Inventory Guidelines and Field Protocol for PathFinder Pilot Study

Lutz Fehrmann

Ryan Carroll

Christoph Kleinn

Johannes Breidenbach

PathFinder Project

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Contents

1 Summary

The PathFinder project explores approaches to complement existing forest monitoring systems through the development of additional field sample survey protocols. This includes implementing a standardized plot design that has the flexibility to be employed in any country. The present document proposes a European-wide field sample survey which is envisioned as a supplement to the functional monitoring programs already in place (largely country-level National Forest Inventories, or NFIs).

Such an effort poses real challenges but also offers new possibilities in terms of harmonized data analysis and reporting capabilities. This approach enables a consistent monitoring framework that can be leveraged regardless of variations in country-specific monitoring programs. Due to evolving information needs and reporting timeframes, effective forest management and policy at the European level increasingly requires relevant data on key forest variables to be delivered with increasing frequency. A key focus of the PathFinder project is on facilitating uniform and timely reporting of forest carbon stocks as well as biodiversity indicators across Europe.

In order to meet this demand, Pathfinder aims to integrate various remote sensing data products and modelling techniques with the proposed supplemental survey design. This extension to the existing systems should help to overcome various harmonization issues and enable high quality co-registration of field measurements with European-wide remote sensing imagery. Data obtained from these efforts can be used to generate purely model-based or model-assisted estimates of key variables at greater frequency time intervals than is currently the case, while still maintaining the ability to generate design-based estimates.

[Here we focus on the plot design. The survey design which considers the integration with existing field surveys, will be the focus in D1.5.]

In this context, the proposed plot design and corresponding pilot study seek to ensure the following:

- Integration with existing sample survey designs (e.g. NFIs)
- Design-unbiased estimates of key forest variables remain a viable option
- Co-registration errors between field measurements and remote sensing data sources are minimized
- All plots can be surveyed within one day, regardless of country and/or site conditions
- Resulting data can be used to perform simulation studies with the goal of further plot design optimization

The plot design proposed here is based on a square plot of 40x40m side length (1600m^2) on which all trees exceeding the defined diameter threshold are recorded. This is combined with two nested circular subplots on which all trees exceeding separately defined diameter thresholds are recorded. Lying deadwood is assessed via a Line Intersect Sampling approach and tree regeneration is assessed on a cluster of four subplots of radius 1.5m (28.3m^2). A more precise overview of the proposed design can be found in Figure 5.

Thresholds, for example with respect to the minimum size of living trees, are typically used in a forest inventory to meet budgetary constraints because the measurement of many small trees would add little information with respect to carbon storage but require a lot of time. We proposed minimum diameter thresholds here to meet the budgetary constraints within the PathFinder project. However, we would like to emphasize that ideally in a final implementation, budgets

should be sufficient to avoid such thresholds completely in order to include all trees into the sample which makes the field data more informative for some remote sensing applications.

Finally, in an effort to facilitate stakeholder engagement and solicit feedback from relevant experts, various co-creation workshops were held prior to the issuance of this report. Major takeaways and suggestions included: 1) a recognition of the design constraints in the context of the pilot study while reiterating the opportunity to facilitate timely, actionable data at the European level; 2) identification of potential challenges and constraints associated with attempting to optimize the sample survey design for both carbon stock and biodiversity indicator assessments simultaneously; 3) noting that monitoring of forest disturbances is a key challenge that requires consideration in the design phase; 4) raising questions about the sample plot size used and should it be sensor agnostic or rather designed for specific datasets and/or spatial resolutions; and 5) discussing concerns over the appropriate minimum diameter thresholds used. This input was ultimately incorporated into the design proposal outlined here.

2 Introduction

2.1 Justification for a standardized European field sample survey

In line with the overall goals of the PathFinder project, a standardized and advanced field survey should be proposed which complements and is integrated within existing national forest monitoring programs, typically National Forest Inventories (NFIs). Despite the fact that many European countries have their own proven NFI in place, the main arguments for additional field data collection are (1) that a consistent link to remote sensing data is not straightforward since the national systems were designed along other criteria, and that (2) shorter-term periodic updates (for example every 2-5 years) by remote sensing support can be challenging.

Harmonizing data from the different NFIs across Europe is problematic since each NFI is tailored to specific national information needs as well as specific site conditions and different forest types. The European National Forest Inventory Network (ENFIN) is working on harmonization of NFI approaches and, in fact, most of the principal information needs and reporting requirements have always been comparable and largely similar. Nevertheless, it remains difficult to harmonize inventory cycles and plot designs across Europe. The country-specific monitoring systems currently deliver estimates of specific target variables with very high precision. It is, therefore, not the idea to replace existing systems with a new standardized European field survey, but rather to supplement these ongoing monitoring programs to better meet evolving information needs.

Harmonization of monitoring across Europe is implemented in the context of the ICP Forest Programme (International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests) launched in 1985. However, similar to the NFIs, the ICP plots can vary in size and shape since implementation is the responsibility of the participating countries. While Level I plot locations might coincide with existing NFI plots, the selection of Level II plots is not based on probabilistic principles.

Acknowledging the variety of methodological NFI approaches of countries across Europe, there is room for amendments and extensions of the existing NFIs that open the possibility of harmonized and consistent data collection and analysis on a European level.

2.2 Relation to existing monitoring systems

Current NFI systems (as well as the ICP Forest Programme) on the national level are facing similar challenges and limitations in many countries. Long-term forest monitoring programs usually strive to maintain long time series of forest observations on permanent sample plots, adding significantly to the scientific value of the data obtained. In this sense, such systems are usually "robust" and conservative in regard to the applied field methods and often rely on design-based analysis of the data. Concurrent developments in remote sensing data access, modelling approaches (including machine learning) and advanced field methods suggest the benefits of adapting the existing systems towards an integration of such techniques. Such an integration holds potential to increase the overall efficiency of forest monitoring efforts at scale and produce model-assisted or model-based updates of core variables like biomass at shorter time intervals. However, the issue of data consistency over time needs to be addressed. Any change in the main design elements of an inventory, or even in the definition of single variables, is therefore challenging and requires careful consideration. As such, these changes cannot easily be implemented into existing NFI systems.

The PathFinder project aims at developing approaches to find a meaningful integration of the well-established NFI and ICP Forest systems at the individual country level by collecting additional standardized field data where needed. This approach would enable a more advanced integration of various modelling and remote sensing techniques and facilitate consistent analysis and reporting. In this sense, the methods suggested here should be seen as amendments or extensions to the current NFI systems and not as a substitute.

This field manual (including definitions and procedures) has the express purpose of standardizing data collection across Europe as an addition to the existing NFIs, in a manner that facilitates complementarity with and integration into existing systems. As such, any proposals are limited to these amendments and need not change the individual NFI systems in general.

The main focus of the suggested sampling and plot design is on remote sensing integration, including freely available imagery as well as data collected via advanced field methods. The proposed extensions of countries´ NFI plot designs is therefore tailored towards a better and more suitable co-registration of field measurements and existing European-wide remote sensing products, like Sentinel 1 and 2 or higher spatial resolution data. Efficient modelling and application of advanced remote sensing analysis requires appropriate training data that typical forest inventory plots often do not provide in the desired quality. Efficiency in this context means that the integration of remote sensing data sources is able to increase the precision of estimates under stable or reduced costs. NFI plots are usually optimized towards an efficient design-based estimation of target variables like volume, basal area or biomass. Co-registration of field plots with remote sensing data therefore has been a lower priority in former times.

Amendments or extensions to existing NFI plots have the potential to increase the efficiency of remote sensing integration without losing the many statistical and practical advantages of already optimized NFI plot designs. Such plots, which may be called “remote sensing integration plots” can provide extra information on selected NFI plots that generate efficient data for the application of model-assisted or model-based estimation.

3 Sampling design

3.1 Sampling frame

The sampling frame of a European field sample survey would include all land area of European countries. Forest area per stipulated definition will be a part of this total land area. In order to define such a European-wide forest area, a consistent forest definition is required. Contrary to the single national NFIs in European countries that are using individual and definitions of forest area, a uniform and practical solution is adapted for the pilot study. In a first step, only for facilitating a quick start of the project activities in the planning phase, we consider the remote sensing derived products of the Copernicus Land Monitoring Service (TDC, DLT, FTY) and respective change masks (TCCM, DLTC) as basis for our planning. At later stages of planning a European monitoring system, a more careful forest/non-forest decision needs to be implemented which requires a more detailed interpretation of each selected sampling location.

Copernicus Land Monitoring Service (2019)	https://land.copernicus.eu/pan-european/high-resolution-layers/forests
Forest Information System for Europe (FISE) (2018)	https://forest.eea.europa.eu/topics/forest-basic-data/basic-data
Eurostat Administrative Units (2020)	https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries

The underlying definition of forest land in the product used in the initial phase is remote sensing based and as such based on quantitative indicators that can be assessed in remote sensing data sources exclusively. We are well aware that such remote sensing products might differ from national forest areas determined by specific quantitative and qualitative criteria of respective forest definitions. This means, forest per definition can potentially also be found outside of the forest mask and vice versa, which will affect all estimates of total forest area and area changes. The products used here adopt the quantitative criteria of the FAO forest definition, like minimum area of 0.5 ha and a minimum tree crown cover of 10%. Qualitative criteria of the FAO or country specific definitions like predominant land use or others cannot be considered. In this respect the provided canopy cover masks are not necessarily completely consistent with forest and/or habitat classifications like the EUNIS habitat classification system. Neither are they necessarily compatible with FAO or ICCP guidelines due to omission of the land use criteria, and also the criterium on potential crown cover or height (e.g. for temporarily unstocked areas). For a later implementation of a European monitoring system, such remote sensing products can only provide an indication of the real forest area and are not sufficient for making clear forest/non-forest decisions. Furthermore, since forest areas will change over time, this fact needs to be accounted for in any long-term operational framework. In such a final system, we would assume the forest area to be an unknown variable whose extent is to be estimated.

According to the above data sources, there are a predicted ~232 million hectares classified as forest land within the 39 European Economic Area (EEA) countries examined here. This means that forest land as defined above represents approximately 48% of the total land area of these countries. See Table 1 below for a breakdown of classified forest area by type and country. The countries with the highest percentage of forest cover are Finland, Slovenia and Sweden (with estimates of 76.6%, 74.0%, and 71.4%, respectively). Sweden and Finland also record the two highest values of total hectares of classified forest land at over 32.1 million and 25.9 million hectares.

Table 1. Remote sensing-based classification of forest areas by forest type.

Country	Forest (1,000 ha)	Non-forest (1,000 ha)	% Forest	Broadleaf (1,000 ha)	Coniferous (1,000 ha)	Mixed (1,000 ha)
Albania	1,408	1,479	48.8%	430	109	870
Andorra	22	25	46.8%	0	15	7
Austria	4,751	3,659	56.5%	455	2,414	1,883
Belgium	1,177	1,898	38.3%	208	192	777
Bosnia	3,593	1,538	70.0%	2,062	315	1,215
Bulgaria	5,144	5,969	46.3%	3,025	569	1,550
Croatia	3,348	2,344	58.8%	2,108	220	1,020
Cypress	221	709	23.7%	0	179	42
Czech Republic	3,535	4,365	44.8%	498	1,567	1,470
Denmark	964	3,392	22.1%	181	191	592
Estonia	3,079	1,473	67.6%	742	576	1,760
Finland	25,923	7,913	76.6%	145	18,574	7,205
France	23,719	31,231	43.2%	7,946	2,620	13,154
Germany	14,940	20,867	41.7%	2,671	5,294	6,976
Greece	6,660	6,632	50.1%	1,224	2,350	3,087
Hungary	2,478	6,835	26.6%	1,630	40	808
Iceland	32	10,270	0.3%	0	0	32
Ireland	910	6,119	12.9%	1	249	660
Italy	13,577	16,542	45.1%	5,893	956	6,728
Latvia	4,390	2,079	67.9%	1,145	849	2,397
Liechtenstein	10	7	59.2%	0	5	5
Lithuania	2,898	3,602	44.6%	718	600	1,579
Luxembourg	137	125	52.2%	42	9	86
Macedonia	1,394	1,154	54.7%	735	40	619
Malta	1	32	1.8%	0	0	1
Monaco	0	0	0.7%	0	0	0
Montenegro	848	545	60.9%	358	109	382
Netherlands	851	2,900	22.7%	42	167	642
Norway	13,618	18,982	41.8%	321	7,277	6,019
Poland	13,077	18,140	41.9%	1,688	5,685	5,704
Portugal	4,559	4,654	49.5%	172	177	4,210
Romania	10,092	13,764	42.3%	5,502	1,220	3,369
Serbia	4,587	4,267	51.8%	2,972	124	1,491
Slovenia	1,506	528	74.0%	691	205	610
San Marino	3	3	53.3%	1	0	2
Spain	21,870	28,778	43.2%	2,287	2,386	17,197
Slovakia	2,690	2,222	54.8%	1,370	420	899
Sweden	32,190	12,883	71.4%	557	24,956	6,677
Switzerland	1,737	2,403	42.0%	198	579	960
All Europe	**231,938**	**250,329**	**48.1%**	**48,017**	**81,238**	**102,684**

3.2 A European grid system

In terms of the choice of sampling locations within the sampling frame defined above, we propose as a starting point the use of a European-wide grid system in the mode of the INSPIRE grid. The INSPIRE (Infrastructure for Spatial Information in the European Community) protocols are designed to facilitate consistent, uniform data georeferencing procedures across Europe. Such a system enables data sharing as well as accurate geolocation of spatial features, thereby permitting harmonized data collection and analysis of the kind proposed here. Specifically, we are using as example here a downloadable reference grid obtained from the European Environment Agency's website which is based on the INSPIRE reference grid specifications.

European Environment Agency (EEA): Reference Grid	https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2
European Commission: INSPIRE Registry	https://inspire.ec.europa.eu/theme/gg

The INSPIRE geographical grid as proposed is based on use of the Lambert Azimuthal Equal Area projection. Importantly, this ensures equal area grid sizes across Europe regardless of location. As noted in the 2009 document "D2.8.I.2 INSPIRE Specification on Geographical Grid Systems – Guidelines" issued by the INSPIRE Thematic Working Group on Coordinate reference systems and Geographical grid systems, such a grid is best suited in cases where consistent statistical analysis is required across grid cells.

Figure 1 below provides a useful visualization of the effect using such an equal area grid can have across Europe. This grid system can be generated at multiple spatial resolutions depending on need (1m, 100m, 1km, 5km, etc.). Intersection of grid points can then be used to generate sampling locations in a uniform fashion across Europe.

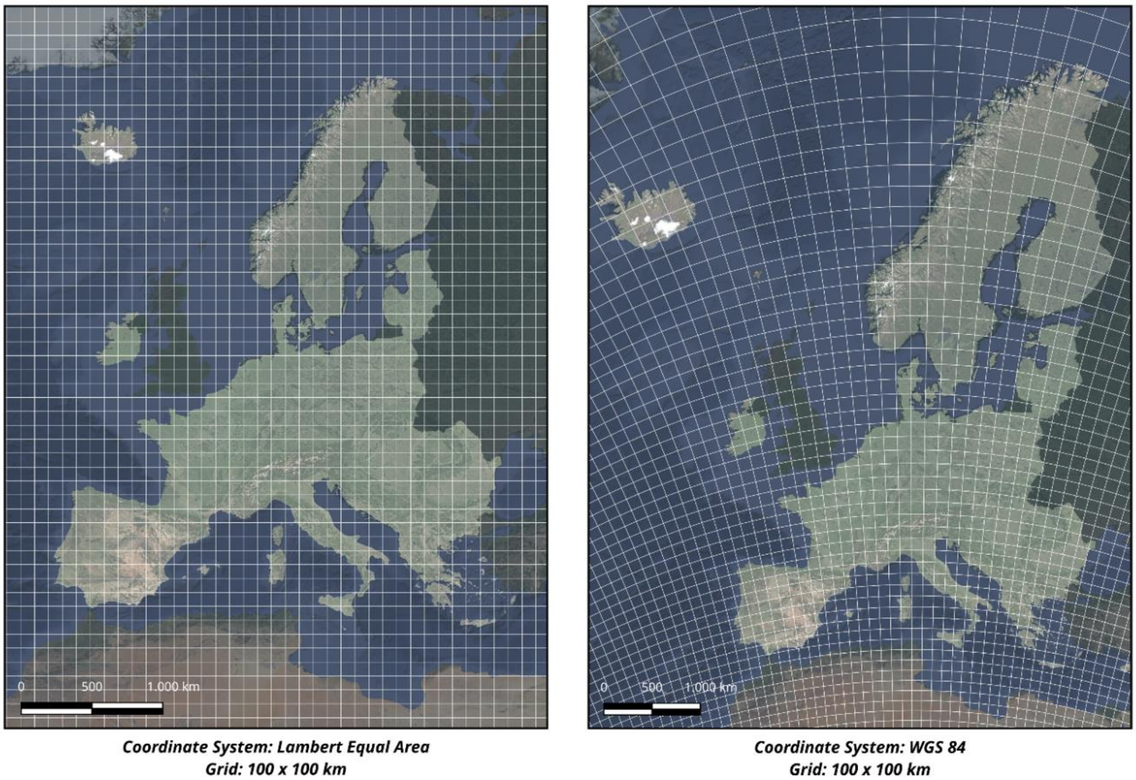


Figure 1. European-wide grid of 100 x 100km showing location and size differences in grid position resulting from different coordinate systems. Use of an equal area projection, such as the Lambert Azimuthal Equal Area (inset left), assures equal grid spacing across Europe. Use of a common projection such as WGS84 (inset right) results in increasingly divergent grid spacing as one moves north. The grid shown here was downloaded from the European Environment Agency website and is based on the INSPIRE grid system.

Whether or not the specific sampling locations will be determined directly from the grid throughout Europe is to be decided in a later project phase, as there are various country-specific limitations on where such forest inventory work can proceed due to legal access issues. Maintaining confidentiality of plot locations is also a concern that needs to be addressed. In some cases, it is likely that the inventory work proposed here will need to have a direct spatial link with existing NFI sampling locations, at least to some degree. Therefore, we expect that the selection of final sampling locations will follow an unaligned systematic design in which points are selected randomly according to certain criteria inside specified INSPIRE grid cells. This would allow attaching the PathFinder plots to existing NFI sampling locations (eventually fulfilling specific stratification criteria).

Depending on the requirements of each individual country this could take place in various ways. The idea suggested here is that a list of some number of potential sampling locations will be generated per stratification class for each country; changing the density of the grid can effectively increase or decrease the availability of potential sampling locations as needed. The grid could, for example, be densified it the case of a smaller country looking to add sampling locations. This could be a starting point for a country-by-country determination as to which sampling locations fit both the sampling stratification requirements of the Pathfinder project and also meet country-specific demands.

3.3 Carbon stocks

The spatial distribution of carbon density across Europe might be a criterion for a stratification of the total forest area into classes of carbon densities in future. For the implementation of n=250 pilot plots in context of the project activities, however, no pre-stratification is planned. A potential stratification scheme might take the forest areas as defined above by the Copernicus Land Monitoring Service (CLMS) Dynamic Land Cover 2019 (or later updated) product as the starting point. These areas could be used to generate a hypothetical forest mask dataset (which essentially represents crown cover and not “real forest area”) that was applied over Europe. This forest mask is intersected with the European Space Agency's Climate Change Initiative (ESA CCI) above-ground biomass dataset from 2020 to assess above-ground carbon stock density across Europe (see Figure 2 below). This dataset was chosen because of the recent time period to which the data corresponds (i.e. 2020, within a year of the 2019 Dynamic Land Cover data from CLMS), as well as its relative reliability and accuracy when compared with the limited number of similar datasets available (see the European Commission Joint Research Committee report from 2020).

