DRAFT. SC19 – Biomass country report. SLOVENIA

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1. Biomass estimation methods and data

1.1 National Forest Inventory sampling description

The data used to estimate Slovenian forest biomass are taken from the 3rd circle of national forest inventory (NFI3) (2000, 2007 and 2012). The 4rd Slovenian National Forest Inventory (NFI4) was finished in 2018. In the NFI3 field sampling locations were systematically distributed over the forest area on the sampling grid 4 km x 4 km. Out of 1,268 locations, 760 locations were within the forest, from 760 plots 746 were measured directly on the field while 14 plots were located within an inaccessible terrain. For those plots, the assessment of the tree number, basal area, and growing stock was done through stereo photo interpretation.

Slovenian field plots consist of four circular concentric fixed areas with radius of 3.09 m (0.3 acre), 7.98 m (2.0 acre), 13.82 m (6.0 acre) and 25.23 m (20 acre). The live standing trees are measured on 6.0-acre circle. On 6.0 acre, trees with diameter at breast height (dbh) $\geq$ 30 cm are measured; on 2.0-acre concentric circle, trees with dbh $\geq$ 10 cm are measured; and on the 0.3-acre concentric circle, all trees with 0 cm < dbh < 10 cm and height $\geq$ 1.3 m are measured. The 20-acre plot is used only for measuring of deadwood biomass and for the stand assessments (Kovač, et al. 2014).

All plots of one NFI cycle are measured within one year. To define the stratum and the forest area in first stage the national land use map is used (MKGP 2018) and in second stage all locations that are near the forest border are visually checked based on the photointerpretation of the latest orthophoto images.

Based on the national legislation (Zakon o gozdovih [Act on Forests] Ur. l. RS nr. 30/1993) forest is (a) a plot of land overgrown with forest trees in the form of stands, which can reach a height of at least 5 m and sized to at least 0.25 ha; (b) A plot of agricultural land in transition to forest land sized to at least 0.25 ha that has not been used for agriculture for the last 20 years and is overgrown with forest trees which can reach a height of at least 5 m and their crown cover should be at least 75% (c) Riverside forest corridors and windbreaks sized to at least 0.25 ha, if their widths are at least one tree-height.

1.2 Methods to derive national and harmonized biomass

In 2012 the estimation of growing stock included stem volume of living trees with dbh >= 10.0 cm over bark, including the bole (wood and bark) up to a stem top diameter of 7.0 cm, and excluding the above-ground part of the stump. Branches with a minimum diameter of 7.0 cm are included. Only standing live trees are included in the growing stock. The estimated growing stock refers to all forest land including inaccessible locations and poorly productive forests.

For estimation of the growing stock volume, the Slovenian NFI applies tariff functions at the individual tree level. The tariffs of Algan (1901), Čokl (1957,1959) and Schaeffer (1949) are used. The tariff functions were adapted to Slovenian forest conditions with data that were collected in 1970. The coefficients of the tariff functions were estimated by Čokl (1959). The selection of tariffs depends on several factors, such as tree species, site quality classes and stand form (i.e. even-aged, uneven-aged and intermediate). The tariff class is determined with tables that are available for different tree species and stand types. As entries to the table the median dbh-class of the growing stock of the stand is

located and the mean height of the stand are used. To estimate the mean stand height a sub-sample of sample trees is measured. No height curve models are applied.

Table 1. Definitions of above-ground biomass used in SC19 and regularly by the Slovenian NFI.

Term	Definition	
Above-ground biomass	SC19	Biomass of living trees with a dbh > 0 cm, including the stem from ground level to the top, all branches (living and dead) and the foliage.
	Slovenian NFI	Biomass of living trees with a dbh ≥ 10.0 cm (in this study including trees with dbh between 0 and 10 cm), including the stem from stump level to the stem top (< 7 cm) and living branches ≥ 7 cm. For other tree compartments the biomass expansion factors were used.

Currently, there is no official national definition of forest biomass. For the Slovenia's National Inventory Report 2018 (GHG emissions inventories 1986 – 2016) the definition of biomass is the same as in this report (Table 1). However, in this study for the national volume and biomass also the trees with the dbh between 0 and 10 cm were included. Due to this reason the reporting national biomass is higher.

