Flanders
State of the Art

Monitoring programme on strict forest reserves in Flanders (Belgium): methods and operational protocols

With an overview of the intensive monitoring sites

Kris Vandekerkhove, Peter Van de Kerckhove, Anja Leyman, Luc De Keersmaeker, Els Lommelen, Marc Esprit, Stefaan Goessens

vlaanderen.be/inbo

Authors:
Kris Vandekerkhove, Peter Van de Kerckhove, Anja Leyman, Luc De Keersmaeker, Els Lommelen, Marc Esprit, Stefaan Goessens.

Research Institute for Nature and Forest (INBO)

Reviewers:
Arno Thomaes and Kristine Vander Mijnsbrugge (INBO)

The Research Institute for Nature and Forest (INBO) is an independent research institute of the Flemish government. Through applied scientific research, open data and knowledge, integration and disclosure, it underpins and evaluates biodiversity policy and management.

Location:
INBO vestiging Geraardsbergen
Gaverstraat 4, B-9500 Geraardsbergen, Belgium
www.inbo.be

e-mail:
kris.vandekerkhove@inbo.be

Way of quoting:
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. Reports of the Research Institute for Nature and Forest 2021(28). Research Institute for Nature and Forest, Brussels.
DOI: doi.org/10.21436/inbor.38677490

D/2021/3241/229
Report number 2021(28)
ISSN: 1782-9054

Responsible publisher:
Maurice Hoffmann

Cover photograph:
Field measurements in the Nature Reserve of Walenbos, using Laser Technology Instruments (LTI) in combination with FieldMap ™ software (IFER). (Photo: Kris Vandekerkhove)

Authors:
Kris Vandekerkhove, Peter Van de Kerckhove, Anja Leyman, Luc De Keersmaeker, Els Lommelen, Marc Esprit, Stefaan Goessens.

Research Institute for Nature and Forest (INBO)

Reviewers:
Arno Thomaes en Kristine Vander Mijnsbrugge (INBO)

Location:
INBO vestiging Geraardsbergen
Gaverstraat 4, B-9500 Geraardsbergen, Belgium
www.inbo.be

e-mail:
Kris.vandekerkhove@inbo.be

Way of quoting:
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. Reports of the Research Institute for Nature and Forest 2021(28). Research Institute for Nature and Forest, Brussels.
DOI: doi.org/10.21436/inbor.38677490

D/2021/3241/229
Report number 2021(28)
ISSN: 1782-9054

Responsible publisher:
Maurice Hoffmann

Cover photograph:
Field measurements in the Nature Reserve of Walenbos, using Laser Technology Instruments (LTI) in combination with FieldMap ™ software (IFER). (Photo: Kris Vandekerkhove)

MONITORING PROGRAMME ON STRICT FOREST RESERVES IN FLANDERS (BELGIUM): METHODS AND OPERATIONAL PROTOCOLS

With an overview of the intensive monitoring sites

Kris Vandekerkhove, Peter Van de Kerckhove, Anja Leyman, Luc De Keersmaeker, Els Lommelen, Marc Esprit, Stefaan Goessens

https://doi.org/10.21436/inbor.38677490

Flanders
State of the Art

Summary

This report provides a detailed description of the measurements that are performed and the field protocols that are applied in the research program on monitoring of unmanaged forests (strict forest reserves) in Flanders (Belgium).

This monitoring program was originally conceptualized in 1997-1999 to fulfill the obligations and commitments on the scientific goals for forest reserves, as they were set by law in the Flemish Forest Decree (1993), the Executive Order of the Flemish Government on Forest Reserves (1995) and the Ministerial Decisions upon designation of new reserves and their management plans. Some of the sites are also part of LTER-Belgium (Cools et al., 2016).

Concepts on forest reserves, and methods of forest reserves ecological monitoring are based on, and in line with long-running programs in most other European countries (Parviainen et al. 2000, Vandekerkhove 1998).

Measuring protocols and data processing were already set from the beginning of the program, and were first published in detail by De Keersmaeker et al. (2005) Since that time, technology and tools have developed, and some minor changes to the method were applied. This report describes in detail the applied tools and methods, and applied SOP's (Standard Operating Procedures).

The report describes in detail the consecutive steps of preparation, execution and data handling for field measurements in strict forest reserves (see table of contents).

In a final chapter of the report, every specific site that is included in the network of intensively monitored sites is described giving some basic information on location in Belgium, climatic conditions, soil type, altitude and the specific monitoring set-up. It is also clarified whether the site has specific divergences from the standard set-up (e.g. different plot size of circular plots or core area).

This report should allow potential users of the data to investigate whether the acquired data meet their requirements or level of detail, in order to include them in their studies. The overview of monitored sites can also be very useful for researchers looking for suitable research sites where detailed and extensive data on dendrometrics and vegetation are already available. We invite interested researchers and potential users of the data to check the available Open Data sources (Forresdat and Forrescalc on GitHub) or to contact the authors for further interdisciplinary and international cooperation.

Samenvatting

Dit rapport geeft een gedetailleerde beschrijving van de metingen die worden uitgevoerd en de veldprotocollen die worden toegepast in het onderzoeksprogramma rond monitoring van onbeheerde bossen (strikte bosreservaten) in Vlaanderen (België).

Dit monitoringprogramma werd oorspronkelijk opgezet in 1997-1999 om te voldoen aan de verplichtingen en verbintenissen rond de wetenschappelijke doelstellingen voor bosreservaten, zoals die bij wet werden vastgelegd in het Vlaams Bosdecreet (1993), het Besluit van de Vlaamse Regering inzake Bosreservaten (1995) en de ministeriële besluiten betreffende de aanwijzing van nieuwe reservaten en hun beheerplannen.

Concepten over bosreservaten en methoden van ecologische monitoring van bosreservaten zijn gebaseerd op, en in overeenstemming met, langlopende programma's in de meeste andere Europese landen (Parviainen et al. 2000, Vandekerkhove 1998).

De meetprotocollen en de gegevensverwerking lagen al vast vanaf het begin van het programma, en werden voor het eerst in detail beschreven door De Keersmaeker et al. (2005) Sindsdien hebben de technologie en het instrumentarium zich verder ontwikkeld, en werden enkele kleine wijzigingen in de methode aangebracht. Dit rapport beschrijft de vandaag gebruikte instrumenten en methoden, en de toegepaste SOP's (Standard Operating Procedures).

Het rapport beschrijft in detail de opeenvolgende stappen van voorbereiding, proefopzet, uitvoering en gegevensverwerking, en de specifieke parameters opgemeten in strikte bosreservaten (zie inhoudsopgave).

In een laatste hoofdstuk van het rapport beschrijven we elke specifieke locatie die deel uitmaakt van het netwerk van intensief gemonitorde sites. We geven basisinformatie mee over de locatie in België, de klimatologische omstandigheden, het bodemtype, de hoogteligging en de specifieke proefopzet. We verduidelijken of de locatie specifieke afwijkingen vertoont van de standaardopzet (bv. afwijkende proefvlakgrootte van cirkelvormige proefvlakken of kernvlaktes).

Dit rapport moet potentiële gebruikers in staat stellen om na te gaan of de verkregen gegevens uit het monitoringnetwerk aan hun vereisten of niveau van detail voldoen, zodat zij ze in hun studies kunnen opnemen. Een aantal van de reservaten maken nu al deel uit van LTER-Belgium, een netwerk voor Lange Termijn Ecologische Onderzoekssites (Cools et al., 2016).

Het overzicht van de bemonsterde locaties kan ook zeer nuttig zijn voor onderzoekers die op zoek zijn naar geschikte onderzoekslocaties, waar al gedetailleerde en uitgebreide gegevens over dendrometrie en vegetatie beschikbaar zijn. Een aantal basisgegevens zijn als open data beschikbaar (een GIS-laag met de proefvlakken, de afgeleide dataset Forresdat en het R-package Forrescalc, beschikbaar via Github). Wij nodigen geïnteresseerde onderzoekers en potentiële gebruikers van de gegevens dan ook uit om contact op te nemen met de auteurs, en hopen dat dit de interdisciplinaire en internationale samenwerking verder kan stimuleren.

Recommendations for management and/or policy

This report provides detailed information on the measuring protocols applied in the monitoring program on strict forest reserves in Flanders.

It is recommended that such a reference document is produced for all standardized monitoring programs and measuring campaigns that are performed at INBO and other research institutions. It should accompany all datasets that are provided as open data sources.

Table of contents

https://doi.org/10.21436/inbor.38677490

1 INTRODUCTION

Since the year 2000, a standardised monitoring program for unmanaged forest reserves has been deployed in a set of reserves in Flanders, Belgium.

This monitoring program was originally conceptualized in 1997-1999 to fulfill the legal obligations and commitments on the scientific goals for forest reserves, as they were explicited in the Flemish Forest Decree (1993), the Executive Order of the Flemish Government on Forest Reserves (1995) and the Ministerial Decisions upon designation of new reserves and their management plans.

Concepts on forest reserves, and methods of forest reserves ecological monitoring are based on, and in line with long-running programs in most other European countries (Parviainen et al. 2000, Vandekerkhove 1998).

Measuring protocols and data handling were developed and determined already from the beginning of the program, and were first published in detail by De Keersmaeker et al. (2005) (in Dutch, with English summary and captions).

Since that time, technology and tools have developed, and some minor changes to the method were applied. This report describes in detail the applied tools and methods, and applied SOP's (Standard Operating Procedures).