European Space Agency’s Climate Change Initiative: Global datasets of above-ground biomass (2020, v4)	https://forest.eea.europa.eu/topics/forest-basic-data/basic-data/forest-above-ground-biomass https://catalogue.ceda.ac.uk/uuid/af60720c1e404a9e9d2c145d2b2ead4e
European Commission, JRC Publications Repository: The Biomass of European Forests	https://publications.jrc.ec.europa.eu/repository/handle/JRC122635

As can be seen in Figure 2 below, much of the higher above-ground biomass (AGB) densities in Europe occur in the region of south-central Europe in the countries of Switzerland, Germany, Austria, Slovenia, the Czech Republic and portions of Italy. Other areas of particularly high biomass concentration can be found in central Romania and along the coast of northern Spain.

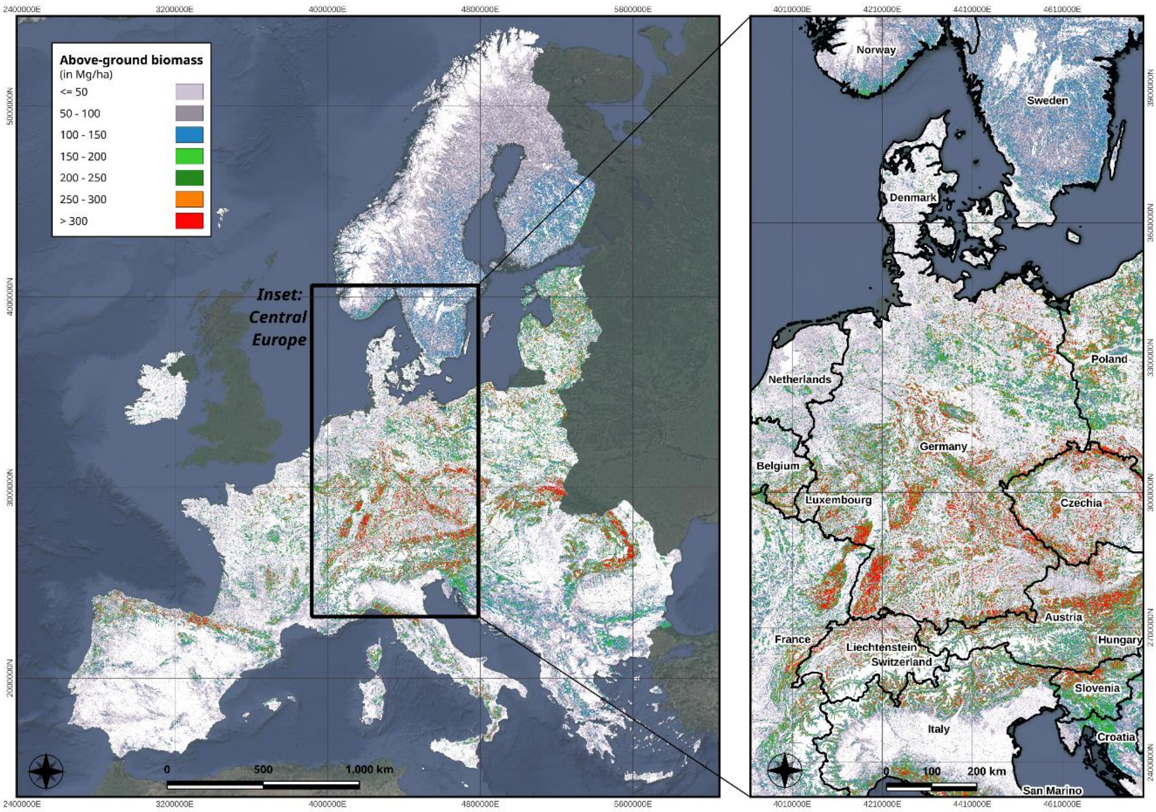


Figure 2. Above-ground biomass estimates across Europe derived from the ESA CCI dataset for the year 2020. Biomass densities are in Mg/ha and are shown only for those areas defined as forest according to the CLMS Dynamic Land Cover 2019 dataset. An inset map of central Europe is shown in the panel on the right for illustrative purposes. Sources: Santoro, M.; Cartus, O. (2023): ESA Biomass Climate Change Initiative (Biomass_cci): Global datasets of forest above-ground biomass for the years 2010, 2017, 2018, 2019 and 2020, v4. NERC EDS Centre for Environmental Data Analysis, 21 April 2023. doi:10.5285/af60720c1e404a9e9d2c145d2b2ead4e. Satellite imagery courtesy of Google.

Considering all forested areas across Europe, we see an estimated mean AGB density of ~84 Mg/ha. Not surprisingly, this value comes with a large amount of variability (standard deviation = 70.8 Mg/ha; coefficient of variation = 84.1%). In addition, much variation in above-ground carbon stocks is observed both within and among countries as can be seen in below. This data was used to identify above-ground biomass ranges for forested areas at both the country-specific scale and at the broader European level.

Table 2. Remote sensing-based estimate of above-ground biomass per country derived from European Space Agency Climate Change Initiative dataset (ESA Biomass CCI 2020). Values shown below are for forested areas as defined by the CLMS Dynamic Land Cover 2019 data, which are consistent with the uniform (remote sensing-based) forest definition referenced above.

Country	Mean AGB (Mg/ha)	Standard deviation per pixel (Mg/ha)	Coefficient of variation
Albania	48.73	42.02	86.2%
Andorra	89.58	61.24	68.4%
Austria	147.72	111.26	75.3%
Belgium	94.82	93.19	98.3%
Bosnia	76.52	51.17	66.9%
Bulgaria	85.02	54.04	63.6%
Croatia	82.09	59.26	72.2%
Cyprus	45.35	36.57	80.6%
Czech Republic	152.27	119.93	78.8%
Denmark	59.57	67.62	113.5%
Estonia	112.76	77.29	68.5%
Finland	63.24	39.46	62.4%
France	79.84	82.30	103.1%
Germany	136.08	114.23	83.9%
Greece	52.41	44.04	84.0%
Hungary	92.56	77.70	83.9%
Iceland	16.35	21.45	131.2%
Ireland	46.24	52.43	113.4%
Italy	85.25	89.99	105.6%
Latvia	119.15	88.03	73.9%
Liechtenstein	140.85	115.68	82.1%
Lithuania	120.91	90.39	74.8%
Luxembourg	119.43	105.30	88.2%
Macedonia	51.22	43.76	85.4%
Malta	11.68	15.11	129.4%
Monaco	142.50	163.11	114.5%
Montenegro	67.31	45.96	68.3%
Netherlands	60.75	67.22	110.6%
Norway	51.15	38.02	74.3%
Poland	128.22	97.92	76.4%
Portugal	47.10	58.72	124.7%
Romania	125.94	108.06	85.8%
Serbia	62.05	47.92	77.2%
Slovenia	140.20	94.93	67.7%
San Marino	26.42	37.27	141.0%
Spain	62.42	83.44	133.7%
Slovakia	157.45	111.37	70.7%
Sweden	59.55	38.42	64.5%
Switzerland	129.77	112.79	86.9%
All Europe	**84.18**	**70.83**	**84.1%**

3.4 Forest type classification

Ecological forest types are another potential criterion for stratifying the forest area. The existing European Forest Type (EFT) classification system distinguishes 14 main classes of forest types that largely resemble ecological or potentially natural forest types. Even if the boundaries between these different types are fuzzy, the main classes can be assumed relatively stable over time.

Unfortunately, spatially-explicit digital data based on the EFT classification scheme were not readily available at the time the present work was completed. For that reason, the CLMS Dynamic Land Cover 2019 product was used instead to develop a stratification scheme. This dataset was available globally at 100m spatial resolution and makes distinctions between open/closed canopy, broadleaf/coniferous, and deciduous/evergreen forest. Nine of the 12 total global classes were found to be present in the European countries analyzed. Within these nine classes, two represented 'Mixed Forest' (open/closed canopies) and two represented an 'Unknown' (open/closed canopies) forest class. The two 'Unknown' forest classes were combined with the 'Mixed Forest' classes for the purposes of this analysis. This reduced the total number of classes to seven (see Figure 3).

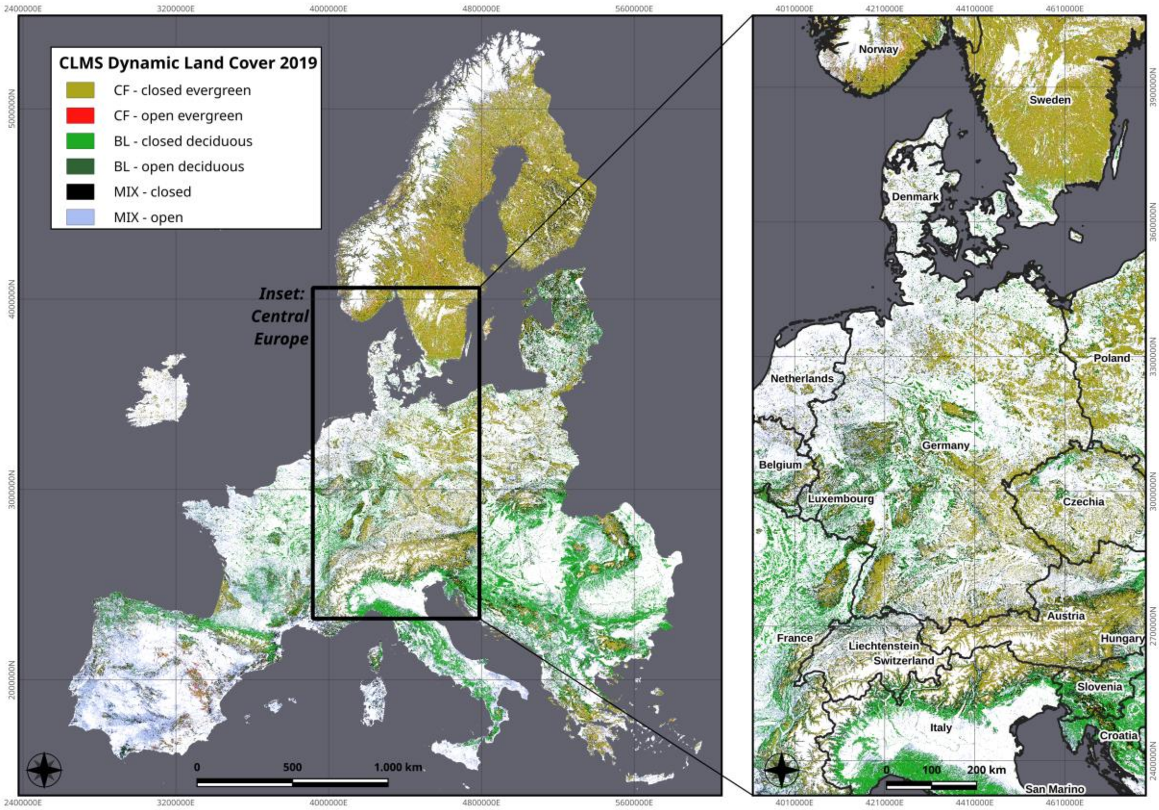


Figure 3. Forest classes across Europe generated using European Union's Copernicus Land Monitoring Service information; https://land.copernicus.eu/en/products/global-dynamic-land-cover/copernicus-global-land-service-land-cover-100m-collection-3-epoch-2019-globe

Table 3. Estimated forest areas in different forest classes and resulting proportional allocation of sample plots in the pilot phase.

Forest classes by type (coniferous, broadleaf, and mixed)	Forest area (1M ha)	Forest area (% of EU)	Mean AGB (Mg/ha)	Total AGB (1M Mg)	Total AGB (% of EU)	Plots (250 total)
Coniferous – closed canopy evergreen	77.2	33.3%	105.1	8,116	41.5%	83
Coniferous – open canopy evergreen	4.0	1.7%	41.8	167	0.9%	4
Broadleaf – closed canopy evergreen	0.0001	<0.01%	51.1	0.01	<0.01%	1
Broadleaf – closed canopy deciduous	44.9	19.3%	126.1	5,654	28.9%	48
Broadleaf – open canopy deciduous	3.2	1.4%	48.1	152	0.8%	3
Mixed forest – closed canopy	38.8	16.7%	98.4	3,818	19.5%	42
Mixed forest – open canopy	63.9	27.5%	25.7	1,643	8.4%	69
Total	**232.0**	**100%**	**84.3**	**19,550**	**100%**	**250**

Looking at the three major forest types (coniferous, broadleaf, and mixed) across Europe, we see that the mixed forest classes occupied the largest share of forest area (44.3%), followed by coniferous forest (35.0%) and broadleaf forest (20.7%). In this stratification scheme, plots were assigned based on the percentage of the total European forest area occupied by a given class. The mixed forest classes received the highest number of plots (111) followed by coniferous forest (87) and broadleaf forest (52).

Of the nearly 20 billion metric tons of estimated AGB across Europe, the coniferous forest type represented the single largest share (42.4%). While the broadleaf forest type occupied less than half the area as mixed forest, they both contributed approximately 30% towards the total AGB value. This can at least partially be explained by the fact that the broadleaf and coniferous types were dominated by closed canopy forests, while the mixed forest type predominantly consisted of open canopy forest. Not surprisingly therefore, the mean estimated AGB density of this type (53 Mg/ha) was lower than for broadleaf (121 Mg/ha) or coniferous (102 Mg/ha).

Considering the higher variability associated with lower AGB values in both the preliminary AGB quartile stratification (ESA CCI 2018 data) and the country statistics shown in above (ESA CCI 2020 data), this could justify the allocation of more sample plots to these areas. A stratification scheme based on the forest classes described here would have this effect. However, this would result in relatively fewer plots allocated to precisely those areas that contribute most to Europe's total AGB. Given the constraint of 250 sampling locations in the context of PathFinder, there are tradeoffs when it comes to deciding where efficiency gains should be concentrated.

A final stratification might therefore consider both the forest type (perhaps collapsed to broader classes) and above-ground carbon density classes. An example as to how that might look is offered below. For more information about the adopted forest type classification see 6.4.12.

3.4.1 Plot selection within countries

The general idea of a future monitoring system on European level is to select sampling locations based on a uniform statistical sampling design. Systematic sampling (or, in case existing plot locations should be considered, systematic unaligned sampling) is the best choice and ensures that different forest types are sampled with a probability proportional to their area. In case that unequal sampling intensities in different forest types promise higher accuracy of estimates, a stratified design with adapted sampling intensity (=grid resolution) can increase the overall efficiency. The pilot study with n=250 plots implemented in the project should serve to research into this and will help to optimize the design of a future monitoring system. For this purpose, information about the variability of target variables and information about cost implications of field work in different forest types is required. Based on the collected data the required sample size to meet certain precision requirements could be estimated. In context of the pilot study itself, an allocation of the 250 plots is already pre-defined and is approximately proportional to the country- or expected forest area. The study is also limited to certain countries who are participating in the pilot inventory.

3.4.2 Plot selection in context of the pilot study (n=250)

In order to ensure that sufficient flexibility exists to accommodate various plot selection scenarios for the establishment of the n=250 pilot plots within the PathFinder project timeframe, a grid of 1x1km cells across Europe is proposed as the starting point. From this dense network of grid cells, estimates of area of each forest type and mean AGB density for each forest type were derived for each grid cell (based on the previously referenced data sources). This derived dataset enables the sub-selection of grid cells containing a minimum area of a specific forest type on a country-by-country basis. From this sub-selection, a distribution of AGB density values per cell can also be determined. This allows for the possibility of sampling a range of site conditions for each forest type within each country. For illustrative purposes an example is given here for the country of Switzerland (Figure 4).

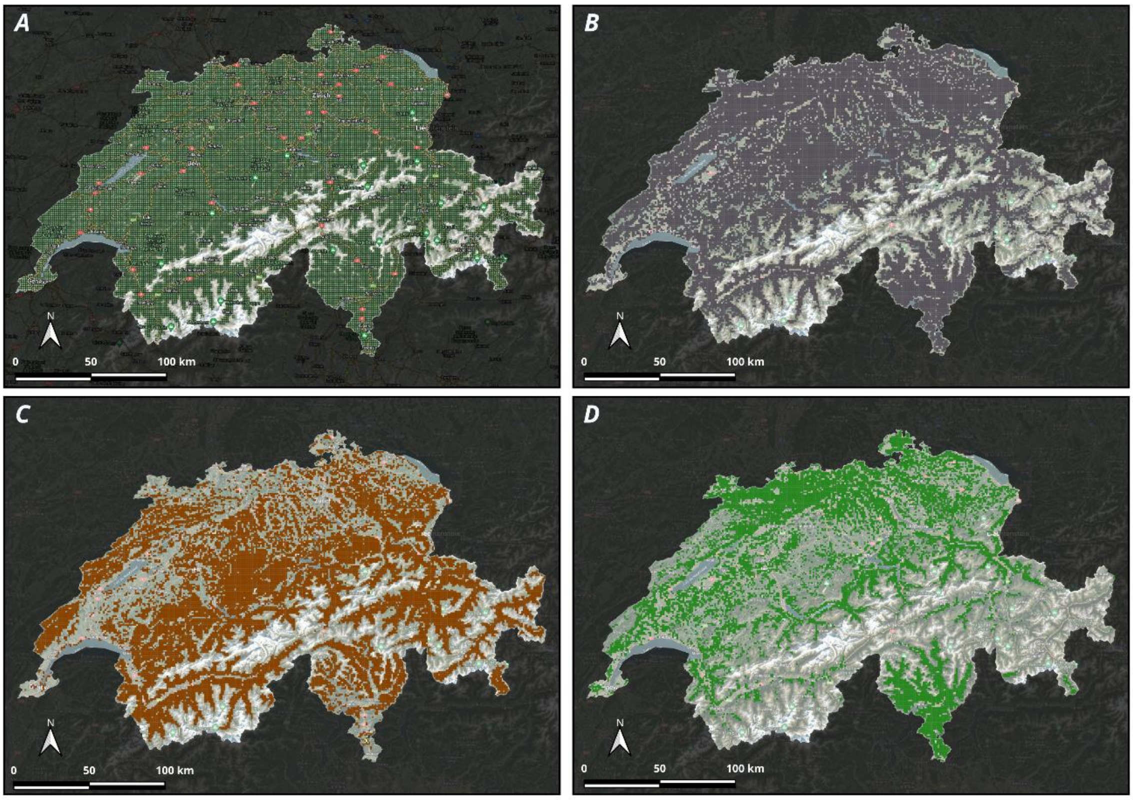


Figure 4. Example distribution of 1km x 1km grid cells for Switzerland based on Lambert Azimuthal Equal Area projection: A) grid cells containing forest in green and non-forest cells removed; B) grid cells containing mixed closed canopy forest (60.2%); C) grid cells containing coniferous closed canopy forest (48.3%); D) grid cells containing broadleaf closed canopy forest (31.0%).

In total there are 40,202 grid cells present in Switzerland, 31,685 (78.8%) of which contain forest. This is a slight underestimation due to only cells completely within the country being selected as well as various alignment issues with the remote sensing-derived data products used in the analysis. Most of the cells without forest are located in the high mountain regions in the southern part of the country as can be seen above.

