Calculation of emission factors for living biomass in Swiss forests prepared for the Swiss GHGI 2019 (1990–2017)

Documentation of data delivery and more recent data

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Summary

For the last two Swiss Greenhouse Gas Inventories (GHGI; FOEN 2017; FOEN 2018), forest emission factors for the years 2006 to 2016 were calculated based on data from National Forest Inventory (NFI) 3 (2004-2006) and NFI4 (2011 to 2015). For the most recent Swiss GHGI 1990-2017 (FOEN 2019), additional NFI4 data of the years 2016 and 2017 were available for calculating emission factors for the years 2006 to 2017. To restrict the reporting years to the most recent NFI, data of the years 2013 to 2017 were selected. Hence, the number of available sample plots for calculating emission factors remained approximately the same as for FOEN 2017 with 3211 plots or five years of data sampling. Differences between data for FOEN 2017 and FOEN 2019 are caused by both data and derivations inconsistencies for all NFI data, as well as by selecting the five most recent data years 2013 to 2017. Plausibility checks of single tree measurements and consistency checks of data derivations and data deliveries resulted in a very small decrease of biomass in growing stock for national estimates (-0.3%) and also only small changes of cut and mortality (+0.6%) and gross growth (+0.7%).

Most differences between NFI4 data for FOEN (2017) and FOEN (2019) are caused by the new data period 2013-2017 (FOEN 2019) compared to 2011-2015 in FOEN (2017). Overall, estimation of biomass in growing stock was 0.57 t ± 4.94 t per ha higher in the NFI 2013-2017 than in the NFI4 2011-2015. This is an increase of +0.22% ±2%. Cut and mortality decreased by -0.25 ± 0.32 t per ha and year mainly due to an decrease of losses in the Plateau. This is a decrease of -4.7% ± 3%. Gross growth decreased by -0.11 ± 0.12 t per ha and year mainly caused by an decrease of gross growth of deciduous trees in the Plateau and the Jura. This is a decrease of -1.8% ± 1%. However, most changes are within two standard errors or slightly above and therefore have to be interpreted with caution.

1   Introduction

Due to the continuous inventory approach implemented with the National Forest Inventory (NFI)4, the Swiss Greenhouse Gas Inventory (GHGI) can be provided with most recent forest data. For the Swiss GHGI 1990-2017 (FOEN 2019), forest emission factors for the years 2006 to 2017 were calculated based on data from the NFI3 (2004-2006) and NFI4 (2013-2017). The number of available sample plots for calculating emission factors was 3211. Forest emission factors for biomass in growing stock, cut and mortality and gross growth are linearly interpolated to an annual basis. This report describes and analyzes changes between the estimation of emission factors for the forestry sector reported in FOEN (2017, 2018) and FOEN (2019).

1.1   TCCCA criteria and verification: specific information for UNFCCC/KP reviewers

This report addresses the criteria for transparency, consistency, comparability, completeness and accuracy (TCCCA):

Transparency is achieved by detailing the various data sets that were used and by providing relevant metadata and references. The methodology is described and referenced in section 2, data sets are compared in section 3 and displayed in the appendix.

Consistency is obtained by relying on data sources that are measured and maintained in a consistent manner (Swiss NFI) and that will be available in the future (regulated by law). It was ensured that the methods were applied consistently and that results are reported correspondingly, including data per unit area, which are independent of temporal changes in the underlying forest area. See section 2.

Comparability is achieved by applying the default method of IPCC to report carbon stock changes by the difference of gains and losses.

Completeness is reached by calculating annual estimates since 1990 for standing stock, gains and losses for all forest regions in Switzerland defined for the GHGI (see section 2.1). Each of the NFIs (1, 2, 3 and 4) are representative random samples for the forest regions in Switzerland defined in the GHGI.

Accuracy is obtained by employing reliable and accurate data and a methodology reported in Brassel and Lischke (2001).

2   Data and methods

NFI4 data 2009-2013 are documented and published in Abegg et al. (2014). NFI 4 data including all data years 2009-2017 will be published early 2020. Metadata are available under http://www.lfi.ch/dienstleist/daten-en.php. The methods of data analysis are published in Brassel and Lischke (2001). Calculation of biomass is documented in Thürig and Herold (2013).