National biomass is calculated based on the volume estimate (VOB) of the individual tree and multiplied with factors for volume-weighted average wood density (WD) and biomass expansion factor (BEF) (Table 2). VOB was calculated based on the methodology described above (tariff functions). The VOB includes volume of stems (dbh ≥ 10 cm) and volume of large branches (≥ 7 cm). Due to increased VOB (including branches) the lower biomass expansion factor (BEF) coefficient was used for the calculation of AGB (BEF in IPPC 2003 for temperate forests ranges between 1.15 and 4.20) (Table 2) (Aalde, et al. 2006).

Table 2: Parameters (WD and BEF) used for selected tree species for biomass calculations

Common name	WD	BEF
	t/m^3	dimensionless
Spruce	0.400	1.15
Beech	0.584	1.15
Fir	0.394	1.15
Oak	0.580	1.15
Scotch Pine	0.420	1.15
Maple	0.520	1.15
Hornbeam	0.630	1.15
Chestnut	0.480	1.15
Black Pine	0.420	1.15
Hop Hornbeam	0.630	1.15
Remaining	0.497	1.15

Reference definition (SoEF) of aboveground biomass (AGB) (here in also "harmonised biomass" SC 19 – e-forest) includes: foliage and seeds, stump, stem (from trees of 0 cm dbh to 10 cm) and stem top. Main differences between the current national and reference definitions are therefore trees from 0 to 10 cm dbh, stump, stem top, branches < 7 cm, foliage and seeds.

The gaps to estimate reference biomass estimates were covered using the following bridges:

1. Estimation of the volume of branches ≥ 7 cm.
2. Estimation of the volume of stumps.
3. Estimation of volume of stem top.
4. Estimation of volume of trees with 0 < dbh < 10 cm.
5. The biomass of branches (including dead) and foliage was calculated based on the functions from literature.

For tree stem, stem top, stump and small trees first the volume was calculated (VOB – volume estimates) and later based on the WD (Table 3) the biomass. For the calculation of branches and foliar biomass the direct functions were used (see the description below).

Table 3: Updated parameters of WD used for selected tree species for biomass calculations

Common name	WD
	t/m^3
Spruce	0.400
Beech	0.584
Fir	0.394
Oak	0.580
Scotch Pine	0.420
Maple	0.520
Hornbeam	0.630
Chestnut	0.480
Black Pine	0.420
Hop Hornbeam	0.630
Alder	0.450
Ash	0.570
Larch	0.460
Other broadleaves	0.580
Other coniferous	0.400

Ad 1: Branches ≥ 7 cm: National tree volume estimation (VOB) includes the volume of stem + bark and also the volume of branches ≥ 7 cm. To get the volume estimation only for the stem + bark for broadleaves the volume of branches ≥ 7 cm was deducted. The volume of thick branches was calculated based on the Austrian NFI function presented by Gschwantner et al. (2019,2006).

$V_{branches\_d>=7cm} = a*dbh^b$ Eq. 1

Ad 2: Stump: For the calculation of volumes of stumps for all species the functions from Austrian NFI were used (Gschwantner, et al. 2019). The average height of the stumps for main tree species was calculated from the NFI deadwood database (including only the height of fresh stumps).

$V_{stump} = a*dbh^b*h_{stump}^c$ Eq. 2

Ad 3: Stem top: Also, for the calculation of volume of stem top the functions from Austrian NFI were used (Gschwantner, et al. 2019).

$V_{stemtop\_d<=7cm} = a*dbh^b$ Eq. 3

$V_{stemtop\_d<=7cm}/V_{stem\_total} = a*1/dbh^b$ Eq. 4

Ad 4: Small trees: Estimation of volume of trees with 0 < dbh < 10 cm was calculated based on the NFI data. Within 0.3-acre plot the dbh and height of those trees is measured, and the volume could be calculated and reported.