Taking the coniferous forest-closed canopy forest type as an example (see Panel C), a total of 19,418 cells (48.3%) contains this forest type with a mean estimated AGB density of 161.9 Mg/ha. If the sample locations are then allocated according to a proportional allocation scheme based on the area of these broader forest types, they should be allocated proportional to the area. Since classified grid cells can contain multiple forest types, the area proportions of cells do not sum up to 100% here (the proportion of coniferous forest is 48.3/(48.3+31+60.2)=34%). This means ~34% of the 11 planned field plots (~4) should be allocated to coniferous forest in Switzerland.

Since the estimation of carbon stocks is an important goal of the monitoring system, we suggest an importance sampling procedure using the remote sensing-based predictions of carbon density as additional information. The goal is to select grid cells proportional to the expected carbon density inside the respective forest type. For this purpose, a cumulative sum over all cells containing the respective forest type can be calculated and a random number between 0 and the cumulative sum of carbon density over all cells can be drawn to select a cell. This procedure does not consider the spatial arrangement of selected cells but ensures a proportional allocation of points to different carbon density classes.

We provide the pre-classified INSPIRE base-grid with 1x1km resolution containing the required information about country, forest type area and carbon density to the countries and/or PathFinder partners who are participating in the pilot study.

4 Plot design

4.1 Introductory comments on plot design

Considering a relatively low number of plots distributed across different forest types over Europe in context of the PathFinder project, it is obvious that the main purpose lies in optimizing the integration of remote sensing data with field-collected plot data. Remote sensing datasets can facilitate and support the collection of training data and/or be used as ancillary data for model-assisted or model-based estimation. However, at the same time the proposed sampling and plot design should also allow derivation of design-based estimates of target variables using the field-collected plot data exclusively. Fulfilling both aspects at the same time requires compromises in regard to the allocation of efficiency gains resulting from the proposed design. In a model-based estimation paradigm, it would be important to collect field data such that co-registration errors and boundary effects are minimized, which usually requires larger plots that are tailored towards an efficient matching between remote sensing pixel values and field observed target variables. In contrast, the statistical efficiency in a design-based setting depends largely on sample size, which leads to the inevitable conclusion that the size of single plots is relatively small in favor of an increased number of plots. Further, using nested plot designs, where plot area is proportional to the selected target variable, is much more efficient compared to measuring all trees on the same fixed plot area.

The main focus of the PathFinder project is to facilitate uniform, consistent reporting on existing carbon stocks (and changes over time) and biodiversity indicators. In regard to carbon reporting, the usual carbon pools need to be considered, including carbon stocks in above-ground biomass, litter, deadwood, below-ground biomass and soil organic matter. In regard to biodiversity indicators, the focus might be on the estimated number of species, species abundance, or the amount of deadwood as proxies for habitat quality for many species.

The guiding principles for the suggested plot layout for a pilot study are:

1) Observation and design-unbiased estimation of target variables is possible,
2) Co-registration errors between field observations and remote sensing products are minimized,
3) Plot data allow further simulations and optimization of the final plot design,
4) For practical reasons and considering typical constrains for field implementation, the complete assessment of a single plot is feasible within one day (in most cases, across different forest types),
5) PathFinder plots can be combined with existing field plots of regular NFIs.

4.2 Plot layout for the pilot study

Considering the beforementioned criteria, the suggested plot design for a pilot study is based on a square plot of 40x40m side length (1.600m²), in which all trees exceeding a defined diameter are recorded and positioned. This basic plot design is combined with nested circular subplots of 14.14m and 7.07m radius (628.3 and 157.1 m² respectively) in which also trees below defined diameter thresholds are included. Lying deadwood, or “Coarse Woody Debris” (CWD) is assessed using a Line Intersect Sampling (LIS) approach along transects where the diameter of lying deadwood pieces is measured at the point of intersection. The same transects are used to assess coverage of ground vegetation classes by line intercept sampling, in which a cover proportion is derived from measurements of line intercepts length falling onto different ground vegetation classes. Finally, the assessment of tree regeneration (trees <7cm) a cluster of 4 regeneration subplots of 1.5m radius each (28.3 m²) is used.

Figure 5 gives an overview about the plot design, the different assessments are described in the following.

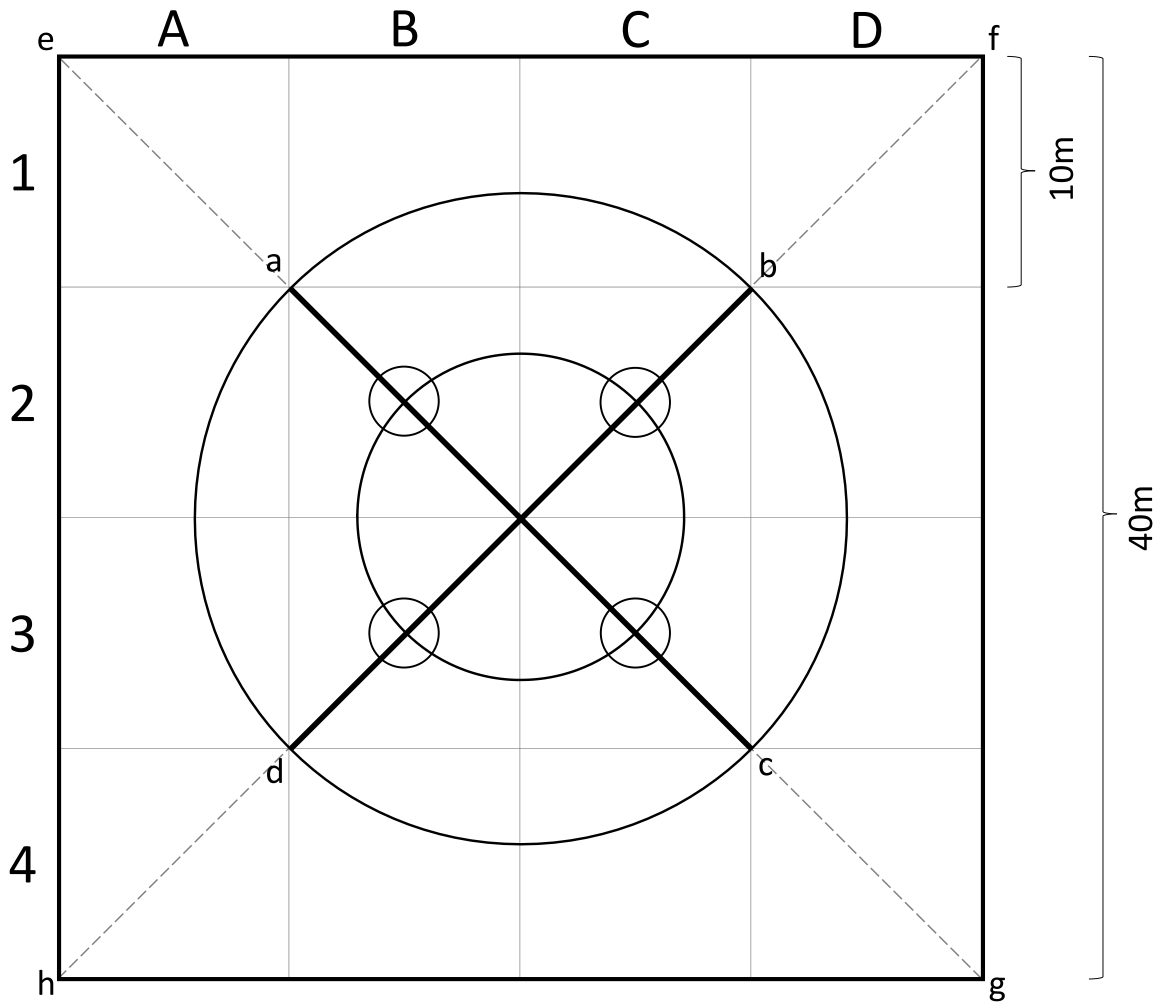


Figure 5. Overview of the plot design for PathFinder pilot study plots.

The quadratic plot can be further subdivided into 10x10m quadrants organized in columns (A,B,C,D) and rows (1,2,3,4) for specific assessments or in case of domain overlap (see 4.4). Specific assessments on the quadrant level are not planned, so that this subdivision of the plot is only necessary in specific cases.

4.3 Diameter thresholds and expansion factors

The idea of the PathFinder project is to develop a uniform plot design and field procedures across all different forest types in Europe. In absence of any restrictions in time and budget, such a design would not incorporate any diameter thresholds and all trees should be measured. However, considering such restrictions, practical and statistical criteria are used to optimize the inventory work in favor of a reduction of costs per plot and increase of sample size. For the planned pilot study, some compromises in regard to temporary diameter thresholds are suggested. These are designed to reduce variations in the workload and the time consumption necessary for plot assessments. Tree density (number of trees per unit area) in different diameter classes shows a high variation between North- and central European beech forest types with multiple canopy layers (where largest trees can reach >70 cm DBH and tree heights > 40m) and e.g. Nordic boreal forests or Mediterranean dry forests. Any fixed plot design for all forest areas across Europe will therefore always remain a compromise and can never be optimized towards specific conditions, like a country specific NFI plot design.

For the planned pilot study in context of the PathFinder project, the implementation of 25 test plots covering different forest types is planned. These plots will generate data that can be used to facilitate further optimization of the plot design itself (plot sizes, diameter thresholds) and for simulation studies on remote sensing integration considering different spatial resolutions. At a later stage the implementation of a set of *n*=250 plots is planned in context of the PathFinder project.

For the pilot study, a potentially higher workload and time consumption per plot is accepted and the following diameter thresholds are planned for the measurement of standing trees:

*Table 4. Plot sizes, DBH thresholds and expected number of trees per plot (based on *Research Plots from different forest types in Germany or **German NFI results).*

Tree DBH	Plot / max. distance	Plot area	Expansion factor	Expected tree counts
DBH ≥ 30 cm	Total plot area 40 x 40m	1,600.00 m²	6.25	23.3*/21.1**
DBH >= 15 and <30	Circular plot 14.14 m radius	628.31 m²	15.92	21.2*/35.2**
DBH < 15 cm	Circular plot 7.07 m radius	157.08 m²	63.66	3.0*/na**
DBH < 7cm	Cluster of 4 subplots, 1.5 m radius each	28.27 m²	353.73	0*/na**

4.4 Accounting for domain overlap

Forest type is a typical domain variable, describing the whole plot area or only parts of the plot. Remote sensing integration plots in context of the PathFinder project have the main purpose to support remote sensing analysis and should therefore preferably fall into a single forest type. Since the PathFinder plots should also allow design-unbiased estimation based on a probabilistic sampling design, it cannot be avoided that plots are selected that might intersect with domain boundaries. This might be the case if a boundary between clearly different forest- or management types intersects the plot area (e.g. an even aged spruce plantation and a natural mixed beech forest in different parts of the plot). In such cases it is necessary to assign multiple forest types and collect data that allow an estimate of area proportions. A delineation of boundaries in the field is time consuming and not efficient. A common alternative in forest inventory analysis and a standard methodology in forest management planning is to use the cumulative basal area of trees in different tree-related domains (e.g. species or canopy layer) as a proxy to estimate area proportions. The basic assumption is that crown projection areas and stand space occupation, which is closely related to basal area, is proportional to the area occupied by different trees. In order to allow for calculating the relative shares on total basal area per plot, the respective domain class needs to be assigned to the single trees and not as a uniform value for the whole plot area. For those domain variables that do not refer to single trees but to subsections of the plot area (like e.g. forest type, ownership classes or similar), assigning them on the tree level is not efficient during data collection (since the same domain class needs to entered for every single tree).

The PathFinder Field App allows this distinction. Area-related domains like forest type can be assigned to the whole plot area (default), or on the level of single plot quadrants. This requires (redundant) entries of the same value for all quadrants in a specific forest type, but later allows disentangling the plot area proportional to these classes. See also 4.5.2 for boundary plots.

4.4.1 Measurement of plot coordinates

In order to minimize co-registration errors between field plots and geo-referenced remote sensing data sources, the plot location and orientation need to be measured as accurately as possible. The coordinates of the plot center, which refers to the selected sampling location, should therefore be measured with a differential GNSS (Global Navigation Satellite System) receiver, preferably using a real-time correction of a local base station and/or an RTK system (Real Time Kinematics) using a local base station (or simulated base station) and a rover unit. The main goal of accurate and precise coordinate measurements is to increase the suitability of collected field data for model building with medium- and high-resolution remote sensing data, which might in future also include airborne LiDAR data or high resolution optical and multispectral imagery captured with UAV platforms (drones). Considering these very high-resolution remote sensing products, it is not only about accurately co-registering the complete plot area with a relatively low number of large pixels (e.g. Sentinel 2), but also single quadrants or even single trees with data of higher spatial resolution, which requires reducing positioning errors below 1-2m or even less.

Identification of plot corner points during field implementation is planned to be done by measuring polar coordinates (horizontal distance and fixed angles of the diagonals from the plot center), which requires accurate measurements of direction angles in the field. Since the plot orientation is fixed based on azimuth from magnetic North using a compass, the current magnetic declination during the assessment period leads to a slight rotation of the plot geometry compared to local projected coordinate systems. Considering the relatively small plot area and the relatively large pixel size of satellite imagery available on a wall-to-wall basis, this minor distortion is accepted in favor of more practical field implementation. Since variations in the magnetic declination and respective correction factors are known for all countries and all points in time, it is in principle possible to correct such distortions during post processing at any time, if required.

4.5 Plot establishment

The PathFinder plot network is planned as bass for a permanent monitoring system, which means a large portion of plots is planned to be revisited and re-measured in regular time intervals. Beside permanent plots, there might be a smaller portion of temporary plots in a final design, however, here we describe the *n*=250 plots established as demonstration plots in context of the project. The selected sampling location (the plot center) and possibly also corner points of the plot should therefore be marked permanently and should enable re-identification of the plot itself, but also all measured trees. This is necessary since changes of volume or carbon stocks should possibly be disentangled and broken down by different categorial variables or domains, which requires an attribution of consecutive repeated measurements and calculation of changes between the inventory periods on the level of single trees. Only if a distinctive re-identification of each single tree on the plot is possible, changes like ingrowth, increment or mortality can later be broken down by species groups or DBH classes.

In order to establish the plot, the following procedure is recommended:

1) Navigate to the selected sample location by using a standard navigation tool or suitable App on the mobile device (plot locations and additional geodata should be uploaded to the device). Activate an independent and higher precision GNSS receiver already on the way to the plot.

2) Once a close proximity to the target position is found, use the GNSS receiver to find the best possible approximation to the target position. Depending on the availability of real-time correction signals, this measurement will likely result in a floating position (RTK FLOAT) around the target position.
3) After establishing and temporarily marking the best approximated position, install the GNSS receiver or RTK rover at this position and start a long-term measurement. For RTK systems the goal would be to reach a FIX of the position (which results in dm or even cm accuracy), in case of regular DGNSS receivers it is the goal to extend the measurement time until the coordinates stabilize. Even a modern RTK system is not always able to deliver a FIX under a close forest canopy or under other distorting factors, like moving branches and leaves.
4) A permanent marking of this position is done after the monopod or stand of the GNSS receiver is removed (see 4.5.1).
5) Outgoing from the plot center, the cardinal directions of the four diagonals from the plot center to the inner- and outer corner points (a-g) are determined (45°, 135°, 225° and 315°) with a precise compass (or calibrated electronic device like Vertex Laser Geo, TruPulse 360 or similar) and average slope angle (in degree) is measured parallel to the ground by using a Suunto clinometer, Vertex or Laser rangefinder. In case a measurement tape is used to determine the distances, the slope corrected distance to the respective corner point is also calculated by the PathFinder Field App. Using the Vertex instrument a direct measurement of corrected horizontal distances outgoing from the sample point is possible.
6) In case the terrain form does not allow measuring an average slope angle (e.g. slope direction is changing because the target position is on another side of a sink or behind a hilltop), the total distance needs to be broken down in subsections.
7) The identified inner- and outer corner points should be marked temporarily using ranging poles or other suitable and visible poles (e.g. plastic tubes). In case of very dense undergrowth and limited visibility, it might be necessary to mark additional border points, e.g. in main cardinal directions North, East, South, West.

The four inner corner points (a, b, c, d) are at the same time the ends of two deadwood- and vegetation transects passing through the plot center from South-West to North-East and North-West to South-East (see 6.8). Further, the centers of the four regeneration subplots (see 6.6) are placed in half the distance between sample point and end of these transects.

4.5.1 Plot marking

Visible and durable marking of the plot location or trees on the plot should be avoided. Permanent marking of the plot center and outer corner points should therefore be done by placing metal tubes belowground or following the country specific standards. This is the standard procedure in forest inventories and allows finding the plot using a metal detector. Commonly, iron marking cores of 25-30 cm are used, but also aluminum tubes are possible. The choice here depends very much on the detectors that should later be used to find the markings and whether a magnetic locator or a metal detector should be used. Magnetic locators are much more expensive, but also have a longer reach (need iron cores), while a usual metal detector is relatively cheap and also suitable for finding other metals. The marking should be inserted such that it is flush with the mineral soil. In case the plot center or a corner point fall on roads or skidding trails, placing metal tubes is not recommended to avoid damages on tires of machinery. In this case the marking can be done using an offset from the position. A drawing (using any suitable App on the mobile device or a photo of a paper drawing) should be done explaining the offset distance and direction. This drawing or file can be uploaded in the PathFinder Field App.

Figure 6. Example of an iron marking pole (25cm) for marking the plot center and corner points.

4.5.2 Boundary correction

For the specific purpose of remote sensing integration, partial plots overlapping the sampling frame into non-forest areas are not preferred and it is recommended to exclude respective plots for modelling relationships between target variables derived from field observations and remote sensing indices. From a design-based perspective, however, also these boundary plots would need to be considered. The forest edge typically has specific characteristics in regard to species composition and tree growth and need to be accounted as part of the population of interest (the forest area). Therefore, if design-based analysis has priority, these boundary plots need special emphasis and corrections to allow unbiased estimation. In principle two different alternative approaches could be applied:

1) determine the plot area inside the forest area: this leads to sample plots of unequal size (those intersecting the boundary are smaller) and requires an appropriate weighting or application of the ratio estimator,
2) mirroring the plot at the forest boundary (back into the forest area) and account the mirrored area twice.

The latter option is a standard technique in forest management inventories using circular plots, but unhandy and impractical for the relatively large quadratic plot proposed here. Since a detailed delineation of the forest boundary is time consuming, a classification of the single plot quadrants is recommended (assigning non-forest to all quadrants whose center points are outside of the forest area, see also 4.4), which is a coarser form of mapping.

4.6 Assessment of standing trees

After installing the plot outer- and inner corner points and ends of the transect lines, standing trees are assessed in a clockwise sweep starting from North direction (order according to increasing direction angle). In very dense forests with limited visibility where trees cannot be identified from the plot center, a different acquisition sequence is allowed. The decision whether a tree is in or out depends on its DBH and distance. All trees with DBH larger than >=30 cm are measured on the total plot area (40x40m), while trees <30 cm or <15 cm are recorded in smaller subplots. Since the measurement of tree heights (on a subsample of trees) will interrupt the workflow, they should be measured independently after all other tree variables have been recorded. Temporary numbering of trees is important to identify the trees for which heights should be measured.

While lying deadwood is another independent entity with different variables, the standing dead trees or standing stem sections as well as stumps are recorded in the tree table using the same diameter thresholds as for living trees. These classes of tree conditions need to be flagged respectively and diameter and height are measured (eventually in different measurement heights).

