Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2021 (GHGI 1990–2019)

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Summary

Switzerland prepares annually a greenhouse gas inventory for reporting under the climate convention UNFCCC and the Kyoto Protocol (KP). The Land Use, Land-Use Change and Forestry (LULUCF) sector of the Swiss inventory includes, inter alia, data for the forest sector, encompassing amongst others C stocks and C stock changes in above- and belowground biomass, dead organic matter, and soil. For the last two Swiss National Inventory Reports 2019 and 2020, C stocks and C stock changes due to gains and losses on Forest land for the years 2006 to 2017 and 2018, respectively, were calculated based on data from the National Forest Inventories NFI3 and NFI4 for common sample plots of the NFI4 subset 2013-2017. For the Swiss NIR submission 2021, data from the NFI5 that started in 2018 were available for calculating C stocks and C stock changes for the years 2006 to 2019. The estimates for the NIR 2021 were thus updated using data from sample plots common to NFI3 and NFI4 based on plots visited in the years 2015 to 2017, as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019. Hence, the number of available sample plots for calculating C stocks and C stock changes remained approximately the same with 3211 plots for the NIRs 2019 and 2020, and 3221 plots for the NIR 2021, respectively, with each corresponding to five years of data sampling.

The estimated mean national C stock in above- and belowground tree biomass was 123.664 ±2.676 (2SE) t C ha^{-1}. C gains and losses resulting from tree biomass growth and drain were 3.023 ±0.080 t C ha^{-1} and -2.501 ±0.171 t C ha^{-1}, respectively. These estimates correspond to a net change of 0.522 ±0.189 t C ha^{--1}. Compared to the estimates used for the previous two NIR submission, the values for C stock are statistically not different with a decrease of 0.045 t C ha^{-1}, ie. well within the margins of error of 2.676 t C ha^{-1}. The differences in gains and losses were in relative terms larger but also within the margin of 2 standard errors, ie. a slight increase in gains of 0.069 t C ha^{--1} (2SE for growth: 0.08 t C ha^{-1} in the current submission) and a slight increase in losses of 0.146 t C ha^{-1} (2SE for drain: 0.171 t C ha^{-1} in the current submission). The differences can be attributed primarily to the updated NFI data, which represent the temporary peaking of national harvest in 2018 in response to the storm Burglind.

Table of Contents

Glossary

The terminology used in this report follows the definitions listed in Annex 4A.1 in Volume 4 of IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2006); country-specific modifications noted where applicable.

basic wood density: Ratio between oven dry mass and fresh stem-wood volume without bark.

bcef[1]: multiplication factor that converts stemwood volume over bark to above-ground biomass.

carbon (C) fraction: Tonnes of carbon per tonne of biomass dry matter.

dbh: diameter at breast height

state and change components in biomass:

- growing stock: total biomass of all living trees > 12 cm dbh estimated for a particular forest inventory.
- growth: gross increase in total biomass of all trees trees > 12 cm dbh between two forest inventories; attributed to C gains and marked with a positive (+) sign.
- drain: decrease in total biomass due to cut (harvest) [2] and natural mortality of trees trees > 12 cm dbh between two forest inventories; attributed to C losses and marked with a negative (-) sign.

total tree biomass: incl above-ground and below-ground elements of trees ≥ 12 cm dbh.

- above-ground: all biomass of trees above the soil including stems, stumps, branches, bark, seeds, and foliage;
- below-ground: all biomass of live roots > 5 mm diameter

[1] country-specific modification: applies to stemwood volume over bark

[2] corresponds to removals defined for the context of forest land in Annex 4A.1 in Volume 4 of IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC 2006).

1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto-Protocol are international treaties to reduce greenhouse gas (GHG) emissions. As a signature state, Switzerland is required to maintain a comprehensive GHG inventory, including emissions and removals from Land Use, Land-Use Change and Forestry (LULUCF). In the first commitment period (2008-2012), Switzerland elected to account for Forest management under Article 3.4. of the Kyoto Protocol; in the second commitment period, the accounting of Forest management under the Kyoto Protocol is mandatory for all parties. Thus, C stock changes in above- and belowground biomass, dead organic matter, and soil have to be reported in Switzerland's National Inventory Report (NIR).

The Swiss National Forest Inventory (NFI) is the primary source of data for estimating the C balance of Swiss forests. The NFI provides data since 1984 collected in different measurement campaigns. Sections 2.1 and 2.2 of this report provide background information on the NFI data. Sections 2.3 to 2.5 document the methodology to obtain estimates on C stocks, gains, and losses from the NFI data that are used for reporting CO_2 emissions and removals in the Forest Land category in the LUUCF sector of Switzerland's NIR 2021 (1990-2019). The estimates for the NIR 2021 are based on updated NFI data representing the most current forest dynamics. Section 2.6 presents the approach to ensure time series consistency and accuracy. Changes in methods and input data are documented in section 2.7. Section 3 of the report presents the estimates obtained from the NFI data and a discussion of the changes in the results compared to the estimates prepared for the NIR submission 2020 (FOEN 2020).

1.1 TCCCA criteria and verification: specific information for UNCFFF/KP

Consistent with good practice outlined in Volumes 1 and 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, the section 2.6 of this report addresses the criteria for transparency, consistency, comparability, completeness and accuracy (TCCCA):

Transparency is achieved by documenting data sources, assumptions and methodologies that were used, including relevant references. The methodology is described in detail to ensure that results can be reproduced. Consistent with decisions 6/CMP.9 and 24/CP.19, the methodology was ensured to be consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) and also with the "Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" (IPCC 2014). Transparency is further ensured by applying the terminology of the IPCC 2006 guidelines.

Consistency is obtained by relying on data sources and methodologies of the Swiss National Forest Inventory that are maintained in a consistent manner and that will be available in the future as regulated by law. It was ensured that the methods were applied consistently, including data per unit area which are independent of temporal changes in the underlying forest area.

Comparability is achieved by estimating carbon stocks and stock changes based on methodologies and formats agreed by the COP and following the inventory guidelines.

Completeness is achieved by addressing all changes in forest carbon stocks due to growth and drain and by including all tree elements associated with above- and belowground C pools. Full geographical coverage was ensured by relying on data from the Swiss National Forest Inventory, which provides a representative random sample for the forest regions in Switzerland.

Accuracy is achieved by applying good practice inventory methodologies based on up to-date scientific knowledge, and on country-specific estimates where possible.

2 Data and Methods

2.1 National Forest Inventory

The Swiss National Forest Inventory (NFI) is the primary source for estimating the C balance of Swiss forests. The inventory is based on permanent sample plots that are revisited in each sampling campaign (Table 1). On each plot living and dead, standing and lying trees and certain shrubs according to a given species list with a diameter at breast height (dbh) > 12 cm (tally trees) are measured in detail (Lanz et al. 2019) providing representative data for further estimation of volume and biomass, among other attributes. The Swiss NFI is now in its 5th cycle. Results of the four completed NFIs are described in EAFV/BFL (1988; NFI1), Brassel and Brändli (1999; NFI2), Brändli (2010; NFI3), and Brändli et al. (2020; NFI4). The inventories NFI1, NFI2 and NFI3 were based on full surveys that were completed within 2 to 3 years and carried out in intervals of approximately 10 years. Since the fourth inventory, which started in 2009, a continuous survey over 9 years is conducted where annually a nationally representative subsample of approximately 12% of the Swiss forests is surveyed and evaluated. Otherwise, the methods to measure data in the field remained identical to the NFI3, including the estimation of total tree biomass, which is based on tree species-specific

- volume estimates of stemwood and branches based on allometries to tree dbh and conversion to biomass using basic wood densities; and
- biomass estimates of foliage and coarse roots based on allometries to tree dbh.

