609 746 ha). Forest cover has been slightly increasing (2 000 ha per year) over last years and this trend is likely to continue. The Czech forests are dominated by coniferous tree species (71.5%), mostly by Norway spruce (50.0%) and Scotch pine (16.2%), whereas broadleaved tree species amount to 27.3%. The reconstructed natural tree species composition is very different with 34.7% of conifers (only 11% of spruce) and 65.3% of broadleaves. Therefore, one of the principal goals after enactment of a new forest law in 1996 was to bring the tree species composition closer to the natural one. That is why it introduced an obligation for forest owners to ensure a minimum share of so-called soil-improving and stabilizing species (mostly broadleaved), when regenerating the forest stand. The goal has also been supported by financial contribution to forest owners. Since 2000, the share of spruce decreased by 4.1% (94 876 ha) and of pine by 1.4% (30 916 ha). Face-to-face with the rather rapid climate change this is not enough yet. A new decree of the Ministry of Agriculture, in force since 1st January 2019, almost doubles the obligatory minimal shares of soil-improving and stabilizing species. It also allows shorter rotation periods as another adaptation measure. These measures will accelerate the change of tree species composition and will have impact on forest related carbon pools.

2.3.2 Description of the future harvest rates under different policy scenarios

The current forest sector outlooks are strongly affected by severe impacts of climate change (increasing air temperatures and lack of precipitation in vegetation season), manifested by unprecedented bark beetle outbreak affecting coniferous (especially spruce) forest stands. After the reference period, we witnessed a temporary decline of annual removals to the level of 15 mil. m^3 first and then, since 2015, an abrupt increase up to the historical maximum of 25.7 mil. in 2018. It is worth adding that in the same period the total mean increment increased from 16.8 mil. m^3 in 2000 to 18 mil. m^3 in 2018, and the total current increment increased from 19.8 mil. m^3 in 2000 to 22.3 mil. m^3 in 2018. This means, however, that annual removals have already exceeded the total mean increment in the very recent years.

The increase of removals since 2015 can be attributed to the growing amount of salvage felling caused by windstorms, drought, bark beetle or other pests. According to official statistics (CzSO), the salvage felling caused by bark beetle, drought and other reasons reached 23 mil. m^3 in 2018, which represents 90% of the total harvest removals. This amount and share will most likely further rise in 2019. On the other hand, the planned harvesting of coniferous species has been completely stopped in state forests since March 2018 (on 56% of the forest area) and significantly reduced in non-state forests.

Due to the above, the future harvest rates become hardly predictable for the nearest years to come. The scenarios of harvest predictions until 2050 evidently require including the expected disturbance regimes, which will most likely affect both harvest rates and development of growing stock more strongly that the adopted policy scenarios. In this spirit, two scenarios for development of the Czech forest resources and the likely wood removals were prepared and processed by the CBM model. They are based on the state of the forest resources as of 2018 according to the stand-wise inventory data collected from the actual (2018) Forest Management Plans. Both scenarios incorporate disturbance regimes, which are assumed to strongly impact forest management. The key management interventions (felling, thinning, planting) would need to correspondingly reflect the assumed disturbance intensity and frequency. By disturbance we mean an insect infestation (bark beetle) accompanying drought spells, which affect dominantly spruce stands. This expectation is based on the currently witnessed (2018/2019) development in the country with a historically high decline of coniferous stands and management, which must (by the provisions of the Czech Forest Act) prioritize sanitary felling of declining stands over the planned forest management. As noted above, in 2018 the share of the unplanned sanitary felling reached 90 % of the entire harvest in the country. At the same time, the total harvest reached almost 26 mil. m^3 of merchantable wood under bark, representing the current technical harvest capacity. This volume is ca. 10 mil. m^3 over the common harvest level during the first decade of this century (2000-2009, abbreviated as 2000s, identical to RP).

- **Red scenario** expectations– intensive disturbance as in 2018 would last three years (2018 to 2020) and resumes to the common harvest level as in 2000s. However, the 3-year intensive disturbance would repeat once per decade (2028-2030, 2038-2040, 2048-2050).
- **Black scenario** expectations – intensive disturbance as in 2018 would progress over more years, using the harvest intensity of about 26 mil. m^3/year as long as there is only 20 % of the current spruce growing stock remaining. That growing stock level (ca. 100 mil. m^3) represents the forest site conditions in the country, which permit a resilient growth performance of spruce-dominated stands for the coming decades. Once the intensive felling would cease, harvest removals would return to the common level as observed in 2000s.

For both scenarios and disturbance years, about 10 000 ha (ca. 1.8 mil. m^3) of unprocessed dead spruce forest stands annually remain standing to be harvested within the next three years as the harvest capacity allows. After each spruce salvage felling, new forest is either regenerated and/or planted by spruce, beech and oak with the affected area share of 20, 30 and 50 %, respectively.

The results of the CBM projections using the two scenarios (Red, Black) are summarized graphically in Figure 1. They document harvest rate levels and reflect the duration and intensity of imposed disturbances. Growing stock is slightly declining under Red scenario, and significantly declining under Black scenario until depletion of harvestable spruce growing stock, rising again as other species groups contribute increasingly to the growing stock total. Both scenarios offer a view on the process of changing tree species composition, which is the very essence of the current Czech forest adaptation policies. Evidently, the more intensive felling of spruce-dominated stands (under Black scenario) speeds-up implementation of adaptation measures in the country. Finally, a projection of the associated carbon stock balance in living biomass is shown, well documenting how disturbances affect the capacity of forest resources to act as a sink or source of CO_2 emissions. Note also, that for simplicity, no wildfires are included, although it may be expected that their influence would gradually rise also in the conditions of the Central-Europe.

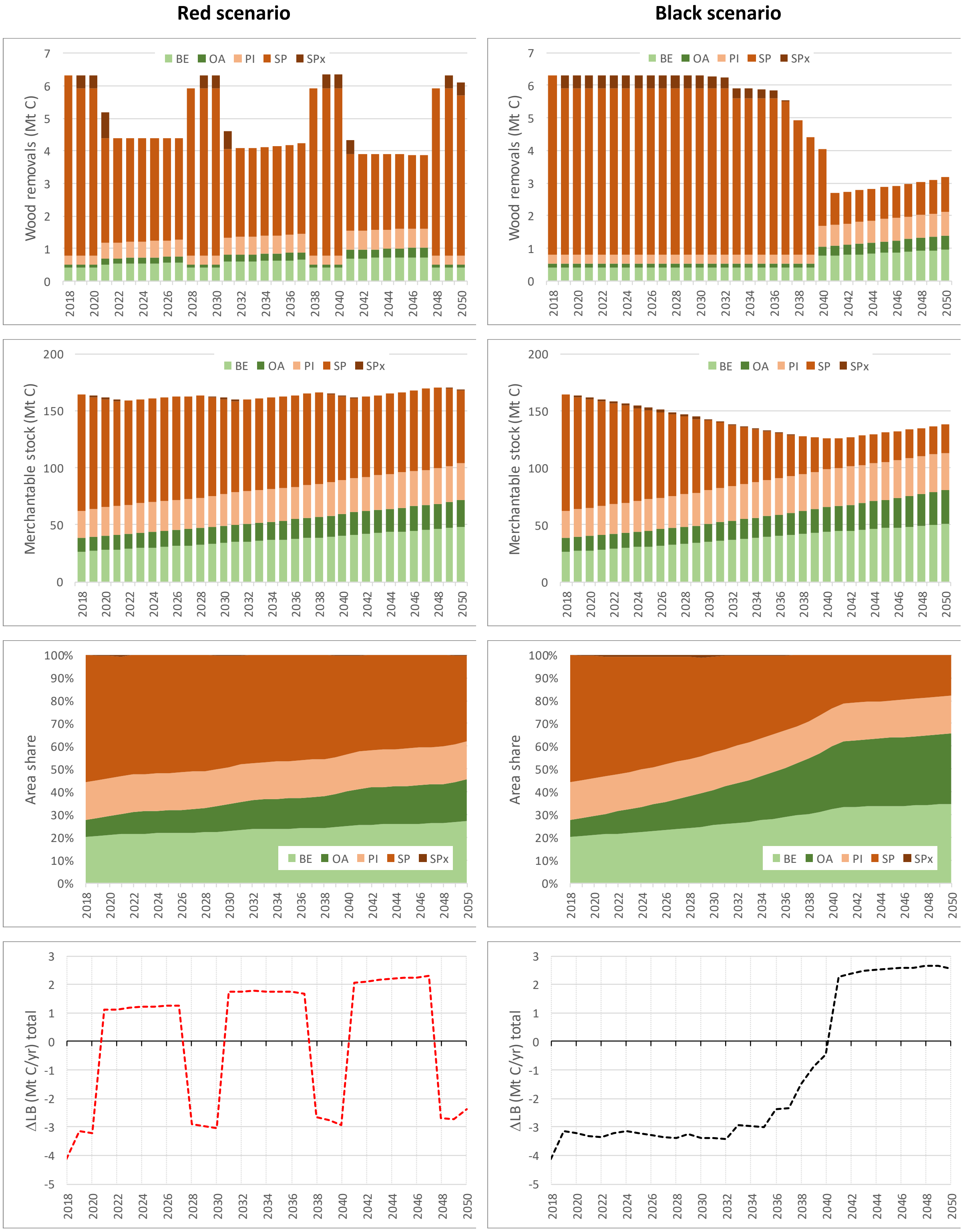

Figure 1: The estimated development of future harvest rates (1st row), growing stock (2nd row), and areal representation of species groups (3th row) for the Red (left column) and Black (right column) scenarios. These figures are shown by the four species groups, here including also the part of dead standing spruce (SPx), which is temporarily left on-site due to insufficient felling capacities during the period of intensive disturbance. Complementarily, the resulting change of carbon stock in living tree biomass for the two scenarios is also shown (4th row).

2.4 The provisions of the Czech Forest Act on sustainable management and biodiversity conservation

Principles of sustainable forest management practice are fully based on the Czech Forest Act, which is one of the strictest in Europe. Every forest owner possessing more than 50 ha is obliged to have a forest management plan (FMP), where maximum amount of wood removals is prescribed and cannot be exceeded. FMP must be approved by the state forest administration and a binding statement of natural protection state administration is an essential part of this process. This binding statement serves as a complex tool for application of all nature protection requirements. Moreover, reforestation must occur within two years after felling.

The same principles apply for smaller forest owners, for which a simplified version of the forest management plan, so called forest management guidelines, are elaborated by the state. Every felling above 3 m^3/ha/year must be announced to the state forest administration in advance. Long-term sustainable forest management practice until 2017/2018 is documented by a stable increase of the total growing stock, resulting from smaller annual removals than annual increment in forests. The observed development of the growing stock is shown in Table 2 for the period 2000-2018 (based on the official data from NDFMP) and a possible development under two defined scenarios (see Section 2.3.2) reflecting the current historical calamity due to insect outbreak is shown for period 2019-2030.

In terms of biodiversity, FMP and guidelines include a binding provision on reforestation species composition with a prescribed minimum share of so-called soil improving and stabilizing tree species. This minimum mandatory share has been significantly increased since 2019. Additionally, the nature protection state authority statement is a mandatory part of the forest management plan approval process. In this way, the specific needs of nature protection and biodiversity, are reflected in any FMP.

Table 2: Data on growing stock – historical (left) and projected by red and black scenarios as in Section 2.3.2.

Year	Historical data: Total growing stock [mil. m^3]	Source
2000	630.5	NDFMP
2001	638.2	
2002	641.0	
2003	650.0	
2004	657.6	
2005	663.2	
2006	672.8	
2007	672.9	
2008	676.4	
2009	678.0	
2010	680.6	
2011	683.0	
2012	685.6	
2013	687.2	
2014	689.0	
2015	692.6	
2016	695.8	
2017	699.0	
2018	702.9	

Year	Projected by scenarios: Red – Total growing stock [mil. m^3]	Black – Total growing stock [mil. m^3]
2019	699.4	699.4
2020	691.0	691.0
2021	682.3	682.3
2022	677.5	673.5
2023	680.0	664.3
2024	682.5	655.0
2025	685.1	645.5
2026	687.7	635.7
2027	690.4	625.8
2028	693.1	615.5
2029	688.2	605.1
2030	679.5	593.7

3. Description of the estimation approach

3.1 Description of the general approach as applied for estimating FRL

The estimation of the FRL in the Czech Republic includes assessment of carbon stock changes in living biomass, changes in deadwood and emission contribution of HWP (Table 3). Potential changes in other carbon pools (litter and soil organic carbon) are not included in FRL of the Czech Republic. The estimation of changes in living biomass and deadwood is aided by a specifically calibrated Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3, further denoted as CBM; Kull et al., 2016), whereas the estimates of HWP contribution is guided by the adopted IPCC methodologies (IPCC 2006, 2014) as used in the Czech emission inventory. Spatially, FRL concerns forest land as defined by the Czech Forest Act (289/1995), which is linked to the cadastral forest land use category and the cadastral system of land use in the country. The specific details on CBM application and details on forest land are described below.

Table 3: General approach applied for estimating the Czech FRL – carbon pools as treated in FRL and estimation approach used. *Above- and below-ground biomass are reported jointly as Living biomass (LB) in this report.

Carbon pools/components	Treatment in FRL	Approach used
Above-ground biomass*	Included as a part of LB	CBM estimate
Below-ground biomass*	Included as a part of LB	CBM estimate
Deadwood	Included	CBM estimate
Litter	Excluded	n/a
Soil organic carbon	Excluded	n/a
Harvested wood products (HWP)	Included	Production approach (IPCC 2006, 2014) linked to CBM harvest estimates

The adopted concept of the CBM estimation over the relevant timeline is summarized in Figure 2. Two runs are performed. For the consistency estimates, the data as of year 2004 were selected to represent Reference period (RP, 2000-2009). These data were primarily used to feed CBM in terms of growing stock volume, and to calibrate increment functions. Forest area as of 2000 was used to start this model run for RP, being identical as forests land remaining forest land (further denoted as FLrFL) in the Czech GHG emission inventory for that year. The model runs for RP were driven by the actual (historical) harvest data and total wood removals (incl. harvest residues and wood not reaching sawmills). These estimates were used to demonstrate consistency with the national GHG inventory data.

For the projection period 2010-2025, data of 2010 represent the initial model conditions for model estimation across this 16-year long period. The CBM projections were generated to maintain tree species composition change trend as within RP and using the harvest demand determined by the ratio of “harvest to biomass available for wood supply” (P_Av, Grassi and Pilli, 2017). This was held identical as in RP (including thinning, salvage logging and final cut). For thinning and final cut, the average volume from the whole RP was used. In case of salvage logging, the average from the last five years of RP was used for projection. This follows Guidance on developing and reporting Forest Reference Levels in accordance with Regulation EU 2018/841, part 2.2.5.

The annual projections for the Compliance Period (CP 1, 2021-2025) constitute the basis of estimating the average values representing FRL (FRL 1). FRL includes carbon stock change for the three carbon components (above-ground biomass, below-ground biomass, deadwood) and the HWP contribution estimated with a help of the projected harvest volumes (Table 3). Note that above- and below-ground biomass carbon pools are reported jointly as living biomass (LB) in this report, because below-ground biomass is determined as a function (fraction) of above ground biomass, hence being perfectly correlated.

