Life PROGNOSES

WP1 & WP2: Methods and Site Descriptions

Margot Vanhellemont

Final version - March 2025

Life PROGNOSES

WP1 & WP2: Methods and Site Descriptions

Author: Margot Vanhellemont (margot.vanhellemont@inbo.be)

This report describes the sites and sampling methods applied during the EU LIFE-PROGNOSES project: PRotection of Old Growth Forests in Europe: Natural heritage, Outline, Synthesis and Ecosystem Services - Strengthening primary and old growth forest protection in Europe by capitalising on World Heritage sites).

Funder: EU-LIFE preparatory project : LIFE20 PRE/BE/000011

Project Administrator: Caroline Celis – Sonian Foundation
Start date: 01-01-2021
End date: 30-06-2025

This report contains:

- a concise description of the methods, i.e., study sites and data collection, of the Life Prognoses project, complementary to the data collection protocol of Kirchmeir et al. (2023)

- a concise description of each of the twelve study sites included in the dataset of the Life Prognoses project: geography and forest, past management, plots included in the project, data collection with indication of how the data collection at the site did differ from the protocol of Kirchmeir et al. (2023)

- a species list with all tree species in the Life Prognoses dataset.

Input for this report provided by: Nathalie Cools, Jonathan De Schrijver, Alfredo Di Filippo, Blaž Fricelj, Christian Fuxjäger, Gerrit Genouw, Jeňýk Hofmeister, Yanitsa Ivanova, Hanns Kirchmeir, Daniel Kozák, Peter Meyer, Anja Leyman, Ana Petritan, Tim Pirc, Klaus Steinbauer, Jonas Stillhard, Peter Van de Kerckhove, Kris Vandekerkhove, Louis Verschuren, Julian Wellhäuser, and Antonia Zichy

Reviewed by: Kris Vandekerkhove and Ruth Vanhaecht

DOI: doi.org/10.21436/inbor.121256273

Contents

1. Methods

1.1. Study sites

The study sites in the Life Prognoses project are component parts and adjacent buffer zones of the UNESCO World Heritage Site “Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe” (except for site Klenovský Vepor) and cover managed and unmanaged beech (*Fagus sylvatica* L.) forests across a range of biogeographical zones in Europe (Table 1). See Chapter 2 for more detailed descriptions of the twelve study sites.

Table 1. Environmental features of the study sites: name (NP = National Park), country (ISO 3166-1 alpha-2 two-letter country codes), latitude and longitude (decimal WGS84), region, mean annual temperature and precipitation for 1981-2010, altitude, soil type according to World Reference Base for Soil Resources (IUSS Working Group WRB, 2015)

site	country	lat	lon	beech forest region	biogeographic region	MAT (°C)	MAP [a] (mm)	altitude (masl)	soil [b]
Abruzzo NP	IT	41.78	13.75	Central Mediterranean	mediterranean	6.2	1369	1500-1800	PH, CH
Central Balkan NP	BG	42.74	24.77	Moesian-Balcanic	alpine	5.8	890	960-1560	CM
Hainich NP	DE	51.08	10.44	Subatlantic-Hercynic	continental	7.3	761	270-480	AL, AT, CM, KS, LP, ST, TC
Kalkalpen NP	AT	48.22	13.79	Alpine	alpine	6.7	1327	460-1360	CM, LP
Kellerwald NP	DE	51.15	8.98	Subatlantic-Hercynic	continental	7.3	775	220-620	CM
Klenovský Vepor	SK	48.55	19.60	Carpathian	continental	6.2	754	540-1250	CM
Krokar	SI	45.54	14.77	Illyrian	alpine	8.9	1447	910-1180	CM, LP
Sinca forest	RO	45.66	25.17	Carpathian	continental	5.9	950	1000-1260	CM
Snežnik	SI	45.57	14.47	Illyrian	alpine	8.9	1447	1350-1450	CM, LP
Sonian forest	BE	50.75	4.42	Atlantic	atlantic	10.6	852	90-130	CM, RT
Stara Planina	BG	42.76	24.55	Moesian-Balcanic	alpine	6.8	612	1240-1480	CM
Uholka forest	UA	23.70	48.31	Carpathian	continental	7.7	1134	530-1200	CM

[a] data from Di Fiore et al. (2022; Abruzzo NP), Abiota Compendium Annex to Central Balkan National Park Management Plan (Central Balkan NP), data from Gauer & Aldinger (2005; Hainich NP, Kellerwald NP), CHELSA data (Karger et al. 2018) (Kalkalpen NP, Sinca forest), E-OBS data v24.0e (Cornes et al. 2018, https://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php; Klenovský Vepor, Stara Planina), meteorological station of Kočevje at 467 m altitude (Krokar, Snežnik), Uccle weather station of the Royal Meteorological Institute (Sonian forest), meteorological station of Carpathian Biosphere Reserve in Uholka at 430 m altitude: 1990-2010 for MAT, 1980-2010 for MAP (Uholka forest)

[b] based on the soil sample plots (Abruzzo NP, Klenovský Vepor, Stara Planina), forest inventory data (Central Balkan NP), unpublished forest site mapping and soil maps (Hainich NP, Kellerwald NP), national park inventory data (Kalkalpen NP), soil maps (Krokar, Snežnik), forest management plans (Sinca forest), soil maps and former soil sampling (Sonian forest), Brändli & Dowhanytsch (2003; Uholka forest)

1.2. Data collection

For five sites, data were collected during the Life Prognoses project following the protocol of Kirchmeir et al. (2023): Abruzzo National Park, Central Balkan National Park, Kalkalpen National Park, Krokar, and Snežnik (Table 2). For sites with an existing local monitoring programme, data from a recent survey collected according to the local protocol were fit into the structure of the Life Prognoses data; the recent survey was complemented with additional soil samples in Kellerwald National Park and Sonian forest, additional plots in managed stands in Sonian forest, and tree-related microhabitats in Sinca and Sonian forest. The data requirements included a minimum plot radius of 10 m (Table 2) and a minimum set of measurements (see Kirchmeir et al. 2023). See the site descriptions in Chapter 2 for detailed information on plots and data collection.

1.3. Dendrometry

In every plot, all standing trees with a diameter at breast height larger than 10 cm (see Table 3 for site-specific diameter thresholds) were measured: diameter at breast height, species, and status (dead or alive). Height was measured for a subset of the living trees and for all snags (i.e., broken dead trees). Snags smaller than 1.3 m and stumps were not measured. Lying deadwood with a diameter larger than 20 cm (see Table 3 for site-specific diameter thresholds) was measured using either Full Area Sampling or Line Intersect Sampling (Table 3). With Full Area Sampling, for deadwood fragments longer than 1 m, diameter at both ends and fragment length were noted. With Line Intersect Sampling, deadwood diameter was measured at the intersection point. If possible, the tree species was noted for each deadwood fragment. All deadwood (i.e., standing intact dead trees, snags, lying deadwood) was assigned a decay stage: hard (i.e., bark still attached), partly decayed (i.e., a knife can penetrate the wood), soft (i.e., falls apart). The presence of established regeneration (i.e., saplings of 30-130 cm height) was assessed in the entire plot or in a subplot (see Table 3) using a threshold of density >1 in 25 m² or cover > 5%. See Kirchmeir et al. (2023) for the more detailed protocol, and Chapter 2 for site-specific deviations from the protocol.

Based on the field data and using local standard methods, the project partners calculated aboveground volumes (stem only and including branches) of intact standing trees (see Table 4), snags (see Chapter 2), and individual log volumes in case of Full Area Sampling. In the case of Line Intersect Sampling, the plot-level lying deadwood volume was calculated using the equation of Van Wagner (1968) and De Vries (1973):

$$V = \frac{\pi^2}{8L} . \sum d_i^2$$

With V mean volume per area unit ($m^3\ ha^{-1}$), L total line length (m), and d_i log diameter at the intersection (cm).

Table 2. The number of plots, plot radius and data collected at each site. Plots lay in either managed (currently or up till 25 years ago) forest, forest that had been set aside for > 25 years, forest that had been untouched by management for > 75 years or in primary forest. The data comes from the Life Prognoses project (white background) or existing local monitoring (grey background). All sites have data on dendrometry, i.e., standing trees, lying deadwood, and tree microhabitats. Soil samples and tree cores for carbon determination have been collected in a subset of the sites.

	plot	**no plots**					**data**			
site	**radius (m)**	**total**	**managed**	**set aside**	**long untouched**	**primary**	**origin** [a]	**year**	**soil** [b]	**wood** [c]
Abruzzo NP	10 [d]	151	50	21	-	80	Prognoses	2022	30	85
Central Balkan NP	10 [d]	120	17	41	16	46	Prognoses	2022-23	-	54
Hainich NP	12.62	393	-	393	-	-	existing	2020-21	-	-
Kalkalpen NP	10 [d]	146	13	18	115	-	Prognoses	2022 [f]	30	12
Kellerwald NP	12.62	979	895	-	84	-	existing	2018 [g]	19	-
Klenovský Vepor	21.85	14	7	-	-	7	existing	2019, 2022 [h]	14	-
Krokar	10	30	10	-	-	20	Prognoses	2022	-	-
Sinca forest	[e]	20	8	-	-	12	existing	2023, 2024	-	-
Snežnik	10	30	9	-	21	-	Prognoses	2022	-	-
Sonian forest	12	145	133	12	-	-	existing + Prognoses	2020, 2023 [i]	30	104 [j]
Stara Planina	21.85	42	-	-	-	42	existing	2022	-	-
Uholka forest	12.62	238	-	-	-	238	existing	2019	-	-

[a] Life Prognoses protocol: Kirchmeir et al. (2023); existing protocols: Meyer et al. (2021) for Hainich NP and Kellerwald NP, Petritan et al. (2015) and Braga et al. (2023) for Sinca forest, Stillhard et al. (2019) for Uholka forest, Vandekerkhove et al. (2021) for Sonian forest, Zemlerová et al. (2023) and Ralhan et al. (2024) for Klenovský Vepor and Stara Planina

[b] number of plots with soil samples

[c] number of trees cored

[d] radius of the plot in the field, corrected for slope afterwards

[e] square plots with sides 35 m (primary) or 50 m (managed)