4.7 Regeneration assessment

Regeneration refers to all trees smaller than the diameter threshold of 7 cm and is assessed in a cluster of four sub-plots placed in the cardinal directions along the diagonals from the plot center to the inner plot corner points. Regeneration trees are counted by species and height class. The minimum height is 25 cm, smaller individuals are ignored! The cluster design ensures that the relatively high spatial variability of forest regeneration is well captured within the plot. It is up to the field teams and depends on local conditions whether the regeneration assessment is done before or after the assessment of down deadwood or ground vegetation cover (eventually all observations along the diagonal transects can be done in parallel). The recommendation, however, is to do the regeneration assessment first to avoid trampling damages!

4.8 Deadwood assessment

The assessment of lying deadwood is based on a Line Intersect (LIS) approach in which the four cardinal directions (viz. the two plot diagonals) are used as sampling elements. Diameter of lying deadwood is measured at the point of intersection with the sample line and allow an estimate of total length of deadwood in the respective diameter classes (and in the following also deadwood volume). In addition, the decay status is assessed in classes. In order to correct for slope or leaning trees, the inclination angle of pieces is also measured.

In context of the pilot study all pieces of deadwood exceeding a diameter of 10 cm at the point of intersection are recorded (together with the distance from the plot center) on the total transect length (14.14m in each direction). At a later stage, once sufficient data are collected, different nested designs can be simulated and tested. For example, different diameter classes could be observed on different length of the transect lines, like lying deadwood < 20 cm is assessed only up to 7.07m distance (radius of smaller plot) and >=20 on total length of 14.14m?

4.9 Assessment of ground vegetation cover

An assessment of coverage of broader classes of non-woody herbaceous ground vegetation is indicated if relevant amounts of green-leaved plant communities are present and detectable (depending on phenological phase). The sampling elements used to derive an estimate of coverage (plant cover per area) are the transect lines also used for the deadwood assessment. Contrary to the deadwood assessment, in which measurements are done at the intersections between the transect line and lying pieces of deadwood only, the ground vegetation survey is based on measuring the length of line intercepts falling on/in specific vegetation classes. From that, an estimate of the cover proportion can be derived over the two transect lines, which represent a cluster.

The intention of this survey is not to identify single species, nor to record the ground coverage for each individual. In order to adapt the surveying efforts and time consumption for the ground survey, the spatial (lengthwise) resolution of observations along the transect lines is set to a minimum intercept length of 1m (intercept lengths are rounded to the meter and entered as integer value).

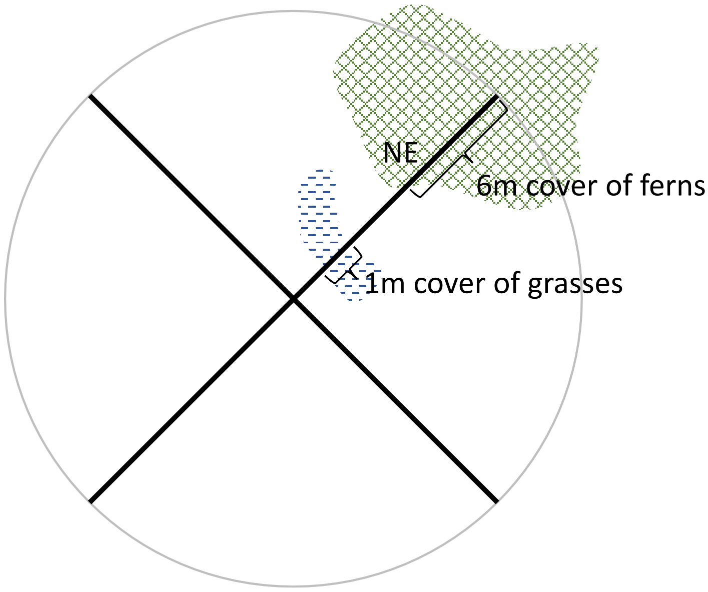


Figure 7. Example of a ground vegetation cover assessment along the North-Eastern (NE) transect line: coverage of ferns (green) is observed on an intercept length of 6m (a proportion of 6/14 ~ 43%) and grass cover on 1m (~7%). Single intercepts shorter than 1m are not recorded.

5 Field procedures, devices and equipment

5.1 Overview and devices

The described plot design is planned considering some practical criteria for field implementation. The size of field plots as well as DBH thresholds suggested for the pilot inventories is fixed having constrains about the available resources in mind, mainly time and cost limitations. One common planning basis in this context is that the complete assessment of a single field plot by a regular trained field team can be done within one day in average, which helps reducing travel, accommodation and labor costs. Average conditions refer to the number of trees included by the respective plot design, which might vary significantly for different forest types across Europe. Therefore, depending on forest type, structural complexity and accessibility, the expected time per plot might vary.

All described field procedures ca be implemented by a two-person field team. In order to ensure that independent field teams across Europe are using exactly the same interpretations and measurement procedures, a careful study of this inventory guidelines and joint training of field crews is recommended.

For the described field procedures and plot assessments, a basic list of common measurement devices and equipment is needed. Since field plot assessments on a European scale is in the responsibility of the participating countries and eventually also tendered to contractors, the use of exactly the same set of measurement devices cannot be guaranteed. Therefore, the following list is a recommendation and the use of alternative standard devices allowing as accurate and consistent measurements is possible.

Table 5. List of devices and materials for plot installment and assessment (as of April 2023).

Device / equipment	Number	Application	Recommended	Alternatives
(D)GNSS receiver	1	Measurement of plot coordinates. Mounting pole is recommended	RTK systems like STONEX S580, EMLID REACH RX / RS+, or similar receivers allowing real-time correction via NTRIP	Many alternatives from Leica, Trimble, Topcon, DJI, and others.
Compass	1 (2)	Measurement of azimuth for trees and plot diagonals to corner points	Suunto KB-14/360R G, or KB-20 360R G or similar with degree (°) scale. A second compass increases flexibility of field team.	Silva or other precise compass with fine scale
Clinometer	1	Measurement of tree- or stem heights. The availability of two alternative clinometers can potentially speed up plot assessments and provides flexibility.	- Vertex IV or V including transponder - TruPulse 200 or 360 or Nikon Forestry Pro	- Haglöf ECII-D electronic clinometer - Suunto PM-5/1520 - Silva Clinomaster - Mirror Relascope

Device / equipment	Number	Application	Recommended	Alternatives
Tape measure 50m	1 (2)	Regular tape measure 50m length for plot installment and assessments on deadwood- and vegetation transects	- A second tape measure (e.g. 30m) could increase flexibility of the field team	
Diameter tape	1	Usual diameter tape (pi-scale) as loose version or on roll with hook		
Folding ruler	1	For regeneration plot assessment		
Tablet	1	Field data collection with PathFinder Field App and use of additional Apps (Qfield, GNSS Receiver, …)	E.g. Samsung Galaxy Tab active 4 or similar (see also 7.2)	Many alternatives for re. cheap tablet computers or using own smartphone (Android)
Mobile hard drive, USB stick or SD card	1	Used to download and safe a backup of the recorded data after every day of field work		
Surveying poles	min. 5	Marking plot center and inner- or outer corner points.	Wooden or plastic surveilling poles (no metal at plot center marking because of compass!)	Alternatively, plastic tubes or other marking poles (e.g. snow poles)
Chalk	10	Normal chalk (no wax chalk!) for temporary marking trees		
Plot marking	1-5 per plot	Iron or aluminum marking core (25-30 cm length)	- Permanent marking is obligatory for the plot center; additional marks can be set on the outer corner points (5 per plot)	
Powerbank	1	Powerbank as additional batterie for tablet or recharging other devices		
First Aid kit	1	Security in the field is in responsibility of field team / contractor	A first aid kit should be available for every field team	
Plastic bags	10	10 small plastic bags to transport leaf or branch or soil samples		

Device / equipment	Number	Application	Recommended	Alternatives
Batteries	5	Enough batteries for devices, usually AA		
Maps	If available	If available an overview map about field plot locations (or prepared field GIS on tablet)	In case of limited mobile network or offline use of tablets, download relevant maps before leaving to the field!	Printed paper maps for orientation

The completeness of equipment and the charging status of batteries and devices should be checked after every work day and/or well ahead of leaving for field work.

5.2 Training of field crews

For training of field crews in the piloting phase, video tutorials on specific measurements and different devices are available on the YouTube Channel "Monitoring of Forest Resources" in this playlist: https://youtube.com/playlist?list=PLOPimAo58o0zVwJ6bAU3RE1t39Q7BrlhT

6 Set of variables

6.1 Introductory comments on the set of core variables

The defined core set of variables refers to the minimum information that should be collected on PathFinder field plots. Regular NFIs often collect more than 150 variables per plot, some of them very specific and addressing detailed information needs. The core list of variables in PathFinder plots is relatively short and reduced to a minimum that is required to produce estimates and contribute to remote sensing analysis in accordance to the project goals. In addition to this core set of variables defined for the pilot inventories, additional variables might be included at a later stage of the PathFinder project.

The variables defined so far refer to different entities or objects, like the assessment itself, the plot (area), single trees, regeneration, lying deadwood and ground vegetation. Protocols for soil sampling are not yet included and will be developed and implemented at a later stage.

6.2 Accounting for phenology and timing

Forest inventories aim at describing the objects of interest in a consistent and uniform manner to ensure a meaningful interpretation of estimates over time. Since field work in large area forest inventories cannot be implemented at one specific point in time (often implementation is done outside the vegetation period), the list of variables and observations is limited to those that can be obtained in a consistent manner independently of vegetation period, phenology or any other changing environmental conditions. This leads to the problem that potentially interesting information for biodiversity assessments, like e.g. the varying species composition in an herb layer, the presence of mushrooms, or other information on the health status, like leaf discoloration, cannot be integrated in regular forest inventories as standard variables. The same holds for observations on fauna, like e.g. the presence or abundance of birds or insects that is variable over time (and would – in addition - require very specific qualifications of the field teams).

The list of variables defined here is therefore tailored towards the main goals of the PathFinder project considering, however, mainly those variables that could be observed and assessed independent of the current vegetation period and phenology. I order to still account for relevant vegetation characteristics that have influence on correlations between recorded variables and spectral reflectance in remote sensing imagery, some basic information on ground vegetation can be collected dependent on the phenological status or season during the assessment. Therefore, respective assessments of vegetation coverage in broader classes are possible, if the plot assessment is done at a suitable season (see 6.3.4).

6.3 General information about the assessment

6.3.1 Country

The ISO 3166 2-alpha country code selected from code list:

Country code	Country
BE	Belgium
HU	Hungary
BG	Bulgaria
MT	Malta
CZ	Czechia
NL	Netherlands
DK	Denmark

Country code	Country
AT	Austria
DE	Germany
PL	Poland
EE	Estonia
PT	Portugal
IE	Ireland
RO	Romania
EL	Greece
SI	Slovenia
ES	Spain
SK	Slovakia
FR	France
FI	Finland
HR	Croatia
SE	Sweden
IT	Italy
IS	Island
CY	Cyprus
LI	Lichtenstein
LV	Latvia
NO	Norway
LT	Lithuania
CH	Switzerland
LU	Luxembourg
UK	United Kingdom

6.3.2 Field team / contractor

Name of the field team leader or the responsible person who is entering the data in the mobile device.

6.3.3 Date

Starting date of the plot assessment as DD.MM.YYYY

6.3.4 Ground vegetation survey

Field work of independent inventory teams across Europe can hardly be synchronized in time, especially if the implementation of PathFinder plots is integrated into the regular NFI field work of different countries. As explained earlier, the core set of variables is therefore limited to those that can be observed independent of different phenological phases. On the other hand, information on vegetation coverage might be very important in context of remote sensing integration, because it might have a strong influence on remote sensing metrics, but it can only be observed in certain phenological stages or the vegetation period between April and October (varying depending on country and climate).

The PathFinder Field App and respective data structure allows collecting information on the coverage of ground vegetation using a transect based Line Intercept (LIS) approach, which only makes sense during the vegetation period of for those plant communities whose coverage can be observed throughout the year.

This Boolean field is used to trigger a ground vegetation survey, if indicated. This means, the input fields for the vegetation survey are shown only if this variable is set to YES.

Unit	Name / Format	Required	Validation / severity
TRUE/FALSE	ground_veg / Boolean	always	Default set to TRUE

6.4 Plot variables

Plot variables are all observations that refer to the plot area or in some cases to interpretations considering also the plot surrounding. Typical examples are forest- or management type or topographic / terrain variables.

6.4.1 Plot id

A unique id of the plot in the PathFinder plot network. This id is a database key field and is either selected from a predefined plot list or entered manually (depending on the final planning of the sampling design, the list of plot ids and plot locations is fixed or allows manual entries).

Unit	Name / Format	Required	Validation / severity
Text	plot_id / varchar 20	always required	Database key field, no duplicates allowed!

6.4.2 NFI (sub-) plot or ICP Forests plot id

In case the plot is installed at a plot- or subplot location of an existing NFI or ICP plot, the respective NFI (sub-) plot id (in the national NFI plot network) can be entered as reference. In case NFI plot ids should be kept confidential, countries can enter any other reference id to link PathFinder plots with national NFI plot locations.

Unit	Name / Format	Required	Validation / severity
Text	nfi_id / varchar 20	Not required	No

6.4.3 Date

Starting date of the plot assessment. In case the plot assessment is continued on another day, only the starting date as DD.MM.YYYY.

6.4.4 Plot status

Status of the plot in the current inventory cycle. Also allows marking inaccessible non-response plots. For the first implementation phase in the PathFinder project a default value of 1 (New plot) is set.

Code	Status	Description
1	New plot	A newly installed plot that was not measured before
2	remeasured	A plot that is remeasured
3	discontinued	A plot that was measured before but is discontinued for any reason (e.g. limited accessibility) and will not be measured again in future.
4	non-response (not accessible)	A plot that is part of the plot network but cannot be accessed in the current inventory cycle. The plot cannot be reached (e.g. temporal flooding or snow cover), but the plot location is not discontinued and remains a sampling location for future assessments.

6.4.5 Plot center coordinate

The coordinate of the plot center in ETRS89 / LAEA Coordinate Reference System (EPSG:3035, European Terrestrial Reference System 1989). For details of this projection see https://epsg.io/3035

Single CRS for all Europe. Used for statistical mapping at all scales and other purposes where true area representation is required.

Please read the instructions on coordinate measurements under 4.4.1! Even if the mobile data collection App allows applying the coordinates of the mobile device, this is not recommended! A manual entry of coordinates (in the right projection!) measured with a high precision DGNSS or RTK system is required!

Unit of measurement	Name / Format	Required	Validation / severity
Centimeter with mm precision, e.g. 17.8	plot_coordinate / Float	always	WARNING: if distance to selected target coordinate >20m (if a list of point coordinates is uploaded before, in the pilot inventory no validation)

6.4.6 Plot marking

The center of the permanent monitoring plots should be marked with iron (or metal) cores or tubes in the ground. Additional marks can be used for the outer corner points. In case the mark can only be installed with an offset, direction and angle need to be specified.

Code	Marking	Description
1	Plot marked (new plot)	The plot center is marked for the first time (new plot)
2	Plot marking found (re-measurement)	The permanent plot mark of an existing plot was found at the right position
3	Marking not found, position reconstructed	The marking of an existing plot was not found (or unusable), but could be reconstructed from distance and angle measurements of identified trees. A new mark is set!
4	Marking with offset (new or existing plot)	Marking is not possible at the plot center (e.g. because on a road, a skidding trail or rocks) and a marking is set using a (documented!) offset direction and angle.

Code	Marking	Description
5	Marking not found, new plot established	The permanent marking was not found and the position cannot be reconstructed. A new marking was done at target position and a plot is installed.
6	Plot discontinued	The plot needs to be discontinued; marking is obsolete

6.4.7 Offset angle

If marking at the plot center is not possible (=4), an offset angle and direction can be entered. This is the angle from the marked position to the plot center in degree (°).

6.4.8 Offset distance

If marking at the plot center is not possible, an offset angle and direction can be entered. This is the horizontal distance between the marked position and the plot center in meter.

6.4.9 Slope angles

Average slope angles in degree (°) measured along the diagonals of the plot in the four cardinal directions NE, SE, SW, NW. For this n:1 relation (4 slope angles per plot) a table with the pre-defined directions is used. In the PathFinder Field App the resulting slope distances to inner- and outer corner points are calculated based on the slope angles (just for information).

6.4.10 Multiple domain assignment

Decision whether a single forest- or management type should be assigned for the whole plot area (default: total plot area in one type) or whether it needs to be assigned on the level of single quadrants (**not recommended**). In case the plot intersects clearly different forest type or management classes, the decision about class membership can be done for each quadrant individually. This, however, should only be done if boundaries of clearly different and spatially aggregated coherent areas for forest- or management types are intersecting the plot area (e.g. an even aged spruce plantation and a mixed beech forest). Smaller groups of trees are not forming a separate forest type! In case of gradual transitions without clear boundaries, a single forest type for the whole plot area should be assigned based on the largest proportion of crown cover area. So called "partial plots" covering multiple forest types are not optimal for modelling with remote sensing data.

6.4.11 Stocking type

Broader forest type characterizing the current stocking. The current stocking can differ from the expected (potentially natural) forest type according to European Forest Type (EFT) classification. In case of discrepancy between current stocking and potential EFT, forest type should be 14.

Code	Stocking	Description
999	Non-forest area	Should be assigned for quadrants outside of the forest
0	temporarily unstocked forest area	Temporarily unstocked area (still forest area!) due to management regime (clear cut) or as result of areal calamities like bark beetle calamity or wind break. Natural or artificial regeneration has not yet reached minimum DBH thresholds (for trees) or minimum height (regeneration).
1	Broadleaf forest	Single-species or mixed broad leaf forest
2	Coniferous forest	Single species or mixed coniferous forest
3	Mixed broadleaf / conifereous forest	Mixed broadleaf / coniferous forest

6.4.12 Forest type

In order to allow a European-wide classification of forest types, the European Forest Type (ETF) classification system (according to European Environmental Agency: https://www.eea.europa.eu/publications/technical_report_2006_9) is used. Forest types across Europe are classified with a hierarchical classification schema up to the second level. As explained in 4.4, the dominant forest type can be assigned for the whole plot area (recommended default), or, in case of significant domain overlap also on the level of single quadrants of the plot if required (not recommended). If an assignment on the quadrant level is indicated, a separate forest type needs to be recorded for every 16 quadrants!

Table 6. European Forest Type (ETF) classification according to European Environmental Agency 2006.