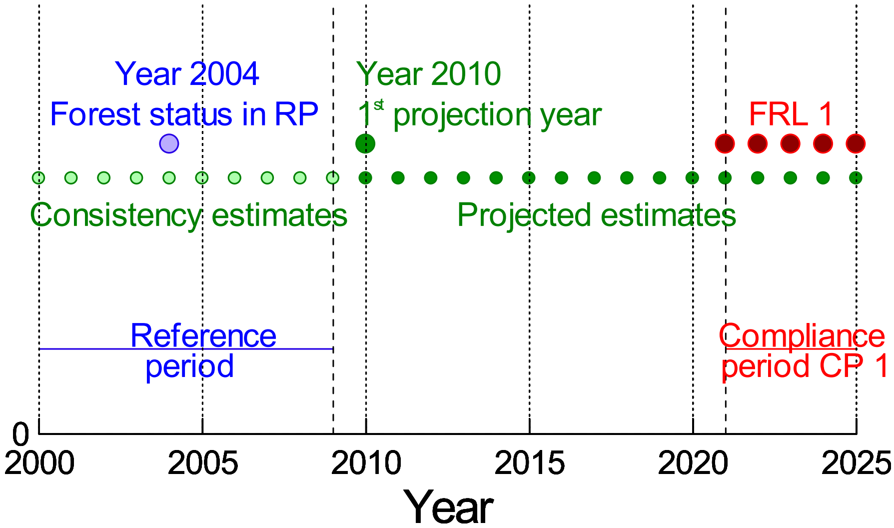

Figure 2: Timeline overview of the FRL estimation approach: Reference period (RP; 2000-2009) is represented by data on forest state as of 2004 used to calibrate growth in CBM. CBM is driven by the reported/historical harvest data for 2000 to 2009 to demonstrate the consistency with the NIR estimates. Year 2010 is the first year of the projection period (PP; 2010 to 2025) and the CBM projected estimates are driven solely by harvest based on "wood removals to biomass available for wood supply" ratio derived from RP. The projection estimates for years 2021 to 2025, resp. the mean of these values, represents FRL 1, the first half of the Compliance period (CP 1).

3.2 Documentation of the data sources as applied for estimating FRL

3.2.1 Data on forest land remain forest land and stratification of the managed forest land

The forest stratification used for estimating the Czech FRL is organized firstly by the categories based on legislatively designated (Forest Act 298/1995) main forest function. This categorization predetermines differences in forest management practices on these forest categories. Secondarily, the adopted stratification identifies forest management practices by the key tree species groups as attribute within area of FLrFL (Table 4).

According to the Czech Forest Act (289/1995), forests in the Czech Republic are defined as "forest stand with its environment and land designated for the fulfilment of forest functions". This definition links directly to the adopted system of land-use representation and land-use change identification in the Czech National Inventory of greenhouse gas emissions in the LULUCF sector, which is exclusively based on the cadastral land-use information of the Czech Office for Surveying, Mapping and Cadastre (COSMC; www.cuzk.cz, NIR 2019). Therefrom, forest land is the land that is declared in the cadastral land-use information of COSMC as a land designated to fulfil forest functions. It is a land with forest stand and land, where forest stands were temporarily removed to allow their regeneration, forest break and unpaved forest road, not wider than 4 m, and land, where forest stands were temporarily removed due to a decision of the state forest administration. All such assigned lands must be managed in an efficient manner in accordance with Forest Act. It is prohibited to use it for any other purposes. Moreover, according to Forest Act, it is obligatory to prepare Forest management plan (FMP) for all forest properties above 50 ha, while for smaller properties, a simpler form of FMP called Forest Management Guidelines (FMG) are mandatorily developed.

Table 4: Adopted stratification of FLrFL area (as of 2000 used for calibration runs under RP and as of 2010 for the projection period 2010 to 2025) for the Czech FRL estimation.

Climatic domain	Major functional category	Species group	Forest management type stratum abbreviation	Forest area (as of 2000) (kha)*	Forest area (as of 2010) (kha)*
Czech Republic	Managed forest	Beech	CZ-MAN-BE	299.4	300.2
		Oak	CZ-MAN-OA	123.6	123.9
		Pine	CZ-MAN-PI	367.4	368.3
		Spruce	CZ-MAN-SP	1175.0	1177.9
	Protection forest	Beech	CZ-PRO-BE	16.8	16.8
		Oak	CZ-PRO-OA	4.7	4.7
		Pine	CZ-PRO-PI	15.9	15.9
		Spruce	CZ-PRO-SP	43.0	43.1
	Special purpose forest	Beech	CZ-SPE-BE	129.0	129.3
		Oak	CZ-SPE-OA	43.7	43.8
		Pine	CZ-SPE-PI	71.4	71.6
		Spruce	CZ-SPE-SP	317.9	318.7

The Czech Forest Act (289/1995) divides forests in the country into three major categories according to their prevailing functions, particularly into protection forests (PRO), special purpose forests (SPE) and commercial (production) forests (MAN). The following definition applies for these categories:

Protection forests (PRO)

a. forests at exceptionally unfavourable sites (debris, stone seas, sharp slopes, ravines, unstable sediment or sand, peatland, spoil banks or spoil heaps etc.)
b. high-elevation forests below the boundary or wooded vegetation protecting forests situated lower and forests on exposed ridges
c. forests in the dwarf pine vegetation zone

Special purpose forests (SPE) - forests that are not protection forests and are situated

a. in zones of hygienic protection of water resources of 1st degree
b. in protection zones of natural healing and table mineral waters
c. on the territory of national parks and national nature reserves

The category SPE can also be applied to forests, where based on a general interest any other forest function is superior to the wood-producing functions. These include the following forests:

d. forests in the first zones of protection country areas and forests in natural reserves and at sights of natural interest
e. spa forests
f. suburban forests and other forests with an increased recreation role
g. forests serving the purposes of forestry research and forestry education
h. forests with increased functions in the area of soil protection, water protection, climate or landscape formation
i. forests necessary for the preservation of biological diversity
j. forests in recognized hunting areas and separate peasantries
k. forests where important public interest calls for a different method of management

Production forests (MAN) are forests that are not included in the category of protection forests or special purpose forests.

The national database of forest management plans and guidelines (NDFMP), administered centrally by the Forest Management Institute (FMI) at Brandýs n. Labem, was used as the main data source on forests in the country. NDFMP represents an ongoing national stand-wise type of forest inventory. It provided detailed data (at the level of individual forest stands) on area share covered by particular tree species. Within each functional forest category (MAN, PRO, SPE), tree species were grouped into four groups of tree species, namely Spruce (SP), Pine (PI), Beech (BE), Oak (OA). All species of the genus *Pinus* were included in the species group Pine, while all other coniferous tree species were then included in the species group SP. All species of the genus *Quercus* were included in the species group Oak, while other broadleaved tree species were included in the species group BE. This gives the stratification framework and resulting Forest Management Types (FMPs) as summarized in Table 4. Note, however, that species groups SP, PI, BE, OA are derived from stand-level data representing species dominance within forest stands.

The Czech FRL estimation concept works with a constant forest area that matches the category Forest and remaining forest land (FLrFL) as used in the Czech emission inventory of the LULUCF sector. For the consistency estimates within reference period (Figure 2), the area of FLrFL as of 2000 (2 607 719 ha) is used. For the projection estimates, the area of FLrFL as of 2010 (2 614 224 ha) for the entire projection period 2010 to 2025, which includes the period of FRL 1 (2021-2021). This meets the requirements of the EU Regulation 2018/841 on LULUCF, which instructs to treat deforestation and afforestation separately. The area of FRrFL includes the total cadastral forest land without the 20-year accumulated afforestation areas, which are discounted. However, clear-cut areas (28 330 ha as of 2010) are also included within FLrFL. The above numbers on FLrFL document that within RP, there was a marginal gain of about 6.5 kha, which represents an increase of FLrFL by 0.2% for that decade.

The total cadastral forest area (and timberland) marginally increased from 2.637 (2.583) Mha in 2000 to 2.655 (2.594) in 2009, the end of RP. A similar trend was retained until 2017, when the total cadastral forest area (and timberland) reached 2.672 (2.608) Mha (Figure 3). The annual net gain of forest area was about 2 kha. Note, however, that forest area is held constant as of 2004 for the entire period of 2000 to 2030 in the adopted concept of the Czech FRL. This meets the requirements of the EU LULUCF Resolution, which instructs to account for deforestation and afforestation separately.

While FLrFL is held constant, species composition does slightly change during the RP. Accordingly, for the projection estimates since 2010, the trends of species ratio RP is retained. Species change follows the general recommendations of the National forest adaptation strategy as declared in the National Forest Programme (MA 2009). Following the species grouping used in this material (Table 4), the share of Spruce category decreased from 58.9 % to 57.0 % within the years 2000-2010. The areas of broadleaved species increased correspondingly – the share of Beech species group increased from 16.0 % to 18.2 %, and the share of Oaks increased from 6.3% 6.9 % in the same period, respectively. It should be noted that the modelling concept mimics this development of species change, as described in the details of CBM application below.

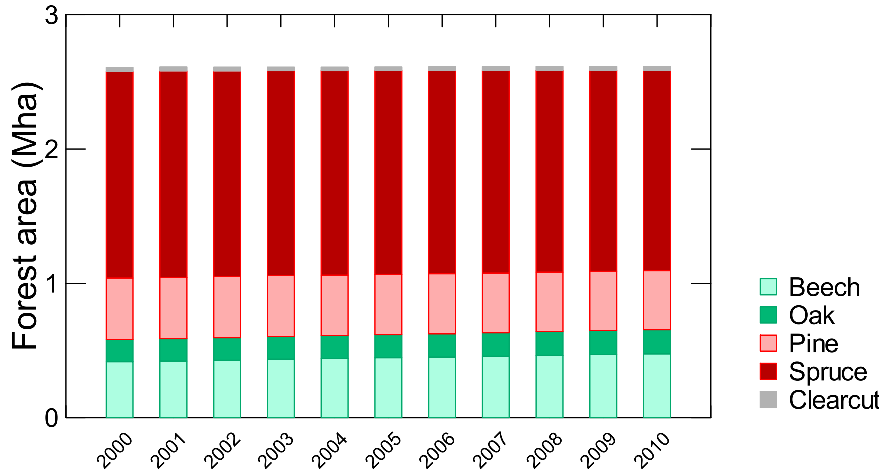

Figure 3: Forest area development and species (species group) composition in the period 2000 to 2010 – data from the Czech NIR 2019 submission. Highlighted is year 2000 that is the initial year of RP and the calibration estimates by CBM (2000-2009), and year 2010, which is the initial year of the projection estimates by CBM (2010-2025).

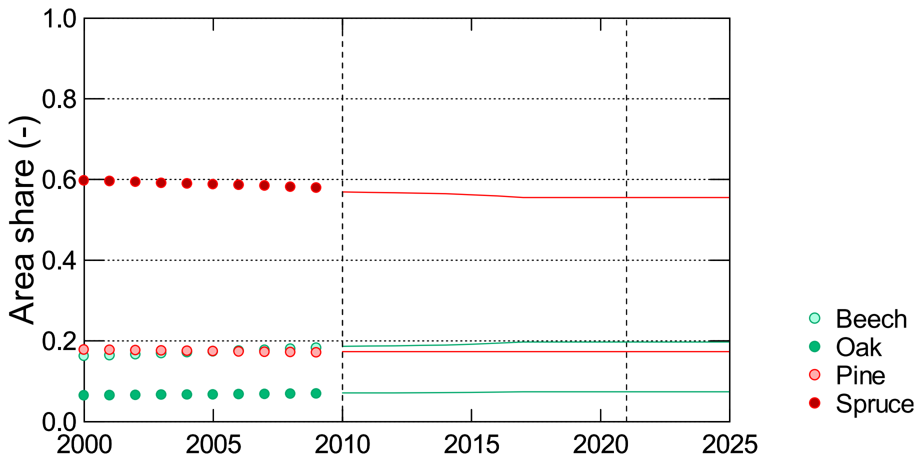

Figure 4: Relative share of species groups on forest area represented by CBM for i) RP and its calibration estimates (symbols) and ii) for the projection period since 2010 until 2025 (lines).

Apart from forest/timberland area, NDFMP contains data on growing stock volume by age classes. The development of age-structure and corresponding volume of growing stock for individual strata by functional types and species groups is shown in Figure 5 and Figure 6, respectively. Complementarily, the current annual increment (CAI) based on the valid Czech Growth and Yield tables (Cerny et al. 1996) estimated for these strata, is also shown (Figure 7). These tables are implemented on updated database NDFMP every year in order to evaluate changes in CAI on the national level. Annually updated CAIs has been used for GHG inventory reporting. Data for years 2000, 2004 and 2009 are shown, representing the development within RP. Year 2004 is the calibration year to represent RP in CBM (cf. Figure 2), while data of year 2000 are used to represent the area of FLrFL and the initial distribution of strata (Table 4).

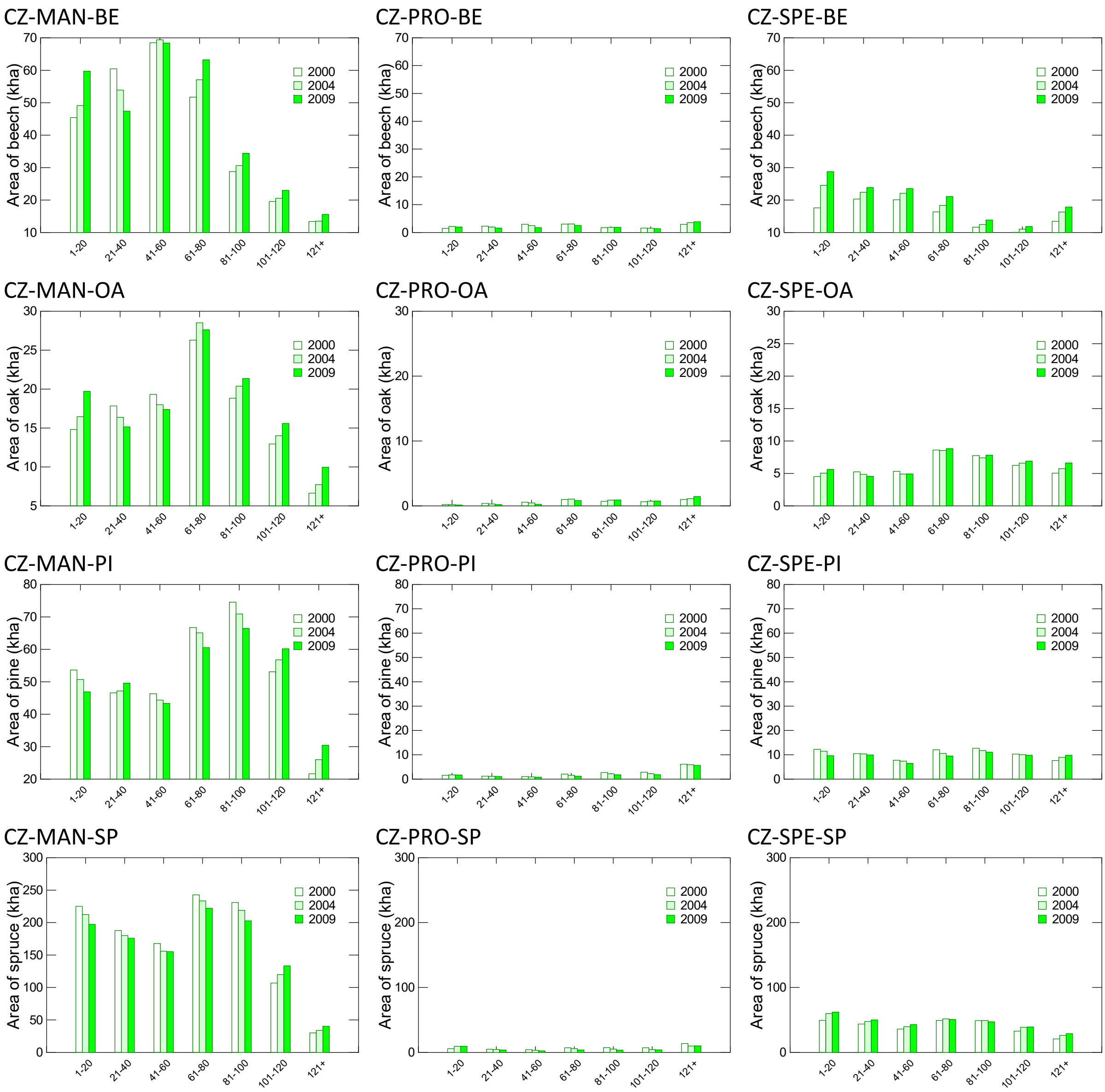

Figure 5: Age class development for the individual strata by functional category, species group and age class – years 2000, 2004 and 2009 are shown. Y-axis retains identical scale for individual species groups to illustrate significance of functional categories.