[f] soil samples collected in 2024

[g] soil samples collected in 2022

[h] 2019 for primary plots, 2022 for managed plots

[i] existing data from 2020; additional Life Prognoses data and plots in 2023

[j] wood cores from Verschuren et al. (2023, unpublished data)

Table 3. Dendrometry: diameter thresholds for standing trees (diameter at breast height) and lying deadwood (diameter at the largest end for Full Area Sampling, diameter at intersection for Line Intersect Sampling), method used for deadwood and regeneration sampling

	diameter threshold (cm)		**lying deadwood**	**regeneration**
site	**standing trees**	**lying deadwood**	**method** [a]	**survey**
Abruzzo NP	7 or 10 [b]	10	LIS: fan 4 x 20 m [d]	full plot
Central Balkan NP	10	10	LIS: cross 2 x 40 m [d]	full plot
Hainich NP	7	20	FAS	subplot [f]
Kalkalpen NP	10	10	own method [e]	transect [g]
Kellerwald NP	7	20	FAS	subplot [f]
Klenovský Vepor	6	6	FAS	full plot
Krokar	5	10	FAS	full plot
Sinca forest	6	15 [c]	FAS	subplot [h]
Snežnik	5	10	FAS	full plot
Sonian forest	5	10	FAS	subplot [i]
Stara Planina	6	6	LIS: fan 5 x 20 m	full plot
Uholka forest	6	7	LIS: fan 3 x 15 m	subplot [j]

[a] FAS = Full Area Sampling; LIS = Line Intersect Sampling

[b] 7 cm for living trees, 10 cm for dead trees

[c] threshold length 3 m

[d] line length in the field, corrected for slope afterwards

[e] intact trees with dbh > 20 cm and dbh inside 10 m radius: assessed as living trees (dbh, length, species, decay stage); intact trees and fragments with dbh 10-20 cm, fragments with dbh > 20 cm, stumps < 1.3 m height: plot-level volume 10-20 cm and > 20 cm using a table (based on middle diameter and length), no info on species or decay stage

[f] 25 m² quadratic sample area with centre 5 m east of the plot centre, in different height classes (among which 50-130 cm; Meyer et al. 2021)

[g] 2 transects of width 40 cm and length 20 m (1 along the slope, 1 along the isohypse); all saplings (no seedlings) smaller than 1.3 m; length transect in regeneration areas = 10 m (if trees > 1.3 m occur between 5-10 m), 5 m (if trees > 1.3 m occur between 2.5-5 m) or 2.5 m

[h] 4 subplots of 10 m² for saplings size 40 cm to 129.9 cm (Petritan et al. 2015)

[i] regeneration 30-50 cm in 3 m radius; 50-200 cm in 6 m radius (Vandekerkhove et al. 2021)

[j] 10 m² circular plot 10 m west from the centre of the main plot for saplings with height 40 - 129.9 cm (Lanz et al. 2013)

Table 4. Allometries used in the study. Tree height was calculated based on site-specific local diameter-height curves. Tree volume (including stem and branches) was calculated based on published tariffs.

site	height	reference
Abruzzo NP	x	Tabacchi et al. (2011)
Central Balkan NP	x	Duhovnikov et al. (1963), Nedyalkov et al. (1983)
Hainich NP	x	Bergel (1973, 1974, 1987)
Kalkalpen NP	x	Kramer & Akça (2008)
Kellerwald NP	x	Bergel (1973, 1974, 1987)
Klenovský Vepor	x [a]	Forrester et al. (2017) [a]
Krokar	x	Kotar (2007)
Sinca forest	x [b]	Giurgiu & Draghiciu (2004), Giurgiu et al. (2004)
Snežnik	x	Kotar (2007)
Sonian forest	x	Dagnelie et al. (1985), Quataert et al. (2011)
Stara Planina	x [a]	Forrester et al. (2017) [a]
Uholka forest	x	Abegg et al. (2013)

[a] no height measured in most recent inventory; diameter-height curves based on previous inventory; stem volume calculated based on diameter only

[b] height of all trees measured in the field; diameter-height curves for *Abies alba* and *Fagus sylvatica* from Petritan et al. (2015)

1.4. Tree-related microhabitats

Each standing tree (dead or alive) with a diameter at breast height > 20 cm was visually assessed for the presence of tree microhabitats (Table 5, Table 6).

Table 5. Tree-related microhabitats used in the Life Prognoses project, from Kirchmeir et al. (2023)

form	type	description	threshold
cavities	woodpecker breeding cavity	breeding cavity (not foraging cavity or cavity attempts)	
	trunk rot-hole	cavity, no soil contact	diameter 10 cm
	base rot-hole [a]	mostly with soil contact	diameter 10 cm
	root buttress [a]	natural hollow between buttress roots, forming a shelter, living wood, no wood mould	width 10 cm length 10 cm depth 10 cm
	dendrotelm [a]	cup-shaped hollow, holds water at least temporarily, healthy bark or decaying wood	diameter 10 cm
injuries & exposed wood	bark loss	bark missing, sapwood exposed, no cavity	width 10 cm length 30 cm
	bark pocket	loose bark, still attached to stem	width 10 cm length 10 cm depth 1 cm
	crack	exposed or rotting wood inside the crack	width 1 cm length 30 cm
crown deadwood	dead crown	crown partly dead	> 25 %
	broken crown	crown top or large limbs broken	> 25 %
excrescences	canker	deformations caused by an infection, dead or living burrs, including witch brooms	diameter 20 cm
fungal fruiting bodies	perennial polypore	perennial fungal fruiting body with woody texture (life span > 1 year)	diameter 10 cm
epiphytic & epixylic structures	mosses, lichens	covering the bottom part of the trunk (up to 3 m)	> 30 %
	climbing plants, vascular plants	covering the bottom part of the trunk (up to 3 m): woody vines, ferns	> 30 %
exudates	exudate	active flow of sap or resin (from crack or burst)	length 10 cm

[a] occurring 0-50 cm above ground level

Table 6. Tree-related microhabitats evaluated at the different sites. Brackets indicate a definition or threshold slightly different from the protocol of Life Prognoses (Kirchmeir et al. 2023). See Table 5 for descriptions of the tree-related microhabitats.

	cavities					**injuries & exposed wood**			**crown deadwood**		**excrescences**	**fungal fruiting bodies**	**epiphytic & epixylic structures**		**exudates**
	woodpecker breeding cavity	**trunk rot-hole**	**base rot-hole**	**root buttress**	**dendrotelm**	**bark loss**	**bark pocket**	**crack**	**dead crown**	**broken crown**	**canker**	**perennial polypore**	**mosses, lichens**	**plants: climbing, vascular**	**exudate**
Abruzzo NP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Central Balkan NP	x	x	x	-	(x) [b]	x	x	x	x	x	(x) [f]	x	x	x	x
Hainich NP	x	x	x	-	-	x	x	x	x	x	-	x	x	-	x
Kalkalpen NP	x	x	-	x	-	x	x	x	x	x	x	x	x	x	x
Kellerwald NP	x	x	x	-	-	x	x	x	x	x	-	x	x	-	x
Klenovský Vepor	x	x	x	x	(x) [c]	x	x	x	(x) [d]	(x) [e]	(x) [g]	(x) [i]	(x) [j]	(x) [j]	x
Krokar	x	x	x	x	x	x	x	x	x	x	(x) [f]	x	x	x	x
Sinca forest	x	x	x	x	x	x	x	x	x	x	(x) [f]	x	x	x	x
Snežnik	x	x	x	x	x	x	x	x	x	x	(x) [f]	x	x	x	x
Sonian forest	x	x	x	x	x	x	x	x	x	x	(x) [h]	x	x	x	x
Stara Planina	x	x	x	x	(x) [c]	x	x	x	(x) [d]	(x) [e]	(x) [g]	(x) [i]	(x) [j]	(x) [j]	x
Uholka forest	x	(x) [a]	-	x	x	x	x	x	x	x	-	x	-	-	-

[a] base rot-hole included in trunk rot-hole
[b] general dendrotelm, instead of base dendrotelm (0-50 cm above ground level)
[c] threshold diameter 15 cm, instead of 10 cm
[d] dead top with diameter > 10 cm at the base of the piece of deadwood, instead of > 25% dead crown
[e] broken crown derived from the status of the trees in the local dendrometry survey (alive with crown damage, dead with crown breakage)
[f] only cankers and burrs, no witch brooms
[g] including witch broom with threshold diameter 50 cm
[h] only cankers
[i] threshold diameter 5 cm, instead of 10 cm
[j] > 10 % of the trunk area covered, instead of > 30 % of the bottom 3 m of the trunk covered

1.5. Rare elements

The presence or absence of rare elements - i.e., Very Large Trees, Coarse Dead Wood, and Pits & Mounds - was evaluated within a radius of 20 m around the plot centre in the plots established for the Life Prognoses project (but see Table 8) and in Sonian forest.

For Klenovsý Vepor and Stara Planina, the presence of Very Large Trees and Coarse Dead Wood was derived from the dendrometric data collected in a 21.85 m radius. For Sinca forest, the presence of Very Large Trees and Coarse Dead Wood was derived from the dendrometric data collected in the full plots in the primary forest (35 m x 35 m). The diameter thresholds for Very Large Trees and Coarse Dead Wood depended on the local site productivity, classified into three categories based on the upper canopy height of fully grown *Fagus sylvatica* trees. At sites with high productivity (i.e., canopy height > 30 m), Very Large Trees had a diameter at breast height > 80 cm and standing or lying Coarse Dead Wood a diameter > 40 cm. At medium productivity (canopy height 20-30 m), the diameter thresholds were 70 cm for Very Large Trees and 35 cm for Coarse Dead Wood. At low-productive sites (canopy height < 20 m), the diameter thresholds were 60 cm for Very Large Trees and 30 cm for Coarse Dead Wood. Rootplates of uprooted trees with soil still attached and the resulting Pit & Mound microrelief were considered present when the relief difference between the bottom of the pit and the summit of the mound was 50 cm or more.

