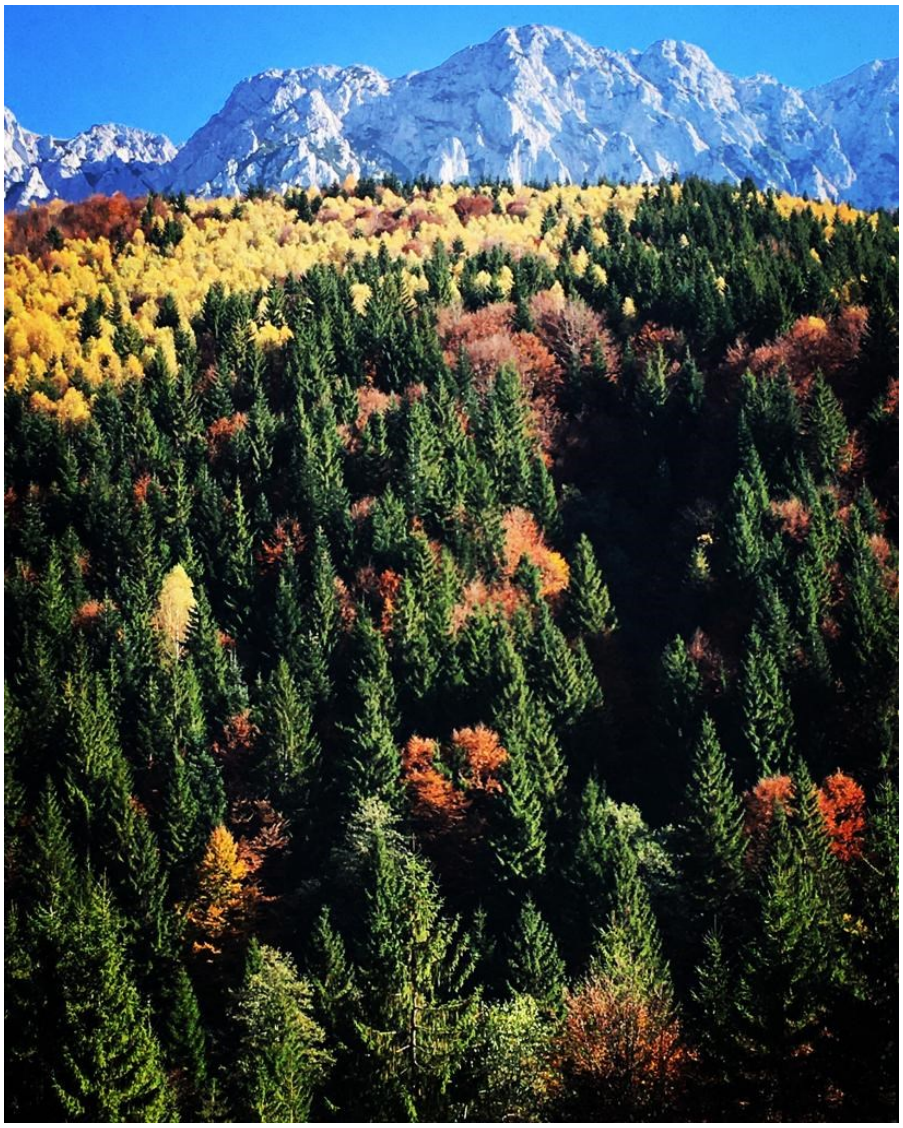
MINISTERUL MEDIULUI,
APELOR ȘI PĂDURILOR



National forestry accounting plan of Romania

FOR THE FIRST COMPLIANCE PERIOD (2021-2025)

Title
National forestry accounting plan of Romania for the first compliance period (2021-2025)

Authors
Albert Ciceu
Raul Gheorghe Radu
Juan García-Duro

Citation
Ciceu, Albert, Radu, Raul and García-Duro, Juan (2019) National forestry accounting plan of Romania. Institutului Național de Cercetare-Dezvoltare în Silvicultură„Marin Drăcea" (INCDS). Voluntari. Romania. pp.57.

Cover photo
Raul Radu

Table of content

ACRONYMS AND ABBREVIATIONS

DW	Deadwood – carbon pool including standing dead trees and stem parts lying on the ground
ETS	European Trading Scheme
EU	European Union
FRA	Forest Resources Assessment
FRL	Forest Reference Level
FMP	Forest management practice
GHGI	Greenhouse Gas Inventory
HWP	Harvested Wood Products
LULUCF	Land Use, Land-Use Change and Forestry
LB	Living biomass
MEWF	Ministry of Environment, Water and Forest
MFL	Managed forest land
NFAP	National Forest Accounting Plan
NFI	National Forest Inventory
NFI	National Forest Fund Inventory
NFF	National Forest Fund
NIR	National Inventory Report (on greenhouse-gas emissions) under UNFCCC
PP	Protection period
RP	Reference period (2000-2009)
UNFCCC	United Nations Framework Convention on Climate Change

ROMANIA NATIONAL ACCOUNTING PLAN OF ROMANIA FOR THE FIRST COMPLIANCE PERIOD (2021-2025)

Chapter 1: General introduction

In June 19, 2018, the 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 (hereinafter referred to as the 'LULUCF Regulation') was published in the Official Journal of the European Union.

LULUCF Regulation forms part of the implementation of the Union's commitments under the Paris Agreement adopted under the United Nations Framework Convention on Climate Change ('UNFCCC') for the sector of land use, land-use change and forestry (hereinafter referred to as the "LULUCF sector"). LULUCF Regulation aims achieving the objectives of the Paris Agreement and meeting the greenhouse gas emission reduction target of the Union for the period 2021-2030.

Following article 8.3 of this regulation, Member States shall establish National Forestry Accounting Plans (NFAP), including a proposed Forest Reference Level (FRL) for the period 2021-2025. This National Forestry Accounting Plan for Romania has been prepared pursuant to LULUCF Regulation.

1.1.General description of the Forest Reference Level (FRL) for Romania

As defined by the LULUCF Regulation, Forest Reference Level (FRL) means "***an estimate, expressed in tones of CO2 equivalent per year, of the average annual net emissions or removals resulting from managed forest land within the territory of Romania in the periods from 2021 to 2025 and from 2026 to 2030, based on the criteria set out in this Regulation;***"

The estimation of the FRL in Romania is in accordance with the LULUCF Regulation and follows the Guidance on developing and reporting FRLs (Forsell et al., 2018). The FRL is constructed based on the best available data for the Reference Period (−RP−; 2000-2009).

The following criteria set out in Section A of Annex IV of Regulation were used in the process of developing the FRL:

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;***

Romania's carbon stock in Living Biomass on forest land (LB) have increased according to the last 3 forest inventories (Fig. 1 and Fig. 2). The vast majority of Romania's forests are between 40 and 80 years old (fig. 1), as a result of historical events (Marinescu et al., 2013; Nita et al., 2018; Olofsson et al., 2011), meaning that it is in the most productive age now. The increase of forest harvest in the last years is directly related to the forest increment, as it has been found to other areas in Europe (Levers et al., 2014) and the world (Brown et al., 2018). Even so, the harvest didn't exceed the increment and indeed the actual felling was lower than the planned felling.

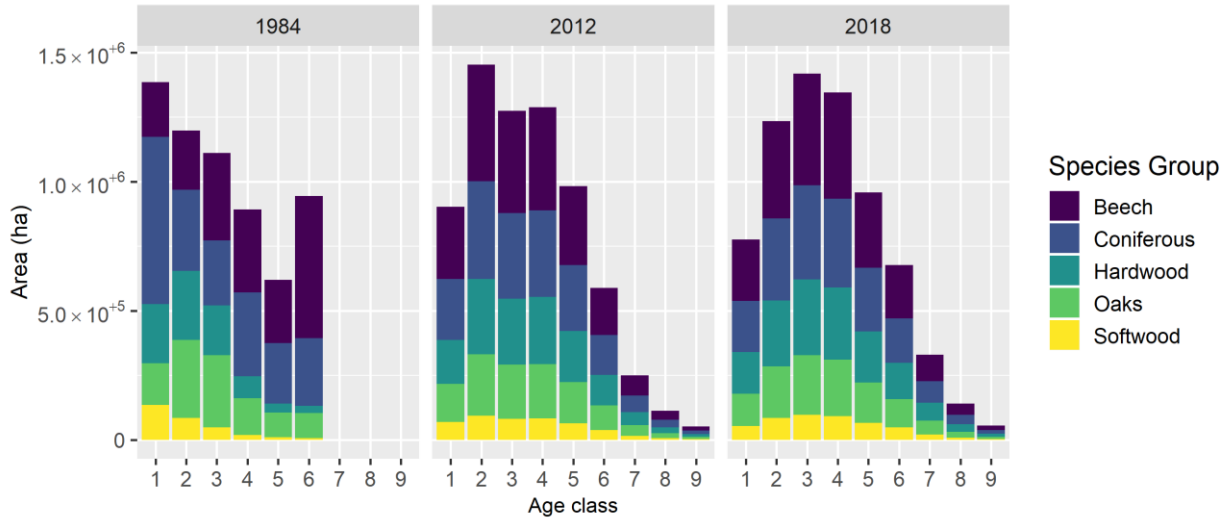


Fig.1. Forest area distribution on 20 year-age classes according to the NFF Inventory in 1984 and NFI2012 and 2018. The 6th class in the 1984 NFFI accounts for all forests above 100 years old while the 9th class in 2012 and 2018 NFI are accounting for all forests above 180 years old.

Besides Living Biomass (LB), forest carbon is retained in other carbon stocks, such as the dead-wood biomass (DW) and soil carbon pool stocks (Dinca et al., 2012; Krueger et al., 2017; Turcu et al., 2013). With the aging process the forest carbon stock in Living Biomass is expected to show a progressively declining sink strength after 2030, similarly to what has been

predicted for other temperate forests with similar age structure (Brown et al., 2018; Curtis and Gough, 2018). This decline in the living biomass, will have an important impact on the remaining forest C stocks (Deng et al., 2016; Lewandrowski et al., 2014; Schulp et al., 2008).

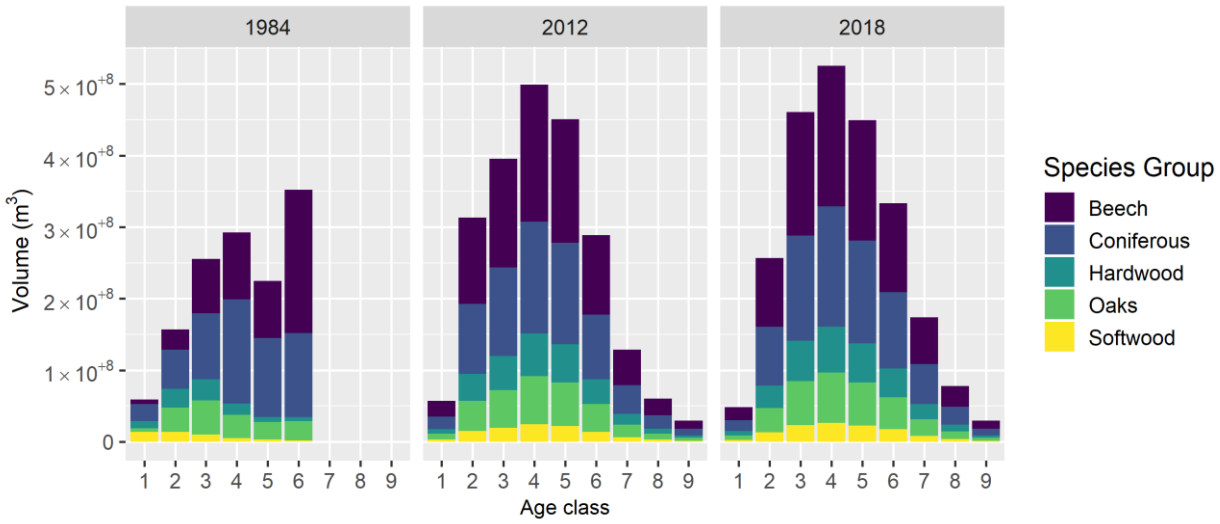


Fig.2. Forest volume distribution on 20 year-age classes according to the NFF Inventory in 1984 and NFI 2012 and 2018. The 6th class in the 1984 NFFI accounts for all forests above 100 years old while the 9th class in 2012 and 2018 NFI are accounting for all forests above 180 years old.

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

The proposed Romanian FRL takes into account the net changes in forest carbon stocks as only annual removals will reduce the atmospheric carbon. The mere presence of carbon stock was not taken into account when projecting FRL. The amount of C accumulated in forest soils in Romania according to both national forest inventories (2012, 2018), 158.2 t/ha, shows an equilibrium between inputs and outputs and hence this stock was not accounted. Available data do not confirm either reject an active role of litter pool in C sequestration in the Reference Period (RP) and thus they got apart from the accounting. In addition, the protected forest according to the management plans and also the ones located in the National parks where no intervention is allowed were removed from the accounting process.

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 FRL has been set in a way that ensures that emissions and removals resulting from biomass use were properly accounted for. The FRL estimation includes all emissions and removals from LB (aboveground biomass and belowground biomass), HWP (Harvested Wood Products) and DW (Deadwood). They are taken into account for projecting FRL in the first compliance period 2021-2025 assuming the continuity of Forest Management Practices (FMP) in the Reference Period.

d. the reference level shall include the carbon pool of harvested wood products, thereby providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values;

The annual harvest was disaggregated into energy wood and HWP, which were subjected to the first-order decay function for the calculation of the carbon pool following (Forsell et al., 2018). HWP were split into a) Sawnwood, b) Wood-panels and c) Paper and paperboard, as having clearly differentiated half-life values (IPCC, 2019)(IPCC 2013).The comparison between instant oxidation and first-order decay function of the HWP is covered in Chapter 4.