Allometries and wood densities were developed using country-specific estimates where possible. Table 2 summarizes the methods to estimate tree volume and biomass. A detailed description of the current methods to estimate volume, biomass, and carbon based on the NFI data can be found in Herold et al. (2019) and Didion et al. (2019).

The estimates of biomass growing stock, growth, and drain that are used for reporting gains and losses in the Swiss NIR are based on sample plots that are classified as accessible forest but not shrub forest (*gemeinsam zugänglicher Wald ohne Gebüschwald*) following the definition of "productive forest" in Switzerland's GHGI (Combination Category 12, cf. Tab. 6-2 in FOEN 2020).

Table 1. Number of surveyed sample plots and trees in the National Forest Inventories NFI1, NFI2, NFI3, NFI4, and NFI5 (first two years 2018-2019) for accessible forest plots without brush forest; note the NFI5 is carried out in the years 2018 to 2026.

	NFI1	NFI2	NFI3	NFI4	NFI5
Inventory cycle	1983-1985	1993-1995	2004-2006	2009-2017	2018-2019
Grid size	1 x 1 km	1.4 x 1.4 km	1.4 x 1.4 km	1.4 x 1.4 km	1.4 x 1.4 km
Terrestrial sample plots	10'981	5'679	5'920	6'042	1'358
Tally trees	128'441	67'297	69'960	71'906	16'343

Table 2. Applied allometric biomass functions, dependencies and references. DBH: tree diameter at breast height; D7: diameter at tree height 7 m.

Tree element	Input parameter	Dataset (N trees)	References
Stemwood over bark incl. stump	DBH, D7, Height, basic wood density	ca. 38'000	ch. 12.2 in Herold et al. (2019) ch. 14.2 in Didion et al. (2019)
Branches: small (< 7 cm) and large (≥ 7 cm diameter)	DBH, basic wood density	14'712	ch. 12.2 in Herold et al. (2019) ch. 14.2 in Didion et al. (2019)
Foliage	DBH	631	Perruchoud et al. (1999) ch. 14.3 in Didion et al. (2019)
Coarse roots (≥ ca. 5 mm in diameter) **- broadleaved trees** **- coniferous trees**	DBH	 443 114	ch. 14.3 in Didion et al. (2019) Wutzler et al. (2008) Zell and Thürig (2013)

2.2 Spatial stratification

The LULUCF sector of the Swiss GHGI uses a primary spatial stratification based on three elevation strata and, additionally for Forest land based on five NFI production regions (chapter 6.1 of the annual inventory reports, e.g. FOEN 2021):

- five NFI production regions: Jura, Central Plateau, Pre-Alps, Alps, Southern Alps
- three elevation classes: <601 m, 601–1200 m, >1200 m.

For Forest land, the resulting 15 spatial strata reflect the heterogeneity of forests in Switzerland and minimize the sampling error for stocks, growth and drain (cf. Lanz et al. 2019). An analysis of variance showed that this spatial stratification and additionally tree species type as a further explanatory variable all significantly explain differences in gross growth (Thürig et al. 2005, re-confirmed in 2017 for data of the period NFI34; Table 3).

Table 3. Analysis of variance of gross growth of data from NFI2 and NFI3. Explanatory variables: Tree species type, NFI production region, and elevation

Strata	Gross growth	
	F-value	p-value
Tree species type: coniferous / broadleaved	421	<0.0001
NFI Production region	45	<0.0001
Elevation classes	34	<0.0001

Following the approach to derive new NFI data biannually that was implement with the NFI4, some strata are aggregated to ensure that a sufficient number of sample plots is available to obtain statistically reliable and representative estimates of means and sampling errors. The strata that are currently merged are

- NFI production region Central Plateau 601-1200 m and >1200 m
- NFI production region Pre-Alps ≤600 m and 601-1200 m
- NFI production region Alps ≤600 m and 601-1200 m.

Table 4 shows the number of sample plots within the resulting 12 strata for the NFI34/5 subset 2015-2019 used for preparing the estimates for the NIR 2021.

Table 4. Number of NFI sample plots by spatial strata in the period NFI34/5 subset 2015-2019 classified as accessible forest plots without brush forest

Elevation zone	Production region					Switzerland
	Jura	Plateau	Pre-Alps	Alps	Southern Alps	
≤ 600	134	385	372	296	59	615
601 - 1200	335	251			158	1369
>1200	67		218	751	195	1237
Total	536	636	590	1047	412	**3221**

2.3 Biomass growing stock, growth, and drain

Estimates of growing stocks, growth, and drain of tree biomass > 12 cm dbh are derived from measurements of individual tally trees on the common plots of two consecutive NFIs. The estimates consider the total tree biomass including stemwood of the entire stem over bark, branches over bark, and coarse roots (Table 2). The growing stock is estimated based on the total biomass of a tree in the second of two consecutive inventories considering all measured living trees on the common sample plots. Growth is calculated as the change in total tree biomass between two consecutive inventories considering the state of a tree as follows:

- A tree is alive and measured in both inventories: difference between the biomass calculated based on the dbh in the first and second inventory.
- A tree is alive and measured in the first inventory and dead (and still present on a sample plot) or harvested (and removed from a sample plot) in the second inventory: difference between the biomass calculated based on the dbh in the first inventory and the modelled

dbh (Herold et al. 2019) at the half point of the NFI period as the exact date of tree death or harvest is not known.

Drain correspond to the total biomass of trees that were alive in the first inventory and were dead or harvested in the second inventory estimated based on the modelled dbh (Herold et al. 2019) at the half point of the NFI period. Biomass data are then used for further calculation of C stocks and C stock changes on Forest land remaining Forest land and for conversions from and to Forest land.

Based on the data from the different NFIs, a time series of stocks, growth, and drain of tree biomass since 1990 is constructed. Data for the periods NFI12 and NFI23 were last derived and documented in Thürig and Herold (2013). The estimates for these two inventory periods were based on all common plots of two consecutive inventories, which were visited approximately 10 years apart. Following the change to a continuous sampling approach with the NFI4, estimates were derived from sample plots that were visited in consecutive years of the NFI4 and the corresponding plots in the NFI3. Since the 5th year of the NFI4, ie. 2013, a window covering 5 consecutive years is selected to obtain a sufficient number of sample plots that ensures statistically robust and accurate estimates, and to minimize the temporal spread between observations in the NFI3 and NFI4. The 5-year window with the corresponding subset of sample plots are updated every two years to obtain the most current and accurate estimates of biomass stocks, growth, and drain (Table 5). The total number of common plots can differ for inter-survey periods as a result of land use changes from or to forest land. The approach is consistent with IPCC 2006 good practice to continuously improve emissions and removal estimates based on new knowledge. It ensures that the biomass estimates used for reporting C stocks and changes in Switzerland's NIR reflect current dynamics in Swiss forest representing, for example, the effects of disturbances. Due to this regular update of the NFI data, the time series since 2006 (ie. after the end of the NFI3) is regularly recalculated.

For this report, data from the NFI5 are available for the first time providing information for 2018 and 2019. To maintain a 5-year window ensuring accurate stock, growth, and drain estimates, values are derived from sample plots common to NFI3 and NFI4 based on plots visited in the years 2015 to 2017 as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019, henceforth NFI34/5 subset 2015-2019. Once the NFI5 is in its 5th year in 2022, estimates will be based on the common plots of NFI4 and NFI5 only.

Table 5. Number of NFI sample plots in each NFI period where the total for a period represents the common plots of two consecutive NFIs based on which biomass stocks, growth and drain are estimated. Note that NFI1, NFI2 and NFI3 were based on full surveys and that the NFI4 and later NFIs have been based on continuous survey over 9 years where annually a nationally representative subsample of approximately 12% of the Swiss forests is surveyed and evaluated. Regularly updated subsets of sample plots selected from the continuous survey are used to represent the most current forest dynamics.