Table 7. Rare elements were evaluated at each site. The diameter threshold for Very Large Trees and Coarse Dead Wood depended on the growing conditions (see main text)

	Very Large Trees	**Coarse Dead Wood**	**Pits & Mounds**
Abruzzo NP [a]	(x)	(x)	x
Central Balkan NP	x	x	x
Hainich NP	-	-	-
Kalkalpen NP	x	-	x
Kellerwald NP	-	-	-
Klenovský Vepor [b]	(x)	(x)	-
Krokar	x	x	-
Sinca forest [c]	(x)	(x)	(x)
Snežnik	x	x	-
Sonian forest	x	x	x
Stara Planina [b]	(x)	(x)	-
Uholka forest	-	-	-

[a] fixed diameter thresholds for Very Large Trees (70 cm) and Coarse Dead Wood (50 cm), independent of the local growth conditions of the plot

[b] presence Very Large Trees and Coarse Dead Wood based on radius 21.85 m

[c] presence Very Large Trees and Coarse Dead Wood based on the full primary forest plots (35 m x 35 m) with area similar to a 20 m radius plot; not derived for the managed forest plots, which were twice as large (50 m x 50 m)

1.6. Soil

The soil and organic layer have been sampled for carbon quantification in managed and unmanaged forest stands in a subset of the sites and plots (see Table 7). The organic layer, i.e., the litter layer, fragmentation layer and organic horizon, was collected within a frame of at least 25 cm x 25 cm. Woody debris with a diameter > 1 cm was excluded. The soil was sampled by either a minipit or an auger at specific depths (i.e., 0-10, 10-30, 30-60, 60-100 cm); the maximum depth reached in stony soils was noted (see Table 7). Bulk density was determined for each soil depth using a 100 cm^3 Kopecky ring.

The organic layer samples were weighed fresh, dried at 40°C and weighed again. The soil samples were weighed fresh and sieved at 1 cm; both fractions were weighed again. The volume % stoniness was visually estimated (see Kirchmeir et al. 2023). The soil samples were dried at 40°C for analysis. The bulk density samples were dried at 105°C and weighed.

Sample processing and chemical analysis were done at the analytic laboratory of the Research Institute Nature and Forest (INBO, Belgium) for the samples collected in Abruzzo National Park, Kalkalpen National Park, Kellerwald National Park, and Sonian forest. The dry organic layer samples were cut up to sizes < 2 mm in a cutting mill and to sizes < 0.2 mm in a knife mill, and a homogenised subsample was taken using a splitter. The dry soil samples were ground to sizes < 2 mm using a jawbreaker mill and further to sizes < 0.02 mm with a planetary ball mill. Dry residue was determined after drying at 105°C (ISO 11465:1993). Total carbon, inorganic carbon (ISO 10694:1995), and total nitrogen (ISO 13878:1998) were determined after dry combustion. The organic carbon content of the soil samples was then calculated as the difference between total and inorganic carbon content.

The dataset of Life Prognoses soil samples was complemented with existing soil data for the site Klenovský Vepor. In Klenovský Vepor, two quantitative soil pits (size 0.5 m^2) were excavated in each plot following Huntington et al. (1988), whose method allows covering the micro-topographic variability in soil conditions and provided a reliable examination of soil mass volume, irrespective of the number and size of stones in the soil. The soil pits were positioned at higher and lower elevations perpendicular to the contour, within 10 m of the plot centre. Litter, the combined fragmentation and humus layer, and mineral soil (0-10, 10-20, and 20-40 cm) were collected from each soil pit. The extracted organic and mineral masses of each soil pit were weighed and sieved through a 1 cm sieve on a mat placed on a flat surface. Soil agglomerates, living roots, deadwood, and stones were separated during sieving. Fresh weight was recorded for the litter, combined fragmentation/humus layer after sieving through 5 mm, and mineral soil after sieving through 2 mm. The samples were oven dried to constant weight at 75°C (litter, combined fragmentation/humus layer) and 105°C (soil). The moisture content was assessed as the difference in sample weight before and after oven drying. The oven-dried samples (except for the litter) were analysed for total carbon and nitrogen content by combusting approximately 15 mg of homogenised sample at 960°C using a vario PYRO cube elemental analyzer (Elementar, Germany).

Table 8. The number of plots in which soil samples - at different depths - or organic layer samples (OL) were collected for the different forest categories (m = managed, s-a = set aside, l-u = long untouched, p = primary) at each site, with a brief description of the sampling method at the site and indicated whether bulk density (BD) was determined and whether the organic layer was sampled entirely (LFH) or split into separate layers

	no plots									**sampling per plot**		
	history				**for soil depth (cm) or organic layer**							
site	**m**	**s-a**	**l-u**	**p**	**0-10**	**10-30**	**30-60**	**60-100**	**OL**	**method**	**BD**	**OL [i]**
Abruzzo NP	9	7	-	15	31	31	17 + 4 [d]	4 + 3 [e]	31 / 4 [f]	1 minipit 30 cm x 30 cm or 50 cm x 50 cm	yes	LF, H
Kalkalpen NP	9	3	18	-	30	29 [b]	-	-	-	composite of 2 samples with Edelmann auger	-	-
Kellerwald NP	10	-	9 [a]	-	19	19	-	-	19	composite of 3 samples with auger; humus pot 593.96 cm²	yes	LFH
Klenovský Vepor	7	-	-	7	14	14 [c]	-	-	14	2 pits 70 cm x 70 cm	- [h]	L, FH
Sonian forest	23	7	-	-	30	30	30	30	24 [g]	composite of 3 samples with auger; 25 cm x 25 cm for OL	yes	LFH

[a] 1 of the 10 sampled long-untouched plots was excluded from analysis due to exceptionally low bulk density and low dry weight organic layer
[b] 1 of the 10-30 cm samples of a set-aside plot got lost
[c] soil depths 10-20 and 20-40 cm sampled instead of 10-30 cm
[d] 4 samples did not reach the full depth: 30-40 cm (2), 30-45 cm (1), 30-50 cm (1)
[e] 3 samples did not reach the full depth: 60-70 cm (1), 60-77 cm (1), 60-80 cm (1)
[f] 31 plots with dry weight; 4 plots with chemical analysis of the organic layer: 1 plot with L & H sampled separately, 3 plots with L sampled
[g] missing or surprisingly high dry-weight organic layer for 6 samples; excluded from the dataset
[h] weight of fine soil (< 2 mm) per surface area
[i] organic layer (OL): litter layer (L), fragmentation layer (F), and humus layer (H) either sampled separately or together (LFH)

2. Site Descriptions

The sites are ordered alphabetically, with the country between brackets. Bulgaria, Germany and Slovenia have two sites. For each site, the forest (geographical location, soil), the past forest management and the data collection are briefly described, with attention to deviations from the Life Prognoses protocol (Kirchmeir et al. 2023), tools applied and allometries used for the calculation of tree volumes.

2.1. Abruzzo National Park (Italy)

Site - Abruzzo, Lazio & Molise National Park: two adjacent valleys with comparable environmental conditions in the municipality of Pescasseroli, L'Aquila province, Abruzzo region. Primary forest on the upper part of the Coppo del Principe valley (one of the five Components of UNESCO WH 1133 in the National Park); recently managed and set-aside forest, mostly young to mature high forest, in Monte Tranquillo valley. Bedrock limestone; elevation 1500-1950 m a.s.l.; slope 0-50°; prevailing aspect north-northeast. Prevailing forest type pure beech forests; minor species *Acer pseudoplatanus* and *Sorbus aucuparia*.

Past management - Primary forest: scarce or no signs of past logging. Set-aside and recently managed forests: converted coppice or overmature coppice with last human interventions (thinning or coppice conversion to high forest) either 30-40 years ago or 10-25 years ago.

Plots - Plots randomly located in cells of a 100 m x 100 m square grid. Plot radius 10 m in the field; horizontal plot size calculated using the slope reported for the plot. In total, 151 plots were sampled, in recently managed (50), set-aside (21) and primary (80) forests. The soil was sampled in 9 recently managed, 7 set-aside and 15 primary plots.

Data collection - within project Life Prognoses, based on Kirchmeir et al. (2023). Fixed diameter thresholds were used for Very Large Trees (70 cm) and Coarse Dead Wood (50 cm), independent of the forest fertility class of the plot. Different diameter thresholds for living standing trees (7 cm) and standing dead trees and snags (10 cm). Height measured using a Vertex IV hypsometer for a subset of living trees (i.e., 1 straight healthy tree per plot for each diameter at breast height class: < 20, 20-39, 40-59, 60-79, > 80 cm) and all standing dead trees and snags. Height-diameter curves were developed for broadleaved and coniferous species, and height was calculated for all living trees. Aboveground tree volume (stem, branches up to 5 cm diameter) calculated from the measured diameter at breast height and the calculated height, based on national species-specific allometries (Tabacchi et al. 2011); snag volume calculated as a cylinder or as an intact tree. Lying deadwood was recorded with Line Intersect Sampling using four lines of 20 m long in the field, approximatively corrected for slope afterwards. The organic layer, soil, and wood were sampled for carbon analysis.

2.2. Central Balkan National Park (Bulgaria)

Site - Located in the most central and highest part of the Balkan range (Stara Planina mountains); elevation mostly above 1000 m. The climate of the northern parts is temperate and of the southern parts transitional continental. Bedrock magma-plutonic, sedimentary, and metamorphous rock. Complex geological structure with flattened ridges, sloping steps, granite over-thrusts, deep gorges, precipices and water caves, surface and underground limestone forms. Dystric cambisols in 97% of the forest area. Beech forest, average age 133 years, on 42% of the area.

Past management - Primary forests never logged, no signs of direct human influence. Managed stands low-intensity selective and sanitation cutting for the heating needs of the mountain huts.

Plots - Randomly located on the intersections of a grid with mesh size 100 m x 100 m, at least 25 m from the forest border. Plot radius 10 m in the field; horizontal plot size calculated afterwards. In total, 120 plots were sampled in managed (17), set-aside (41), long-untouched (16) and primary (46) forests. No soil samples were collected.