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

A constant ratio between solid and energy use of forest biomass as documented in 2000-2009 period (Table 1) was assumed. National consumption for energy and export was calculated for each of three HWP categories Sawnwood, Wood-based panels and Paper and paperboard. The average ratio for each category was then used in the commitment period 2021-2025. The HWP for exports were taken into account in the FRL for excluding a double counting problem.

Table 1. Total amount of harvest and the ratio of Energy wood and HWP by year for the RP.

		Energy	Sawnwood		Wood-panels		Paper and paperboard	
Year	Total harvest (m3)	Production *ratio*	Production *ratio*	Exports *ratio*	Production *ratio*	Exports *ratio*	Production *ratio*	Exports *ratio*
2000	14284700	0.536	0.238	0.163	0.021	0.011	0.024	0.008
2001	13410300	0.541	0.228	0.137	0.033	0.019	0.029	0.012
2002	16383100	0.544	0.226	0.133	0.036	0.027	0.023	0.011
2003	16691500	0.473	0.254	0.156	0.046	0.031	0.027	0.013
2004	17082100	0.429	0.269	0.166	0.056	0.041	0.027	0.013
2005	15671300	0.435	0.276	0.147	0.065	0.045	0.024	0.008

Year	Total harvest (m3)	Energy Production *ratio*	Sawnwood Production *ratio*	Sawnwood Exports *ratio*	Wood-panels Production *ratio*	Wood-panels Exports *ratio*	Paper and paperboard Production *ratio*	Paper and paperboard Exports *ratio*
2006	15684000	0.446	0.222	0.150	0.088	0.059	0.028	0.008
2007	17237600	0.455	0.240	0.138	0.073	0.050	0.032	0.011
2008	16704600	0.458	0.227	0.114	0.115	0.054	0.025	0.006
2009	16519900	0.414	0.218	0.137	0.141	0.066	0.021	0.004
Average	15966910	0.473	0.240	0.144	0.067	0.040	0.026	0.009

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

Romania's forest management plans, which set the intensity of harvest, are consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the Romania's national forest policies, EU forest strategy and the EU biodiversity strategy. The forest management plans follow the biodiversity conservation principle which provides protection to forest areas that distinguish themselves through a high biodiversity and promotes silvicultural practices to maintain or increase the biodiversity. Also, more than half of the Romania's forest have a protection goal (The state of the Forest in Romania 2017, MEWF). Biodiversity is supported the by the Romania's forest management plans which promote native species and mixed forest by supporting natural forest types through the regeneration composition as it is referred in the National Forest Regulations. On the 14 May 2019 Romania had an area of 6,947.22 ha of virgin forest and 22,116.36 ha of quasi-virgin forests, these areas are kept aside from construction of the FRL. The total area of national and natural parks with different levels of protection sum 1.67 mil ha.

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

Romania's projections reported under Regulation (EU) No 525/2013 consider all policies and measures undertaken at the national level (the EU ETS, the renewable energy target, the energy efficiency target, the promotion of clean an energy efficient road transport, etc.) as well as the GHG emission evolution established for non-EU ETS sectors. The projection built under

the Regulation (EU) No 525/2013, which accounts for the whole LULUCF sector does not consider forest alone but the overall trend of FRL is in accord with it.

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 model used is able to reproduce historical data from the National Greenhouse Gas Inventory. Data used for building FRL is consistent with greenhouse gases inventories and relevant historical data and is based on transparent, complete, consistent, comparable and accurate information. Chapter 4. demonstrates that this criterion is met.

This national forestry accounting plan (NFAP) follows Annex IV section B of the LULUCF Regulation which sets out the main components that the NFAP shall contain. Romania has developed the NFAP according to the proposed common table of content as it follows in the next sections.

Chapter 2: Preamble for the FRL

2.1. Carbon pools and greenhouse gases included in the FRL

The Romanian FRL includes the following carbon pools: Living Biomass (-LB-; above and below ground) and Deadwood (DW). Also, the carbon pool of Harvested Wood Products (HWP) is included. The balance in these pools are expressed in terms of tones of CO_2 equivalent and determined pursuant to Regulation (EU) No 525/2013.

2.2. Demonstration of consistency between the carbon pools included in the FRL

FRL is based on the same definitions, methodologies and historical data as applied in the national Greenhouse Gas Inventory (GHGI).

National Forest Inventory (NFI) is the main source of data regarding LB carbon pool. Romania has two NFI inventories carried between 2008-2012 and 2013-2018 based on re-sampling of permanent plots. A third Forest Fund Inventory from 1984 based on management plans was used also for a quality control of the forest age class distribution.

Annual data from the National Institute of Statistics (NIS) on felling and HWP was used. NIS data are based on the annual reports of each forest district in Romania. Data regarding harvested volume, surface where regeneration cuttings were applied are submitted each year to the NIS and constitute the best available data.

2.3. Description of the long-term forest strategy

The main long-term forestry strategies are set by the *National Forest Strategy 2018-2027*. Romanian forestry is performed based on eleven basic principles defined by the Forestry Code, aimed to comply with the six criteria of sustainable forest management defined by the Ministerial Conference on the Protection of Forests in Europe and the three guiding principles set out in European Union's EU strategy for forests and forestry sector. Same principles are shared by Romanian National Forestry Strategy.

The main objective of the Romanian National Forestry Strategy is `Harmonizing the forest functions with the present and future requirements of the Romanian society through the

sustainable management of the national forest resources. This is implemented through the following five strategic **objectives** and their measures:

I. *Efficiency of the institutional framework and regulation of a necessary activity in the forestry field*
II. *Sustainable management of the National Forest Fund (NFF)*
III. *Increasing the competitiveness and sustainability of the forest industries, bioenergy and bioeconomy as a whole*
IV. *Developing an efficient system of public awareness and communication*
V. *Development of scientific research and forestry education*

The most important **measures** derived from the objectives on the sustainable management of the National Forest Fund are the following:

A. *Extension of the area of forests and other lands with forest vegetation*
    a. Identification of forest vegetation that fulfills the conditions of classification as a forest and its inclusion in the National Forest Fund (NFF), through the creation of mechanisms of co-interest of the owners;
    b. Identification and afforestation of lands unfit for agricultural uses;
    c. Implementation of the national system of forest protection belts;
    d. Assuring the availability of forest reproductive material;
    e. Supporting measures for degraded land afforestation and for the creation of forest belts.
B. *Harmonizing the national system of indicators for the sustainable management of forests with the European system*
    a. Permanent update of indicators for the sustainable management of forests in European and national context;
    b. Implementing and correlating the national forestry program with the sustainable forest management indicators.
C. *Conservation and improvement of forest ecosystems biodiversity*
    a. Identification and conservation of virgin and quasi-virgin forests, riparian forests, forest habitats and rare, threatened, endangered species;
    b. Protecting the biological diversity of forest ecosystems, forests with natural and quasi-natural structures;

c. Conservation of marginal habitats, wetlands occupied by forest vegetation, and of protected and vulnerable species;
d. Building a compensation system for the restrictions imposed by the requirements of the Natura 2000 network in order to ensure the sustainable management of forests within the protected natural areas.

D. *Continuous adaptation of forests to climate change*
   a. Adapting forest regeneration practices to the needs imposed by climate change
   b. Continuous adaptation of the forest management system to improve their capacity to adapt to climate change;
   c. Maintaining and improving the system of monitoring and surveilling the action of destabilizing biotic and abiotic factors;
   d. Promoting natural regeneration by applying the appropriate intensive and semi-intensive treatments;
   e. Promote diversified compositions, focusing on the conservation and restoration of the genetic biodiversity of forest species with ecological requirements compatible with the local environmental conditions.;
   f. Restoration of destroyed forests as a result of the effects of climate change;
   g. Selecting and promoting biotypes of trees resistant / adapted to climate change and extending their use in forest regeneration systems;

E. *Development of the National Forest Fund management system*
   a. Increasing the forest fund by raising proportion of national forest covered in management plans
   b. Supporting certification system compatible with the management practices adopted at national level;
   c. Continuous monitoring of forest management plans implementations;

F. *Evaluation and monitoring, forest functions, ecosystem services provided by forest and forest resources*
   a. Implementation the national forest inventory;
   b. Building / improvement of the methodological system regarding the quantification of the forest functional services and the ecosystem services; designing a payment system for ecosystem services;
   c. Increasing carbon storage capacity in the context of sustainable forest management.

G. *Extension in the integrated system of the torrential hydrographic basins*
    a. Creating a singular and integrated system for the management of torrential hydrographic basins to reduce the effects of extreme natural events;
    b. Continuous monitoring of the watershed correction process state from the National Forest Fund;
H. *Increasing the degree of accessibility of the National Forest Fund*
    a. Increasing the density of forest transport routes;
    b. Accessibility of stands;
    c. Rehabilitation / safeguarding of forest transport routes affected by natural disasters;
    d. Adaptation of the forest road network to the current technical characteristics of the means of forest transport;
    e. Promoting the construction of forest roads on hillslopes;
I. *Developing an integrated information system for forestry*
    a. Achieving the interoperability of the forestry information system;
    b. Optimization of the SUMAL subsystem for wood traceability. Interconnection with users' computer systems;
    c. Improving the subsystem's statistical indicators for forestry;
J. *Extension of wood harvesting technologies which are performant in terms of technical, ecological and economic rates;*
    a. Stimulating the acquisition and use of efficient wood harvesting technologies with low environmental impact;
    b. Limiting the use of aggressive technologies towards the environment;

K. *Increasing the contribution of the forestry sector to rural development*
    a. Prioritize the use of forest goods and services for the benefit of local communities;
    b. Involving local communities in decision-making processes for forest management and protection;

These measures will have as effect an increase of the area occupied by forests and forest vegetation in Romania; building the national system of forest protection belts; maintaining and improving the forest ecosystems biodiversity; decrease the share of illegal cuts by the existence of a national, functional, harmonized system with the European system to monitor the origin

and the traceability of the wood material; stimulating the use of efficient and low impact wood harvesting technologies;

2.3.1. Normative framework

The forest system is regulated at national level by the following major normative regulations:

Document title	Description of the document
1. Law no 46/2008 – Forestry Code, republished, with subsequent amendments and completions.	Forestry Code
2. Law no 171/2010 regarding the establishment and sanctioning of forest contraventions, as subsequently amended and supplemented;	This law provides for contraventions to the regime regarding forest management, organization, the integrity of the forest fund, forest surveillance and protection, forest regeneration and woody resources valorization, woody resources exploitation and non-woody products harvest, as well as control of the application of the rules regarding wood products traceability, tracking and sanctioning.
3. Law no. 100/2010 regarding afforestation of degraded lands;	The normative act details point 53, from the annex to the Forest Code, and refers to degraded lands suitable for afforestation regardless of the form of property, for which it is proposed to improve them by afforestation works, in order to protect the soil, to restore the hydrological balance and to improve the conditions of the environment..
4.Law no 289/2002 regarding forest protection curtains	Forest belts are defined as formations with forest vegetation, established by planting, with different lengths and relatively narrow widths, located at a

	certain distance from each other or from a target, in order to protect it against the effects of harmful factors. Their classification, according to art. 2, is the following: a) for the protection of agricultural lands against harmful climatic factors and for improving the climatic conditions in the protected perimeter; b) anti-erosion, for protection of soils subjected to erosion phenomena; c) for the protection of communication and transport paths, in particular against snowfalls; d) for the protection of dams and banks against currents, floods, ice and others; e) for the protection of populations and of diverse economic and social objectives.
5.Law no 56/2010 regarding the accessibility of the National Forest Fund	Accessibility is an important factor in the sustainable management of the National Forest Fund. It can be achieved by: 1. road construction works; 2. intervention works through investment in the existing roads, in order to maintain their integrity and functionality The forest roads and railways network ensure forest accessibility for the execution of forestry works, for the fire prevention and extinction and for the exploitation of forests under ecological and cost-effective conditions.
6. Government Emergency Ordinance no. 85/2006 on establishing the modalities for assessing the damages caused to the forest vegetation from forests and from outside them, approved with modifications and completions by Law no. 84/2007;	Under the law, damage is understood as the alteration of the appearance, of the physical integrity and / or the physiological characteristics of tree(s) or stand / plantation / natural regeneration, as the result of logging, degrading, destroying, removing from the roots the trees, seedlings or shoots, cutting standing tree branches,

	followed or not by their appropriation, in illegal conditions
7. Government Decision no. 1076/2009 for the approval of the Regulation for the protection of the Forest Fund	It aims at safeguarding the National Forest Fund against illegal occupants of land from the Forestry Fund, illegal logging, theft, destruction and degradation of forests or objects of any kind located in the forestry fund, pasture, as well as against other harmful acts for Forest Fund integrity.
8. Government Decision no. 617/2016 for the approval of the Regulation for the recovery of the wood from the Forest Fund public property	The volume of timber established to be harvested annually from the public property Forest Fund is the one included in the acts of enhancement and is validated by the organizers, according to the regulation of valorization of the wood resources from the public property Forest Fund. In order to ensure the transparency of the commercialization of the wood products, the administrators of the public Forest Fund property have the obligation to ensure the publicity of the negotiations of wood products.
9. Government Decision no. 864/2016 regarding the approval of the scheme "The minimum aid for forestry services for the Forest Fund private property of legal and natural persons carrying out economic activities, if the area of forest property is less than or equal to 30 ha" and the Procedure for granting from the state budget the costs of forestry services for the Forest Fund private property of legal and natural persons	The purpose is to provide forest services for the entire area of the national Forest Fund. Under the scheme, the minimum aid is granted in the form of payment from the state budget to forest owners whose total area is less than or equal to 30 ha. This way the owners will benefit free forest services.

who do not carry out economic activities, if the area of the forestry property is less than or equal to 30 ha.	
11. Technical norms regarding compositions, schemes and technologies of forest regeneration and afforestation of degraded lands, approved by O.M. no. 1648/2000 (no. 1);	Technical norms regarding compositions, schemes and technologies of forest regeneration and afforestation of degraded lands
12. Technical norms for forest stand care and management, approved by O.M. no. 1649/2000 (no. 2);	Technical norms for applying silvicultural practices for forest stands
13. Technical norms regarding the choice and application of treatments, approved by O.M. no. 1650/2000 (no. 3);	Technical norms regarding the choice and application of silvicultural systems
14. Technical norms for the evaluation of the volume of wood destined for commercialization, approved by O.M. no. 1651/2000 (no. 4);	Technical norms for the evaluation of the volume of wood destined for commercialization
15. Technical rules for forest management planning, approved by O.M. no. 1672/2000 (no. 5);	Technical rules for forest management planning
16. Technical norms regarding the protection of forests, approved by O.M. no. 1652/2000 (no. 6);	Technical norms regarding the protection of forests

17. Technical norms regarding the annual control of the regenerations, approved by the O.M. no. 1653/2000 (no. 7);	Technical norms regarding the annual control of the regenerations
18. Norms for preventing and extinguishing fires in the forest, approved by O.M. no. 1654/2000 (no. 8);	Norms for preventing and extinguishing fires in the forests

2.3.2. Overall description of the forests and forest management in Romania and the adopted national policies

In Romania forest land (Fig. 3) is defined by the Forestry Code (Law no. 46/19.03.2008) as forest with a minimum area of 0.25 ha with trees that reach a minimum of 5 meters at maturity in situ. This definition is used by forest management plans. Global Forest Resources Assessment (FRA) 2005 defines forest land as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ". Forest land is defined by NFI as forest lands that are included in the forest management plans and other lands outside of the management plans that meet the requirements of FRA.