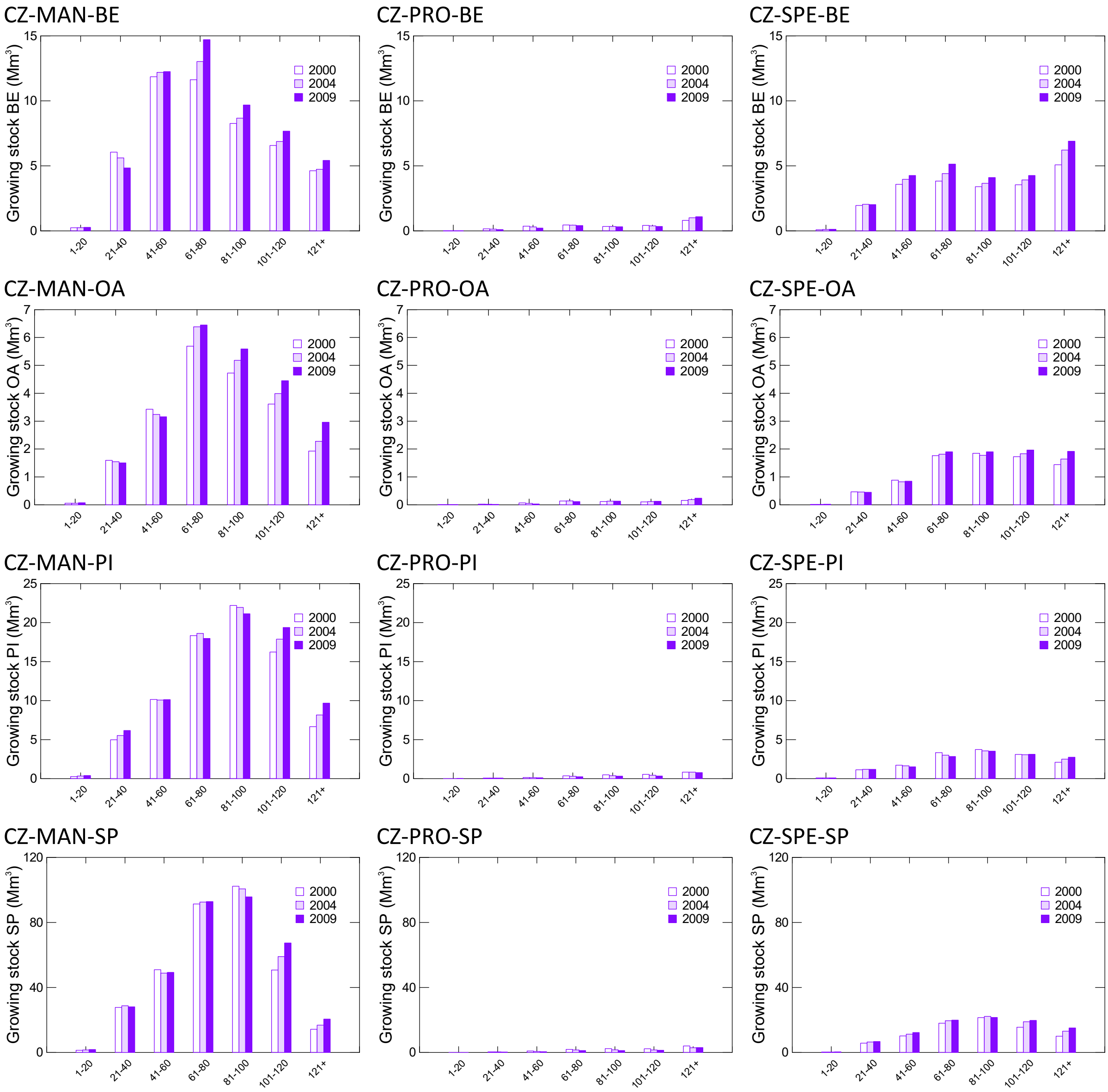

Figure 6: Growing stock volume for the individual strata by functional category, species group and age class – years 2000, 2004 and 2009 are shown. Y-axis retains identical scale for individual species groups to illustrate significance of functional categories.

Figure 5 and Figure 6 illustrate a common development of age structure with increasing proportion of older age classes and sub-normal proportion of younger age classes. In long-term, this development is considered as one of the potential threats to sustainable wood supply for the future decades. Figure 7 shows development of CAI during the period of 2000 to 2017: CAI increases for most of the strata. This is due to several factors including an effect of management practices on age class structure and species composition, as well as the likely effects of environmental change (N-deposition, temperature, CO_2).

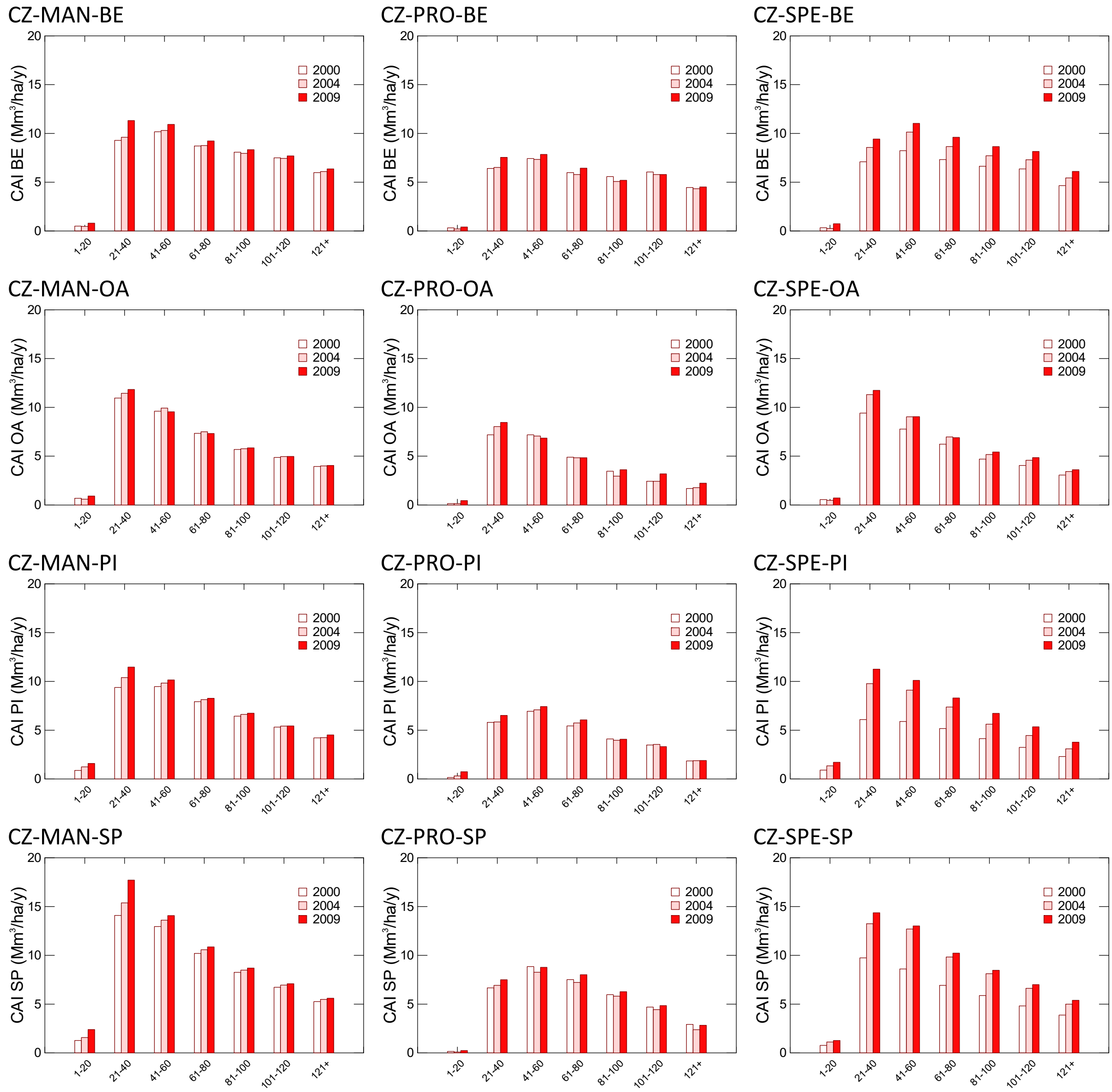

Figure 7: Current annual increment (CAI) for the individual strata by functional categories, species groups (BE, OA, PI, SP) and age classes – years 2000, 2004 and 2009 are shown. Y-axis retains identical scale for individual species groups to illustrate significance of functional categories.

3.2.2 Data sources on deadwood carbon pool

Data on above-ground deadwood (DW) are available from two main sources – sample-based inventory projects: the landscape inventory project CzechTerra and the National Forest Inventory (NFI). It should be noted that these data remain uncertain for deriving trends in carbon stock change in DW pool and its components. This is because these data are not fully comparable due to the adopted specific definitions of the DW components that differ between the both sources. Table 4 offers the overview of the available national empirical data on deadwood that can be indicatively used to verify the estimates of CBM for changes in deadwood carbon pool at the level of two components - standing and lying DW, respectively, as used for NIR (2018, 2019).

Table 5: Deadwood (carbon pools – available estimates (Mg C/ha) at the national scape from the CzechTerra (CZT) and NFI campaigns. Pools not included in NIR (2018, 2019) are noted by italics.

Deadwood pool	CZT 1	CZT 2	NFI 1*	NFI 2
Years	2008-2009	2014-2015	2001-2004	2011-2015
	Mg C/ha			
Standing deadwood	1.14	1.21	0.60	0.56
Stumps	-	-	-	0.53
Lying deadwood	0.98	0.37	0.85	1.13
Lying branches	-	-	-	0.94
Total included for NIR	2.12	1.58	1.45	3.15

* *NF1 1 data on DW were reported only in volume units. The estimation of the corresponding carbon content values shown here were derived from a ratio of DW_carbon_amount/wood_volume from CZT 1 data.*

The development in forestry sector of the very recent years (since 2017) suggests a notable increase in both standing and lying deadwood due to the unprecedented decline of coniferous forest stands suffering from severe water deficit conditions accompanied by uncontrolled bark-beetle outbreak (see also Section 2.3.2). This development has not been quantified in terms of carbon in deadwood components yet.

3.2.3 Description of forest management practices

The four main forest management practices (FMP) applicable for the tree species groups of Beech, Oak, Pine and Spruce, are described in qualitative terms in Table 6. The quantitative terms are listed at the level of individual FMT strata (Table 4) in Table 7. They include the following forest characteristics: actual (2004) rotation length, regeneration period, thinning regime and final felling age span.

The definition of the biomass removal as a function of the age and state of the forest (age class) was used for the description of FMPs (Table 7). Biomass removals in quantitative terms is not defined according to each specific activity, but directly as a function of the age and state of the forest and expressed as proportion of harvest to biomass available for wood supply (P_Av). These values are also shown in Table 7 and the observed P_Av values were used to calibrate harvest during Projection (PP) and Compliance (CP) period (Section 3.3.4).

Cleanings, which are also a part of the regular forest management in the Czech Republic, are not defined in Table 7, because amount of wood cut by cleanings is insignificant; it generally concerns young trees with dimensions under the limit of merchantable wood (7 cm over bark).

Determination of age classes associated with final harvest for the particular strata (Table 7) is based on the analysis of average rotation length and regeneration period, which was calculated in NDFMP.

Table 6: Qualitative terms of Forest Management Practices (FMP) applied during the RP

Forest Management Practices		
Index	**Short description of practice**	**Determination of actual biomass removal**
FMP_{spruce}	FMP_{spruce} consists of natural regeneration or planting of seedlings, pre-commercial thinning of young stands, one thinning every ten years until the age 80 and a final harvest through partial cutting or clear-cutting. Salvage felling caused by abiotic and biotic agents occur at the age 21 to 140. The harvest schedule and biomass removals in harvests are regulated by Forest Act (Act No. 289/1995 on Forests and amendments to some acts), defined in detail in the Framework management guidelines of the Regional Plans of Forest Development.	Biomass removals used in the FRL are based on observations of actual harvests in Reference period 2000-2009. Biomass removals are set by a ratio of "harvest to biomass available for wood supply" determined through calculating harvest probability for a given age class using the method described in JRC technical report "Projecting the EU forest carbon net emissions in line with the "continuation of forest management": the JRC method (Grassi and Pilli, 2017), listed as Alternative 1 for the harvest module in Guidance on FRL (Forsell et al. 2018).
FMP_{pine}	FMP_{pine} consists of natural regeneration or planting of seedlings, pre-commercial thinning of young stands, one thinning every ten years until the age 80 and a final harvest through partial cutting or clear-cutting. Salvage felling caused by abiotic and biotic agents occur at the age 21 to 140. The harvest schedule and biomass removals in harvests are regulated by Forest Act (Act No. 289/1995 on Forests and amendments to some acts), defined in detail in the Framework management guidelines of the Regional Plans of Forest Development.	Biomass removals used in the FRL are based on observations of actual harvests in Reference period 2000-2009. Biomass removals are set by a ratio of "harvest to biomass available for wood supply" determined through calculating harvest probability for a given age class using the method described in JRC technical report "Projecting the EU forest carbon net emissions in line with the "continuation of forest management": the JRC method (Grassi and Pilli, 2017), listed as Alternative 1 for the harvest module in Guidance on FRL (Forsell et al. 2018).
FMP_{beech}	FMP_{beech} consists of natural regeneration or planting of seedlings, pre-commercial thinning of young stands, one thinning every ten years until the age 80 and a final harvest through shelterwood system. Salvage felling caused by abiotic and biotic agents occur at the age 21 to 140. The harvest schedule and biomass removals in harvests are regulated by Forest Act (Act No. 289/1995 on Forests and amendments to some acts), defined in detail in the Framework management guidelines of the Regional Plans of Forest Development.	Biomass removals used in the FRL are based on observations of actual harvests in Reference period 2000-2009. Biomass removals are set by a ratio of "harvest to biomass available for wood supply" determined through calculating harvest probability for a given age class using the method described in JRC technical report "Projecting the EU forest carbon net emissions in line with the "continuation of forest management": the JRC method (Grassi and Pilli, 2017), listed as Alternative 1 for the harvest module in Guidance on FRL (Forsell et al. 2018).
FMP_{oak}	FMP_{oak} consists of natural regeneration or planting of seedlings, pre-commercial thinning of young stands, one thinning every ten years until the age 80 and a final harvest through partial cutting or clear-cutting. Salvage felling caused by abiotic and biotic agents occur at the age 21-140. The harvest schedule and biomass removals in harvests are regulated by Forest Act (Act No.	Biomass removals used in the FRL are based on observations of actual harvests in Reference period 2000-2009. Biomass removals are set by a ratio of "harvest to biomass available for wood supply" determined through calculating harvest probability for a given age class using the method described in JRC technical report "Projecting the EU forest carbon net emissions

Forest Management Practices		
Index	Short description of practice	Determination of actual biomass removal
	289/1995 on Forests and amendments to some acts), defined in detail in the Framework management guidelines of the Regional Plans of Forest Development.	in line with the "continuation of forest management": the JRC method (Grassi and Pilli, 2017), listed as Alternative 1 for the harvest module in Guidance on FRL (Forsell et al. 2018).