2.1   Spatial stratification

The NFI4 2013-2017 data include approximately 54% of all NFI4 plots of the accessible forest in Switzerland (3211 out of ca. 6000). Due to the large variability between sample plots, a minimum number of sample plots is needed to obtain reliable and representative estimates of means and sampling errors. Small strata did not include a sufficient number of plots (Table 1) and were merged with neighboring strata for the most recent GHGI (FOEN 2019). The following strata were aggregated and treated as single strata:

- Plateau 601-1200 and >1200: new stratum Plateau > 600 m (263 plots)
- Pre-Alps ≤ 600 and 601-1200 m: new stratum Pre-Alps ≤ 1200 m (368 plots)
- Alps West ≤ 600 and 601-1200 m: new stratum Alps West ≤ 1200 m (150 plots)
- Alps East ≤ 600 and 601-1200 m: new stratum Alps Est ≤ 1200 m (152 plots)

Table 1   Number of sample plots by spatial strata in NFI4 2013-2017.

Alt	Jura	Plateau	Pre-Alps	Alps West	Alps East	Southern Alps	Switzerland
≤ 600	132	362	19	11	6	57	587
601 - 1200	338	256	349	139	146	162	1390
>1200	73	7	212	338	389	215	1234
Total	543	625	580	488	541	434	3211

2.2   Time series consistency and accuracy

Data, data base and derivations of the Swiss NFI are continuously checked for plausibility and consistency and small inconsistencies are corrected. To guarantee time series consistency and accuracy, older data deliveries are always compared with the most recent data delivery. In this case, data delivered for FOEN (2017, 2018) were compared to recalculated data with the adjusted data base. Comparisons between recalculated data and data delivered for FOEN (2017, 2018) resulted in in a very small decrease of biomass in growing stock for national estimates (-0.3%) and also only small changes of cut and mortality (+0.6%) and gross growth (+0.7%). Those small changes result from the small adjustments and corrections of data and data derivations and substantiate the high consistency and accuracy of the time series.

2.3   Root-shoot ratio

For transparency, the root-shoot ratio of all reported categories is displayed in Table 2. Those root-shoot ratios are not used for calculation and only serve as metadata for transparency.

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Table 2 Root-shoot ratio of all reported categories.

Alt		Jura	Plateau	Pre-Alps	Alps	Southern Alps	CH
		%	%	%	%	%	%
≤ 600	Con	28	27	28	30	29	27
	Bro	18	17	19	22	26	18
	All	21	21	22	24	26	21
601 - 1200	Con	29	27	27	30	34	29
	Bro	19	16	19	23	30	20
	All	24	21	24	27	31	24
>1200	Con	34	34	32	34	36	34
	Bro	23	27	23	27	28	26
	All	31	34	31	34	34	33
Total	Con	30	27	29	34	35	31
	Bro	19	16	19	23	29	20
	All	24	21	26	32	32	27

3 Result

3.1 NFI data for FOEN 2019

NFI data delivered for FOEN 2019 are displayed in Table 2 to Table 4.

Table 3 Biomass of living trees 2013-2017 of the common and accessible forest area NFI 3/2013-2017. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

Alt		Jura	±	Plateau	±	Pre-Alps	±	Alp West	±	Alp East	±	Southern Alps	±	CH	±
		1000 kg/ha	%	1000 kg/ha	%	1000 kg/ha	%	1000 kg/ha	%	1000 kg/ha	%	1000 kg/ha	%	1000 kg/ha	%
≤ 600	Con	71.68	12	110.29	6	122.74	25	45.40	40	188.30	47	15.88	53	92.51	5
	Bro	193.23	8	148.13	6	157.12	22	156.80	25	36.13	38	164.57	8	159.01	4
	All	264.91	5	258.42	3	279.85	16	202.19	16	224.43	38	180.45	7	251.52	3
601 - 1200	Con	136.13	6	139.08	7	210.78	5	108.92	11	179.46	8	28.51	21	145.63	3
	Bro	138.80	5	151.23	7	116.92	7	91.00	14	80.88	11	193.83	10	130.97	3
	All	274.94	3	290.30	4	327.69	3	199.92	8	260.34	6	222.35	8	276.61	2
>1200	Con	151.30	9	156.41	17	205.40	5	212.94	4	201.68	4	142.76	6	192.17	2
	Bro	58.04	18	22.92	62	16.60	19	10.06	20	9.78	19	40.51	13	19.27	8
	All	209.34	7	179.33	19	222.00	5	222.99	4	211.46	4	183.27	5	211.43	2
Total	Con	123.13	5	122.64	4	205.82	4	179.60	4	195.58	4	81.98	7	153.62	2
	Bro	140.10	4	148.00	4	83.05	6	36.37	12	29.11	10	115.69	7	93.62	2
	All	263.24	2	270.63	2	288.87	2	215.96	3	224.70	3	197.67	4	247.24	1