Data collection - within project Life Prognoses, based on Kirchmeir et al. (2023). Height measured with Silva ClinoMaster 1015/2025 for at least three living upper-canopy trees per plot for the frequent tree species and for all dead trees and snags. Height was calculated for trees with no measured height using species-specific diameter-height curves fit by Fieldmap. Tree volume (stem volume, and branch volume as % of the stem volume) for intact trees was calculated based on Duhovnikov et al. (1963) and Nedyalkov et al. (1983). Snag volumes are calculated as cylinders for snags up to 5 m in height; based on Duhovnikov et al. (1963) and Nedyalkov et al. (1983) for snags over 6 m in height. Lying deadwood was recorded with Line Intersect Sampling using a line-oriented north-south and a line-oriented east-west: each 40 m long in the field, corrected for slope afterwards. Tree-related microhabitat ‘root buttress’ not evaluated; ‘dendrotelm’ presence not restricted to the stem base (0-50 cm above ground level); ‘canker’ contains cankers and burrs, no witch brooms. Wood cores from 55 *Fagus sylvatica* trees: 26 from extensively or formerly managed forest (*F. sylvatica* >95 %, age class 160-180 yrs, altitude 1450 m, selective and sanitation cutting for firewood for local hut), 28 from primary forest (*F. sylvatica* >95 %, age class 160-180 yrs, altitude 1100 m, Severen Dzhendem Reserve). Coring - length 30 cm, diameter 5.15 cm, 1 core per tree - in 2022 and 2023. Additionally, 1 *Picea abies* was cored in the formerly managed forest.

2.3. Hainich National Park (Germany)

Site - Located in the centre of Germany bordering the Thuringia basin; 275-480 m a.s.l. Sub-atlantic climate with annual precipitation 750-800 mm, of which nearly half falls within the vegetation period. Bedrock triassic shell limestone covered with loess of varying thickness; humus form mainly L to F Mull.

Past management - Single tree selection or shelterwood cutting until either the 1960s or 1997.

Plots - Centres of the circular sample plots (horizontal radius 12.62 m) on the intersections of a grid with mesh size 100 m x 100 m (Meyer et al. 2021). All 393 plots are in the set-aside forest. No soil samples were collected.

Data collection - 2020 inventory, following Meyer et al. (2021); data fit into the Life Prognoses data frame. No assessment of Very Large Trees, Coarse Dead Wood, and Pits & Mounds in a 20 m radius circle. Regeneration was recorded for a 25 m² quadratic subplot with a centre 5 m east of the plot centre, in different height classes (class 50-130 cm used for the dataset). Tree height was measured with a Vertex IV hypsometer for at least three trees per plot for frequently represented tree species, covering the entire diameter at the breast height range of the species. All tree heights were measured for rare tree species, and for snags and trees with severe crown loss. Species-specific diameter-height curves fitted by FieldMap

(IFER) were used to calculate the height for the trees with no measured height. Tree volume (stem + branches up to 7 cm diameter) was calculated with diameter and height using Bergel (1973, 1974, 1987); snag volume was calculated as a truncated cone. The diameter threshold for lying deadwood is 20 cm. Tree-related microhabitats 'root buttress', 'dendrotelm', 'canker', and 'climbing plants, vascular plants' were not evaluated.

2.4. Kalkalpen National Park (Austria)

Site - Part of the Eastern Alps (Northern Limestone Alps), dominated by rugged terrain of limestone and dolomite bedrock. Shallow rendzinas soils on slopes, richer brown soils in gentler areas. Humus form varies by altitude: mull humus in lower, mixed forests; and raw humus at higher elevations. Humid continental climate with cold, snowy winters and mild, rainy summers. Montane mixed forests of *Fagus sylvatica*, *Picea abies*, and *Abies alba*; subalpine coniferous zones; alpine meadows.

Past management - Heavily exploited since mediaeval times (extensive clear-cutting). Only small patches of natural forest remaining. National Park was established in 1997; a gradual return to natural, old-growth forests.

Plots - Plots in the National Park (set aside, long untouched) on a 300 m x 300 m grid representing different forest types, elevations, and exposures. Managed plots outside the National Park chosen by local experts in representative locations. Plot radius 10 m in the field; horizontal plot size calculated afterwards. In total, 146 plots were sampled in managed (13), set-aside (18) and long-untouched (115) forests. Soil samples were collected in 7 managed and 23 unmanaged plots.

Data collection - conducted within the Life Prognoses project, following the forest inventory scheme of Kalkalpen National Park (Naturrauminventur Nationalpark Kalkalpen 2014, unpublished). Coarse Dead Wood in a 20 m radius was not evaluated. Regeneration (all saplings - no seedlings - smaller than 1.3 m) monitored on two transects (1 along the slope, 1 along the isohypse) of width 40 cm and length 20 m; transect length adjusted in regeneration areas to 10 m (if trees > 1.3 m occur between 5-10 m), 5 m (if trees > 1.3 m occur between 2.5-5 m) or 2.5 m (if trees > 1.3 m occur between 0-2.5 m). Height was measured for a subset of standing trees and for all snags; height was calculated for all living and dead standing trees based on species-specific diameter-height curves (non-abundant species with similar growth forms lumped together). The stem volume (V_{stem}) of intact trees is calculated using Denzin's volume equation:

$$V_{stem} = DBH^2/1000 + (DBH^2/1000 \times (H_{act} - H_{norm}) \times DVC$$

With *DBH* diameter at breast height (cm), H_{act} actual height (m), H_{norm} normal height (m), and *DVC* the volume correction factor (Kramer & Akça 2008). Aboveground volume of broken trees calculated as the difference between the volume of the intact tree corresponding to the measured diameter at breast height (based on the diameter-height curve and Denzin's volume equation) and the volume of the missing part (using Denzin's volume equation, with height = intact tree height - height broken part, and diameter calculated based on the intercept theorem as the diameter of the broken stem multiplied by the ratio between the height of the broken part and the intact height). Branch volume (diameter > 7 cm) is calculated as 12% of stem volume, based on Gschwantner et al. (2019), who report that large branches constitute 3-21% of broadleaved growing stock. Root biomass is 26.5% based on data reviewed by Körner et al. (1993) and Wirth et al. (2004). Lying deadwood was assessed with the custom method. Intact lying trees with a diameter at breast height > 20 cm and diameter at breast height inside the 10 m radius were assessed as living trees: diameter at breast height, length, species, and decay stage noted. For intact trees with a diameter at breast height 10-20 cm, fragments with a diameter > 10 cm, and stumps < 1.3 m height: plot-level volume determined in two classes (diameter 10-20 cm and > 20 cm) with table-based on middle diameter and length; no info on species or decay stage. Soil was sampled with an Edelmann auger (diameter 7 cm, maximum length 40 cm). Wood cores collected in 12 plots: 1 tree cored per plot (9 *Fagus sylvatica*, 3 *Picea abies*); at breast height; corer 60 cm, diameter 5.15 cm; in June 2024.

2.5. Kellerwald National Park (Germany)

Site - Situated in the north-western part of the Hessian mountainous region; 300-675 m a.s.l. Sub-atlantic climate with annual precipitation 650-800 mm, of which nearly half falls within the vegetation period. Part of the Rhineland Slate Mountains; dominant bedrock devonic Greywacke; fairly shallow and rocky cambisols with poor nutrient supply prevalent; dominant humus form Moder.

Past management - Forest management until the 1990s; National Park designated in 2004. Past management mostly shelterwood cutting; no signs of silvicultural treatment in some stands on steep slopes and ridges.

Plots - Centres of the circular sample plots (horizontal radius 12.62 m) on the intersections of a grid with mesh size 100 m x 100 m (Meyer et al. 2021). A total of 979 plots, in managed (895) and long-untouched (84) forests. Soil samples were collected in 10 managed and 10 long-untouched plots.

Data collection - 2018 inventory, following Meyer et al. (2021); data fit into the Life Prognoses data frame. No evaluation of Very Large Trees, Coarse Dead Wood, and Pits & Mounds in a 20 m radius. Regeneration was recorded for a 25 m² quadratic subplot with a centre 5 m east of the plot centre, in different height classes (class 50-130 cm used for the dataset). Tree height was measured with a Vertex IV for at least three trees per plot of frequently represented tree species covering the entire diameter at the breast height range. All tree heights were measured for rare tree species, snags and trees with severe crown loss. Species-specific diameter-height curves fitted by FieldMap were used to calculate the height for the trees with no measured height. Tree volume (stem + branches with a diameter up to 7 cm) was calculated with diameter and height using Bergel (1973, 1974, 1987); snag volume was calculated as a truncated cone. The diameter threshold for lying deadwood is 20 cm. Tree-related microhabitats 'root buttress', 'dendrotelm', 'canker', and 'climbing plants, vascular plants' were not evaluated. The organic layer was collected with a humus pot (593.96 cm²). Mineral soil was sampled with an auger at depths of 0-10 cm and 10-30 cm as stoniness in most (but not all) plots did not allow deeper sampling.

2.6. Klenovský Vepor (Slovakia)

Site - Klenovský Vepor forest reserve and lower parts neighbouring the reserve in the Vepor Hills, central Slovakia, Western Carpathians. Not part of the UNESCO World Heritage Site "Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe". Climate temperate, continental; bedrock vulcanic (andesite); prevalent Cambisols; mull humus. Montane mixed forest with a mixture of *Fagus sylvatica*, *Abies alba* and *Picea abies*.

Past management - Primary forests never logged, no signs of direct human influence (mixed forests dominated by *Fagus sylvatica*, admixed with *Abies alba* and *Picea abies*). Managed plots differ in time since the last management activity and lay in either recently logged forest, thinned stands, mature forest, or old mature forest (various tree species compositions but mostly dominated by either *Fagus sylvatica* or *Picea abies*).

Plots - Primary forest plots on a grid with a cell size of 10 ha, with 1 plot per grid cell; managed forest plots in managed stands in the proximity of the primary forest area. In total, 14 plots were sampled, in managed (7) and primary (7) forests. Soil samples were collected in all 14 plots before the Life Prognoses project.