The second cycle of NFI (2013-2018) reports a forest cover of 29.5 % of the country surface.

The most abundant 10 species in Romania are beech (31%), Norway spruce (20%), sessile oak (8%), common hornbeam (7%), fir (4%), black locust (4%), Turkey oak (4%), pedunculate oak (2%), Hungarian oak (2%) and birch (1%).

Forest ownership in Romania is divided in private ownership (35%) and public ownership (65%). After the state-owned forest in the communist area, from the year 1990, a reparatory measure for the abusive nationalization of the forest has started. Forest ownership from forest national fund has gradually transferred from state own forest to private, a process which is still in progress. This transfer of ownership has been regulated by a series normative acts law no. 18/1991, 1/2000 and 247/2005. The first law in 1991 restricted the area of forest to be received by a private owner to maximum of 1 hectare. The next two ones come to complete the process, to reunite all the surface own before the nationalization process. The actual change in property

has seen a high increase after the year 2000. The official data reports, in 2005, 65% of the forest fund was public and in 2017 only 48.6 %.

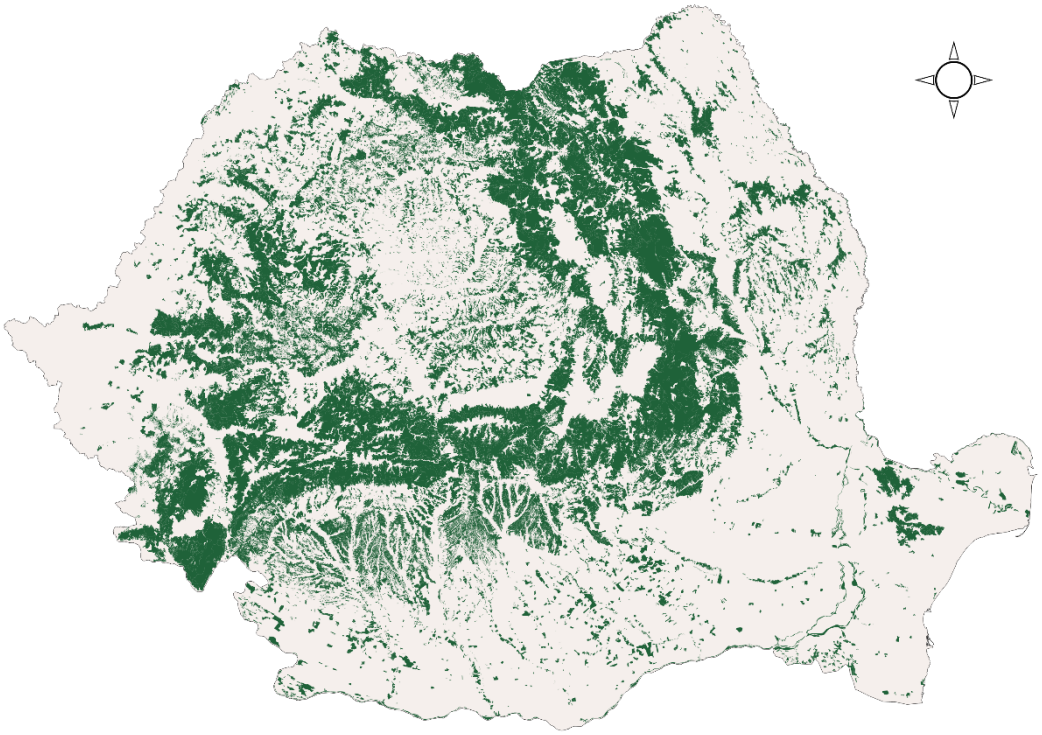


Fig. 3. Forest distribution in Romania.

The whole forest land can be considered managed as cuttings are also applied and accounted by the forestry district personnel (Fig. 4) in areas outside of National Forest Fund or not included in forest management plans. Also, the protected forest is considered managed as non-intervention is also a type of management applied.

The first inventory of the Romanian NFF has been developed in 1970's by aggregating all forest managements plans (Table 2). Also, an early statistic was released in 1964 from aggregating data at a regional level, as being described in the historical records. The following forest fund inventories (1974, 1980, 1984) were developed using automatic procedures which allowed a much higher input data and better results. By the 1980 inventory the authorities obtained data disaggregated at a forest district level and stand level.

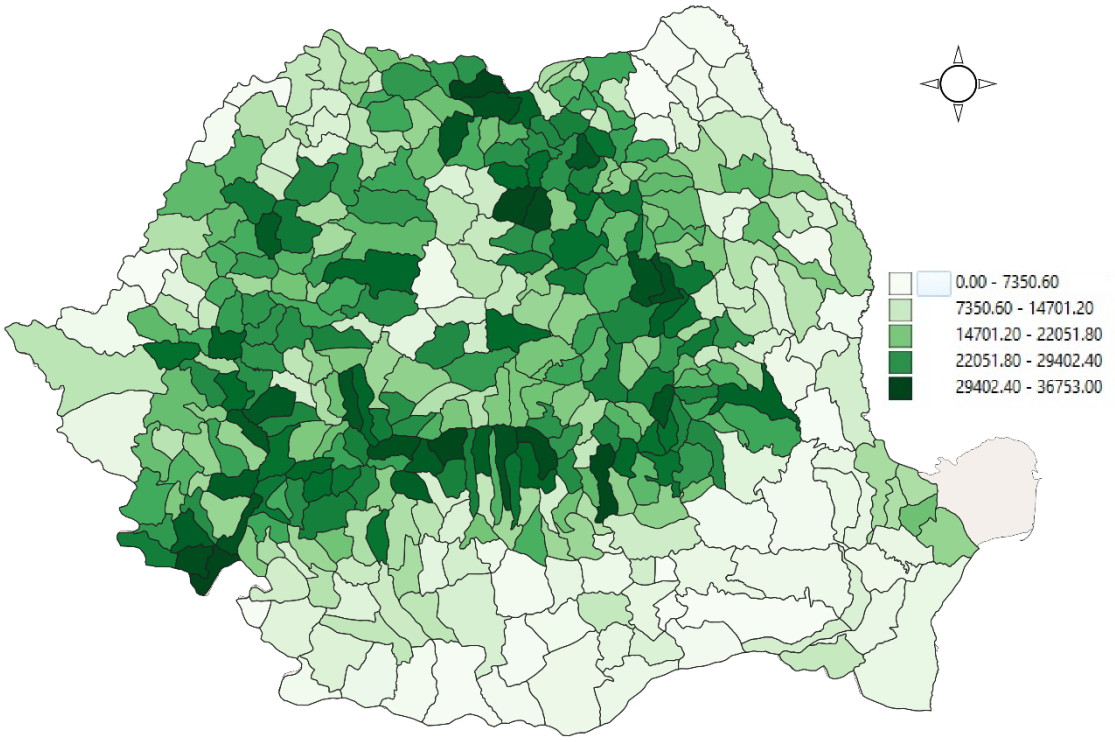


Fig. 4. Forest district delimitation and the forested land area reported in the first management plan after the year 1990's.

Table 2: Quantitative data from the aggregation of the managements plans before 1990's from historical records.

Year	Forest area (thousands ha)	Volume (thousands m^3)	Growth (m^3 / ha)	Volume (m^3/ha)
1964	5783.0	1246.9	4.9	221
1970	5772.6	1256.6	5.0	222
1974	5754.0	1230.0	4.7	218
1980	5747.6	1268.9	5.6	223
1984	5748.4 482.5*	1287.8 53.7*	5.7 5.4*	227 114*

*Data available from other institutions than the Ministry of Silviculture; available only for year 1984.

Romania reported a total of 6 230 900 mil ha and a total volume 1341.5 thousand mil m^3 in 1984 NFFI (National Forest Fund Inventory) whereas in the last NFI the surface covered by forest is 6 929 047 ha.

Romania's forest growing stock increased considerably according to the last three national inventories (1984, 2012 and 2018) from 1.3 billion m^3 in 1984 to 2.2 and 2.3 billion m^3 in 2012 and 2018 respectively. Also, the mean volume per hectare shows the same increase, from 227 m^3 per hectare in 1984 to 321 and 339 m^3 per hectare in 2012 and 2018 respectively.

The estimated growing stock is increasing yearly with 58 622 945 m^3 with a mean of 8.5 m^3 per hectare according to the 2018 NFI results while in 1984 NFFI the estimated growing stock increased yearly with 34 600 000 m^3 with a value of 5.6 m^3 per hectare.

Forest silvicultural practices promote natural regeneration of the forest, the surface covered by close to nature silvicultural practices increased considerable in the last 30 years (Fig. 5). Conservation sums cover more than half of the annual surface covered by cuttings in 2018. The harvested volume is low and it is applied only in old-age forests with protection purpose in order to maintain a good sanitary state of the forest. Shelterwood group system is also largely applied in Romania, its applicability increased in the last years.

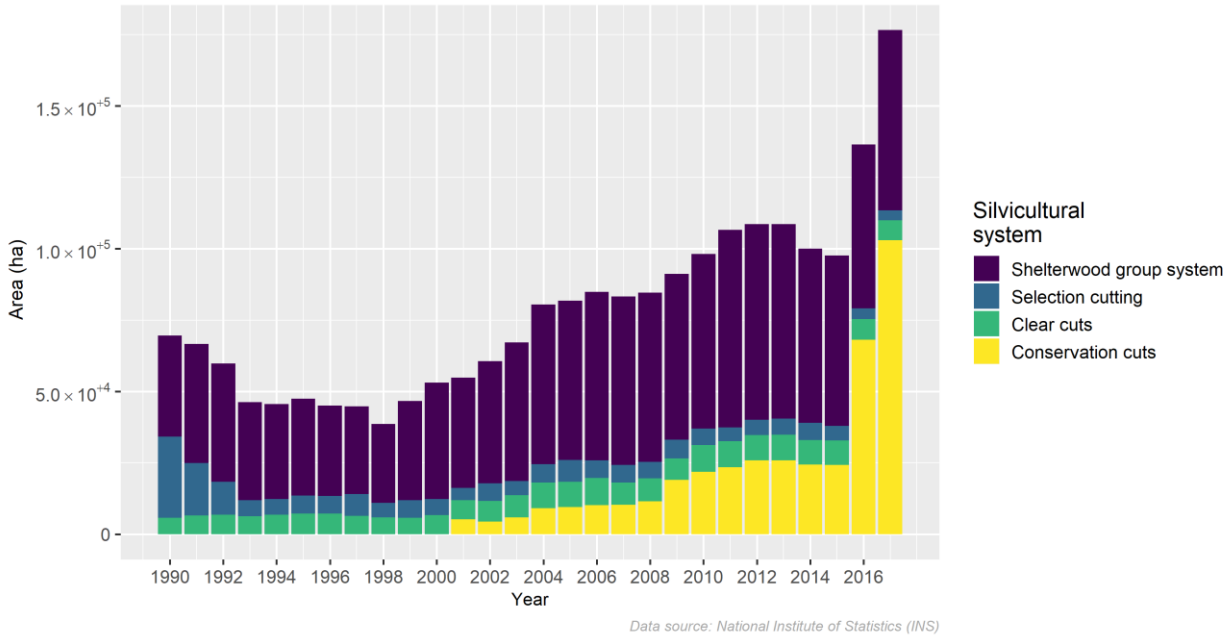


Fig.5. Surface covered by each silvicultural system applied in the last 27 years.

Total harvested volume has increased in the last 30 years with values ranging from 12 mil m^3 to 18 mil m^3 (Fig.6). Coniferous species and beech have the main harvested ratio with an increasing trend in the last years. The other three groups of species (Oaks, Hardwood and Softwood species) maintain same ration of the total harvested volume every year.