GHGI time series	Reference	NFI period	NFI subset[1]	forest in previous period	Converted to forest since previous period	Total for period
				Number of sample plots		
1990–1995	**Thürig and Herold (2013)**	**NFI12**	N/A[1]	N/A[2]	N/A[2]	5456
1996–2005		**NFI23**	N/A[1]	5370	211	5581
2006-2011		**NFI34**	2009-2011	1860	107	1967
2006-2012, recalculated	**Thürig (2014)**		2009-2012	2475	138	2613
2006-2014, recalculated	**Thürig et al. (2015)**		2009-2013	3105	166	3271
2006-2016, recalculated	**Thürig et al. (2017)**		2011-2015	3115	165	3280
2006-2018, recalculated	**Thürig et al. (2019)**		2013-2017	3046	165	3211
2006-2019[3], recalculated	**this report**	**NFI34/5[3]**	2015-2019	3022	199	3221

[1]NFI1, NF2, and NFI3 were based on full surveys; NFI4 and NFI5 are continuous surveys and values are updated regularly

[2]not applicable in this first NFI period

[3]for the period NFI34/5 sample plots common to the NFI3 and the sample plots in NFI4 visited in the years 2015 to 2017 and common to NFI4 and NFI5 visited in the years 2018 and 2019 were considered

2.4 Conversion of stocks, gains, and losses from biomass to carbon

The estimated growing stock, gains, and losses in biomass are converted to carbon using a mean C fraction of 0.5 in dry matter based on estimates for broadleaved and coniferous trees in table 4.3 in Volume 4 of the 2006 IPCC guidelines.

2.5 Annual values of C stocks and losses

Annual changes in harvested tree volume in Swiss forests are quantified accurately in the Swiss harvest statistics database. These data are used to derive annual estimates of losses. To this end, biomass drain is annualized based on annual harvest statistics data on harvested volume in the 5

production regions. Annual weighting factors are calculated based on the ratio between the harvested volume in a particular year and the mean of the annual harvests falling within a NFI period (considering also the subsets of the period NFI34, cf. Table 5). The annual weighting factors are then multiplied with the drain estimate for the NFI period to produce annual estimates of losses. This approach corresponds broadly to the logging factor method proposed by Röhling et al. (2016).

Annual values of C stocks are derived based on the biomass growing stock 2005, determined from common plots of the NFI23 (Brändli 2010), and i) backward calculation for the time period before 2005, where the annual growing stock equals the growing stock 2005 minus the net change of the growth estimated for a NFI period and the annualized drain, and ii) forward for the time period after 2005, where the annual growing stock equals the growing stock 2005 plus the net change of the growth estimated for a NFI period and annualized drain.

2.6 QA/QC

The preparation of the data on biomass and C stocks, gains, and losses applies procedures to ensure the estimates meet the reporting requirements set out in the IPPC 2006 guidelines.

2.6.1 *Time series consistency*

Data, data base and derivations of the Swiss NFI are continuously checked for plausibility, accuracy, and consistency, and identified issues are evaluated and, if required, corrected and biomass and C stocks, gains, and losses are recalculated. In particular, it is ensured that the same coefficients and methods for equivalent calculations at all points in the time series are used.

The approach to biannually update the estimates based on the most current NFI data that are available from the continuous survey approach implemented with NFI4 may introduce differences in the time series between reported C stocks, gains, and losses in two NIR submissions. In addition, the annually updated weighting factors for losses (section 2.5) may also contribute to variability in the reported values. Nevertheless, this approach ensures that C gains and losses reported in a NIR are based on the most current and accurate NFI data.

To analyze time series consistency and accuracy, current estimates of biomass stocks, growth, and drain are compared with data derived for use in recent NIR submissions. Hence, estimates presented in this report that are based on the NFI34/5 subset 2015-2019 (Table 5) are compared with the data prepared based on the NFI34 subset 2013-2017 that were the basis of the NIR submissions in 2019 and 2020 (FOEN 2019, 2020).

2.6.2 *Completeness*

Estimates of biomass stocks, growth, and drain include all tree elements. The approach to separately estimate growth, and drain ensures that all changes in the C stocks of the living biomass are addressed. The approach implicitly accounts for C that accumulated in trees before they reached the measurement threshold of 12 cm used in the Swiss NFI. The approach ensures accuracy as the country-specific allometries to estimate total tree biomass do not apply to trees < 12 cm dbh. Furthermore, trees with dbh < 12 cm contribute only little to total forest biomass and C stock (Peichl and Arain 2006). Dunger et al. (2012) estimated this contribution to 1-2% for forests with similar forest structure as Switzerland.

In the productive forest in Switzerland, understory vegetation presents only a small component of the above-ground biomass carbon pool, ie. < 1% based on estimates for herbaceous vegetation in the Swiss NFI in Didion (2020b). Consistent with the inventory guidelines (Annex 4A.1, Vol. 4, IPCC 2006), this vegetation layer was not included in the living biomass estimates for Switzerland's GHGI. It was ensured that the exclusion was used in a consistent manner throughout the inventory time series. This approach also ensures consistency with the model based forest management reference level where understory vegetation cannot be estimated and predicted accurately.

2.6.3 *Verification*

Based on the estimates of total above-ground tree biomass growing stock and the corresponding estimates of stemwood volume, biomass conversion and expansion factors are calculated and compared with IPCC 2006 default values (Table 4.5, Vol. 4).

2.6.4 *Uncertainty*

The NFI methodology calculates the statistical random sampling error (ch. 2.5 in Lanz et al. 2019) and reports this by default. In the results section, this error is reported for comparability with NFI publications. The total uncertainty of the net C stock change of tree biomass on forest land reported in the NIR additionally considers uncertainties related to the temporal aspect of sampling from different 5-year subsets of the period NFI34 (section 2.3), allometric relationships, basic wood density, and C fraction (ch. 6.4.3.1 in FOEN 2020). For the allometric relationship to estimate volume and the conversion to total tree biomass, a sampling uncertainty of 21.2% and a model uncertainty of 22.2% is assumed based on Lehtonen and Heikkinen (2016). For carbon content in solid wood an uncertainty of 2% is assumed based on 2% relative standard deviation (RSD) in Monni et al. (2007), and 4-8% RSD in Lamlom and Savidge (2003). The uncertainty

associated with the harvest statistics, which are used for annualizing C stocks and losses (section 2.5), is not addressed as it cannot be derived mathematically (cf. Röhling et al. 2016).

2.6.5 *Documentation*

The NFI estimates are retrieved from the NAFIDAS database (Traub et al. 2017; https://www.wsl.ch/en/projects/the-data-analysis-system-nafidas.html). The procedure to parametrize the database analyses to obtain reproducible estimates, and the methodology to produce the estimates of biomass stocks, growth, and drain are documented in (Didion 2020a). Separate copies of the documentation and the estimates used for reporting are maintained at WSL and FOEN.

Forest statistics data are maintained by the Federal Statistical Office and are available online at https://www.pxweb.bfs.admin.ch/pxweb/en/px-x-0703010000_102/-/px-x-0703010000_102.px/?rxid=2d2cb270-c3c9-409f-9dac-1dab90d24785.

2.7 Methodological improvements and updates of input data

2.7.1 *Improvements and updates compared to the GHGI 2020*

Methodological improvements

Since the previous submission, a methodological improvement was implemented to correct a minor error in the bias correction for measured trees, which addresses the uneven distribution of tree dbh in the data set used for estimating tree volume functions in comparison with the NFI data (ch. 12.2 in Herold et al. 2019). This correction resulted in minor differences in the estimate of growth and drain.