Data collection - inventory in 2019 (primary plots) and 2022 (managed plots), following Zemlerová et al. (2023) and Ralhan et al. (2024); data fit into the Life Prognoses data frame. No separate field assessment of rare elements in a 20 m radius. The presence of Very Large Trees and Coarse Dead Wood derived from the dendrometric inventory in the 21.85 m radius plots. No data on Pit & Mound presence. Regeneration evaluated in size class 50-130 cm, with no distinction with regard to origin (natural vs planted). Height measured for a subset of trees to fit diameter-height curves during the 2014 inventory; height estimated for all intact living trees based on diameter at breast height measured in 2019 or 2022; snags in height categories. Tree volume (stem only as well as stem and branches for living trees) was calculated using measured diameter at breast height based in the allometries of Forrester et al. (2017). Tree-related microhabitats were evaluated for all trees with diameter at breast height > 6 cm according to Larrieu et al. (2018). Conversion, with types from Table 4 in Larrieu et al. (2018) and diverging thresholds between brackets: woodpecker breeding cavity (small woodpecker breeding cavity, medium-sized woodpecker breeding cavity, large woodpecker breeding cavity, woodpecker flute); trunk rot-hole (trunk rot-hole, semi-open trunk rot-hole, chimney trunk rot-hole); base rot-hole (trunk base rot-hole, chimney trunk base rot-hole); root buttress (root-buttress concavity); dendrotelm (dendrotelm - threshold diameter 15 cm); bark loss (bark loss); bark pocket (bark shelter, bark pocket); crack (crack, lightning scar); dead crown (dead top - diameter > 10 cm at the base of the piece of deadwood); broken crown derived from the status of the trees in the local dendrometry survey (alive with crown damage, dead with crown breakage); canker (witch broom - threshold diameter 50 cm, burr, canker); perennial polypore (perennial polypore (threshold diameter 5 cm); mosses, lichens (bryophytes, foliose and fruticose lichens - > 10 % of the trunk area covered); climbing plants, vascular plants (ivy and lianas - > 10 % of the trunk area covered, ferns - > 5 fronds); exudate (sap run, heavy resinosis). Two soil pits of 70 cm x 70 cm frame per plot (samples not pooled). Litter layer (OL) and combined fragmentation + humus layer (OF+OH) were sampled separately, sieved through mesh size 10 and 5 mm, dried at 75°C, and weighed. Soil sampled at three depths (0-10, 10-20, 20-40 cm), sieved through mesh size 10 and 2 mm, dried at 105°C, and weighed (fine soil <2 mm, fine stones 2-10 mm, bigger stones >10 mm). Due to stoniness, bulk density was not assessed but the dry weight of fine soil (fraction < 2 mm) per surface area was determined. Total carbon and total nitrogen were determined on the samples of the fragmentation/humus layer and the three soil depths (PYRO cube elemental analyzer).

2.7. Krokar (Slovenia)

Site - Forest reserve Virgin Forest Krokar and nearby managed forests in the Dinaric mountain range, southern Slovenia. Elevation 910-1180 m asl. Temperate continental climate: mean annual temperature

8.9°C, mean annual precipitation 1447 mm. The northern part reserve with dolomite bedrock; the southern part is limestone. Leptosols and cambisols. Ilyrian beech forests - *Aremonio-Fagion*, *Isopyro-Fagetum* Košir 1962.

Past management - Primary forests never logged, no signs of direct human influence. Managed stands representative of the typical silvicultural systems in the area, primarily irregular shelterwood.

Plots - Plots in the forest reserve randomly selected on a 100 m x 100 m grid; managed plots randomly selected in stands proposed by local foresters. In total, 30 plots were sampled, in managed (10) and primary (20) forests. No soil samples were collected.

Data collection - within project Life Prognoses, based on Kirchmeir et al. (2023). Presence Pit & Mound structures not recorded. The decay stage of standing dead wood was not evaluated in the field; set to 'hard' for the data analysis. Height is measured on a subset of living trees; height is calculated for living trees with no measured height and for dead trees and snags. Tree volume (stem, branches) was calculated with Vlado Puhek's regression equations based on diameter at breast height and tree height (Kotar 2007). Tree-related microhabitat canker contains cankers and burrs, no witch brooms.

2.8. Sinca forest (Romania)

Note - The sampling in Sinca forest was not part of the Life Prognoses project, but was kindly supplied to be added to the dataset by Catalin and Any Mary Petritan.

Site - Primary fir-beech forest of the Unesco Codrul Secular Sinca Virgin Forest Reserve in the Southern Carpathians and neighbouring managed forest. Temperate continental climate: mean annual temperature 5.9°C, mean annual precipitation 950 mm. Steep slopes 30-40°; elevation 850-1350 m a.s.l.; bedrock crystalline schist; mainly cambisols with ample water and nutrient supply; moder humus. Forest type *Pulmonario rubrae-Fagetum Soo* (1964) with variable proportions of *Fagus sylvatica* and *Abies alba*, in accordance with the Natura 2000 habitat 91V0 Dacian beech forest (Symphylo-Fagion).

Past management - No signs of human impact in the primary part. Managed stands group shelterwood system (Femelschlag) since 2009 (see Braga et al. 2023); no signs of human impact before 2009.

Plots - In the centre of randomly selected cells of a systematic grid of 100 m x 100 m: 12 plots (35 m x 35 m) in the forest reserve (cf. Petritan et al. 2015), 8 plots (50 m x 50 m) in the managed stands (cf. Braga et al. 2023).

Data collection - 2023-2024 inventory, following Petritan et al. (2015) and Braga et al. (2023); data fit into the Life Prognoses data frame. Height measured for all trees and snags with a Vertex IV hypsometer; height calculated for every living *Abies alba* and *Fagus sylvatica* tree using diameter-height curves from Petritan et al. (2015): $h = 1.3 + dbh^2 / (6.82174 + 0.80184\ dbh + 0.014052\ dbh^2)$ for *Abies alba* (R^2 0.95), $h = 1.3 + dbh^2 / (0.919801 + 0.750678\ dbh + 0.018154\ dbh^2)$ for *Fagus sylvatica* (R^2 0.92). Volume of intact trees calculated with national species-specific models (Giurgiu & Draghiciu 2004: stem volume for *Abies alba*, stem volume with all branches for *Fagus sylvatica*); crown volume calculated with national species-specific models as percentage of stem volume for *Abies alba* and as percentage of stem and branch volume for *Fagus sylvatica* (Giurgiu et al. 2004: $8.3788\ dbh^{-0.103}$ for *Abies alba*, $8.3502\ dbh^{0.1859}$ for *Fagus sylvatica*). The volume of snags is calculated as a truncated cone, with a diameter at the breakpoint measured with an optical calliper. Lying deadwood is measured when the base diameter > 15 cm and the length > 3 m. Tree-related microhabitats were evaluated following the Life Prognoses protocol (Kirchmeir et al. 2023) for the primary forest plots and three of the managed forest plots in 2024, and following the catalogue of tree microhabitats of Kraus et al. (2016) for the five remaining managed forest plots. Conversion, with codes from Kraus et al. (2016) between brackets: woodpecker breeding cavity (C11, C12, C13); trunk rot-hole (CV23, CV24, CV32); base rot-hole (CV21, CV22); root buttress (GR12); dendrotelm (CV42); bark loss (IN11, IN13); bark pocket (BA11, BA12); crack (IN31, IN32); dead and broken crown determined considering the 25% threshold; canker (GR31, GR32); perennial polypore (EP12); mosses, lichens (EP31); climbing plants, vascular plants (EP32); exudate (OT11, OT12).

2.9. Snežnik (Slovenia)

Site - Snežnik Forest Reserve and nearby managed forests in the Dinaric mountain range, southern Slovenia. Elevation 1350-1450 m asl. Temperate continental climate: mean annual temperature 8.9°C, mean annual precipitation 1447 mm. Mainly limestone bedrock, partly dolomitic with rendzina soil. Leptosols and cambisols. Ilyrian beech forests - *Aremonio-Fagion.*

Past management - Long-untouched forest under irregular shelterwood until 1969. Sampled managed stands representative of the typical silvicultural systems in the area, primarily irregular shelterwood.

Plots - Plots in the forest reserve randomly selected on a 100 m x 100 m grid; managed plots randomly selected in stands proposed by local foresters. In total, 30 plots were sampled, in managed (9) and primary (21) forests. No soil samples were collected.

Data collection - within project Life Prognoses, based on Kirchmeir et al. (2023). Presence Pit & Mound structures not recorded. Decay stage of standing dead wood not evaluated in the field and set to 'hard' for the data analysis. Height is measured on a subset of living and dead trees; height is calculated for trees with no measured height and for snags. Tree volume (stem, branches) was calculated with Vlado Puhek's regression equations based on diameter at breast height and tree height (Kotar 2007). Tree-related microhabitat canker contains cankers and burrs, no witch brooms.

2.10. Sonian forest (Belgium)

Site - A strict forest reserve (one of the Component parts of the UNESCO UNESCO World Heritage Site 1133) and adjacent managed forest stands in the centre of the Sonian forest (*Zoniënwoud*, *Forêt de Soignes*), a forest complex of about 5000 ha, 15 km south of Brussels. Slightly undulating flat area 70-120 m a.s.l. Tertiary calcium-rich sandstone and flint stone covered with a 3-8 m thick layer of quaternary niveo-aeolic loess deposits of the Würm glaciation (FAO classification: Luvisols and Podzoluvisols). The upper soil layer is lessivated and acidic (pH H_2O 4.0-4.5), and deeper soil layers are more saturated with base cations: productive forest soil reflected in the canopy heights of over 45 m. Moder humus (sensu Zanella et al. 2022). Climate is characterised by a mean annual temperature of 10.6 °C, and annual precipitation of 852 mm (1981-2010, Uccle, Royal Meteorological Institute, www.meteo.be). Atlantic acidophilous beech forest: *Milio-Fagetum* sensu Noirfalise (1984), European habitat type 9120, EUNIS code G1.62. Ground vegetation is scarce and dominated by *Pteridium aquilinum* (L.) Kuhn and *Milium effusum* L.; scarce occurrence of

Oxalis acetosella L., *Convallaria majalis* L., and *Anemone nemorosa* (L.) Holub. From: Vandekerkhove et al. (2018)

Past management - Ancient woodland intensively used by man over the last two millennia. Between the 8th and 12th century, iron was excavated and processed in low-furnaces, causing overexploitation of the forest; especially beech trees were cut. From the 14th century onward, forest management was strictly regulated and grazing restricted: *tire et aire* management regime of clear-cuts with reserved trees on areas of 8-15 ha, rotation period of 80-100 years, about 30-50 trees per ha left for a second rotation to yield timber of larger dimensions and function as seed trees. Since second half 19th century: less intensive long-rotation high forests with selective thinning and small group cuts (*Femelslag*). Forest reserve with core area of ca. 20 ha (250-year old stand, set aside in 1983), first extension area of ca. 100 ha (stands 20-250 years old, set aside in 1995, last thinning 1992-1993), and second extension area of ca. 100 ha (stands 20-200 years old, set aside in 2010). For Life Prognoses: core area and first extension considered ‘set aside’ (not managed for > 25 years), second extension area and buffer zone considered ‘managed’ (set aside < 25 years ago).