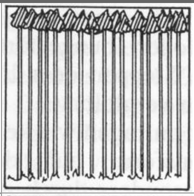
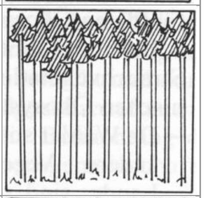
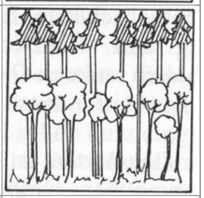
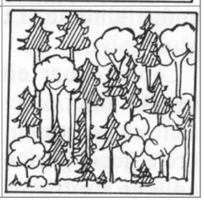
Level 1 code	Level 1 type	Level 2 code	Level 2 type
1	Boreal forest	1.1	Spruce and sprucebirch boreal forest
		1.2	Pine and pinebirch boreal forest
2	Hemiboreal forest and nemoral coniferous and mixed broadleavedconiferous forest	2.1	Hemiboreal forest
		2.2	Nemoral Scots pine forest
		2.3	Nemoral spruce forest
		2.4	Nemoral Black pine forest
		2.5	Mixed Scots pinebirch forest
		2.6	Mixed Scots pinepedunculate oak forest
3	Alpine coniferous forest	3.1	Subalpine larcharolla pine and dwarf pine forest
		3.2	Subalpine and mountainous spruce and mountainous mixed sprucesilver fir forest
		3.3	Alpine Scots pine and Black pine forest
4	Acidophilous oak and oakbirch forest	4.1	Acidophilous oakwood
		4.2	Oakbirch forest
5	Mesophytic deciduous forest	5.1	Pedunculate oak–hornbeam forest
		5.2	Sessile oak–hornbeam forest
		5.3	Ashwood and oakash forest
		5.4	Mapleoak forest
		5.5	Limeoak forest
		5.6	Maplelime forest
		5.7	Lime forest
		5.8	Ravine and slope forest
		5.9	Other mesophytic deciduous forests
6	Beech forest	6.1	Lowland beech forest of southern Scandinavia and north central Europe
		6.2	Atlantic and subatlantic lowland beech forest
		6.3	Subatlantic submountainous beech forest
		6.4	Central European submountainous beech forest
		6.5	Carpathian submountainous beech forest
		6.6	Illyrian submountainous beech forest
		6.7	Moesian submountainous beech forest

Level 1 code	Level 1 type	Level 2 code	Level 2 type
7	Mountainous beech forest	7.1	South western European mountainous beech forest (Cantabrians, Pyrenees, central Massif, south western Alps)
		7.2	Central European mountainous beech forest
		7.3	ApennineCorsican mountainous beech forest
		7.4	Illyrian mountainous beech forest
		7.5	Carpathian mountainous beech forest
		7.6	Moesian mountainous beech forest
		7.7	Crimean mountainous beech forest
		7.8	Oriental beech and hornbeamoriental beech forest
8	Thermophilous deciduous forest	8.1	Downy oak forest
		8.2	Turkey oak, Hungarian oak and Sessile oak forest
		8.3	Pyrenean oak forest
		8.4	Portuguese oak and Mirbeck's oak Iberian Forest
		8.5	Macedonian oak forest
		8.6	Valonia oak forest
		8.7	Chestnut forest
		8.8	Other thermophilous deciduous forests
9	Broadleaved evergreen forest	9.1	Mediterranean evergreen oak forest
		9.2	Olivecarob forest
		9.3	Palm groves
		9.4	Macaronesian laurisilva
		9.5	Other sclerophlyllous forests
10	Coniferous forests of the Mediterranean, Anatolian and Macaronesian regions	10.1	Mediterranean pine forest
		10.2	Mediterranean and Anatolian Black pine forest
		10.3	Canarian pine forest
		10.4	Mediterranean and Anatolian Scots pine forest
		10.5	AltiMediterranean pine forest
		10.6	Mediterranean and Anatolian fir forest
		10.7	Juniper forest
		10.8	Cypress forest
		10.9	Cedar forest
		10.10	Tetraclinis articulata stands
		10.11	Mediterranean yew stands
11	Mire and swamp forest	11.1	Conifer dominated or mixed mire forest
		11.2	Alder swamp forest
		11.3	Birch swamp forest
		11.4	Pedunculate oak swamp forest
		11.5	Aspen swamp forest
12	Floodplain forest	12.1	Riparian forest
		12.2	Fluvial forest

Level 1 code	Level 1 type	Level 2 code	Level 2 type
		12.3	Mediterranean and Macaronesian riparian forest
13	Non riverine alder, birch, or aspen forest	13.1	Alder forest
		13.2	Italian alder forest
		13.3	Boreal birch forest
		13.4	Southern boreal birch forest
		13.5	Aspen forest
14	Plantations and self-sown exotic forest	14.1	Plantations of sitenative species
		14.2	Plantations of notsitenative species and selfsown exotic forest

6.4.13 Forest structure

The vertical structure describes the variability of tree heights and the layering of a stand. Structure is observed by visual estimation of mean conditions on the plot and the direct plot surrounding. This variable is also of interest for remote sensing integration, as it influences the correlation and saturation of ground-based estimates and RS based predictions.

Code	Structural complexity	Description	
1	one layer, same heights	single layer forest, like even aged plantation, all trees of same heights	
2	one layer, variable heights	single layer vertical layer, but varying heights	
3	multiple layers	multiple clear layers	
4	variable structure in gaps	variable structure in gaps	
5	complete variable	complete variable (natural forest)	

6.4.14 Quadrants

In case "Multiple domain assignment" is set to TRUE (checked), forest type and management regime can be assigned for each quadrant of the plot separately. This requires a table structure allowing to enter values for all 16 quadrants. Even if a separate assignment for each quadrant of the plot is possible and the data structure allows this, the recommended default is that plots are selected that are completely within a single forest- or management type. Data collected in the PathFinder project have the main purpose of supporting remote sensing modelling and "split plots" overlapping relevant domain boundaries might have negative influence on the model quality.

6.4.15 Plot comments

Relevant free text comments explaining special situations (might include information about how to access the plot or an explanation for inaccessible non-response plots).

6.4.16 Plot file upload

The PathFinder Field App allows uploading a file (max. 3MB) if required. This file can be a hand drawing (or, if required another photo or a photo of a drawing), providing relevant explanations about the plot location (e.g. offset of markings of corner points in case they fall on a road) or also specific plot characteristics relevant to explain specific conditions possibly influencing the reflection or spectral signature (or RADAR backscatter) in satellite imagery and/or characterizing biotope and habitat characteristics.

Figure 8. Typical relevant situations that might largely influence the multispectral reflectance or RADAR backscatter of satellite sensors: open water surfaces or partially flooded plots, a continuous coverage of large-leaved non-woody plants or massive coverage of tree crowns by climbers. Such situations would justify mapping in a hand drawing or uploading an additional photo. Such observations do also inform about habitat characteristics and biodiversity.

Typical examples are standing water / riverbeds or temporarily flooded areas, the existence of large-leaved and large area-covering climbers reaching into upper canopy layers, a continuous coverage of specific plants in the herb or bush layer possibly leading to high reflections in the NIR band (because of large leaves with high chlorophyll content), sealed or artificial surfaces and others. An upload of such drawings is not mandatory and should only be used in special cases that require further explanation!

6.4.17 Plot photo

The PathFinder Field App allows taking a photo of the plot center to describe surrounding conditions and support re-location of the plot in a following inventory cycle. The photo should be taken in landscape format from larger distance (if visibility allows) and should possibly show the marked sample point and surrounding trees.

6.5 Tree variables

Tree variables are all attributes observed or measured on single trees included by the plot design.

6.5.1 Stem ID

Unique ID number per tree (stem) and plot. Trees should be assessed and numbered in ascending order according to their azimuth (bearing) starting from North direction (clockwise). Tree stems bifurcating below 1.3m (the reference height for DBH measurement), get individual stem IDs and are recorded as multiple stems.

Tree numbers should be marked temporarily in direction to the plot center with chalk or temporal tree marking paint in about 1m height. Durable or long-lasting paint or markings should be avoided in any case! Forest inventory plot locations should not be visible and all indications of conducted plot assessments should disappear as soon as possible! Instead of using chalk or paint, the use of temporal tags or signs pinned on the tree bark only during the time of plot measurements is recommended.

Identification of stems in remeasurements

During remeasurements of existing plots, trees (stems) should be identified by their stem id (identified by azimuth, distance, species and dimensions) and the existing id of the past inventory cycles should be used! For new trees (ingrowth that has not been measured before), new stem ids are given that start at a hundred number higher than all old stem ids (e.g. if 46 stems were numbered in the last inventory cycle, new stems in the current inventory cycle get numbers 100, 101, 102, …).

Unit	Name / Format	Required	Validation / severity
Integer number	stem_id / Integer number	always	ERROR: Defined as database key field the value requires to be unique.

6.5.2 Tree status

Status of this tree in the current inventory cycle. In context of pilot inventories and newly established plots, the default is set to 1=new tree on new plot.

Code	Status	Description
0	Discontinued tree (out)	The tree was measured in an earlier inventory cycle, but is definitely out of the plot
1	New tree (on new plot)	All trees measured for the first time on a newly installed plot
2	New tree (forgotten before)	A tree that is measured for the first time, but should have been measured already in the last inventory cycle (unlikely to be ingrowth)
3	New tree (ingrowth)	A tree measured for the first time (on a re-measured plot) that is likely ingrowth (tree DBH suggests that it has grown over diameter threshold since last inventory cycle)
4	Re-measured tree (ongrowth)	A re-measured tree that was identified by its tree id and is measured repeatedly
5	Harvested tree (harvest)	A tree that was measured in the last inventory cycle (identified by tree id and/or stem position) but was harvested after the last inventory (stump can be identified)
6	Dead tree (mortality)	A tree that was alive and recorded in the last inventory, but died since the last inventory or a dead tree on a newly installed plot
7	Dead tree (remaining)	A dead tree that was measured and already dead in the last inventory cycle (long lasting standing deadwood)

6.5.3 Old tree number

In case of repeated measurements this is the old tree number of this tree in the last assessment.

6.5.4 Tree / stem condition

Basic condition of the stem or tree recorded. The default is set to “standing alive” and need to be changed only for dead or broken trees or standing stem sections. Since standing deadwood and tree stumps are recorded in the tree table, it should be marked here respectively.

Code	Condition	Description
0	standing alive (default)	standing alive tree
1	standing dead tree	A standing dead tree (complete with crown)
2	standing dead stem part	A standing broken dead tree or tree stem higher 1.3m
3	broken or deformed crown	A living tree with broken crown (or any other unusual relation between DBH and height) that should be excluded for modelling height curves
4	tree stump	Tree stump

6.5.5 Horizontal distance

Horizontal distance between the marked sampling location and the central stem axis of the tree in 1.3m height in m (with decimeter precision). For stumps or standing stem sections smaller 1.3m height, it refers to the stem position in lower height.

Horizontal distance can be measured from the sample point to the stem axis (e.g. using Vertex) or in opposite direction (e.g. using a laser rangefinder). In case a laser rangefinder is used outgoing from the plot center, the measured distance needs to be corrected by adding ½ of the tree's DBH (since the laser is reflected from the stem surface and does not refer to the stem axis). In flat terrain application of a tape measure is possible, in sloped terrain this is not recommended and electronic devices offering automatic slope correction should be preferred.

Unit of measurement	Name / Format	Required	Validation / severity
Meter with decimeter precision, e.g. 7.8	tree_hdist / Float	always	WARNING: Depending on recorded diameter and horizontal distance is checked against the maximum distance.

6.5.6 Tree / stem diameter (DBH)

Stem Diameter at Brest Height (DBH) is measured for all standing trees (or included stems) in 1.3m measurement height from the ground (in cm with mm precision) perpendicular to the stem axis by diameter tape. Any obstacles, like climbers (e.g. ivy), loose pieces of bark, or mosses should be removed from the stem to allow a tight fit of the tape. The tape should lie in one level (90° to stem axis) around the stem. For larger DBH and rough bark, usage of a tape with mounting hook is recommended.

In case stumps or tree sections smaller than 1.3m height, the diameter measurement refers to an alternative measuring height.

Figure 9. DBH measurement with diameter tape (here 35.9 cm).

Figure 10 shows some examples of DBH measurements in special situations or on trees (stems) with deformations, which are the following:

- For trees (stems) standing at slopes, the measurement height 1.3m refers to the upper side of the slope. Reference is the top of the mineral soil, in case of larger accumulation of litter or branches, they should be removed or measurement height is measured with a reference stick,
- The same rule holds for leaning trees, where 1.3m is measured on the leaning side,
- In case of stem deformation at 1.3m, an average of two measurements (above and below) is calculated,
- Trees bifurcating below 1.3m are recorded as two stems and DBH is measured for each. In order to trace the affiliation of multiple stems to one individual, only one azimuth and distance (to the main stem or center) is measured,

- In case of larger deformation in the lower stem section, a diameter at different measurement height need to be measured (see also 6.5.7) and this different height to be recorded, as well.

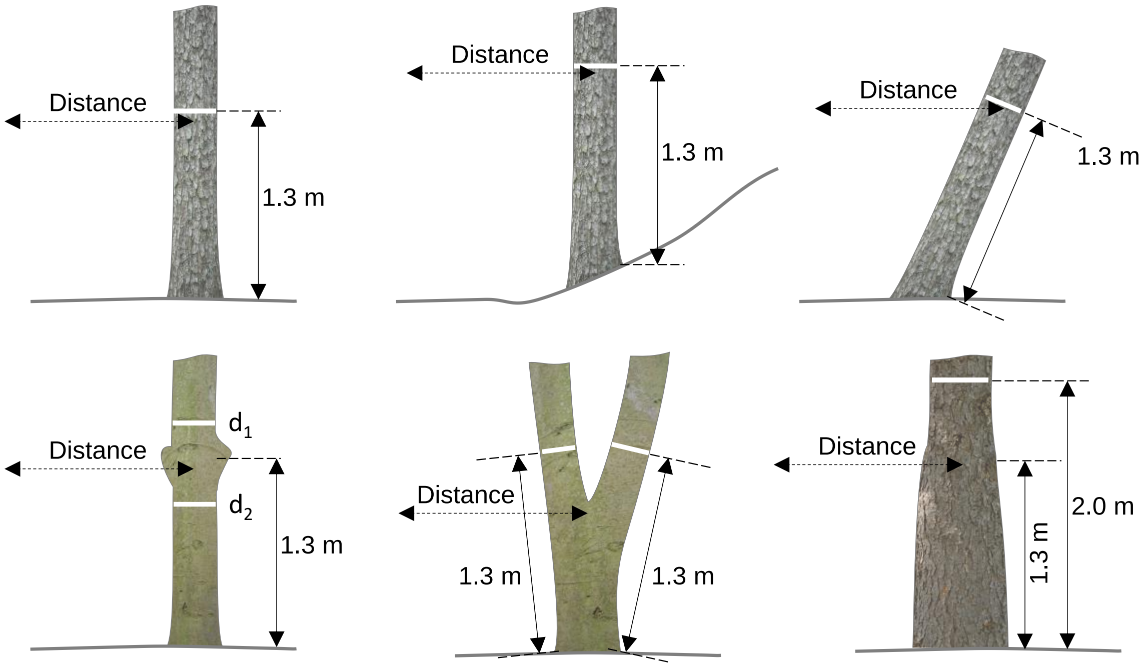


Figure 10. Overview of DBH measurements in special situations.

Measurement with caliper

In any case the use of a diameter tape is recommended, since it results in higher accuracy, especially in re-measurements of trees at multiple points in time! If, for any reason, the measurement is not taken with a diameter tape, but with a caliper, the direction of the measurement matters and needs to be controlled carefully. Therefore, if a caliper is used, the following instructions hold:

1) For the first measurement, the fork of the caliper should always point to the plot center! If country specific definitions differ (e.g. the fork should point to the center), this can also be done. It is then important to use the same rule also for re-measurements.
2) For trees ≥ 30cm (in the first measurement), a second measurement is taken perpendicular (90°) to the first direction and DBH is calculated as average from both measurements. For trees < 30cm only one measurement is taken.

Unit of measurement	**Name / Format**	**Required**	**Validation / severity**
Centimeter with mm precision, e.g. 17.8	diameter / Float	always	WARNING: if tree dbh > 1m WARNING: if dbh and distance do not comply with plot design

6.5.7 Height of D-measurement

The height for diameter measurements is set to 1.3m as default (DBH), but might need to be shifted to another measurement height in exceptional special cases. A deviating measuring height can be entered in meter with dm precision (e.g. 1.8m).

Unit of measurement	Name / Format	Required	Validation / severity
Meter with dm precision, e.g. 1.8	d_height / Float	always	Default 1.3m

6.5.8 Azimuth

Azimuth (the direction angle between magnetic North and the imagined stem axis) is measured from the sampling position (plot center) to the tree in degree (0-360°) by mechanical or electronic compass (e.g. Suunto compass or TruPulse 360).

For the correct measurement the device should not be fixed at any metal poles or stands: it is recommended instead to mark the plot center with a surveilling pole and to find a position 1-2m behind the marked plot center (on the opposite side of the tree direction) to correctly align the surveilling pole with the stem axis (at 1.3m height) of the tree (see Figure 11). Such a procedure increases accuracy of azimuth measurement. In areas with limited visibility because of dense understory, a higher position at the stem (for upright standing trees) might still be visible. In some cases where trees cannot be seen at all, a helper in the field team might temporarily mark intermediate locations along the line of sight.

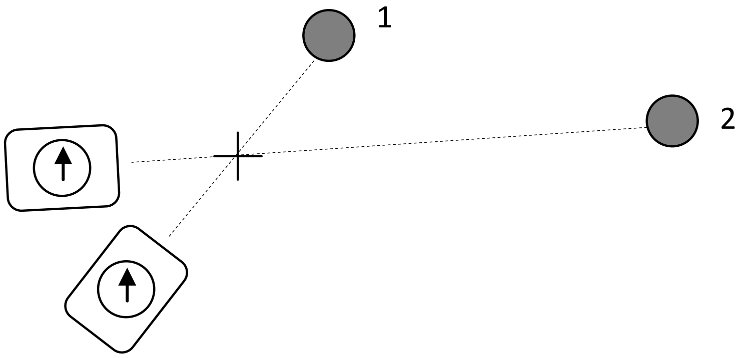


Figure 11. Measurement of azimuth (direction angle) using a compass.

Unit of measurement	Name / Format	Required	Validation / severity
Angle in degree (0-360°), e.g. 135	tree_azimuth / integer	always	Error: range limited to 0-360

6.5.9 Tree species

A tree species list of common European tree species was compiled from country specific NFI species lists by the European National Forest Inventory Network (ENFIN) and is used as taxonomic backbone in context of the pilot inventory. The list contains 282 tree (and some shrub) species identified to the species level plus entries that refer to the genus level (together 363 entries). In addition, it contains the classes “Other broadleaved” and “Other coniferous” for unidentified species. Since one of the main goals of the PathFinder project is to support reporting on biodiversity indicators (where species richness is one of them), an identification of tree species to the species level is important. In case an identification of the species or genus is not possible during field work, a sample ID could be entered as reference to a leaf sample collected in the field. Tree species are selected from the defined species list by typing a species code, the scientific name or the common (English) name.

The species list can be found in the attachment 8.1.

6.5.10 Manual entry of tree species

In case the tree species cannot be found in the species list, but is known, this field can be used to type the scientific name (Latin name) of the species. In case the Latin name is not known, but a common (preferable English) name it can be used instead.

Unit of measurement	Name / Format	Required	Validation / severity
Alpha-numeric	tree_spec_man / varchar 50	Not required	Only if tree_spec code is NULL

6.5.11 Tree sample

Allows entering an id or reference to a collected sample of leaves or twigs for later identification of tree species to the species level (only shown if tree species is not identified).

Unit of measurement	Name / Format	Required	Validation / severity
Alpha-numeric	tree_sample / varchar 20	Not required	Only if tree_spec code is NULL

6.5.12 Tree height

Tree height is defined as vertical distance between the tree top (highest point) and the level of the ground at the base of the stem and is measured in meter with dm precision (e.g. 23.7m).

