Federal Ministry
Republic of Austria
Sustainability and Tourism

National Forestry Accounting Plan for Austria

final

Submission in accordance to the EU LULUCF Regulation
(Regulation (EU) 2018/841)

Vienna, 2019

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Content

1 General Introduction

1.1 General description of the forest reference level for Austria

The forest reference level (FRL) proposed by Austria consists of the following mean values for the periods 2021-2025 and 2026-2030:

Table 1 Mean values of CO_2 sinks (-) and CO_2 sources (+) for the projected periods 2021-2025 and 2026-2030 for the five carbon pools, the HWPs and the FRL

C-pool	Mean 2021-2025 (Gg CO_2eq.)	Mean 2026-2030 (Gg CO_2eq.)
Above ground biomass	-1,149	-174
Below ground biomass	207	438
Deadwood	-169	-202
Litter + Soil C	-548	-548
HWP	-2,874	-2,666
Forest fire[1]	0.27	0.27
FRL[2] (instantaneous oxidation)	**-1,659**	**-485**
FRL (incl. HWP)	**-4,533**	**-3,151**

Austria intends to make use of the provisions of Article 10 (Accounting for natural disturbances) of the LULUCF regulation[3], as applicable, and will provide information as requested under Article 10 (2) of the LULUCF regulation as soon as data for the period 2001 to 2020 is available. We would like to note, that the modelled biomass changes in the FRL already account for biomass losses due to mortality.

[1] The values for forest fire represent the average CH4 and N2O emissions expressed in CO2eq for the period 2000 to 2009

[2] Forest Reference Level

3 Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU

1.2 Consideration to the criteria as set in Annex IV of the LULUCF Regulation

Consideration of Annex IV A. Criteria and guidance for determining forest reference level

a) *The reference level shall be consistent with the goal of achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, including enhancing the potential removals by ageing forest stocks that may otherwise show progressively declining sinks.*

The Austrian FRL represents a net-sink in both periods, 2021 to 2025 and 2026 to 2030. In line with the LULUCF regulation, the Austrian FRL was derived by applying the concept of sustainable forest management for the reference period 2000 to 2009 in the respective accounting period. The management in the reference period ensured an overall sink of the considered pools of Managed Forest Land and HWPs in Austria. Consequently, the Austrian Forest Reference Level defines a baseline which represents net-sinks for Managed Forest Land and HWPs for the commitment periods 2021 to 2025 and 2026 to 2030 (chapter 4.1).

b) *The reference level shall ensure that the mere presence of carbon stocks is excluded from accounting.*

The methodology for calculating the Austrian FRL is not based on an estimation of carbon stocks, but on carbon stock changes of the pools (chapters 3.1, 3.3, 4.1).

c) *The reference level should ensure a robust and credible accounting system that ensures that emissions and removals resulting from biomass use are properly accounted for.*

The Austrian FRL is calculated in accordance with the methodologies laid down in the LULUCF regulation.

d) *The reference level shall include the carbon pool of HWPs, thereby providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values.*

The Austrian FRL includes the carbon pool of HWPs on basis of instantaneous oxidation and on basis of the first-order decay function and half-life values as defined in the LULUCF regulation (chapters **Fehler! Verweisquelle konnte nicht gefunden werden.**, 3.3.3).

e) *A constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 shall be assumed.*

The changes of the carbon pool of HWPs during the periods 2021 to 2025 and 2026 to 2030 of the Austrian FRL were estimated on basis of a constant ratio between solid and energy use of forest biomass as documented in the reference period from 2000 to 2009 (chapters 3.3.3).

f) *the reference level should be consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU forest strategy, Member States' national forest policies, and the EU biodiversity strategy.*

For more than 100 years sustainable management has been integrated in a well-established legal institutional and economic framework. A range of regulatory and economic instruments exists to safeguard a sustainable management, conservation and development of forest ecosystems. These are supported by manifold educational and informational measures.

The overall principles of the Forest Act (Federal Law Gazette I Nr. 1975/440, as amended), which are stipulated in § 1, are the preservation of the forest area, the preservation of the productivity of forest sites and their functions, and the preservation of yields for future generations; i.e. sustainable management (chapter 2.3.1).

These principles guide any forest management activity undertaken in Austria, including during the reference period 2000 to 2009 and are an integral part of the calculation of the FRL, to appropriately represent a continuation of the long-standing Austrian tradition of managing forests in a sustainable way.

The FRL indicates a further increase of the standing stock in the Austrian forests during the FRL periods. The modelling simulated the replanting of the same species as being harvested. This ensures the sustainability of the existing tree species diversity in the Austrian forests. Single tree harvests were simulated to continue in uneven aged forests, by that diverse forest structures are maintained. The FRL simulations suggest a further increase in the dead wood stock in the Austrian forests. All simulated management operations took into account the local situation at the NFI plots, e.g. adequate, reduced or no harvest in the various protected forest areas and appropriate management in protective forests at exposed terrain.

g) *the reference level shall be consistent with the national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013.*

The FRL is estimated on the same data (e.g. NFI, BEF,…) and tools which are also applied for the national projections of anthropogenic greenhouse gas emissions. Nevertheless, there are substantial differences in the framework conditions established in the LULUCF regulation, compared to those used for calculating projections:

- Estimates for the FRL are based on a continuation of the management in period 2000 to 2009. Therefore, the application of the forest increment and yield model CALDIS-VB V0.1 is sufficient for estimating the FRL. But, the purpose of the projections is to integrate all potential influences on the forest management, particularly changes in the existing economic and political framework conditions for forest management, changes in wood demand and use. Therefore, the projections under Regulation (EU) No 525/2013 are based on an additional integration of an economic forest and wood market model tailored for the Austrian conditions (FOHOW). As a first step FOHOW estimates the future specific wood demand for the different wood commodities and uses. In a next step this specific wood demand is satisfied by harvest in the Austrian forest (estimated with CALDIS-VB V0.1) and/or wood import, depending on availability, prices, costs, limitations, etc. So, for projections CALDIS-VB V0.1 implements the required (from FOHOW) and possible harvest (from the Austrian conditions), the regeneration of the forests and estimates the increment of the forests. This is a stepwise procedure of the interlinked models from year to year.
- The changes in the HWP pools for the FRL estimates are based on a constant ratio between solid and energy use. While for projections under Regulation (EU) No 525/2013 the HWP stock changes are based on the harvested assortments and tree species.
- The FRL has to be estimated for Managed Forest Land which equals the category 4.A.1 (Forest land remaining forest land). But, the projections are estimated for the total categories, so for category 4.A (Forest land) which includes also the land use changes to Forest land, a significant net sink in Austria.

Therefore, the tools applied and basic input data are the same in both, the FRL and the national projections, however the results differ.

Table 2 provides the results of the projections under Regulation (EU) No 525/2013 submitted by Austria in 2019.

Table 2 Mean values of CO_2 sinks (-) and CO_2 sources (+) for the projected periods 2021-2025 and 2026-2030 for the category Forest land (4.A) and the HWPs according to Austria's projections under Regulation (EU) No 525/2013 submitted in the year 2019

Category	Mean 2021-2025 (Gg CO_2eq.)	Mean 2026-2030 (Gg CO_2eq.)
Forest land	-2,727	-2,211
HWP	-2,342	-2,090

h) the reference level shall be consistent with greenhouse gas inventories and relevant historical data and shall be based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level shall be able to reproduce historical data from the National Greenhouse Gas Inventory

The Austrian FRL is fully consistent with the Austrian GHG inventory (chapters 2.1, 2.2, 4.2). The FRL is therefore complete (including all pools, gases and areas, exactly as for the Austrian GHG inventory), consistent (using same input data, approaches and tools as for the GHG inventory) and comparable with the results of the GHG inventory. The estimates were carried out with tools ensuring the highest possible accuracy and by applying QC steps similar to those for the Austrian GHG inventory (chapter 4.2.1).

Table 3 Equivalence table for the inclusion of the Annex IV B. elements in the Austrian NFAP reportx IV B

Annex IV B. paragraph item	**Elements of the national forestry accounting plan according to Annex IV B.**	**Chapter in the NFAP**
(a)	A general description of the determination of the forest reference level	3
(a)	Description of how the criteria in LULUCF Regulation were taken into account	1.2
(b)	Identification of the carbon pools and greenhouse gases which have been included in the forest reference level	2.1
(b)	Reasons for omitting a carbon pool from the forest reference level determination	NA
(b)	Demonstration of the consistency between the carbon pools included in the forest reference level	2.2
(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	3, 4
(c)	A description of documentary information on sustainable forest management practices and intensity	2.3.1, 3.2.2
(c)	A description of adopted national policies	3.2.2
(d)	Information on how harvesting rates are expected to develop under different policy scenarios	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	3.1
(ii)	Emissions and removals from forests and HWPs as shown in greenhouse gas inventories and relevant historical data	3
(iii)	Forest characteristics, including: - dynamic age-related forest characteristics - increments - rotation length and - other information on forest management activities under 'business as usual'	3
(iv)	Historical and future harvesting rates disaggregated between energy and non-energy uses	3.3.3

2 Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included in the forest reference level

The Austrian FRL includes all pools (aboveground and belowground biomass, dead wood, litter, soil, HWPs) and greenhouse gases, consistent with the Austrian GHG inventory. No carbon pool was omitted in the estimates of the FRL.

Carbon stock changes of the Austrian forests not-in-yield are neither yet reported in the Austrian GHG inventory nor included in the FRL. These forests are without any access and are therefore not harvested. The current NFI-cycle includes a first repetition of the stock assessment of these forests. So, with completion of this NFI-cycle in 2021 data will be available and the Carbon stock changes of these forests will be estimated. This information will be Future reporting in the GHG inventory and inclusion in the Austrian FRL on basis of a technical correction will be realised after finalization of the current NFI-cycle (see chapter 4.2.1).

2.2 Demonstration of consistency between the carbon pools included in the forest reference level

All Carbon pools of the FRL are consistent to the Carbon pools of the Austrian GHG inventory. The methods applied are the same as for deriving the Austrian GHG inventory or – in case of modelling vs. measured historic data – the models are based on and calibrated by the input data from the Austrian NFIs (since 1981) and are able to reconstruct historic results (see chapters 3.1, 4.2).

The FRL is estimated for a constant area which represents the area of subcategory 4.A.1 (forest land remaining forest land) in the year 2009 (as in Austria's GHG inventory submission 2018) – see chapter 3.1. Therefore, the FRL will need to be adjusted for the real afforestation and deforestation impacts and the changing managed forest land area once the related parameters for period 2021 to– 2025 are available.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forests and forest management in Austria and the adopted national policies

Austria is one of the most densely forested countries in Europe with forests covering 48 % of the federal territory. Ever since the beginning of the Austrian Forest Inventory in 1961 a continuous increase in forest cover has been observed in Austria (by almost 300 000 hectares to date). Austrian forests have been a significant net carbon sink since the start of the NFIs in 1960 (Umweltbundesamt 2000, 2018), the standing stock has steadily increased (not only due to forest area increase but also on a per-ha basis) (BFW 2011). The Austrian forests have a high share of coniferous trees with more than 70 %, most of them spruce. Broadleaved wood covers about one quarter of forest area with increasing tendency. The share of mixed forests is increasing according to the last NFIs (improving resilience against climate change).

Typically for a Central European Alpine country, Austria has a high variety of climatic, site and growth conditions, and consequently a large number of forest communities and tree species. The forest ownership structure is also rather diverse, with a majority of the forests in private hands, some big forest enterprises, but about half of the forest area represents small scale ownerships which do not live by their forest. The varying conditions according to the Alpine landscape further diversify the management and harvest conditions in technical and economic sense. All these impacts lead to a combination of various practical forest management practices which cannot be described by strict management regimes but with probabilities of certain interventions in the forests due to the combination of framework conditions at the simulated plot and intervention probabilities as observed in the past. The Austrian FRL simulation and modelling fully reflects this broad range of forest management in Austria, specifically on basis of the observed results in the NFI period 2007/09. Consequently, there are no schemes of forest management of certain forest strata and conditions but a large variety of combinations depending on the growth conditions, species combination, stem wood dimensions and assortments, (economic) conditions for harvest and wood extraction, specific non-economic forest functions (e.g. protective and protected forests), ownership specifics among several other influences. Consequently, each simulated NFI plot and assessed tree for the FRL is treated individually following a hierarchic list of model components and decision trees as well as intervention probabilities as observed in the reference period 2000 to 2009 (the approach is described in detail in chapter 3. This implies that policies and measures are only indirectly effecting the simulation of the Austrian FRL, namely as far as they are reflected in the results and forest management as detected for the period 2000 to 2009. Of course, the results for this period as well as the FRL are impacted by and follow the regulatory framework conditions for forest management as laid down in the Austrian Forest Act.

Sustainable forest management has been a guiding principle of Austrian forest management policy for more than 100 years, balancing the relevant ecological, economic and social functions. Austrian forest management mainly focuses on the targets to maintain biodiversity, productivity, regeneration capacity and vitality of forests and to improve adaptation to changing – specifically climatic – conditions. A range of regulatory, financial and informational tools are being applied to safeguard a sustainable management, conservation and development of the forests. Principles of forest management in Austria and specific provisions are stipulated in the Forest Act (Federal Law Gazette I No. 1975/440, as amended), e.g. general bans on forest clearcuts/deforestation and on forest destruction, requirements for reforestation after fellings, sustaining forest (soil) productivity, specific protection and management measures against pests and other disturbances, restrictions on forest litter removal, provisions on harvest, haulage and forest protection. In order to balance the various interests in forest use and to assure the many benefits of the Austrian forest in the long term, the Federal Minister of Agriculture, Forestry, Environment and Water Management has adopted the Austrian Forest Program in 2005 and the Austrian Forest Strategy 2020+ in (2016). The strategy was jointly developed by 85 institutions involved in forest policy within the scope of the Austrian Forest Dialogue, its primary objective is to ensure and optimize all dimensions of sustainable forest management in a balanced way, paying special attention to the added value and the potential of the Austrian forestry and timber sectors. The strategy should help ensure the multifunctional services that forests render for present and future generations.

Both the Austrian Forest Strategy 2020+ and also the Austrian Climate and Energy Strategy, #mission 2030 (2018) emphasize the importance of a sustainable forest management strategy. The land use related policies and measures identified in the #mission 2030 are defined with the aim to achieve the target laid down in Article 4 of the LULUCF Regulation, in particular through:

- continuously increasing tree growth and timber harvesting in Austrian forests on the basis of sustainable forest management, with the aim of increasing carbon storage in forests and HWPs in the long term and
- increasing the use of domestic timber in construction and utilizing the manifold opportunities of the bio-economy

The final "Integrated National Energy and Climate Plan" for Austria which has been submitted end of 2019 to the European Commission is based on the policies and measures laid down in the #mission 2030 and other related domestic strategies. A list of policies and measures can be found on page 138f of the NECP for Austria, a summary on page 12.

The Austrian Program for Rural Development 2014-2020 also provides for support measures, e.g. for preventive action to protect forests from forest fires and natural disasters as well as to restore forest ecosystems after those events, and for increasing the resilience of forest ecosystems. The EU agricultural policy post-2020 should be developed with a view to support – amongst others – EUs environmental and climate policy.

Further details can be found in Austria's Forest Report 2015 (BMLFUW 2015), Austria's Seventh National Communication (2018) and in the Progress Report on LULUCF Actions Austria (BMLFUW 2016).

2.3.2 Description of future harvesting rates under different policy scenarios

Results of the "Holzkettenprojekt"

In 2015 a project ("Holzkettenprojekt") was finalized which simulated the Carbon stock changes in the Austrian forests and HWPs pools as well as the avoided emissions until 2100 due to the use of wood products instead of products based on substitute materials (Braun et al. 2016). Five scenarios were defined and estimated:

a) a reference scenario representing " business as usual";
b) a scenario simulating an increase of the demand of wood for energy by 20 % until 2100;
c) a scenario simulating an increase of the demand for solid wood use by 20 % until 2100;
d) a variant of scenario c above, with more optimistic wood import conditions and
e) a scenario simulating a moderate increase in standing stocks by harvest decreases at the forest stands with low growth.