Plots - Systematic sampling on alternating intersections of 100 m x 100 m grid. Subset of existing plots selected in the forest reserve: beech-dominated, homogeneous age structure (i.e., entire plot within or outside former final cuts). Additional plots in the surrounding managed forest: beech-dominated, across a range of age classes. In total, 145 plots were sampled, in managed (80) and set-aside (65) forests (Table S1). The soil was sampled in 15 managed and 15 set-aside plots.

Table S1. Number of plots in which dendrometric data or soil data (*grey italic*) were collected in the Sonian forest, for the different management and stand age categories

	two-aged	even-aged					
		10-30	30-60	60-150	>150	total	data
managed	35	3	4	17	21	80	dendro
	2	*2*	*3*	*5*	*3*	*15*	*soil*
set aside > 25 yrs	8	-	-	29	16	53	dendro
	0	*-*	*-*	*5*	*3*	*8*	*soil*
set aside > 40 yrs	-	1	1	1	9	12	dendro
	-	*1*	*1*	*0*	*5*	*7*	*soil*
total	43	4	5	46	46	145	dendro
	2	*3*	*4*	*11*	*11*	*30*	*soil*

Data collection - 2020 inventory with additional plots and additional measurements for Life Prognoses in 2023: dendrometry following Vandekerkhove et al. (2021); tree-related microhabitats, rare elements and soil according to Kirchmeir et al. (2023). Original data fit into the Life Prognoses data frame. Dendrometric measurements in concentric circular plots: radius of 18 m for trees with a diameter at breast height > 40 cm, radius of 12 m for trees with diameter at breast height > 5 cm, radius 6 m for regeneration of 50-130 cm height, and radius 3 m for regeneration 30-50 cm height. Lying deadwood with a diameter at the large end > 10 cm was inventoried with Full Area Sampling in the 18 m radius. To be more in line with the 10 m radius plots of the plots sampled for the Life Prognoses project, data for standing trees and lying deadwood were extracted for virtual plots with a radius of 12 m. Height was measured with a Vertex hypsometer on a selection of trees to fit diameter-height curves; height was calculated for all living and intact standing dead trees using local species-specific diameter-height curves. Stem volumes of intact trees were calculated based on measured diameter and calculated height with the two-entry volume tables of Dagnelie et al. (1985), and with Quataert et al. (2011) for beech and oak. Snag volumes are calculated as cylinders. Crown volumes of intact trees were calculated based on tree diameter with the one-entry volume tables of Dagnelie et al. (1985). Tree-related microhabitat cankers are strictly cankers (containing dead or decaying tissue), no burrs or witch brooms. The organic layer was collected with a 25 cm x 25 cm frame. Mineral soil was sampled with a set of augers: diameter 30 mm (0-10, 10-30 cm), 25 mm (30-60 cm), and 20 mm (60-100 cm). Bulk density samples were collected with the Edelmann auger and Kopecky ring sampling set.

Wood cores from 39 old living *Fagus sylvatica* trees sampled in the forest reserve in October 2021 (Verschuren et al. 2023) and 65 younger *Fagus sylvatica* trees sampled in the forest reserve and neighbouring thinned stands in October 2021 and May 2023 (unpublished data Verschuren et al.). Old trees: mean diameter at breast height 98.5 cm; planted in 1775, managed intensively for 200 years with regular thinning and possibly some pruning early on, set aside in 1983. Young trees forest reserve: mean diameter at breast height 38.0 cm; estimated pith years 1935, 1947 and 1955. Young trees thinned stand: mean diameter at breast height 48.8 cm; estimated pith years 1910, 1930 and 1959. Two perpendicular cores per tree were collected with a 2-threaded 5.15 mm Haglöf increment borer. Cores soaked for 20h in an 80◦C heated water bath, extracted with a Soxhlet-extraction for 6 h using a 0.43 to 1 toluene - ethanol mixture, dried, stored in paper straws, and conditioned in a climate chamber at 65 % RH and 20 ◦C. Tree ring measurements with X-ray micro-computed Tomography (resolution 50 µm) at the Centre for X-ray Computed Tomography of Ghent University. See Verschuren et al. (2023) for further details. Weighted mean density at sampling height was calculated across the wood core using the mean ring density-weighted by the basal area increment of the ring.

2.11. Stara Planina (Bulgaria)

Site - Part of Central Balkan National Park. Climate temperate continental. Bedrock magma-plutonic, sedimentary, and metamorphous rock. Kambisoils with mostly mull humus form. Montane mixed beech-dominated forests.

Past management - Primary forests with no signs of direct human interventions; higher altitudes of primary forest polygons probably grazed in the past to a small degree.

Plots - Plot pairs randomly located in the interior 3.39 ha of 10 ha grid cells. All 42 plots are in primary forest. No soil samples were collected.

Data collection - Inventory in 2022, following Zemlerová et al. (2023) and Ralhan et al. (2024); data fit into the Life Prognoses data frame. No separate field assessment of rare elements in a 20 m radius. The presence of Very Large Trees and Coarse Dead Wood derived from the dendrometric inventory in the 21.85 m radius plots. No data on Pit & Mound presence. Regeneration evaluated in size class 50-130 cm, with no distinction with regard to origin (natural vs planted). Height measured for a subset of trees to fit diameter-height curves during the 2017 inventory; height estimated for all intact living trees based on diameter at breast height measured in 2022; snags in height categories. Tree volume (stem only as well as stem and branches for living trees) is calculated based on measured diameter at breast height based on Forrester et al. (2017). Tree-related microhabitats were evaluated for all trees with diameter at breast height > 6 cm according to Larrieu et al. (2018). Conversion, with types from Table 4 in Larrieu et al. (2018) and diverging thresholds between brackets: woodpecker breeding cavity (small woodpecker breeding cavity, medium-sized woodpecker breeding cavity, large woodpecker breeding cavity, woodpecker flute); trunk rot-hole (trunk rot-hole, semi-open trunk rot-hole, chimney trunk rot-hole); base rot-hole (trunk base rot-hole, chimney trunk base rot-hole); root buttress (root-buttress concavity); dendrotelm (dendrotelm - threshold diameter 15 cm); bark loss (bark loss); bark pocket (bark shelter, bark pocket); crack (crack, lightning scar); dead crown (dead top - diameter > 10 cm at the base of the piece of deadwood); broken crown derived from the status of the trees in the local dendrometry survey (alive with crown damage, dead with crown breakage); canker (witch broom - threshold diameter 50 cm, burr, canker); perennial polypore (perennial polypore (threshold diameter 5 cm); mosses, lichens (bryophytes, foliose and fruticose lichens - > 10 % of the trunk area covered); climbing plants, vascular plants (ivy and lianas - > 10 % of the trunk area covered, ferns - > 5 fronds); exudate (sap run, heavy resinosis).

2.12. Uholka forest (Ukraine)

Note - In the Life Prognoses project, Chornohora reserve was foreseen to be sampled, made impossible due to the war in Ukraine. WSL-Switzerland kindly provided their dataset on Uholka forest as a replacement.

Site - Primary beech forest of the Uholka reserve of the Uholka Shyrokyi Luh massif in Transcarpathia, southwest Ukraine; part of the Carpathian Biosphere Reserve. Atlantic-continental climate with a mean annual temperature of 7.7°C (1990-2010) and mean annual precipitation of 1134 mm (1980-2010; meteorological station of Carpathian Biosphere Reserve in Uholka at 430 m altitude). Relief fragmented and divided by several narrow valleys of mountain streams; elevation 400-1350 m a.s.l.; mainly flysch formations, limestone and calcareous conglomerates. From: Hamor & Brändli (2013)

Past management - No known significant human intervention.

Plots - Systematic cluster sampling: rectangular grid with side lengths 445 m and 1235 m, a cluster of two sample plots 100 m apart at each grid point, horizontal plot radius 12.62 m (Lanz et al. 2013). All 238 plots are in primary forest. No soil samples were collected.

Data collection - Second inventory, in 2019, following Stillhard et al. (2019); data fit into the Life Prognoses data frame. Not evaluated: the presence of Very Large Trees, Coarse Dead Wood and Pit & Mound structures in a radius of 20 m. Regeneration, i.e. saplings with height 40-129.9 cm, sampled in a 10 m² circular plot 10 m west from the centre of the main plot. Height measured with a Vertex hypsometer for all snags and for a subsample of living trees, i.e., all intact trees in the first quadrant of the plot and all intact trees with a diameter at breast height > 60 cm. Height predicted for all intact trees based on a fit between diameter and measured heights. Aboveground volumes of intact trees (stem, branches up to 7 cm diameter) and snags were calculated as described in Abegg et al. (2013). Tree-related microhabitats assessed following Stillhard et al. (2019), mostly similar to the Life Prognoses protocol. Between brackets for each TreM, the section from Stillhard et al. (2019) and deviation from the Life Prognoses protocol: woodpecker breeding cavity (MID 464: Woodpecker breeding cavity); trunk rot-hole (MID 466: Deep tree cavity); base rot-hole (MID 466: Deep tree cavity - not evaluated separately, included with trunk rot-hole);

root buttress (MID 467: Root-buttress cavities); dendrotelm (MID 471: Dendrotelm - only on living trees); bark loss (MID 452: Bark lesion - only on living trees); bark pocket (MID 469: Bark pockets); crack (MID 468: Wide crack); dead crown (MID 448: Deadwood in crown); broken crown (MID 445: Crown breakage); canker (not included because of different threshold); perennial polypore (MID 461: Polypore on stem); mosses, lichens (not included because of different threshold); climbing plants, vascular plants (not included because of different threshold); exudate (not included because of different threshold).