Ad 5: Branches and foliage: For the calculation of biomass for branches and foliage the functions of naighbouring countries were applayed. Eckmüllner (2006) presented functions for biomass estimation of branches and needles for spruce and scots pine, while Rubatscher (2006) for larch. The functions don't include the volume of dead branches and for this reason the Italian correction factors were used (1.025 for spruce, 1.036 for pine and 1.026 for larch) to increase the biomass of branches. Ledermann and Neumann (2006) presented the functions to calculate the biomass of branches for fir, beech, oak and hornbeam. For fir the function includes the biomass of needles and dead branches. For beech, oak and hornbeam only the biomass of live and dead branches is included. To calculate the biomass of leaves for those three tree species the BH values were calculated based on the Montero et al. (2005). To all other remaining tree species, the same functions were applied (described above). The function of trees species was selected based on the similar crown (habitus) structure. For example the scotch pine function (Eckmüllner 2006) was applied also for black pine.

1.3 Processing of data in SC19

1.3.1. Selection of plots

In 2012 on sampling grid 4 x 4 km in total 760 plots were in forest land. Within this study 746 have been used. 14 plots are located in very steep terrain and could not be measured by the field teams. For those plots we have only assessment of total growing stock, basal area and number of trees. Those parameters were assessed using stereo photointerpretation of aerial images. Due to this there is no tree species information available for those plots and for this reason they are not included into the study.

For the decision if plot is located within forest or not National land use map was used (MKGP 2018). The map is in shp format and it is updated parallel with the availabilities of new aerial images. To avoid the map digitalisation errors all locations for which the digitalised line of forest border was in the radii of 100 m were checked on the aerial images and based on the national definition of forest (see chapter 1.1) location was characterised as forest or no forest.

1.3.2. The dataset

The dataset used from each plot are plot coordinates, NUTS (terrestrial units for statistics), species, volume and biomass. The theoretical coordinates are shifted to the INSPIRE grid cell. Each plot has also its Global Positioning location (GPS). The accuracy of coordinates varies between plots due to the different GPS signal quality and different GPS devices.

Based on the 2012 NFI survey the estimation of total growing stock in Slovenian forests was 405 ± 17 million m³, growing stock per hectare was 333.7 ± 13.6 m³/ha and the most important tree species (% of growing stock) were: *Picea abies* (31.1 %), *Fagus sylvatica* (31.1 %), *Abies alba* (7.4 %), *Quercus petraea* (5.6 %), *Pinus sylvestris* (4.4 %), *Acer pseudoplatanus* (3.3%), *Carpinus betulus* (2.3 %), *Castanea sativa* (1.6 %), *Pinus nigra* (1.6 %) and *Ostrya carpinifolia* (1.5 %).

In total for the 2012 NFI 45 different tree species were reported. In the category "other broadleaves" and "other coniferous" 26 individual trees were included. For those trees the information on tree species is not available. The list of tree species with at least 100 individual trees in the NFI 2012 database are shown in the Table 4.

Table 4. List of tree species with at least 100 trees in the Slovenian NFI3

Species	Number of trees in NFI database 2012
Fagus sylvatica	3866
Picea abies	3047
Abies alba	671
Quercus petraea	621
Carpinus betulus	546
Pinus sylvestris	520
Ostrya carpinifolija	496
Acer pseudoplatanus	455
Pinus nigra	283
Castanea sativa	275
Quercus cerris	180
Fraxinus ornus	163
Fraxinus excelsior	137
Alnus glutinosae	134
Robinia pseudoacacia	110
Tilia cordata	107
Larix decidua	100

1.3.3. Derivation of NUTS Region codes for the plot data

The NUTS selected to obtain the estimates are at level 3. The used NUTS classification is from year 2016 (version date 1.1.2018) downloaded as shp file from this location:

(https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts)

Slovenia is divided on two NUTS2 regions (East Slovenia and West Slovenia) and on 12 NUTS3 regions (Figure 1 and Table 4). Due to low number of sampling points on 4 x 4 km grid only the NUTS2 regions are used in this analysis. Together there were 453 NFI plots in eastern Slovenia (SI03) and 307 NFI plots in western Slovenia (SI04) (Table 4).