All scenarios demonstrate the positive impact of the forestry and wood sector on the Austrian GHG balance, in particular by avoiding GHG emissions from products with a higher carbon footprint. The accumulated GHG savings and avoided emissions of the reference scenario for a period of 90 years until 2100 equal 20 times the total annual GHG emissions of Austria. The results of the scenarios with increased wood demand showed lower GHG savings in the order of 17 times the annual GHG emissions of Austria. This is caused by an increase in harvest rates above the total increment, which resulted in a decrease in forest biomass stocks (=a net-source). Despite the forests becoming a net-source, these scenarios also showed positive overall GHG savings. The scenario simulating a moderate carbon stock increase in forests (half the increase compared to historic years) showed the highest total GHG savings until 2100 in the order of around 25 times the annual national GHG emissions. These higher GHG savings were partly based on increases in carbon stock in the forests and also strongly influenced by a rather constant wood extraction for sawnwood production, which allowed maintaining the GHG saving effects of wood products at a high level. However it should be noted that this scenario requires a higher amount of substitute products – which are assumed to be produced using fossil fuels – to maintain the product service as indicated by the reference scenario. This would lead to an increase in fossil fuel emissions compared to the reference scenario by three times the current annual GHG-emissions of Austria until 2100.

The study shows the huge GHG savings of the whole Austrian forest and wood chain, consisting of the forest carbon stocks as well as material and energy use, under different management scenarios. Each element of the wood chain (forests, the HWP pool and the product substitution) contributes to the overall effect, with the product substitution (which influences the GHG balance of other sectors than LULUCF) providing by far the highest share in most scenarios.

Results of the project "CareforParis"

Recently (November 2019), a successor project ("CareforParis") was finalised which simulated the development of the GHG balance of the Austrian wood based sector (C stock changes in the Austrian forests and HWPs pools as well as the avoided emissions through the use of wood products) until 2150 under different climate change scenarios and adaptation measures in the Austrian forests. The methodological approach was further improved and the definitions of the framework conditions were changed, so the results of both projects cannot be compared.

Six scenarios were defined and estimated:

a) a reference scenario (R4.5) representing " business as usual" under a regionalised climate trend of IPCC RCP4.5;
b) a reference scenario (R8.5) representing " business as usual" under a regionalised climate trend of IPCC RCP8.5;
c) a scenario simulating "business as usual" under a regionalised climate trend of IPCC RCP8.5 but with an additional increase of natural disturbances (KAL);

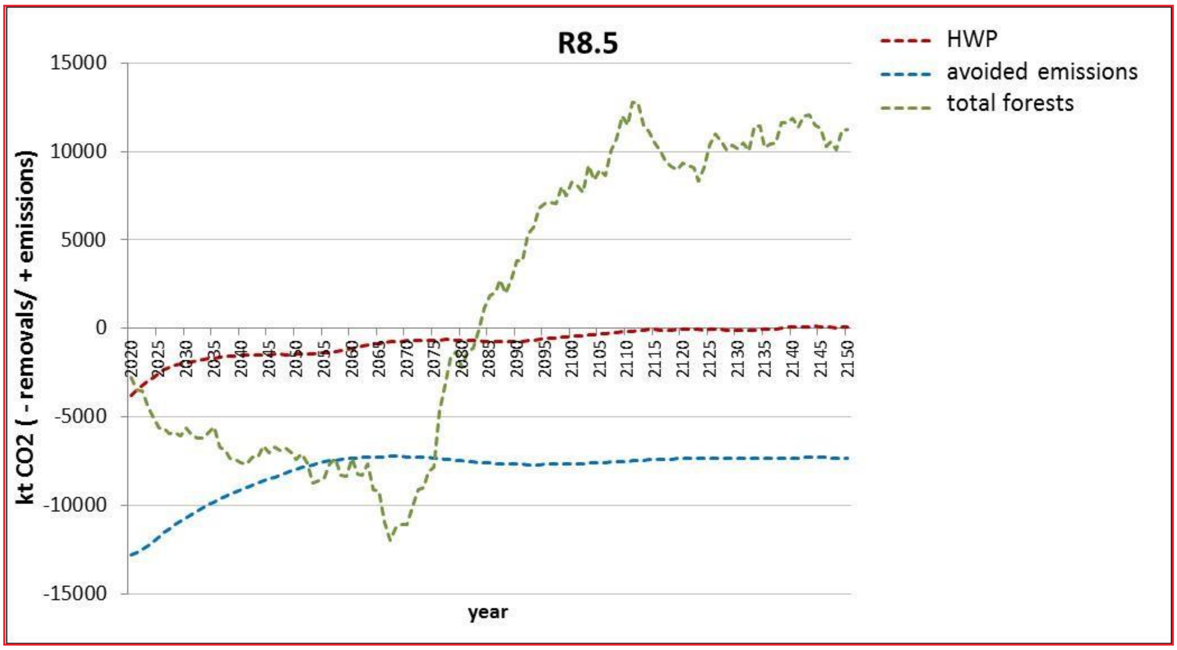
d) a scenario simulating the adaptation measure of shortening the age of trees of final cuttings (UZV) in order to increase the resiliance against storm damages under a regionalised climate trend of IPCC RCP8.5;
e) a scenario simulating the adaptation measure of changing the species composition (BAW) during regeneration measures of the forests in order to a better fit to a regionalised climate trend of IPCC RCP8.5 and
f) a scenario simulating a moderate increase in standing stocks by harvest decreases at the forest stands with highest growth (VAU).

The project "CareforParis" confirmed the overall GHG saving effects of the forestry and wood sector which sustains until 2100 and even beyond, up to 2150. All scenarios show a declining forest net-sink (including HWP), which will turn into a net-source in the next 20 years (scenario d) and up to 90 years (scenario f).

Climate change has major impacts on the overall GHG savings. The reference scenario based on a regional R4.5 climate scenario shows an overall GHG saving until 2150 which is equal to 20 times the annual national GHG emissions. These overall GHG savings decline in an R8.5 climate scenario by 40%, and up to 60% in case increased impacts of droughts and strorms are considered. On the basis of the R8.5 climate scenario three different variations have been calculated, of which two scenarios considered active management responses to climate change (shortening of the rotations length – scenario d – and changes in tree species composition – scenario e) and the last scenario considered further increases in forest biomass stocks due to increases in protected areas. Whereas scenario d results in an increase in harvest rates, which leads to the forests becoming a net-source as of 2040, scenario e leads to a higher total Carbon sequestration in the forests. This however comes at the expense of a lower production of wood products, which requires the production of substitute products. Those products where considered to be produced using fossil fuels and lead to an emission equal to 4.5 annual GHG emissions of Austria. Scenario f considered a moderate reduction in harvest rates and resulted in the highest overal GHG savings, but also requires a high share of substitute products, leading to fossile emissions in the magnitute of four times the annual emissions, in order to sustain the service of the amount of wood products as in scenario R8.5.

The results of "CareforParis" will be published in the next months. The CO2 emissions and removals of the forest, the HWP pool and the avoided emissions of the scenario b (reference scenario on the basis of the R8.5 climate scenario)are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

Figure 1: Trends of GHG emissions (+) and removals as well as avoided emissions by wood products (-) of the Austrian forests and the HWP pool in scenario R8.5 of the "CareforParis" project



3 Description of the modelling approach

3.1 Description of the general approach as applied for estimating the forest reference level

The construction of the forest reference level is based on the following data sources and national modelling approaches:

- Field data from the Austrian National Forest Inventory (NFI, BFW 2011) including three full inventory cycles conducted in 1992/96, 2000/02 and 2007/09 covering the whole forest area of Austria.
- Results from projections for C-stock changes in biomass and deadwood for the two time periods 2021-2025 and 2026-2030 using the growth, harvest and mortality models implemented in the simulation program CALDIS-VB V0.1.
- Results from projections for C-stock changes in litter and soil for the two time periods 2021-2025 and 2026-2030 using the soil carbon model Yasso15.
- Estimates for the HWP carbon pool changes as based on the future harvest rates for the two time periods 2021-2025 and 2026-2030 by CALDIS-VB V0.1 and the ratio of HWP production as documented for the reference period 2000 to 2009.

Data from the Austrian National Forest Inventory (NFI) are available since the first inventory cycle conducted between 1961 and 1970. Further forest inventory cycles were carried out in the periods 1971–80, 1981–85, 1986–90, 1992–96, 2000–02 and 2007–09. The recent NFI started in 2016 and its assessment will be finished in 2021. A midterm assessment of the NFI 2016/21 based on half of the NFI plots is currently available (NFI 2016/18). The results have been used to additionally demonstrate that the modelling results perfectly match the NFI results. The NFI of Austria is the main data provider for the greenhouse gas reporting of the forest land sector. Measured data for the forest area, stem wood volume increment and drain of the growing stock are the main basis for the fulfilment of the reporting obligations. The models used to construct the FRL are building upon the same data source for the reference period 2000-2009. The forest growth simulator CALDIS-VB V0.1 (LEDERMANN et al., 2017a) served as the basis for the calculation of the biomass increment, harvest and standing deadwood in accordance with the sustainable forest management practices as applied in the reference period 2000-2009. Simulation runs were started from the most recent NFI (2007/09) which covers results of the forest parameters (e.g. area, stock, increment, drain) for the observation period from NFI 2000/02 to NFI 2007/09 and consequently perfectly matches the reference period 2000 to 2009 for the FRL. Simulation runs were performed until 2030. Projected individual tree data were then aggregated to higher level information analogously to a NFI assessment. The projection of the FRL is based on the same climatic conditions as they had been observed in the reference period from 2000 to 2009. A more detailed description of the growth simulator CALDIS-VB V0.1 and its application can be found in chapter 3.3.1.

The litter and soil carbon stock changes were calculated with the Yasso15 model. The latest version that was available as an R script was used and was made available on request by the authors of the model (https://en.ilmatieteenlaitos.fi/yasso-description). The climate data for Yasso15 were extracted from the same data set as used in the forest growth model CALDIS-VB V0.1. The annual litterfall was calculated from the standing stock of stems by country and species specific biomass equations that have been used for the Austrian GHG inventory. The chemical quality of different types of the annual litterfall was derived from a database that is maintained by the user community of Yasso.

The FRL was estimated for a constant area of Managed Forest Land as in 2009 which represented 3.822 Mio ha (subcategory 4.A.1 "Forest land remaining forest land", Austria's GHG submission in 2018). However, consistent with the Austrian GHG inventory GHG emissions and removals were calculated for the Managed Forest Land 0f the forests-in-yield only (3.307 Mio ha in 2009). So far, only for these forests carbon stock changes are reported in the Austrian GHG inventory. Carbon stock changes for the Austrian forests not-in-yield (i.e. without harvest) will be estimated after finalization of the recent NFI and reported in the GHG inventory and an adequate projection and adjustment for the FRL will be made then (chapter 4.2.1).

The FRL modelling approach for the biomass and dead wood stock changes exactly simulates the way it is done in the Austrian GHG inventory. In a first step, the increment and total drain of stem wood as well as the dead wood stocks are modelled for the total Forest Land (4.A) including the deforestation harvest in the year of land-use changes from Forest Land to other land uses. This corresponds exactly to the way the NFI assesses these parameters for the Austrian forests. From these total stem volume increment, drain and dead wood stock changes (expanded and recalculated to total tree biomass changes expressed in C) the increment, drain and dead wood stock changes of total tree biomass of the land-use change areas to Forest Land in 20 years transition as well as the biomass and dead wood loss in the year of land-use change from Forest Land to other land uses are subtracted. These subtracted land-use change removals/emissions were taken from the Austrian GHG inventory for the year 2009 (Austria's GHG submission in 2018, Umweltbundesamt 2018) – corresponding to a constant 4.A.1 area as in 2009 (technical corrections will be needed for the real land use change emissions as well as for the real areas of Managed Forest Land in the commitment period – see chapter 4.2.1). This approach exactly matches the method of the Austrian GHG inventory and results in the biomass and dead wood stock changes for the subcategory 4.A.1 which corresponds to the category Managed Forest Land (see Umweltbundesamt 2018).

For a better comparison of the match of the FRL estimates with the NFI results and with the GHG inventory results the figures in this report are shown in two different ways: The results expressed in stem wood volumes correspond to total Forest Land as assessed by the NFI (they depict the total increment, drain and dead wood stock changes in comparison to the NFI results). The results expressed in t CO_2 show the category 4.A.1 and are compared with the results of the Austrian GHG inventory for this category.

Due to an implementation and simulation of exactly the same management practices of the reference period and revegetation measures with the same tree species as harvested the area covered by deciduous trees increases from 27.7% (2010) to 29.2% (2030). Consequently the area of coniferous trees decreases from 72.3% (2010) auf 70.8% (2030). Please note: Although the revegetation is based on exactly the same tree species as harvested throughout the simulation period a shift in the represented area of coniferous and deciduous occurs due to the differences in represented basal and crown cover areas between young and old trees (basal and crown cover areas represent the basis for estimating the area share of coniferous and deciduous trees).

3.2 Documentation of data sources as applied for estimating the forest reference level

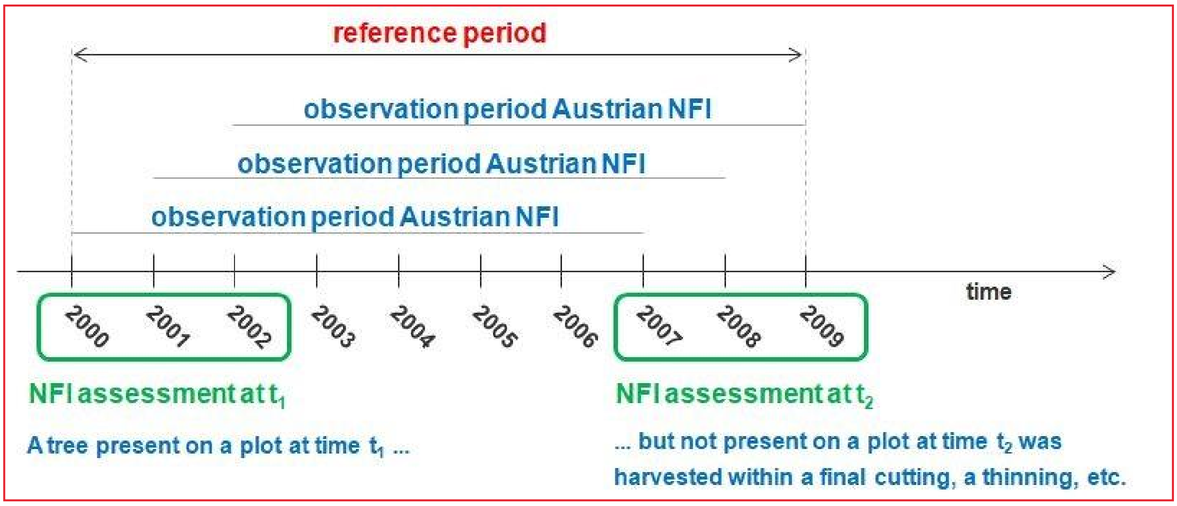
3.2.1 Documentation of stratification of the managed forest land

For the renewal of a harvested forest stand, i.e. a NFI plot, exactly those tree species were considered which were present on the respective plot at beginning of the simulation runs. Due to the tree- and plot-level modelling approach, a stratification of the forest land according to forest type, fertility class, regions, soil types or climate zones is not adequate because each NFI-plot and tree is individually simulated and the individual-tree growth/harvest model CALDIS-VB V0.1 automatically considers the individual growth/yield and management circumstances at plot level and for each tree at the plot.