3. Species List

Tree species are listed according to the percentage of living stems with diameter at breast height > 10 cm in the plots at the sites. Sites are ordered alphabetically. Species not native to Europe indicated by *.

species	Abruzzo NP	Central Balkan NP	Hainich NP	Kalkalpen NP	Kellerwald NP	Klenovský Vepor	Krokar	Sinca forest	Sonian forest	Snežnik	Stara Planina	Uholka forest
Fagus sylvatica L.	95	83	69	61	81	74	87	55	82	96	94	98
Abies alba Mill.	-	5	-	2	<1	4	7	45	-	-	5	<1
Picea abies (L.) H. Karst.	-	<1	<1	25	7	11	-	<1	-	1	-	-
Acer pseudoplatanus L.	5	1	7	6	<1	6	5	-	1	2	1	1
Fraxinus excelsior L.	-	<1	15	2	<1	4	-	-	<1	-	-	<1
Carpinus betulus L.	-	4	3	-	2	-	-	-	7	-	-	<1
Quercus robur L.	-	-	<1	-	<1	-	-	-	8	-	-	-
Larix decidua Mill.	-	-	<1	3	3	-	-	-	-	-	-	-
Ostrya carpinifolia Scop.	-	5	-	-	-	-	-	-	-	-	-	-
Quercus petraea (Matt.) Liebl.	-	-	1	-	3	-	-	-	-	-	-	-
Acer platanoides L.	-	<1	1	-	<1	1	-	-	<1	-	-	<1
Tilia cordata Mill.	-	-	2	-	-	-	-	-	<1	-	-	-
Pinus sylvestris L.	-	-	-	1	1	-	-	-	<1	-	-	-
Sorbus aucuparia L.	<1	<1	-	-	<1	<1	1	-	<1	-	-	-
Larix spp.	-	-	<1	-	1	-	-	-	<1	-	-	-
Aria edulis (Willd.) M.Roem.	-	-	-	1	-	-	-	-	-	<1	-	-
Betula pendula Roth.	-	-	-	-	1	<1	-	-	<1	-	-	<1
Larix kaempferi (Lamb.) Carrière *	-	-	-	-	<1	-	-	-	1	-	-	-
Acer campestre L.	-	<1	<1	-	<1	-	-	-	<1	-	-	-
Acer hyrcanum Fisch. & C.A.Mey.	-	<1	-	-	-	-	-	-	-	-	-	-
Carpinus orientalis Mill.	-	<1	-	-	-	-	-	-	-	-	-	-
Corylus colurna L.	-	<1	-	-	-	-	-	-	-	-	-	-
Cornus spp.	-	<1	-	-	-	-	-	-	-	-	-	-
Prunus cerasus L.	-	<1	-	-	-	-	-	-	-	-	-	-
Torminalis glaberrima (Gand.) Sennikov & Kurtto	-	<1	<1	-	-	-	-	-	-	-	-	-
Taxus baccata L.	-	<1	-	-	-	-	-	-	-	-	-	-
Acer spp.	-	-	<1	-	-	-	-	-	-	-	-	-
Betula spp.	-	-	<1	-	<1	-	-	-	-	-	-	-
Corylus avellana L.	-	-	<1	-	<1	-	-	-	-	-	-	-
Picea jezoensis (Siebold & Zucc.) Carr.	-	-	<1	-	-	-	-	-	-	-	-	-
Populus tremula L.	-	-	<1	<1	<1	-	-	-	-	-	-	-
Prunus avium L.	-	-	<1	-	<1	-	-	-	-	-	-	-
Quercus spp.	-	-	<1	-	<1	-	-	-	-	-	-	-
Salix caprea L.	-	-	<1	-	<1	-	-	-	-	-	-	<1
Tilia spp.	-	-	<1	-	<1	-	-	-	-	-	-	-
Tilia platyphyllos Scop.	-	-	<1	-	-	-	-	-	-	-	-	-
Ulmus glabra Huds.	-	-	<1	<1	<1	<1	<1	-	-	-	<1	<1
Ulmus spp.	-	-	<1	-	-	-	-	-	-	-	-	-
Aesculus hippocastanum L.	-	-	-	-	<1	-	-	-	-	-	-	-
Alnus glutinosa (L.) Gaertn.	-	-	-	-	<1	-	-	-	-	-	-	-
Crataegus spp.	-	-	-	-	<1	-	-	-	-	-	-	-
Malus sylvestris (L.) Mill.	-	-	-	-	<1	-	-	-	-	-	-	-
Pinus strobus L. *	-	-	-	-	<1	-	-	-	-	-	-	-
Pseudotsuga menziesii (Mirbel) Franco *	-	-	-	-	<1	-	-	-	-	-	-	-
Quercus rubra L. *	-	-	-	-	<1	-	-	-	-	-	-	-
Robinia pseudoacacia L. *	-	-	-	-	<1	-	-	-	-	-	-	-
Sambucus nigra L.	-	-	-	-	<1	-	-	-	-	-	-	-
Salix spp.	-	-	-	-	<1	-	-	-	-	-	-	-
Acer negundo L. *	-	-	-	-	-	-	-	-	<1	-	-	-
Castanea sativa Mill.	-	-	-	-	-	-	-	-	<1	-	-	-

4. References

Abegg M, Hobi ML, Kaufmann E, Lanz A (2013) Data management and statistical evaluation. In: Commarmot B, Brändli U-B, Hamor F, Lavnyy V (eds): Inventory of the largest primeval beech forest. A Swiss-Ukrainian scientific adventure. Birmensdorf, Swiss Federal Research Institute WSL; L'viv, Ukrainian National Forestry University; Rakhiv, Carpathian Biosphere Reserve. pp. 35-39

Bergel D (1973) Formzahluntersuchungen an Buche, Fichte, europäischer und japanischer Lärche zur Aufstellung neuer Massentafeln. [Form factor studies on beech, spruce, European larch and Japanese larch as a basis for new volume tables] Allgemeine Forst- und Jagdzeitung 144(5/6): 117-124 [in German]

Bergel D (1974) Massentafeln für Nordwestdeutschland Teil 2: Eiche, Roteiche, Kiefer. [Volume tables for northwestern Germany Part 2: oak, red oak, pine] Göttingen, Niedersächsische Forstliche Versuchsanstalt [in German]

Bergel D (1987) Derbholz-Massentafeln Teil 3 Nordwestdeutschland. Douglasie, Fichte, Kiefer, Europäische Lärche. [Tree volume tables for northwestern Germany Part 3: douglas, fir, pine, European larch] Göttingen, Niedersächsische Forstliche Versuchsanstalt [in German]

Braga CI, Crisan VE, Petritan IC, Scarlatescu V, Vasile D, Lazar G, Petritan AM (2023) Short-term effects of anthropogenic disturbances on stand structure, soil properties, and vegetation diversity in a former virgin mixed forest. Forests 14: 742. doi: 10.3390/f14040742

Brändli U-B, Dowhanytsch J (2003) Urwälder im Zentrum Europas. Ein Naturführer durch das Karpaten-Biosphärenreservat in der Ukraine. [Virgin forests in the centre of Europe. A nature guide to the Carpathian Biosphere Reserve in Ukraine] Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research WSL; Rakhiv, Carpathian Biosphere Reserve. pp. 76-107

Cornes RC, Van der Schrier G, Van den Besselaar EJM, Jones PD (2018) An ensemble version of the E-OBS temperature and precipitation datasets. Journal of Geophysical Research: Atmospheres 123: 9391-9409. doi: 10.1029/2017JD028200

Dagnelie P, Palm R, Rondeux J, Thill A (1985) Tables de cubage des arbres et des peuplements forestiers. [Tariffs for trees and forest stands]. Les presses agronomiques de Gembloux, Gembloux [in French]

De Vries PG (1973) A general theory on line intersect sampling with application to logging residue inventory. Mededelingen Landbouwhogeschool Wageningen 73-11

Di Fiore L, Brunetti M, Baliva M, Förster M, Heinrich I, Piovesan G, Di Filippo A (2022) Modelling *Fagus sylvatica* stem growth along a wide thermal gradient in Italy by incorporating dendroclimatic classification and land surface phenology metrics. International Journal of Biometeorology 66: 2433-2448. doi: 10.1007/s00484-022-02367-2

Duhovnikov J, Mateev A, Nedyalkov S, Krastanov K (1963) Обемни, сортиментни и сбегови таблици за високостъблен бук [Volume-rate tables for single beech trees], София, Земиздат, 133 с. [in Bulgarian]

Forrester DI, Tachauer IHH, Annighoefer P, Barbeito I, Pretzsch H, Ruiz-Peinado R, Stark H, Vacchiano G, Zlatanov T, Chakraborty T, Saha S, Sileshi GW (2017) Generalized biomass and leaf area allometric equations for European tree species incorporating stand structure, tree age and climate. Forest Ecology and Management 396: 160-175. doi: 10.1016/j.foreco.2017.04.011

Gauer J, Aldinger E (eds) (2005) Waldökologische Naturräume Deutschlands. Forstliche Wuchsgebiete und Wuchsbezirke mit Karte 1:100.000. [Forest ecological growing zone of Germany: forest growing zone and growing area, with map of 1:100.000]. Mitteilungen des Vereins für forstliche Standortskunde und Forstpflanzenzüchtung, 43, 324 p. [in German]

Giurgiu V, Draghiciu D (2004) Modele matematico-auxologice si tabele de productie pentru, arborete. [Mathematic-auxologic models and yield tables for forest stands] Ceres Publishing House, Bucharest [in Romanian]