The current report describes in detail the consecutive steps of preparation, execution and data handling for field measurements in strict forest reserves. The following topics are covered :

- Selection of sites for monitoring
- Overview of the standard measuring scheme
- Preparatory phase : implementation of the Field measuring scheme to the site (desktop)
- Set-up in the field of the measuring scheme :
    - Grid of circular nested plots
    - Core area
- Field protocol for measurements in circular plots
    - Soil samples
    - Dendrometric measurements
        - Standing trees (living/dead)
        - Lying dead wood
        - Rejuvenation (trees <5 cm DBH)
    - Vegetation relevés
    - Georeferenced oriented photographs
    - Fish-eye-photographs

https://doi.org/10.21436/inbor.38677490

- Field protocol for measurements in core areas
    - Soil samples
    - Dendrometric measurements
        - Standing trees (living/dead)
        - Lying dead wood
        - Rejuvenation (trees <5 cm DBH)
    - Vegetation relevés
    - Georeferenced oriented photographs
    - Fish-eye-photographs

- Field protocol for additional measurements
    - Full survey of 'Particular elements' (Biotope Mapping) : VLT & CWD
    - Vegetation 'facies' mapping
- Data handling, calculations and open data
    - Data control
    - Calculations of tree and fragment volumes
    - Calculation of derived measures (N, G, V,...)
    - Open dataset FORRESDAT and the R-package FORRESCALC

In a final chapter of the report, every specific site that is included in the network of intensively monitored sites is described giving some basic information on location in Belgium, climatic conditions, soil type, altitude and the specific monitoring set-up. It is also clarified whether the site has specific divergences from the standard set-up (e.g. different plot size of circular plots or core area).

2 SELECTION OF SITES FOR MONITORING

For the selection of sites that should be eligible for monitoring of natural dynamics, a set of basic criteria are applied. They are based on international recommendations (EU-COST-E4, Projektgruppe Naturwaldreservate,… all compiled in Vandekerkhove, 1998).

By 'monitoring network' is meant: the set of unmanaged forests where the intensive monitoring method is applied. This is a selection from the full set of strict forest reserves in Flanders.

For this purpose, these reserves have to meet international criteria. This means:

- The continuity of non-intervention is guaranteed through legal status or management plans
- the network must be representative of the forest types present in Flanders
- the area of the selected forests must be sufficiently large: they must meet the criterion of Minimum Structure Area (MSA). This minimal area varies between 15 and 50 ha, dependent of the vegetation type.

Vandekerkhove (1998) and De Keersmaeker et al. (2005) elaborated on these criteria:

- In Flanders, about 25 different climax forest communities can be distinguished at vegetation association level. A representative network should encompass examples of these communities resulting in at least 20 reserves. Five forest types are too fragmented, or are embedded in other types.

- For all these communities, the sites that most closely refer to ‘natural’ forests are selected. This means sites that are most complete or characteristic on species composition, show a wide age distribution, and/or longest time since last intervention.

- In order to be representative, this network must also take into account the phytogeographical differences (e.g. *Quercion* forests both in the Atlantic district and in the Subatlantic district of the Campine region)

- If the monitored network of strict reserves is limited to 'seminatural' forests, its function as a reference is strongly limited since the forests in Flanders are often highly anthropogenic. After all, more than 60% of the Flemish forest area consists of poplar and conifer stands. Therefore, it is necessary to complement the network with these antropogenic forest types, adding up to the network.

- For a set of Atlantic forest types (*Endymio-Carpinetum, Carici remotae-Fraxinetum, Alnion*), Flanders has a role to play at international level. These types are therefore deliberately overrepresented in the network.

The current network covers a total of about 20 sites. This means that the network is still not complete. More sites are added if possible. This depends on the available manpower, but also on the availability of suitable sites. In some forests that are predestined to be included in the network, some preliminary management interventions are still being performed (e.g. removal of invasive exotic tree species). Once these interventions are concluded, these sites are eligible to be added. An overview of the sites currently included in the network is given below.

 https://doi.org/10.21436/inbor.38677490

Fig1. Map of Belgium showing an overview of the network of sites with intensive monitoring.

Table 1. Overview of the monitored sites

Site	**Forest type**	**Survey years**
Hannecartbos	Coastal dune forest	1991, 2001, 2011
Wijnendalebos	Atlantic oak-beech	2002,2012
Kluisbos	Atlantic beech	2019
Bos t'Ename	Atlantic beech and alluvial	2015
Bos Ter Rijst	Atlantic beech	2005, 2015
De Heirnisse	Base-rich alder forest	2003, 2013
Liedekerkebos	Atlantic oak-beech	1985, 1996, 2006, 2016
Coolhembos	Alder swamp forest	2004, 2014
Muizenbos	Alluvial forest	2008, 2018
Withoefse heide	Quercion/Pine	2003, 2012
Sevendonk	Quercion/Alnion	2007, 2017
Hallerbos – Jansheideberg	Atlantic Beech	2004, 2014
Sonian Forest - Kersselaerspleyn Core area - Kersselaerspleyn CP - Harras Core area - Extension2011+Harras CP	Atlantic Beech/ oak-beech	 1986, 2000, 2010, 2020 2000, 2010, 2020 2009, 2019 2020
Rodebos	Subatlantic Beech/Alluvial	1991, 2001, 2011
Meerdaalwoud - Everzwijnbad - Pruikenmakers - De Heide (CwS)	Subatlantic oak-hornbeam	2002, 2012 2006, 2016 2016
Walenbos	Alluvial / Alder Swamp	1991, 2001, 2011
Kolmontbos	Subatlantic oak-hornbeam	2020

3 STANDARD MEASURING PROTOCOL

3.1 BACKGROUND

The standard methodology for the monitoring of strict forest reserves in Flanders was developed, based on experience and methods in neighboring countries (Kätzler 1984; Bücking 1989; Peterken & Backmeroff 1988; Koop 1989; Albrecht 1990; Althoff et al. 1993; Projektgruppe Naturwaldreservate 1993; Mountford et al. 1999) the guidelines of the European COST-action E4 (Hochbichler et al. 2000) and some own preliminary studies (Van Den Meersschaut & Lust, 1997a,b; Van Den Meersschaut et al. 2000). From these some global requirements and conclusions were drawn:

A decent monitoring of the reserve should involve at least the basic dendrometric measurements (species, DBH, height of upper storey, regeneration), combined with vegetation relevés. Analysis and typology of the soil should also be done, at least once at the beginning of the monitoring.

Two sampling methods are commonly used in Europe for monitoring of strict reserves:

- systematic grids of sample plots (often circular plots)

- larger full-survey plots with fixed or variable size (often called 'core area')

In the 1950s to 1980s, also strip transects were sometimes used (e.g. Leibundgut, 1982; Mayer, 1976; Korpel', 1995). They have a good demonstrative value, but have shown drawbacks considering repositioning (positional error), data analysis and extrapolation.

Both sample plot grids and core areas have their advantages and opportunities. A standardised grid of sampling plots will produce reliable data on the variability and development of the whole reserve, while as the core area will provide more detailed (spatially explicit) information on the ecological processes that trigger the spontaneous development, and the interactions between tree layer, soil and ground vegetation. It is therefore advisable to apply a combined sampling, with both sample plots and core areas.

The sample plots are preferably circular plots (less edge effects and uncertainty on the relocation), with a minimum size of 500 m². Within this plot, subplots can be established for measurements on regeneration and ground vegetation. Core areas should at least have a surface of 0.5 ha, square or rectangular, with a minimum width of two times the tree height (60-80 m).

In order to produce reliable data for the whole reserve (accuracy levels of 5 to 10 %) on basal area, species composition and stem number, based on data from the sampling plots, a sample size of at least 15-20 % of the total area is needed (Van den Meersschaut et al. 2000).

Measurements should be repeated at least every 10 years. This interval is long enough to detect changes, and not too long to miss out on some developments (Hochbichler et al., 2000).

https://doi.org/10.21436/inbor.38677490

3.2 OVERALL SETUP

Based on these requirements and recommendations, a standard methodology was developed, combining a grid of permanent sample plots with a core area (fig 1).

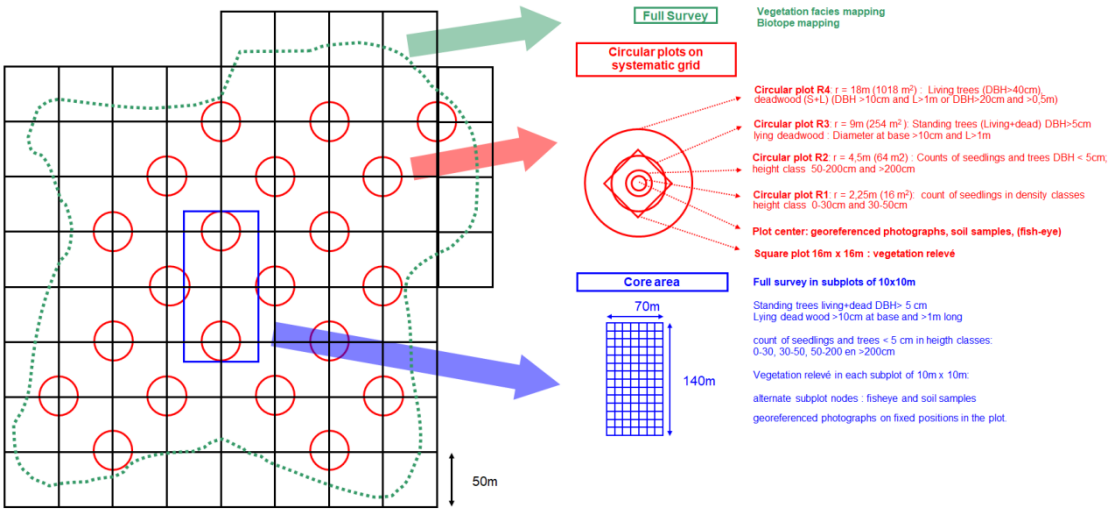


Fig 2. Visualisation of the monitoring layout, combining a core area with grid-based circular plots

The grid system consists of circular nested plots with widest radius of 18 m (=1018 m²) set out on the alternatingly selected nodes of a 50m x 50m grid. The total area covered by the 18m radius plots amounts to 15- 20% of the area of the forest reserve.