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Table 4 Annual cut and mortality of living trees LFI3/2013-2017 in biomass, common and accessible forest area NFI 3/2013-2017. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%
≤ 600	Con	2.65	19	5.33	9	2.73	56	1.98	60	7.21	51	0.31	96	4.11	8
	Bro	4.54	15	4.03	12	4.33	35	2.38	49	5.06	90	3.82	15	4.11	8
	All	7.19	12	9.36	7	7.06	28	4.36	50	12.27	62	4.13	15	8.22	6
601 - 1200	Con	3.66	11	6.05	11	6.47	10	2.26	23	3.52	23	0.30	57	4.30	6
	Bro	2.08	13	3.97	14	2.14	16	1.79	32	1.53	32	1.29	17	2.27	7
	All	5.74	9	10.02	9	8.61	9	4.06	19	5.05	19	1.60	18	6.57	5
>1200	Con	2.95	28	2.58	37	3.05	22	2.39	17	2.21	14	0.99	24	2.25	9
	Bro	0.77	28	1.78	94	0.05	43	0.11	29	0.07	35	0.33	29	0.17	15
	All	3.71	24	4.36	45	3.10	22	2.50	16	2.28	14	1.32	19	2.42	8
Total	Con	3.32	9	5.60	7	5.13	9	2.35	14	2.61	12	0.63	22	3.48	4
	Bro	2.47	10	3.98	9	1.48	15	0.64	27	0.51	28	1.18	11	1.81	5
	All	5.79	7	9.58	5	6.62	8	2.98	12	3.13	12	1.81	10	5.29	3

Table 5 Annual gross growth of living trees LFI3/2013-2017 in biomass, common and accessible forest area NFI 3/2013-2017. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%
≤ 600	Con	2.07	14	4.16	6	3.30	26	1.26	39	4.46	45	0.30	71	3.24	5
	Bro	5.07	8	4.87	5	4.61	16	5.04	26	1.68	55	5.11	10	4.90	4
	All	7.15	6	9.03	3	7.91	10	6.30	20	6.14	21	5.41	10	8.14	2
601 - 1200	Con	3.45	6	4.84	7	5.49	5	2.37	11	3.28	8	0.52	25	3.78	3
	Bro	3.06	5	4.95	7	2.93	7	2.17	12	2.24	13	3.61	14	3.26	4
	All	6.51	3	9.78	4	8.42	3	4.53	7	5.52	7	4.13	12	7.04	2
>1200	Con	3.19	11	3.56	19	4.33	7	4.00	4	3.95	5	3.07	7	3.83	3
	Bro	1.08	20	0.60	60	0.41	19	0.23	23	0.28	18	0.79	17	0.43	9
	All	4.27	9	4.16	22	4.74	6	4.23	4	4.23	5	3.86	6	4.26	2
Total	Con	3.09	5	4.43	4	5.01	4	3.47	4	3.78	4	1.72	8	3.70	2
	Bro	3.25	5	4.85	4	2.10	6	0.89	11	0.82	11	2.46	9	2.48	3
	All	6.34	3	9.28	2	7.11	3	4.36	4	4.60	4	4.18	6	6.18	1

3.2 Comparison between NFI data 2011-2015 and 2013-2017

To analyze differences between data delivered for the FOEN 2017 and FOEN 2018 (NFI 2011-2015) and the FOEN 2019 (NFI 2013-2017), NFI data delivered for FOEN (2017,2018), shown in the Appendix (A1 to A3), were compared with the new data years 2013-2017 delivered for FOEN (2019),

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displayed in Table 3 to Table 5. Comparisons were done on the original level of 15 strata without aggregated strata (see Table 1).