3.2.2 Documentation of sustainable forest management practices as applied in the estimation of the forest reference level

Rotation length is a key component for defining sustainable forest management practices in a typical even-aged forest management system (age-class system) in which final cuttings are mainly done by clear felling. Rotation length mainly depends on growing conditions (tree species composition, site productivity) and the economic objectives of the forest owner. Therefore, rotation length has to be defined for the various production classes at the forest enterprise level. However, information regarding rotation length is **not** available for the Austrian NFI plots. For this reason we developed a harvesting model based on the observed cuttings within the reference period 2000-2009. Representative data were available from the Austrian NFI 2000/02 and 2007/09. It is known from these data for which reason a sample tree has been removed from the NFI plot (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 2: Schematic representation of the data used for developing the applied harvesting model



In order to consider the main management objectives in Austria, we developed two harvesting models, one for coppice forests and one for high forests. Each model consists of several sub-models (LOGIT-models) which have been developed in a hierarchical order (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The LOGIT-models estimate the probability that a specific event – for example, a final cutting or the removal of a specific tree

– will take place. The coefficients of the LOGIT-models were estimated by logistic regression from the NFI data:

$$P_{(y)} = \frac{1}{1+e^{b.X}}$$

where *y* is the specific event to be modelled (final cutting, thinning, etc.), and *b.X* is a linear combination of estimated coefficients and predictor variables.

Predictor variables of the plot-level models for high forests are: mean and maximum diameter (dbh), mean and maximum tree height, stand basal area per hectare, percent share of conifers, ownership, logging distance (to the nearest forest road), slope and relief. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the behaviour of the plot-level models that predict the probability for final cuttings (solid lines) and thinning operations (dotted lines). The model clearly shows that the probability of a final cutting increases with increasing stand height while the probability of thinning reaches its highest values at a stand height of approximately 17 m. The model also shows that stand density in terms of basal area per hectare plays a more important role for thinning than for final harvests.

Figure 3: Flow chart for the application of the newly developed harvesting model

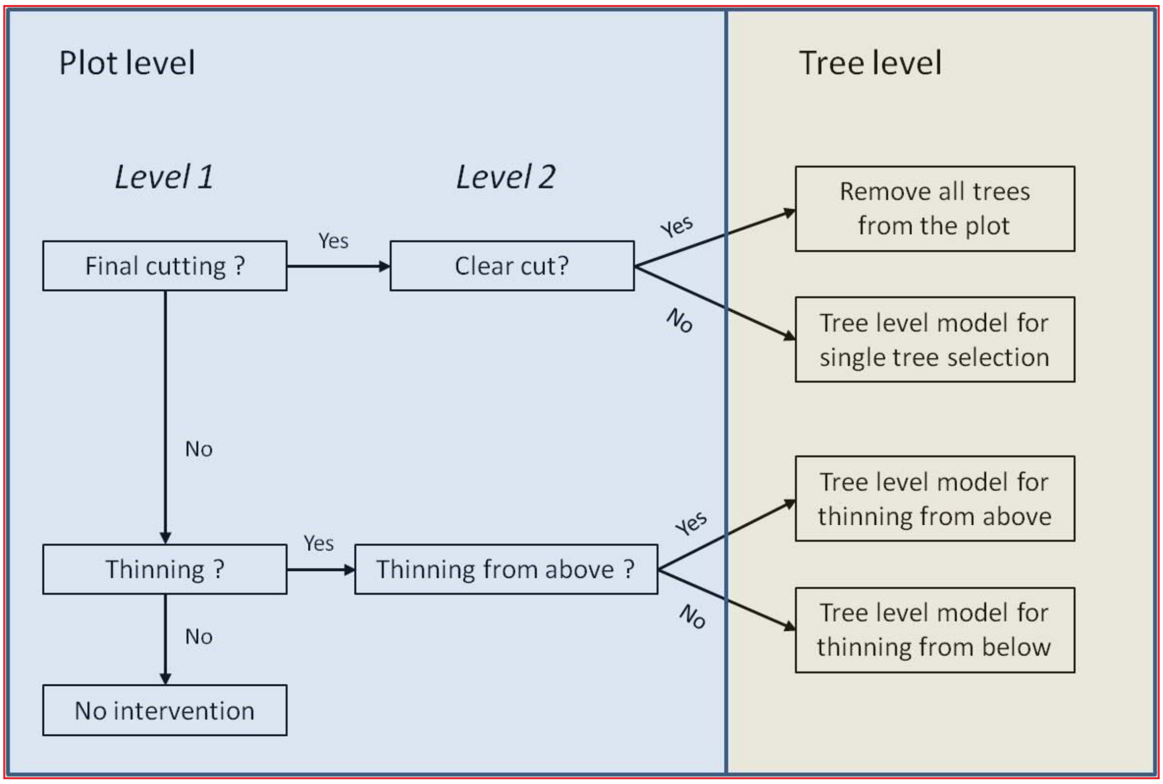


Figure 4: Behaviour of the plot-level models predicting the probabilities of final cuttings (solid lines) and thinning operations (dotted lines)

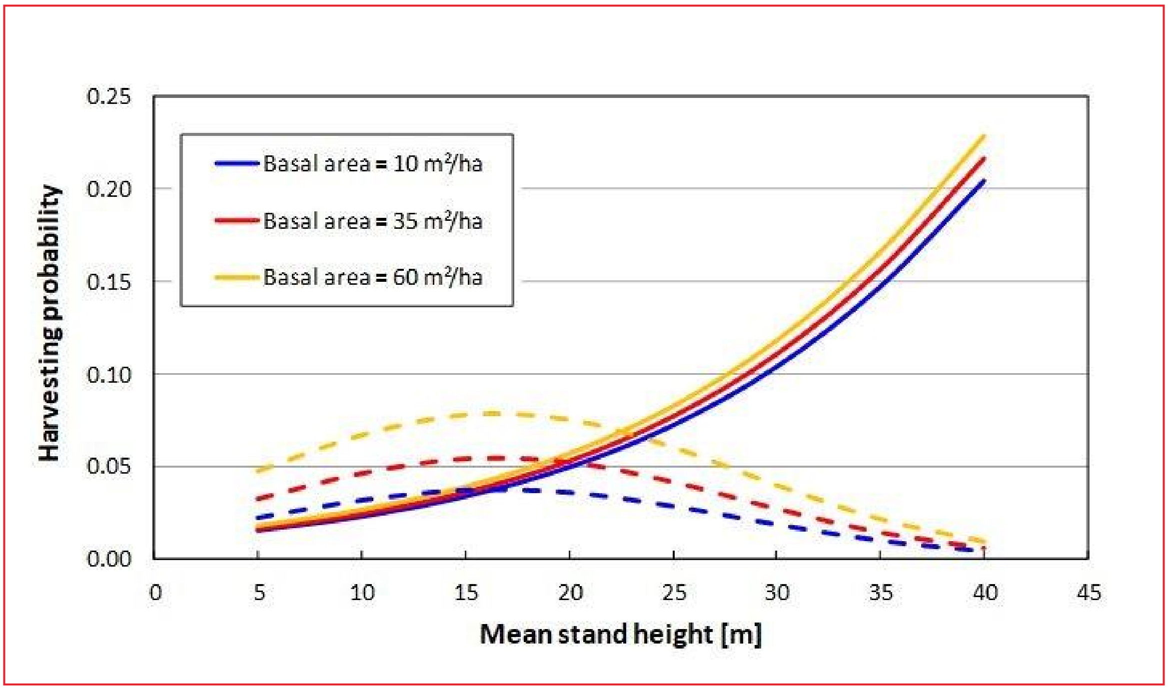


Figure 5: Behaviour of the plot-level model predicting the probability of a final cutting depending on logging distance and slope

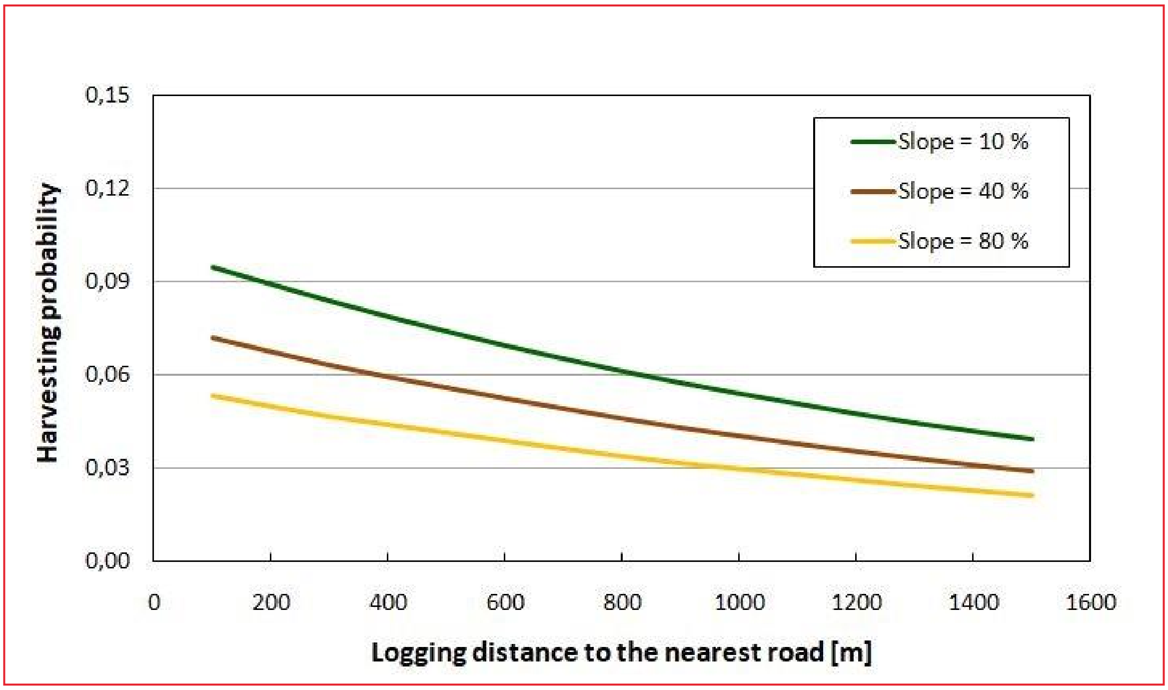
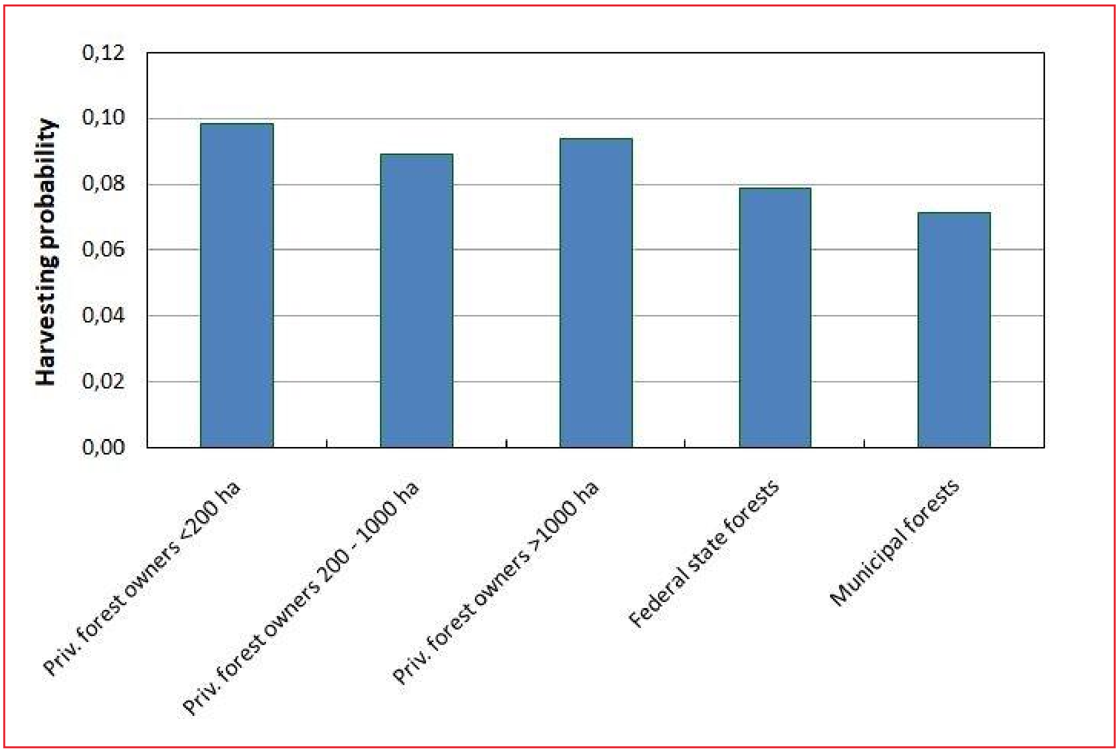


Figure 6: Behaviour of the plot-level model predicting the probability of a final cutting with regard to forest ownership



Fehler! Verweisquelle konnte nicht gefunden werden. shows that the probability of harvesting decreases with increasing logging distance and slope. This harvesting behaviour is mainly due to economic reasons because the costs for harvesting depend very much on the terrain in which the harvesting operations have to be done. The behaviour of the Austrian forest owners with regard to final cuttings is depicted in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Within the reference period 2000-2009 the small-scale private forests owners (< 200 ha) have been the most active forest owners because the probability of a final cutting is highest for this group. In contrast, the probability of a final cutting is lowest for the group representing municipal forests.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the behaviour of the plot-level model predicting the probability of clear felling under the condition that a final cutting took place. With regard to slope this model behaves in an opposite direction as the model that predicts a final cut. While the probability of a final cut decreases as slope increases (see **Fehler! Verweisquelle konnte nicht gefunden werden.**), the probability of clear felling increases as slope increases. This behaviour can be explained by the fact that in steep terrain a cable logging system is needed to transport the logs or the harvested trees to the nearest forest road. However, such a logging system is rather expensive. For economic reasons a minimum amount of harvested volume is required in such a situation, which makes a clear felling more likely. The model also shows that the probability of clear felling is dependent on the ownership.