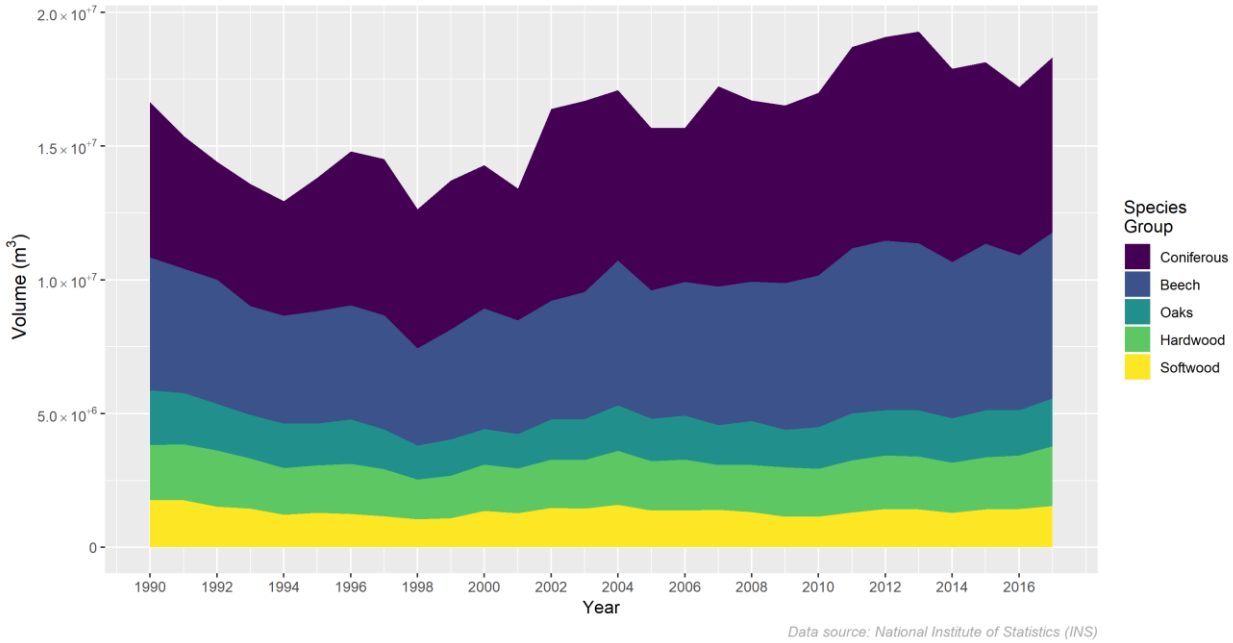


Fig.6. Volume harvested for groups of species in the last 27 years.

The forest area reported by forest districts each year as being affected by illegal logging is aggregated at the national level by the Ministry of Environment, Waters and Forest (MEWF) and included in the total harvest statistics (Table 3).

Table 3. Reported volume of illegal logging by the National Institute of Statistics.

Year	Total volume (m^3)	Vol. from state forest (m^3)	Vol. from private forest (m^3)	Vol. from outside Forest Fund (m^3)
2007	175743	3260	7157	41317
2008	174542	2957	12373	59263
2009	179475	5674	9362	34478
2010	189892	2696	9379	68403
2011	266220	5403	20185	98244
2012	331408	7052	7716	130853
2013	915100	-	-	-
2014	291900	-	-	-
2015	153400	-	-	-
2016	191400	-	-	-
2017	203800	-	-	-

If the methodological concerns on the elaboration of NFI 2008-2012 and IFN 2013-2018 are solved and/or there is any reliable source regarding illegal logging is available in the future, technical corrections will be applied to the accounting plan. The corrections would be funded on the availability of better data and Romania would even consider disaggregating harvest into illegal logging and the regular silvicultural harvest.

2.3.3 Description of future harvesting rates under different policy scenarios

Romania's harvest rate is based on the allowed annual cut of each management plan. The sum of each management plan annual cut value is registered at a national level and its adopted by law as the maximum harvest that is allowed in Romania's forests in that year. Forest management plan annual cut is based on yield regulation method by the increment indicator which takes into account the growth rates of the stands, the distribution of the stands on class ages, the number of stands that reached the harvesting age, the management objectives and other aspects.

The actual harvested volume every year has never reached the value of the allowed maximum cut. (Table 4). Romania annual harvest reached a maximum of 92% percent from the annual allowed cut.

Table 4. Total allowable harvest reported by the National Institute of Statistics.

Year	Actual felling (mil m^3)	Allowable Harvest (mil m^3)	Actual felling percentage from the total allowable cut %
2005	15.7	20.3	0.77
2006	15.7	22.3	0.70
2007	17.2	22.3	0.77
2008	16.7	18.1	0.92
2009	16.5	18.6	0.89
2010	16.9	19.7	0.86
2011	18.7	21	0.89
2012	19.0	21.1	0.90
2013	19.2	21.1	0.91
2014	17.8	22.1	0.81
2015	18.1	22.2	0.82
2016	17.2	22.0	0.78
2017	18.3	22.0	0.83

Romania has not considered building future scenarios as the method used in the management plans to set the level of harvest adapts to the state of the forest condition. The harvest intensity in Romania are based on long term research and introduced in the legal framework. Modifications in these regulations will have scientific basis. Currently there is no scientific concern regarding Romania's harvest intensity, periodicity and silvicultural practices. In this regard Romania has not considered future scenarios.

Chapter 3. Description of the modelling approach

3.1. Description of the general approach as applied for estimating the FRL

The modelling approach complies with the LULUCF Regulation and follows the Guidance on developing and reporting FRL in accordance with Regulation (EU) 2018/841. The information used in building FRL is in consistency with the Romania GHGI. The main data providers for building FRL based on forest structure, management practices and – intensities in managed forests in the reference period are the NFI, MEWF and the NIS.

Forest age structure, the available growing stock, the stocking level and the yield class for the reference period were reconstructed from 2008-2012 NFI data using a regressive model considering the NFI as the state of the forest in 2010. This inventory was assumed as the best available data on forest structure since the previous forest inventory, the 1984 NFI, did not gather information of the whole Romanian forest but only the one in the "Forest Fund" (forest included in the management plans) and the regulations and forest state have significant changes in the following 15 years, until the reference period.

The input data on harvest were obtained from the NFI and the MEWF. Harvest data were also stratified on the main species and group of species in Romania: Conifer, Beech, Oaks, Hardwood and Softwood. The same stratification was made by NFI department showing a consistency between the three data sources: NFI, NIS and MEWF. Data input of volume harvested and the surface covered by each silvicultural system applied in Romania in the reference period was stratified in the same manner.

NFI growth data were initially considered for forest growth but they were finally disregarded because of the following:

a) the modeling approach is not able to replicate official harvest records and Greenhouse gasses emissions using NFI growth (Fig. 7).

b) The NFI growth rate is unusually high - more than expected from the Romanian forest structure - and also there is an inconsistency with the last National Forest Fund 1984,

c) the growth according to NFI (approx. 58 million m^3/yr^{-1}) is around twice the growth from the last National Forest Fund (approx.33) and higher than the yield tables at full stocking values,

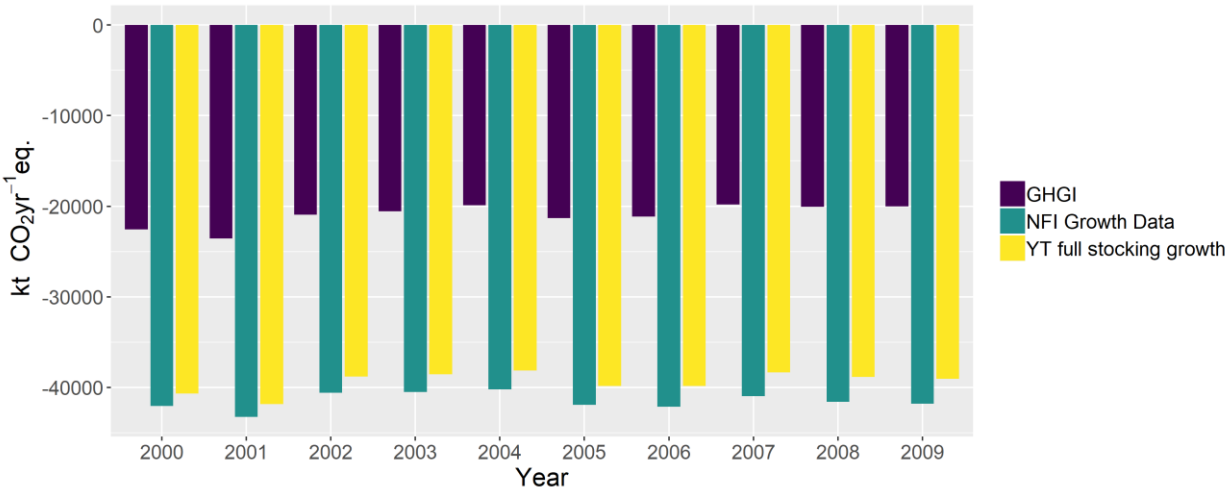


Fig. 7. CO_2 equivalent emissions as reported in the Greenhouse Inventory and emissions after the modelling approach using NFI growth data and the yield tables (YT) full stocking growth data.

d) the forestry sector in Romania holds an active discussion on the validity of NFI methodology and their results.

After the previous argumentation and to preserve data consistency regarding GHGI, yield tables (Giurgiu & Draghiciu, 2004) are considered the best available data at the moment and hence the forest growth (in volume per hectare) for each stratum, namely group species and yield class, was predicted using the functions under the official Romanian yield tables (Giurgiu & Draghiciu, 2004).

Thinning rates and sanitary felling rates were obtained based on the national regulations (Norma 3, 2000) which describes for each species the thinning intensity and periodicity. The established harvest rates take into account the available volume for harvest and also the national regulations (Norma 5, 2000) for each species and yield class.

Natural disturbances and illegal logging are taken into account at forest district level to correct harvested volume and forest stock. That means that both natural disturbances and illegal logging are considered together with regular forest management and legal logging statistics, and hence are actually taken into account in the modelling approach.

The model first reconstructs the forest structure during the reference period fitting the GHGI data by subtracting the annual growth and adding the harvested volume from the growing stock.

After finding the best fit the model saves the necessary information and simulates forest ageing and increment maintaining the same ratio of harvest as in the reference period.

The tools used for age dynamic simulation Python scripting language and R statistical software.

3.2. Documentation of data sources as applied for estimating the FRL

The main sources of information for building FRL (Table 5) are the NFI, MEWF and the NIS.

The Romanian NFI is designed as a continuous forest inventory (CFI), with a periodicity of the inventory cycle of five years. It is based on systematic sampling, combines repeated measurements on permanent plots with measurements on temporary plots and is a two-step NFI (forest assessments and measurements on orthophoto images and then on the field). NFI uniformly covers the entire territory of the country and is based on a 4 × 4 km network. The density of the network is higher in the plain area (2 × 2 km) due to the very low coverage with forest vegetation.

MEWF and the NIS gather information every year from each forest district through a questionnaire called “SILV”. This questionnaire is divided in four topics. “SILV I” refers to the surface and changes in surface of the forest fund which doesn’t cover the whole forest cover area. “SILV II” is accounting the financial status of each forest district. “SILV III” refers to harvested volume and surface covered by each silvicultural system. “SILV IV” is accounting the areas of each forest district covered by regeneration cuttings and the reforestation areas. Information for the previous year is submitted each year by the forest districts at latest on 13.02.

Table 5. Data sources used for describing forest characteristics in the developing of the FRL.

Forest characteristics	Data sources	Data sources Stratum ID where the characteristics and reference are relevant
MFL	GHG NIR 2019	All
Area of the species	NFI 2008-2012	All
Age structure	NFI 2008-2012	All
Species composition	NFI 2008-2012	All

Forest characteristics	Data sources	Data sources Stratum ID where the characteristics and reference are relevant
Growing stock	NFI 2008-2012	All
Harvest	MEWP, NIS	All
Stocking	NFI 2008-2012	All
Current annual increment	Yield tables	All
Aboveground biomass	NFI 2008-2012 data using a regressive model, IPCC 2006 GL	All
Belowground biomass	NFI 2008-2012 data using a regressive model, IPCC 2006 GL	All
HWP	GHG NIR 2019	All

The previous National Inventory Reports on greenhouse-gas emissions (NIR) had as data input the 1984 NFF inventory which was repeated over 25 years. Forest growth was estimated through the yield tables and added to the growing stock. NFI 2008-2012 came with new data regarding forest age structure which was used to build the FRL. In order to keep the consistency with the GHGI for the Reference Period (RP) the current annual increment for the FRL was computed using the same yield tables as the ones used at the time the GHGI was built.

There is an active discussion on IFN methodology and results and the accuracy of the other data providers. If new and more accurate data are available and if significant improvements to data sources are proven, technical corrections will be applied to the FRL projection.

3.2.1 Documentation of stratification of the managed forest land

The forested area of Romania is under the regulation of the National Forest Code (LAW no. 46 of 19.03.2008). According to the regulation, in Romania "*all the forests, the land for afforestation, auxiliary land used for cultivating purpose, production or forest administrative, ponds, river belts and other land for forestry purposes including non-productive ones, included in forestry managements plans on January 1, 1990"* is considered to be the National Forest Fund.

Area of the total forest vegetation in Romania (Table 6) is compose of:

1. Forest area of the national forest fund under forest management plans
2. Forest area outside the national forest fund

The definition of forest according to the forest code: art.2 align (1) *"terrains with area of at least 0.25 ha covered by trees; trees must have at least 5 m high at the maturity in normal conditions of vegetation".*

According to art.6 align. (1) "all the National Forest Fund is subject of the forest regime". The align. (2) of the same article states that the forest vegetation outside of the forest fund are also subject of forest technical norms on the evaluation of the stock, harvest and the regulation of the wood transport, and the volume of harvest is to be reported and accounted to the national amount of harvest.

The NFF area reported by the MEWF for the year 2009 is 6.495 million hectares from which 6.334 million hectares are covered by forest. The area reported by Romania in the GHGI from 2019 report for year 2009 is 6.6399 million hectares. (http://www.mmediu.ro/app/webroot/uploads/files/2016-12).

Table 6. The area of Managed Forest Land (MFL) used for building the FRL.