Updates of input data

New, more recent NFI data were available to estimates biomass and C stocks, gains, and losses as documented in sections 2.1 and 2.3. Further, the harvest statistics data for 2019 were included in the derivation of annual values of losses (section 2.5).

3 Results

3.1 Biomass growing stock, growth, and drain

Table 6 to Table 8 present the biomass growing stock, growth and drain estimates that are used for calculating C stocks, gains, and losses for the NIR. The estimates are based on the data collected in period of the NFI34/5 subset 2015-2019. The data are presented based on the spatial stratification used in the NIR, ie. five production regions and 3 elevation classes with merged strata as documented in section 2.2. In addition, the estimates are presented for coniferous and broadleaved tree species. The data for growing stock and drain in Table 6 and Table 8 are the original estimates obtained from the NFI database, ie. before annualizing drain with forest statistics data, and stock with annual data of drain. The estimated mean national biomass growing stock was 247.327 ±5.352 (2SE) t ha^{-1}. Biomass growth and drain were 6.045 ± 0.160 t $ha^{-1}$and - 5.002 ±0.342 t ha^{-1}, respectively.

Table 6. Mean and double standard error of biomass stocks of living trees based on measured trees on 3221 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2015 to 2017 as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	72.243	17.910	102.818	12.950	193.855	18.816	136.618	18.512	13.118	17.072	86.279	9.706
	Broadl.	192.963	26.744	152.973	15.678	124.106	15.794	108.110	16.118	172.663	26.326	167.273	12.472
	All	265.206	27.118	255.791	15.924	317.961	18.830	244.728	20.904	185.781	26.400	253.552	12.874
601m – 1200m	Conifer	144.976	16.526	121.071	16.826	193.855	18.816	136.618	18.512	42.275	24.300	142.012	8.744
	Broadl.	142.225	14.154	160.954	24.322	124.106	15.794	108.110	16.118	181.746	26.478	136.422	8.342
	All	287.201	16.876	282.025	25.518	317.961	18.830	244.728	20.904	224.021	34.636	278.434	9.978
>1200m	Conifer	134.714	26.312	121.071	16.826	212.908	21.386	200.786	11.020	145.957	19.112	190.447	8.450
	Broadl.	48.543	19.436	160.954	24.322	23.71	8.672	9.544	2.566	39.245	10.238	18.951	2.972
	All	183.256	29.114	282.025	25.518	236.617	22.328	210.33	10.788	185.203	18.696	209.399	8.396
Total	Conifer	125.514	11.678	110.041	10.124	200.707	13.950	182.516	9.288	86.74	13.818	149.948	5.156
	Broadl.	143.167	10.92	156.131	12.712	88.001	10.660	37.607	5.320	113.396	12.960	97.379	4.422
	All	268.681	11.936	266.171	12.426	288.708	13.246	220.123	8.826	200.136	15.846	247.327	5.352

Table 7. Mean and double standard error of gross growth of living trees based on the change of measured trees on 3221 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2015 to 2017 as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	1.984	0.508	3.753	0.458	5.037	0.47	2.756	0.38	0.353	0.504	2.932	0.326
	Broadl.	4.634	0.79	4.82	0.466	2.972	0.388	2.477	0.422	5.11	1.174	4.814	0.372
	All	6.618	0.808	8.573	0.49	8.009	0.494	5.234	0.51	5.463	1.192	7.746	0.392
601m – 1200m	Conifer	3.33	0.414	4.619	0.616	5.037	0.47	2.756	0.38	0.679	0.49	3.632	0.226
	Broadl.	3.073	0.352	5.159	0.748	2.972	0.388	2.477	0.422	3.154	0.7	3.258	0.226
	All	6.403	0.462	9.777	0.786	8.009	0.494	5.234	0.51	3.833	0.81	6.89	0.276
>1200m	Conifer	3.158	0.792	4.619	0.616	4.212	0.544	3.971	0.268	2.989	0.5	3.81	0.21
	Broadl.	0.916	0.34	5.159	0.748	0.374	0.184	0.277	0.088	0.99	0.346	0.444	0.086
	All	4.075	0.896	9.777	0.786	4.586	0.572	4.248	0.278	3.979	0.558	4.254	0.22
Total	Conifer	2.972	0.306	4.095	0.37	4.74	0.358	3.625	0.22	1.717	0.326	3.567	0.138
	Broadl.	3.193	0.302	4.954	0.402	2.038	0.266	0.903	0.146	2.424	0.378	2.478	0.126
	All	6.165	0.368	9.049	0.428	6.778	0.38	4.529	0.242	4.142	0.444	6.045	0.16

Table 8. Mean and double standard error of the mean biomass drain including tree harvest and natural mortality based on the observed change on 3221 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2015 to 2017 as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	-2.597	0.998	-4.835	0.898	-5.418	1.104	-2.312	0.612	-0.000	0.068	-3.792	0.664
	Broadl.	-2.806	0.854	-4.428	0.946	-2.355	0.776	-1.689	0.604	-3.173	1.020	-3.826	0.630
	All	-5.403	1.278	-9.263	1.306	-7.773	1.446	-4.001	0.920	-3.139	1.014	-7.619	0.926
601m – 1200m	Conifer	-3.061	0.676	-5.035	1.168	-5.418	1.104	-2.312	0.612	-0.605	0.554	-3.596	0.420
	Broadl.	-2.482	0.698	-4.691	1.222	v2.355	0.776	-1.689	0.604	-1.316	0.428	-2.535	0.378
	All	-5.543	0.990	-9.726	1.656	-7.773	1.446	-4.001	0.920	-1.922	0.764	-6.131	0.590
>1200m	Conifer	-3.397	1.650	-5.035	1.168	-3.103	1.370	-2.072	0.434	-1.256	0.708	-2.207	0.386
	Broadl.	-0.629	0.490	-4.691	1.222	-0.202	0.142	-0.173	0.082	-0.297	0.186	-0.232	0.072
	All	-4.026	1.804	-9.726	1.656	-3.306	1.386	-2.245	0.444	-1.553	0.740	-2.439	0.396
Total	Conifer	-2.987	0.532	-4.915	0.712	-4.586	0.868	-2.141	0.356	-0.817	0.394	-3.102	0.264
	Broadl.	-2.331	0.490	-4.532	0.748	-1.581	0.504	-0.604	0.184	-1.110	0.258	-1.900	0.204
	All	-5.318	0.732	-9.447	1.024	-6.167	1.060	-2.745	0.410	-1.927	0.480	-5.002	0.342

3.2 Net change of biomass growing stock

The net biomass stock change is calculated as the difference between biomass growth and drain, ie. 6.045 ± 0.16 t ha^{-1} (2SE; Table 7) and -5.002 ± 0.342 t ha^{-1} (2SE; Table 8), respectively. The uncertainty associated with the net change is estimated based on the statistical random sampling error reported with NFI estimates for growth and drain:

$$SE_{net-change} = \sqrt{0.16^2 + 0.342^2}$$

The net stock change is thus a sink of 1.043 ±0.378 t ha^{-1} or 0.522 ±0.189 t C ha^{-1}.

The approach to calculate the standard error of the net change assumes the random variables growth and drain to be independent, and may results in a small overestimation of the uncertainty estimate for the net change. This can be assumed to compensate here for excluding errors associated with allometric relationships, basic wood density, and C fraction (cf. section 2.6.3).

In the NIR (ch. 6.4.3.1 in FOEN 2020), uncertainties related to random sampling error, as well as the temporal aspect, allometric relationships, basic wood density, and C fraction are combined by adding relative uncertainties using equation 3.1 in Volume 1 of the IPCC 2006 guidelines.