Unit of measurement	Name / Format	Required	Validation / severity
Meter with dm precision (e.g. 27.8)	tree_height / float	Only if generated random number ≤0.3 and tree_condition >=2	WARNING: for tree height >50m WARNING: tree_height (m) < 2* diameter (cm)

Tree heights are measured on a subset of the included trees in order to reduce the number of time-consuming height measurements. Trees for height measurements are identified after all DBHs were measured. For later remote sensing integration and as basis for modelling of plot biomass, a dominant height of the stocking stand is known to be more suitable (e.g. a basal-area weighted Lorey's height or a height resembling the tree of mean basal area). Such specific stand-describing variables, however, can later be derived from height curves (DBH-height models) for different species groups. Therefore, the selection of sample trees for height measurements is based on species and canopy layer. For each combination of species and layer 3 heights should be measured (if available). Only standing alive trees without broken crowns are considered. **In addition to these required height measurements, additional heights should be measured in case the random sample is not well covering the different species or in case there is suspicion that the selected heights are not well representing the whole range of tree dimensions.**

Tree height can be measured with different devices depending on site conditions and availability, like mechanical clinometers (Suunto, Silva Clinomaster, Blume-Leiss, Haga, …) or electronic devices (Haglöf electronic clinometer, TruPulse, Nikon Forestry Pro, Vertex, and similar). All of the listed devices are based on the trigonometric principle (see Figure 12), measuring distances and angles, and for the application some common important prerequisites should be considered:

1) The distance from which tree height is measured should be at least 1 better 1.5 times the tree height (for correct interpretation of tree top, see Figure 14),
2) In case of remarkable offset between the tree top and the stem position (to which the distance is measured), the measurement should be taken perpendicular to the direction of offset ("from the side") to avoid errors due to wrong baseline distance (see Figure 13),
3) In case mechanical devices are used that allow measuring height from fixed distances (Suunto, Silva, Blume-Leiss, Haglöf electronic clinometer, Haga, …), a slope correction need to be considered (if the line of sight for the distance measurement is not a horizontal distance),

$$h = h_1 - (-)h_2$$
$$h_1 = e \cdot \tan \alpha_1$$
$$h_2 = e \cdot \tan(-)\alpha_2$$

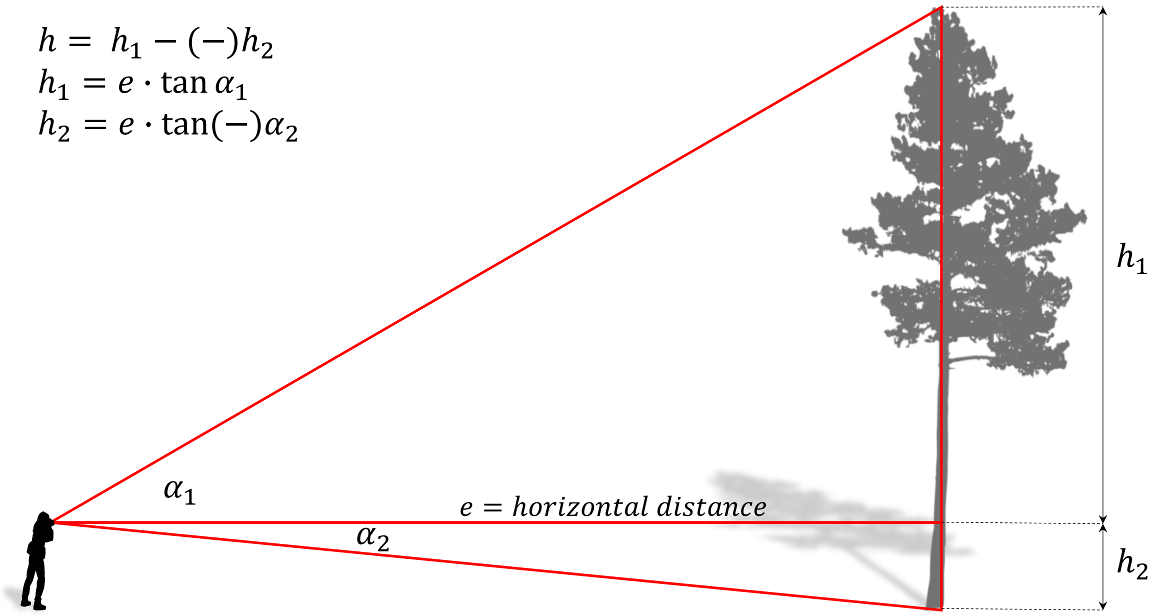


Figure 12. General principle of a three-point tree height measurement following the trigonometric principle as used by all of the suggested devices.

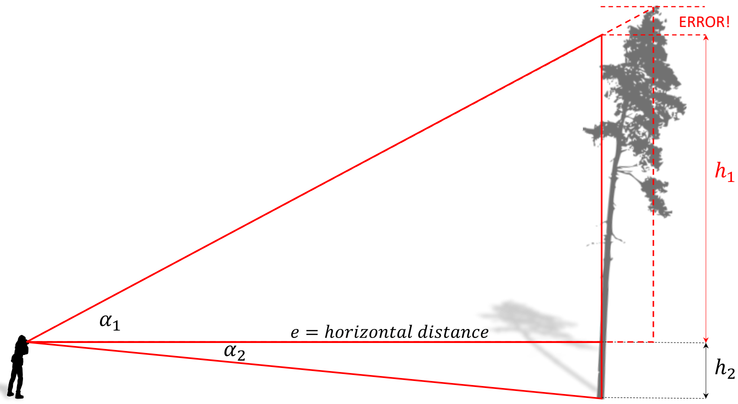


Figure 13. Possible error in tree height measurement due to leaning trees or offset between stem axis and tree top.

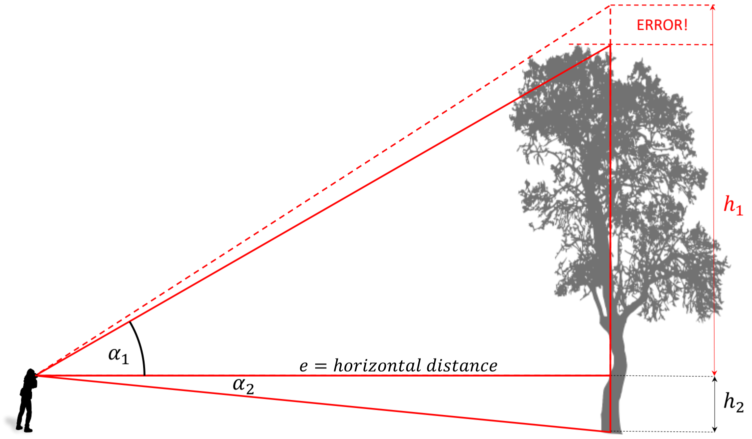


Figure 14. Possible error in tree height measurement due to limited visibility / identification of the highest position of the crown.

6.5.13 Height to crown base

In addition to total tree height, crown base height is measured as the height to the first strong living branch of the crown. From this crown length can be calculated and, under certain assumptions about crown form, also crown volume and surface, which might be relevant in context of further remote sensing integration. Usually, height to crown base can be measured from the same position that was used to measure tree height.

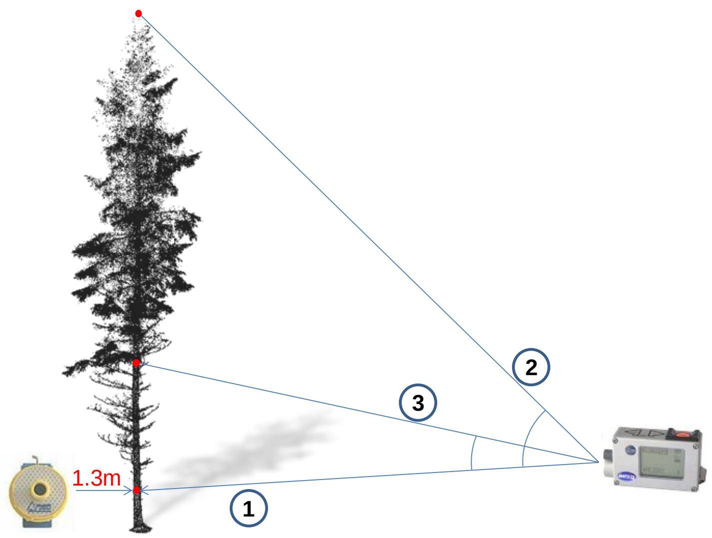


Figure 15. Measurement of total tree height and height to crown base using Vertex and transponder.

Unit of measurement	Name / Format	Required	Validation / severity
Meter with dm precision (e.g. 9.5)	tree_hcb / float	Only if tree_height not empty	ERROR: if tree_hcb > tree_height

6.5.14 Tree canopy layer

Describes in which horizontal canopy layer the tree is growing. The interpretation of “layers” in forest planning and management often refers to a combination of vertical layering of the tree crowns and also considers age classes (in fact it is a distinction of rel. homogeneous species/age class/layer cohorts). Here, the interpretation refers only to the vertical layers that are clearly separated. Since the interpretation should be comparable across all forest types and countries, only broader classes are used. In forests without clear layers and close to nature conditions (trees dimensions are varying and all height classes can be found), assigning a layer is not possible. Therefore, this variable is not relevant, if forest structure is set to "completely variable".

Code	Layer	Description
0	Overstory / supernatants	Single remnant trees of the former forest generation that are much older and larger than the main canopy. Stocking degree or canopy cover is <0.3 (if stocking density is higher, these trees form the main canopy!).
1	Main canopy	The main canopy / layer of the current species or species combination that has the largest share on basal area and crown cover (also the main species of commercial interest). EVERY managed forest area has a main canopy layer!
2	Understory	A second layer clearly lower than the main canopy layer.
99	No layers	Forest structure is completely variable, no clear layers can be distinguished

6.5.15 Tree detectability from remote sensing

The expected detectability of single trees in remote sensing imagery (aerial view) is an important variable in context of model building and application. Considering a strong saturation effect in the relationship between field observed biomass and vegetation indices derived from optical remote sensing data, especially in multi-layer forest stands, this variable informs about the proportion of trees (and tree crowns) that is possibly detectable in optical remote sensing products. The proportion of field observed trees having a low or no probability to be detected from above may affect the strength of the modelled relationships between field-observed and remotely-sensed observations.

The detectability of each single tree is assessed by visual interpretation and assignment in classes ranging from "completely visible" to "not visible", assuming leaf-on conditions. The interpreter should consider a potential acquisition angle of spaceborne satellite sensors of up to ~10° off nadir, so that space filling is evaluated in a slightly open upwards cone.

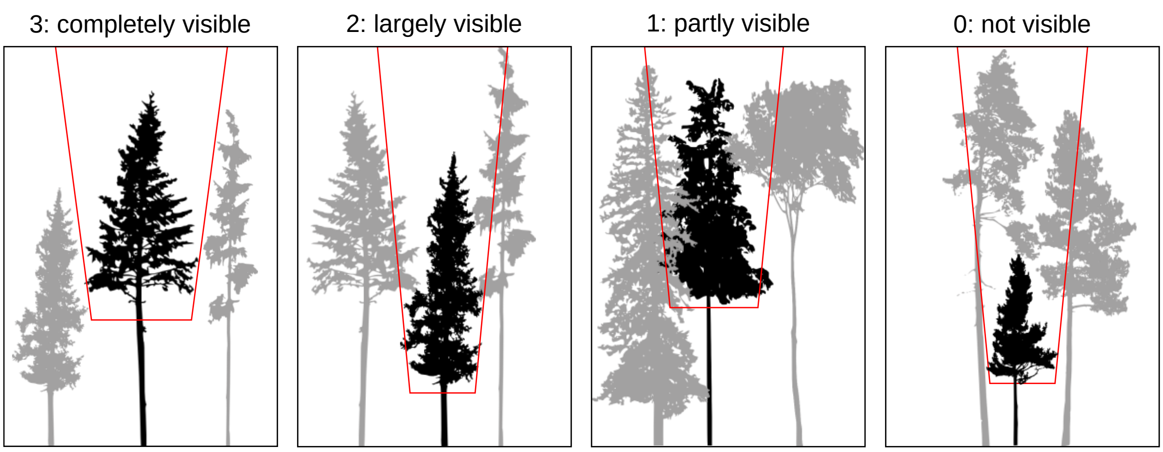


Figure 16. Classification of expected detectability of individual trees in remote sensing data sources.

Unit of measurement	Name / Format	Required	Validation / severity
Selection from code list	detectability / Integer number	If tree_condition = 0	

6.6 Tree damages

For trees >30 cm up to three damages can be assigned. Some of the listed damages can also be seen as valuable micro habitats.

Code	Layer	Description
1	Skidding damage	Bark or stem damaged by skidding. Skidding damages occur at the lowest part of the stem or the roots (<1.5m).
2	Felling damage	Stem or bark damaged by neighboring trees that were felled.
3	Broken crown	Completely or partly broken crown
4	Cancer / necrosis	Cancer or partly detached bark or smaller (sometimes slimy) spots of necrosis
5	Rezinosis	Resin effusion at stems of conifers
6	Bark beetles	Bark beetle infection at conifers
7	Stem rotting (by fungi infection) on living trees	Partly rotting stem
8	Drought stress	Tree is affected by drought stress and parts of the crown are dry. In leaf off condition dry branches stand out due to partially detached or cracked bark
9	Other damages	Specify

6.7 Regeneration assessment

Tree regeneration is assessed with a cluster of four small regeneration micro-plots installed in cardinal direction on the diagonals of the plot in 7m (7.07) from the plot center.

6.7.1 Regeneration subplot

Selection of cardinal direction from code list.

6.7.2 Species

Tree species selected from species list (see 8.1). In case the species is not in the list, a manual entry is possible in the next field.

6.7.3 Manual species entry

In case the tree species cannot be found in the species list, but is known, this field can be used to type the scientific name (Latin name) of the species. In case the Latin name is not known, but a common (preferable English) name it can be used instead.

Unit of measurement	Name / Format	Required	Validation / severity
Alphanumeric	reg_spec_man / varchar 50	Not required	Only if reg_spec code is NULL

6.7.4 Regeneration sample

Allows entering an ID or reference to a collected sample of leaves or twigs for later identification of tree species to the species level (only shown if tree species is not identified).

Unit of measurement	Name / Format	Required	Validation / severity
Alpha-numeric	reg_sample / varchar 20	Not required	Only if reg_spec code is NULL

6.7.5 Regeneration height class

Regeneration is counted separately in different height classes.

Code	Height class	Description
1	< 50 cm	All tree regeneration <50cm (Minimum height of seedlings is 10cm!)
2	50-130cm	Tree regeneration between 50 and 130 cm height
3	>130 cm (<7cm DBH)	All tree regeneration >130 cm and <7cm DBH

6.7.6 Regeneration count

The count of individuals in the respective species and height class.

6.8 Deadwood assessment

Lying deadwood (stem sections, branches) is assessed along two line transects outgoing from the sample point in the four directions NE, SE, SW, NW with a length of 14.14m each (length identical to the radius of the outer nested circular plot). At each intersection between the transect lines and lying pieces of deadwood, the diameter is measured at the point of intersection (perpendicular to the stem/branch axis). In addition, the decay status of the wood is assessed in 4 classes.

6.8.1 Deadwood transects

Transects are observed one by one and identified by their directions from North-East to North-West (NE, SE, SW, NW) defined as code list (see 4.8).

6.8.2 Horizontal distance

Horizontal distance from sample point to point of intersection rounded to nearest decimeter. This information is not required for estimation and is only assessed during the piloting face. It allows simulating shorter transect lines during plot optimization and validating the findings from the TLS assessment of deadwood.

Unit of measurement	Name / Format	Required	Validation / severity
Meter with dm precision (e.g. 6.7)	dead_hdist / Float	always	Error: if dead_hdist>transect length

6.8.3 Wood type

A distinction whether the deadwood is coniferous or broadleaved wood, which has a strong influence on the decay dynamics.

6.8.4 Deadwood diameter

Diameter of the lying stem or branch at point of intersection, measured perpendicular to stem / branch axis in cm. For lying deadwood pieces the use of a caliper is recommended. If only a diameter tape is available (that cannot be wrapped around ground touching deadwood), it is possible to measure the half circumference and double the diameter read from the tape.

Unit of measurement	Name / Format	Required	Validation / severity
Centimeter	dead_diam / Integer	always	Warning: if below diameter threshold

6.8.5 Decay status

The decay status of lying deadwood is assessed in 5 classes from fresh to completely decayed according to the following classes:

Code	Status	Description
1	Intact, fresh	Recently dead, with still fresh cambium (also remaining logging residuals) with complete bark and hard wood texture. Bark and cambium of original color.
2	Intact to partly decayed	Bark partly missing or loose, wood texture still hard and solid only slight decay. Cambium decayed; knife blade penetrates a few mm. Bark color still original.
3	Partly decayed	Partly soft or semi-soft consistency (knife penetrates <2cm). Bark only partly present and color changing.
4	Strongly decayed	Strongly decayed, no bark left (only fragments), partly soft and block structure, knife penetrates >2cm.
5	Completely decayed	Completely fragmented and powdery texture

6.9 Assessment of coverage in ground vegetation

As explained in 4.9, an assessment of ground vegetation is limited to those points in time (phenological stages) at which the coverage of herbaceous plants is possible (or relevant coverage can also be observed independent from seasonality). Intercept length >1m are rounded to the meter, segments <1m are not recorded. For some cover classes (e.g. berry bushes) an identification outside the vegetation period is possible, however, a larger snow cover in winter would make observations on ground vegetation completely impossible. In this case the variable “Ground vegetation survey” on the uppermost level of the survey should be set to “FALSE” (uncheck!).

6.9.1 Vegetation transects

Selection of the transect line (directions NE, SE, SW, NW from the center point) from code list (see also 6.8.1 and 4.8).

6.9.2 Vegetation cover class

A broad class of relevant vegetation cover that might influence the spectral signature on the plot.

Code	Cover class	Description
1	Herbaceous plants	Any form of areal coverage of herbaceous plants
2	Ferns	Areal coverage of large-leaved ferns (no single individuals)
3	Grasses	Areal coverage of grasses
4	Berry bushes	Coverage of berry bushes, like blueberry, lingonberry or similar (detectable also outside vegetation period)

5	Berry thicket (rubus)	Areal thicket of blackberry / raspberry or similar
6	Mosses	Areal coverage of a layer of mosses
7	Other	Any other areal coverage of non-woody herbaceous plant communities. Might include invasive perennials or any other form of green-leaved vegetation layer

6.9.3 Intercept length

For line intercepts >1m round the length to closest meter.

Unit of measurement	Name / Format	Required	Validation / severity
meter	Intercept_length / Integer number	always	ERROR: max. <=14

7 PathFinder Field App

7.1 Introductory comment

In the PathFinder project, field data are collected with a mobile App (Openforis Collect Mobile) for which a survey definition was adapted and configured according to the specifications of this field manual. The current version of the App is provided in the project repository (Teamworks) and made available to the field teams. The field App was developed by WP1, Task 1.1.1 as an example for a mobile data collection. At a later stage of the project WP1, Task 1.4 is responsible for data management and database design.

7.2 Recommendation on mobile devices

The Openforis Collect Mobile App is available for Android devices exclusively!

In case new mobile devices are to be procured in context of the project, it is recommended to look for more stable and tough models, which are preferably rain-resistant. Screen size can be relatively small (~10’’). Models like Samsung Galaxy Tab Active3 or 4 have been proven to be very useful for field work in many inventory projects at the Chair of Forest Inventory and Remote Sensing, University Göttingen. Equipping the devices with an additional SD card allows saving backup files on the flash drive (in addition to the data exports into the device download directory), which is a further precaution against data loss.

If no tablets are available, the App can be installed on any Android smartphone without problems. The only drawback might be the relatively small screen size.

7.3 Download of Openforis mobile data collection App

The App “Openforis Collect Mobile” can be downloaded from the Playstore (Android only!):

https://play.google.com/store/apps/details?id=org.openforis.collect&hl=de&gl=US

Once the App is installed, the provided survey definition (*.collect-mobile) file can be imported into the App.