Area of managed forest land (mil ha)		
GHGI reported for year 2009 **6.6399**	Forest included into the National Forest Fund **6.334**
	Forest outside the National Forest Fund **0.3059**

The stratification of the Managed Forest Land (MFL) is based on consistency between the data sources and the GHGI from the reference period. The strata used refer to the main species and group of species in Romania, the productivity yield class of the species and FMPs (Forest Management Practices). The MFL was stratified into different 14 strata (Table 7).

MFL stratification on group species includes Conifers, Beech, Oaks, Hardwood broadleaves and Softwood broadleaves. There same classification is used by the NFI and the other two data providers. The species that are covered by each group species strata is presented in the table 8 below.

Table 7. The distribution of the FMP's for each stratum.

Stratification of the managed forest according to the associated management practices.							
Availability for wood supply	Main Group Species	Yield class	% distribution of forest management practices				
			FMP1	FMP2	FMP3	FMP4	TOTAL
Not protected	Conifers	1-5	58	32	10	-	100
	Beech	1-5	-	80	20	-	100
	Oaks	1-5	-	88	12	-	100
	Hardwoods	1-5	13	71	17	-	100
	Softwoods	1-5	62	19	19	-	100
Protected	All	All	-	-	-	100	100

Table 8. Species group stratification

ID	Species group	Tree species included
CO	Conifers	**Norway spruce** *(Picea abies L.),* **Silver fir** *(Abies alba Mill.),* **Scotch pine** *(Pinus sylvestris L.),* **Swiss stone pine** *(Pinus cembra L.)*, **Black pine** *(Pinus nigra Arn.),* **European larch** *(Larix decidua Mill.),* **Dwarf pine** *(Pinus mugo Turra),* **European yew** *(Taxus baccata L.),* **White pine** *(Pinus strobus L.),* **Douglas fir (Pseudotsuga menziesii Mirb.)**
BE	Beech	**European beech** *(Fagus sylvatica L.)*
OA	Oaks	**Common oak** *(Quercus robur L.),* **Sessile oak** *(Quercus petraea Liebl.)* **Turkey oak** *(Quercus cerris L.),* **Hungarian oak** *(Quercus frainetto Ten.),* **Pubescent oak (***Quercus pubescens)*
HB	Hardwood Broadleaves	**European hornbeam** *(Carpinus Betulus L.),* **Maple Sycamore** *(Acer pseudoplatanus L.),* **Norway maple** *(Acer platanoides L.),* **Field maple** *(Acer campestre L.),* **Common ash** *(Fraxinus excelsior L.),* **Narrow-leafed ash** *(Fraxinus angustifolia Vahl.),* **Manna ash** *(Fraxinus ornus L.),* **Common locust** *(Robinia pseudoacacia L.),* **Elm** *(Ulmus glabra Huds.),* **European white elm** *(Ulmus leavis Pall.),* **Field elm** *(Ulmus minor Mill.),* **Wild cherry** *(Prunus avium L.),* **Eastern black walnut** *(Juglans nigra L)*, **European wild pear** *(Pyrus pyraster L.),* **Horse-chestnut** *(Aesculus hippocastanum L.),* **Sweet chestnut** *(Castanea sativa Mill.)*, **Wild service tree** *(Sorbus torminalis L.),* **Rowan** (*Sorbus aucuparia L.)*

ID	Species group	Tree species included
SB	Softwood Broadleaves	**Silver Linden** *(Tilia tomentosa Moench.)*, **Linden Small-leaved** *(Tilia cordata Mill.),* **Large-leaved lime**, *(Tilia platyphyllos Scop.),* **Birch Silver** *(Betula pendula Roth*), **Downy birch** *(Betula pubescens Ehrh.),* **Poplar Black** *(Populus nigra L.)*, **White poplar** *(Populus alba L.),* **Grey *poplar*** *(Populus x casescens)*, **Aspen** *(Populus tremula L.),* **Hybrid poplars** *(Populus x Sacrau-79, Populus x Ro-16, Populus x I-214)*, **Crack willow** *(Salix fragilis L.),* **White willow** *(Salix alba L.), Salix sp.*

The area of MFL for the Reference period (RP) corresponds with the value submitted in 2019 NIR for the year 2009. The area in each group species strata (Table 9) was calculated from the NFI 2008-2012 plots and the same ratios were applied to the area of forest managed land from 2019 NIR. Each stratum was kept constant throughout the simulations for the FRL.

Table 9. Area (ha) by species group strata in the reference period.

Availability for wood supply	Main Group Species	Yield class	Area (ha)
Not protected	Conifers	1-5	1696377
	Beech	1-5	2023306
	Oaks	1-5	1067300
	Hardwoods	1-5	1310772
	Softwoods	1-5	420068
Protected	All	All	122081
Total			6639904

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

Forest in Romania is sustainable managed through forest management plans. Forest management plans follow the principles of sustainable management set in Rio de Janeiro in 1992 at the Rio de Janeiro Earth Summit. Forest management plans divided forest land in six intervention intensities based on the type of ecosystem service the forest land is providing. The yearly allowable cut is set with the regard of forest continuity, the dynamic of the growing stock and taking into account the ecosystem services forest provides. Forest silvicultural systems applied in Romania promote natural regeneration; the most common of them being shelterwood group system, selection cutting and conservation cuttings (Table 10). The afforestation and reforestation legislation framework (Norma 1, 2000) support the species

compositions according to the natural distribution of the species. They also promote mixed forest stands increasing the level of biodiversity in the forest ecosystems.

Table 10. The area of regeneration reported by the NIS for the RP.

Year	Total artificial regeneration(ha)	Artificial regeneration conifers(ha)	Artificial regeneration broadleaves(ha)	Natural regeneration
2000	12701	5865	6836	9869
2001	13539	6572	6967	10720
2002	16448	6714	9734	13561
2003	14772	4606	10166	10428
2004	14100	4449	9651	10356
2005	14389	5418	8971	12665
2006	15533	4970	10563	12020
2007	10716	4483	6233	12013
2008	11244	4374	6870	11934
2009	10962	4697	6265	11890

In the reference period with the respect to the mentioned above in Romania were applied the following four FMPs as described in the following tables (Tables 11 to 13). Table 11 indicate the main characteristics of the different FMP: how the regeneration is implemented, when thinning are applied and how final harvest is performed.

Table 11. Description of the FMP used for the estimation of the FRL.

Index	Silvicultural system	Group species	Regeneration	Thinning (years)	Harvest
FMP1	Clear cuts	Conifers Hardwood Softwood	Artificial regeneration	~10 – (0.75·$Harvest_{age}$)	Clear cuts (maximum 3 ha)
FMP2	Shelterwood 1 group system	Conifers Beech Oaks Hardwood Softwood	Natural regeneration	~10 – (0.75·$Harvest_{age}$)	The biomass is removed through 3 cuttings during 20 years span
FMP3	Shelterwood 2 group system	Conifers Beech Oaks Hardwood Softwood	Natural regeneration	-	The biomass is removed through continuous cuttings from all age classes
FMP4	Protection	Conifers			

Index	Silvicultural system	Group species	Regeneration	Thinning (years)	Harvest
		Beech	Natural regeneration	-	-
		Oaks			
		Hardwood			
		Softwood			

The period of application of different management operations, like thinning and final harvest, depend on the length of the exploitation cycles, which are function of the FMP and the production class. A generalization of the exploitation cycles used in Romanian forestry is reported in Table 12.

Table 12. Harvesting exploitation age for each FMP

Forest harvest starting age					
Index	**Harvest age by production class**				
	I	**II**	**III**	**IV**	**V**
FMP1	130	110	100	100	90
FMP2	140	120	110	110	90
FMP3	Continuous cutting				
FMP4	No-intervention				

Thinning and final felling are not restricted to the given age-class (20 year), as the data in the reference period shows a large variability in the timing of both thinning and final felling.

Table13. Quantitative description of the FMPs realized during the reference period in the Romanian forests

Forest management practice	Group species	Age class	Commercial thinning (% stock harvested)	Age class	Final cut (% stock harvested)
FMP1	Conifers	2-4	5.1	>5	21.5
	Hardwood	1-3	1.6	>3	1.3
	Softwood	1-3	18.2	>3	28.9
FMP2	Conifers	2-4	10.5	>5	9.7
	Beech	2-4	29.8	>5	31.4
	Oaks	2-4	15.7	>5	18.1
	Hardwood	2-4	10.8	>5	10.5
	Softwood	2-4	9.0	>5	8.6
FMP3	Conifers	4-9	3.0		
	Beech	4-9	6.7		
	Oaks	4-9	2.5		
	Hardwood	4-9	2.9		
	Softwood	4-9	9.0		
FMP4	All	-			

The ratios intensity of harvest are computed taking into account the probability of harvest given by the volume in the age classes and the harvest legislation applied in Romania.

3.3. Detailed description of the modelling framework as applied in the estimation of the FRL

The FRL is estimated based on a modeling algorithm build in Python programming language. The model simulates the ageing process of the forest, forest growth and harvest. The length of the time-step of the simulation is one year. The model output is the area, LB volume, harvested volume and DW for the different silvicultural systems applied and each species group, the overall HWP were also computed. Detailed information of the modelling framework for each of the modules is describe

Starting year of the FRL modeling approach

The starting year for the projection is 2010; the same year is used to reconstruct the forest structure and harvest ratio during the Reference period (RP) using the model backwards and meeting the consistency criteria of the FRL. As indicated in previous sections, this decision was taken because of the large time-gap between the two NFI's (1984 and 2010) and, because of the difference between methodologies, the NFI 2008-2010 data were considered the best available data as they reflect very accurately the forest structure for the RP.

In order to develop FRL "*on the continuation of the sustainable forest management practice, as documented in the period from 2000 to 2009*" data on the age structure within a stratum - FMP of the reference period is necessary. The best way to estimate for the reference period the forest structure on age classes was to construct backward the available growing stock, the stocking level and the yield class data using regressively the model from the 2010 NFI data.

To achieve this task the result (surface and volume according to age structure) from the NFI first cycle reported to a surface of 6 900 962,264 ha was reduced using the same ratios between forest characteristics to the value corresponding to the GHGI for the year 2009 (6 639 904 ha) reported in the last NIR 2019.

The intensity of the harvest according to FMP for the reference period was calculated and the average was used for the projection of the reference level for the compliance period.

Required data

In order to be able to simulate age related forest characteristics the inputs must be stratified in regard with their age. NFI 2008-2012 data was the main source for age related forest characteristics.

The following information and methods were used as input data and for building the model framework: a) NFI 2008-2012 growing stock (m^3), area (ha) and yield class for each species and for 9 age classes of 20 years were used to define forest state in 2010. b) Growth and volume per hectare of each group of species (Conifers, Beech, Oaks, Hardwood, Softwood), computed through weighted nonlinear regression for different species compositions, using yield data as input. c) Thinning and harvest ratios provided for each tree species and age class as percentage of the volume that must be thinned or harvest.

The data available of areas covered by silvicultural systems was used to determine the probability of harvest of each species group and silvicultural system (FMP). The regeneration is made based on the volume harvest from each silvicultural system applied during the Reference period 2000-2009.

Age structure module

The input data on 20 year-age classes is first split in 1- year age classes. The area is equally split for each age class while the growing stock data is proportionally split using as reference the volume per hectare from the yield tables (Fig. 8).

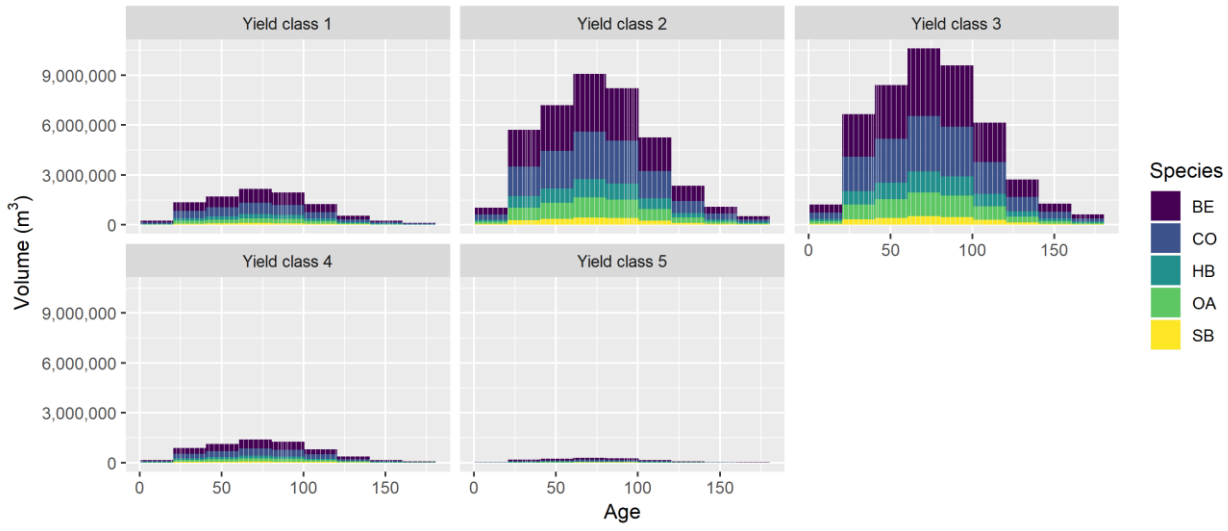


Fig. 4. Forest structure on 20 years equal classes.