Table 6 Biomass of living trees Difference of estimates between data delivery for FOEN 2017 and FOEN 2019. Positive numbers indicate an increase, negative number a decrease in the estimate for 2019 compared to 2017. The columns 'SE' contain twice the standard error which was estimated for the data prepared for the FOEN 2019. Green labeled figures indicates changes larger than twice the standard error. Except for the aggregated strata, the original biomass estimates are shown in Tables 2 and A1. Data are stratified by 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and conifers (Con) or broadleaved (Bro) trees.

Elevation		Jura 1000 kg/ha	± 2 SE	Plateau 1000 kg/ha	± 2 SE	Pre-Alps 1000 kg/ha	± 2 SE	Alp West 1000 kg/ha	± 2 SE	Alp East 1000 kg/ha	± 2 SE	Southern Alps 1000 kg/ha	± 2 SE	CH 1000 kg/ha	± 2 SE
≤ 600	Con	1.08	17	6.62	13	22.37	61	9.54	36	104.05	177	-0.02	17	6.03	9
	Bro	6.57	31	4.82	18	-27.70	69	-1.29	78	-136.42	27	-7.46	26	0.82	13
	All	7.65	26	11.44	16	-5.34	90	8.25	65	-32.37	171	-7.48	25	6.85	15
601 - 1200	Con	-2.43	16	-19.38	19	5.53	21	0.97	24	20.13	29	7.38	12	-2.20	9
	Bro	-1.42	14	7.99	21	9.50	16	1.54	25	1.68	18	12.03	39	5.76	8
	All	-3.84	16	-11.40	23	15.02	20	2.51	32	21.82	31	19.42	36	3.57	11
>1200	Con	-1.27	27	-22.35	53	-32.05	21	12.10	17	-9.71	16	-1.35	17	-5.03	8
	Bro	4.13	21	11.18	28	-9.67	6	-1.80	4	-0.56	4	6.87	11	-0.90	3
	All	2.85	29	-11.16	68	-41.73	22	10.29	18	-10.27	17	5.52	18	-5.94	8
Total	Con	-0.71	12	-5.48	10	-6.31	16	8.10	14	0.02	16	-4.05	11	-1.90	6
	Bro	-0.10	11	6.61	12	0.34	10	-0.24	9	-2.10	6	14.07	16	2.47	4
	All	-0.81	11	1.12	11	-5.97	12	7.85	13	-2.07	13	10.02	16	0.57	5

The difference between the estimate of biomass in growing stock for FOEN 2019 (based on NFI 2013-2017) and FOEN 2017 (based on NFI4 2011-2015) was generally closely within two standard errors of the values for the FEON 2017 (Table 6). However, differences may indicate trends in the development of growing stocks. Coniferous growing stocks in the Plateau and in the Pre-Alps decrease. Overall, estimation of biomass in growing stock was 0.57 t ± 4.94 t per ha (2SE) higher in the NFI 2013-2017 than in the NFI 2011-2015. This is a plus of +0.22% ±2%.

The difference between the estimate of biomass in cut and mortality for FOEN 2019 (based on NFI 2013-2017) and FOEN 2017 (based on NFI 2011-2015) was generally closely within two standard errors of the values for the FOEN 2019 (Table 7). However, in the Plateau, cut and mortality significantly decreased. Also in Jura and Southern Alps, cut and mortality decreased. Overall, cut and mortality decreased by -0.25 ± 0.32 t biomass per ha and year mainly due to an decrease of losses in the Plateau and the Southern Alps.

The difference between the estimate of biomass in gross growth for FOEN 2019 (based on NFI 2013-2017) and FOEN 2017 (based on NFI4 2011-2015) was generally within two standard errors of the values for the FOEN 2019 (Table 8). Gross growth decreased by -0.11 ± 0.12 t per ha and year. This is mainly due to a significant decrease of coniferous gross growth in the Plateau between 600 and 1200 m. In the other areas, gross growth was quite stable.