Table 7: Quantitative terms of Forest Management Practices (FMP) applied during RP (2000-2009). The proportion of realized wood harvest to biomass available for wood supply (P_Av) by individual management interventions representing wood removals (CBM coding DIST2, DIST3, DIST3b, DIST4) at the level of individual strata is also shown. These proportions (P_Av) determine the harvest levels also during the projection period (2010 to 2025)

FMP	Strata	Average rotation length (years)	Average regenera-tion period (years)	Parameter	Thinning (DIST2)	Salvage felling with clear-cut (DIST3)	Salvage felling without clear-cut (DIST3b)	Final harvest (DIST4)
FMP_{beech}	CZ-MAN-BE	108.0	30.9	Age (years)	21-80	21-140	21-140	91-190
				P_Av (%)	0.49	0.56	0.28	1.81
	CZ-PRO-BE	146.8	48.1	Age (years)	21-80	-	-	121-190
				P_Av (%)	0.43	-	-	1.49
	CZ-SPE-BE	121.7	35.6	Age (years)	21-80	21-140	21-140	101-190
				P_Av (%)	0.35	0.29	0.15	0.81
FMP_{oak}	CZ-MAN-OA	125.8	30.1	Age (years)	21-80	21-140	21-140	111-190
				P_Av (%)	0.45	0.39	0.19	1.55
	CZ-PRO-OA	152.0	46.7	Age (years)	21-80	-	-	121-190
				P_Av (%)	0.64	-	-	2.28
	CZ-SPE-OA	135.4	33.2	Age (years)	21-80	21-140	21-140	111-190
				P_Av (%)	0.40	0.25	0.12	0.62
FMP_{pine}	CZ-MAN-PI	113.9	27.1	Age (years)	21-80	21-140	21-140	101-190
				P_Av (%)	0.67	0.47	0.24	1.52
	CZ-PRO-PI	154.7	54.9	Age (years)	21-80	-	-	121-190
				P_Av (%)	1.23	-	-	1.71
	CZ-SPE-PI	121.4	29.1	Age (years)	21-80	21-140	21-140	111-190
				P_Av (%)	0.99	0.61	0.31	1.76
FMP_{spruce}	CZ-MAN-SP	108.8	33.3	Age (years) (years)	21-80	21-140	21-140	91-190
				P_Av (%)	0.96	1.11	0.55	1.89
	CZ-PRO-SP	146.1	49.2	Age (years)	21-80	-	-	111-190
				P_Av (%)	1.75	-	-	3.05
	CZ-SPE-SP	122.4	37.0	Age (years)	21-80	21-140	21-140	101-190
				P_Av (%)	1.10	0.91	0.46	2.26

3.3 Detailed description of the modeling framework and estimation approaches

The mandatory components of FRL include carbon changes in living tree biomass and deadwood, as well as the contribution of HWP. These components were estimated by adopting the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3, here denoted also as CBM), which was originally developed to meet the carbon accounting needs in Canada (Kull et al., 2016). CBM represents a flexible modelling framework that has also been applied for carbon-accounting purposes in European countries (Pilli et al., 2017, 2013). CBM is an inventory based, yield-data driven model that simulates the stand- and landscape-level carbon (C) dynamics of above- and below-ground biomass, and dead organic matter (DOM) including soil (Kurz et al., 2009). In its spatial representation beyond single stands, it can be flexibly set up to represent administrative and climate regions.

CBM is executed by the following instructions related to age class distribution and handling of defined natural (wildfires) and anthropogenic disturbances (felling, thinning), increment and growing stock:

(A) Steps Prior to a Simulation

- (1) Run quality control check on input data.
- (2) Load input data from MS-Access database to executable.
- (3) Convert merchantable volume yield tables into C increment tables that provide biomass C increments for each biomass pool, referenced to stand age.

(B) Steps During Simulation Initialization

- (4) Populate each inventory record with its classifiers and age, and initialize biomass and DOM C stocks.
  - (a) Start with empty C pools at age 0,
  - (b) Calculate biomass and DOM dynamics for *n* years (where *n* is the regional average natural disturbance return interval),
    - (i) For each annual time step
      - • Look up appropriate aboveground biomass increments and add to current aboveground biomass pools
      - • Calculate belowground biomass C as a function of aboveground biomass
      - • Calculate biomass turnover and add this C to the appropriate DOM pools. If biomass net increment is negative, then add this amount to turnover
      - • Calculate decay rates (applying modifiers to base decay rates)
      - • Calculate transfers between DOM pools and release to atmosphere
  - (c) Run disturbance by wildfire (or other stand-replacing disturbance),
  - (d) Determine total slow C at the end of an initialization cycle,
  - (e) Compare total slow C with values at end of previous cycle,
  - (f) If the slow DOM pools have not yet stabilized (>1% change) then keep the values at the end of the cycle, reset age to 0 and go back to (b).
- (5) Once the slow pools have stabilized and a minimum of 10 iterations have been run, keep the DOM values at the end of the cycle, disturb using designated stand-initiating disturbance type and then grow the record to its age in the inventory. Populate biomass and DOM C pools with the resulting values.

(C) Steps During a Simulation

(6) For each year, apply disturbances.

(a) For each disturbance event,

(i) Apply disturbance controls

• Select records until the target to disturb is met,

(ii) Apply land-use classification changes (where applicable),

(iii) Transfer carbon between pools using the specified disturbance matrix,

(iv) Append future growth multipliers resulting from disturbance (where applicable),

(v) Adjust stand age as appropriate for the type of disturbance,

(vi) Apply transition rules (where applicable).

(7) For each year and inventory record, apply biomass and DOM dynamics.

(a) Apply land-use classification changes for afforested or deforested stands 20 years after the original disturbance,

(b) Look up appropriate aboveground biomass increments from Step 3 and add to current aboveground biomass pools,

(c) Calculate belowground biomass C as a function of aboveground biomass,

(d) Calculate biomass turnover and add this C to the appropriate DOM pools using litterfall turnover rates. If biomass net increment is negative, then add this amount to turnover,

(e) Calculate decay rates (applying modifiers to base decay rates),

(f) Calculate transfers between DOM pools and release to atmosphere.

(8) Run internal QC check on simulation.

(D) Steps After a Simulation

(9) Provide output in user-friendly format.

(a) Summarize fluxes and stocks by time step, pools, disturbance types, land-use class and classifiers,

(b) Load output into MS-Access database,

(c) User can view results through pre-defined or customizable graphs and tables.

3.3.1 Input data - climate, forest growing stock, biomass equations and increment

Since the model application is guided by retaining maximum consistency with the greenhouse gas inventories (requested by the LULUCF regulation of EU 2018/841), no detailed climate stratification was used in for the simulated domain of the country. The mean representative climate indices including mean annual temperature (8.0°C) and precipitation (801 mm/year) were used. These were derived from the historical climatic records (2000-2009) originating from the data derived at the level of individual forest plots (n=604) of the statistical Landscape inventory CzechTerra (Cienciala et al. 2016). No climate trend was considered for the simulated period since 2018 (or since 2000 for consistency estimates) until 2030.

Within the simulated domain, the individual species-specific forest stand strata (Table 4) are primarily characterized by age classes (10-year bins used for CBM), corresponding areas and growing stock volumes. At that level they are linked to appropriate yield curves and parameters of the adopted silvicultural treatment. During the model run, a library of yield tables defines the gross merchantable volume production by age and species group, representing volume production in absence of natural disturbance and management practices (Pilli et al., 2013). In annual time step, CBM applies the net annual increment determined by actual periodic increment in managed stands as derived from actual data. Merchantable stem volume is converted to biomass using species specific stand-level equations (Boudewyn et al., 2007), partitioning volume production into stemwood, other (tops, branches, sub-merchantable trees) and foliage components.

For the Czech FRL, we used the country-specific biomass equations that were identical as used for the country by Pilli et al. (2017) with exceptions of the species-specific stem volume to above-ground biomass equations (Eq. 7 of Boudewyn et al, 2007). These were reparametrized on the basis of tree biomass equations that include beech (Wutzler et al., 2008), oak (Cienciala et al., 2008a), pine (Cienciala et al., 2006) and spruce (Wirth et al., 2004) on the empirical material collected within the CzechTerra landscape survey (Cienciala et al., 2016). The default (Pilli et al., 2017) and the altered parameters are listed in Table 8.

Table 8: Altered parameters of Eq. 7 (Boudewyn et al., 2007) for conversion of merchantable volume into above-ground tree biomass; new (default as in Pilli 2017) values are shown, together with the database code number

Species	Parameter *a*	Parameter *b*	CBM Database Code
Beech sp.	0.837 (0.825)	0.946 (0.957)	314
Oak sp.	0.807 (0.791)	0.965 (0.962)	320
Pine sp.	0.466 (0.830)	0.995 (0.874)	319
Spruce sp.	0.495 (0.914)	0.987 (0.871)	318

NDFMP data for year 2004 were used as activity data on forest resources to characterize forest growing stock during RP (Table 3) and to derive the increment as used in CBM at the level of individual strata. The input data included forest growing stock (V, merchantable volume under bark in m^3), corresponding areas (A, ha) and current annual increment (CAI, m^3) for age classes defined by 10-year bins. The

The applicable CAI was estimated by FMI based on the current growth and yield tables (Cerny et al. 1996), which are an inherent part of the Czech Forest Act. The historical increment was derived from the actual age class structure for the individual species-specific strata (Table 4). Both CAI and historical increment were expressed as function of age, using the combined exponential and power function (Sit 1994) as used by (Pilli et al., 2013), namely

$$CAI_t = a \times t^b \times c^t \quad \text{Eq. 1}$$

where t is age (years), and a, b, c are the parameters to be fitted, with a controlling the maximum increment and b, c controlling the shape of the curve.

3.3.2 Input data – harvest volumes

The activity data on annual harvest volumes are available from regular surveys performed annually by the Czech Statistical Office (CzSO). Since 2010 this data source (CzSO) includes also the estimates of the extracted logging residues volume, while that fraction was estimated based on expert judgement for earlier period, i.e., also for RP. All logging residues are used as an energy source. The reported harvest data for RP are summarized in Table 9. They include roundwood, fuelwood as well as extracted logging residues. For the period 2000-2009, the extracted volume of logging residues was derived from the ratios of 5 and 15 % of the planned (thinning and final cut) and unplanned (i.e., salvage) harvest volume, respectively. This is identical approach as used in the NIR. The extracted logging residues are incorporated in average amount of salvage felling and planned cuts, which are used for CBM calibration runs (in RP) and implicitly also for projection estimates within P_Av (Section 3.2.3, Table 7), which drives harvest volume for the projection period (2010-2025).

Table 9: Annual harvest volumes of roundwood (used as industrial roundwood and fuelwood) as reported to FAO by the Czech Republic (source FAO, FMI, CzSO), including removals of logging residues (sources - IFER , NIR reports).

Year	Roundwood	of which		Other extracted (residues)
		Industrial roundwood	Fuelwood	
	th. m^3	th. m^3	th. m^3	th. m^3
2000	14 441	13 467	974	921
2001	14 374	13 283	1 091	846
2002	14 541	13 526	1 015	1 003
2003	15 140	13 930	1 210	1 451
2004	15 601	14 381	1 220	1 116
2005	15 510	14 236	1 274	1 041
2006	17 678	16 240	1 438	1 490
2007	18 508	16 638	1 870	2 414
2008	16 187	14 307	1 880	1 884
2009	15 502	13 769	1 733	1 438

The important aspect of the harvest volume is distinction of sanitary felling. These are unplanned harvest intervention conducted in connection with natural disturbances including insect outbreaks, windstorms, fungal infestation and others. The Czech Forest Act make sanitary felling mandatory and it must be prioritized over the planned forest interventions in order to minimize damage and/or further spreading of infestation. The share of sanitary felling is reported annually and indicates stability of forest stands and forest management.

The reported harvest by planned and sanitary (unplanned) shares for the period 2000 to 2018 is shown, together with the other extracted wood (residues), in Figure 8. As observed, there is a significant trend in time within RP for both total harvest (confirmed at $p=0.038$) and even strongly so for sanitary felling ($p=0.024$). Due to this, the estimated reference felling for CBM projection runs were derived from the harvest data in RP by averaging the planned harvest across entire RP, whereas the sanitary felling was averaged across the last five year of RP (2005 to 2009), as schematically shown in Figure 8. These harvest quantities were used as the initial input into the CBM model and the calibration procedure for P_Av outlined in Section 3.3.4.

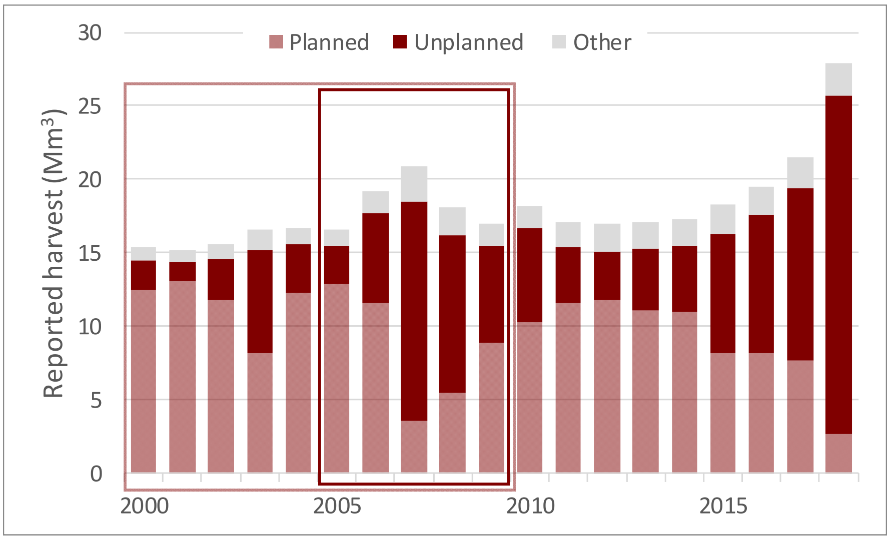

Figure 8: The reported harvest showing the share of planned and unplanned (sanitary) volumes for the period 2000 to 2018. Averaging of harvest within RP is indicated (see text for details).

3.3.3 Implementation of forest management and disturbance interventions

All forest management interventions as well as unplanned disturbances (fires) are defined within CBM by so called disturbance events. For the purpose of the Czech FRL estimation, the following disturbance events (DIST.) were considered and implemented: forest fire (DIST. 1), removals by thinning (DIST. 2), salvage logging interventions defined as sanitary felling of dead, dying or damaged trees after windstorm, insect or fungal infestation or other reasons (DIST. 3, 3a, 3b), planned final cut (DIST. 4) and clear-cut with slash-burn (DIST. 5). These interventions are summarized in Table 10.