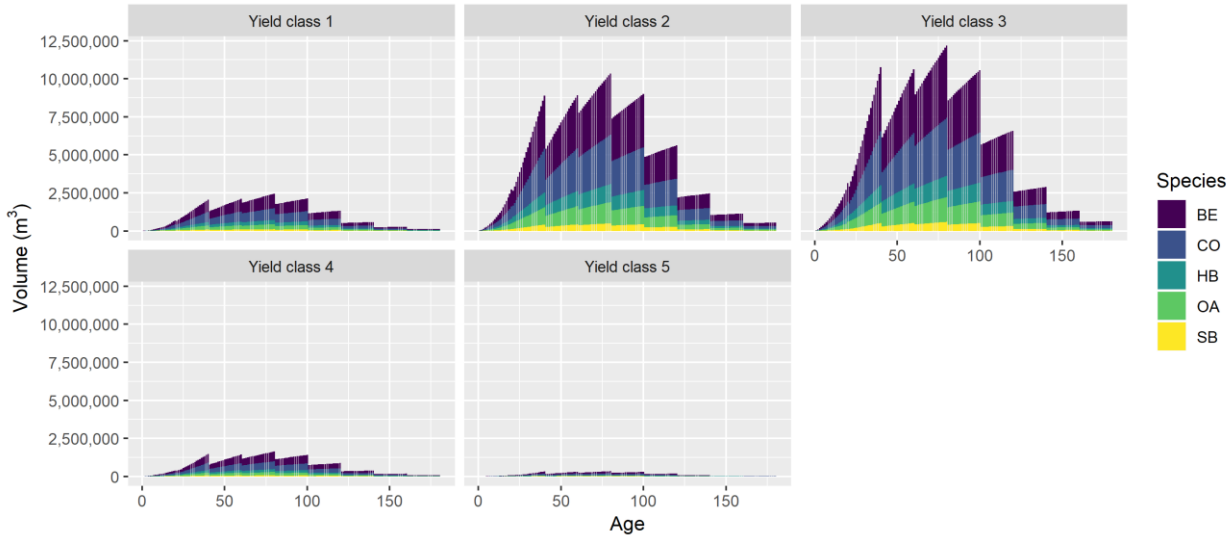


Fig. 8. Conversion to 1-year age classes according.

Growth module

The data source used for computing the annual growth of each species group are the yield tables. One of the several reasons for choosing this data source instead on the NFI data is the inconsistency of the data source with the criteria set out in Section A of Annex IV of Regulation: *"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 data source used in the Reference period (RP) for GHGI is the 1984 NFFI, whose values were rolled over the next 25 years. The mean volume per hectare and mean increment per hectare are strongly different than the values of the 2008-2012, NFI resulting in a higher sink during the RP.

Due to the lack of information of the species composition and their growth during the RP and also because of the stratification in species group used at the national level the Romanian yield tables were used to produce growth curves for each of the group species.

The Romanian yield tables (Giurgiu & Draghiciu, 2004) include 21 species with 5 yield classes each. Due to stratification in species group it was necessary to build group species models having as a reference the species included in each species group.

The species included in the species group to build the model of growth and increment of the stand are presented in Table 14. The Chapman-Richards growth equation was used to fit the data from the yield tables of each species. Using nonlinear weighted regression different species mixture where given inside to the species. The species mixture inside of each group species was chosen based on the best fit of the 2000-2009 GHGI data and between the limits of NFI statistics.

Table14. Species group stratification

ID	Species group	Tree species included in the model
CO	Conifers	**Norway spruce** *(Picea abies L.),* **Silver fir** *(Abies alba Mill.),* **Scotch pine** *(Pinus sylvestris L.),* **Black pine** *(Pinus nigra Arn.),* **European larch** *(Larix decidua Mill.),*
BE	Beech	**European beech** *(Fagus sylvatica L.)*
OA	Oaks	**Common oak** *(Quercus robur L.),* **Sessile oak** *(Quercus petraea Liebl.)* **Turkey oak** *(Quercus cerris L.),* **Hungarian oak** *(Quercus frainetto Ten.)*
HB	Hardwood Broadleaves	**European hornbeam** *(Carpinus Betulus L.),* **Common locust** *(Robinia pseudoacacia L.)*
SB	Softwood Broadleaves	**Silver Linden** *(Tilia tomentosa Moench.)* **Birch Silver** *(Betula pendula Roth*), **Poplar Black** *(Populus nigra L.)*, **White poplar** *(Populus alba L.),* **White willow** *(Salix alba L.)*

For each yield class a weighted nonlinear regression was used to fit the different growth curves of the species that are included in a certain group species. For example, the conifers group has five species in the yield tables (Fig. 9). Their growth curves were used to create a growth curve for conifers group using as weight different composition inside of the group species (Fig. 10).

The combination of species weights inside of each species group did not necessarily correspond with national statistics. Nevertheless, were excluded all the combinations where any of the species belonging to the group is absent.

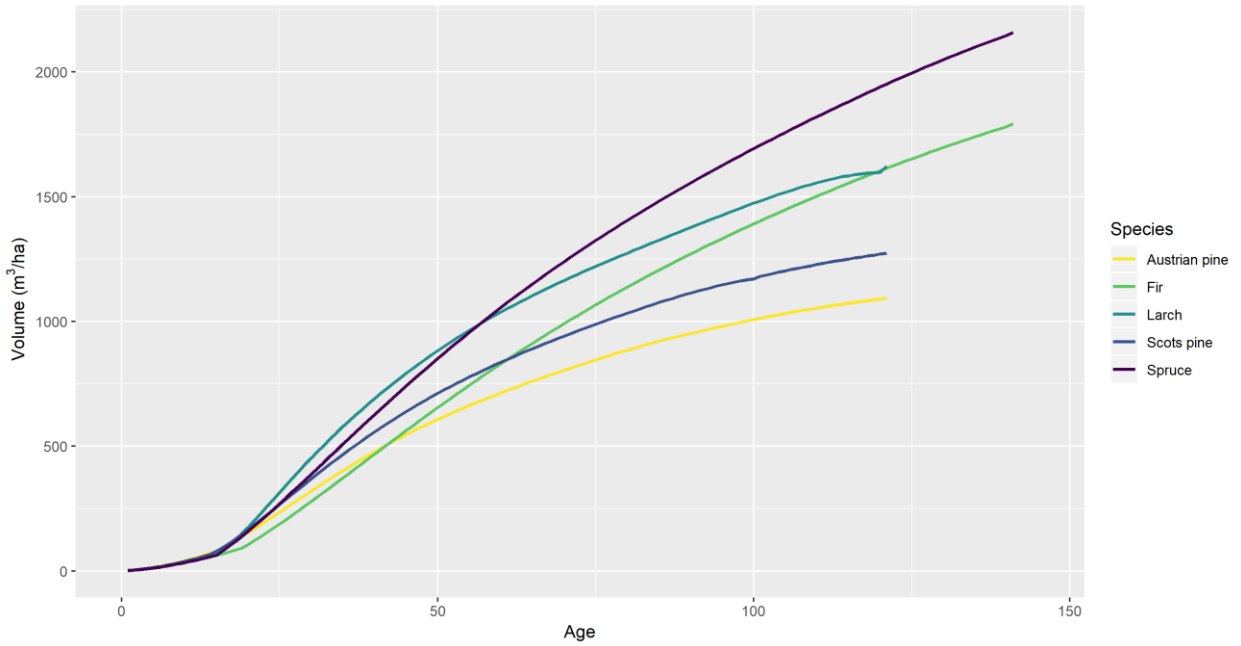


Fig. 9. The volume per hectare curves for the conifer group species according to the Romanian yield tables for the yield class I.

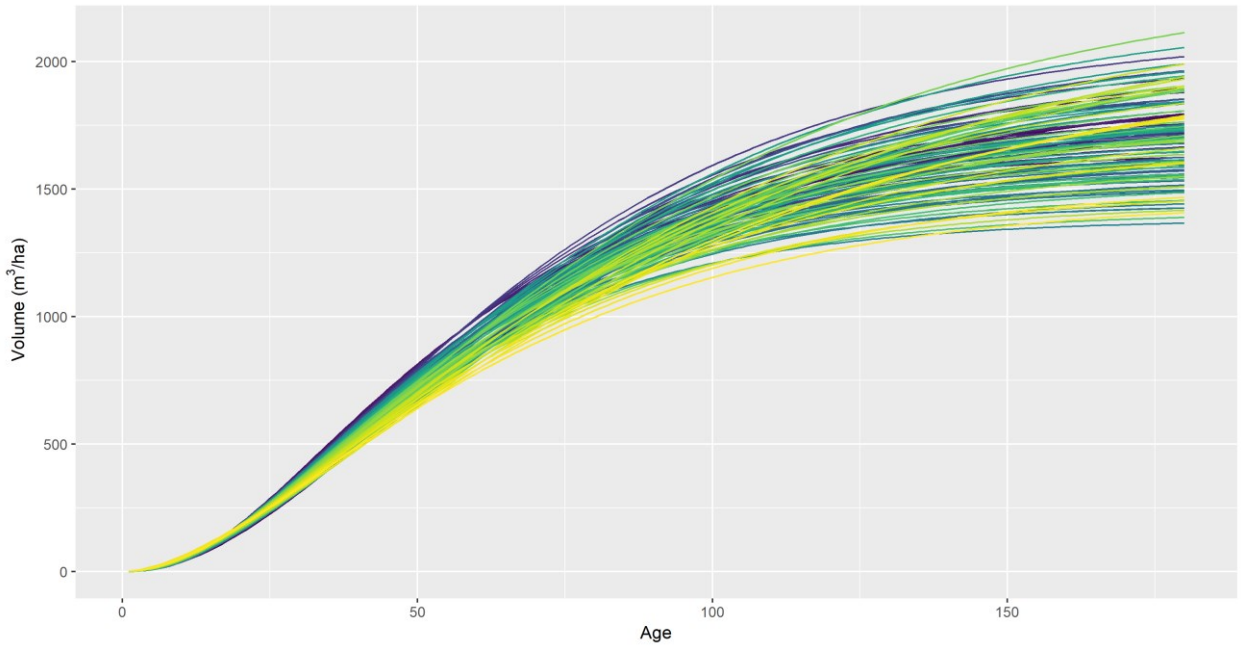


Fig. 10. The volume per hectare curves for the conifers group species for different mixtures. Each line represents an age volume curve at a different mixture between species. For example, the yellow curves define a bigger proportion of the Pines species and a lower one of spruce inside the conifers group growth. The green curves represent a higher proportion of the fir species in inside of the conifers group species. The dark blue line represents a higher a proportion of spruce inside of the conifers group species.

Using the derivate function of Richard-Chapman the current increment per hectare was computed for each of the species mixtures inside of the group species (Figure 11).

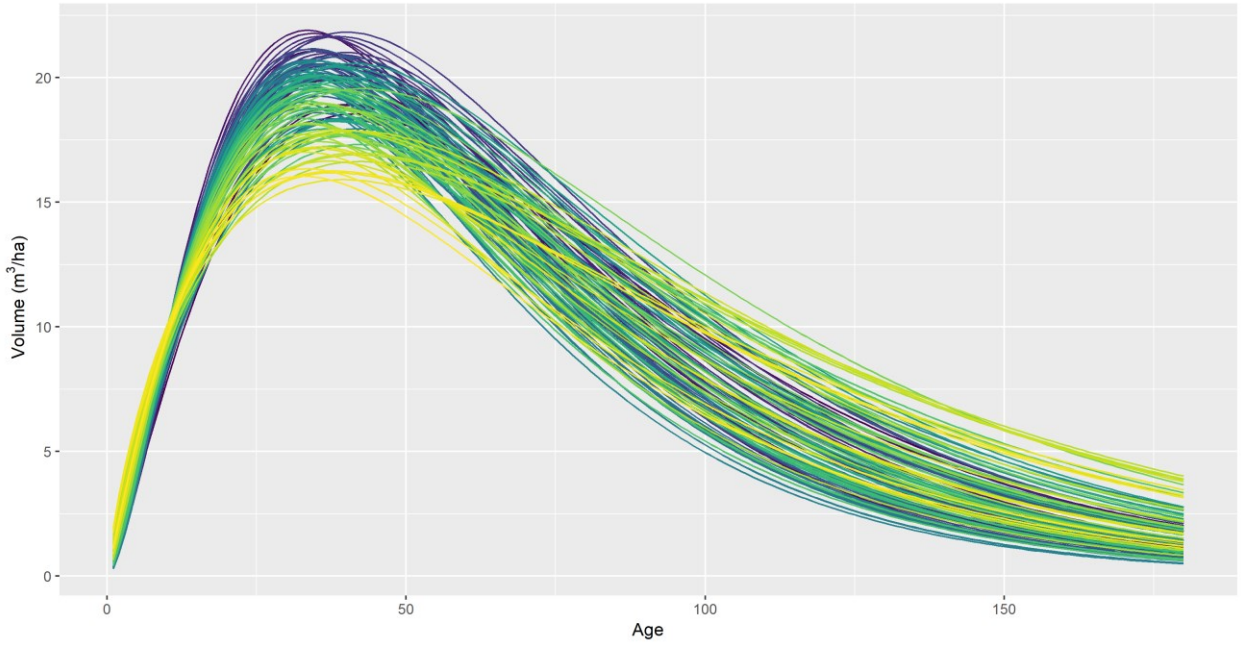


Fig. 11. The mean increment per hectare curves for the conifer species group for different mixtures. Each line represents an age increment curve at a different mixture between species. For example, the yellow curves define a bigger proportion of the Pines species and a lower one of spruce inside the conifers group growth. The green curves represent a higher proportion of the fir species in inside of the conifer species group. The dark blue line represents a higher a proportion of spruce inside of the conifer species group.

Knowing that the yield tables values are given for a full stocking (maximum density of trees and crown cover). The value of the increments computed as described above are reduced to the value of the stocking of each species group and age. The stocking level of each group species and age were measured by 2008-2012 NFI data and they are maintained constant during the simulations.

Harvest module

The harvest module calculates the harvest, thinning and sanitary feelings ratios of each species and silvicultural system as documented during the reference period. An average ratio of each type of harvest documented during the reference period, is computed and used to simulate the harvest for each group species. The equivalent area of the harvested volume of clear cuts and Shelterwood I silvicultural systems are transferred at each simulation step in the first class (youngest class). Shelterwood II silvicultural system includes the selection cutting and conservation cuttings which are continuous cuttings applied on multiple age classes. These

silvicultural systems don't necessarily create gaps in the forest cover needed for plant recruitment and no surface was moved to the first class.