3.3 Comparison between NFI data 2013-2017 and 2015-2019

Figure 1 shows the time series of national estimates of gains and losses based on the NFI data used for reporting in the NIR 2020 (ie. based on sample plots of the NFI34 subset 2013-2017) and for the NIR 2021 (ie. based on sample plots of the NFI34/5 subset 2015-2019). The time series data include the effects of annualizing drain (section 2.5). Table 9 to Table 11 present quantitatively the differences between the estimates from both datasets for all 12 strata (section 2.2); note that for enhanced transparency the unmodified estimates in biomass, ie. not annualized stocks and drain, are shown (section 2.5). Compared to the estimates prepared for the previous two NIR submission (Thürig et al. 2019), the values for biomass growing stock are statistically not different with a decrease of -0.090 t ha^{-1}, ie. well within the margins of error (5.352 t ha^{-1}, Table 9). The differences in biomass growth and drain were in relative terms larger but also within the margin of 2 standard errors, ie. a slight increase in growth of 0.138 t ha^{-1} (SE for growth is 0.16 t ha^{-1}, Table 10) and a slight increase in biomass drain of 0.292 t ha^{-1} (SE is 0.342 t ha^{-1}, Table 11). The differences in growth and drain between the two NIR submissions can be attributed primarily to the updated NFI data, which represent the temporary peaking of national harvest in 2018 in response to the storm Burglind (BAFU 2018). In addition,

adjustments and corrections of data and data derivations (section 2.7.1) contributed to the differences between the current data and the data for the previous NIR submissions.

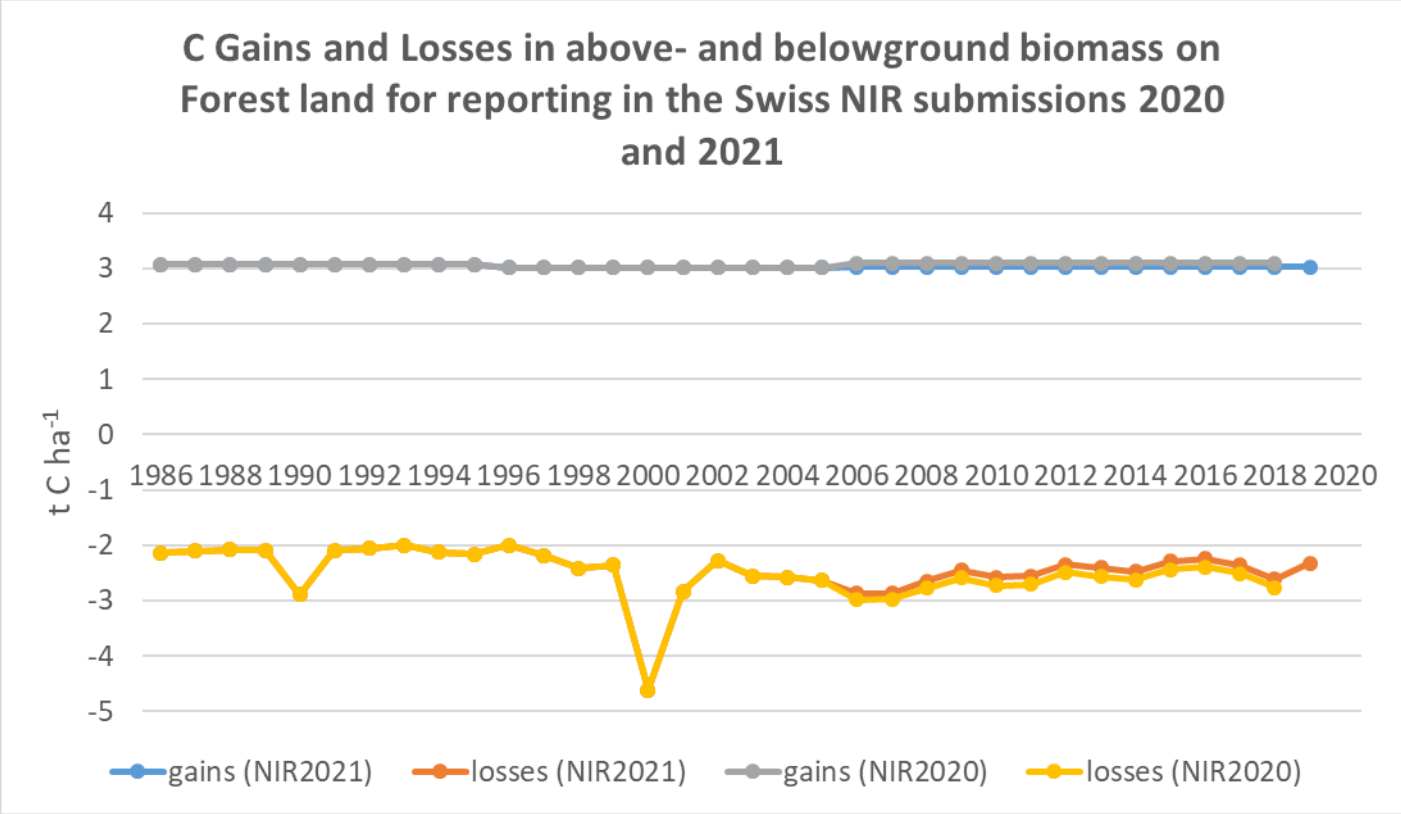

Figure 1. Time series of national estimates of C gains and losses calculated in this report based on data from the period NFI34/5 subset 2015-2019 for reporting in the NIR 2021 and in (Thürig et al. 2019) based on data from the period NFI34 subset 2013-2017 for reporting in the NIR 2020.

Table 9. Difference in the estimated mean biomass growing stock of living trees based on data used for reporting to the NIR 2020 (ie. using data from the NFI34 subset 2013-2017) and the NIR 2021 (ie. using data from the NFI34/5 subset 2015-2019). Differences are shown in comparison with the double SE of biomass growing stock data prepared for this report for the NIR 2021 (Table 6). Data are stratified by five production regions, three elevation classes and tree species type. Cells with grey background indicate merged elevation strata. Negative values indicate a decrease in the mean of the estimated stocks for data for the NIR 2021 (Table 6) compared to the data for the NIR 2020 (Table A - 1), positive values indicate an increase. Values in bold indicate a difference in the estimated means that is larger than the double standard error.

		Production region										Switzerland	
Elevation class	**Species Type**	**Jura**		**Plateau**		**Pre-Alps**		**Alps**		**Southern Alps**			
		diff. in means	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**
		1000 kg ha^{-1}											
≤ 600m	**Conifer**	-0.559	17.910	7.469	12.950	12.185	18.816	5.615	18.512	2.764	17.072	6.229	9.706
	Broadl.	0.266	26.744	-4.839	15.678	-5.029	15.794	**-20.669**	**16.118**	-8.096	26.326	-8.259	12.472
	All	-0.293	27.118	2.630	15.924	7.156	18.830	-15.053	20.904	-5.332	26.400	-2.030	12.874
601m – 1200m	**Conifer**	-8.844	16.526	**18.467**	**16.826**	12.185	18.816	5.615	18.512	-13.762	24.300	3.622	8.744
	Broadl.	-3.421	14.154	-13.145	24.322	-5.029	15.794	**-20.669**	**16.118**	12.088	26.478	-5.451	8.342
	All	-12.264	16.876	5.322	25.518	7.156	18.830	-15.053	20.904	-1.674	34.636	-1.828	9.978
>1200m	**Conifer**	16.588	26.312	**18.467**	**16.826**	-7.506	21.386	6.112	11.020	-3.195	19.112	1.719	8.450
	Broadl.	9.496	19.436	-13.145	24.322	-7.110	8.672	0.363	2.566	1.262	10.238	0.317	2.972
	All	26.085	29.114	5.322	25.518	-14.615	22.328	6.475	10.788	-1.934	18.696	2.035	8.396
Total	**Conifer**	-2.380	11.678	**12.596**	**10.124**	5.109	13.950	5.499	9.288	-4.760	13.818	3.674	5.156
	Broadl.	-3.064	10.920	-8.134	12.712	-4.951	10.660	-5.059	5.320	2.292	12.960	-3.764	4.422
	All	-5.444	11.936	4.463	12.426	0.158	13.246	0.440	8.826	-2.468	15.846	-0.090	5.352

Table 10. Difference in the estimated mean biomass gross growth of living trees based on data used for reporting to the NIR 2020 (ie. using data from the NFI34 subset 2013-2017) and the NIR 2021 (ie. using data from the NFI34/5 subset 2015-2019). Differences are shown in comparison with the double SE of biomass gain data prepared for this report for the NIR 2021 (Table 7). Data are stratified by five production regions, three elevation classes and tree species type. Cells with grey background indicate merged elevation strata. Negative values indicate a decrease in the mean of the estimated growth for data for the NIR 2021 (Table 7) compared to the data for the NIR 2020 (Table A - 2), positive values indicate an increase. All differences in the estimated means were within the margin of double standard errors.