Table 7 Annual cut and mortality in biomass Difference of estimates between data delivery for FOEN 2017 and FOEN 2019. Positive numbers indicate an increase, negative number a decrease in the estimate for 2019 compared to 2017. The

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columns 'SE' contain double the standard error which was estimated for the data prepared for the FOEN 2019. Green labeled figure indicates changes larger than twice the standard error. Except for the aggregated strata, the original biomass estimates are shown in Tables 3 to and A2. Data are stratified by 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE
≤ 600	Con	-0.42	1.01	-0.59	0.96	0.50	3.06	-0.43	2.38	2.55	7.35	-0.02	0.59	-0.42	0.66
	Bro	0.06	1.36	-1.12	0.97	1.24	3.03	0.96	2.33	0.74	9.10	0.11	1.15	-0.58	0.66
	All	-0.36	1.73	-1.70	1.31	1.74	3.95	0.53	4.36	3.30	15.21	0.09	1.24	-1.00	0.99
601 - 1200	Con	-0.41	0.81	-0.58	1.33	0.04	1.29	0.36	1.04	-0.10	1.62	-0.45	0.34	-0.31	0.52
	Bro	-0.39	0.54	0.31	1.11	-0.03	0.69	-0.06	1.15	-0.02	0.98	-0.03	0.44	-0.08	0.32
	All	-0.80	1.03	-0.27	1.80	0.01	1.55	0.32	1.54	-0.12	1.92	-0.46	0.57	-0.39	0.66
>1200	Con	1.69	1.65	1.22	1.91	0.44	1.34	0.13	0.81	0.08	0.62	-0.06	0.47	0.26	0.40
	Bro	0.24	0.43	1.78	3.35	-0.06	0.04	-0.01	0.06	0.00	0.05	-0.01	0.19	0.01	0.05
	All	1.92	1.78	3.00	3.92	0.38	1.36	0.12	0.80	0.08	0.64	-0.07	0.50	0.26	0.39
Total	Con	-0.14	0.60	-0.55	0.78	0.18	0.92	0.18	0.66	0.04	0.63	-0.23	0.28	-0.12	0.28
	Bro	-0.23	0.49	-0.46	0.72	-0.02	0.45	0.03	0.34	-0.02	0.29	0.08	0.26	-0.13	0.18
	All	-0.37	0.81	-1.02	0.96	0.16	1.06	0.20	0.72	0.03	0.75	-0.14	0.36	-0.25	0.32

Table 8 Annual gross growth of living trees in biomass Difference of estimates between the data delivery for FOEN 2017 and FOEN 2019. Positive numbers indicate an increase, negative number a decrease in the estimate for 2019 compared to 2017. The columns 'SE' contain double the standard error which was estimated for the data prepared for the FOEN 2019. Green labeled figure indicates changes larger than twice the standard error. Except for the aggregated strata, the original biomass estimates are shown in Tables 4 and A3. Data are stratified by 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE	1000 kg/ha	± 2 SE
≤ 600	Con	-0.32	0.58	0.19	0.50	0.70	1.71	-0.17	0.98	1.67	4.01	0.01	0.42	0.08	0.32
	Bro	-0.07	0.81	-0.19	0.49	-0.67	1.48	0.97	2.62	-1.16	1.85	0.37	1.02	-0.11	0.39
	All	-0.38	0.86	0.00	0.54	0.03	1.58	0.81	2.52	0.51	2.58	0.38	1.08	-0.03	0.33
601 - 1200	Con	-0.26	0.41	-0.70	0.68	0.06	0.55	-0.52	0.52	0.14	0.53	0.15	0.26	-0.27	0.23
	Bro	0.04	0.31	0.51	0.69	0.11	0.41	0.15	0.52	0.28	0.58	-0.35	1.01	0.13	0.26
	All	-0.23	0.39	-0.20	0.78	0.17	0.51	-0.37	0.63	0.42	0.77	-0.20	0.99	-0.14	0.28
>1200	Con	0.01	0.70	-0.31	1.35	-0.49	0.61	-0.02	0.32	-0.09	0.40	-0.03	0.43	-0.11	0.23
	Bro	0.04	0.43	0.58	0.72	-0.11	0.16	-0.04	0.11	-0.02	0.10	0.19	0.27	0.01	0.08
	All	0.06	0.77	0.27	1.83	-0.60	0.57	-0.06	0.34	-0.11	0.42	0.17	0.46	-0.11	0.17
Total	Con	-0.22	0.31	-0.21	0.35	-0.10	0.40	-0.17	0.28	0.00	0.30	-0.09	0.28	-0.15	0.15
	Bro	-0.03	0.33	0.13	0.39	-0.03	0.25	0.05	0.20	0.03	0.18	0.20	0.44	0.04	0.15
	All	-0.25	0.38	-0.08	0.37	-0.13	0.43	-0.12	0.35	0.04	0.37	0.10	0.50	-0.11	0.12