Change in carbon stocks in Living Biomass (LB)

The carbon stock change in LB was estimated using a stock change method according to the equation 3.2.3 of the IPCC 2006 GL. This method requires biomass carbon stock inventories for a given forest area at two points in time. Biomass change is the difference between the biomass at time t_2 and time t_1, divided by the number of years between the inventories. First the belowground volume is estimated for the whole forest land by using Root-to-shoot ratios in Table 4.4 of IPCC 2006 GL (0.2 for conifers, 0.3 for Quercus species and 0.24 for other broadleaved species). Other species here include the strata for Romania Beech (BE), Hardwood broadleaves (HB) and Softwood broadleaves (SB), also in accordance with (Vande Walle et al., 2005) Biomass expansion factors (BEF2).

ANNUAL CHANGE IN CARBON STOCKS IN LIVING BIOMASS IN FOREST LAND REMAINING FOREST LAND (STOCK CHANGE METHOD)

equation 3.2.3 of the IPCC 2006 GL

$$\Delta CFF_{LB} = (C\ t_2 - C\ t_1) / (t_2 - t_1) \text{ and}$$

$$C = [V \bullet D \bullet BEF_2] \bullet (1 + R) \bullet CF$$

$\Delta C\ FF_{LB}$ = annual change in carbon stocks in Living Biomass (-LB-; includes above- and belowground biomass) in forest land remaining forest land, tonnes C yr^{-1}

$C\ t_2$ = total carbon in biomass calculated at time t_2, tonnes C

$C\ t_1$ = total carbon in biomass calculated at time t_1, tonnes C

V = merchantable volume, $m^3\ ha^{-1}$

D = basic wood density, tonnes d.m. m^{-3} merchantable volume

BEF_2 = biomass expansion factor for conversion of merchantable volume to aboveground tree biomass, dimensionless.

National values of wood density (D) for each group of species were taken from (Giurgiu et al., 2004) in order to convert merchantable volume to biomass.

Harvested Wood Products module

At every time-step of the simulation the harvested volume is disaggregated in fuelwood and three HWP products (Sawnwood, Wood panels and Paper and paperboard). For the purposes of FRL estimation, constant ratios of sawn wood, wood-based panels and paper to final harvest

were calculated as an average from the reference period and applied to the Projection period (PP) 2010-2025, for which harvested volume was simulated. Both internal and export production are taken into account for projecting FRL starting with 1990 HWP FAO official statistics. To the energetic use of wood (fuelwood) an instantaneous oxidation is applied (Table 15). The HWP are subjected to the first-order decay function for the calculation of the carbon pool, following (Forsell et al., 2018). HWP have clearly differentiated half-life. Their half-life values were set after table 2.8.2 in IPCC 2013 GL for KP as 35 years for Sawnwood, 25 years for Wood panels and 2 years for Paper and paperboard.

Carbon pool balance in HWP was converted to net CO_2 emissions to be integrated in the overall emissions framework.

Table 15. Harvest by energy and non-energy usage in the reference period

Year	Total harvest (m^3)	Energy Production (m^3)	HWP Production (m^3)	Energy Production ratio	HWP Production Ratio
2000	14284700	7652400	6632300	0.536	0.464
2001	13410300	7253200	6157100	0.541	0.459
2002	16383100	8915200	7467900	0.544	0.456
2003	16691500	7896080	8795420	0.473	0.527
2004	17082100	7332100	9750000	0.429	0.571
2005	15671300	6824055	8847245	0.435	0.565
2006	15684000	6995690	8688310	0.446	0.554
2007	17237600	7841400	9396200	0.455	0.545
2008	16704600	7651438	9053162	0.458	0.542
2009	16519900	6846591	9673309	0.414	0.586
Average	**15966910**	**7520815**	**8446095**	**0.473**	**0.527**

Deadwood (DW)

DW data was not reported or available during the Reference period (RP) even so, NFI 2008-2012 and NF1 2013-2018 on dead wood were used to build the reference period stock. The DW stock shows a significant change between the 2 inventories as presented in Table 16.

Table 16. Dead Wood stock volume (DW)

Conifers					
DW on the ground stock (m^3)			DW standing stock (m^3)		
2008-2012	2013-2018	Stock Difference	2008-2012	2013-2018	Stock Difference
32105840	28177737	-3928103	26180995	33424997	7244002

Broadleaves					
DW on the ground stock (m^3)			DW standing stock (m^3)		
2008-2012	2013-2018	Stock Difference	2008-2012	2013-2018	Stock Difference
36199710	35795374	-404336	27365959	40802903	13436944

The DW stock was reconstructed for the refence period, using a mean ratio (Table 17) between the DW and the growing stock as reported by NFI.

Table 17. Dead wood ratio used to build the deadwood stock

Group species	DW standing (%) with respect to the growing stock	DW on the ground (%) with respect to the growing stock
Conifers	0.042	0.041
Broadleaves	0.023	0.022

The stock change method was used to compute the annual change in DW stock Eq. 3.2.12 from IPCC. The DW categories were converted from volume to biomass using the coefficients for DW standing density and DW on the ground density in Přívětivý et al. (2017). The default IPCC 2006 value for C content in biomass was used to computed the C stock.

Calibration

The aim of the calibration was to adjust simulation process to reproduce GHG inventory as accurately as possible. This phase is applied to check if the entire time series of estimates (i.e. historical estimates and projected estimates) is consistent and where inconsistencies are found, to adjust the projected estimates.

When reconstructing the reference period, the model was able to reproduce the trend being consistent with the historical estimates but over estimating the removals for the entire period. (Fig. 12).

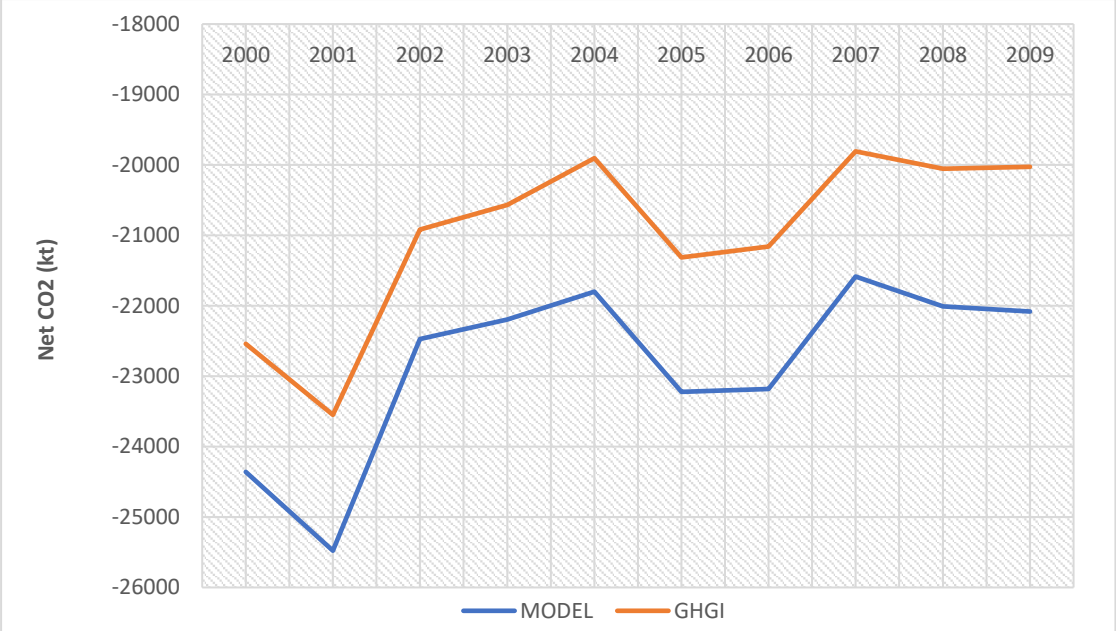


Fig. 12. Net CO2 emissions for the reference period according to GHGI and the modelling approach before calibration.

An adjustment ratio of the projected estimates was calculated by comparing the overlap between the annual estimates and produce a correction factor to be applied to the increment (Table 18, Fig. 13)

Table 18. Calibration ratio applied as multiples to increments

Year	**MODEL Net CO_2 (kt)**	**GHGI Net CO2 (kt)**	**Inventory/Model** (Calibration ratio)
2000	-24360.422	-22543.017	0.925
2001	-25477.429	-23548.403	0.924
2002	-22474.206	-20918.468	0.931
2003	-22193.914	-20569.435	0.927
2004	-21798.423	-19903.330	0.913
2005	-23222.603	-21313.799	0.918
2006	-23181.362	-21159.537	0.913
2007	-21585.109	-19807.912	0.918
2008	-22009.964	-20052.610	0.911
2009	-22083.618	-20025.673	0.907

The calibrated model was used to project FRL for the compliance period.

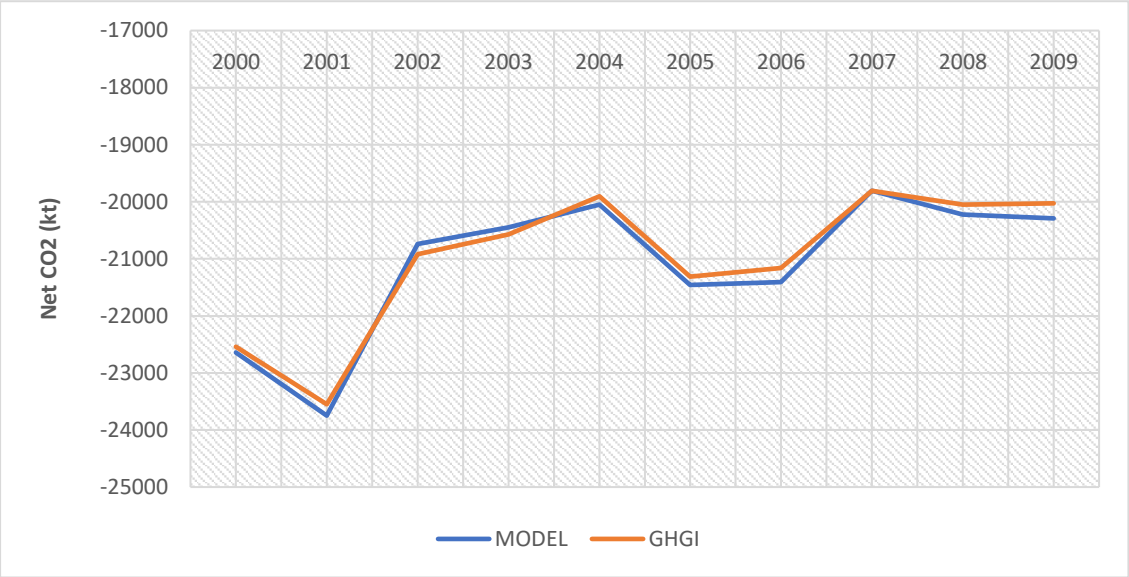


Fig. 13. Net CO2 emissions for the reference period according to GHGI and the modelling approach before calibration

Chapter 4. Forest Reference Level

4.1. Detailed description of the development of the carbon pools

4.1.1 Living Biomass (aboveground and belowground)

The size of the C stock in LB for the Projected period (PP) was set around 667841.6 kt C retained in 2084641316 above and belowground m^3. Notwithstanding the small decline in the sink strength in the second half of the PP, the C stock in LB will be a very significant C sink, accounting for 21637.3 kt of CO2 equivalents. The annual overall stock and net stock change in the carbon pool of LB projected by the model is shown in table 19.

Table 19. Annual stock and net stock change in the carbon pool of LB projected by the FRL model

Year	Growing stock (Volume m^3)	Growing stock (kt C)	Net change (kt C)	Net change (kt CO2 eq.)
2009	1929565278	617500.2	5597.7	-20510.9
2010	1946775647	623097.9	5894.9	-21599.9
2011	1964920503	628992.7	5950.4	-21803.4
2012	1983244408	634943.1	5986.5	-21935.7
2013	2001685752	640929.6	6009.5	-22019.9
2014	2020202769	646939.1	6021.9	-22065.2
2015	2038761574	652961.0	6025.0	-22076.9
2016	2057332847	658986.0	6020.0	-22058.4
2017	2075890363	665006.0	6007.5	-22012.7
2018	2094410435	671013.6	5988.2	-21941.8
2019	2112871209	677001.7	5962.4	-21847.2
2020	2131252116	682964.1	5930.4	-21730.1
2021	2149533752	688894.5	5882.0	-21552.6
2022	2167664841	694776.5	5822.0	-21333.0
2023	2185609117	700598.5	5749.5	-21067.4
2024	2203326926	706348.0	5664.5	-20755.7
2025	2220778789	712012.5	5566.4	-20396.5

FRL excluding HWP and assuming instantaneous oxidation is -21021 kt CO2 (Fig. 14).