Table 10: Set of specific disturbance events used in CBM for the Czech FRL estimation

Identification and name	Input type	Description, data source and CP 1 projection set-up
DIST. 1 Forest fire	Area	Unintended fire events (wildfires) due to natural or unplanned human intentional or negligent causes of ignition. Excludes prescribed burning of forest residues. **Data source:** official statistics collected by Fire Rescue Service of the Czech Republic **Projection:** average area burnt by fires in RP 2000-2009 (343 ha/year) was used for CP by CBM
DIST. 2 Thinning	Mass (Volume)	Specific thinning intensities are recommended in the Forest act for the main tree species (Spruce, Pine, Oak, Beech) based on stocking and age class. **Data source:** official statistics collected by Czech Statistical Office – area, total amount of wood cut by thinning **Methodology:** data from the official statistics were recalculated for the defined strata using the share of main tree species removals to total removals and the proportion of forest area AGEID3 - AGEID8 (21-80 year) according to prevailing functional category. **Projection:** The specific quantity for individual strata (Forest Management Types) was derived as described in Section 3.3.4

Identification and name	Input type	Description, data source and CP 1 projection set-up
DIST. 3 Salvaging with clear-cut and species change	Mass (Volume)	Salvage felling caused by biotic and abiotic agents results in clear-cut areas. The salvage felling occurs mainly in production forests (MAN) and special purpose forests (SPE) in the country. **Data source:** official statistics collected by Czech Statistical Office – total amount of wood from salvage felling **Methodology:** salvage felling was allocated in the categories of production forests (MAN) and special purpose forests (SPE). Data from the official statistics were attributed to the defined strata using the share of main tree species removals to total removals and the proportion of annual clear-cut area of production forests (MAN) and special purpose forests (SPE) as registered in the NDFMP. Tree species composition change was implemented modelled using Transitions in CBM. Spruce stands after salvage felling were replaced by beech (53%), oak (14%) and spruce (33%). These percentage shares were calibrated on real change of tree species compositions reported in NDFMP. **Projection:** DIST. 3 is applicable for CP identically as described here.
DIST. 3a Salvaging with clear-cut and no species change	Mass (Volume)	Salvage felling caused by biotic and abiotic agents that results in clear-cut area is used similarly as DIST 3 for strata without species change. **Projection:** DIST3a is used similarly as DIST. 3, but with no species change. The specific quantity for individual strata (Forest Management Types) was derived as described in Section 3.3.4
DIST. 3b Salvaging (soft) without clear-cut and species change	Mass (Volume)	Salvage felling caused by biotic and abiotic agents which do not result in clear-cut areas, but only distributed fragmental biomass removals. It means it is not a stand replacing disturbance event. **Data source:** official statistics collected by Czech Statistical Office – total amount of wood cut by salvage felling **Methodology:** Salvage felling that occurred in protection forests (PRO) was included in production forests (MAN) and special purpose forests (SPE) salvage felling. They were not calculated separately. Figures from the official statistics were recalculated on the defined strata using the share of main tree species removals to total removals and the proportion of annual clear-cut area of production forests (MAN) and special purpose forests (SPE) registered in the NDFMP. **Projection:** The specific quantity for individual strata (Forest Management Types) was derived as described in Section 3.3.4
DIST. 4 Final harvest	Mass (Volume)	Final harvest represents intentional felling that is based on rotation and regeneration period. **Data source:** official statistics collected by Czech Statistical Office - total wood removals minus amount of thinning and minus amount of salvage felling. **Methodology:** Figures from the official statistics were recalculated on the defined strata using the share of main tree species removals to total removals and the proportion of annual clear-cut area of production forests (MAN), special purpose forests (SPE) and protection forest (PRO) registered in the NDFMP. **Projection:** The specific quantity for individual strata (Forest Management Types) was derived as described in Section 3.3.4
DIST. 5 Clear-cut with slash-burn	Area	Clear-cut with slash-burn is a disturbance type which is used in CBM only for stand initialization.

The observed activity data on the reported spatial extent of forest wildfires since 2000 until 2009 and the applied average of RP (343 ha/year) for the projection years 2010 to 2030 (DIST. 1) are shown in Figure 9. Due to a high inter-annual variability, there is no significant trend neither in area or in number of forest fires during RP. However, when considering a longer time frame such as from 1970s until 2017, there is a significant trend in number of fires (p=0.003; data not shown), although area burnt remains about constant due to the gradually improving national fire prevention system.

The flow of carbon among various ecosystem carbon pools caused by a disturbance or management event represented in CBM is described by so called disturbance matrices. Composing the CBM simulations, the default disturbance matrices were specifically calibrated to domestic conditions and prevailing management procedures according to available information and expert judgement.

The specific adjustments are explained in a form of disturbance matrices, where rows define the originating pools and columns represent the target pools. The key aspects of disturbance matrices are summarized in Table 11. The complete disturbance matrices as used in CBM are documented in Supplementary material S1.

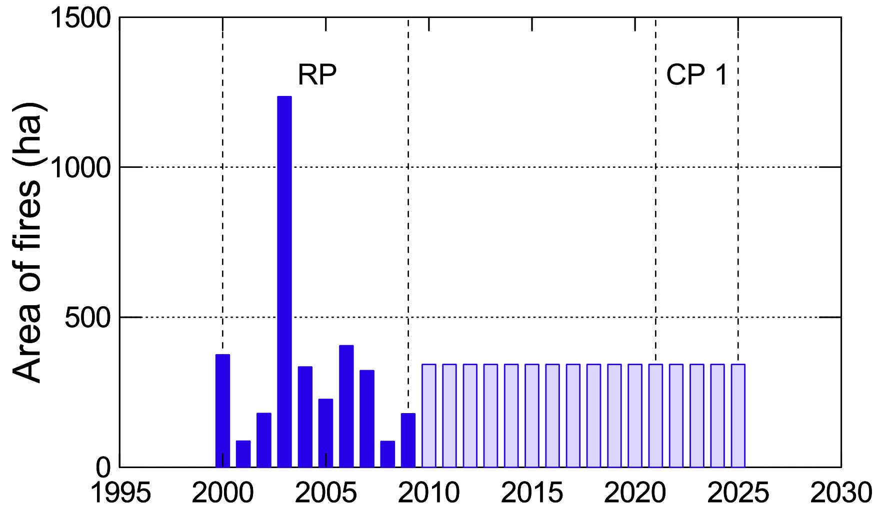

Figure 9: The reported area of forest fires in 2000-2009 (RP) and the prescribed areas for the projected estimates since 2010 to 2025 (including CP 1), estimated as the average of RP.

Table 11: List of disturbance events and description of the applicable disturbance matrices used in CBM for the Czech FRL estimation

Disturbance event	Description of corresponding disturbance matrix
DIST. 1 Forest fire	Since canopy fires are not common in the country, only surface wildfires area assumed. Disturbance matrix leaves the main part (98%) of merchantable wood unaffected and acts mainly on ground surface carbon pools.
DIST. 2 Thinning	Disturbance matrix assumes thinning intensity of 10% of merchantable wood extracted and passed to products.
DIST. 3 Salvaging with clear-cut, with species change	Disturbance matrix assumes using 100% of softwood merchantable and hardwood merchantable wood as products.
DIST. 3a Salvaging with clear-cut, no species change	
DIST. 3b Salvaging (soft) without clear-cut, no species change	Disturbance matrix assumes harvesting 20% of merchantable volume extracted and passed to products.
DIST. 4 Final harvest	Disturbance matrix describes regular final cut as common in the country. Major part of merchantable wood (95%) is harvested and passed to products.
DIST. 5 Clear-cut with slash-burn	Disturbance matrix describes final cut together with burning the remaining residues. Major part of merchantable wood (95%) is harvested as products – used only for model initialization.

3.3.4 Calibrating wood removals by P_Av - assuring consistency of management practices

The approach for modelling management practices associated with wood removal applicable for the projection period since 2010 to 2025 follows the JRC methodology (Grassi and Pilli, 2017), which corresponds to Alternative 1 of Forsell et al (2018) – Maintain the "harvest to biomass available for wood supply" (P_Av) ratio. It was used at the level of individual strata (Table 4, Table 7) and implemented in the following steps:

1) Initially, the consistency estimates for RP were made by CBM, using disturbance events for thinning DIST. 2, salvage logging (DIST. 3, DIST. 3a, DIST 3b) and final planned harvest (DIST. 4) defined in the import file by target type "Merchantable carbon" for the reference period (2000-2009) based on the official statistics and reported values.
2) For the projection period since 2010 to 2025, the average derived harvest values as estimated from RP (Section 3.3.2) were used as static input defined by target type "Merchantable carbon" in the CBM import file (Figure 10 left).
3) The first CBM projection run was made.
4) The amount of harvest obtained by CBM as output was compared with the available biomass in each stratum (i.e., biomass carbon in eligible 20-yr age classes for each stratum and disturbance type), to determine average P_Av for each stratum and harvest disturbance type applicable for the projection period.
5) The average P_Av ratios were applied for every stratum and on biomass available for wood supply to derive the new amounts of merchantable carbon to harvest during projection period in the following run of CBM.
6) The updated version of the import file with the revised harvest data was imported in CBM and the successive simulation was carried out.

7) Steps 4 to 6 were repeated until equilibrium in P_Av was reached. At this stage, P_Av during projection period (including CP 1) basically equals the corresponding average P_Av observed for RP, with the corresponding harvest level applicable for the projection period (Figure 10 right).

In this way, consistency of management practices was fully ensured, both in terms of adopted removals and in terms of other quantitative parameters, which are preserved identical for projection period including CP 1 as those observed for RP. The specific P_Av values and other quantitative parameters of adopted management practices are reported jointly in Table 7.

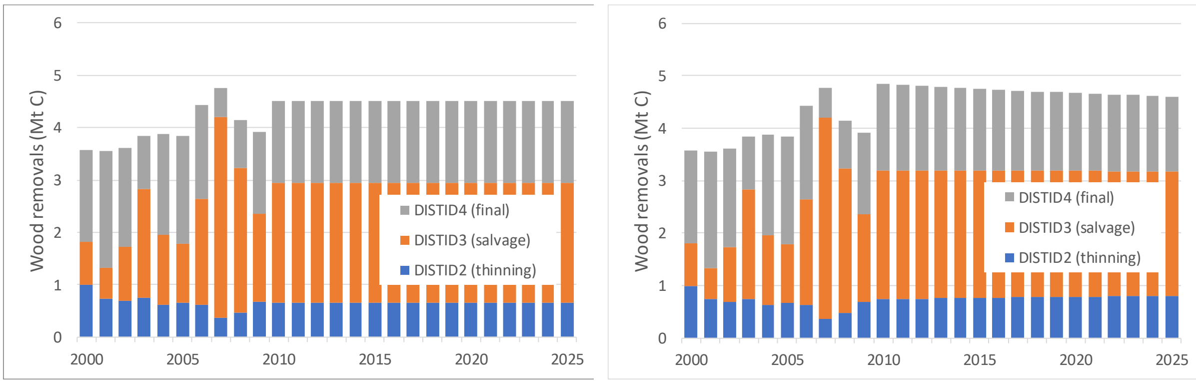

Figure 10: Wood removals (Mt C) in CBM associated with thinning (DIST. 2), salvage logging (DIST. 3) and final harvest (DIST. 4) for period 2000 to 2025. Wood removals for RP (2000-2009) are based on the reported harvest data (CzSO), whereas the removals for the projection period since 2010 are derived with help of CBM based on calibrated P_Av (right). The static harvest averages applied initially for the calibration of P_Av applicable for the projection period are also shown (left).

The resulting wood removals expressed in amount of carbon at the level of the relevant management interventions for projection period (2010-2025), as well as removals based on reported harvest for RP (2000-2009), are graphically summarized in Figure 10. This figure shows the removals aggregated at the level of management practices thinning (DIST. 2), salvage logging (DIST. 3) and final cut (DIST. 4). A companion Figure 11 details the information on removals by management practices at the level of individual strata – given by forest category and species group.

It is apparent in Figure 10 that the share of wood removals changes during CP. Since the applied management practices remain constant by its spectrum (types of management interventions), restrictions given by predefined age span (Table 7) and intensity due to the constant strata-specific P_Av, the only reason for the observed development in projection period is the dynamic development of age structure. Functioning of age class module of CBM is demonstrated in Section 4.3.1.

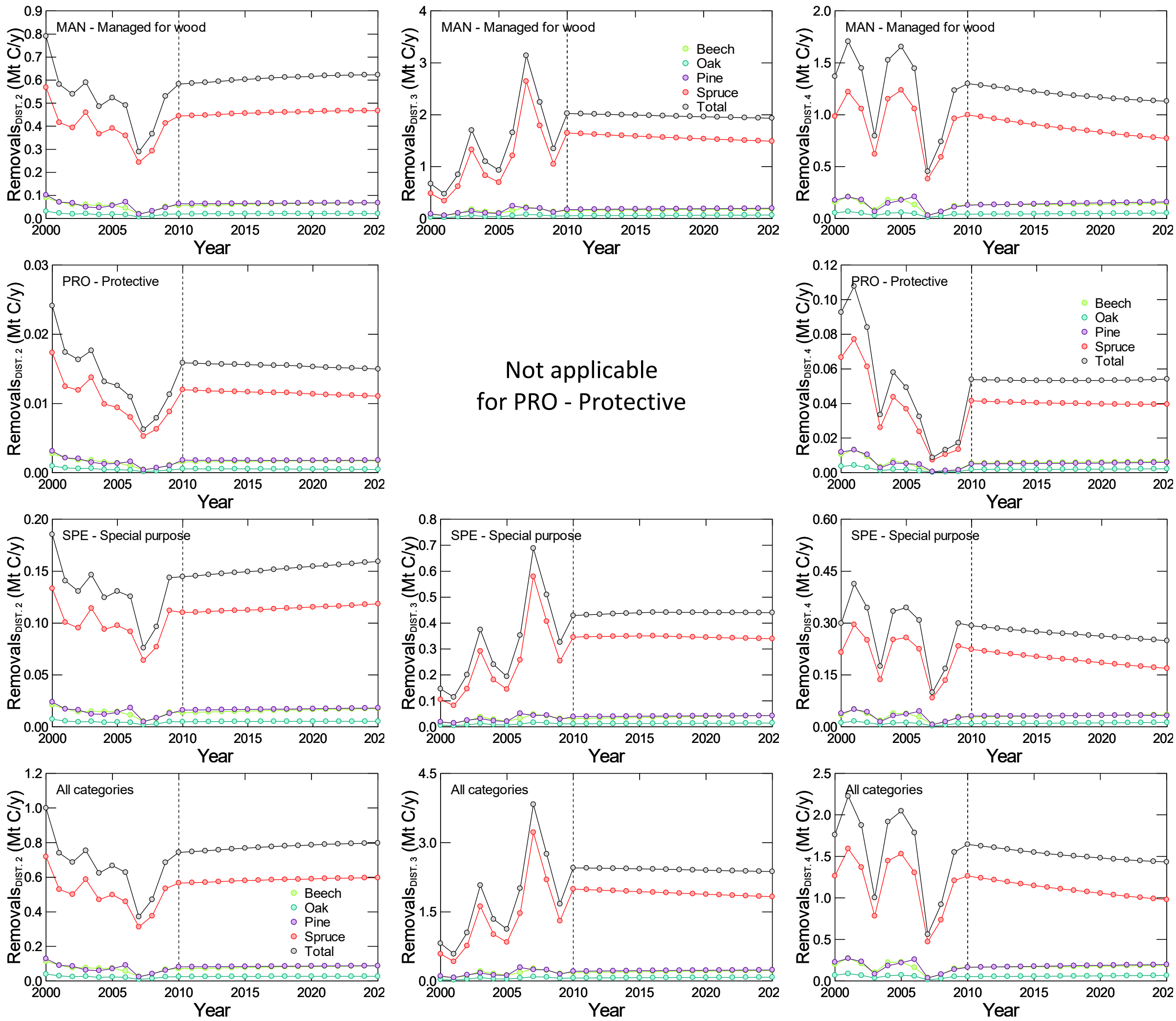

Figure 11: Strata-specific removals by the relevant disturbances – thinning (DIST. 2; left), salvage logging (DIST. 3; middle) and final cut (DIST. 4). The consistency and projected estimates are visually split by a horizontal line at year 2010, the first year of the projected period.