The grid is standard oriented North-South, however if a useful and permanent reference line in the field is available (e.g. a straight road or path), then the basic orientation of the grid is aligned with this field reference.

In these sample plots basic measurements are performed on woody vegetation (position, species, DBH, height of selected trees, regeneration) and herbaceous layer. The plot design and the methodology of the measurements are identical to the ones in the Flemish Forest Inventory (except for additional detailed measurements of lying dead wood), thus allowing immediate comparison. At the first sampling survey, these measurements are combined with soil samples.

Also oriented digital photographs are taken from the center point of the plot. These repeated snapshots do not deliver quantitative data, but can be very illustrative for changes over time. At the first survey, also fish-eye images were made to quantify canopy cover.

The core area is located in the most representative part of the reserve and is aimed to perform more intensive and spatially explicit measurements. The standard dimensions of the core area are 70x140 m, which is in accordance with the Dutch methodology (Koop, 1989). All trees are identified, positioned and measured, vegetation and regeneration is mapped in detail in 10 m x 10 m subplots, soil and light conditions are analysed.

All plot and tree positions and measurements are performed and stored electronically using FieldMap technology, and regularly transferred to a central geodatabase ('mother database'), of which new versions are regularly back-upped.

The methodology is flexible, as it can be adjusted to local conditions as long as it meets the minimal requirements. In the forest reserve of Sonian Forest for example, the radius of the largest circular plot was expanded to radius 30m, as tree dimensions and distances are extraordinary high in this site. Size extension was necessary in order to comply with the basic principles of Kramer & Akça (1982), Richter & Grossmann (1959) or Spurr (1952) pointing out that an individual plot should at least contain respectively 25 to 30, 12 to 14 or 20 to 30 trees per plot. By simultaneously widening the grid to 100 x 100 m , the sample size of 20% could be respected. Also the core area at this site is considerably larger than required, covering 10.75 ha instead of 1 ha. This large scale full survey is based on the fact that detailed dendrometric information was available for this area from 1986 and 1991, providing opportunities for interesting detailed comparisons.

In other sites, full grid surveys were not possible due to inaccessibility of the site (e.g. swamp forests such as Coolhem forest). In that case, only one or two core areas were set up. These core areas can be standard size or smaller, again due to inaccessibility, homogeneity or border effects (e.g. 50x100 m).

The systematic grid of circular plots is mainly to be considered as a classic systematic sampling, allowing for a global overview on the diversity of the site and the development and diversification of the area as a whole: what is the distribution of tree species, stem number, basal area, vegetation types and species, etc. and how do they develop. However, as these plots are permanent, they can also be considered as individual, be it small permanent plots, allowing precise analysis of changes at plot and individual tree level (e.g. diameter increments). For spatial analysis, they are less useful, as the size of the plot is too limited.

The need for more detailed analysis on spatial patterns in trees and soil condition and interactions between tree layer, regeneration and ground vegetation, is covered by measurements in the core area.

Fig 3. Site ‘Jansheideberg’ in the forest of Hallerbos: an example of Atlantic lowland beech forest (Endymio-Fagetum) with typical spring aspect of bluebells (*Hyacinthoides non-scriptus*)

Fig 4. Monumental decaying beech tree in SFR Joseph Zwaenepoel (Sonian Forest)

4 PREPARATORY PHASE

4.1 SITE BACKGROUND INFORMATION

When a site is selected for monitoring, and before the sampling set-up is decided in the field, a thorough analysis of the land-use and management history of the site is made. Also, an overview of existing knowledge and research at the site is compiled.

Part of this data consists of maps (historical maps, vegetation maps, forest mapping, management plans, ortho-photographs...) which - if necessary - are digitised and georeferenced so that they can be combined in a GIS environment.

The most important findings, and a detailed reconstruction of the forest management can be integrated in a monitoring report (e.g. Vandekerkhove et al. 2012), or compiled in a separate scientific report (so-called 'basisrapport') (e.g. Baeté et al., 2002, 2003a,b,c, 2004a,b,c, 2006a, b, c, 2007; Smets et al., 2005).

This survey not only serves the interpretation of observed developments later on, but can also help to determine the selection of a particular configuration of the grid and especially the location of the core area. These core areas are selected in the most representative parts of the forest, preferably in stands with long forest continuity and stand structure, or at sites where previous intensive research was performed.

Also the set-up and size of the sampling can be adapted if older monitoring grids are available. For instance in the sites of Liedekerkebos, Sonian Forest, Walenbos,... sampling transects and plots formerly sampled in the 1980's (Van den Meersschaut et al. 1999; Van den Berge et al. 1990) and 1990's (Koop et al., 1992a,b,c) were continued and, where necessary, further elaborated to make sure that also older surveys could be integrated in the dataset.

4.2 PRE-SELECTION OF THE SAMPLING DESIGN

4.2.1 Selection of the sample grid

Based on the basic information compiled in previous phase, and the topography of the site, the grid system for the circular sample plots is selected. In a GIS, all relevant map data are compiled (borders, aerial photographs, stand maps from management plans, topographical maps,...).

This is superimposed by a theoretical grid of 50x50m, which is standard North-South oriented.

If a useful and permanent reference line in the field is available, such as a pattern of straight paths in a deviating direction, which can greatly simplify the site work or greatly reduce the number of edge effects, then the basic orientation of the grid will be aligned with this field reference.

The exact location of the grid is chosen on the basis of the information collected. The aim is to achieve maximum integration of previous research and the topography and shape of the reserve.

 https://doi.org/10.21436/inbor.38677490

On this theoretical grid, every alternating node is selected as a sample plot (thus resulting in a mesh width of 71 m). Gridpoints that are too close to the border of the reserve (< 30m) or where the plot hits a non-abolished road, is excluded from the design. However, if this results in a too low number of samples per site or stratum (see above), plots can also be shifted for a few meters along one of the grid lines.

This results in two possible options, depending on the selected starting node. From these alternatives, the one is selected that gives the best results :

- Lowest number of abolished grid points (e.g. near the forest edge or on operational roads and tracks)
- For sites where different 'strata' occur (e.g. different forest types, different management of management history), the option with the most representative stratified sample

The standard setup consists of a grid with circular nested plots with widest radius of 18 m (=1018 m²) resulting in a total covered area between 15 and 20% of the total area.

In exceptional cases it is possible to deviate from the standard grid if this clearly represents an added value, for example if another grid from previous research is already present. In this situation, their size and location was respected as was the case e.g. in Liedekerkebos and Withoefse heide (radius 20 m), in Sonian forest, the plots have a 30m radius, and the mesh width is extended to 100m.

4.2.2 Selection of the core area

The **core area** has a standard surface area of 9800 m² or 0.98 ha, with standard dimensions of 70 m x 140 m. This was inspired and is in line with the Dutch Forest Reserves monitoring programme (Bijlsma & Clerckx, 2019).

If this size cannot be realized (for reasons of heterogeneity, edge effects or inacessibility), a smaller plot of 50x100 m is selected.

The core area is preferably spatially linked to the grid (see figure 2), but the position of the core area in the integral forest reserve can be freely chosen.

Usually the core area is plotted in a part of the reserve that is representative and homogeneous. In a few cases (e.g. Jansheideberg, Muizenbos) the core area is deliberately positioned on the boundary between contrasting stands, or along a gradient (e.g. Rodebos). This is only the case if this choice is supported by a clear research hypothesis (e.g.: tree species effects of ground vegetation, forest dynamics in stands with a contrasting management history...)

5 SET-UP IN THE FIELD

5.1 GRID OF CIRCULAR NESTED PLOTS

After the optimal sampling design is selected by a desk-top analysis, the resulting layout is materialized in the field after a reality check.

A clearly identifiable point, e.g. an intersection of forest tracks, identifiable on maps and aerial photographs, is taken as the starting point for positioning of the grid. From this point, the grid points on the terrain are positioned and then permanently marked with Feno-markers.

In the period 2000-2007, the positioning of the grid was done using a theodolite (electronic tachymeter or total station type Leica TC 805) and d-GPS (Trimble Pathfinder II). Since the implementation of FieldMap-technology, the grid is materialized using the integrated digital compass combined with a laser-rangefinder. The positional error using this configuration amounts to a maximum of 10-20 cm per reference point.

In some cases, minor adjustments to the grid are made. Circles that fall on paths are maintained if the path is not paved and no longer operational. Circles that fall on paved paths, which will be used permanently, can be shifted in the direction of either axis of the grid. Circles that intersect the reserve boundary or are partially located in the buffer zone (= 30m wide outer border of the reserve, where safety fellings are allowed) will in principle be eliminated. If this results in the total sample covering less than 20% of the reserve, or an unbalance in the different 'strata' (if occurring) also a number of plots at these edges will be shifted inwards.

Fig 5. A Feno-marker is used to indicate the plot center (photograph by Bruno De Vos)

https://doi.org/10.21436/inbor.38677490

5.2 CORE AREA

The position of the core area is chosen meticulously during a site visit, based on the preliminary literature and map study. The core area must be representative of the reserve and the forest type for which the reserve was selected. It is preferably chosen centrally in the reserve and is quite homogeneous (both vegetation type and tree type). If possible, a site should also be selected where interesting dynamics can be expected in the short term.