Figure 7: Behaviour of the plot-level model (Level 2) predicting the probability of clear felling under the condition that a final cutting took place

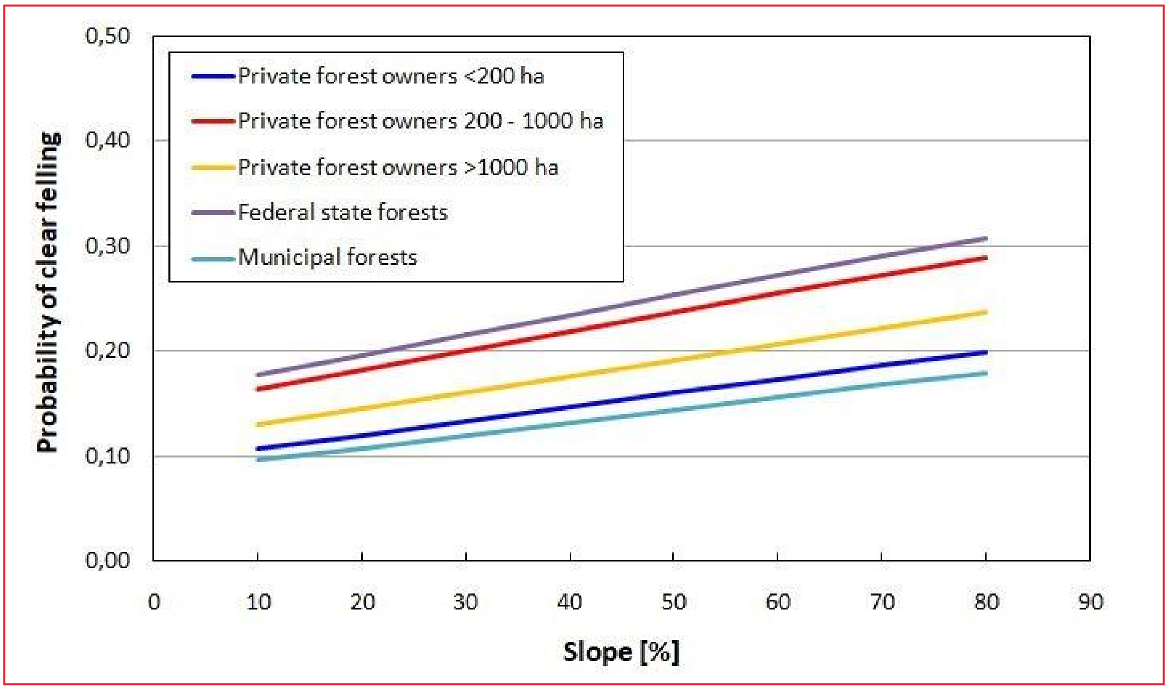


Figure 8: Behaviour of the tree-level model predicting the probability of removing a single tree from a plot under the condition that a final cutting took place

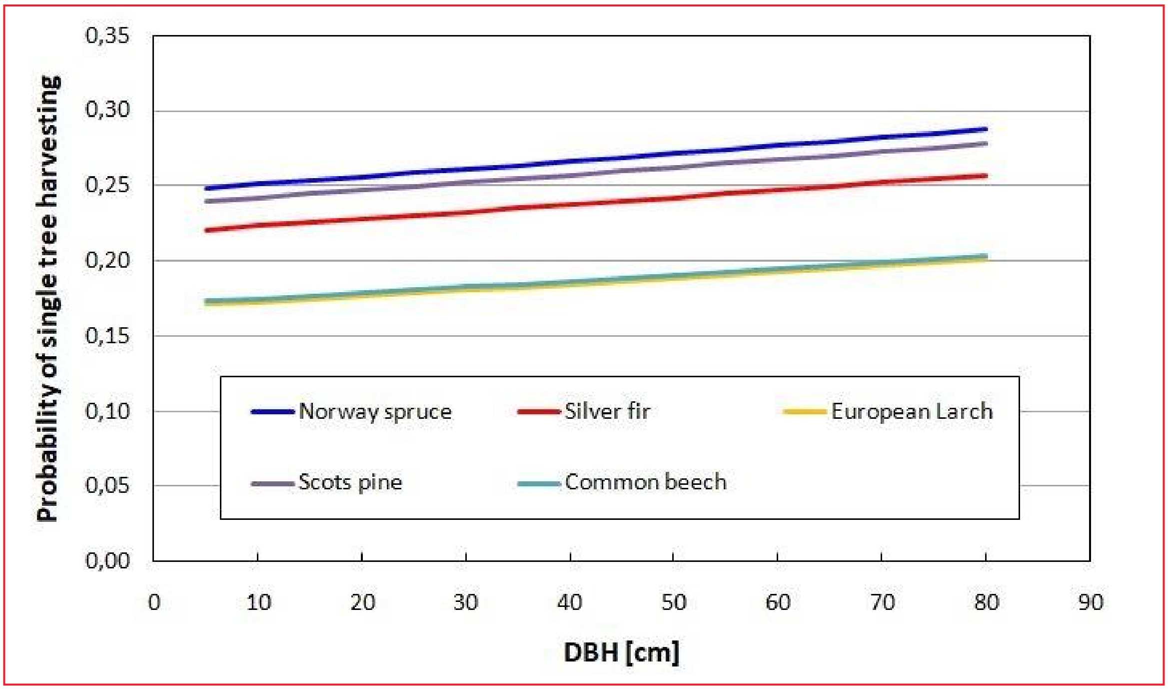
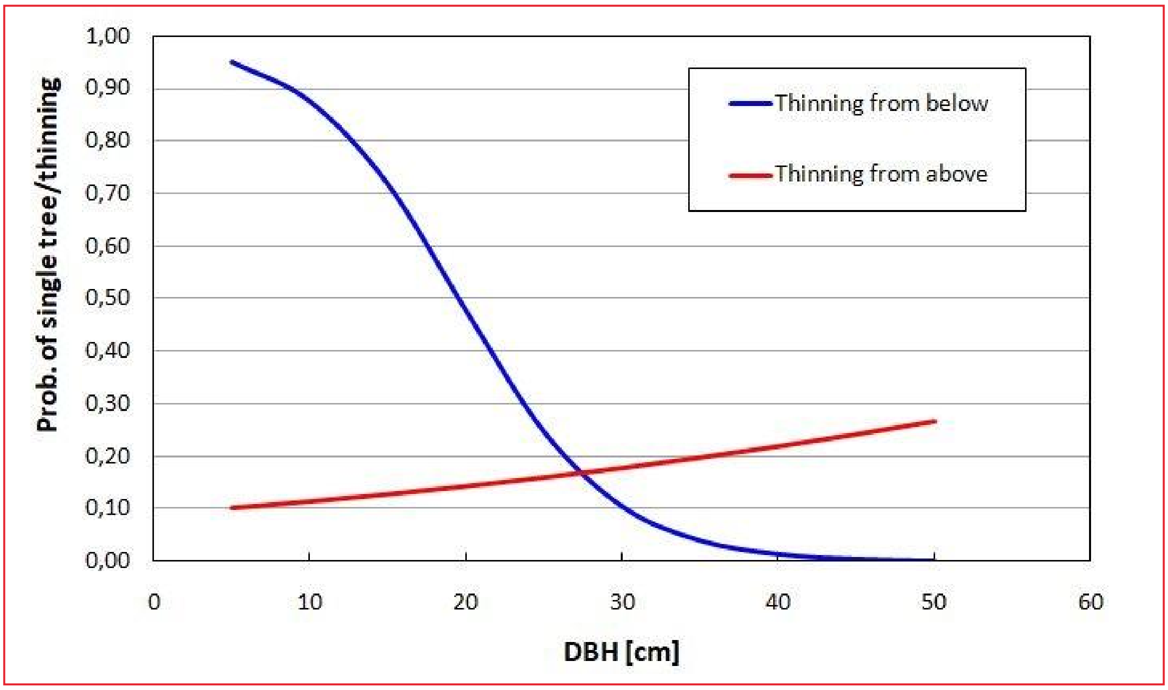


Figure 9: Behaviour of the plot-level model (Level 2) predicting the probability of clear felling under the condition that a final cutting took place



If a final cutting took place but was not done as clear felling, then a tree level model estimates the probability of a single tree to be removed from a NFI plot. The behaviour of this model is shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**. In a single tree harvesting operation trees with larger DBH are preferred because the probability for removing a single tree increases with increasing DBH. The model further shows the preferences for tree selection with regard to the most important tree species. The most preferred species is Norway spruce followed by Scots pine, silver fir, common beech and European larch. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the behaviour of the tree-level model predicting the probability of removing a single tree from a plot under the condition that a thinning took place. The model clearly shows the differences between thinning from above and thinning from below. If a thinning from below takes place, mainly trees with small diameters are removed while in a thinning from above trees with large diameters are preferred.

The decrease in total increment since the last two consecutive NFIs 2000/02 and 2007/09 correlates very well with the trend of the future increment simulations between 2020 and 2030 which also indicate a relatively gentle decrease from 28.6 Mio m^3 to 27.8 Mio m^3. This dynamic can be explained by a shift in the age-class distribution as a consequence of the continuation of the management practices as in the reference period. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows that the current annual increment observed within the reference period 2000-2009 is highest in age-classes 40-60 and 20-40. However, these are the two age-classes with the largest extent in the decrease of forest area (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Also the increase in harvest rates in the NFI period 2007/09 correlates very well with the trend of the future simulation results until 2030 as indicated by the model runs. It is important to emphasize that the figures of the simulated mean annual increment are always higher than the figures of the simulated mean annual harvest rates demonstrating the required assurance and continuation of the sustainable forest management from the reference period to the FRL period.

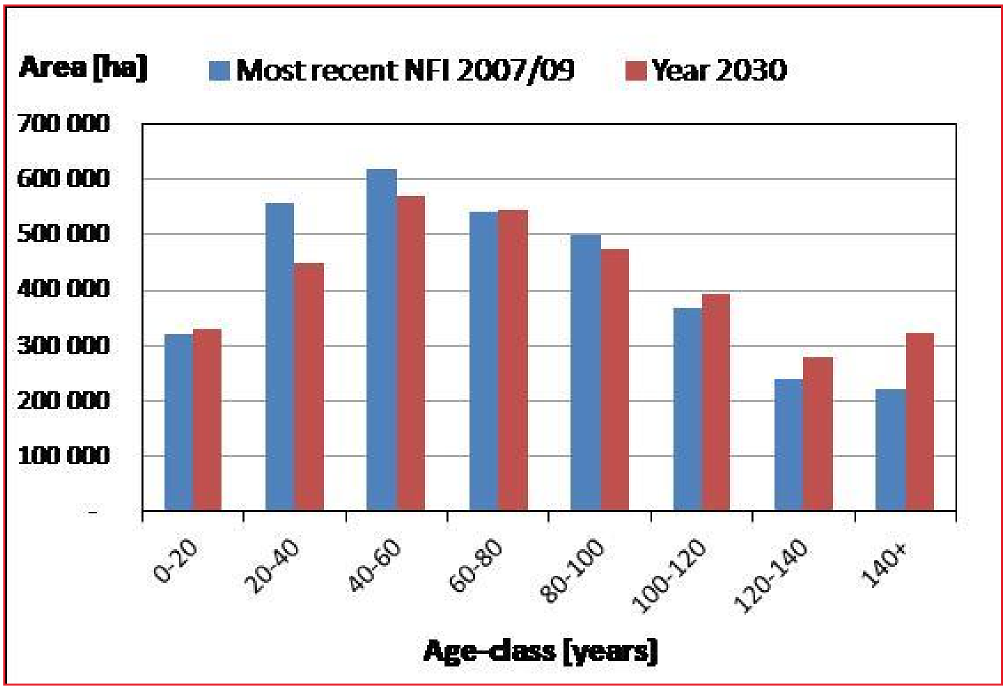
Table 4 Total annual increment and drain (m^3 stem wood) for the periods 2021/25 and 2026/30 for total Forest Land (including harvest due to land-use change from Forest Land)

	Mean 2021-2025 (Mio m^3)	**Mean 2026-2030** (Mio m^3)

	Mean 2021-2025 (Mio m³)	Mean 2026-2030 (Mio m³)
Total annual increment	28.6	27.8
Total annual drain	27.2	27.5

Figure 10: Current total annual increment by age-classes for total Forest Land observed by NFI within the reference period 2000-2009

Figure 11: Current annual increment by age-classes for total Forest Land observed by NFI within the reference period 2000-2009 and modelled for the year 2030



3.3 Detailed description of the modelling framework as applied in the estimation of the forest reference level

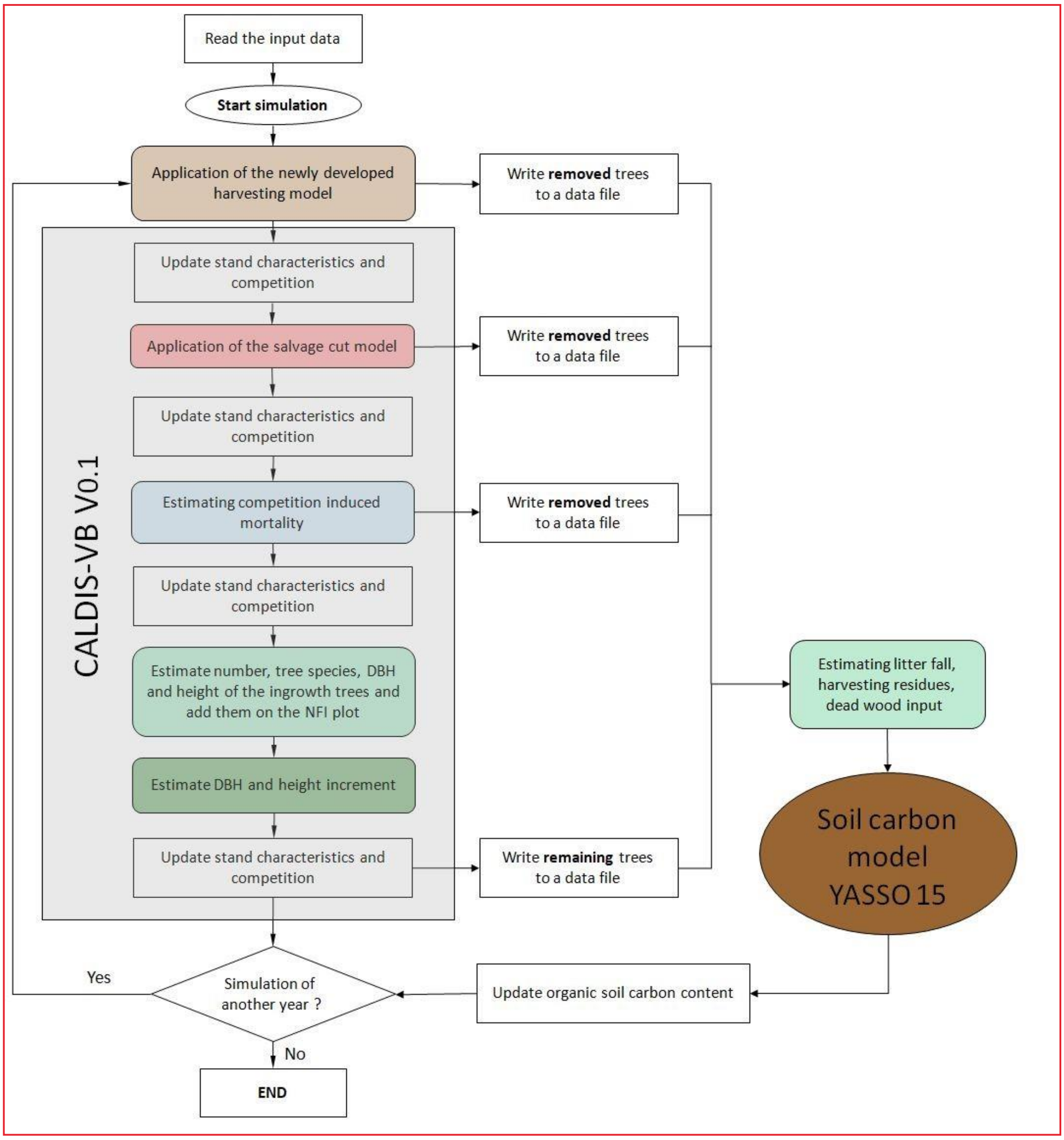
3.3.1 Modelling biomass growth and harvest and change of standing dead wood stocks

CALDIS-VB V0.1 is a climate-sensitive individual-tree based forest growth model (LEDERMANN et al., 2017a) that consists of the following sub-models: a basal area increment model (KINDERMANN 2010), a height increment model (GSCHWANTNER et al. 2010) , an ingrowth model (LEDERMANN, 2002), a harvest model (LEDERMANN et al., 2017b) and a model describing salvage cuts and tree mortality (LEDERMANN 2017). CALDIS-VB V0.1 is based on the same model concept and was parameterized from the same data set as PROGNAUS (PROGNosis for AUStria: Monserud and Sterba, 1996; Hasenauer, 2000; Ledermann, 2006). The only difference between CALDIS-VB V0.1 and PROGNAUS is that CALDIS-VB V0.1 uses climate variables in addition to the predictor variables of PROGNAUS. The basal area increment model, the height increment model and the mortality model of

PROGNAUS have been validated several times (e.g. STERBA and MONSERUD, 1997; STERBA, 1999; MONSERUD and STERBA, 1999; STERBA et al., 2001; LEDERMANN, 2010). PROGNAUS was also used for the construction of the Austrian forest management reference level for the period 2013-2020. CALDIS-VB V0.1 uses a set of tree species-specific, mathematical-statistical equations to project height and diameter growth as well as natural mortality of individual trees. The growth projections are based on climatic parameters (temperature and precipitation) and on tree, stand and site characteristics. The estimation of natural tree mortality is only based on tree, stand and site characteristics. A model for salvage cutting and incidental fellings is also integrated in CALDIS-VB V0.1. An ingrowth model estimates the renewal of forest stands. Both models resort to tree, stand and site characteristics. The model for salvage cutting requires climate and wind speed data, too. CALDIS-VB V0.1 was developed from Austrian NFI data covering the time period from 1981-2009. Because the NFI data are representative for the whole forest land in Austria, the model can be applied to all combinations of species composition, stand structure, stand treatment, and site conditions as observed in the Austrian NFI. CALDIS-VB V0.1 was successfully applied in a study on greenhouse gas dynamics in Austria (BRAUN et al. 2016).