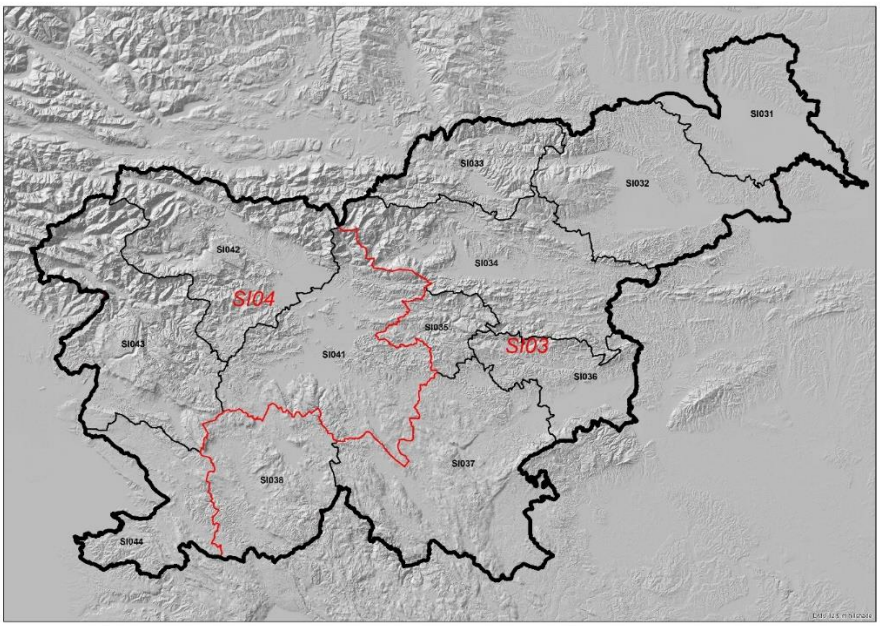


Figure 1. NUTS3 (black) and NUTS2 (red) regions in Slovenia.

Table 5. NUTS3 Region codes considered for this analysis

Country Code	NUTS2 code	NUTS3 code	NUTS3 label	Nr. of plots 4 x 4 km grid	Nr. of forest plots 2012 4 x 4 km grid
SI	SI04	SI044	Obalno-kraska	62	34
SI	SI04	SI043	Goriska	144	103
SI	SI04	SI042	Gorenjska	133	90
SI	SI04	SI041	Osrednjeslovenska	145	80
SI	SI03	SI038	Primorsko-notranjska	92	72
SI	SI03	SI037	Jugovzhodna Slovenija	171	123
SI	SI03	SI036	Posavska	63	36
SI	SI03	SI035	Zasavska	29	17
SI	SI03	SI034	Savinjska	143	84
SI	SI03	SI033	Koroska	65	49
SI	SI03	SI032	Podravska	138	50
SI	SI03	SI031	Pomurska	83	22

2. Presentation of biomass estimates

The forest biomass estimates were calculated for NUTS2 regions and additionally for main tree species groups. Stratification for NUTS2 regions and not for NUTS3 regions was chosen due to low number of NFI plots in Slovenia (4 km x 4 km systematic grid has 760 plots). The biomass was calculated based on the currently used national biomass definition and based on the harmonized biomass definition (Table 1). Additionally, the calculations were done using both the national estimation method and e-Forest estimation method. Results were also calculated and delivered by species, but due to the large number of species, results are summarized in report to the agreed species groups (Table 6). The number of species (taxon) included in each defined species group for this report is shown in Table 4.

Table 6. Number of species present in the 2012 Slovenian NFI included in each defined species group

Species group	Number of present species (taxon) in Slovenian NFI
Abies sp.	1
Acer sp.	5
Alnus sp.	2
Betula sp.	1
Carpinus sp.	1
Castanea sp.	1
Eucalyptus sp.	0
Fagus sp.	1
Fraxinus sp.	3
Larix sp.	1
Other broadleaves	17
Other conifers	2
Picea sp.	1
Pinus halepensis	0
Pinus nigra	1
Pinus pinaster-pinea	0
Pinus sp.	1
Pinus sylvestris	1
Populus sp.	2
Pseudotsuga menziesii	1
Quercus robur-petraea-rubra	3
Quercus section Cerris-Mesobalanus	1
Quercus section Lepidobalanus	1
Quercus sp.	1
Quercus suber	0
Salix sp.	1

2.1 National estimates by NUTS regions and agreed species groups

The National estimates results obtained using both the national estimates and the E-Forest system are shown in Table 7 for NUTS2 regions and in Table 8 for selected tree species groups. In Table 8 the selected tree species were grouped based on the draft defined within SC13. Not all of the tree species from the list are present in the Slovenian forests and those tree species have been moved to the bottom of the table. The same applies for the Table 10 in next section.