The core area is often directly linked to the grid: the points at 20 and 120 m on the central axis are grid points of the sampling plots. The core area is also permanently marked with Feno-markers as follows: 4 vertices, and on the central axis after 20, 70 and 120 meters, where points 20 and 120 are already part of the grid of sample circles.

6 SOIL SAMPLING

The soil survey is performed during winter at the first survey-campaign. Samples are taken on fixed positions in the circular sample plots and in the core area.

In the sample plots, thickness of litter layer is measured with a ruler and mineral topsoil is sampled at fixed depth (0-10 cm) using a 3cm diameter auger, taking 5 subsamples within each plot, close to the center of the plot. These subsamples are aggregated to one soil sample, dried to constant weight at 40°C.

In the core area, detailed data on the micro-variability of soil conditions is aimed at. Therefore, 85 fixed points are sampled. Again at least 3 subsamples are taken with an auger, in the immediate vicinity of the selected grid-point (< 1m away), alternately located on the 10 m x 10 m grid of the core area. One row outside the core area is also sampled, to allow for interpolation (Figure 6).

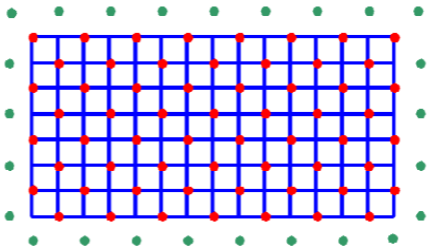


Fig 6. Grid points in the core area where 60 fish-eye photographs are taken and mineral soil (0-10 cm) is sampled (red dots). Soils are additionally sampled in 28 grid points outside the core area (green dots).

Sample preparation

Soil samples are stored in a sealed plastic bag and stored at 4°C. The samples are weighed and dried for 7 days at 40°C in a ventilated oven. The dried soil samples are weighed again and grinded into particles with a diameter of less than 2 mm. This is done by means of a soil crusher Cross Beater Mill SK100 (Eijkelkamp).

The moisture content is determined at 40°C and at 105°C. The analyses are done on the samples dried at 40°C and the results are corrected with a factor that takes into account the difference in moisture content at 40° and 105°.

Sample analysis

Samples are analyzed on moisture content (weighing fresh and after drying), texture (Sand, Loam, Clay fraction), Carbon content (loss of ignition), pH-$CaCl_2$, CEC (Ca, K, Na, Mg, Al, H), Kjelldal-N and plant-available P using the Standardized Operation Procedures also applied in ICP-Forests, and described by Cools & Devos (2016).

https://doi.org/10.21436/inbor.38677490

7 FIELD PROTOCOL FOR MEASUREMENTS IN CIRCULAR PLOTS

7.1 DENDROMETRIC MEASUREMENTS

7.1.1 WHAT is measured ?

The circular sample plots for dendrometric measurements are a set of circular nested plots with different size depending on the dimensions of the woody elements. Details on HOW all elements are measured are given below in chapter 7.1.2.

7.1.1.1 **Sample circle A4 = radius 18 m (1018 m²)**

Living trees
Threshold : DBH of 40 cm and more

- Positioning of all living trees with DBH (= Diameter at Breast Height = 130 cm height) of 40 cm and more

- Positioning of all coppice stools with shoots with a DBH of 40 cm and more

- Species identification of all positioned individuals

- DBH of all positioned trees and shoots

- Height measurement on a selection of trees and shoots of coppice stools (see below)

- IUFRO-vitality classes (Leibundgut 1956) (see below)

Dead trees
Threshold : Standing dead trees, shoots and snags with DBH>10 cm and height > 1.3m; lying dead wood fragments with DBH>10 cm and length > 1m or DBH>20 cm and length >50 cm

- Snags (= broken at stem or primary branch level) with DBH>10 cm and height > 1,3m : positioning, DBH, height, species and decay stage

- Coppice stools and multi-stemmed trees with dead shoots/stems with DBH>10 cm and height > 1,3m: position and species of the stool, DBH of every dead shoot + decay stage. Height is derived from height curves (see below).

- Standing dead trees (complete tree): DBH + annotation of crown reduction class if present (see below). Height is derived from height curves (see below), decay stage.

- Lying deadwood : segmented in individual sections (stem section, branch limbs, even if still connected); each segment that meets size criteria : Positioning (position base + position top), Diameter at both ends, species (if possible), decay stage;

For trunk base of lying dead trees: type of origin : uprooting (pit+mound) or breakage is registered. Dead branches in living trees are not registered (only dead stems and shoots in coppice stools or other multi-stemmed trees). Tree stumps of harvested trees are also normally not registered (only in explicit cases when also managed stands are included in the monitoring)

7.1.1.2 **Sample circle A3 = radius 9 m (254 m²)**

Living trees
Threshold : DBH of 5 cm and more

Measurements identical to circle A4, but lower DBH threshold of 5 cm:

- Positioning of all living trees with DBH of 5 cm and more

- Positioning of all coppice stools with shoots with a DBH of 5 cm and more

- Species determination of all positioned individuals

- DBH of all positioned trees and shoots

- Height measurement on a selection of trees and shoots of coppice stools

- Determination of the IUFRO vitality classes of each positioned tree or shoot;

Dead trees

Threshold and Measurements:
Standing deadwood : DBH-threshold of 5 cm (i.s.o. 10 cm in A4).
Lying dead wood : no extra measurements in A3.

Snags: positioning, DBH, Height, species, decay stage

Standing dead trees : positioning, DBH, Crown reduction, species, decay stage

Lying dead wood segments : position and DBH (base+top), species, decay stage

7.1.1.3 **Sample circle A2 = radius 4.5 m (63.6 m²)**

Threshold: living trees with DBH< 5cm and height >50 cm : counting of individuals per species in 2 height classes :
50 - 200 cm
> 200 cm

Since 2014, impact of game on the young trees is also registered: number of trees per species impacted by browsing or by fraying (roedeer)

Observations are made in the summer half year, during the vegetation survey (see further).

7.1.1.4 **Sample circle A1 = radius 2.25 m (16 m²)**

Seedlings (living trees smaller than 50 cm in height)

- Count by species in 2 height classes:
< 30 cm
30 - 50 cm

Count in frequency classes : 1, 2-5, 6-10, 11-20, 21-40, 41-60, 61-100,>100, >1000
Since 2014, also game impact is registered: number of young trees per species impacted by browsing of fraying (roedeer). For large numbers, percentages of impacted trees are noted.

 https://doi.org/10.21436/inbor.38677490

7.1.2 HOW : details and protocols for measurement

7.1.2.1 Standing single trees (living/dead)

Positioning of trees was originally performed with a theodolite (Leica TC805) measuring distance and Azimuth of the tree from the plot center. Since 2007, these measurements are done using Laser Technology Instruments (LTI) in combination with FieldMap-software IFER). The measurement device combines FieldMap software, a field computer and measuring hardware : Laser Forest Pro - LTI (distance, vertical angle) and Mapstar digital compass – LTI (Azimuth, horizontal angles).

Fig 7. FieldMap-measuring configuration showing telescopic sight, Laser Forest Pro (below) and Mapstar digital compass (vertical box-shaped device on the left).

First, the team navigates towards the selected reference position (plot center) for measurement, using the navigation tool of FieldMap. Then all tree positions are measured in relative or local coordinates to the circle plot center. The device is positioned on the center point, or a selected position that has been measured relative to the plot centre (mirror at the center point, device distance and angle to the mirror measured).

Next, the mirror is placed in front of the selected tree: a position is measured and the tree is registered (ID-code).

The **species** of the tree is determined. Most species are identified up to species level. As measurements are performed in winter time, not all identifications are possible. In some cases, a tree is revisited during the summer campaign (vegetation and regeneration) for decisive identification. Willows (*Salix*) are subdivided in two groups (round-leafed willows type *Salix caprea* and lancet-leafed willows, type *Salix alba*).

The **diameter at breast height** (**DBH** = at 1.30m above ground level) is measured using a measuring tape or a caliper. For caliper measurements, two perpendicular measurements are done, pointing in the direction and transversal to the direction of the plot center, and the average value is registered. For exceptional situations, measurements follow the guidelines as shown in figure 8.

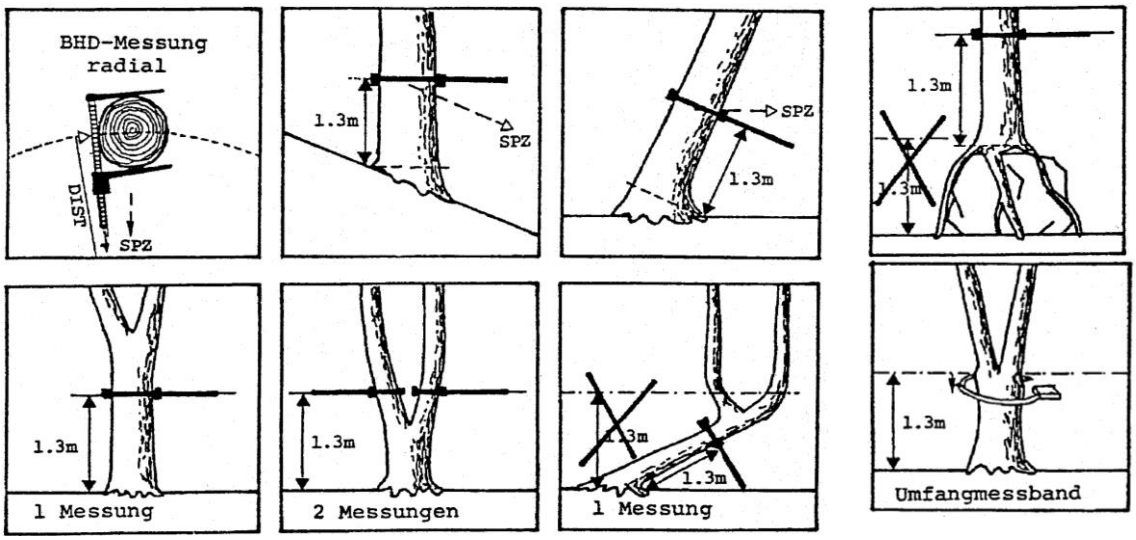


Fig 8. Guidelines for measuring the DBH, also in peculiar situations (figure from Kärcher & Förster, 1994; Keller, 2005)

After registration of the diameter, the location of the tree is automatically corrected by the software to represent the middle of the stem. If the center of the stem is located beyond the radius of the respective sample circle, a warning is given ("Tree is outside the plot, Accept anyway?"), so the tree can be removed from the plot.