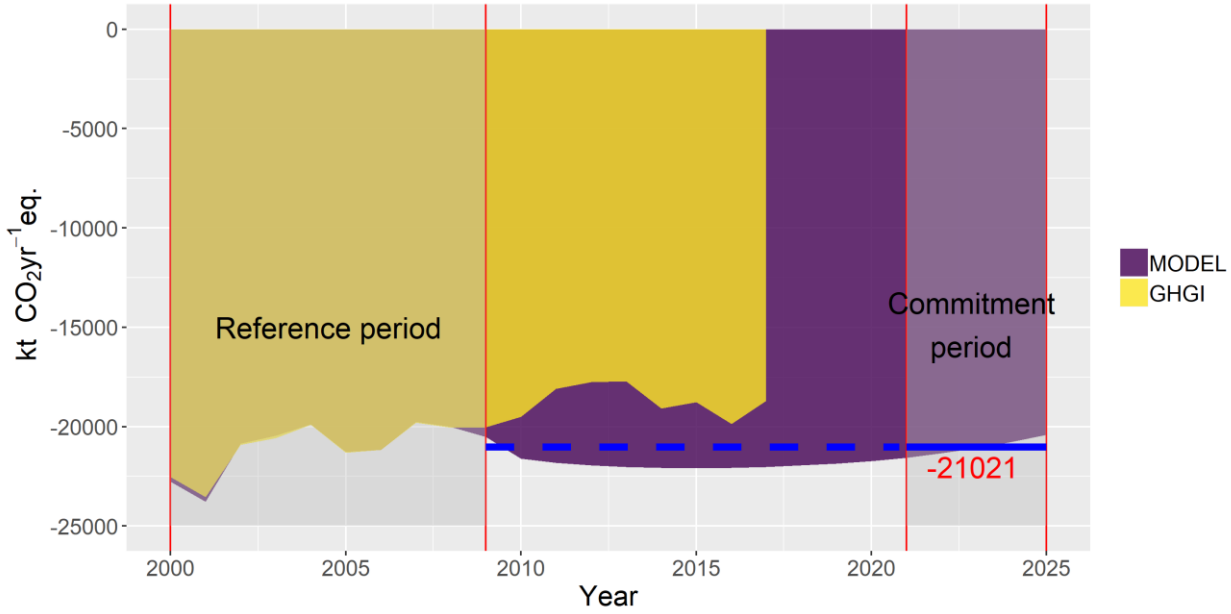


Fig. 14. FRL excluding HWP and projection for the Commitment period, measured as CO_2 equivalent emission assuming instantaneous oxidation.

4.1.2 Harvested Wood Products (HWP)

HWP products account for removals between -3328 and -2574 CO_2 during the projection period. Projected values in Table 20 and Fig. 15 show that HWP will contribute to the forest carbon sequestration until the end of the commitment period 2021-2025, retaining around 2592.6 annual kt of CO_2 equivalent.

Table 20. HWP stock emission in CO_2 equivalents FRL projection

Year	HWP CO_2 (kt)	Year	HWP CO_2 (kt)
2010	-3328.3	2018	-2674.7
2011	-3180.1	2019	-2634.5
2012	-3066.0	2020	-2598.4
2013	-2972.9	2021	-2581.2
2014	-2894.9	2022	-2574.9
2015	-2828.2	2023	-2580.7
2016	-2770.5	2024	-2598.4
2017	-2719.7	2025	-2627.9

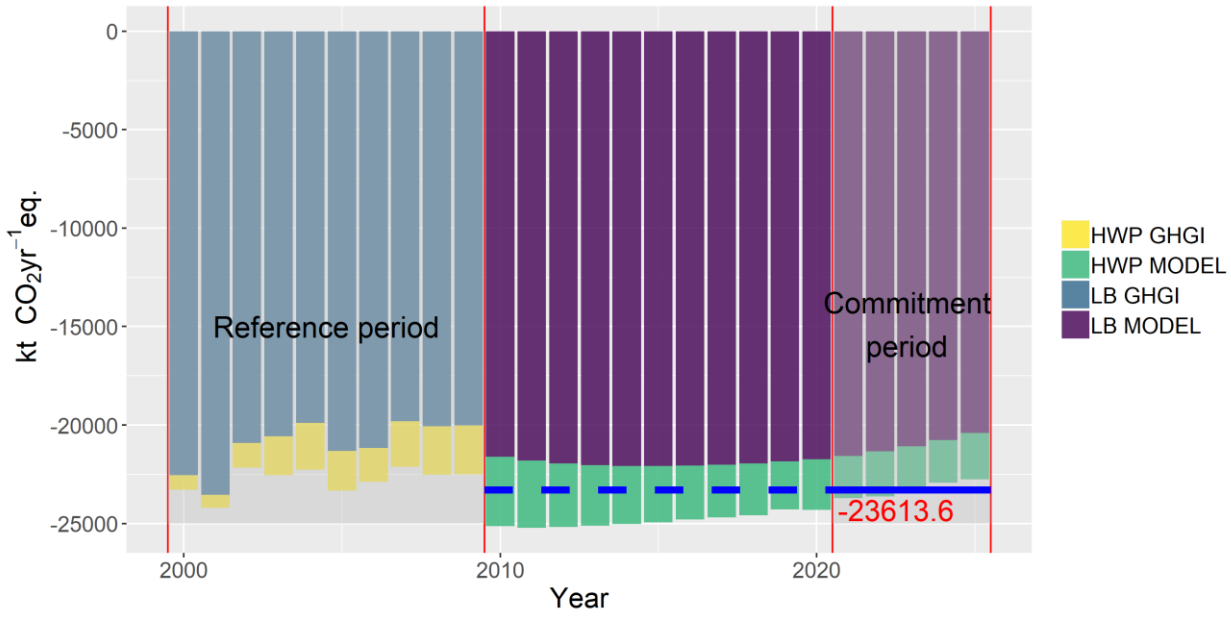


Fig. 15. FRL including HWP and projection for the Commitment period, measured as CO_2 equivalent applying first order decay function and half-life values.

FRL including HWP for Romania in the period 2021 – 2025 C sequestration is around -23613.6 kt CO2.

4.1.2 Deadwood

The removals projected by the DW pool during the commitment period is around -454.6 CO2 (kt) per year (Tables 21).

Table 21. Projection in CO_2 equivalent emission from the DW carbon stock.

Year	Growing stock m^3	DW C (tones)	DW C net change (tones)	DW CO2 (kt)
2010	1946775647	13199353	127290.8	-466.4
2011	1964920503	13326644	128530.3	-471.0
2012	1983244408	13455174	129354.2	-474.0
2013	2001685752	13584529	129886.4	-475.9
2014	2020202769	13714415	130177.8	-477.0
2015	2038761574	13844593	130259.1	-477.3
2016	2057332847	13974852	130151.6	-476.9
2017	2075890363	14105004	129873.4	-475.9
2018	2094410435	14234877	129437.4	-474.3
2019	2112871209	14364314	128852.5	-472.1
2020	2131252116	14493167	128127.1	-469.5
2021	2149533752	14621294	127153.6	-465.9
2022	2167664841	14748448	125908.8	-461.4
2023	2185609117	14874356	124364.0	-455.7

Year	Growing stock m^3	DW C (tones)	DW C net change (tones)	DW CO2 (kt)
2024	2203326926	14998720	122524.0	-449.0
2025	2220778789	15121244	120387.4	-441.1

4.2. Consistency between the carbon pools and the latest national inventory report

The model used to construct the FRL was able to reproduce historical data from the GHGI. This ability was demonstrated in the Chapter 3.3, part Model calibration.

The model does not reproduce the last GHGI after the reference period because of the strong increase in the harvest applied in Romania (Fig.16). The reason behind the increase in harvest after 2010 is the improvement of harvest technology and the increase of demand on the wood market.

Due to this changes the annual feeling reached 91% percent of the annual allowed cut while during the reference period the annual feeling reached values of approx. 80% from the annual allowed cut.

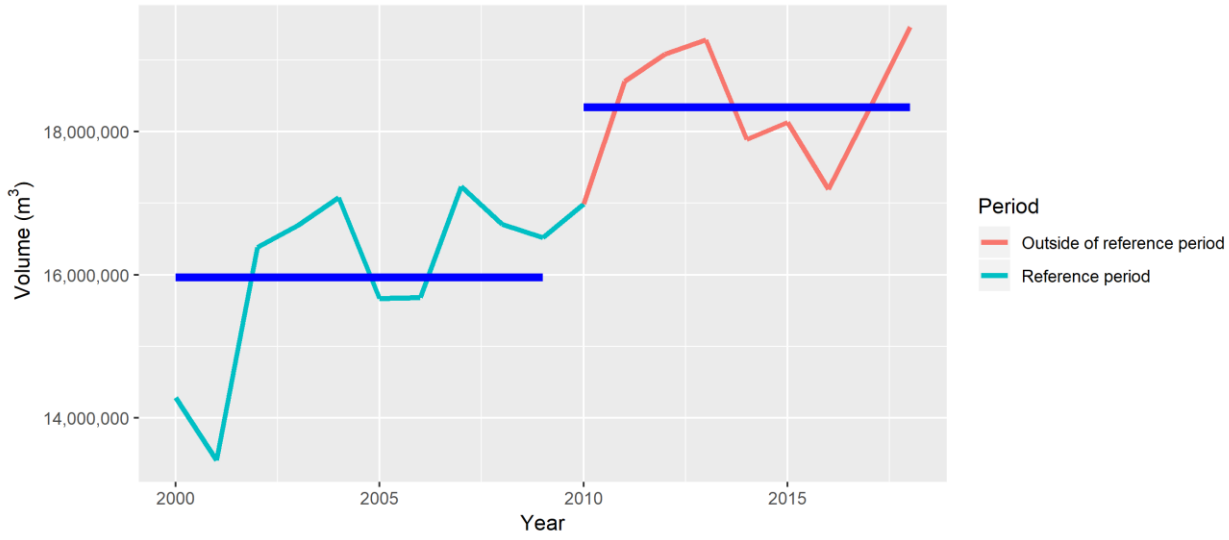


Fig. 16. Romania forest harvest, the two blue lines represent the mean value of the harvest during the reference period (2000-2009) and outside of the reference period (2010-2018)

4.3. FRL

Based on the simulations of the forest development and application of the carbon estimation approaches applied in the national inventory report, the reference level for the first commitment period 2021-2025 is summarized as illustrated in Table 22.

Table 21. FRL summary

Removals	Kt CO_2 eq.	FRL without HWP kt CO_2 eq.	FRL with HWP kt CO_2 eq.
LB	-21 021	21 475.6	24 068.2
DW	-2 592.6		
HWP	-454.6		

References

Brown, M.L., Canham, C.D., Murphy, L., Donovan, T.M., 2018. Timber harvest as the predominant disturbance regime in northeastern U.S. forests: effects of harvest intensification. Ecosphere 9, e02062. https://doi.org/10.1002/ecs2.2062

Curtis, P.S., Gough, C.M., 2018. Forest aging, disturbance and the carbon cycle. New Phytol. 219, 1188–1193. https://doi.org/10.1111/nph.15227

Deng, L., Zhu, G., Tang, Z., Shangguan, Z., 2016. Global patterns of the effects of land-use changes on soil carbon stocks. Glob. Ecol. Conserv. 5, 127–138. https://doi.org/10.1016/j.gecco.2015.12.004

Dinca, L., Spârchez, G., Dinca, M., Blujdea, V., 2012. Organic Carbon Concentrations and Stocks in Romanian Mineral Forest Soils. Ann. For. Res. 55, 229–241.

Forsell, N., Dore, C., Sánchez Jiménez, B., Rüter, S., Rincón Cristóbal, J.J., Gusti, M., Federici, S., Korosuo, A., Gardiner, J., Brajterman, O., European Commission, Climate Action DG, ICF, International Institute for Applied Systems Analysis (IIASA), Aether, 2018. Guidance on developing and reporting Forest Reference Levels in accordance with Regulation (EU) 2018/841.

Giurgiu, V., Decei, I., Drăghiciu, D., 2004. Metode şi tabele dendrometrice. Ed. Ceres.

IPCC, 2019. 2019 Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Switzerland.

Krueger, I., Schulz, C., Borken, W., 2017. Stocks and dynamics of soil organic carbon and coarse woody debris in three managed and unmanaged temperate forests. Eur. J. For. Res. 136, 123–137. https://doi.org/10.1007/s10342-016-1013-4

Levers, C., Verkerk, P.J., Müller, D., Verburg, P.H., Butsic, V., Leitão, P.J., Lindner, M., Kuemmerle, T., 2014. Drivers of forest harvesting intensity patterns in Europe. For. Ecol. Manag. 315, 160–172. https://doi.org/10.1016/j.foreco.2013.12.030

Lewandrowski, J., Kim, C.S., Aillery, M., 2014. Carbon sequestration through afforestation under uncertainty. For. Policy Econ. 38, 90–96. https://doi.org/10.1016/j.forpol.2013.06.014

Marinescu, E., Marinescu, I.E., Vlăduţ, A., Marinescu, S., 2013. Forest Cover Change in the Parâng-Cindrel Mountains of the Southern Carpathians, Romania, in: Kozak, J., Ostapowicz, K., Bytnerowicz, A., Wyżga, B. (Eds.), The Carpathians: Integrating Nature and Society Towards Sustainability. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 225–238. https://doi.org/10.1007/978-3-642-12725-0_17

Nita, M.D., Munteanu, C., Gutman, G., Abrudan, I.V., Radeloff, V.C., 2018. Widespread forest cutting in the aftermath of World War II captured by broad-scale historical Corona spy satellite photography. Remote Sens. Environ. 204, 322–332. https://doi.org/10.1016/j.rse.2017.10.021

Olofsson, P., Kuemmerle, T., Griffiths, P., Knorn, J., Baccini, A., Gancz, V., Blujdea, V., Houghton, R.A., Abrudan, I.V., Woodcock, C.E., 2011. Carbon implications of forest restitution in post-socialist Romania. Environ. Res. Lett. 6, 045202. https://doi.org/10.1088/1748-9326/6/4/045202

Schulp, C.J.E., Nabuurs, G.-J., Verburg, P.H., 2008. Future carbon sequestration in Europe—Effects of land use change. Agric. Ecosyst. Environ. 127, 251–264. https://doi.org/10.1016/j.agee.2008.04.010

Turcu, D.O., Oliver, M., Cântar, I., Nicolae, C., 2013. Research on litter and humus amounts in a beech natural forest 17, 181–184.

Vande Walle, I., Van Camp, N., Perrin, D., Lemeur, R., Verheyen, K., Van Wesemael, B., Laitat, E., 2005. Growing stock-based assessment of the carbon stock in the Belgian forest biomass. Ann. For. Sci. 62, 853–864. https://doi.org/10.1051/forest:2005076