The newly developed harvesting model (see chapter 3.2.2) was implemented in the forest growth simulator CALDIS-VB V0.1 in order to represent the same forest management practices as it was documented between the two consecutive NFI assessments 2000/02 and 2007/09. This extended version of CALDIS-VB V0.1 was set up on the most recent NFI assessment in 2007/09 and run until the year 2030. All implemented LOGIT-models, i.e. the harvesting model and the models for salvage cuts and natural mortality, estimate a probability that the respective event will occur. Therefore, we used uniformly distributed random numbers to decide whether the described event should occur. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the simulation procedure that was applied to each of the 7964 Austrian NFI plots.

Figure 12: Flow chart of the full simulation procedure including CALDIS-VB V0.1, the newly developed harvesting model and the soil carbon model Yasso15



For the projection of the FRL we have decided to use the same climatic conditions as they had been observed in the reference period from 2000 to 2009. For the implementation of this procedure we also used uniformly distributed random numbers. For a specific year within the projection period we randomly selected a year within the reference period (2000-2009) and used these climate data for the model projections. This selection procedure was repeated until the end of the projection period was reached. In order to cover the probabilistic nature of the model application, 100 simulation runs were carried out and the results used for FRL represent the mean values of these 100 repetitions.

The derivation of above and below ground biomass and related carbon stocks of the Austrian forest was calculated applying the same expansion and conversion ratios as for the annual national greenhouse gas reporting under UNFCCC for the period 2000 to 2009.

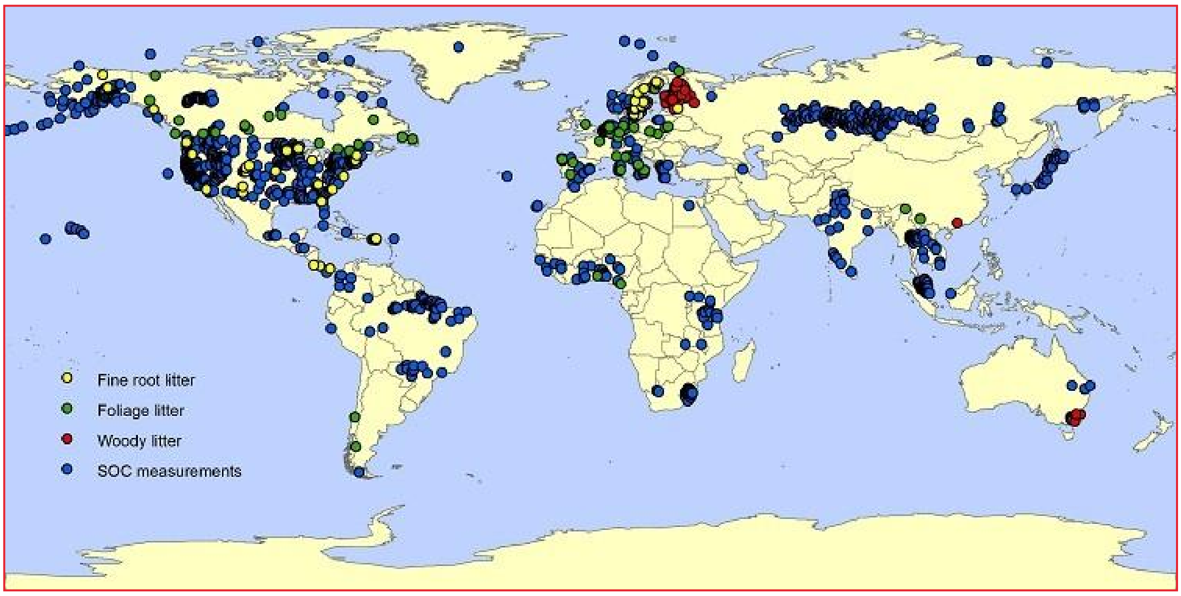
Dead wood stocks were modelled by means of the models that estimate salvage cuts and natural tree mortality. Both models had been developed from those trees of the Austrian National Forest Inventory (NFI) that changed their status from alive to dead within the periods of two consecutive NFI assessments. The salvage cut model estimates the dieback of trees due to storm events, dry spells, snow-breakage, and bark beetle attacks. A given percentage of these dead trees is assumed to remain as standing dead trees in the stand providing one source of influx to the dead wood stocks. On the other hand, the natural mortality model estimates the dieback of trees due to inter- and intra-specific competition. Also here, a given percentage of these dead trees is assumed to remain as standing dead trees in the stand while the other part is assumed to become down woody debris. The standing dead trees remaining in the stand estimated by the natural mortality model provide the other source of influx to the dead wood stocks. Note that only standing dead trees are considered for dead wood stocks while lying woody debris is considered as litter influx to the litter and soil modelling (this approach is consistent to the Austrian GHG inventory). The two sources of outflux from dead wood stocks are: outflux due to harvesting, which is estimated via the newly developed harvest model, and outflux when a standing dead tree falls down and becomes part of the lying woody debris. The latter is estimated with a simple annual rate that was derived from the Austrian NFI data.

3.3.2 Modelling litter and soil C changes

For estimating **litter** and the **soil organic carbon** the Yasso15 model was used. It is an update of the original Yasso model that later evolved into Yasso07 and finally Yasso15 (LISKI et al. 2009, 2005; https://en.ilmatieteenlaitos.fi/yasso-description) was applied (BFW, 2015).

Yasso was introduced by Jari Liski (https://en.ilmatieteenlaitos.fi/cv-jari-liski). The acronym of the program is the Finnish term for 'soil'. A regularly updated description of the model and the source code are publicly available (description: https://en.ilmatieteenlaitos.fi/yasso-description; source code: https://github.com/JariLiski/Yasso15/blob/master/y15_subroutine.f90). Yasso15 is a decomposition model for organic matter. It is based on 18,500 data records from decomposition experiments that have been conducted worldwide (Repo et al. 2017).

Figure 13: The data for the decomposition model Yasso have been collected in different climatic zones and forest types (Figure from https://en.ilmatieteenlaitos.fi/yasso-description#Yasso15)



It was the explicit intention of the author to provide a tool for national greenhouse gas inventories. The program is widely used in Europe (e.g. Finland, Estonia, Switzerland, Czech Republic, Norway, Romania, Austria, Spain) and references for the different applications are available:

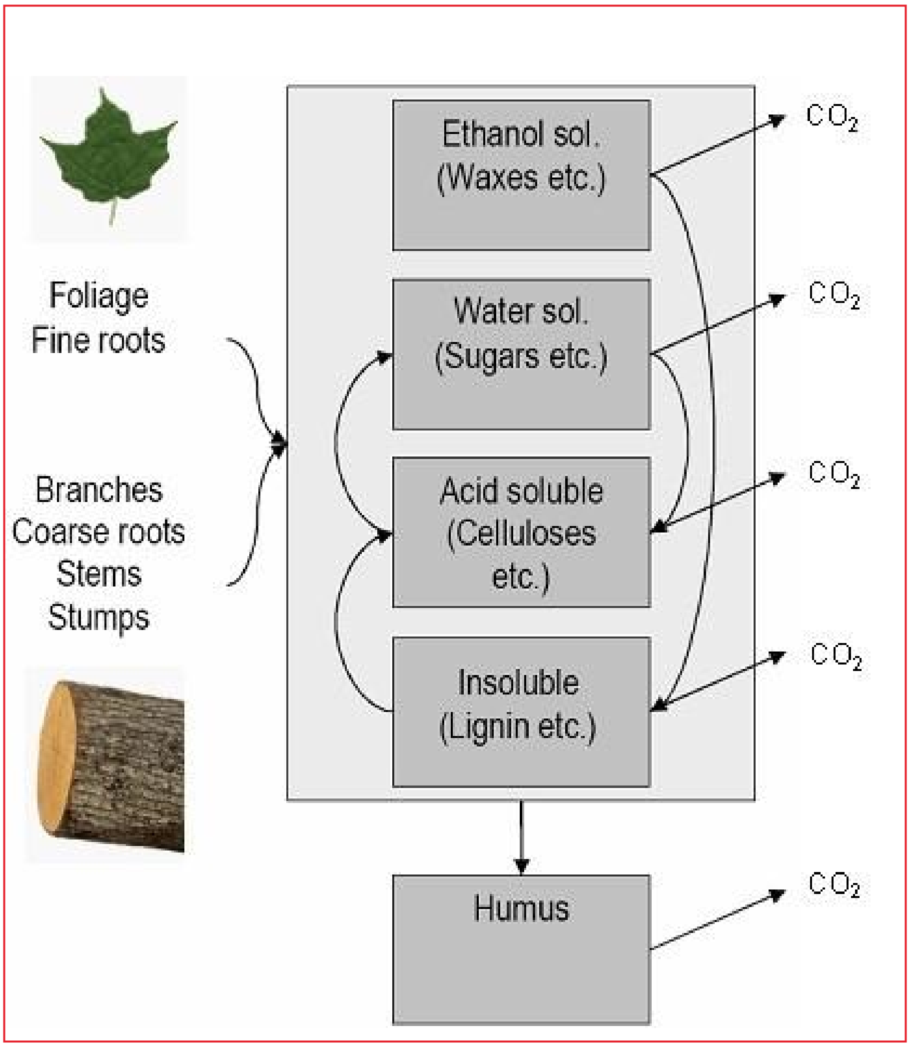
- https://en.ilmatieteenlaitos.fi/yasso-publications;
- https://en.ilmatieteenlaitos.fi/yasso-publications#Presentations

Yasso was developed as an alternative for other more complex models that are requiring input data that are available on highly-instrumented experimental sites, but are rarely available for the majority of plots of a National Forest Inventory. Consequently, the concept of Yasso was

- to be globally applicable;
- to require readily accessible input data;
- to give a good estimate of changes in the soil carbon pool over time.

Organic matter is divided into 5 operationally defined classes, acid soluble, ethanol soluble, water soluble organic matter and humus. Each chemical class undergoes a specific pathway upon decomposition and releases CO_2 to the atmosphere. The decomposition pathway reflects the understanding of the decay of soil organic matter where microbial processes are transforming organic matter. The released CO_2 during decomposition can be understood as heterotrophic soil respiration (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The fractionation procedure is operationally defined and is described in Gholz et al. (2000) and Vavrova et al. (2009).

Figure 14: Flowchart of Yasso15 based on a graphical representation on the webpage of Yasso (https://en.ilmatieteenlaitos.fi/yasso-description)



Yasso15 uses an externally calculated input of organic matter to the soil. The carbon input is derived from the standing stock, harvest (residues) and dead wood input of the forest as captured by the results of the Austrian National Forest Inventory (for the reference period) and from the CALDIS-VB V0.1 simulation. Forest Inventory data and a specific forest management strategy have been incorporated in the simulation of the forest biomass (see chapter 4.2.3).

Moreover, the model requires the annual mean temperature, the temperature amplitude between warmest and coldest month and the total annual precipitation as climate data.

The external parameters were calculated in several steps:

- The climate data were derived from the same dataset as those that have been used for the climate parameters of the CALDIS-VB V0.1 simulations for the FRL.
- The litter input to the soil was estimated from tree characteristics that are available in the output of CALDIS-VB V0.1 simulations for the FRL.
- Species- and compartment specific decomposition parameters were assigned to the litter

Stem volume was converted to stem mass by species dependent factors for wood density. The mass of the compartments needles/leaves, branches, fine roots and coarse roots was estimated by biomass functions that are used in the Austrian GHG reporting scheme.

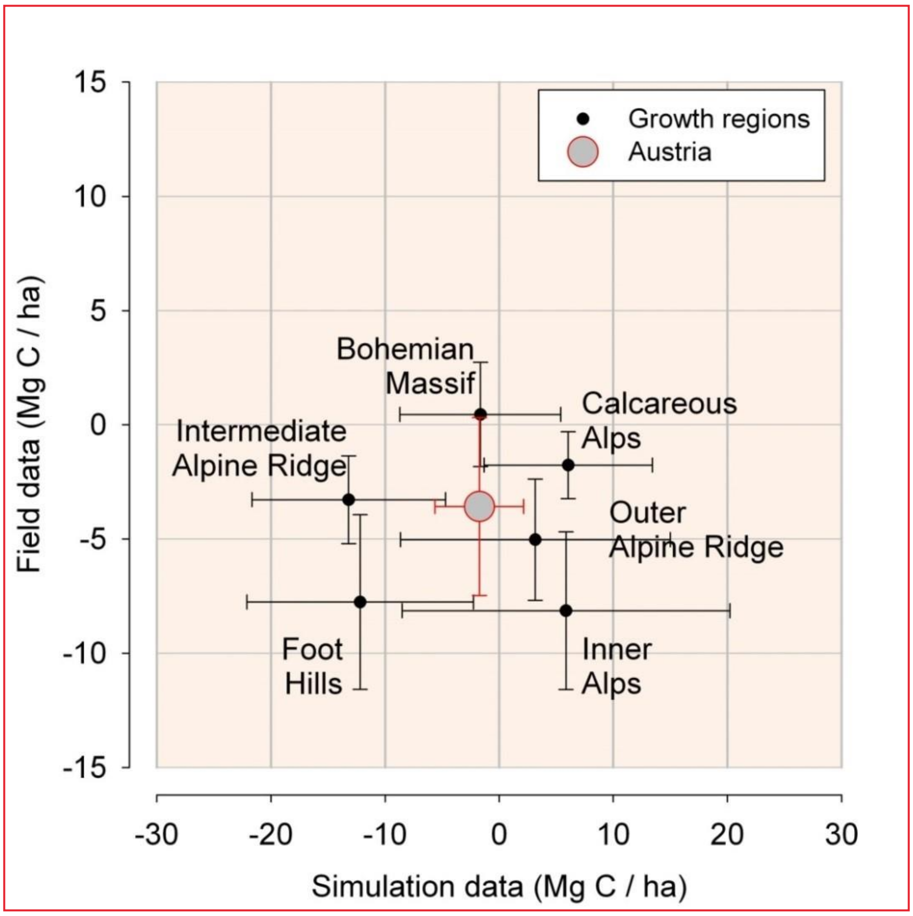
The turnover of the compartments was taken from literature values and observations (Kögel-Knabner et al., 1988; Järvenpää et al., 2017). From these data the annual input of organic matter from the standing stock (aboveground and belowground sources) was calculated. In addition, carbon inputs from disturbances were considered. Tree mortality and wood extractions (harvests) were reflected by a consistent pattern that describes the fate of organic matter and quantifies the residues remaining in the forest. The data transformation from the simulated forest biomass to the input file for Yasso15 was done in R.

The climate data required for Yasso15 were derived from the same climate dataset as for the CALDIS-VB V0.1 simulations for the FRL.

The calculations were performed in annual time steps in an R implementation of Yasso15. In order to obtain a relevant starting point for the Yasso15 runs a spin-up process was performed. For each site a stand development was simulated with the forest growth model. The starting point was a zero-year old plantation that was allowed to grow for 100 years. The simulated growth was driven by climate data from the period 1960/90. It was checked and ensured that after 100 years the classes of soil organic matter (acid soluble, ethanol soluble, water soluble organic matter and humus; see above) reach equilibrium, indeed.

The results of Yasso were tested against Austrian field measurements. For the period 1989 to 2006 a comparison of field data with simulation data was available. The field data were derived from a repetition of the more than 500 plots of the Austrian Forest Soil Inventory to a repeated assessment on 136 plots in 2006 (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Moreover, the results of Yasso have been confirmed against field data in a climate manipulation experiment for calcareous soils (Schindlbacher et al., 2009).