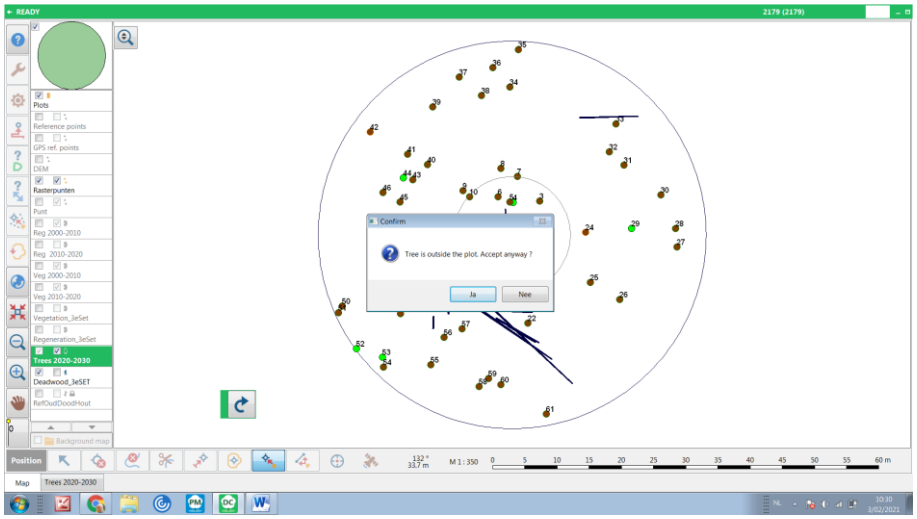


Fig 9. Warning shown on the field computer indicating that a measured tree is outside of the plot.

Height measurements are performed on a selection of trees. Originally a vertex (type Haglöf DME 201) was used. Now, height measurements are usually performed with the Laser Forest Pro (LTI), heights are directly added into the FieldMap database. The choice between instruments to measure height is based on the presence of very tall trees (35 – 50m) in the plots, for these trees the distance range of the instrument has to be large enough.

https://doi.org/10.21436/inbor.38677490

For practical reasons, the height measurements should preferably be carried out in the winter half year when deciduous trees are off-leaf.

Not all tree heights are measured. A selection of trees is made for every species over the different DBH classes Usually the following DBH classes (cm) are used:

5 – 10
10 – 20
30 – 40
40 – 50
50 – 70
70 – 90
90 – 110
>110

At least 10 tree heights are measured per diameter class and per tree species, for the whole reserve (or specific subareas if distinct site conditions within the reserve). Trees are selected based on good visibility of the top. Crooked, tilted or bended trees are excluded from the selection, as they are not representative for the large majority of trees. When selecting trees for height measurements in the sample circles, attention is also paid to the distribution of the individuals per tree species or per tree species group, over the whole of the reserve area. Dead trees are generally excluded from height measurements.

Based on these measurements, tree heights are generated for all trees, using tree height curves that are calculated based on the DBH/height measurements, in the Field-Map Inventory Analyst tool. In further calculations of tree volumes, these calculated heights (CalcHeights) and measured DBH values are applied in tariff formulas (see below).

Heights (and volumes) of dead standing trees with an intact crown are generated from the tree curve of living trees. Volumes are calculated as for living trees. **Height of snags** (dead trees broken at trunk or primary limb level), however, is always registered. Their volumes are calculated using DBH, stem length and tree taper equations incorporated in the FieldMap software. **For living and dead standing trees with partial crown** (part of the crown broken out), tree volumes are calculated as for intact trees, but corrected for the lost crown volume. The share of missing crown is estimated and registered in a specific field (CrownVolumeReduction), for later correction of calculated crown wood volumes. Used classes are: 25 , 50, 75 and 100% (based on resp. 10-40% , 40-60%, 60-90% or > 90% of the original crown volume missing).

For dead standing trees, also the **decay stage** of the tree is registered (for details on decay classes, see below at 'lying dead wood').

Furthermore, the 3x3 **IUFRO-vitality classes** (Leibundgut, 1956) are annotated for every living tree and shoot:

Height class :
B: Bovenetage (Upper canopy) : tree height > 2/3 canopy height
M: Middenetage (Mid canopy): tree height = 1/3 to 2/3 canopy height
O: Onderetage (Lower canopy): tree height = <1/3 of canopy height

Vitality class :
KR: (Krachtig ontwikkelde bomen): vigorous tree
N: (Normaal ontwikkelde bomen): normal vitality
KW: (Kwijnende bomen): languishing tree

Near Future Growth Potential (Hall et al. 1978):
V: (Voorgroeiende bomen): predominant tree
M: (Meegroeiende bomen): co-dominant tree
A: (Achterblijvende bomen): suppressed tree

7.1.2.2 **Lying dead wood**

Lying dead wood is registered and measured as dead wood segments. Complete trees or tree crowns, even if still in one piece, are subdivided in cylindric or truncated cone segments.

For each segment with a length of 1m and diameter of 10 cm and more at the largest end (or 50 cm long and >20cm diameter), the **position and diameter at both ends** are measured (Dbase, Dtop).

If the fragment crosses the border of the plot, still both positions and diameters are measured: the FieldMap-software includes a tool that automatically cuts off the part outside of the sample plot when calculating volumes (see below)

For the stem segment of uprooted trees, the base diameter is measured at approx. 1.30m from the treebase (to avoid the root buttress bias), and the status (uprooted vs. broken) is registered.

For each segment tree species is identified (in so far as possible). If too far decayed for species determination, genus is noted, or broadleaved/conifer.

In order to get a picture of the distribution of the dead wood over the different decomposition classes, a **decay stage** is assigned to all measured dead wood segments (table 6.1). These decay stages are based on the classification developed in the Nat-Man project (Christensen and Vesterdal, 2003), and described in De Keersmaeker et al. 2005 and Dhiedt et al. 2019. The assignment is based on visual characteristics (presence of bark, etc.) and on the softness of the wood (table 6.1). For this purpose it is investigated how far the wood can be penetrated with a knife.

Each measured dead wood fragment is assigned to one representative stage of decomposition. If one fragment (e.g. the stem) has a very large variation of decomposition stages over its full length or when a part is still alive, the element is subdivided in separate segments. They are handled as separate fragments, with diameter and position measurements at both ‘ends’, so the volume can be assigned to one specific decay stage.

https://doi.org/10.21436/inbor.38677490

Table 2:Description of the 6 decay stages of dead wood

Decay Class	Stage Description
1+	Clearly dead this year (e.g. : fallen during the summer storm) : there are still dried leaves or tree buds on the tree
1	Dead for a maximum of 2-3 years: all branches, even the smallest ones, are still present; the bark is intact and the wood is hard
2	Superficially decayed : bark is loose (begins to peel off); wood may not be penetrated with a knife blade for more than 1 cm.
3	Moderately decayed: bark largely peeled off; wood can be penetrated with a knife blade over several cm (especially sapwood: heartwood -if present- is still predominantly hard)
4	Largely decayed: bark has gone, the whole trunk is decayed and soft; only lying deadwood, standing trees have fallen over; cross-section oval
5	Remains in the litter layer: you can still see where a tree was (diverging vegetation; slight elevation in the terrain), some fragments and mold remaining;

7.1.2.3 **Multi-stemmed trees and coppice stools**

The position of the center of the stool is measured by placing the mirror in the center of the stool itself. The stool receives a separate ID for living and dead shoots. All living resp. dead shoots that meet the size requirements are measured separately and linked to this position (separate 'shoot'-layer). For all shoots, DBH and status (living/dead) is registered. For living shoots also IUFRO-classes are registered. .

This allows for two alternative density calculations: based on number of individuals, or based on shoots (counting every shoot as a unit).

For selected tree height measurements, shoots are treated similar to single trees: a selection of shoots in different DBH-classes can be selected for height measurement. However, if single-stem trees are available for a specific species/DBH combination, these are preferred.

Volume calculations for coppice follow specific procedures (see chapter on tree volume calculations).

7.1.2.4 **Linking measurements of individual trees/shoots and dead wood segments in subsequent surveys**

In order to register and calculate changes for individual trees (e.g. DBH increment, mortality) between subsequent surveys, the two datasets can be linked based on the position of a tree within the plot.

For this purpose, the previous survey of standing trees is 'copied' (including tree ID) and 'updated' in the new dataset. (new DBH, new status dead or alive, decay stage...) In most cases this leads to straightforward results.