Table 7. Biomass of trees (total in million metric tons and mean in metric tons per ha) in forests by NUTS 2 using: a) National definition and calculation system b) National definition and E-Forest estimator.

NUTS CODE	NUTS LABEL	Trees biomass according to the National definition and calculation system		Trees biomass according to the National definition and E-Forest system	
		Total (Mt)	Mean (t/ha)	Total (Mt)	Mean (t/ha)
SI03	Eastern Slovenia	149.79	206.83	149.79	206.83
SI04	Western Slovenia	83.48	170.10	83.48	170.10

Table 8. Biomass of trees (total in million metric tons and mean in metric tons per ha) in forests by species using: a) National definition and calculation system b) National definition and E-Forest estimator.

Species group	Trees biomass according to the National definition and calculation system		Trees biomass according to the National definition and E-Forest system	
	Total (Mt)	Mean (t/ha)	Total (Mt)	Mean (t/ha)
Abies sp.	13.69	11.27	13.69	11.27
Acer sp.	9.09	7.48	9.09	7.48
Alnus sp.	2.32	1.91	2.32	1.91
Betula sp.	0.93	0.77	0.93	0.77
Carpinus sp.	7.12	5.86	7.12	5.86
Castanea sp.	3.69	3.04	3.69	3.04
Fagus sp.	85.81	70.63	85.81	70.63
Fraxinus sp.	3.64	2.99	3.64	2.99
Larix sp.	2.14	1.76	2.14	1.76
Other broadleaves	11.82	9.72	11.82	9.72
Other conifers	0.11	0.09	0.11	0.09
Picea sp.	58.19	47.90	58.19	47.90
Pinus nigra	3.20	2.63	3.20	2.63
Pinus sp.	0.63	0.52	0.63	0.52
Pinus sylvestris	0.60	0.50	8.52	7.01
Populus sp.	0.68	0.56	0.68	0.56
Pseudotsuga menziesii	0.62	0.51	0.62	0.51
Quercus section Cerris-Mesobalanus	2.51	2.06	2.51	2.06
Quercus section Lepidobalanus	0.59	2.48	0.59	2.48
Quercus robur-petraea-rubra	17.45	14.36	17.45	14.36
Quercus sp.	0.08	0.06	0.08	0.06
Salix sp.	0.44	0.37	0.44	0.37
Eucalyptus sp.	0	0	0	0
Pinus halepensis	0	0	0	0
Pinus pinaster-pinea	0	0	0	0
Quercus suber	0	0	0	0

The estimates between both calculation systems (national calculation system and E-forest estimator) don't differ. In national calculation system the average biomass is calculated from the total plot biomass and the number of plots in each stratum. The forest area estimation is used for the calculation of total biomass.

2.2 Harmonised estimates by NUTS regions and agreed species groups

The harmonized estimates results obtained using both the national estimates and the E-Forest systems are shown in Table 9 (NUTS2) and Table 10 (species groups).

Table 9. Biomass of trees (total in million metric tons and mean in metric tons per ha) in forests by NUTS 2 using: a) Harmonized definition and national calculation system b) Harmonized definition and E-Forest estimator.

NUTS CODE	NUTS LABEL	Trees biomass according to the harmonized definition and calculation system		Trees biomass according to the harmonized definition and E-Forest system	
		Total (Mt)	Mean (t/ha)	Total (Mt)	Mean (t/ha)
SI03	Eastern Slovenia	176.22	243.33	176.22	243.33
SI04	Western Slovenia	99.54	202.82	99.54	202.82

Table 10. Biomass of trees (total in million metric tons and mean in metric tons per ha) in forests by species using: a) Harmonized definition and calculation system b) National definition and E-Forest estimator.