		Production region										Switzerland	
Elevation class	**Species Type**	**Jura**		**Plateau**		**Pre-Alps**		**Alps**		**Southern Alps**			
		diff. in means	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**
		1000 kg ha^{-1}											
≤ 600m	**Conifer**	0.089	0.508	0.403	0.458	0.337	0.47	0.054	0.38	-0.056	0.504	0.306	0.326
	Broadl.	0.438	0.79	0.052	0.466	0.046	0.388	-0.181	0.422	0.001	1.174	0.088	0.372
	All	0.527	0.808	0.455	0.49	0.382	0.494	-0.128	0.51	-0.055	1.192	0.394	0.392
601m – 1200m	**Conifer**	0.116	0.414	0.185	0.616	0.337	0.47	0.054	0.38	-0.156	0.49	0.147	0.226
	Broadl.	-0.014	0.352	-0.328	0.748	0.046	0.388	-0.181	0.422	0.456	0.7	0.004	0.226
	All	0.102	0.462	-0.142	0.786	0.382	0.494	-0.128	0.51	0.300	0.81	0.151	0.276
>1200m	**Conifer**	0.028	0.792	0.185	0.616	0.118	0.544	0.003	0.268	0.080	0.5	0.022	0.21
	Broadl.	0.165	0.34	-0.328	0.748	0.037	0.184	-0.021	0.088	-0.198	0.346	-0.018	0.086
	All	0.192	0.896	-0.142	0.786	0.154	0.572	-0.018	0.278	-0.118	0.558	0.004	0.22
Total	**Conifer**	0.114	0.306	0.334	0.37	0.267	0.358	0.009	0.22	0.005	0.326	0.133	0.138
	Broadl.	0.058	0.302	-0.099	0.402	0.063	0.266	-0.051	0.146	0.032	0.378	0.005	0.126
	All	0.172	0.368	0.235	0.428	0.330	0.38	-0.043	0.242	0.036	0.444	0.138	0.16

Table 11. Difference in the estimated mean biomass drain including tree harvest and natural mortality based on data used for reporting to the NIR 2020 (ie. using data from the NFI34 subset 2013-2017) and the NIR 2021 (ie. using data from the NFI34/5 subset 2015-2019). Differences are shown in comparison with the double SE of biomass loss data prepared for this report for the NIR 2021 (Table 8). Data are stratified by five production regions, three elevation classes and tree species type. Cells with grey background indicate merged elevation strata. Negative values indicate a decrease in the mean of the estimated drain for data for the NIR 2021 (Table 8) compared to the data for the NIR 2020 (Table A - 3), positive values indicate an increase. Values in bold indicate a difference in the estimated means that is larger than the double standard error.

		Production region										Switzerland	
Elevation class	**Species Type**	**Jura**		**Plateau**		**Pre-Alps**		**Alps**		**Southern Alps**			
		diff. in means	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**	**diff. in means**	**2 SE of mean**
		1000 kg ha^{-1}											
≤ 600m	**Conifer**	0.055	0.998	0.498	0.898	0.849	1.104	**0.641**	**0.612**	**0.344**	**0.068**	0.322	0.664
	Broadl.	**1.736**	**0.854**	-0.403	0.946	-0.094	0.776	0.062	0.604	0.644	1.020	0.282	0.630
	All	**1.791**	**1.278**	0.094	1.306	0.756	1.446	0.703	0.920	0.987	1.014	0.603	0.926
601m – 1200m	**Conifer**	0.602	0.676	0.926	1.168	0.849	1.104	**0.641**	**0.612**	-0.303	0.554	**0.702**	**0.420**
	Broadl.	-0.406	0.698	-0.779	1.222	-0.094	0.776	0.062	0.604	-0.021	0.428	-0.265	0.378
	All	0.196	0.990	0.147	1.656	0.756	1.446	0.703	0.920	-0.325	0.764	0.436	0.590
>1200m	**Conifer**	-0.448	1.650	0.926	1.168	-0.057	1.370	0.224	0.434	-0.269	0.708	0.043	0.386
	Broadl.	0.137	0.490	-0.779	1.222	**-0.151**	**0.142**	-0.086	0.082	0.031	0.186	-0.058	0.072
	All	-0.312	1.804	0.147	1.656	-0.209	1.386	0.138	0.444	-0.237	0.740	-0.015	0.396
Total	**Conifer**	0.337	0.532	0.683	0.712	0.550	0.868	0.347	0.356	-0.183	0.394	**0.383**	**0.264**
	Broadl.	0.138	0.490	-0.554	0.748	-0.097	0.504	-0.031	0.184	0.067	0.258	-0.091	0.204
	All	0.475	0.732	0.129	1.024	0.452	1.060	0.316	0.410	-0.116	0.480	0.292	0.342

3.4 Verification

Based on the estimates of biomass growing stock (Table 5) and corresponding estimates of stemwood volume (Table A - 4), biomass conversion and expansion factors (BCEF) were calculated (Table 11) and compared with default values for temperate forests from Table 4.5 in Vol.4 of the IPCC 2006 guidelines. Note that for technical reasons biomass growing stock and stemwood volume in the Swiss NFI are include bark. The resulting national mean BCEF of 0.622 ±0.001 t m-3 for conifers and 0.83 ± 0.003 t m-3 for broadleaves compares well with the default values for a growing stock level > 200 m3 ha-1 of 0.7 (0.35-0.9) and 0.8 (0.55-1.1).

3.5 Identified potential improvements

Consistent with IPCC 2006 good practice, areas of possible improvement are identified for future implantation, including

- recalculations of all data back to NFI1 to account for data base revisions over 10 years consistent with good practice;
- restrict weighting of data on drain to trees that were actually harvested to improve accuracy as proposed by Röhling et al. (2016);
- use of a single national weighting factor to replace the existing approach that results in a bias in harvest in the higher elevation classes to improve accuracy;
- additional plausibility checks of the estimates by stratum based on actual number trees affected in addition to the number of plots to improve accuracy and transparency.