3.3.5 Carbon stock change in deadwood components by CBM

Carbon flow among deadwood and other carbon components in CBM are driven by disturbance matrices (S1) and by the implemented disturbance events (Section 3.3.3). The CBM deadwood components definitions do not fully match the deadwood components as used in NIR (2018, 2019). The deadwood components with their relevant description are summarized in Table 12.

Table 12: Matching deadwood components as used in NIR and CBM

NIR deadwood components	**Description (NIR 2019)**	**CBM deadwood components**	**Description** (Kurz et al., 2013)
Standing deadwood	Standing dead trees (DBH>7cm)	Stem snags	Dead standing stem wood of merchantable size including bark
Lying deadwood	Lying timber (diameter > 7cm)	Medium DOM	Coarse woody debris on the ground

The NIR component of Standing deadwood is well-mirrored in CBM by the component Stem snags. Similarly, the component of Lying deadwood of merchantable size is generally represented by the CBM component Medium DOM (dead organic matter). Changes in Other components of deadwood (i.e., branches and smaller stem dimensions) are not included, which is identical Lying deadwood as used for NIR (2018, 2019). Hence, for FRL, only the CBM components Stem snags stems and medium DOM are included. They correspond to Standing deadwood and Lying deadwood, respectively, as also correspondingly represented in NIR.

3.4 Contribution of HWP

3.4.1 Estimation of HWP contribution

The methodology for estimating the contribution of HWP to emissions and removals was based on IPCC (2006) and IPCC (2014). The latter material was followed to adopt the agreed principles on accounting for HWP, which includes only domestically produced and consumed HWP. The estimation follows the Tier 2 method of first order decay, which is based on Eq. 2.8.5 of IPCC (2014). This equation considers carbon stock in the HWP categories, which is reduced by an exponential decay function using the specific decay constants. The default half-life constants were used for the major HWP categories: 35 years for sawnwood, 25 years for wood-based panels and 2 years for paper and paperboard. The second part of Eq. 2.8.5 (IPCC 2014) adds the material inflow in the particular year and HWP categories.

The activity data (production and trade of sawnwood, wood-based panels and paper and paperboard) were derived and/or directly used from the FAO database on wood production and trade (http://faostat3.fao.org/download/F/FO/E). The following criteria for HWP activity data apply:

- Only data originating from domestic harvest are considered.
- HWP data originate exclusively to area of land use category 4.A.1 Forest land remaining Forest land, as used in NIR for UNFCCC reporting. This means that it is assumed that no HWP originate from the category 4.A.2 Land converted to Forest land (a conservative assumption for the young forests stands until 20 years in the Czech conditions, noting also the related provision of IPCC (2014) of good practice on HWP entering the accounting framework). Next, it also means that the fraction of wood products (sawnwood, wood-based panels, paperboard) originating from Deforested land (Forest land converted to other land use categories and Deforestation activity under KP LULUCF accounting) is discounted and treated on the basis of instantaneous oxidation. This is fully retained using the appropriate (identical) share of Deforested land as documented in the Czech NIR (2018, 2019). Hence, although the fraction corresponding to source material originating from deforested land is quantitatively insignificant (0.02% in both 1990 and 2017), the HWP contribution of this fraction was estimated using instantaneous oxidation (IPCC 2014), which is a formal requirement of the EU LULUCF Regulation.
- Any HWP from solid waste disposal sites (not occurring in the national circumstances) and HWP harvested for energy purposes (Table 9) is accounted for in the basis of instantaneous oxidation

The activity data of HWP for RP that results from the above criteria are shown in Figure 12. They represent exclusively data originating from domestic forest, with the share attributed to Deforestation

(D; permanent land-use conversion from Forest land in the context of Kyoto Protocol LULUCF activity under Art. 3.3), identical as used in in the Czech NIR (2018, 2019). The fraction of D of the total forest area is low, with maximum of 0.053% (1998) and minimum of 0.015 % (1990). The average fraction of D estimated for RP is 0.023 %.

The estimation procedure of HWP contribution is identical as that used and described in the Czech NIR (CHMI 2018, 2019), but differs in adopting the initial estimation year, which is in this case 1990. The inflow activity data for this year are represented by 5-year averages for the period 1990-1994 as recommended by Forsell *et al.* (2018).

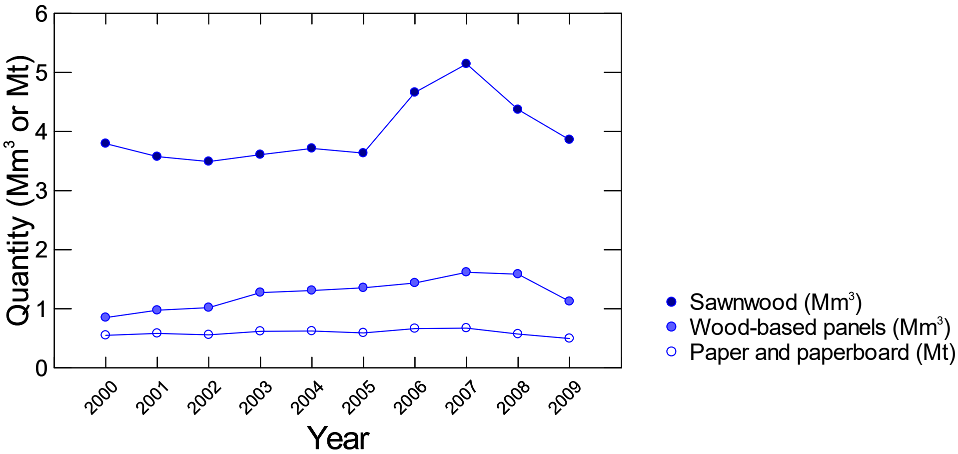

Figure 12: HWP activity data for RP – production of Sawnwood, Wood-based panels and Paper and paperboard.

3.4.2 Projection of HWP contribution for the period 2010 to 2025

The methodological approach for projection of HWP contribution meets the requirement of EU LULUCF regulation (criterion e) of Annex IV.A) on preserving a constant ratio between solid and energy use of forest biomass as documented in RP. This is ensured by adopting the following estimation procedure:

- Calculating the annual rate of change of the projected harvest as compared to the average of the historic harvest within RP (2000-2009). The harvest projected for the period 2010 to 2025 is the CBM output expressed in units of carbon.
- Using these annual change rates to the RP average of carbon inflow to the HWP pool in order to project the future carbon inflow to the HWP pool (i.e., feedstock for production of the HWP categories sawnwood, wood-based panels and paper and paperboard, reflecting the solid wood use)
- Estimating future emissions using the methods outlined in Section 3.4.1 and activity data (carbon inflow) as in the above two points of this section

The historical estimates of the HWP inflow for RP and the projected CBM-aided estimates (2010-2025) by the major HWP categories are visualized in Figure 13.

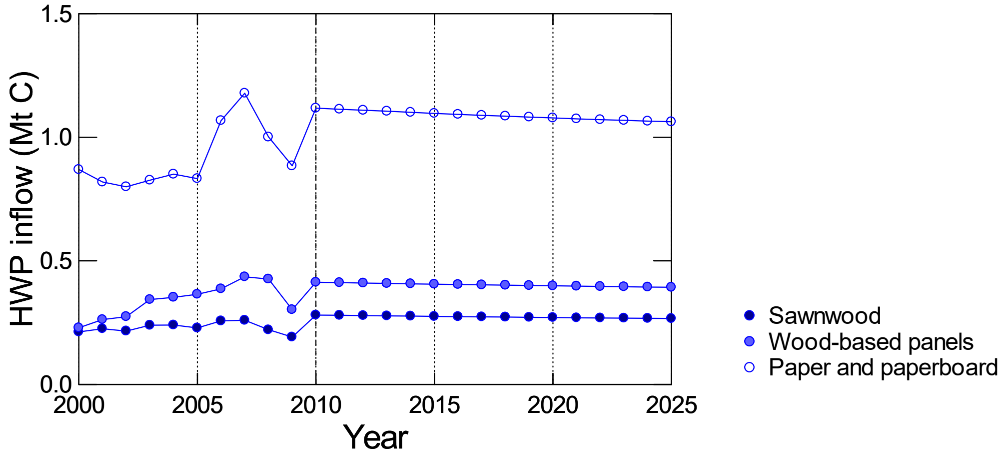

Figure 13: HWP inflow by the major categories – Sawnwood, Wood-based panels and Paper and paperboard. The dashed line indicates the first year of the projection period since 2010, when inflow is estimated based on the harvest ratio during RP.

4. Forest reference level

The forest reference level (FRL) for the compliance period 2021-2025 (CP 1) is estimated as -3 801.35 kt CO_2 eq., in which the HWP pool constitutes -1 099.49 kt CO_2 eq. If instantaneous oxidation of HWP was assumed, the FRL for CP 1 would be -2 208.23 kt CO_2 eq. These estimated values are shown in Table 13, together with the underlying data for all contributing components, i.e., Living biomass, Deadwood and HWP. Complementary information and comments to the estimated FRL and individual carbon pools is provided in the text below.

Table 13: FRL and its components – underlying data for CP 1 in terms of carbon and the resulting FRL 1 expressed in units of CO_2 eq.

Component	ΔC in CP 1 (kt C/y)	FRL for CP 1 (kt CO_2 eq.)
Living biomass	599.93	**-2 199.75**
Deadwood	2.31	**-8.48**
HWP contribution	434.49	**-1 593.13**
Total (with HWP)	1036.73	**-3 801.35**
Total (without HWP)	602.24	**-2 208.23**

4.1 Development of carbon pools – consistency estimates for RP

The consistency estimates show time series of the individual carbon pools, i.e., living biomass, deadwood and HWP for the RP. The corresponding data as reported in and/or estimated for the Czech NIR (submission 2019, 2020) for RP are shown overlaid by symbols.

4.1.1 Living biomass (above- and below-ground carbon pools)

Above- and below-ground biomass carbon pools are reported jointly as living biomass (LB; Section 3.1). The development of carbon stock changes in LB (ΔLB) is shown in total in Figure 14 in comparison with the ΔLB estimates reported in the Czech NIR. The coefficient of determination (R^2) and generally well-matching ΔLB values on y-axis generally indicate a good relative and absolute correspondence, respectively, between the NIR data and CBM estimates.

The statistical tests between the modelled (CBM) and observed (NIR) estimates of ΔLB confirmed the tight absolute and relative match of these quantities: R^2 reached 0.98 (adj.) and the slope parameter 0.998, i.e., practical unity. Similarly, the stringent paired t=test confirmed no statistically significant difference (p=0.076 and 0.264 with NIR 2019, 2020, respectively). This demonstrates the ability of the model to reproduce the observed data for the key component of the FRL, and the key category (carbon stock change in living biomass for 4.A.1 Forest land remaining Forest land) in the emission inventory as reported in the NIR.

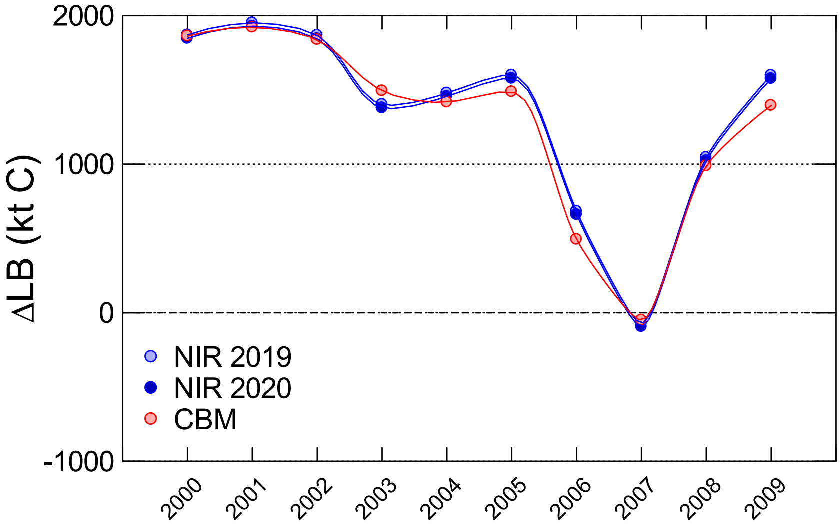

Figure 14: Carbon stock change in living biomass (ΔLB) - the NIR estimates for years 2000 to 2009 (NIR submissions 2019, 2020) and the CBM model consistency estimates for RP.

4.1.2 Deadwood (DOM)

As described in Section 3.3.5, the amount of carbon in the relevant deadwood components in CBM (Table 12) is based on disturbance events and its related disturbance matrices. The estimation of carbon stock change in deadwood (ΔDW) is shown in Figure 15 together with the reported NIR (2018, 2019) estimates. It can be observed that ΔDW oscillates around zero line on the identical scale as used for ΔLB.

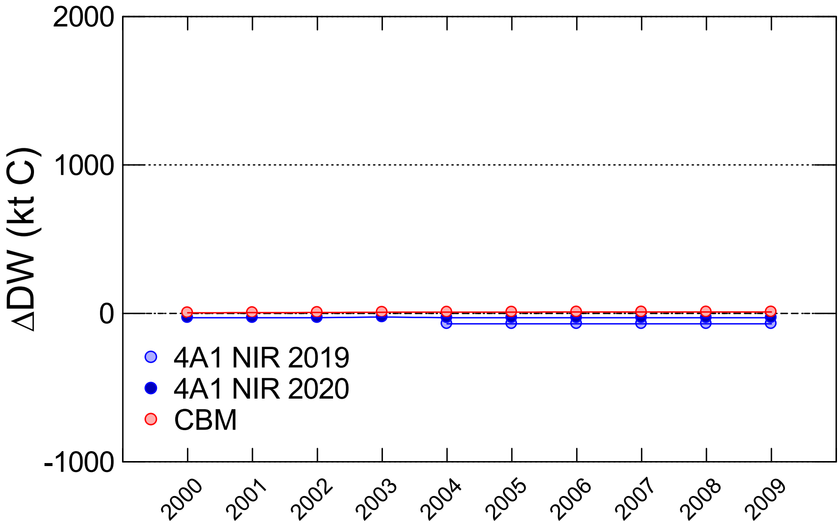

Figure 15: Carbon stock change in deadwood (ΔDW) - estimates for the NIR (2019, 2020) and the CBM model consistency estimates. The y-scale is held identical as for ΔLB to facilitate an easy comparison of changes in these two pools and (in)significance of ΔDW in this comparison.

The rigorous verification of ΔDW remains challenging due to the issues discussed in Section 3.3.2. There is a general lack of adequate verification data of DW (field observations) during the GHG emission reporting period under UNFCCC. Herewith, this carbon pool undergoes revision in NIR, which is indicated by somewhat different estimates for the two latest NIR submissions. More updates on ΔDW are expected in the nearest future in connection with the recent developments in the country.

4.1.3 HWP contribution

The HWP contribution for RP, expressed in terms of carbon stock change (ΔHWP), is shown in Figure 16. Data for the period 2000-2009 are equal to those reported in the NIR due to the identical methodology and constraints adopted. The later includes specifically the carbon inflow (Figure 13), which is solely based on the observed (reported) HWP data. Only the projection estimates (2010 to 2025; shown in Table 14) are aided by the CBM model estimates by the derived P_av ratio as described in Section 3.4.2. HWP contribution (ΔHWP) reflects a specific, longer-term dynamics of carbon pool stored in products, and it is just partially correlated with harvest rate.