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3.3 Uncertainty

Total uncertainty of net carbon stock change in living biomass in terms of carbon per unit area ($U_{liv.biom.}$) arises from different sources: 1) sampling error of measured NFI data (Köhl 1994) to estimate gains and losses in stem wood over bark from the NFI, 2) whole-tree biomass estimation, incl. biomass expansion, 3) variability in carbon content, and 4) variation in wood density. $U_{liv.biom}$ is calculated as the sum of the single uncertainty components. In this report, we calculate the uncertainty of the random sample gains and losses in stem wood over bark. The other components are calculated in the most recent FOEN 2017. Total $U_{liv.biom}$ is calculated by adding all *relative uncertainties* following equation 6.4 in chapter 'Quantifying Uncertainties in Practice' (IPCC 2000).

In Switzerland, gains and losses are estimated as random variables from the NFI. The uncertainty of gains and losses in stem wood over bark is approximated by sampling theory as the sample variance of the NFI plots (Brassel and Lischke 2001). Net change of stem wood over bark is calculated as the difference between gains and losses. The uncertainty of the two combined random variables is calculated by the law of error propagation (Eq. 1).

$$SE_{gains - losses} = (SE_{gains}^2 + SE_{losses}^2)^{0.5}$$ <div align="right">Eq. 1</div>

where SE_{gains} and SE_{losses} are in absolute values. Absolute estimates for standing stock and its Standard Errors (SE) can be calculated from Abegg et al. 2014:

Absolute values of *gains* = 8.95 +- 2% = *8.95 ± 0.179 m^3 ha^{-1} $year^{-1}$*

Absolute values of *losses*: 7.64 +- 4% =   *7.64 ± 0.306 m^3 ha^{-1} $year^{-1}$*

The net carbon stock change in stem wood over bark is calculated as the difference between gains and losses and results in 1.31 m^3 stem wood over bark per ha and year. The uncertainty of this estimate can be calculated with Eq. 1.

$$SE_{gains - losses} = (0.179^2 + 0.306^2)^{0.5} = ±0.35 \ m^3 \ ha^{-1} year^{-1}$$

Equation 1 assumes the random variables gains and losses to be independent. This may results in an overestimation of the error estimation. However, this is partly compensated by disregarding model errors in the estimation of stem wood volumes from the measured dbh, d7 and tree height.

In FOEN 2017, uncertainties of all four components are combined by adding *relative uncertainties* following equation 6.4 in chapter 'Quantifying Uncertainties in Practice' (IPCC 2000). Relative uncertainty is calculated as the ratio of $SE_{gains - losses}$ (±0.35 m^3 ha^{-1} $Jahr^{-1}$) and the absolute sink value (1.31 m^3 ha^{-1} $Jahr^{-1}$). This results in a relative uncertainty of the estimation of net carbon stock change in stem wood over bark of ±27%.

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4 Literature

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Appendix

Data delivery FOEN 2017

A1 Biomass of living trees 2011-2015 of the common and accessible forest area NFI 3/2011-2015. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%
≤ 600	Con	70.6	12	103.67	6	100.37	24	35.86	41	84.25	48	15.9	59	86.48	6
	Bro	186.66	8	143.31	6	184.82	22	158.08	22	172.55	45	172.03	9	158.19	4
	All	257.26	5	246.98	4	285.19	14	193.94	18	256.8	34	187.93	8	244.67	3
601 - 1200	Con	138.56	6	158.46	6	205.25	5	107.95	11	159.33	8	21.13	24	147.83	3
	Bro	140.22	5	143.24	7	107.42	7	89.46	15	79.2	11	181.8	11	125.21	3
	All	278.78	3	301.7	4	312.67	3	197.41	8	238.52	6	202.93	10	273.04	2
>1200	Con	152.57	8	178.75	17	237.45	5	200.84	5	211.39	4	144.11	6	197.2	2
	Bro	53.91	16	11.74	46	26.27	18	11.86	19	10.34	20	33.64	14	20.17	8
	All	206.49	6	190.48	15	263.73	5	212.7	4	221.73	4	177.75	5	217.37	2
Total	Con	123.84	5	128.12	5	212.13	4	171.5	4	195.56	4	86.03	7	155.52	2
	Bro	140.2	4	141.39	5	82.71	6	36.61	12	31.21	10	101.62	8	91.15	3
	All	264.05	2	269.51	3	294.84	3	208.11	4	226.77	3	187.65	4	246.67	1