Figure 15: Simulation and against field data. The soil carbon change of the Austrian Forest Soil Inventory (1989) versus Biosoil (2006) against simulated data with Yasso07 in the same time span. The results differ somehow for Austrian regions, but the result of the simulated average value for Austria (grey bullet) is in close agreement with the measured one



3.3.3 Estimating the HWP stock changes

The production approach on domestic harvest according to the IPCC KP Supplement was applied to estimate the changes in the HWP stocks in the projection period. The half-lifes as contained in LULUCF Regulation as well as the methodologies, which are consistent with the

IPCC KP Supplement, were used. This is consistent with the estimates for the Austrian GHG inventory.

The related criteria of the EU LULUCF Regulation were followed and the average ratio of solid to energetic wood use in the reference period 2000 to 2009 was calculated. For that purpose the carbon stocks of HWPs from total Forest Land produced in each of the years 2000 to 2009 expressed in t C were related to the stem wood drain from total Forest Land expressed in t C in each of these years (**Fehler! Verweisquelle konnte nicht gefunden werden.**). A mean ratio was calculated for these years for each, sawnwood, panels and paper. These mean ratios were used to derive the produced carbon stocks of sawnwood, panels and paper for the modelled years from 2010 to 2030 on basis of the modelled stem wood drain carbon stocks for total Forest Land for the same period. This procedure ensures a fixed solid to energy wood ratio for calculation of the FRL as required by the EU LULUCF Regulation, namely 62 % of drain is carbon inflow from harvest to solid wood products and the rest is energetic wood use (**Fehler! Verweisquelle konnte nicht gefunden werden.**). The annual HWP production for total Forest Land was reduced in a next step by the amount of HWP which is due to harvest at afforestation and deforestation areas in both, the reference period and the simulated period (on average about 1%). The annual carbon inflow by HWPs and annual carbon outflow from the HWP pools due to the 1st order decay function and half-lifes defined in the EU LULUCF regulation result in the carbon stock changes of the HWP pool in the FRL periods (chapter 4.1.5).

Table 5 HWP production and stem wood drain in the reference period (Austrian GHG inventory; Umweltbundesamt 2018) and in the simulation period for total Forest Land in Gg carbon and Percent.

Gg C	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	
Sawn wood	1251	1307	1421	1507	1458	1459	1437	1724	1667	1127	
Wood panels	363	489	601	628	572	581	678	716	729	540	
Paper and paperboard	737	786	848	953	899	931	991	1078	1117	868	
Stem wood drain	3539	3591	4224	4826	4677	4675	5422	6002	6151	5135	
% of stem wood drain	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Mean 2000-09**
Sawn wood	35%	36%	34%	31%	31%	31%	27%	29%	27%	22%	30%
Wood panels	10%	14%	14%	13%	12%	12%	13%	12%	12%	11%	12%

Gg C	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Paper and paperboard	21%	22%	20%	20%	19%	20%	18%	18%	18%	17%	19%
Total share of solid wood use (sum)	66%	72%	68%	64%	63%	64%	57%	59%	57%	49%	62%

Gg C	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sawn wood	1587	1620	1600	1612	1565	1585	1593	1602	1611	1619	1636
Wood panels	641	655	647	651	632	641	644	648	651	654	661
Paper and paperboard	1010	1031	1018	1025	996	1008	1013	1020	1025	1030	1041
Stem wood drain	5231	5342	5276	5314	5159	5226	5252	5283	5311	5338	5395
% of stem wood drain	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Sawn wood	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Wood panels	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%
Paper and paperboard	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Total share of solid wood use (sum)	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%

Gg C	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Sawn wood	1639	1622	1648	1635	1657	1658	1645	1664	1661	1675
Wood panels	663	655	666	661	670	670	665	673	671	677
Paper and paperboard	1043	1032	1049	1040	1054	1055	1046	1059	1057	1065
Stem wood drain	5405	5346	5433	5389	5463	5467	5422	5487	5475	5521
% of stem wood drain	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Sawn wood	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Wood panels	12%	12%	12%	12%	12%	12%	12%	12%	12%	12%

Gg C	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Paper and paperboard	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Total share of solid wood use (sum)	62%	62%	62%	62%	62%	62%	62%	62%	62%	62%

4 Forest Reference Level

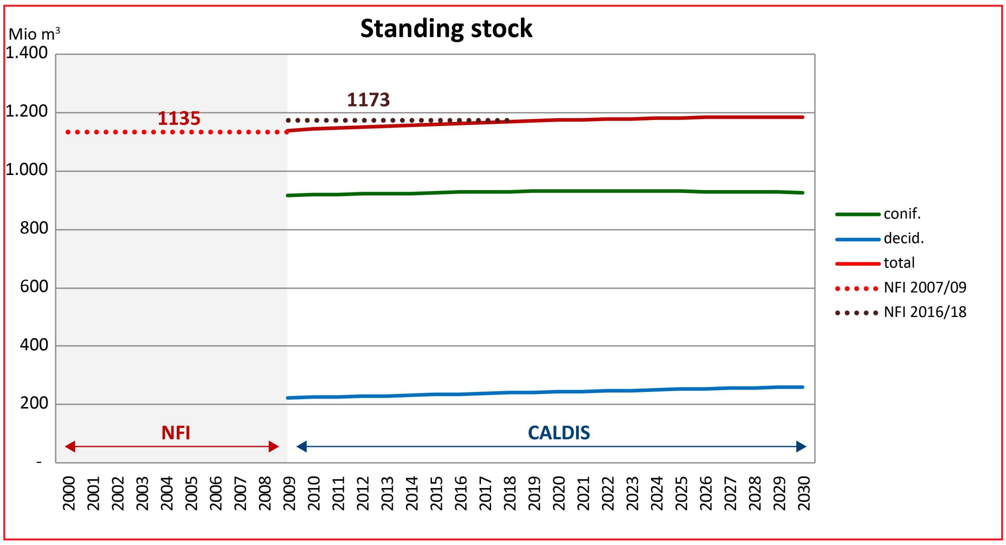
The calculations of the Forest Reference Level consider all carbon pools in the same way as in the annual national greenhouse gas inventory of Austria (Umweltbundesamt, 2018). The development of standing stock, increment and drain (m^3/ year) form the bases of the calculations for the carbon stock changes in the pools (kt CO_2).

The FRL was estimated for a constant area of Managed Forest Land as in 2009 which represented 3.822 Mio ha (subcategory 4.A.1 "Forest land remaining forest land", Austria's GHG submission in 2018).

The figures expressed in m^3 stem wood increment and drain in chapter 4 include the results of the Austrian National Forest Inventory (NFI) for the total Forest Land from the periods 2000/02 and 2007/09 as used in the National Greenhouse Gas Inventory (GHGI) for the years 2000-2009 and the related results of the simulations with CALDIS-VB V0.1 for the years 2009-2030. However, the figures of biomass increment and drain expressed in t CO2 from chapter 4.1.1 onwards represent the recalculation for the Managed Forest Land only by subtracting from the total Forest Land results the Afforestation and Deforestation emissions and removals in 2009 (see chapter 3.1). This approach is consistent to the estimates in the Austrian GHG inventory. This estimate will require a future technical correction for the real increase of area of Managed Forest Land and for the real Afforestation and Deforestation emissions and removals once these results are known in 2026 (see chapter 4.2.1).

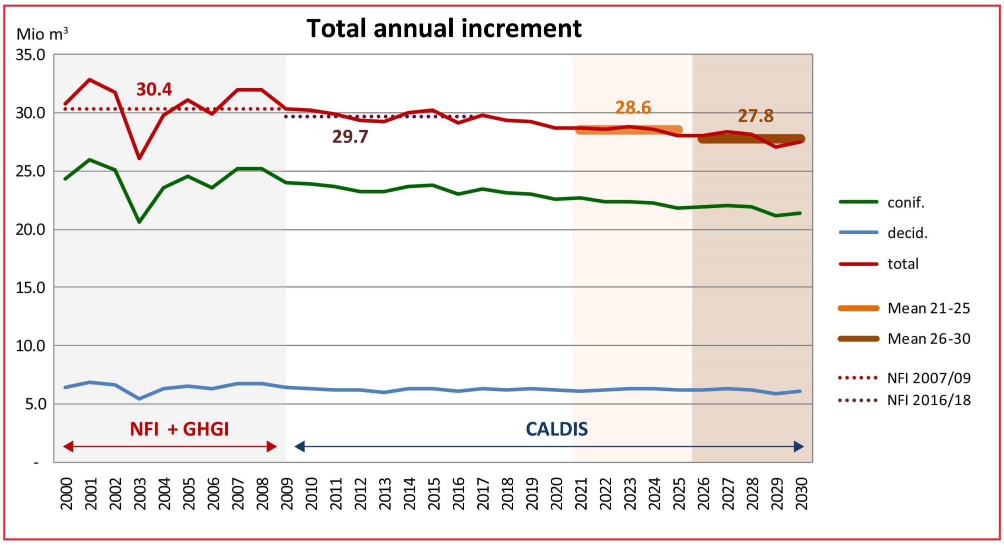
The development of the standing stock underlines the sustainable forest management for the time period 2021-2030. Since the first NFI assessment in the early 1960ies the standing stock continuously increased in Austria and reached a value of 1,135 Mio m^3 at the NFI 2007/09. The simulation with CALDIS -VB V0.1 shows that the standing stock increases to 1,185 Mio m^3 in 2030 if the management practices and conditions from the reference period are considered. The development of standing stock shows a slight increase for coniferous trees from 919 Mio m^3 (2010) to 926 Mio m^3 (2030) whereas for deciduous trees the standing stock increases from 225 Mio m^3 to 260 Mio m^3 (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 16: NFI standing stem wood stock observed in 2000-2009, 2010-2018 and standing stem wood stock based on CALDIS simulation divided into coniferous and deciduous trees (2009-2030)



A minor adjustment of CALDIS-VB V0.1 was carried out to exactly match the total annual increment observed in the NFI period 2000/02 to 2007/09 (30.4 Mio m^3). Even for the following period 2010 to 2018 the modelled and measured average total annual increment exactly match (29.7 Mio m^3, see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The slight decrease of the total annual increment is explained in detail in chapter 3.2.2.

Figure 17: Total annual stem wood increment (Mio m^3) for the total Forest Land observed in NFIs 2000-2009, 2010-2018 and simulated with CALDIS (2010-2030); mean values for the two FRL periods 2021-2025 and 2026-2030



The results of the CALDIS-VB V0.1 simulations show a total annual drain of 26.1 Mio m³ for the year 2009. This matches very well with the average results from the NFI period 2000/02 to 2007/09 (25.9 Mio m³). Even for the following period 2010 to 2018 the modelled and measured average total annual drain match very well (26.2 Mio m³ measured vs. 26.5 Mio m³ modelled, see **Fehler! Verweisquelle konnte nicht gefunden werden.**). The continued implementation of the management as in period 2000 to 2009 leads to slight increases of the annual drain with mean values of 27.2 and 27.5 Mio m³ for the FRL periods 2021-25 and 2026-30, respectively (see **Fehler! Verweisquelle konnte nicht gefunden werden.**). **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the drain intensity of total Forest Land for the reference period according to the NFI 2007/09 and GHG inventory (Umweltbundesamt 2018) and for the projection period 2010 to 2030 according to the CALDIS-VB V0.1 simulations disaggregated in coniferous and deciduous as in the NFI and GHG inventory.

Figure 18: Total annual stem wood drain (Mio m³) for the total Forest Land observed in NFIs 2000-2009, 2010-2018 and simulated with CALDIS (2010-2030); mean values for the two FRL periods 2021-2025 and 2026-2030

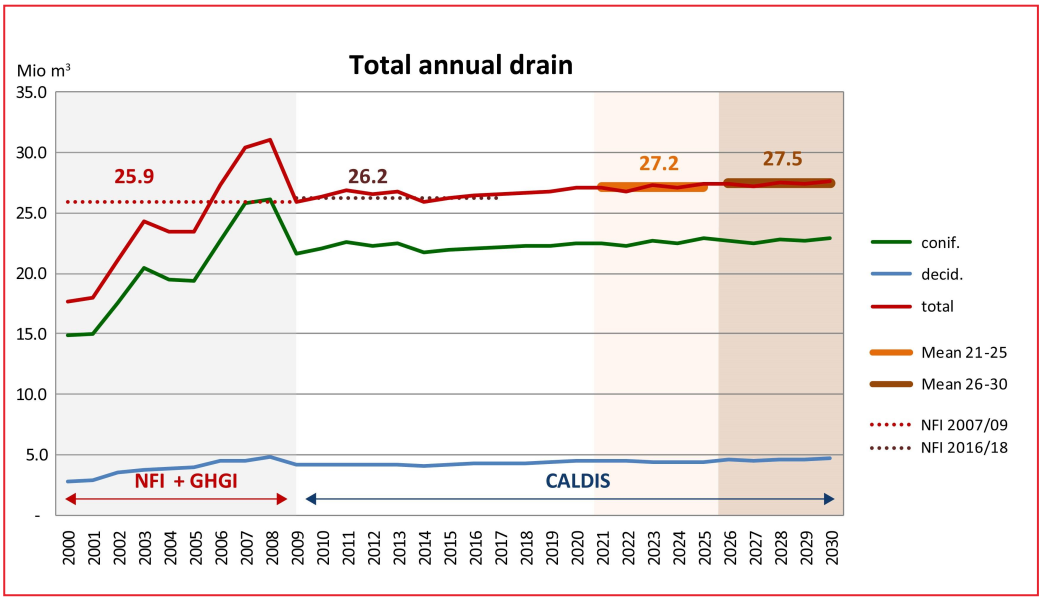


Table 6 Coniferous and deciduous stem wood drain for total Forest land in the reference period (Austrian NFI and GHG inventory; Umweltbundesamt 2018) and in the simulation period 2010 to 2030 in Mio m^3

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
coniferous drain (Mio m3)	14.9	15.0	17.6	20.5	19.5	19.4	22.7	25.8	26.2	21.7
deciduous drain (Mio m3)	2.9	3.0	3.6	3.8	4.0	4.1	4.6	4.6	4.9	4.2

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
coniferous drain (Mio m3)	22.1	22.6	22.3	22.5	21.8	22.0	22.1	22.1	22.3	22.3	22.6
deciduous drain (Mio m3)	4.2	4.3	4.3	4.3	4.2	4.3	4.3	4.4	4.4	4.5	4.5

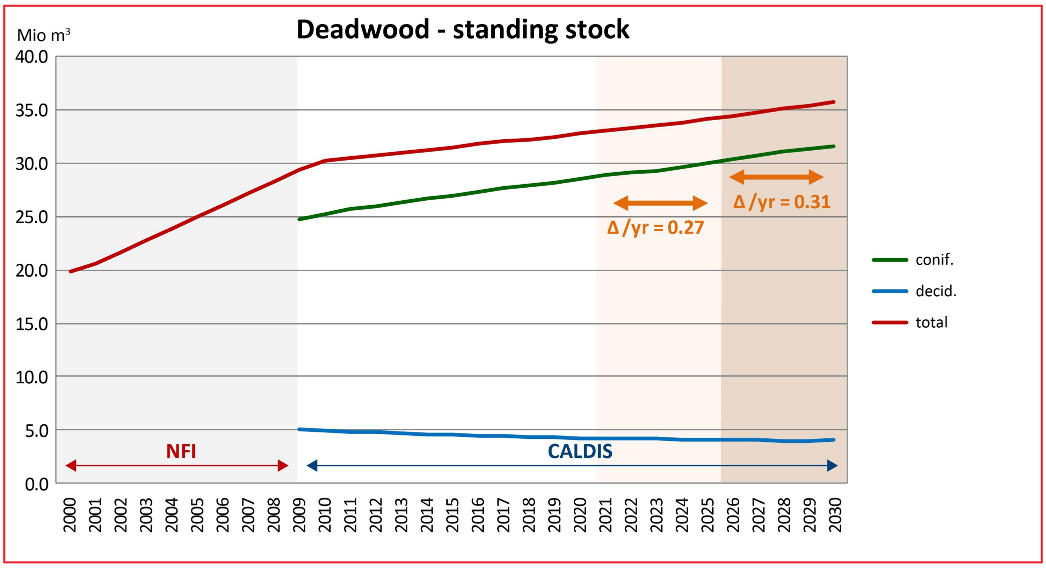
year	2021	2022	2023	2024	2025	2026	2027	2018	2029	2030	
coniferous drain (Mio m3)	22.5	22.3	22.8	22.6	23.0	22.8	22.6	22.9	22.7	22.9	22.5
deciduous drain (Mio m3)	4.6	4.6	4.5	4.5	4.5	4.7	4.6	4.7	4.7	4.8	4.6

The estimates on stock changes in dead wood include only standing dead wood, because any falling dead tree (part) is accounted for as a C flux to the litter and soil in the modelling of litter and soil C stock changes. The approach is the same in the GHG inventory and in the FRL simulations.