No specific statistics demonstrating consistency of the HWP estimates during RP is applicable, as no comparative modelling is involved in these estimates.

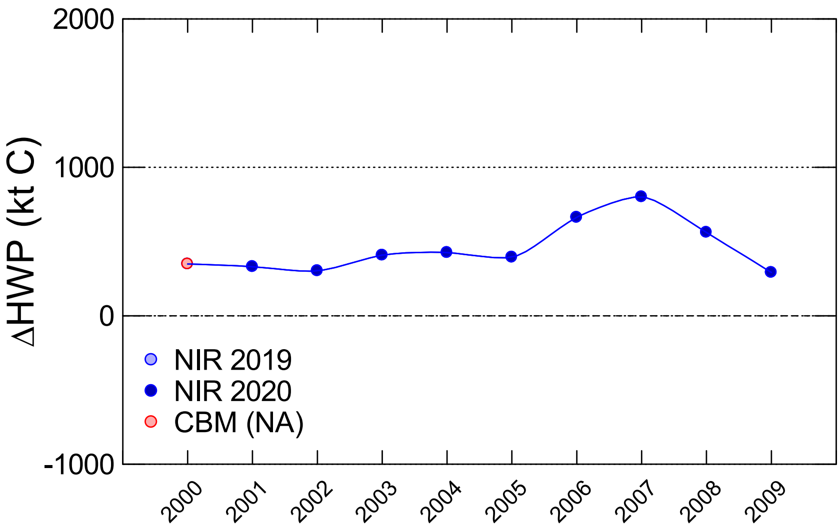

Figure 16: HWP contribution in terms of carbon stock change (ΔHWP) for RP. The NIR estimates are shown by circles. There are no specific CBM-aided estimates for RP, therefore CBM is labeled as not applicable (NA). The y-scale is held identical as for ΔLB and ΔHWP.

4.1.4 Total carbon stock change

The modelled (CBM) and observed (NIR 2019, 2020) and estimates of the total carbon stock change (ΔTotal including ΔLB, ΔDW and ΔHWP) for RP is shown in Figure 17. There is an apparent good relative and absolute correspondence, respectively, between the NIR data and the independent CBM model estimates.

Similarly as for ΔLB, the statistical tests between the modelled (CBM) and observed (NIR) estimates of ΔTotal confirmed the tight absolute and relative match of these quantities: R^2 (adj.) reached 0.96 and the slope parameter 0.997, i.e., practical unity. Similarly, the stringent paired t=test confirmed no statistically significant difference (p=0.736 and 0.970 with NIR 2019, 2020, respectively). Similarly, the hypotheses of equality of two variances was confirmed (p = 0.966). This means that inter-annual variability within the projected time series in not larger than that reported in NIR.

This demonstrates the ability of the model to reproduce the observed data as reported in the NIR for category 4.A.1 Forest land remaining Forest land, including the three components of the national FRL.

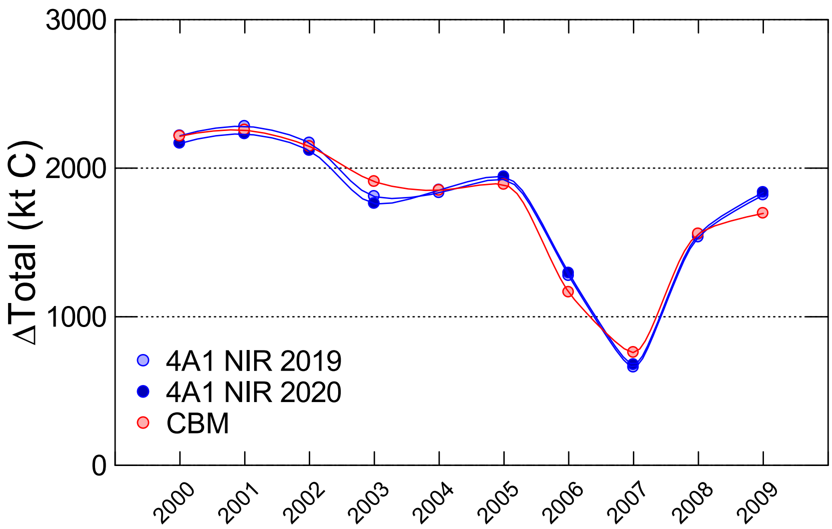

Figure 17: Total carbon stock change (ΔTotal) including ΔLB, ΔDW and ΔHWP - the NIR estimates for years 2000 to 2009 (NIR submissions 2019, 2020) and the CBM model consistency estimates for RP.

4.2 Development of carbon pools – projection estimates for 2010 – 2025

Development of carbon pools as projected by the CBM model for the projection period is shown in Table 14. The values of the total ΔLB entering the FRL estimate for CP 1 make an average of 599.93 kt C, corresponding to -2 199.75 kt CO_2 eq. The values of ΔDW entering the FRL estimate make an average of 2.31 kt C, corresponding to -8.48 kt CO_2 for CP 1. The mean contribution of HWP applicable for CP 1 is 434.49 kt C, which is -1593.13 kt CO_2, based on the average of the estimates for years 2021-2025. The corresponding mean value for the total carbon stock change (ΔTotal) is 1036.73 kt C, which corresponds to the final FRL 1 estimate of -3 801.35 kt CO_2 eq. (Table 13).

Table 14: The projected estimates of carbon stock change in living biomass (ΔLB), deadwood (ΔDW) and harvested wood products (ΔHWP) for the projected period 2010 to 2025. This includes the Compliance period (CP 1, 2021-2025, in bold).

Year	ΔLB (kt C/y)	ΔDW (kt C/y)	ΔHWP (kt C/y)	ΔTotal (kt C/y)
2010	128.73	-3.46	709.62	834.90
æ2011	166.84	-2.93	673.85	837.76
2012	211.67	-2.29	643.73	853.11
2013	245.69	-1.92	616.56	860.33
2014	278.58	-1.41	591.79	868.96
2015	314.75	-1.02	569.71	883.45
2016	349.82	-0.58	549.21	898.45
2017	386.96	-0.11	530.08	916.93
2018	422.65	0.25	512.41	935.30
2019	455.33	0.74	495.19	951.26
2020	493.64	1.11	478.79	973.54
2021	**530.44**	**1.54**	**462.71**	**994.69**
2022	**563.76**	**1.88**	**448.07**	**1 013.70**
2023	**600.83**	**2.30**	**433.80**	**1 036.93**
2024	**634.57**	**2.71**	**420.45**	**1 057.73**
2025	**670.05**	**3.14**	**407.42**	**1 080.62**

4.3 Consistency between FRL and the latest NIR

Verifying consistency between the estimates of the modelling tool used to asses FRL (i.e. CBM in this case) and the NIR (2018, 2019) data has three phases (Forsell et al. 2018): i) consistency of management practices, ii) consistency of emission and removal estimates (level and trend) and iii) consistency of the time series.

Ensuring consistency of management practices is described separately in Sections 3.2.3 and 3.3.4 of this material. That information is not explicitly included in the NIR reports and concerns documentation of management practices (Section 3.2.3) and methodology ensuring consistency of management practices (Section 3.3.4).

The following text complements the information on consistency for quantitative estimates, including level and trend, and consistency of the time series shown on the resulting total estimates (ΔTotal) including all components and expressed in term of CO_2 eq. units. Also, the consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013 is discussed in chapter 4.3.4.

4.3.1 Living biomass (above- and below-ground carbon pools)

The ability of CBM to reproduce the empirical data and estimates concerning living biomass is demonstrated on a) age class structure (areas by age classes) and b) carbon stock change in LB (ΔLB), merging both above- and below ground biomass pools (Section 3.1).

Age structure development is one of the relevant indicators for assessing model performance and ability to reproduce empirical data. Figure 18 demonstrate this comparing the age structure from empirical data of NDFMP as used in NIR, and CBM estimates based on the calibration year 2004. Figure 18 shows both the first (2000) and last (2009) year of the 10-year long RP used for consistency estimates. CBM is driven by known harvest demand, but dynamic strata-specific age structure. The good match (insignificant differences) of the empirical and CBM areas by age class was statistically confirmed for both years by Two-Sample Kolmogorov-Smirnov and Sign Tests as implemented in Systat v. 13.1 (Systat Inc., USA).

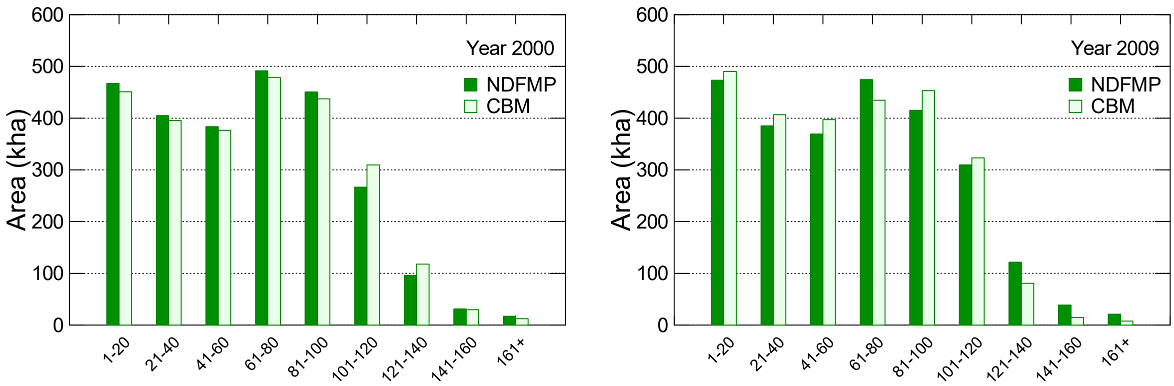

Figure 18: Age class distribution – empirical (known) data of NDFMP and estimates by CBM. Data of 2000 (left), the first year of consistency estimates (see Figure 2) are shown, as well as data of 2009 (right), the last year of consistency estimates.

Level consistency of emission estimates are demonstrated on estimated ΔLB, comparing CBM and NIR estimates for the calibration period (Figure 2; n = 10 years). These are shown in Figure 14 for total ΔLB and described by the appropriate statistical tests (regression and the passed paired t-test). These confirmed the level agreement between the modelled (CBM) and observed (NIR) estimates.

Verifying trends of CBM and NIR estimates of ΔLB includes checking inter-annual variability and trendlines when applying moving average (Forsell et al 2018). For this, variance was checked by hypothesis of equality of two variances, which was confirmed by p-value (0.986) for total biomass.

4.3.2 Deadwood

Consistency of ΔDW estimates can be judged by comparing CBM and NIR estimates as shown in Figure 15. As the available empirical information on deadwood components for the country is limited, no reasonable consistency check of CBM deadwood estimates could be elaborated (see also Section 4.1.2). It should be noted that deadwood emissions are generally negligible relative to the other major carbon pools entering FRL estimation. This applies also for the Czech NIR (NIR 2018), where ΔLB and HWP contribution constitute so called key categories by level and trend, whereas ΔDW remains quantitatively insignificant.

4.3.3 HWP contribution

An explicit demonstration of the consistency in level and trend for the estimated HWP contribution as described in this report and in the NIR (2018, 2019) is not needed – activity data, methods and constraints are identical for the consistency estimates in RP (Figure 2). This applies both for the level and trend consistency checks.

4.3.4 FRL as the sum of living biomass, deadwood and HWP contribution

The total sum of the carbon pool components (ΔTotal including ΔLB, ΔDW and ΔHWP), the basis of the FRL 1 estimate, is shown for RP in Figure 17 and for the projection period in Table 14. The consistency check for ΔTotal is described in Section 4.1.4.

Figure 19 below offers the composite information on both the consistency and projection estimates for ΔTotal, in this case already converted into CO_2 equivalents. This allows consistency interpretation for the entire time series 2000 to 2025.

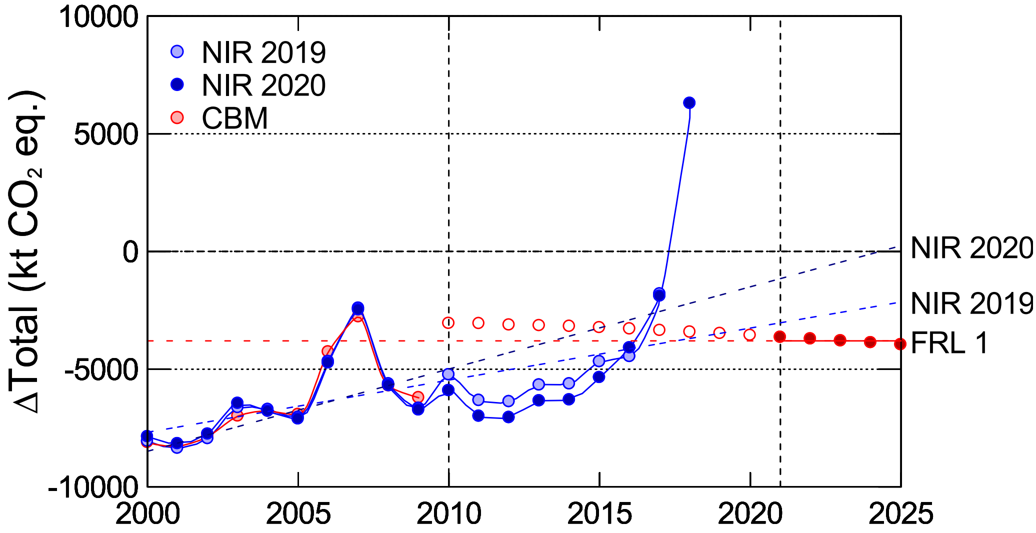

Figure 19: Total estimate of emissions/removals (ΔTotal) expressed in kt CO_2 eq. including the components living biomass, deadwood and HWP. Data based on NIR are shown by blue circles (NIR submissions 2019 and 2020 shown), and CBM simulation is shown by red circles for RP and projection period, including CP 1 estimates forming FRL 1. The trend lines based on the NIR (2019, 2020) data are also shown by dashed lines.

The following can be observed in Figure 19:

1) tight match between the NIR and CBM model estimates for RP, in which harvest demand is set identical, which was also verified statistically in Section 4.1.4
2) specific trends for the NIR estimates and the CBM model projections due to a different harvest demand applied since 2010
3) the resulting estimates for FRL 1 under CP 1 period (2021-2025) at -3 801.35 kt CO_2 eq.

4) the NIR reported data as of 2019 and 2020 (coming) submission that slightly differ due to recalculations of some components forming ∆Total. Note that only NIR 2020 provides the latest data on ∆Total as estimated for 2018
5) the trend lines based on the reported NIR values, being both significantly above the FRL 1 estimates, which – in contrast to the NIR data – are constrained by the mandatory requirements from EU Regulation 2010/841 on LULUCF.

There is an apparent consistency between the FRL estimates (Figure 19) and the national projections of anthropogenic greenhouse gas emissions reported by the Czech Republic under Regulation (EU) No 525/2013 (submission 2019). Those were prepared for the period until 2040 using anther modelling tool (EFISCEN, Schelhaas et al. 2007). In contrast to CBM, EFISECEN works on a 5-year time step. For the years 2020 and 2025, the projection by EFISCEN and the two scenarios under Regulation (EU) No 525/2013 suggested a source of emission in 2020 (0.55 and 1.25 Mt CO_2 eq.) and a small sink in 2025 (-1.74 and -1.09 Mt CO_2 eq.) for the LULUCF sector, which is dominated by the trends in the category 4.A Forest land. This is in line with the emission trends of the NIR (2019, 2020) data. At the same time, the estimated FRL 1 is suggesting a significantly stronger sink capacity of the Czech forestry. This is due to the mandatorily imposed estimation constraints by Regulation EU 2018/84 for the FRL estimation, whereas such constraints are absent for the projections under Regulation (EU) No 525/2013. In this way, the projections under these two EU regulations are fully consistent.