Species group	Trees biomass according to the Harmonized definition and calculation system		Trees biomass according to the Harmonized definition and E-Forest system	
	Total (Mt)	Mean (t/ha)	Total (Mt)	Mean (t/ha)
Abies sp.	15.76	12.97	15.76	12.97
Acer sp.	11.04	9.09	11.04	9.09
Alnus sp.	3.29	2.71	3.29	2.71
Betula sp.	1.43	1.18	1.43	1.18
Carpinus sp.	9.33	7.68	9.33	7.68
Castanea sp.	4.54	3.74	4.54	3.74
Fagus sp.	96.64	79.54	96.64	79.54
Fraxinus sp.	5.17	4.26	5.17	4.26
Larix sp.	2.05	1.69	2.05	1.69
Other broadleaves	17.09	14.07	17.09	14.07
Other conifers	0.11	0.09	0.11	0.09
Picea sp.	71.96	59.22	71.96	59.22
Pinus nigra	3.56	2.93	3.56	2.93
Pinus sp.	0.68	0.56	0.68	0.56
Pinus sylvestris	0.60	0.49	9.30	7.65
Populus sp.	0.91	0.75	0.91	0.75
Pseudotsuga menziesii	0.62	0.51	0.62	0.51
Quercus section Cerris-Mesobalanus	2.98	2.45	2.98	2.45
Quercus section Lepidobalanus	0.73	0.60	0.73	0.60
Quercus robur-petraea-rubra	17.90	14.73	17.90	14.73
Quercus sp.	0.09	0.08	0.09	0.08
Salix sp.	0.59	0.48	0.59	0.48
Eucalyptus sp.	0	0	0	0
Pinus halepensis	0	0	0	0
Pinus pinaster-pinea	0	0	0	0
Quercus suber	0	0	0	0

3. Discussion

3.1 Deviations from the harmonized definition

In Slovenia, there is no official definition of the term "above-ground biomass". For the national reporting, the above ground biomass is calculated based on the volume of trees (volume of the stem (dbh ≥ 10 cm) + large branches (≥ 7 cm)) using the BEF and wood density factors. In this study, the national volume and biomass includes also the volume of small trees (dbh < 10 cm).

In general, it was possible to follow the harmonized biomass definition. However, Slovenia never developed special bridging functions and consequently, the harmonization was possible only with the help of using selected volume functions from the neighboring countries, especially Austria (chapter 1.2). Based on those functions firstly the harmonized tree volume was calculated. This volume includes only the stem volume (from dbh > 0 cm) from ground level to the top. Based on the wood density factor then the biomass was calculated. In last step for each tree also the biomass of all branches (living and dead) and the foliage was added based on the functions described in the chapter 1.2.

The harmonized biomass is for 18 % higher than the national estimation using the BEF functions. The main reason for the differences could be the fact that the harmonized definition includes also branches < 7 cm, stump, top, and foliage, which are excluded from the national definition and not very well defined by the BEF function. Another reason could be the use of volume functions from neighboring countries. The functions were developed only for selected tree species and for specific dbh range. Within this study, the functions were used also for other tree species with similar crown structure. The selection of the function to an individual tree species was done based on the expert opinion.

Results of this study show that the harmonized biomass estimates are generally higher than national estimates for 99 % of the plots.

3.2 Differences between the national estimator and E-Forest estimator

There are no differences between National and E-Forest estimates for both national and harmonized biomass estimations. In the national estimation first the average for all plots is calculated and later the average is multiplied with the area of stratum to calculate the total stratum biomass (for example NUTS region).