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Appendix I: Data prepared for Switzerland's NIR submission 2020 (1990-2018)

Table A - 1. Mean and double standard error of biomass stocks of living trees based on measured trees on 3211 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2013 to 2017 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3); data based on Table 3 in Thürig et al. (2019).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	71.684	17.204	110.287	13.234	206.040	20.604	142.233	17.068	15.882	28.768	92.508	16.834
	Broadl.	193.229	30.917	148.134	17.776	119.077	14.289	87.441	13.991	164.567	17.417	159.014	26.331
	All	264.913	26.491	258.421	15.505	325.117	19.507	229.675	18.374	180.449	31.076	251.522	25.263
601m – 1200m	Conifer	136.132	16.336	139.538	19.535	206.040	20.604	142.233	17.068	28.513	28.768	145.634	11.975
	Broadl.	138.805	13.880	147.809	20.693	119.077	14.289	87.441	13.991	193.834	17.417	130.971	38.767
	All	274.937	16.496	287.347	22.988	325.117	19.507	229.675	18.374	222.347	31.076	276.606	35.575
>1200m	Conifer	151.302	27.234	139.538	19.535	205.402	20.540	206.898	12.414	142.762	16.134	192.166	17.131
	Broadl.	58.039	20.894	147.809	20.693	16.600	6.308	9.907	2.774	40.507	3.715	19.268	10.532
	All	209.341	29.308	287.347	22.988	222.002	22.200	216.805	13.008	183.269	16.917	211.434	18.327
Total	Conifer	123.134	12.313	122.637	9.811	205.816	16.465	188.015	7.521	81.980	15.647	153.622	11.477
	Broadl.	140.103	11.208	147.997	11.840	83.051	9.966	32.548	5.208	115.688	5.823	93.615	16.196
	All	263.237	10.529	270.634	10.825	288.866	11.555	220.563	8.823	197.668	13.482	247.237	15.813

Table A - 2. Mean and double standard error of gross growth of living trees based on the change of measured trees on 3211 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2013 to 2017 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3); data based on Table 5 inThürig et al. (2019).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	2.073	0.580	4.156	0.499	5.374	0.537	2.810	0.393	0.297	0.533	3.238	0.422
	Broadl.	5.072	0.812	4.872	0.487	3.018	0.362	2.296	0.367	5.111	0.531	4.902	1.022
	All	7.145	0.857	9.028	0.542	8.391	0.503	5.105	0.511	5.408	0.665	8.140	1.082
601m – 1200m	Conifer	3.446	0.414	4.804	0.673	5.374	0.537	2.810	0.393	0.523	0.533	3.779	0.261
	Broadl.	3.059	0.306	4.831	0.676	3.018	0.362	2.296	0.367	3.610	0.531	3.262	1.011
	All	6.505	0.390	9.635	0.771	8.391	0.503	5.105	0.511	4.133	0.665	7.041	0.992
>1200m	Conifer	3.186	0.701	4.804	0.673	4.330	0.606	3.974	0.238	3.069	0.395	3.832	0.430
	Broadl.	1.081	0.432	4.831	0.676	0.411	0.156	0.256	0.072	0.792	0.099	0.426	0.269
	All	4.267	0.768	9.635	0.771	4.740	0.569	4.230	0.254	3.861	0.423	4.258	0.463
Total	Conifer	3.086	0.309	4.429	0.354	5.007	0.401	3.634	0.218	1.722	0.302	3.700	0.276
	Broadl.	3.251	0.325	4.855	0.388	2.101	0.252	0.852	0.136	2.456	0.180	2.483	0.442
	All	6.337	0.380	9.284	0.371	7.108	0.426	4.486	0.269	4.178	0.368	6.183	0.501

Table A - 3. Mean and double standard of the mean biomass drain including tree harvest and natural mortality based on the observed change on 3221 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2013 to 2017 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3); data based on Table 4 in Thürig et al. (2019).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		1000 kg/ha											
≤ 600m	Conifer	2.652	1.008	5.333	0.960	6.267	1.253	2.953	0.945	0.309	1.609	4.114	0.593
	Broadl.	4.542	1.363	4.025	0.966	2.262	0.678	1.751	0.736	3.817	1.001	4.108	1.145
	All	7.194	1.727	9.358	1.310	8.529	1.365	4.704	1.223	4.126	2.023	8.222	1.238
601m – 1200m	Conifer	3.663	0.806	5.961	1.311	6.267	1.253	2.953	0.945	0.302	1.609	4.297	0.344
	Broadl.	2.076	0.540	3.913	1.017	2.262	0.678	1.751	0.736	1.295	1.001	2.270	0.440
	All	5.739	1.033	9.874	1.777	8.529	1.365	4.704	1.223	1.597	2.023	6.567	0.575
>1200m	Conifer	2.949	1.651	5.961	1.311	3.046	1.340	2.295	0.505	0.987	0.619	2.249	0.474
	Broadl.	0.766	0.429	3.913	1.017	0.051	0.044	0.087	0.040	0.328	0.048	0.174	0.190
	All	3.714	1.783	9.874	1.777	3.097	1.363	2.382	0.524	1.316	0.639	2.423	0.500
Total	Conifer	3.324	0.598	5.598	0.784	5.135	0.924	2.487	0.448	0.634	0.627	3.485	0.279
	Broadl.	2.469	0.494	3.978	0.716	1.484	0.445	0.573	0.218	1.177	0.288	1.809	0.259
	All	5.793	0.811	9.576	0.958	6.619	1.059	3.060	0.490	1.811	0.751	5.294	0.362

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Appendix II: Data for verification

Table A - 4. Mean and double standard error of growing stock volume based on the stemwood over bark of living trees based on measured trees on 3221 sample plots common to NFI3 and sample plots in NFI4 visited in the years 2015 to 2017 as well as sample plots common to NFI4 and NFI5 visited in the years 2018 and 2019 that were classified as accessible forest but not shrub forest. Data are stratified by five production regions, three elevation classes and trees species type. Cells with grey background indicate merged elevation strata. Note the SE represents the statistical random sampling error (section 2.6.3).

		Production region										Switzerland	
Elevation class	Species Type	Jura		Plateau		Pre-Alps		Alps		Southern Alps			
		mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE	mean	± 2SE
		m^3/ha											
≤ 600m	Conifer	122	15	172	11	158	51	141	56	22	15	145	8
	Broadl.	236	16	178	9	241	47	243	62	218	17	199	7
	All	358	19	350	11	399	60	384	76	240	19	343	9
601m – 1200m	Conifer	243	14	201	15	339	17	228	16	68	20	238	7
	Broadl.	180	9	187	14	150	10	124	10	208	13	165	5
	All	423	14	388	17	489	16	353	17	277	23	403	8
>1200m	Conifer	204	20	282	71	335	18	308	9	215	15	292	7
	Broadl.	59	12	23	21	28	5	12	2	48	6	23	2
	All	263	21	306	77	363	18	320	9	263	15	315	7
Total	Conifer	208	10	185	9	332	12	284	7	130	11	241	4
	Broadl.	179	7	180	7	109	7	46	3	134	7	117	3
	All	387	9	364	9	440	11	330	7	265	11	358	4

Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2022 (GHGI 1990–2020)

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Supplement 1 to the report Didion et al. (2020): Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2021 (GHGI 1990–2019)

16 July 2021

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Commissioned by the Federal Office for the Environment FOEN

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Switzerland prepares annually a greenhouse gas inventory for reporting under the climate convention UNFCCC and the Kyoto Protocol (KP). The Land Use, Land-Use Change and Forestry (LULUCF) sector of the Swiss inventory includes, inter alia, data for the forest sector, encompassing amongst others C stocks and C stock changes (CSC) in above- and belowground biomass, dead organic matter, and soil.

In an effort to improve Switzerland's GHG accounting with regard to the criteria for transparency, consistency, comparability, completeness and accuracy. Since the previous submission (Didion et al. 2020; FOEN 2021), no methodological changes were implemented and no new NFI data were available. Compared to Didion et al. (2020; Figure 1) and FOEN (2021; Table 6-15), the time series of C stock and CSC was extended with estimates for the year 2020 (Table 1) for

- gains by assuming that they remained constant at the level of NFI34-5 2015-2019;
- losses by calculating a weighting factor for 2020 based on the harvest statistics data on harvested volume for 2020 and the mean of harvested volume in the period 2006-2019 (section 2.5 in Didion et al. 2020);
- stocks by adding gains and losses for 2020 to the stock estimate from 2019 (section 2.5 in Didion et al. 2020).