Giurgiu V, Decei I, Draghiciu D (2004) Metode si tabele dendrometrice [Dendrometric methods and tables] Ceres Publishing House, Bucharest [in Romanian]

Gschwantner T, Alberdi I, Balázs A, Bauwens S, Bender S, Borota D, Bosela M, Bouriaud O, Cañelas In Donis J, Freudenschuss A, Hervé J-C, Hladnik D, Jansons J, Kolozs L, Korhonen KT, Kucera M, Kulbokas G, Kuliešis A, Lanz A, Lejeune P, Lind T, Marin G, Morneau F, Nagy D, Nord-Larsen T, Nunes L, Pantić D, Paula JA, Pikula T, Redmond J, Rego FC, Riedel T, Saint-André L, Šebeň V, Sims A, Skudnik M, Solti G, Tomter SM, Twomey M, Westerlund B, Zell J (2019) Harmonisation of stem volume estimates in European National Forest Inventories. Annals of Forest Science 76: 24. doi: 10.1007/s13595-019-0800-8

Hamor F, Brändli U-B (2013) The Uholka-Shyrokyi Luh protected massif – an overview. In: Commarmot B, Brändli U-B, Hamor F, Lavnyy V (eds): Inventory of the largest primeval beech forest. A Swiss-Ukrainian scientific adventure. Birmensdorf, Swiss Federal Research Institute WSL; L'viv, Ukrainian National Forestry University; Rakhiv, Carpathian Biosphere Reserve. pp. 13-17

Huntington T, Ryan D, Hamburg S (1988) Estimating soil nitrogen and carbon pools in a northern hardwood forest ecosystem. Soil Science Society of America journal 52: 1162-1167. doi: 10.2136/sssaj1988.03615995005200040049x

IUSS Working Group WRB (2015) World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome

Karger DN, Conrad O, Böhner J, Kawohl T, Kreft H, Soria-Auza RW, Zimmermann NE, Linder HP, Kessler M (2018) Data from: Climatologies at high resolution for the earth's land surface areas. Dryad Digital Repository. doi:10.5061/dryad.kd1d4

Kirchmeir H, Vandekerkhove K, Di Filippo A, Prior A, Di Fiore L, Vanhaecht R (2023) Mapping guideline and field survey protocol for the assessment of old-growth status and ecosystem services (biodiversity & carbon) in beech forests. Internal Report Life Prognoses

Körner C, Schilcher B, Pelaez-Riedl S (1993) Vegetation und Treibhausproblematik: eine Beurteilung der Situation in Österreich unter besonderer Berücksichtigung der Kohlenstoff-Bilanz. [Vegetation and the greenhouse effect problem: an assessment of the situation in Austria with particular attention to the carbon balance] In: ÖAW. Anthropogene Klimaänderungen: Mögliche Auswirkungen auf Österreich – mögliche Maßnahmen in Österreich. [Anthropogenic climate change: possible effects on Austria - possible measures in Austria] Dokumentation. Austrian Academy of Sciences, Vienna, 6.1-6.46

Kotar M (2007) Gozdarski priročnik. [Forestry manual]. 7. izdaja. Ljubljana, Biotehniška fakulteta Univerze v Ljubljani, Oddelek za gozdarstvo in obnovljive gozdne vire: 414 str. [in Slovene]

Kramer H, Akça A (2008) Leitfaden zur Waldmesslehre. 5 Auflage. [Forest measurement guide] Frankfurt am Main, Sauerländer, 280 p. [in German]

Kraus D, Bütler R, Krumm F, Lachat T, Larrieu L, Mergner U, Paillet Y, Rydkvist T, Schuck A, Winter S (2016) Catalogue of tree microhabitats – Reference field list. Integrate+ Technical Paper

Lanz A, Brändli U-B, Commarmot B, Ginzler C (2013) The inventory - aims, methods and sampling design. In: Commarmot B, Brändli U-B, Hamor F, Lavnyy V (eds): Inventory of the largest primeval beech forest. A Swiss-Ukrainian scientific adventure. Birmensdorf, Swiss Federal Research Institute WSL; L'viv, Ukrainian National Forestry University; Rakhiv, Carpathian Biosphere Reserve. pp. 19-25

Larrieu L, Paillet Y, Winter S, Bütler R, Kraus D, Krumm F, Lachat T, Michel AK, Regnery B, Vandekerkhove K (2018) Tree related microhabitats in temperate and Mediterranean European forests: A hierarchical typology for inventory standardization. Ecological Indicators 84: 194-207. doi: 10.1016/j.ecolind.2017.08.051

Meyer P, Brössling S, Bedarff U, Schmidt M, Fricke C, Tewes C, Nagel R (2021) Monitoring of forest structure and vegetation in Hessian strict forest reserves. North Western German Forest Research Institute

Nedyalkov S, Rashkov R, Tashkov K (1983) Справочник по дендробиометрия. [Handbook of dendrobiometry]. София, Земиздат, 614 с [in Bulgarian]

Noirfalise A (1984) Forêts et stations forestières en Belgique [Forests and forest site types in Belgium]. Presses Agronomiques, Gembloux [in French]

Petritan IC, Commarmot B, Hobi ML, Petritan AM, Bigler C, Abrudan IV, Rigling A (2015) Structural patterns of beech and silver fir suggest stability and resilience of the virgin forest Sinca in the Southern Carpathians, Romania. Forest Ecology & Management 356: 184-195. doi: 10.1016/j.foreco.2015.07.015

Quataert P, Van der Aa B, Verschelde P (2011) Opstellen van tarieven voor inlandse eik en beuk in Vlaanderen ten behoeve van het berekenen van houtvolumes: statistische evaluatie van de regressiemodellen en overzicht van de resultaten (technisch rapport deel III). [Development of tariffs for oak and beech in Flanders, for the calculation of wood volumes: statistical evaluation of the regression models and overview of the results - technical report part III]. Research report INBO.R.2011.17. Research Institute for Nature and Forest, Brussels [in Dutch]

Ralhan D, Rodrigo R, Keith H, Stegehuis AI, Pavlin J, Jiang Y, Rydval M, Nogueira J, Fruleux A, Svitok M, Mikoláš M, Kozák D, Dušátko M, Janda P, Chaskovsky O, Roibu C-C, Svoboda M (2024) Tree structure and diversity shape the biomass of primary temperate mountain forests. Forest Ecosystems 11: 100215. doi: 10.1016/j.fecs.2024.100215

Stillhard J, Abegg M, Keller S, Düggelin C, Brändli U-B (2019) Sample plot inventory in the primeval beech forest Uholka-Schyrokyj Luh. Instructions for the second inventory 2019. Swiss Federal Research Institute for Forest, Snow and Landscape Research WSL, Birmensdorf

Tabacchi G, Di Cosmo L, Gasparini P (2011) Aboveground tree volume and phytomass prediction equations for forest species in Italy. European Journal of Forest Research 130: 911-934. doi: 10.1007/s10342-011-0481-9

Van Wagner CE (1968) The line intersect method in forest fuel sampling. Forest Science 14: 20-26. doi: 10.1093/forestscience/14.1.20

Vandekerkhove K, Van de Kerckhove P, Leyman A, De Keersmaeker L, Lommelen E, Esprit M, Goessens S (2021) Monitoring programme on strict forest reserves in Flanders (Belgium): methods and operational protocols - With an overview of the intensive monitoring sites. Report INBO.R.2021.28. Research Institute for Nature and Forest, Brussels

Vandekerkhove K, Vanhellemont M, Vrska T, Meyer P, Tabaku V, Thomaes A, Leyman A, De Keersmaeker L, Verheyen K (2018) Very large trees in a lowland old-growth beech (*Fagus sylvatica* L.) forest: Density, size, growth and spatial patterns in comparison to reference sites in Europe. Forest Ecology and Management 417: 1-17. doi: 10.1016/j.foreco.2018.02.033

Verschuren L, De Mil T, De Frenne P, Haneca K, Van Acker J, Vandekerkhove K, Van den Bulcke J (2023) Heading for a fall: The fate of old wind-thrown beech trees (*Fagus sylvatica*) is detectable in their growth pattern. Science of the Total Environment 903: 166148. doi: 10.1016/j.scitotenv.2023.166148

Wirth C, Schumacher J, Schulze E-D (2004) Generic biomass functions for Norway spruce in Central Europe—a meta-analysis approach toward prediction and uncertainty estimation. Tree Physiology 24: 121–139. doi: 10.1093/treephys/24.2.121

Zanella A, Ponge J-F, Jabiol B, Van Delft B, De Waal R, Katzensteiner K, Kolb E, Bernier N, Mei G, Blouin M, Juilleret J, Pousse N, Stanchi S, Cesario F, Le Bayon R-C, Tatti D, Chersich S, Carollo L, Englisch M, Schrötter A, Schaufler J, Bonifacio E, Fritz I, Sofo A, Bazot S, Lata J-C, Iffly J-F, Wetzel CE, Hissler C, Fabiani G, Aubert M, Vacca A, Serra G, Menta C, Visentin F, Cools N, Bolzonella C, Frizzera L, Zampedri

R, Tomasi M, Galvan P, Charzynski P, Zakharchenko E, Waez-Mousavi SM, Brun J-J, Menardi R, Fontanella F, Zaminato N, Carollo S, Brandolese A, Bertelle M, Zanella G, Bronner T, Graefe U, Hager H (2022) A standardized morpho-functional classification of the planet's humipedons. Soil Systems 6: 59. doi: 10.3390/soilsystems6030059

Zemlerová V, Kozák D, Mikoláš M, Svitok M, Bače R, Smyčková M, Buechling A, Martin M, Larrieu L, Paillet Y, Roibu C-C, Petritan IC, Čada V, Ferenčík M, Frankovič M, Gloor R, Hofmeister J, Janda P, Kameniar O, Majdanová L, Markuljaková K, Matula R, Mejstřík M, Rydval M, Vostarek O, Svoboda M (2023) Natural disturbances are essential determinants of tree-related microhabitat availability in temperate forests. Ecosystems 26: 1260-1274. doi: 10.1007/s10021-023-00830-8