However, it sometimes may reveal obvious errors, e.g. tree species changes. In this case, the identification is verified and the record is immediately corrected in the field, if needed in the previous survey.

Some results however lead to uncertainties during the data control phase after field measurements. For instance : an ingrowing tree has surpassed the diameter threshold of circle A4 (40 cm DBH), but was not registered in previous sampling: was it below that threshold at that time, or was it forgotten ? A dead tree in survey 1 is registered alive in survey 2 : which of both surveys was wrong in the field ? A large tree from survey 1 is no longer present in survey 2, but cannot be found, not even in the deadwood layer in the field.

A simple registration in the field during the latest survey can clarify most of these uncertainties.

Therefore, since 2020, different possible 'transfers' between consecutive surveys are actively registered in the field during the survey campaign using standard typologies, and allowing for more reliable data check and corrections of the dataset afterwards.

These registrations are :

- New tree - new plot : plot not measured in previous survey
- New : new tree, omitted by mistake in previous survey
- New - ingrowth : first measurement, not measured in previous survey as DBH was below threshold value
- Living - living : living tree in survey 1 is still alive in the next survey
- Living - harvested : registered alive in first survey, harvested in second (stump visible)
- L-Ds : living tree in previous survey, now standing dead
- Ds-Ds: standing dead in both surveys
- Ds-Living: 'lazarus' tree : the tree is still alive, the assessment in the first survey was wrong
- Ds-harvested : standing dead tree cut (stump)
- Undue: measured by mistake in previous survey (e.g. outside plot)
- L-deforested : living tree missing because plot was deforested between two surveys (remeasurement no longer possible, but old measursement still relevant)
- Ds-deforested

Standing trees (dead or alive) that fall down between two surveys, transfer from the 'tree layer' to the separate 'lying deadwood layer', and are no longer registered in the tree layer.

For deadwood segments :

The deadwood segments are registered in a separate lying deadwood layer. As for the standing trees, the layer of previous survey is loaded in the application, but not copied to the new layer. New deadwood measurements are performed in a new layer while the old deadwood fragments (lines) are displayed in the background. If a link is possible, the ID of the object is linked to the former measurement. Here again different situations may occur :

- Living- Lying deadwood (Dl) : tree was windthrown between both surveys: ID link is made, if possible (for the stem section) with the ID of the dead standing tree in previous survey
- Ds - Dl : idem for lying stem of a tree that was dead standing in previous survey.
- Dl - Dl : lying segment is linked to its ID in former survey : this is only done for the stem segment or primary limbs, not for individual branches (for obvious reasons).

7.1.2.5 **Rejuvenation (trees <5 cm DBH)**

Since rejuvenation is most evident in leaf, this registration is carried out during the growing season. Rejuvenation here means all woody vegetation with a DBH < 5cm.

In order to monitor the regeneration of the woody species, the rejuvenation is counted per height class.

In the sample circle A2 (radius of 4.5 m), all rejuvenation is exactly counted per species in the height classes 50 - 200 cm and > 200 cm.

In the sample circle A1 (radius of 2.25 m) all rejuvenation in the height classes 0 - 30 cm and 30 - 50 cm are attributed to frequency classes (see before: 1, 2-5, 6-10, 11-20, 21-40, 41-60, 61-100, >100, >1000). In case of very large numbers, which are uniformly distributed over the plot surface, only a section of the plot surface is checked and extrapolated to the entire surface.

7.2 VEGETATION RELEVÉS

Vegetation relevés are made in square permanent plots of 16 m x 16 m (256 m²), centered on the grid point, with the corners in the four cardinal directions at 11.3 m from the central grid point.

One vegetation survey consists of two samplings: one in spring (april 1st-may 31st) and a second visit in summer (june 15th - september 15th) in order to register both spring and summer species at their optimal development. Both records are integrated to one result, taking into account the record with the highest cover (*cfr*. Mölder et al., 2014). In case no spring aspect is present at the site, the first sampling is skipped.

All herbaceous species (vascular plants) and woody species (< 200cm) are identified, and their cover is estimated using the extended Londo scale (Londo, 1984; see below). If required or preferred, these cover data can be transformed into percentage values using the midpoint value of the respective class.

Bryophytes are not identified, only their overall cover is registered (see below)

Since 2015, a new parameter 'Browse index' was added for every registered species:

- No traces of browsing
- Traces of browsing (< 5% of individuals browsed)
- Significant traces of browsing (> 5% of individuals browsed).damage

Identification of vascular plats follows Lambinon et al. (1998). All species of the herb layer are identified up to species level. Exceptions are:

- *Rubus fruticosus*: identified as agglomerate (but *Rubus caesius* and *Rubus idaeus*)

- Young individuals of *Dryopteris dilatata* and *D. carthusiana* (if the distinction is unclear)

- Non-flowering *Epilobium* species, certain unidentifiable grasses and sedges,

- Seedlings of *Fraxinus excelsior* and *Acer* spp., or *Betula* and *Salix* spp., ... that cannot be distinguished.

As for the woody layer, the general rule applies that as much as possible is determined at species level, but not at the expense of reliability.

The **cover** of a herbaceous species or layer is defined as the horizontal projection of that layer within the borders of the plot. A species rooting outside the plot may thus have a cover within the plot, and is registered.

Finally, also the total cover of the moss layer, herbaceous layer, shrub layer (2-8m height) and tree layer (> 8m height) is estimated (upper limit being the top height of typical shrubs like Hazel). For these layers, only the total percentage coverage is estimated (i.e. no coverage of individual species).

The moss layer cover always concerns the non-epixylic ('terrestrial') mosses of the plot area. Species on dead wood are therefore not included in the terrestrial moss layer, because dead wood is considered a specific substrate/layer.

Vascular plants growing on rootplates, on dead wood, epiphytes on living trees, submerged or floating on water, are also registered but explicitly assigned to a their specific 'layer'. All plants not assigned to such specific layer are considered to be terrestrial.

If applicable, the area covered by open water, by water plants and the % of bare soil due to disturbance by game is registered.

Table 3. The extended decimal scale of Londo (1984) applied in the vegetation monitoring, to estimate species cover.

Cover (%)	**Annotation**
<1	.1
1-3	.2
3-5	.4
5-10	1-
10-15	1+
15-25	2
25-35	3
35-45	4
45-55	5
55-65	6
65-75	7
75-85	8
85-95	9
95-100	10

For species with cover < 1%, additional abundance classes are allocated, based on the number of individuals (except for species that do not allow to discriminate individual plants, e.g; *Rubus spp., Lamium galeobdolon, Holcus mollis,*...)

 https://doi.org/10.21436/inbor.38677490

Table 4. Species abundance classes, applied for the class .1

Abundance	Annotation
1-3	r
3-20	p
20-100	a
>100	m

7.3 FISH-EYE-PHOTOGRAPHS AND LIDAR-SCANS

Hemispheric crown photography is a technique that is applied to quantify canopy cover and gap percentages. A digital camera (Nikon Coolpix 990) equipped with a fish-eye converter lens (type FC-E8 with a viewing angle of 183° and a focal length adjustment of x 0.21) is mounted to a tripod, at an elevation of approximately 1m above ground level in the center of the sample plot and a zenithal image is taken of the tree canopy (with the top of the horizontal image facing north).

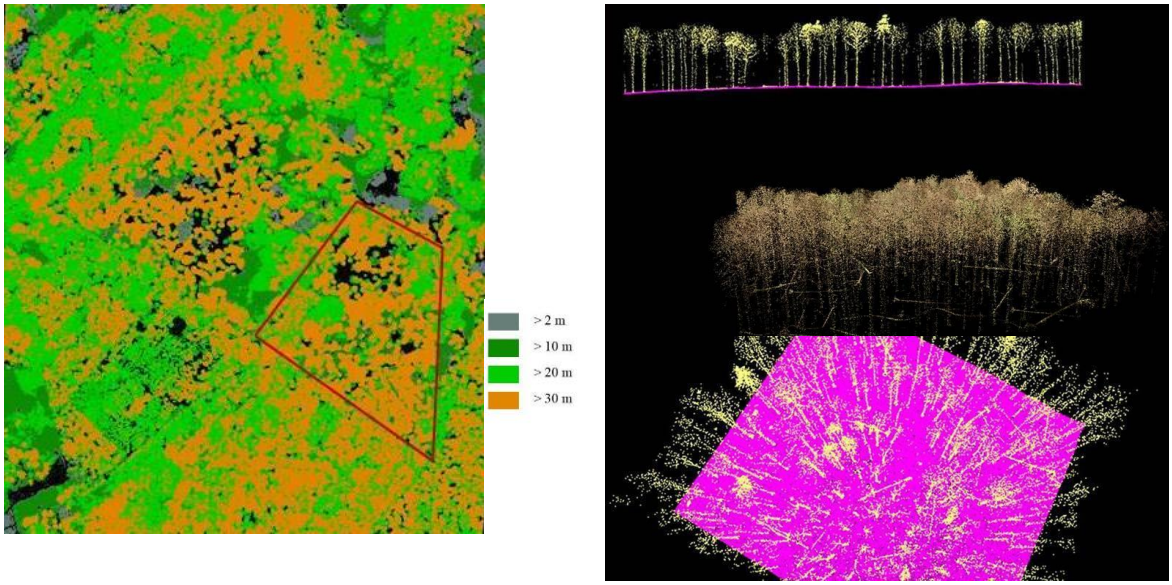
The resulting image is processed using the software Hemiview 2.1, resulting in binary black-and-white images with calculation of visual sky percentages. Based on this result, a Leaf Area Index (LAI) can be calculated. This makes it possible to generate a 'light map' using kriging extrapolations and compare it with the stem positioning and vegetation

However, it must be said that this technique faces many challenges: pictures must be taken in leaf-on period, in full overcast conditions or early morning/evening before full sunrise resp. sunset. This makes the time window for acceptable conditions very narrow and difficult to practically organise. Moreover, the images not only give satisfactory representations of the local conditions, as the presence of nearby stems or branches (close to the lens) have a disproportionate influence on the result. This is why Fish-eye surveys were only performed during the first survey period, and not repeated during subsequent survey rounds.