Based on the data of the Austrian NFI the mean value of standing dead stem wood is 6.1 m^3/ha for the period 2000/02 and 8.4 m^3/ha for the period 2007/09. This amounts to an increase of total standing dead stem wood of around 10 Mio m^3 between 2000 and 2009.

Based on the CALDIS-VB V0.1 simulation the deadwood stock increases to a total amount of 36 Mio m^3 until 2030. The mean values of the annual changes in the FRL periods amount to 0.27 Mio m^3 (2021-2025) and 0.31 Mio m^3 (2026-2030) (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 19: Dead stem wood stock of total Forest Land based on NFI data (2000-2009) and simulation runs with CALDIS (2010-2030); mean values of the annual deadwood stock changes (Mio m³) are shown for the two FRL periods 2021-2025 and 2026-2030



4.1 Forest reference level and detailed description of the development of the carbon pools

The modelled data on annual increment and drain are the basis for the calculation of changes in above ground biomass, below ground biomass and dead wood. The methodology is described in detail in chapter 3.

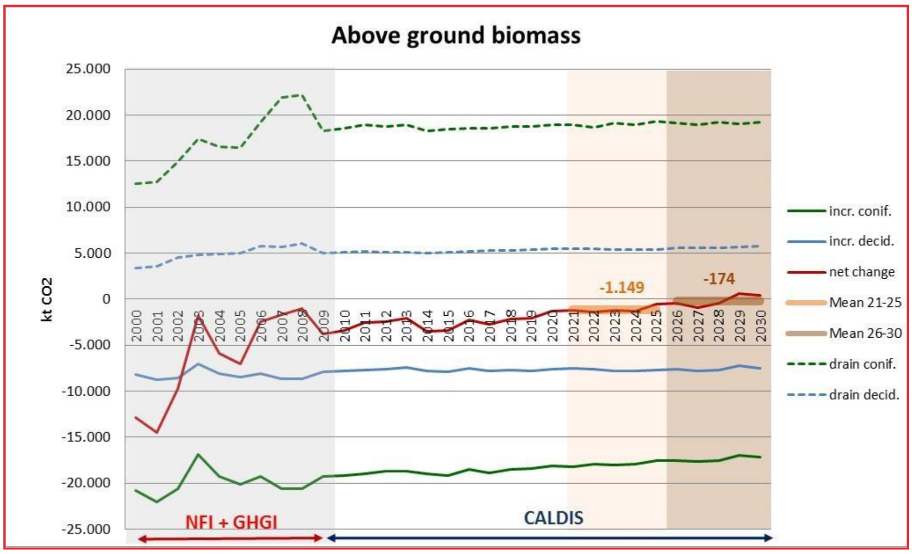
The modelled values for all individual pools of the FRL start with the year 2010. For demonstration purposes the modelled values of the year 2009 are compared to those based on the NFI and GHG inventory for this year.

As described in chapter 3.1 the modelled carbon increment, carbon drain and carbon stock changes of dead wood for total Forest Land were recalculated to those for Managed Forest Land by subtracting the respective carbon stock changes of Afforestation land and Deforestation harvest in 2009. This approach is completely consistent to the one applied in the Austrian GHG inventory.

4.1.1 Above ground biomass

Based on the modelled results for the stem wood increment and drain of total Forest land, the conversion and expansion to total aboveground tree biomass as in the Austrian GHG inventory as well as the recalculation to Managed Forest Land (see before and in chapter 3.1) the net changes in forest above ground biomass for Managed Forest Land results in a carbon sink of -1,149 kt CO_2 for the reporting period 2021-2025 and -174 kt CO_2 for the reporting period 2026-2030 (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 20: Development of the aboveground biomass changes from 2000 to 2030 for Managed Forest Land based on NFI data (2000-2009) and as in the Austrian GHG inventory (Umweltbundesamt 2018) and simulation runs with CALDIS (2010-2030); mean values for the two FRL periods 2021-2025 and 2026-2030



The modelled results for 2009 match very well with those of the Austrian GHG inventory (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

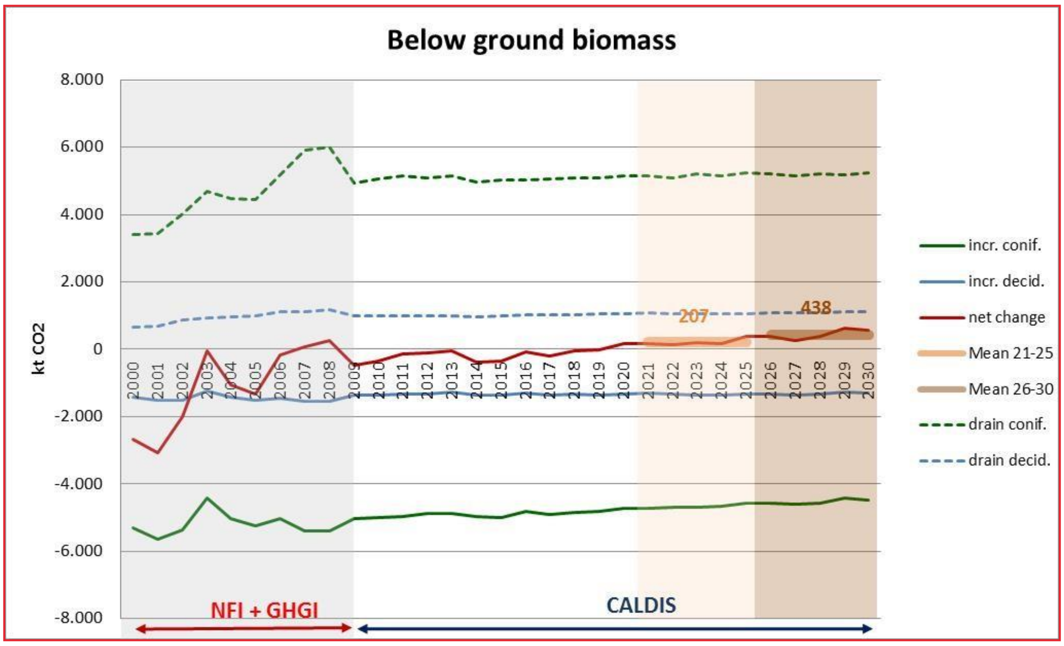
Table 7 Aboveground biomass (AGB) drain for Managed Forest land in 2009 as in the Austrian GHG inventory (Umweltbundesamt 2018) and as modelled by the FRL simulations

AGB increment in 2009 (Mio t CO_2)		AGB drain in 2009 (Mio t CO_2)	
modelled	GHG inventory	modelled	GHG inventory
-27.4	-27.1	23.4	23.3

4.1.2 Below ground biomass

Based on the modelled results for the stem wood increment and drain of total Forest land, the conversion and expansion to total belowground tree biomass as in the Austrian GHG inventory as well as the recalculation to Managed Forest Land (see before and in chapter 3.1) the net changes in forest below ground biomass results in a carbon source of 207 kt CO_2 for the reporting period 2021-2025 and 438 kt CO_2 for the reporting period 2026-2030 (see**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 21: Development of the belowground biomass changes from 2010 to 2030 for Managed Forest Land based on NFI data (2000-2009) and as in the Austrian GHG inventory (Umweltbundesamt 2018) and simulation runs with CALDIS (2010-2030); mean values for the two FRL periods 2021-2025 and 2026-2030



The modelled results for 2009 match very well with those of the Austrian GHG inventory (*Table 8*).

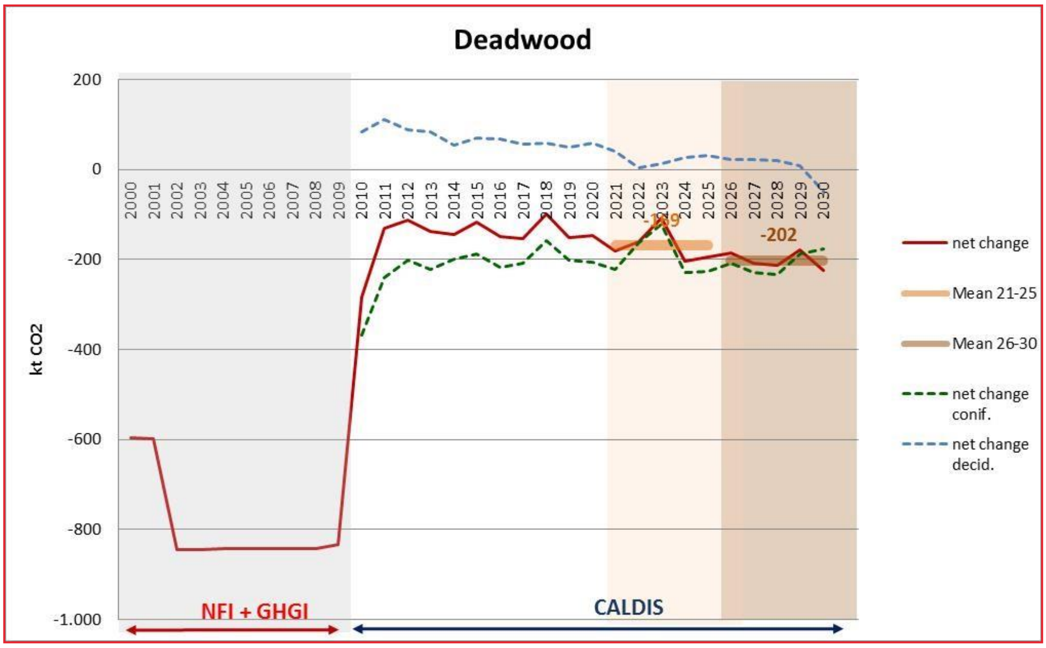
Table 8 Belowground biomass (AGB) drain for Managed Forest land in 2009 as in the Austrian GHG inventory (Umweltbundesamt 2018) and as modelled by the FRL simulations

BGB increment in 2009 (Mio t CO_2)		BGB drain in 2009 (Mio t CO_2)	
modelled	GHG inventory	modelled	GHG inventory
-6.5	-6.4	6.0	5.9

4.1.3 Deadwood

Based on the modelled results for the changes of dead stem wood of total Forest land, the conversion and expansion to total deadwood mass as in the Austrian GHG inventory as well as the recalculation to Managed Forest Land (see before and in chapter 3.1) the dead wood stock changes represent a mean annual carbon sink of –169 kt CO_2 for the FRL period 2021-2025 and -202 kt CO_2 for the reporting period 2026-2030.

Figure 22: Dead wood stock changes based on NFI data (2000-2009) and as in the Austrian GHG inventory (Umweltbundesamt 2018) and simulation runs with CALDIS (2010-2030); mean values of the annual stock changes (kt CO2) is shown for the two FRL periods 2021-2025 and 2026-2030



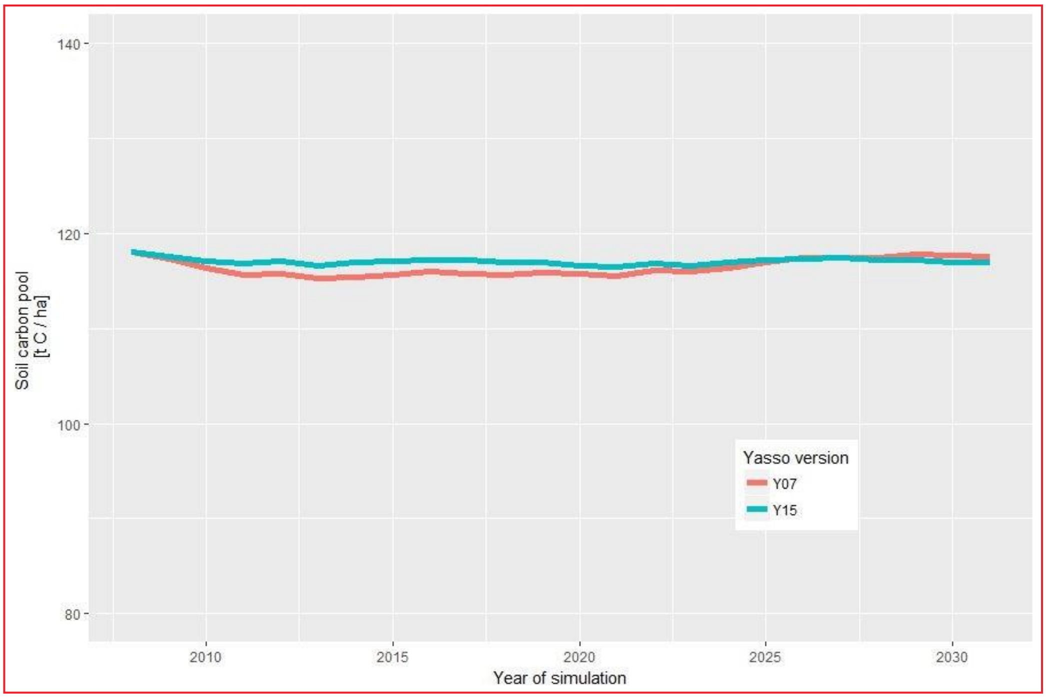
4.1.4 Soil and Litter calculated with Yasso15

During the simulation period 2010-2031 the litter plus soil carbon pool shows a slight decrease with a somewhat irregular pattern and varies between 116.5 and 118 t C per hectare. Irregularities are representing the harvesting pattern and disturbances that occasionally increase the soil C pool by the provision of coarse woody debris and belowground litterfall.

An issue is the use of different versions of Yasso. For the simulation of the soil carbon pool in the Austrian GHG inventory the version Yasso07 was used. In 2015 the version Yasso15 was released and will be used until an even newer version will come out.

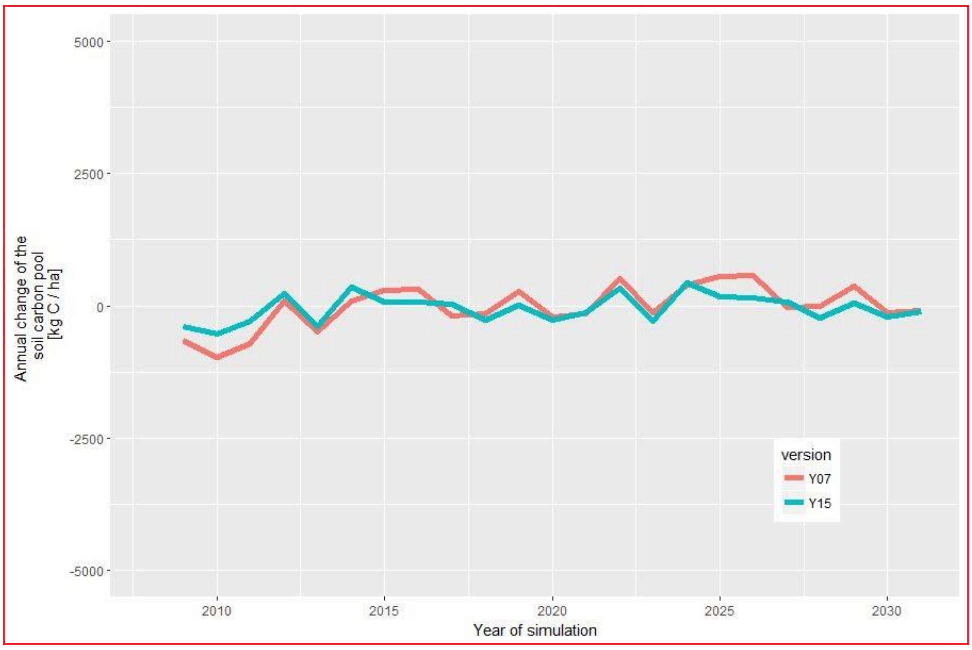
A comparison of the two model versions was made with the entire dataset. The parameterization data were identical and the simulation was run with the two versions of the model. The results are shown below. The differences are negligible. Considering the extremely high consistency of the simulation results we consider it to be justified to follow the irregular updates of Yasso and to use the latest release for the FRL projection. Nevertheless, it should be noted that the complete historic time series of the Austrian GHG inventory will be recalculated with the new Yasso15 version and the approach as for the FRL simulations (see chapter 4.2.1).