As the harvested volume increased in 2020 by 4% compared to 2019 (FSO 2021), losses increased correspondingly, and the rate of net change declined (Table 1). The estimated net change for productive forest (CC12) in Switzerland from 2019 to 2020 was a sink of 0.61 t C ha^{-1} yr^{-1} compared to a sink of 0.70 t C ha^{-1} yr^{-1} for 2018 to 2019.

Detailed information is available in (Didion et al. 2020) on the consistency with IPCC reporting criteria (section 1.1), the methodology (section 2) including verification and uncertainty estimation, and estimates of gains and losses (section 3).

Swiss Federal Institute for Forest,
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Table 1. Carbon stocks, losses (negative sign), gains (positive sign), and net change (negative sign indicating a source; positive sign indicating a sink) in living biomass for productive forest (CC12; see ch. 6.4.1 in FOEN 2021) stratified for NFI production region (NFI) and elevation zone (Elev.). See Table 6-15 in FOEN (2021) for data for 2019.

NFI	**elevation**	**Stock** [C ha^{-1}]		**Losses** [t C ha^{-1} yr^{-1}]		**Gains** [t C ha^{-1} yr^{-1}]		**Net change** [t C ha^{-1} yr^{-1}]	
		2019	2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
1	1	137.50	138.21	-2.52	-2.60	3.31	3.31	0.79	0.71
1	2	142.59	143.12	-2.56	-2.68	3.20	3.20	0.64	0.53
1	3	95.63	95.70	-1.80	-1.97	2.04	2.04	0.24	0.07
2	1	128.85	128.35	-4.40	-4.78	4.29	4.29	-0.11	-0.49
2	2	148.02	147.89	-4.61	-5.01	4.89	4.89	0.27	-0.13
2	3	148.02	147.89	-4.61	-5.01	4.89	4.89	0.27	-0.13
3	1	158.69	159.23	-3.43	-3.46	4.00	4.00	0.58	0.54
3	2	158.69	159.23	-3.43	-3.46	4.00	4.00	0.58	0.54
3	3	132.89	133.69	-1.44	-1.48	2.29	2.29	0.85	0.81
4	1	125.31	126.28	-1.79	-1.64	2.62	2.62	0.82	0.98
4	2	125.31	126.28	-1.79	-1.64	2.62	2.62	0.82	0.98
4	3	117.51	118.68	-0.95	-0.95	2.12	2.12	1.17	1.17
5	1	102.73	103.57	-1.98	-1.89	2.73	2.73	0.75	0.84
5	2	112.31	113.23	-1.26	-1.00	1.92	1.92	0.66	0.92
5	3	112.00	113.37	-1.09	-0.62	1.99	1.99	0.90	1.37
Switzerland		131.12	131.73	-2.32	-2.42	3.02	3.02	0.70	0.61

Swiss Federal Institute for Forest,
Snow and Landscape Research WSL

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Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2023 (GHGI 1990–2021)

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Supplement 2 to the report Didion et al. (2020): Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2021 (GHGI 1990–2019)

28 July 2022

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Commissioned by the Federal Office for the Environment FOEN

Swiss Federal Institute for Forest,
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Switzerland prepares annually a greenhouse gas inventory for reporting under the climate convention UNFCCC and the Kyoto Protocol (KP). The Land Use, Land-Use Change and Forestry (LULUCF) sector of the Swiss inventory includes, inter alia, data for the forest sector, encompassing amongst others C stocks and C stock changes (CSC) in above- and belowground biomass, dead organic matter, and soil.

In an effort to improve Switzerland's GHG accounting with regard to the criteria for transparency, consistency, comparability, completeness and accuracy. Since the previous submission (Supplement 1 in Didion et al. 2020; FOEN 2022), no methodological changes were implemented and no new NFI data were available. Compared to the supplemental data for the NIR submission 2022 in Didion et al. (2020; Table 1 in Supplement 1) and FOEN (2022; Table 6-15), the time series of C stock and CSC was extended with estimates for the year 2021 (Table 1) for

- gains by assuming that they remained constant at the level of NFI34-5 2015-2019;
- losses by calculating a weighting factor for 2021 based on the harvest statistics data on harvested volume for 2021 and the mean of harvested volume in the period 2006-2019 (section 2.5 in Didion et al. 2020);
- stocks by adding gains and losses for 2021 to the stock estimate from 2020 (section 2.5 and Supplement 1 in Didion et al. 2020).

As the harvested volume increased in 2021 by 4% compared to 2020 (FSO 2022), losses increased correspondingly, and the rate of net change declined (Table 1). The estimated net change for productive forest (CC12) in Switzerland from 2020 to 2021 was a sink of 0.51 t C ha^{-1} yr^{-1} compared to a sink of 0.61 t C ha^{-1} yr^{-1} for 2019 to 2020.

Detailed information is available in Didion et al. (2020) on the consistency with IPCC reporting criteria (section 1.1), the methodology (section 2) including verification and uncertainty estimation, and estimates of gains and losses (section 3).

Swiss Federal Institute for Forest,
Snow and Landscape Research WSL

Table 1. Carbon stocks, losses (negative sign), gains (positive sign), and net change (negative sign indicating a source; positive sign indicating a sink) in living biomass for productive forest (CC12; see ch. 6.4.1 in FOEN 2022) stratified for NFI production region (NFI) and elevation zone (Elev.) for the Swiss NIR 2023. See Table 6-15 in FOEN (2022) for data for 2020 and 2019/2020, respectively.

NFI	**elevation**	**Stock** [C ha^{-1}]		**Losses** [t C ha^{-1} yr^{-1}]		**Gains** [t C ha^{-1} yr^{-1}]		**Net change** [t C ha^{-1} yr^{-1}]	
		2020	2021	2019/2020	2020/2021	2019/2020	2020/2021	2019/2020	2020/2021
1	1	138.21	138.68	-2.60	-2.84	3.31	3.31	0.71	0.47
1	2	143.12	143.37	-2.68	-2.94	3.20	3.20	0.53	0.26
1	3	95.70	95.51	-1.97	-2.23	2.04	2.04	0.07	-0.20
2	1	128.35	128.04	-4.78	-4.59	4.29	4.29	-0.49	-0.31
2	2	147.89	147.96	-5.01	-4.82	4.89	4.89	-0.13	0.07
2	3	147.89	147.96	-5.01	-4.82	4.89	4.89	-0.13	0.07
3	1	159.23	159.34	-3.46	-3.89	4.00	4.00	0.54	0.11
3	2	159.23	159.34	-3.46	-3.89	4.00	4.00	0.54	0.11
3	3	133.69	134.33	-1.48	-1.66	2.29	2.29	0.81	0.64
4	1	126.28	127.09	-1.64	-1.81	2.62	2.62	0.98	0.80
4	2	126.28	127.09	-1.64	-1.81	2.62	2.62	0.98	0.80
4	3	118.68	119.76	-0.95	-1.04	2.12	2.12	1.17	1.08
5	1	103.57	104.13	-1.89	-2.17	2.73	2.73	0.84	0.56
5	2	113.23	113.99	-1.00	-1.16	1.92	1.92	0.92	0.76
5	3	113.37	114.63	-0.62	-0.74	1.99	1.99	1.37	1.25
Switzerland		131.73	132.24	-2.42	-2.51	3.02	3.02	0.61	0.51

References

Didion M, Thürig E, Rösler E (2020) Data on C stocks and C stock changes in above- and belowground tree biomass on forest land prepared for the Swiss NIR 2021 (GHGI 1990–2019). Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf. avl. online at http://www.climatereporting.ch

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