Fig 10. Result of fish-eye photography: left= original image; right= binary image for visual sky to derive gap share and LAI;

Newly available remote-sensing information, such as LiDAR-scans will provide more reliable opportunities to derive canopy gap patterns, and subsequent shade casting and LAI-estimates. An airborne LiDAR-scan for the full area of Flanders was flown in 2013 and is readily available for analysis (point cloud density approx. 12 points per m²). Today also UAV (drones) equipped with LiDAR-scanners are available, and provide new opportunities for detailed 3-D scans (above and below upper canopy) of the forest canopy structure.

Fig 11. Possibilities for canopy analysis based on LiDAR: some preliminary exercises. left : result based on a detailed scan at Sonian forest (red polygon : large core area); right: result based on the full-area (mid-resolution) LiDAR scan of Flanders (figure made by Erwin Meylemans of Flanders Heritage)



7.4 REPEAT PHOTOGRAPHY

From the grid points, digital photographs are taken in one or more directions that give a characteristic forest image. These photographs do not serve further numeric and statistical analysis (but see: Hendrick & Copenheaver, 2009; Hammond et al., 2020). They do provide very illustrative images of changes over time in the vegetation, decay of wood, etc... as illustrated in the examples below. They are very useful in presentations of the results to a wider audience.

Plot code, angle and date are noted in the grid-point-layer of of the FieldMap project. After downloading the digital photos, the photos are given an unambiguous file name that includes site name, year, plotcode and angle of the photograph. The photos are collected in a central data directory for every site.

https://doi.org/10.21436/inbor.38677490

Fig 12. Repeat photography illustrating the increase in cover of *Anemone nemorosa*, and the slow decay of oak stems, compared to small beech fragments (above: Bos Terrijst; mid: Pruikenmakers (Meerdaal Forest), below: Harras Core Area (Sonian Forest);left: first sampling event and right second sampling event, 10 years later.

Fig 13. Decaying oak tree and spectacular decline of *Rubus fruticosus* in the reserve of Wijnendalebos between 2002 (upper) and 2012 (lower picture)

https://doi.org/10.21436/inbor.38677490

8 FIELD PROTOCOL FOR MEASUREMENTS IN CORE AREAS

8.1 WHAT IS MEASURED?

The standard core area of 140 by 70 m is subdivided into 98 square subplots of 10 by 10 m (100 m²), whereas small core areas (50m x 100m) consist of 50 subplots. The following dendrometric data are collected per 10 m x 10 m subplot:

Living trees

- Positioning of all trees with DBH of 5 cm and more

- Positioning of all coppice stools with shoots of 5 cm and more

- Species determination of all positioned trees and stools

- DBH of all positioned trees and all shoots > 5cm

- Height measurement on a selection of trees (cfr. circular plots)

- Determination of IUFRO vitality classes of each positioned tree or shoot

- Rejuvenation: counting by species of trees with a diameter of less than 5 cm in 4 height classes:

  -Classes 50-200 cm and >200 cm : exact numbers

  - Classes 0-30 cm and 30-50 cm: frequency classes: 1, 2-5, 6-10, 11-20, 21-40, 41-60, 61-100, >100, >1000

Standing dead wood

- Positioning of all standing dead trees and shoots with DBH of 5 cm and more and height > 1,3m

- Species determination of all positioned trees and stools (as far as possible)

- DBH of all positioned trees and all shoots > 5cm + decay stage

- Height measurement of all snags (standing trees snapped at stem level)

Lying dead wood

- Positioning of all lying dead wood fragments with a diameter at the wide end of 10 cm or more and a minimum length of 1 m (or diameter of 20 cm or more and a minimum length of 0.5 m)

- Species determination (if possible) of all positioned fragments

- Diameter measurement (Dbasis/Dtop) of all positioned dead wood fragments

- Determination of the decomposition stage of all fragments.

Tree stumps of formerly harvested trees are normally not registered.

//

Vegetation: Full vegetation relevé, including estimate of tree-shrub-herb-moss-layer for every 100 m² subplot.

Repeat photography and fish-eye photographs

On the central transect of the core area, photographs are taken at points with coordinates 20.35, 70.35 and 120.35 on the central axis of the plot. Photographs are taken from those fixed points in a direction that reveals meaningful results. The photographs are repeated from the same location and in the identical direction.

During the first survey campaign, also fish-eye photographs were made in the core area, on fixed nodes of subplot-grid, as illustrated in fig.6 (chapter 6).

8.2 HOW: MEASURING PROTOCOLS

Measuring procedures and protocols in the core area are identical as in the circular plots (see chapter 7).

 https://doi.org/10.21436/inbor.38677490

9 FIELD PROTOCOL FOR ADDITIONAL MEASUREMENTS

9.1 FULL SURVEY OF 'PARTICULAR ELEMENTS' (BIOTOPE MAPPING)

Some elements and structures are very rare, and can be 'missed' using sampling techniques, even if the sampling density is as high as in this monitoring programme (15-20% of the reserve area). This can involve specific topographic elements such as ponds, rivulets, rocky outcrops, antropogenic structures (buildings,...) and growing/breeding sites of rare species. They mainly have an illustrative value, appealing to a wider public, but can also provide interesting topics for future investigation.

This survey is of particular interest for rare dendrometric elements: very large trees and coarse woody debris. These elements can be very scarce in recently established reserves, and even in old reserves, the density of very large trees seldom surpasses 10 trees per ha (Vandekerkhove et al. 2018), resulting in estimations with very wide confidence intervals. The extrapolation of the results from the sampling can thus result in strong over- or underestimations of the density and presence of these specific elements with very high ecological relevance. Therefore, a full survey is made of all very large trees and large dimensioned dead wood elements:

VLT = Tree with DBH > 95 cm - For tree species that do not reach such dimensions, threshold can be lowered to 50 cm (*Betula, Alnus, Sorbus*) or 70 cm (*Carpinus, Acer*,...).

Large dead wood element = dead wood fragment (standing or lying) of 40 cm Diameter or more. (exceptionally lowered to 30 cm, e.g. in sites dominated by trees in DBH-class 30-40cm).

Position, species and diameter of these elements are registered; for deadwood also decay stage (similar to sampling plot registrations)

The methodology is described in detail by Govaere & Vandekerkhove (2005).

This mapping is done during the summer half-year, in the most productive period of the vegetation by systematically going through the entire forest reserve to be monitored, where all particular elements are mapped and registered with FieldMap technology. One team of two people can cover on average 3-10 ha in one day, depending on the density of elements and accessibility of the terrain.

9.2 DOMINANT VEGETATION TYPE MAPPING ('FACIES' MAPPING)

Based on the vegetation sampling plots, a set 5-15 relevant 'vegetation facies' are derived, based on combinations of dominant species (e.g. *Pteridium*-facies; *Rubus fruticosus*-facies; *Anemone+Lamium* facies,...). These patches are then mapped over the full area of the reserve. This characterization of the vegetation is the result of a "best professional judgment" and is based on the characteristic species. Some prior knowledge of the forest reserve (previous site visits and literature data) is indispensable to quickly develop an unambiguous typology. This

mapping should be done in the period with the most productive plant growth. In forest reserves with spring flora, the area-wide mapping will take place in late spring.

A ‘facies’ mapping has been done once in most sites (during the first survey) and can be repeated at later times. In some cases, selected ‘facies’ can be re-mapped is considered relevant. For instance in the forest reserve of Bos Terrijst it was observed that dense vegetations of *Allium ursinum* signicantly increased between two surveys: this specific facies was separately remapped during the second survey.

Fig 15. left : Example of a vegetation facies map for the reserve of Wijnendalebos - right: extension of the facies of *Allium ursinum* in Bos Terrijst between 2005 (dark green) and 2015 (light green = extension)

Fig 16. Repeat photographs illustrating the significant extension of *Allium ursinum* in Bos Terrijst between 2005 and 2015.

https://doi.org/10.21436/inbor.38677490

10 DATA CONTROL, DATA PROCESSING AND DATA STORAGE

10.1 DATA CONTROL

After completing the field measurements, a thorough data check is performed.

An internal procedure stipulates the steps to be undertaken during data control.

Part of the checks are performed in access, part of the checks using R-scripts. Over time all checks will be implemented in R.

Improbabilities (unrealistic dbh, height, dbh-height relationship, …) are detected, as well as missing values (dbh, decaystage for deadwood, height in case of snag, ...) and trees outside the plot boundaries.

These are corrected based on the available data, or if necessary, the site is revisited and uncertainties are checked and corrected in the field.

Once the data are thoroughly checked, they are ready for storage in the 'mother'-database and consecutive data processing.

10.2 DATA PROCESSING

10.2.1 Overview

Part of the data processing is done in the data processing module of Fieldmap: FM Inventory Analist (www.fieldmap.cz).

This is a very powerful and user-friendly software package, that allows us

- to build species specific diameter-height models
- to calculate volume of lying deadwood fragments inside the plot boundary

All other analyses are done using R-scripts.

To facilitate data processing in R, the package 'forrescalc' was developed: see https://inbo.github.io/forrescalc/ for further information on the package.