Figure 23: Simulated soil carbon pool with Yasso07 and Yasso15



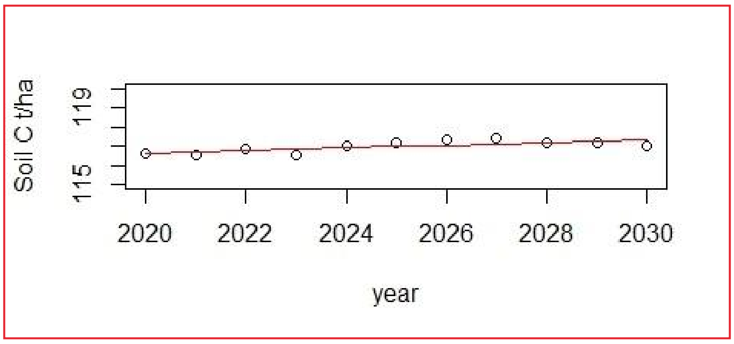
Fehler! Verweisquelle konnte nicht gefunden werden. shows the annual changes of the soil carbon pool. The pattern is mainly reflecting management effects. During the simulation period there are periods of carbon accumulation and depletion in the soil. The maximum annual carbon increase during the simulation period is 430 kg C / ha, the highest annual decrease is 530 kg C / ha. Overall, a slight decrease in the soil carbon pool of 1110 kg C/ha during the simulation period (2010-2031) is simulated.

Figure 24: Annual change of the soil carbon pool calculated with identical input data sets and two different versions of Yasso



Annual changes of the soil carbon pool reflecting a composite of several thousand sites are difficult to interpret. Therefore, averaging the change over a longer time span gives a more**Fehler! Verweisquelle konnte nicht gefunden werden.** reasonable picture and robust figures for the FRL period (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 25: Change of soil carbon during the relevant period of 2021 to 2030. The dots represent the annually assessed soil carbon pool, the red line shows the trend of a linear regression



The linear regression during the reference period of 2021 to 2030 has a slope of 0.068, suggesting an increase of the litter plus soil carbon pool of 68 kg C / ha / year. The regression has an adjusted R^2 of 0.50 with a significance of 0.09%.

The model results on the average annual change in the litter plus soil C stock used for the current Austrian GHG reporting show a carbon loss of 0.2 t C/ha/year for forest land remaining forest land. However, it should be noted that the complete historic time series of the Austrian GHG inventory will be recalculated with the new Yasso15 version and the approach as for the FRL simulations (see chapter 4.2.1).

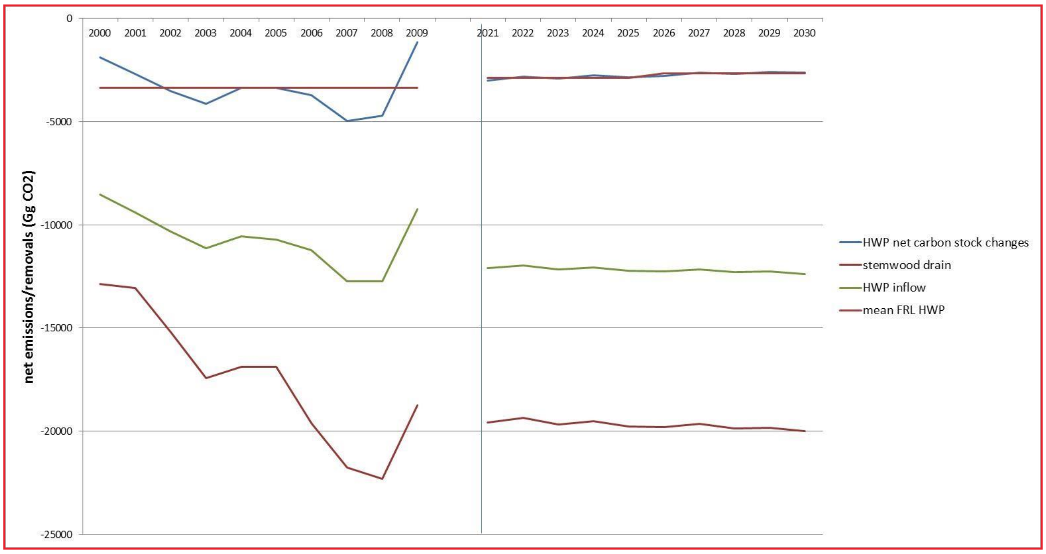
The modelled total FRL litter plus soil C stock changes of Managed Forest Land in the FRL period (an average gain in litter and soil of 825 kt CO_2/year) are completed by soil carbon stock losses due to increases in macadam or paved forest roads (these represent forest land in Austria). In order to be consistent with the Austrian GHG reporting under UN-FCCC and with the EU LULUCF regulation an annual increase in macadam or paved forest roads as for the reference period was also estimated for the projection period 2010 to 2030. This results in an annual soil carbon loss in the FRL periods due to building of forest roads which equals an annual emission of 277 kt CO_2/year. The method of estimate is the same as for the Austrian GHG inventory and described in the Austrian NIR (Umweltbundesamt 2018).

Consequently, the complete estimates for litter and soil C changes of Managed Forest Land show average annual net removals of 548 kt CO_2/yr for both FRL periods.

4.1.5 HWPs

The estimates according to chapter 3.3.3 lead to slightly lower average net HWP carbon stock increases for Managed Forest Land in the FRL periods compared to the reference period, namely on average 2874 kt CO_2/yr for the period 2021 to 2025 and 2666 kt CO_2/yr for the period 2026 to 2030 (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 26: HWP net carbon stock changes, HWP inflow and stem wood drain of Managed Forest Land in the reference period and in the FRL periods



4.2 Consistency between the forest reference level and the latest national inventory report

Both, the figures reported under the UNFCCC in forest land as well as the forest reference level are based on the results of the Austrian NFI. The emissions/removals reported under the UN-FCCC category 4.A Forest Land are based on the results of increment and harvest according to the NFI periods 1986/90, 1992/96, 2000/02 and 2007/09.

The CALDIS-VB V0.1 model simulations for FRL are also based on the status (e.g. area, standing stock) of the Austrian forests as assessed by the NFI 2007/09 and the Austrian GHG inventory for the year 2009 (Umweltbundesamt 2018). The area of Managed Forest Land which was used for the simulations represents 3.822 Mio ha (subcategory 4.A.1 "Forest land remaining forest land", Austria's GHG submission in 2018). However, consistent with the Austrian GHG inventory GHG emissions and removals were calculated for the Managed Forest Land 0f the forests-in-yield only (3.307 Mio ha in 2009; see chapter 3.1).

The models for estimating salvage cuts and natural mortality were developed from Austrian NFI data collected in the course of five assessment cycles: 1981/85, 1986/90, 1992/96, 2000/02 and 2007/09. In this regard it is important to note that the underlying data represent mean quantities for longer time periods (5-8 years). Hence, the models will never be able to estimate the amount of salvage cuts for a specific event, for example the storm event Kyrill. The best way for an evaluation of the model results is therefore to compare the model predictions to the observed quantities of the different NFI periods. The annual salvage cuts comprised 2.2 Mio m^3 in the NFI 1986/90, 1.9 Mio m^3 in the NFI 1992/96, 1.0 Mio m^3 in the NFI 2000/02 and 3.1 Mio m^3 in the NFI 2007/09. The model predictions for the period 2021-2030 vary between 1.7 Mio m^3 and 2.2 Mio m^3 per year with a mean of 2.1 Mio m^3 per year, and are clearly within the range of the observed values of the NFI assessments. The same is true for the natural mortality model that predicts an annual amount of 1.7 Mio m^3 for the period from 2021-2030 which is within the range of the NFI observations that range from 1.3 to 2.4 Mio m^3 per year.

CALDIS-VB V0.1 is based on the same model concept and was parameterized from the same data set as PROGNAUS (PROGNosis for AUStria: Monserud and Sterba, 1996; Hasenauer, 2000; Ledermann, 2006). The only difference between CALDIS-VB V0.1 and PROGNAUS is that CALDIS-VB V0.1 uses climate variables in addition to the predictor variables of PROGNAUS. The basal area increment model, the height increment model and the mortality model of PROGNAUS have been validated several times (e.g. STERBA and MONSERUD, 1997; STERBA, 1999; MONSERUD and STERBA, 1999; STERBA et al., 2001; LEDERMANN, 2010). PROGNAUS was also used for the construction of the Austrian forest management reference level for the period 2013-2020.

The excellent fit between modelled and measured increment and drain for both parameters and units, m^3 stem wood and t CO_2 total tree biomass, is demonstrated in chapters 4 and 4.1.

The basic approach of running the soil carbon model Yasso15 is unchanged to the approach used for the Austrian GHG inventory. Climate data, site data, and forest inventory data are used as drivers of the soil carbon model. The model Yasso is specifically designed to utilize data of a National Forest Inventory for the estimation of the soil carbon stock. In order to estimate the carbon input to the soil several assumptions need to be made.

- The annual carbon input to the soil from needles and leaves can be estimated from the annually calculated needle/leaf biomass and a turnover rate (longevity) of the needles and leafs.
- The annual belowground carbon input to the soil can be estimated from the standing stock of the roots (as a fraction of the total tree biomass), a valid distinction between the mass of fine roots and coarse roots, and a valid assumption of the longevity of fine roots and coarse roots.
- The harvesting pattern defines the input of coarse woody debris (stumps, roots, tree tops, harvesting residues) to the soil.

- The herbaceous vegetation and shrubs and the understory that are not assessed in the National Forest Inventory are not relevant for the annual soil carbon flow.

There have been some changes in the calculation of the litter and soil carbon pool for the projection period to 2030 as compared to the Austrian GHG inventory:

- The used model version of Yasso is different. Previously Yasso07 has been used, currently Yasso15 is used. The version Yasso15 uses an updated set of variables for the decomposition process of soil organic matter. The excellent fit of the results of both model versions was demonstrated in chapter 4.1.4
- The chemical characterization of the different fractions of soil organic matter is unchanged. The percentage of organic matter belonging to the AWENH fractions (acid-soluble, water soluble, ethanol soluble fraction, unsoluble organic matter and humic substance) is unchanged.
- The spin up procedure of Yasso15 was changed. Instead of calculating the average carbon input of the entire simulation period as starting value as steady state condition, an independent growth of the stand for approximately 100 years prior to the simulation period was used. The growth of the stand was initiated by a plantation of trees of age zero. The growth of the stand was simulated until the culmination of the average growth rate. When point in time is reached the timing of harvesting is ideal. Forest managers are ascertaining this point in time.
- Yasso15 introduced and uses a leaching factor that represents carbon losses from litterbags during the decomposition process. The leaching factor can be used to account for different types of carbon losses that are otherwise unaccounted in the model. The user manual describes cases where leaching factors between -0.000167 and -0.91717 have been used. For all sites of our calculations a uniform leaching factor of -0.07 has been used.
- The preparation of the input file for Yasso15 was ported from SAS to R.

A difference in the approach of calculating the forest reference level to the GHG reporting for UNFCCC is the selection of sites. In the Austrian Forest Inventory each assessment unit comprises a tract of 4 plots where tree characteristics are monitored. At one plot of each tract (denoted as 0/0) soil characteristics are recorded in the Austrian Forest Soil Inventory System. The simulation of the soil carbon pool for the Austrian GHG inventory was based on plot information (plot 0/0) and the standing stock, the harvesting pattern, and tree mortality were reported on a plot basis, based on measurements on the plot of the National Forest Inventory.

For the calculations of the forest reference level no field measurements were available. Instead, the calculations were based on the output of the FRL simulations with CALDIS-VB V0.1. The CALDIS-VB V0.1 model offers single-tree information (stem diameter, stem height, height of canopy, stem volume) and information on the fate of individual trees (dieback, harvest) on an annual basis. The fate of each tree according to the simulation can be tracked on an annual basis.

The latest National Forest Inventory in Austria is currently under way. Upon its completion in 2021 the time series of the forest litter plus soil carbon pool changes will be re-calculated for the complete historic time series of the GHG inventory by using the new Yasso15 model version and approach (for economic reasons and in order to avoid a doubling of work this is not done before the completion of the current NFI cycle, see chapter 4.2.1). This will be announced in the planned improvements of the next Austrian NIR in 2020. This may lead to an adjustment of the forest litter and soil C changes in the Austrian GHG inventory.

4.2.1 Future technical corrections of the Austrian FRL

The Austrian FRL will be adjusted to ensure consistency between the GHG inventory and the FRL. This will be the case for any methodological change of the GHG inventory which has also an impact on the FRL estimate.

There are already known three such required technical corrections for the Austrian FRL in the future:

- The Austrian FRL is estimated on basis of a constant area of Managed Forest Land in Austria as reported in the Austrian GHG inventory for the year 2009 (Umweltbundesamt 2009). The FRL estimates subtract C stock changes due to Afforestation and Deforestation as in the year 2009 from the modelled results for the total Austrian Forest Land (see chapter 3.1). Consequently, the FRL will be technically corrected by the real area of Managed Forest Land and the real emissions and removals of Afforestation land and Deforestation harvest in the FRL period. This will be done as soon as data are available for the area of Managed Forest Land, Afforestation and Deforestation for the period 2021-2025.
- Consistent with the Austrian GHG inventory, the Austrian FRL does not yet include the carbon stock changes of forests not-in-yield. These forests have no access and are not harvested for this reason. So far, only one (the last) NFI included an assessment of the biomass stocks of the Austrian forests not-in-yield. With a repetition of this assessment in the currently running NFI cycle, Austria will be in a position to estimate the carbon

stock changes of the forests not-in-yield and will then include those estimated in the GHG inventory.We will also apply a technical correction of the FRL for the C stock changes of forests not-in-yield in all pools.

- The litter and soil carbon stock changes of the Austrian FRL were already estimated with the new Yasso15 model version starting from 2010 on, while the related figures of the GHG inventory are based on the previous Yasso07 model version (the excellent fit of both model versions was demonstrated in chapter 4.1.4). This decision was taken in view that the complete historic time series will be also recalculated with the new Yasso15 version and approach and in order to avoid unnecessary doubling of work. This will likely lead to changes in the figures of the historic litter and soil C stock changes of Forest Land in the Austrian GHG inventory, but may also affect the FRL by eventually starting from a different litter and soil C stock level for the FRL projections from 2010 onwards compared to the Yasso15 model runs for the FRL estimates at hand. If this will be the case, the modelling runs will be carried out for the historic GHG inventory time series and for the FRL periods 2021 to 2025 and 2026 to 2030. In order to save resources and avoid double work, the new Yasso15 estimates for the historic time series will be carried out once the results of the current NFI will become available. This will be in 2021 and the new estimates will be ready for submission 2022. Austria will announce this recalculation in its planned improvements in its next NIR in 2020.

5 References

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