7.4 General Settings

In the general Openforis Collect Mobile settings menu, an individual “Crew ID” should be set before data collection starts. This Crew ID becomes part of the file name of exported data and helps to track from which device (=team) the data were entered and exported. To avoid the use of non-unique Crew IDs of independent field teams in different countries, use the following style: Country code_crew number.

7.5 Other settings

It is recommended to use the (default) Theme “Dark theme” of the App (black background, white font) for better visibility under different illumination conditions and because it is energy saving (battery holds much longer). To increase the visibility of describing text, the font size can be increased, which is useful especially for small screens. Since the App might change the appearance of navigation menus on the left side of the screen (on smaller screens they are not visible in portrait mode), the landscape format is sometimes useful. Therefore, it is not recommended to lock the screen orientation to portrait mode. The automatic screen orientation of the mobile device should be enabled to allow using both perspectives if needed.

7.5.1 File size of photos

Even if a maximum file size for photos is set in the survey definition (3MB per photo), this setting is overwritten by the default device settings of the camera. Modern mobile devices with good cameras might produce large files in very high resolution, which is not required. Problems might arise during export and submission of exported data if many plots are assessed (the file size of exported collect-data files becomes huge, which makes the export unhandy to share). Here we recommend limiting the file size of photos to ~3MB (or reducing the pixel resolution to a meaningful amount, like ~5 Megapixel or lower). This setting can be done in the default camera App of the mobile device.

While exporting data from the mobile App, the user can also decide to exclude photos from the data file, which reduces file size dramatically. This is recommended if only data should be exported and shared.

7.6 Export and backup of data

Plot data should be exported every day (after field work has ended) and send to the client or a designated data analysis unit (still to be defined). The Openforis App allows two different ways of exporting data: 1) Data export (including or excluding photos) into the download directory of the mobile device, or 2) a backup on a SD card (if available).

The delivered export files should be imported into the Collect Database (a Collect Desktop installation) that needs to have the same survey definition. From here data can be exported to .csv files for further processing. This workflow is intended for the initial pilot phase with 250 plots only, WP 1.4 is developing data management workflows that are able to store and read the exported collect-data files directly and that do not rely on any specific software.

8 Attachments

8.1 Tree species list

Table 7. Tree species list used in PathFinder pilot study.

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
1	ACAC_cya	Fabaceae	Acacia cyanophylla	Blue-leaved Acacia	OTHER_BROADLEAVES	B	081.004.009
2	ACAC_cyc	Fabaceae	Acacia cyclops	Coastal Wattle	OTHER_BROADLEAVES	B	081.004.006
3	ACAC_dea	Fabaceae	Acacia dealbata	Silver Wattle	OTHER_BROADLEAVES	B	081.004.003
4	ACAC_far	Fabaceae	Acacia farnesiana	Sweet Acacia	OTHER_BROADLEAVES	B	081.004.001
5	ACAC_kar	Fabaceae	Acacia karoo	Sweet Thorn	OTHER_BROADLEAVES	B	081.004.002
6	ACAC_lon	Fabaceae	Acacia longifolia	Sydney Golden Wattle	OTHER_BROADLEAVES	B	081.004.005
7	ACAC_mea	Fabaceae	Acacia mearnsii	Black Wattle	OTHER_BROADLEAVES	B	081.004.004
8	ACAC_mel	Fabaceae	Acacia melanoxylon	Australian Blackwood	OTHER_BROADLEAVES	B	081.004.007
9	ACAC_pyc	Fabaceae	Acacia pycnantha	Golden Wattle	OTHER_BROADLEAVES	B	081.004.008
10	ACAC_ret	Fabaceae	Acacia retinodes	Swamp Wattle	OTHER_BROADLEAVES	B	081.004.010
11	ACAC_sp.	Fabaceae	Acacia sp.	Acacia species	OTHER_BROADLEAVES	B	081.004.999
12	ACER_cam	Sapindaceae	Acer campestre	Field Maple	ACER	B	095.001.003
13	ACER_gra	Sapindaceae	Acer granatense	Pomegranate Maple	ACER	B	095.001.010
14	ACER_hel	Sapindaceae	Acer heldreichii	Heldreich's Maple	ACER	B	095.001.006
15	ACER_hyr	Sapindaceae	Acer hyrcanum	Hyrcanian Maple	ACER	B	095.001.011
16	ACER_lob	Sapindaceae	Acer lobelii	Lobel's Maple	ACER	B	095.001.002
17	ACER_mon	Sapindaceae	Acer monspessulanum	Montpellier Maple	ACER	B	095.001.013
18	ACER_neg	Sapindaceae	Acer negundo	Box Elder	ACER	B	095.001.015
19	ACER_obt	Sapindaceae	Acer obtusatum	Blunt-leaved Maple	ACER	B	095.001.009
20	ACER_opa	Sapindaceae	Acer opalus	Italian Maple	ACER	B	095.001.008
21	ACER_pla	Sapindaceae	Acer platanoides	Norway Maple	ACER	B	095.001.001
22	ACER_pse	Sapindaceae	Acer pseudoplatanus	Sycamore Maple	ACER	B	095.001.005
23	ACER_sac	Sapindaceae	Acer saccharinum	Silver Maple	ACER	B	095.001.020
24	ACER_sem	Sapindaceae	Acer sempervirens	Cretan Maple	ACER	B	095.001.014
25	ACER_ste	Sapindaceae	Acer stevenii	Steven's Maple	ACER	B	095.001.012
26	ACER_tat	Sapindaceae	Acer tataricum	Tatarian Maple	ACER	B	095.001.004
27	ACER_tra	Sapindaceae	Acer trautvetteri	Trautvetter's Maple	ACER	B	095.001.007
28	AESC_hip	Sapindaceae	Aesculus hippocastaneaum	Horse Chestnut	CASTANEA	B	097.001.001

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
29	AILA_alt	Simaroubaceae	Ailanthus altissima	Tree of Heaven	OTHER_BROADLEAVES	B	090.001.001
30	AILA_sp.	Simaroubaceae	Ailanthus sp.	Chinese Tree of Heaven	OTHER_BROADLEAVES	B	090.001.999
31	ALNU_cor	Betulaceae	Alnus cordata	Italian Alder	ALNUS	B	034.002.005
32	ALNU_glu	Betulaceae	Alnus glutinosa	Common Alder	ALNUS	B	034.002.002
33	ALNU_inc	Betulaceae	Alnus incana	Grey Alder	ALNUS	B	034.002.004
34	ALNU_vir	Betulaceae	Alnus viridis	Green Alder	ALNUS	B	034.002.001
35	AMEL_can	Rosaceae	Amelanchier canadensis	Canadian Serviceberry	OTHER_BROADLEAVES	B	080.030.003
36	AMEL_gra	Rosaceae	Amelanchier grandiflora	Snowy Mespilus	OTHER_BROADLEAVES	B	080.030.004
37	AMEL_ova	Rosaceae	Amelanchier ovalis	Snowy Mespilus	OTHER_BROADLEAVES	B	080.030.001
38	AMEL_sp.	Rosaceae	Amelanchier sp.	Serviceberry species	OTHER_BROADLEAVES	B	080.030.999
39	AMEL_spi	Rosaceae	Amelanchier spicata	Low Serviceberry	OTHER_BROADLEAVES	B	080.030.002
40	ARBU_and	Ericaceae	Arbutus andrachne	Eastern Strawberry Tree	OTHER_BROADLEAVES	B	132.012.002
41	ARBU_sp.	Ericaceae	Arbutus sp.	Strawberry Tree species	OTHER_BROADLEAVES	B	132.012.999
42	ARBU_une	Ericaceae	Arbutus unedo	Mediterranean Strawberry Tree	OTHER_BROADLEAVES	B	132.012.001
43	BERB_vul	Berberidaceae	Berberis vulgaris	European Barberry	OTHER_BROADLEAVES	B	063.005.001
44	BETU_hum	Betulaceae	Betula humilis	Dwarf Birch	BETULA	B	034.001.003
45	BETU_nan	Betulaceae	Betula nana	Arctic Birch	BETULA	B	034.001.004
46	BETU_pen	Betulaceae	Betula pendula	Silver Birch	BETULA	B	034.001.001
47	BETU_pub	Betulaceae	Betula pubescens	Downy Birch	BETULA	B	034.001.002
48	BUXU_bal	Buxaceae	Buxus balearica	Balearic Boxwood	OTHER_BROADLEAVES	B	102.001.002
49	BUXU_sem	Buxaceae	Buxus sempervirens	Common Boxwood	OTHER_BROADLEAVES	B	102.001.001
50	BUXU_sp.	Buxaceae	Buxus sp.	Boxwood species	OTHER_BROADLEAVES	B	102.001.999
51	CARP_bet	Betulaceae	Carpinus betulus	European Hornbeam	CARPINUS	B	035.001.001
52	CARP_ori	Betulaceae	Carpinus orientalis	Oriental Hornbeam	CARPINUS	B	035.001.002
53	CAST_sat	Fagaceae	Castanea sativa	Sweet Chestnut	CASTANEA	B	036.003.001
54	CELT_aus	Cannabaceae	Celtis australis	European Hackberry	OTHER_BROADLEAVES	B	037.003.001
55	CERA_sil	Fabaceae	Ceratonia siliqua	Carob Tree	OTHER_BROADLEAVES	B	081.002.001
56	CERC_sil	Fabaceae	Cercis siliquastrum	Judas Tree	OTHER_BROADLEAVES	B	081.001.001
57	CHAM_hum	Arecaceae	Chamaerops humilis	Mediterranean Dwarf Palm	OTHER_BROADLEAVES	B	194.001.001
58	CINN_cam	Lauraceae	Cinnamomum camphora	Camphor Tree	OTHER_BROADLEAVES	B	065.999.999
59	CORN_mas	Cornaceae	Cornus mas	Cornelian Cherry	OTHER_BROADLEAVES	B	127.001.004

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
60	CORN_san	Cornaceae	Cornus sanguinea	Common Dogwood	OTHER_BROADLEAVES	B	127.001.001
61	CORN_sp.	Cornaceae	Cornus sp.	Dogwood species	OTHER_BROADLEAVES	B	127.001.999
62	CORY_ave	Betulaceae	Corylus avellana	Common Hazel	OTHER_BROADLEAVES	B	035.003.001
63	CORY_sp.	Betulaceae	Corylus sp.	Hazel species	OTHER_BROADLEAVES	B	035.003.999
64	CRAT_aza	Rosaceae	Crataegus azarolus	Azarole Hawthorn	OTHER_BROADLEAVES	B	080.034.021
65	CRAT_lac	Rosaceae	Crataegus laciniata	Cut-leaf Hawthorn	OTHER_BROADLEAVES	B	080.034.020
66	CRAT_lae	Rosaceae	Crataegus laevigata	Midland Hawthorn	OTHER_BROADLEAVES	B	080.034.005
67	CRAT_mon	Rosaceae	Crataegus monogyna	Common Hawthorn	OTHER_BROADLEAVES	B	080.034.014
68	CRAT_sp.	Rosaceae	Crataegus sp.	Hawthorn species	OTHER_BROADLEAVES	B	080.034.999
69	ERIC_arb	Ericaceae	Erica arborea	Tree heather	OTHER_BROADLEAVES	B	132.001.009
70	ERIC_man	Ericaceae	Erica manipuliflora	No common name	OTHER_BROADLEAVES	B	132.001.012
71	ERIC_sco	Ericaceae	Erica scoparia	Broom heather	OTHER_BROADLEAVES	B	132.001.016
72	ERIC_sp.	Ericaceae	Erica sp.	Heath	OTHER_BROADLEAVES	B	132.001.999
73	EUCA_cam	Myrtaceae	Eucalyptus camaldulensis	River red gum	EUCALYPTUS	B	121.002.007
74	EUCA_gom	Myrtaceae	Eucalyptus gomphocephalus	Tuart	EUCALYPTUS	B	121.002.005
75	EUON_eur	Celastraceae	Euonymus europaeus	European spindle	OTHER_BROADLEAVES	B	100.001.001
76	EUON_sp.	Celastraceae	Euonymus sp.	Spindle	OTHER_BROADLEAVES	B	100.001.999
77	FAGU_syl	Fagaceae	Fagus sylvatica	European beech	FAGUS	B	036.001.001
78	FICU_car	Moraceae	Ficus carica	Common fig	OTHER_BROADLEAVES	B	038.004.001
79	FICU_sp.	Moraceae	Ficus sp.	Fig	OTHER_BROADLEAVES	B	038.004.999
80	FRAN_aln	Rhamnaceae	Frangula alnus	Glossy buckthorn	OTHER_BROADLEAVES	B	103.004.001
81	FRAX_ang	Oleaceae	Fraxinus angustifolia	Narrow-leaved ash	FRAXINUS	B	139.004.004
82	FRAX_exc	Oleaceae	Fraxinus excelsior	European ash	FRAXINUS	B	139.004.003
83	FRAX_orn	Oleaceae	Fraxinus ornus	Manna ash	FRAXINUS	B	139.004.001
84	FRAX_pal	Oleaceae	Fraxinus pallisae	No common name	FRAXINUS	B	139.004.005
85	FRAX_pen	Oleaceae	Fraxinus pennsylvania	Green ash	FRAXINUS	B	139.004.002
86	GLED_sp.	Fabaceae	Gleditsia sp.	Honey locust	OTHER_BROADLEAVES	B	081.003.999
87	HIPP_rha	Elaeagnaceae	Hippophae rhamnoides	Sea buckthorn	OTHER_BROADLEAVES	B	108.001.001
88	ILEX_aqu	Aquifoliaceae	Ilex aquifolium	English holly	OTHER_BROADLEAVES	B	099.001.001
89	ILEX_can	Aquifoliaceae	Ilex canariensis	Canary Island holly	OTHER_BROADLEAVES	B	099.001.004
90	ILEX_sp.	Aquifoliaceae	Ilex sp.	Holly	OTHER_BROADLEAVES	B	099.001.999
91	JUGL_cin	Juglandaceae	Juglans cinerea	Butternut	OTHER_BROADLEAVES	B	033.001.003

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
92	JUGL_nig	Juglandaceae	Juglans nigra	Black walnut	OTHER_BROADLEAVES	B	033.001.001
93	JUGL_reg	Juglandaceae	Juglans regia	Persian walnut	OTHER_BROADLEAVES	B	033.001.002
94	JUGL_sp.	Juglandaceae	Juglans sp.	Walnut	OTHER_BROADLEAVES	B	033.001.999
95	LABU_alp	Fabaceae	Laburnum alpinum	Scotch laburnum	OTHER_BROADLEAVES	B	081.008.002
96	LABU_ana	Fabaceae	Laburnum anagyroides	Common laburnum	OTHER_BROADLEAVES	B	081.008.001
97	LABU_sp.	Fabaceae	Laburnum sp.	Laburnum	OTHER_BROADLEAVES	B	081.008.999
98	LAUR_azo	Lauraceae	Laurus azorica	Azores laurel	OTHER_BROADLEAVES	B	065.001.002
99	LAUR_nob	Lauraceae	Laurus nobilis	Bay laurel	OTHER_BROADLEAVES	B	065.001.001
100	LIGU_vul	Oleaceae	Ligustrum vulgare	Wild privet	OTHER_BROADLEAVES	B	139.006.001
101	LIRI_tul	Magnoliaceae	Liriodendron tulipifera	Tulip tree	OTHER_BROADLEAVES	B	064.001.001
102	LONI_sp.	Caprifoliaceae	Lonicera sp.	Honeysuckle	OTHER_BROADLEAVES	B	164.006.999
103	MAGN_sp.	Magnoliaceae	Magnolia sp.	Magnolia	OTHER_BROADLEAVES	B	064.001.999
104	MALU_dom	Rosaceae	Malus domestica	Apple tree	OTHER_BROADLEAVES	B	080.027.006
105	MALU_sp.	Rosaceae	Malus sp.	Apple tree	OTHER_BROADLEAVES	B	080.027.999
106	MALU_syl	Rosaceae	Malus sylvestris	Wild apple	OTHER_BROADLEAVES	B	080.027.003
107	MORU_alb	Moraceae	Morus alba	White mulberry	OTHER_BROADLEAVES	B	038.002.002
108	MORU_nig	Moraceae	Morus nigra	Black mulberry	OTHER_BROADLEAVES	B	038.002.001
109	MORU_sp.	Moraceae	Morus sp.	Mulberry	OTHER_BROADLEAVES	B	038.002.999
110	MYRI_fay	Myricaceae	Myrica faya	Faya	OTHER_BROADLEAVES	B	032.001.002
111	MYRT_com	Myricaceae	Myrtus communis	Common myrtle	OTHER_BROADLEAVES	B	121.001.001
112	OCOT_foe	Lauraceae	Ocotea foetens	Stinkwood	OTHER_BROADLEAVES	B	064.999.999
113	OLEA_eur	Oleaceae	Olea europaea	Olive tree	OTHER_BROADLEAVES	B	139.007.001
114	OLEA_sp.	Oleaceae	Olea sp.	Olive tree	OTHER_BROADLEAVES	B	139.007.999
115	OSTR_car	Betulaceae	Ostrya carpinifolia	Hop hornbeam	OTHER_BROADLEAVES	B	035.002.001
116	PAUL_tom	Paulowniaceae	Paulownia tomentosa	Empress tree	OTHER_BROADLEAVES	B	154.999.999
117	PERS_ind	Lauraceae	Persea indica	Indian laurel	OTHER_BROADLEAVES	B	065.002.001
118	PHIL_ang	Oleaceae	Phillyrea angustifolia	Narrow-leaved Phillyrea	OTHER_BROADLEAVES	B	139.008.001
119	PHIL_lat	Oleaceae	Phillyrea latifolia	Broad-leaved Phillyrea	OTHER_BROADLEAVES	B	139.008.002
120	PHOE_can	Arecaceae	Phoenix canariensis	Canary Island date palm	OTHER_BROADLEAVES	B	194.002.002
121	PHOE_sp.	Arecaceae	Phoenix sp.	Date palm	OTHER_BROADLEAVES	B	194.002.999
122	PICC_exc	Oleaceae	Picconia excelsa	Canary Island bayberry	OTHER_BROADLEAVES	B	139.009.002
123	PIST_atl	Anacardiaceae	Pistacia atlantica	Mount Atlas mastic tree	OTHER_BROADLEAVES	B	094.003.001
124	PIST_len	Anacardiaceae	Pistacia lentiscus	Mastic tree	OTHER_BROADLEAVES	B	094.003.004