A2 Annual cut and mortality of living trees LFI3/2011-2015, common and accessible forest area NFI 3/2011-2015. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

		Jura		Plateau		Pre-Alps		Alp West		Alp East		Southern Alps		CH	
Alt		1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	±%	1000 kg/ha	± %	1000 kg/ha	±%	1000 kg/ha	±%
≤ 600	Con	3.07	20	5.92	11	2.23	38	2.41	55	4.66	66	0.33	99	4.53	9
	Bro	4.48	15	5.15	12	3.09	42	1.42	60	4.32	108	3.71	18	4.69	9
	All	7.55	12	11.06	8	5.32	28	3.83	51	8.97	85	4.04	18	9.22	6
601 - 1200	Con	4.07	11	6.63	11	6.43	10	1.90	28	3.62	21	0.75	86	4.61	6
	Bro	2.47	15	3.66	15	2.17	18	1.85	34	1.55	29	1.32	19	2.35	8
	All	6.54	10	10.29	9	8.60	9	3.74	22	5.17	17	2.06	33	6.96	5
>1200	Con	1.26	31	1.36	42	2.61	20	2.26	16	2.13	16	1.05	26	1.99	9
	Bro	0.53	35	0.00	.	0.11	49	0.12	39	0.07	33	0.34	32	0.16	17
	All	1.79	27	1.36	42	2.72	19	2.38	16	2.20	15	1.39	21	2.16	9
Total	Con	3.46	10	6.15	8	4.95	9	2.17	14	2.57	13	0.86	31	3.60	4
	Bro	2.70	11	4.44	9	1.50	17	0.61	28	0.53	26	1.10	13	1.94	6
	All	6.16	8	10.60	6	6.46	8	2.78	13	3.10	12	1.95	15	5.54	4

A3 Annual gross growth of living trees LFI3/2011-2015, common and accessible forest area NFI 3/2011-2015. Data are stratified for 5 NFI-regions, 3 elevation levels (meter above sea level from DEM25) and for conifers (Con) or broadleaved (Bro) trees.

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Alt		Jura 1000 kg/ha	±%	Plateau 1000 kg/ha	±%	Pre-Alps 1000 kg/ha	±%	Alp West 1000 kg/ha	±%	Alp East 1000 kg/ha	±%	Southern Alps 1000 kg/ha	±%	CH 1000 kg/ha	±%
≤ 600	Con	2.39	13	3.97	6	2.60	33	1.43	41	2.79	39	0.29	82	3.16	6
	Bro	5.14	8	5.06	6	5.28	20	4.07	36	2.84	49	4.74	11	5.01	4
	All	7.52	5	9.03	3	7.88	14	5.49	24	5.63	41	5.03	11	8.17	3
601 - 1200	Con	3.71	6	5.54	6	5.43	5	2.88	13	3.14	9	0.37	24	4.05	3
	Bro	3.02	6	4.44	7	2.82	8	2.02	17	1.96	13	3.96	15	3.13	4
	All	6.73	4	9.98	4	8.25	4	4.90	9	5.10	7	4.33	13	7.18	2
>1200	Con	3.18	9	3.87	11	4.82	7	4.02	5	4.04	5	3.10	9	3.94	3
	Bro	1.04	22	0.02	425	0.52	20	0.27	21	0.30	18	0.60	27	0.42	10
	All	4.21	8	3.89	10	5.34	7	4.29	5	4.34	5	3.69	8	4.37	3
Total	Con	3.31	5	4.64	5	5.11	4	3.64	5	3.78	5	1.81	9	3.85	2
	Bro	3.28	5	4.72	4	2.13	7	0.84	14	0.79	11	2.26	11	2.44	3
	All	6.59	3	9.36	3	7.24	3	4.48	4	4.56	4	4.08	6	6.29	1