4.4 Interpretation and comments to the estimated FRL

It is apparent from the emission trends shown Figure 19 in that the estimated FRL (FRL 1) for CP 1 is overly optimistic in its expectation of the sink strength of the Czech Forestry. The discrepancy between FRL 1 and the actual emission trend (over 3 300 kt CO_2/yr during CP 1) is obvious.

The key reason for the observed discrepancy is the set of methodological constraints imposed by the EU LULUCF Regulation 2018/841. Specifically, the mandatory requirement on maintaining harvest or harvest ratios (i.e., management practices as described) at the levels observed in RP (2000-2009) when estimating FRL, is for the Czech Republic extremely unfavorable.

In contrast to the adopted rules for FRL estimation, the Czech forestry currently faces an unprecedented decline of coniferous forest stands due to severe drought accompanied by an uncontrolled bark beetle outbreak, resulting in compulsory increased salvage logging (while for FRL it is mandatorily kept at the levels as in reference period). This harvest trend is shown in Figure 8. For the nearest years to come, this negative development is expected to further intensify – e.g., the harvest level for 2019 is estimated at about 30 mil. m^3. Note also that the management interventions (sanitary felling) are mandatory with the adopted national policies - prioritizing and executing sanitary felling is requested by the Czech Forest Act (289/1995) as the only means that can slow down the bark beetle outbreak. It should be noted that the current decline of coniferous stands is beyond the harvest capacities in the country and some of the deadwood is left (and allowed to be left) on site by the new ministerial decree issued in April 2019 to facilitate the most effective use of limited harvesting capacities to fight the bark beetle outbreak and to target yet living trees just infested by bark beetles. This trend also affected the projections of future development of the Czech forest resources elaborated in Section 2.3.2.

In view of the above, the adopted accounting rules imposed by the EU LULUCF Regulation are grossly unfavorable for the country, leading to the FRL estimate that underrates the actual development of the Czech forestry sector. In its effect, it leads to penalizing the Czech forestry sector once more, in addition to the current damage and economic, ecological and social consequences caused by the observed historical dieback of forests in the country. It is strongly recommended that this issue be specifically addressed by representatives of the European Commission and the Czech Republic when assessing this plan and by the authorized policymakers when considering a future adaptation of EU accounting rules.

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List of supplementary material

S1 – Disturbance matrices

S2 – Explanatory note for the current FRL revision

DISTID 1 Wildfire	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable	0.98																			0.02										
SW foliage		0.98											0.02																	
SW other			0.98												0.02															
SW sub-merch				0.98											0.02															
SW coarse roots					0.98										0.01	0.01														
SW fine roots						0.98							0.01	0.01																
HW merchantable							0.98															0.02								
HW foliage								0.98					0.02																	
HW other									0.98						0.02															
HW sub-merch										0.98					0.02															
HW coarse roots											0.98				0.01	0.01														
HW fine roots												0.98	0.01	0.01																
Above ground very fast soil C													0.73					0.10								0.17				
Below ground very fast soil C														0.73					0.10							0.17				
Above ground fast soil C															0.73			0.10								0.17				
Below ground fast soil C																0.73			0.10							0.17				
Medium soil C																	0.88	0.05								0.07				
Above ground slow soil C																		0.99								0.01				
Below ground slow soil C																			1.00											
SW stem snag																	0.02			0.90						0.08				
SW branch snag															0.10						0.80					0.10				
HW stem snag																	0.02					0.90				0.08				
HW branch snag															0.10								0.80			0.10				
Black C																								1.00						
peat																									1.00					

DISTID 2 Thinning

DISTID 2 Thinning	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable	0.90																													0.10
SW foliage		0.90											0.10																	
SW other			0.90																		0.10									
SW sub-merch				0.90																	0.10									
SW coarse roots					0.90										0.05	0.05														
SW fine roots						0.90							0.05	0.05																
HW merchantable							0.90																							0.10
HW foliage								0.90					0.10																	
HW other									0.90														0.10							
HW sub-merch										0.90													0.10							
HW coarse roots											0.90				0.05	0.05														
HW fine roots												0.90	0.05	0.05																
Above ground very fast soil C													1.00																	
Below ground very fast soil C														1.00																
Above ground fast soil C															1.00															
Below ground fast soil C																1.00														
Medium soil C																	1.00													
Above ground slow soil C																		1.00												
Below ground slow soil C																			1.00											
SW stem snag																				1.00										
SW branch snag																					1.00									
HW stem snag																						1.00								
HW branch snag																							1.00							
Black C																								1.00						
peat																									1.00					

DISTID 3(a) Salvage with clearcut	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable																														1.00
SW foliage													1.00																	
SW other															0.90											0.10				
SW sub-merch															0.90											0.10				
SW coarse roots															0.50	0.50														
SW fine roots													0.50	0.50																
HW merchantable																														1.00
HW foliage													1.00																	
HW other															0.90											0.10				
HW sub-merch															0.90											0.10				
HW coarse roots															0.50	0.50														
HW fine roots													0.50	0.50																
Above ground very fast soil C													1.00																	
Below ground very fast soil C														1.00																
Above ground fast soil C															1.00															
Below ground fast soil C																1.00														
Medium soil C																	1.00													
Above ground slow soil C																		1.00												
Below ground slow soil C																			1.00											
SW stem snag																				1.00										
SW branch snag																					1.00									
HW stem snag																						1.00								
HW branch snag																							1.00							
Black C																								1.00						
peat																									1.00					

DISTID 3b Salvage without clearcut	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable	0.80																													0.20
SW foliage		0.80											0.20																	
SW other			0.80												0.20															
SW sub-merch				0.80											0.20															
SW coarse roots					0.80										0.10	0.10														
SW fine roots						0.80							0.10	0.10																
HW merchantable							0.80																							0.20
HW foliage								0.80					0.20																	
HW other									0.80						0.20															
HW sub-merch										0.80					0.20															
HW coarse roots											0.80				0.10	0.10														
HW fine roots												0.80	0.10	0.10																
Above ground very fast soil C													1.00																	
Below ground very fast soil C														1.00																
Above ground fast soil C															1.00															
Below ground fast soil C																1.00														
Medium soil C																	1.00													
Above ground slow soil C																		1.00												
Below ground slow soil C																			1.00											
SW stem snag																				1.00										
SW branch snag																					1.00									
HW stem snag																						1.00								
HW branch snag																							1.00							
Black C																								1.00						
peat																									1.00					

DISTID 4
Final cut

	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable	0.05																													0.95
SW foliage		0.05											0.95																	
SW other			0.05												0.85											0.10				
SW sub-merch				0.05											0.85											0.10				
SW coarse roots					0.05										0.48	0.48														
SW fine roots						0.05							0.48	0.48																
HW merchantable							0.05																							0.95
HW foliage								0.05					0.95																	
HW other									0.05						0.85											0.10				
HW sub-merch										0.05					0.85											0.10				
HW coarse roots											0.05				0.48	0.48														
HW fine roots												0.05	0.48	0.48																
Above ground very fast soil C													1.00																	
Below ground very fast soil C														1.00																
Above ground fast soil C															1.00															
Below ground fast soil C																1.00														
Medium soil C																	1.00													
Above ground slow soil C																		1.00												
Below ground slow soil C																			1.00											
SW stem snag																				1.00										
SW branch snag																					1.00									
HW stem snag																						1.00								
HW branch snag																							1.00							
Black C																								1.00						
peat																									1.00					

DISTID 5
Slash and burn
Stand initialization

	SW merchantable	SW foliage	SW other	SW sub-merch	SW coarse roots	SW fine roots	HW merchantable	HW foliage	HW other	HW sub-merch	HW coarse roots	HW fine roots	Above ground very fast soil C	Below ground very fast soil C	Above ground fast soil C	Below ground fast soil C	Medium soil C	Above ground slow soil C	Below ground slow soil C	SW stem snag	SW branch snag	HW stem snag	HW branch snag	Black C	peat	CO2	CH4	CO	NO2	products
SW merchantable	0.05																													0.95
SW foliage		0.05											0.95																	
SW other			0.05												0.30						0.65									
SW sub-merch				0.05											0.95															
SW coarse roots					0.05										0.48	0.48														
SW fine roots						0.05							0.48	0.48																
HW merchantable							0.05																							0.95
HW foliage								0.05					0.95																	
HW other									0.05						0.30								0.65							
HW sub-merch										0.05					0.95															
HW coarse roots											0.05				0.48	0.48														
HW fine roots												0.05	0.48	0.48																
Above ground very fast soil C													1.00																	
Below ground very fast soil C														1.00																
Above ground fast soil C															1.00															
Below ground fast soil C																1.00														
Medium soil C																	1.00													
Above ground slow soil C																		1.00												
Below ground slow soil C																			1.00											
SW stem snag																	0.10									0.70				0.20
SW branch snag																					1.00									
HW stem snag																	0.10									0.70				0.20
HW branch snag																							1.00							
Black C																								1.00						
peat																									1.00					

Explanatory note

Technical recommendations on Annex IV, Section A Criteria

a) Demonstrate how the goal of achieving a balance between anthropogenic emissions and removals will be achieved in the second half of the century. Provide qualitative and quantitative information until at least 2050 consistent with the long-term strategy required under Regulation (EU) 2018/1999.

In the case of the Czech Republic, the scenarios of harvest predictions until 2050 require including disturbance regimes, which are expected – based on the recent development - to affect both harvest rates and development of growing stock more strongly that the adopted policy scenarios.

Two scenarios for development of the Czech forest resources and the likely wood removals were prepared and processed by the CBM model. They are described in detail in chapter 2.3.2 Description of the future harvest rates under different policy scenarios.

e) Provide complete and transparent information on logging residues. Provide information on dataset used and methods applied to assess the use of the logging residues across the entire time series and on the method applied for projecting these quantities beyond 2017.

A detail information is in Chapter 3.3.2 Input data – harvest volumes.

For the period 2000-2009, the extracted volume of logging residues was derived from the ratios of 5 and 15 % of the planned (thinning and final cut) and unplanned (i.e., salvage) harvest volume, respectively. This is identical approach as used in the NIR. The extracted logging residues are incorporated in average amount of salvage felling and planned cuts, which are used for CBM calibration runs (in RP) and implicitly also for projection estimates within P_Av (Section 3.2.3, Table 6), which drives harvest volume for the projection period (2010-2025).

f) Provide information on the provisions of the Czech Forest Act on sustainable management and biodiversity conservation together with a table that shows the evolution from 2000 to 2030 of the total forest growing stock.

The required information was added to a new chapter 2.4 The provisions of the Czech Forest Act on sustainable management and biodiversity conservation. For the growing stock development, the official data from NDFMP were used for the period 2000-2018. For the period 2019-2030, results of the two defined scenarios described in Chapter 2.3.2 (Description of the future harvest rates under different policy scenarios) were used.

g) Demonstrate the consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013. Provide explanations for possible differences between national projections and the proposed FRL.

The consistency with the national projections of anthropogenic greenhouse gas emissions reported under Regulation (EU) No 525/2013 is demonstrated and described in Chapter 4.3.4.

h) Estimate the FRL based on the area under forest management as indicated in Annex IV, Part B (e) i. Demonstrate the ability of the model used to construct the FRL to reproduce historical data from the national GHG inventory. Demonstrate the consistency between historical data from the national GHG inventory and modelled data for estimating the FRL for the reference period.

Provide information on the changes in the level of agreement in the period 2000-2017 between the projected increment and the actual increment and assess its potential impact on the FRL.

Based on the recommendation from EU EG on LULUCF voiced in its 3rd meeting held on 2nd and 3rd October 2019, the modelling concept for the Czech Republic was changed accordingly, starting the projection estimates since 2010 (instead of 2018 earlier), just after RP. Hence, the consistency runs are limited to RP, not to 2017 as earlier. The current annual increment (CAI) based on the valid Czech Growth and Yield tables (Cerny et al. 1996) estimated for these strata, is shown (Figure 7). These tables are implemented on updated database NDFMP every year in order to evaluate changes in CAI on the national level. Annually updated CAIs has been used for GHG inventory reporting. Data for years 2000, 2004 and 2009 are shown, representing the development within RP. Year 2004 is the calibration year to represent RP in CBM (cf. Figure 2), while data of year 2000 are used to represent the area of FLrFL and the initial distribution of strata (Table 3), as recommended by h). The model reproduction of historical data and consistency of estimates is fully documented and discussed in Chapters 4.1, 4.3 and 4.4u.

Technical recommendations on Annex IV, Section B Elements

b) Noting the inclusion of additional carbon pools in the FRL, include those pools in the next submission of the national GHG inventory to ensure consistency between the FRL and the national GHG inventory.

The consistency between the carbon pools included in the FRL and those in the Czech emission inventory is fully retained. The consistency of emission and removal estimates and for the carbon pools included in the FRL and the contribution of HWP is detailed in section 4.3 Consistency between FRL and the latest NIR of this document.

c) Provide information if the factors used in the national GHG inventory have also been applied to the FRL. Assure that modelling starts the year after describing the state of the forest.

For the projection period 2010-2025, data of 2010 represent the initial model conditions for model estimation across this 16-year long period. A detail information is in Chapter 3.1 Description of the general approach as applied for estimating FRL.

d) Provide detailed information on how harvesting rates are expected to develop under different policy scenarios.

Two scenarios for development of the Czech forest resources and the likely wood removals were prepared and processed by the CBM model. They are in detail described in Chapter 2.3.2 Description of the future harvest rates under different policy scenarios.

e) i Provide the area under forest management consistent with Table 4.A.1 ("Forest land remaining Forest land") from the latest national GHG inventory using the year preceding the starting point of the projection.

An information is provided in Chapter 3.2.1 Data on forest land remaining forest land (category 4.A.1 in NIR) and stratification of the managed forest land, in detail in the Table 3: Adopted stratification of FLrFL area (as of 2000 used for calibration runs under RP and as of 2010 for the projection period 2010 to 2025) for the Czech FRL estimation.

e) ii Harmonize the information for comparison between table 8 and figure 10. 14

The time scale of Figure 10 is set from year 2000 now, showing only data for RP, making the information fully harmonized with Table 8.

e) iii Provide information on the use of the forest age to determine the current annual increment and on how the annual area from an age-class to the following is calculated.

The required information was added to Chapter 3.3 Detailed description of the modelling framework and estimation approaches, where a description of CBM instructions related to age class distribution and handling of defined natural (wildfires) and anthropogenic disturbances (felling, thinning), increment and growing stock was incorporated.

e) iv Provide information on dataset used and methods applied to assess the use of the logging residues across the entire time series and on the method applied for projecting these quantities.

A detail information is in Chapter 3.3.2 Input data – harvest volumes.

For the period 2000-2009, the extracted volume of logging residues was derived from the ratios of 5 and 15 % of the planned (thinning and final cut) and unplanned (i.e., salvage) harvest volume, respectively. This is identical approach as used in the NIR. The extracted logging residues are incorporated in average amount of salvage felling and planned cuts, which are used for CBM calibration runs (in RP) and implicitly also for projection estimates within P_Av (Section 3.2.3, Table 6), which drives harvest volume for the projection period (2010-2025).