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
125	PIST_ter	Anacardiaceae	Pistacia terebinthus	Terebinth	OTHER_BROADLEAVES	B	094.003.002
126	PLAT_ace	Platanaceae	Platanus acerifolia	London plane	OTHER_BROADLEAVES	B	079.001.002
127	PLAT_ori	Platanaceae	Platanus orientalis	Oriental plane	OTHER_BROADLEAVES	B	079.001.001
128	PLAT_sp.	Platanaceae	Platanus sp.	Plane	OTHER_BROADLEAVES	B	079.001.999
129	PLEI_can	Primulaceae	Pleiomeris canariensis		OTHER_BROADLEAVES	B	134.999.999
130	POPU_alb	Salicaceae	Populus alba	White poplar	POPULUS	B	031.002.001
131	POPU_nig	Salicaceae	Populus nigra	Black poplar	POPULUS	B	031.002.008
132	POPU_tre	Salicaceae	Populus tremula	European aspen	POPULUS	B	031.002.004
133	POPU_x c	Salicaceae	Populus x canescens	Grey poplar	POPULUS	B	031.002.002
134	PRUN_arm	Rosaceae	Prunus armeniaca	Apricot tree	OTHER_BROADLEAVES	B	080.035.005
135	PRUN_avi	Rosaceae	Prunus avium	Sweet cherry tree	OTHER_BROADLEAVES	B	080.035.014
136	PRUN_cerasi	Rosaceae	Prunus cerasifera	Cherry plum	OTHER_BROADLEAVES	B	080.035.007
137	PRUN_cer	Rosaceae	Prunus cerasus	Sour cherry	OTHER_BROADLEAVES	B	080.035.015
138	PRUN_dom	Rosaceae	Prunus domestica	Plum	OTHER_BROADLEAVES	B	080.035.010
139	PRUN_dul	Rosaceae	Prunus dulcis	Almond	OTHER_BROADLEAVES	B	080.035.002
140	PRUN_lus	Rosaceae	Prunus lusitanica	Portuguese laurel	OTHER_BROADLEAVES	B	080.035.020
141	PRUN_mah	Rosaceae	Prunus mahaleb	Mahaleb cherry	OTHER_BROADLEAVES	B	080.035.016
142	PRUN_pad	Rosaceae	Prunus padus	Bird cherry	OTHER_BROADLEAVES	B	080.035.017
143	PRUN_per	Rosaceae	Prunus persica	Peach	OTHER_BROADLEAVES	B	080.035.001
144	PRUN_ser	Rosaceae	Prunus serotina	Black cherry	OTHER_BROADLEAVES	B	080.035.018
145	PRUN_sp.	Rosaceae	Prunus sp.	Cherry/plum/peach/almond (unknown species)	OTHER_BROADLEAVES	B	080.035.999
146	PRUN_spi	Rosaceae	Prunus spinosa	Blackthorn/sloe	OTHER_BROADLEAVES	B	080.035.008
147	PYRU_amy	Rosaceae	Pyrus amygdaliformis	Almond-leaved pear	OTHER_BROADLEAVES	B	080.026.008
148	PYRU_com	Rosaceae	Pyrus communis	European pear	OTHER_BROADLEAVES	B	080.026.013
149	PYRU_pyr	Rosaceae	Pyrus pyraster	Wild pear	OTHER_BROADLEAVES	B	080.026.004
150	PYRU_sp.	Rosaceae	Pyrus sp.	Pear (unknown species)	OTHER_BROADLEAVES	B	080.026.999
151	QUER_aln	Fagaceae	Quercus alnifolia	Golden oak	QUERCUS_CERRIS	B	036.004.026
152	QUER_can	Fagaceae	Quercus canariensis	Algerian oak	QUERCUS_CERRIS	B	036.004.020
153	QUER_cer	Fagaceae	Quercus cerris	Turkey oak	QUERCUS_CERRIS	B	036.004.008
154	QUER_coc	Fagaceae	Quercus coccifera	Kermes oak	QUERCUS_CERRIS	B	036.004.003
155	QUER_con	Fagaceae	Quercus congesta	Evergreen oak	QUERCUS	B	036.004.018
156	QUER_dal	Fagaceae	Quercus dalechampii	Dalechamp oak	QUERCUS	B	036.004.012
157	QUER_fag	Fagaceae	Quercus faginea	Portuguese oak	QUERCUS_LEPIDOBALANUS	B	036.004.021
158	QUER_fra	Fagaceae	Quercus frainetto	Hungarian oak	QUERCUS_CERRIS	B	036.004.016

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159	QUER_fru	Fagaceae	Quercus fruticosa	Shrubby oak	QUERCUS	B	036.004.028
160	QUER_har	Fagaceae	Quercus hartwissiana	Persian oak	QUERCUS	B	036.004.013
161	QUER_ile	Fagaceae	Quercus ilex	Holm oak	QUERCUS_CERRIS	B	036.004.004
162	QUER_lus	Fagaceae	Quercus lusitanica	Lusitanian oak	QUERCUS	B	036.004.022
163	QUER_mac	Fagaceae	Quercus macrolepis	Valonia oak	QUERCUS	B	036.004.007
164	QUER_mas	Fagaceae	Quercus mas	Mediterranean oak	QUERCUS	B	036.004.009
165	QUER_pal	Fagaceae	Quercus palustris	Pin oak	QUERCUS	B	036.004.002
166	QUER_ped	Fagaceae	Quercus pedunculiflora	Pedunculate oak	QUERCUS	B	036.004.015
167	QUER_pet	Fagaceae	Quercus petraea	Sessile oak	QUERCUS_ROBUR	B	036.004.011
168	QUER_pol	Fagaceae	Quercus polycarpa	Mexican blue oak	QUERCUS	B	036.004.010
169	QUER_pub	Fagaceae	Quercus pubescens	Downy oak	QUERCUS_LEPIDOBALANUS	B	036.004.019
170	QUER_pyr	Fagaceae	Quercus pyrenaica	Pyrenean oak	QUERCUS_CERRIS	B	036.004.017
171	QUER_rob	Fagaceae	Quercus robur	English oak	QUERCUS_ROBUR	B	036.004.014
172	QUER_rub	Fagaceae	Quercus rubra	Northern red oak	QUERCUS_ROBUR	B	036.004.001
173	QUER_tro	Fagaceae	Quercus trojana	Macedonian oak	QUERCUS_CERRIS	B	036.004.006
174	RHAM_ala	Rhamnaceae	Rhamnus alaternus	Italian buckthorn	OTHER_BROADLEAVES	B	103.003.001
175	RHAM_cat	Rhamnaceae	Rhamnus catharticus	Common buckthorn	OTHER_BROADLEAVES	B	103.003.008
176	RHAM_lyc	Rhamnaceae	Rhamnus lycioides	Spiny broom	OTHER_BROADLEAVES	B	103.003.003
177	RHAM_sp.	Rhamnaceae	Rhamnus sp.	Buckthorn (unknown species)	OTHER_BROADLEAVES	B	103.003.999
178	RHUS_cor	Anacardiaceae	Rhus coriaria	Sumac	OTHER_BROADLEAVES	B	094.001.001
179	RHUS_typ	Anacardiaceae	Rhus typhina	Staghorn sumac	OTHER_BROADLEAVES	B	094.001.002
180	ROBI_pse	Fabaceae	Robinia pseudoacacia	Black locust	OTHER_BROADLEAVES	B	081.030.001
181	SALI_alb	Salicaceae	Salix alba	White willow	SALIX	B	031.001.003
182	SALI_atr	Salicaceae	Salix atrocinerea	Grey willow	SALIX	B	031.001.039
183	SALI_bab	Salicaceae	Salix babylonica	Weeping willow	SALIX	B	031.001.004
184	SALI_can	Salicaceae	Salix cantabrica	Cantabrian willow	SALIX	B	031.001.043
185	SALI_cap	Salicaceae	Salix caprea	Goat willow	SALIX	B	031.001.041
186	SALI_cin	Salicaceae	Salix cinerea	Grey sallow	SALIX	B	031.001.038
187	SALI_ele	Salicaceae	Salix eleagnos	Rosemary willow	SALIX	B	031.001.057
188	SALI_fra	Salicaceae	Salix fragilis	Crack willow	SALIX	B	031.001.002
189	SALI_pur	Salicaceae	Salix purpurea	Purple willow	SALIX	B	031.001.058
190	SALI_vim	Salicaceae	Salix viminalis	Common osier	SALIX	B	031.001.056
191	SAMB_ebu	Adoxaceae	Sambucus ebulus	Dwarf elder	OTHER_BROADLEAVES	B	164.001.001

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
192	SAMB_nig	Adoxaceae	Sambucus nigra	Elderberry	OTHER_BROADLEAVES	B	164.001.002
193	SAMB_rac	Adoxaceae	Sambucus racemosa	Red Elderberry	OTHER_BROADLEAVES	B	164.001.003
194	SAMB_sp.	Adoxaceae	Sambucus sp.	Elderberry	OTHER_BROADLEAVES	B	164.001.999
195	SOPH_jap	Rosaceae	Sophora japonica	Japanese Pagoda Tree	OTHER_BROADLEAVES	B	081.005.001
196	SORB_ari	Rosaceae	Sorbus aria	Whitebeam	OTHER_BROADLEAVES	B	080.028.005
197	SORB_auc	Rosaceae	Sorbus aucuparia	Rowan or Mountain Ash	OTHER_BROADLEAVES	B	080.028.002
198	SORB_cha	Rosaceae	Sorbus chamaemespilus	Dwarf Whitebeam	OTHER_BROADLEAVES	B	080.028.004
199	SORB_dom	Rosaceae	Sorbus domestica	Service Tree	OTHER_BROADLEAVES	B	080.028.001
200	SORB_int	Rosaceae	Sorbus intermedia	Swedish Whitebeam	OTHER_BROADLEAVES	B	080.028.015
201	SORB_lat	Rosaceae	Sorbus latifolia	Broadleaf Whitebeam	OTHER_BROADLEAVES	B	080.028.016
202	SORB_mou	Rosaceae	Sorbus mougeotii	Mougeot's Whitebeam	OTHER_BROADLEAVES	B	080.028.010
203	SORB_sp.	Rosaceae	Sorbus sp.	Whitebeam	OTHER_BROADLEAVES	B	080.028.999
204	SORB_tor	Rosaceae	Sorbus torminalis	Wild Service Tree	OTHER_BROADLEAVES	B	080.028.003
205	TAMA_afr	Tamaricaceae	Tamarix africana	African Tamarisk	OTHER_BROADLEAVES	B	113.002.001
206	TAMA_can	Tamaricaceae	Tamarix canariensis	Canary Islands Tamarisk	OTHER_BROADLEAVES	B	113.002.002
207	TAMA_sp.	Tamaricaceae	Tamarix sp.	Tamarisk	OTHER_BROADLEAVES	B	113.002.999
208	TILI_cor	Malvaceae	Tilia cordata	Littleleaf Linden or Small-leaved Lime	OTHER_BROADLEAVES	B	105.001.005
209	TILI_pla	Malvaceae	Tilia platyphylos	Large-leaved Linden or Broad-leaved Lime	OTHER_BROADLEAVES	B	105.001.003
210	TILI_sp.	Malvaceae	Tilia sp.	Linden or Lime	OTHER_BROADLEAVES	B	105.001.999
211	TILI_tom	Malvaceae	Tilia tomentosa	Silver Linden or American Linden	OTHER_BROADLEAVES	B	105.001.001
212	ULMU_can	Ulmaceae	Ulmus canescens	Grey Elm or Hoary Elm	OTHER_BROADLEAVES	B	037.001.005
213	ULMU_gla	Ulmaceae	Ulmus glabra	Wych Elm or Scotch Elm	OTHER_BROADLEAVES	B	037.001.001
214	ULMU_lae	Ulmaceae	Ulmus laevis	European White Elm	OTHER_BROADLEAVES	B	037.001.006
215	ULMU_min	Ulmaceae	Ulmus minor	Dwarf Elm	OTHER_BROADLEAVES	B	037.001.004
216	ULMU_sp.	Ulmaceae	Ulmus sp.	Elm	OTHER_BROADLEAVES	B	037.001.999
217	VIBU_lan	Adoxaceae	Viburnum lantana	Wayfaring Tree or Hobble Bush	OTHER_BROADLEAVES	B	164.002.002
218	VIBU_opu	Adoxaceae	Viburnum opulus	Guelder Rose or European Cranberrybush	OTHER_BROADLEAVES	B	164.002.001
219	ABIE_alb	Pinaceae	Abies alba	Silver Fir	ABIES	C	026.001.006
220	ABIE_cep	Pinaceae	Abies cephalonica	Greek Fir	ABIES	C	026.001.008
221	ABIE_gra	Pinaceae	Abies grandis	Grand Fir	ABIES	C	026.001.002

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
222	ABIE_las	Pinaceae	Abies lasiocarpa	Subalpine Fir	ABIES	C	026.001.003
223	ABIE_neb	Pinaceae	Abies nebrodensis	Sicilian Fir	ABIES	C	026.001.007
224	ABIE_nor	Pinaceae	Abies nordmanniana	Caucasian Fir or Nordmann Fir	ABIES	C	026.001.005
225	ABIE_pin	Pinaceae	Abies pinsapo	Spanish Fir	ABIES	C	026.001.009
226	ABIE_pro	Pinaceae	Abies procera	Noble Fir	ABIES	C	026.001.001
227	ABIE_sib	Pinaceae	Abies sibirica	Siberian Fir	ABIES	C	026.001.004
228	CEDR_atl	Pinaceae	Cedrus atlantica	Atlas Cedar	OTHER_CONIFERS	C	026.006.002
229	CEDR_deo	Pinaceae	Cedrus deodara	Deodar Cedar	OTHER_CONIFERS	C	026.006.001
230	CEDR_lib	Pinaceae	Cedrus libani	Cedar of Lebanon	OTHER_CONIFERS	C	026.006.003
231	CEDR_sp.	Pinaceae	Cedrus sp.	Cedar	OTHER_CONIFERS	C	026.006.999
232	CHAM_law	Cupressaceae	Chamaecyparis lawsoniana	Port Orford Cedar or Lawson Cypress	OTHER_CONIFERS	C	028.002.001
233	CRYP_sp.	Cupressaceae	Cryptomeria sp.	Japanese Cedar or Sugi	OTHER_CONIFERS	C	027.004.999
234	CUPR_ari	Cupressaceae	Cupressus arizonica	Arizona Cypress	OTHER_CONIFERS	C	028.001.004
235	CUPR_lus	Cupressaceae	Cupressus lusitanica	Mexican Cypress or Cedar	OTHER_CONIFERS	C	028.001.003
236	CUPR_mac	Cupressaceae	Cupressus macrocarpa	Monterey Cypress	OTHER_CONIFERS	C	028.001.002
237	CUPR_sem	Cupressaceae	Cupressus sempervirens	Mediterranean Cypress	OTHER_CONIFERS	C	028.001.001
238	CUPR_sp.	Cupressaceae	Cupressus sp.	Cypress	OTHER_CONIFERS	C	028.001.999
239	JUNI_com	Cupressaceae	Juniperus comunis	Common Juniper	OTHER_CONIFERS	C	028.005.002
240	JUNI_oxy	Cupressaceae	Juniperus oxycedrus	Prickly Juniper or Cade Juniper	OTHER_CONIFERS	C	028.005.003
241	JUNI_pho	Cupressaceae	Juniperus phoenicea	Phoenicean Juniper	OTHER_CONIFERS	C	028.005.006
242	JUNI_sab	Cupressaceae	Juniperus sabina	Savin Juniper	OTHER_CONIFERS	C	028.005.010
243	JUNI_sp.	Cupressaceae	Juniperus sp.	Juniper	OTHER_CONIFERS	C	028.005.999
244	JUNI_thu	Cupressaceae	Juniperus thurifera	Spanish Juniper	OTHER_CONIFERS	C	028.005.007
245	JUNI_vir	Cupressaceae	Juniperus virginiana	Eastern Red Cedar or Virginia Cedar	OTHER_CONIFERS	C	028.005.011
246	LARI_dec	Pinaceae	Larix decidua	European Larch	LARIX	C	026.005.002
247	LARI_kae	Pinaceae	Larix kaempferi	Japanese Larch	LARIX	C	026.005.001
248	META_sp.	Cupressaceae	Metasequoia sp.	Dawn Redwood	OTHER_CONIFERS	C	035.002.999
249	PICE_abi	Pinaceae	Picea abies	Norway Spruce	PICEA	C	026.004.001
250	PICE_eng	Pinaceae	Picea engelmannii	Engelmann spruce	PICEA	C	026.004.004
251	PICE_gla	Pinaceae	Picea glauca	White spruce	PICEA	C	026.004.003

no	Code	Family	Scientific name	Common name	spgrp_EFDAC	Type	spcode_EFDAC
252	PICE_omo	Pinaceae	Picea omorika	Serbian spruce	PICEA	C	026.004.007
253	PICE_ori	Pinaceae	Picea orientalis	Oriental spruce	PICEA	C	026.004.002
254	PICE_pun	Pinaceae	Picea pungens	Colorado blue spruce	PICEA	C	026.004.005
255	PICE_sit	Pinaceae	Picea sitchensis	Sitka spruce	PICEA	C	026.004.006
256	PINU_ban	Pinaceae	Pinus banksiana	Jack pine	PINUS	C	026.007.004
257	PINU_can	Pinaceae	Pinus canariensis	Canary Island pine	PINUS	C	026.007.012
258	PINU_cem	Pinaceae	Pinus cembra	Swiss stone pine	PINUS	C	026.007.014
259	PINU_con	Pinaceae	Pinus contorta	Lodgepole pine	PINUS	C	026.007.001
260	PINU_hal	Pinaceae	Pinus halepensis	Aleppo pine	PINUS_HALEPENSIS	C	026.007.011
261	PINU_hel	Pinaceae	Pinus heldreichii	Bosnian pine	PINUS	C	026.007.010
262	PINU_leu	Pinaceae	Pinus leucodermis	Macedonian pine	PINUS	C	026.007.100
263	PINU_mug	Pinaceae	Pinus mugo	Mugo pine	PINUS	C	026.007.008
264	PINU_nig	Pinaceae	Pinus nigra	Austrian pine	PINUS_NIGRA	C	026.007.006
265	PINU_pina	Pinaceae	Pinus pinaster	Maritime pine	PINUS_PINASTER	C	026.007.002
266	PINU_pine	Pinaceae	Pinus pinea	Stone pine	PINUS_PINASTER	C	026.007.013
267	PINU_pon	Pinaceae	Pinus ponderosa	Ponderosa pine	PINUS	C	026.007.005
268	PINU_rad	Pinaceae	Pinus radiata	Monterey pine	PINUS	C	026.007.003
269	PINU_sp.	Pinaceae	Pinus sp.	Pine (unspecified)	PINUS	C	026.007.999
270	PINU_str	Pinaceae	Pinus strobus	Eastern white pine	PINUS	C	026.007.018
271	PINU_syl	Pinaceae	Pinus sylvestris	Scots pine	PINUS_SYLVERSTRIS	C	026.007.007
272	PINU_unc	Pinaceae	Pinus uncinata	Swiss mountain pine	PINUS	C	026.007.009
273	SEQU_sp.	Cupressaceae	Sequoiadendron sp.	Sequoia (unspecified)	OTHER_CONIFERS	C	027.002.999
274	TAXO_dis	Cupressaceae	Taxodium distichum	Bald cypress	OTHER_CONIFERS	C	027.003.001
275	TAXU_bac	Taxaceae	Taxus baccata	English yew	OTHER_CONIFERS	C	029.001.001
276	TAXU_sp.	Taxaceae	Taxus sp.	Yew (unspecified)	OTHER_CONIFERS	C	029.001.999
277	TETR_art	Cupressaceae	Tetraclinis articulata	Sandarac tree	OTHER_CONIFERS	C	028.004.001
278	THUJ_pli	Cupressaceae	Thuja plicata	Western red cedar	OTHER_CONIFERS	C	028.003.001
279	THUJ_sp.	Cupressaceae	Thuja sp.	Arborvitae (unspecified)	OTHER_CONIFERS	C	028.003.999
280	TSUG_can	Pinaceae	Tsuga canadensis	Eastern hemlock	OTHER_CONIFERS	C	026.003.002
281	TSUG_het	Pinaceae	Tsuga heterophylla	Western hemlock	OTHER_CONIFERS	C	026.003.001
282	TSUG_sp.	Pinaceae	Tsuga sp.	Hemlock (unspecified)	OTHER_CONIFERS	C	026.003.999
283	OTHE_con	OTHER	Other conifer	Other conifer	OTHER_CONIFERS	C	999
284	OTHE_bro	OTHER	Other broadleaves	Other broadleaves	OTHER_BROADLEAVES	B	998

8.2 Database schema overview