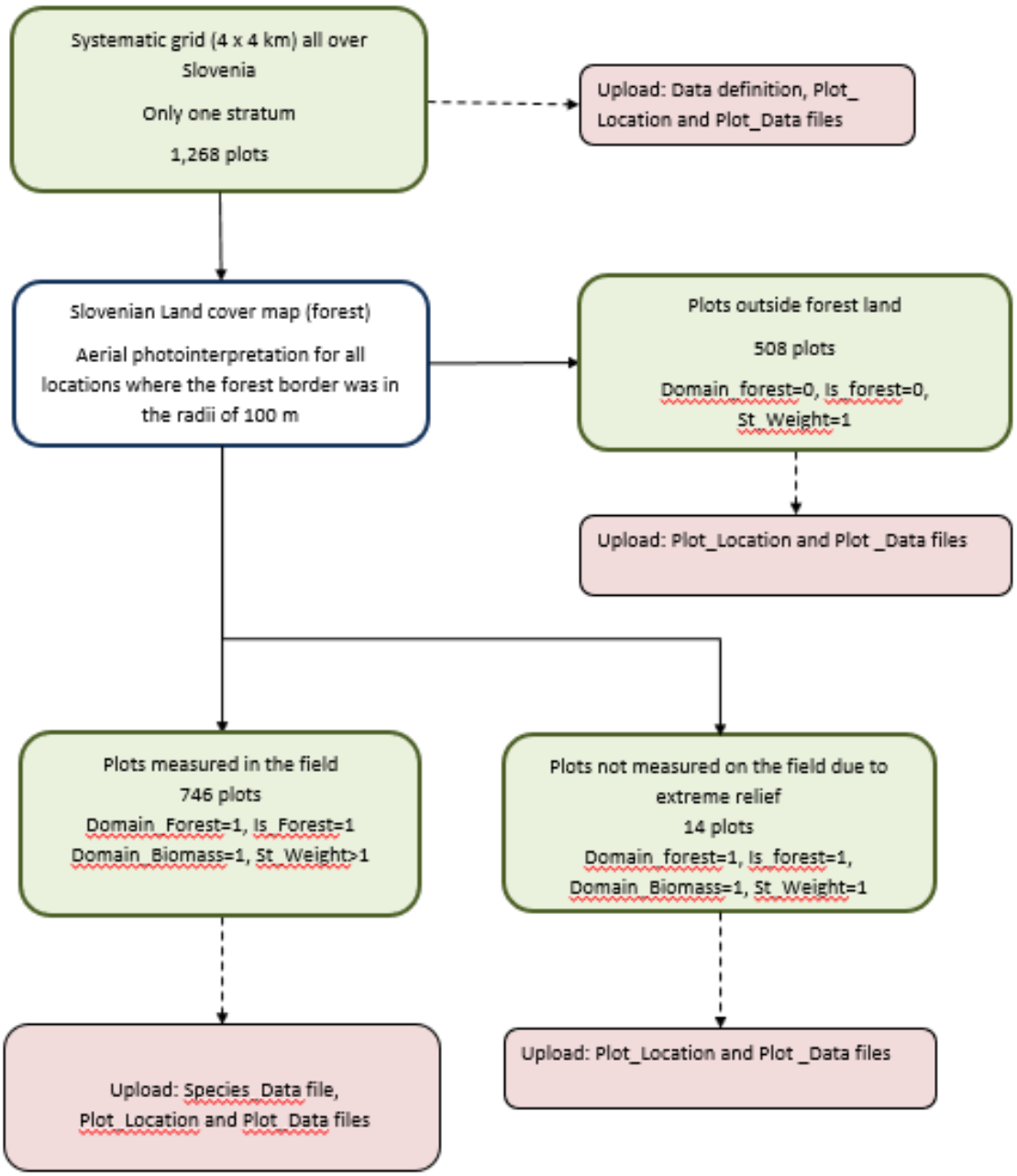
For the calculation of biomass for tree species the total biomass per species was divided with the number of NFI plots located within forest and multiplied with the known area of forest within the country.

For some of the tree species the estimations are questionable due to the low number of sample trees in the NFI3 data base (for example *Pseudotsuga menziesii*, *Quercus* section *Lepidobalanus*, *Salix* ….) (see Table 4 for tree species with at least 100 trees in the NFI3 database).

3.3 Plans for improving the biomass estimation

From the results, it is possible to get an insight into the differences between different biomass calculation methods. In the future, the methodology of calculations (tree volume and biomass) should be improved in Slovenia. This study is the beginning of testing new calculation methods for more harmonized reporting on the quantity of wood biomass and some of the knowledge will be used for next national biomass reports.

Annex. Flowchart of Slovenian decision tree for data uploaded to the E-Forest platform within SC19



In all the cases Is_partitioning_plot=0. The plots of the grid correspond to Slovenian lands. Data derived from the Third Slovenian National Forest Inventory (Slovenian Forestry Institute, SFI).

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