10.2.2 Volume calculations

10.2.2.1 **Intact standing trees**

The volume of standing trees with an intact crown, both dead and alive, are calculated based on two parameters: (1) diameter at breast height and (2) total height of the tree.

Only for a selection of trees tree height is measured in the field. These measurements are used to create **diameter-height curves** for every tree species. This is done for every site separately.

For every site, one of the two functions below is selected, depending on the best fit.

$$H = 1.3 + exp\ exp\left(P1 + \frac{P2}{DBH}\right) \qquad (exponential\ function)$$

Or

$$H = 1.3 + \frac{DBH^2}{(P1 + P2.DBH)^2} \qquad (Näslund\ function)$$

(with P1 and P2 = calculated parameters)

This best fitting diameter-height function is constructed (formula and parameters), using the measured tree heights per diameter class and species, and the statistical tools provided in the FieldMap Inventory Analyst module (for details on the applied functions and spatial statistics, we refer to FieldMap IA-technical background information).

Based on these species specific diameter-height curves, a calculated tree height is generated for every tree (CalcHeight). Uncommon species, with insufficient tree height measurements to generate specific diameter-height curves, are allocated to the diameter-height curve of the site (for all tree species combined).

These calculated height values, together with the DBH, are then used to calculate the individual tree volume using **tree volume tables with two entries** (DBH and height).

The applied volume tables are described by Dagnelie et al. (1985). For large beech and oak trees, the tables by Quataert et al (2011) are applied. For poplars tables of Dik (1990) are used, for Corsican pine the tables of Berben (1983). Species not listed in one of these tables are calculated with the formula for a species with a similar growth form (see table below).

All calculations of volumes are performed using the formula and coefficients as given in the table below. The applied formulas are identical to the ones applied in the NFI.

The volume calculations result in specific values for the bole and the crown, separately. The total volume is then the combination of both these values. Volume calculations include bole and branch volumes up to a diameter of 7 cm (merchantable timber, over bark).

Table 5. Formula for the calculation of the bole volume (over bark), with coefficients for the most common tree species

Source	Species	Group	a	b	c	d	e	f	g	type
Quataert	Quercus ro/pe	1	0,1645	-0,005612	0,0000291	0	-0,00725	0,00025	0,0000023	1
Dagnelie	Quercus rubra	2	-0,02149	0,00095069	-0,0000043068	-0,000000070329	-0,00074299	0	0,0000037969	1
Quataert	Fagus sylvatica	3	-0,01115	0	-0,00000856	-0,00000004996	0	0,0000256	0,000003633	1
Dagnelie	Betula spp.	4	-0,011392	-0,0001001	0,00002829	-0,00000018695	-0,00059573	0	0,0000030811	1
Dik	Populus spp.	5	-4,608923	3,005989	-1,3209	1,605266	5,410272	0	0	2
Dagnelie	Acer spp.	6	0,010343	-0,0014341	0,000034521	-0,00000013053	0,00077115	0	0,0000030231	1
Dagnelie	Fraxinus exc.r	7	-0,039083	0,0019935	-0,000016148	-0,000000006419	-0,00098341	0	0,0000038373	1
Dagnelie	Ulmus spp.	8	-0,034716	0,0013586	-0,000013402	-0,00000005698	0,00016516	0	0,0000038818	1
Dagnelie	Prunus avium	9	-0,002311	-0,00037474	0,000015103	-0,000000025175	0,00033282	0	0,0000031943	1
Dagnelie	Pinus sylvestris	10	-0,039836	0,0015505	-0,0000061835	0,000000048022	0,000073997	0	0,0000029607	1
Dagnelie	Picea abies	11	-0,010929	0,0013945	-0,0000095965	-0,00000025164	-0,0027922	0	0,0000048985	1
Dagnelie	Pseudotsuga	12	-0,019911	0,00059559	0,000012901	-0,00000018587	0,00071591	0	0,0000039892	1
Dagnelie	Larix spp.	13	-0,03088	0,0014885	-0,0000049257	-0,00000012313	-0,0011638	0	0,0000041134	1
Berben	Pinus nigra	14	-0,002846	0	-0,00000022785	0	-0,00024768	0	0,0000039082	1

Type : Formula type 1: a + b * C130 + c *(C130 ^2)+ d *(C130 ^3) + e*H + f*H* C130 + g*H*(C130 ^2)
Formula type 2 (poplar, Dik): 1/1000 * (exp(1.10597 * log(Height) + 1.78865 * log(D) - 3.07192) - exp(-4.608923 * log(D) + 3.005989 * log(Height) - 1.3209 * log(Height)*log(Height)+ 1.605266 * log(D) * log(Height) + 5.410272))

https://doi.org/10.21436/inbor.38677490

Other tree species are allocated to one of these 'groups' :

- *Carpinus, Quercus palustris*: group 1
- *Sorbus aucuparia, Tilia spp*. : group 2
- *Castanea sativa* : group3
- *Alnus spp., Salix spp*. : group 4
- *Aesculus spp., Cornus spp., Crataegus, Rhamnus, Ilex, Juglans, Malus, Mespilus, Prunus spinosa, Sambucus* : group 7

For trees (living and dead) with **significant loss of crown volume** (e.g. breakage of a primary branch) this is registered during field measurement, using 4 crown loss categories (for estimated respective crown volume reductions of 10-40% , 40-60%, 60-90% or more than 90%). A correction of the calculated crown volume is performed accordingly, based on this relative crown loss.

10.2.2.2 **Snags**

For snags (=tree that snapped at trunk level) both DBH and height are always measured. As the diameter at the snapping point cannot be measured, the volume of a snag is calculated as a cylinder based on DBH and measured height.

10.2.2.3 **Lying deadwood**

Lying deadwood is measured by subdividing every lying tree in single stem and branch segments (even if still connected). The volume of each segment is then calculated using the Smalian's formula for truncated cones. This formula states that the volume of a log can be closely estimated by multiplying the average of the surface areas of the two log ends by the log's length.

$$Volume = \left(\frac{\pi . r^2 + \pi . R^2}{2}\right) . L$$

where:

- L = length as calculated by the software, based on the position of base and top end
- R = diameter at the base
- r = diameter at the top

This formula is incorporated in the FieldMap software. Logs that cross the plot border are "cut of" (using incorporated GIS tools), and volume is then calculated by replacing total length and diameter with length and diameter on the intersection point.

For the stem segment of uprooted trees, the base diameter is measured at approx. 1.30m from the tree base (to avoid the root buttress bias).

10.2.3 Plot level results

Plot level results are calculated using the R package 'forrescalc' (https://inbo.github.io/forrescalc/).

These results include:

- Dendrometric values of living trees:
  - tree number, basal area and volume per hectare
  - for all species combined, on species level and/or per diameter class (size class distribution)
- deadwood volume:
  - standing, lying and total deadwood volume per hectare
  - per decay stage, diameter class and/or species
- regeneration:
  - total number per hectare
  - number per height class and/or per species
- vegetation:
  - total cover per vegetation layer
  - number of species
  - cover per species
  - browsing index

These plot level results are the base for further analyses.

10.2.4 Further analyses

Plot level results allow for easy calculation of forest level results and comparison between subsequent periods.

Analyses across all forest reserves, taking into account different strata (f.e. soil type, forest age, period not managed, main tree species….), is also possible.

The package 'forrescalc' contains some functions especially made for these kind of analyses.

The function "*compare_periods*" compares for each plot the differences between subsequent periods.

The function "*create_statistics*" allows to create statistics on the level of a single forest reserve and/or a specified stratum.

The data on plot characteristics (soil type, elevation, vegetation type,...) are included in separate tables, that are stored in a local database, with back-up on a web server.

10.3 DATA STORAGE

All plot level results are stored in the open access git repository 'forresdat' (https://github.com/inbo/forresdat)

The raw data remains in the central geodatabase ('mother database') which is stored locally and regularly back-upped on a webserver.

11 DESCRIPTION OF THE SITES INCLUDED IN THE INTENSIVE MONITORING PROGRAMME

11.1 BOS TERRIJST

Basic information on the site :

Surface area: total reserve : 48.98 ha Monitored area = 38,40 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,0843903135; N: 50,7191175357

Altitude : 55-76 m ASL

MAT : 10.1 °C **MAP:** 804 mm/y

Soil types : Aca + Aba + Adp - Haplic Luvisols (Siltic)

Habitat-types: 9130, 91E0

Vegetation types: Endymio-Carpinetum, Endymio-Fagetum, Alno-Padion - EEA: 6.6.2 & 6.11.2

Official reserve status : 1996

Unmanaged since : 2003

Last commercial harvest/planting intervention: 1981-1983

some tending and thinning in young stands of beech in 1980's and 1990's; limited introductory management upon installation of strict reserve : girdling and felling of a few *Quercus rubra*, Douglas fir and larch in 2000-2003.

Specifications for this survey:

NONE – standard measurement protocol

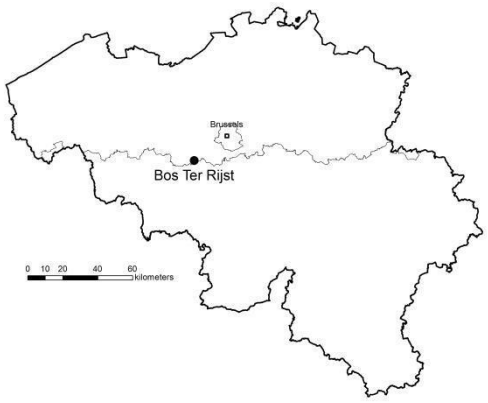
Number of circular plots : 50

Core Area : Yes (70x140m)

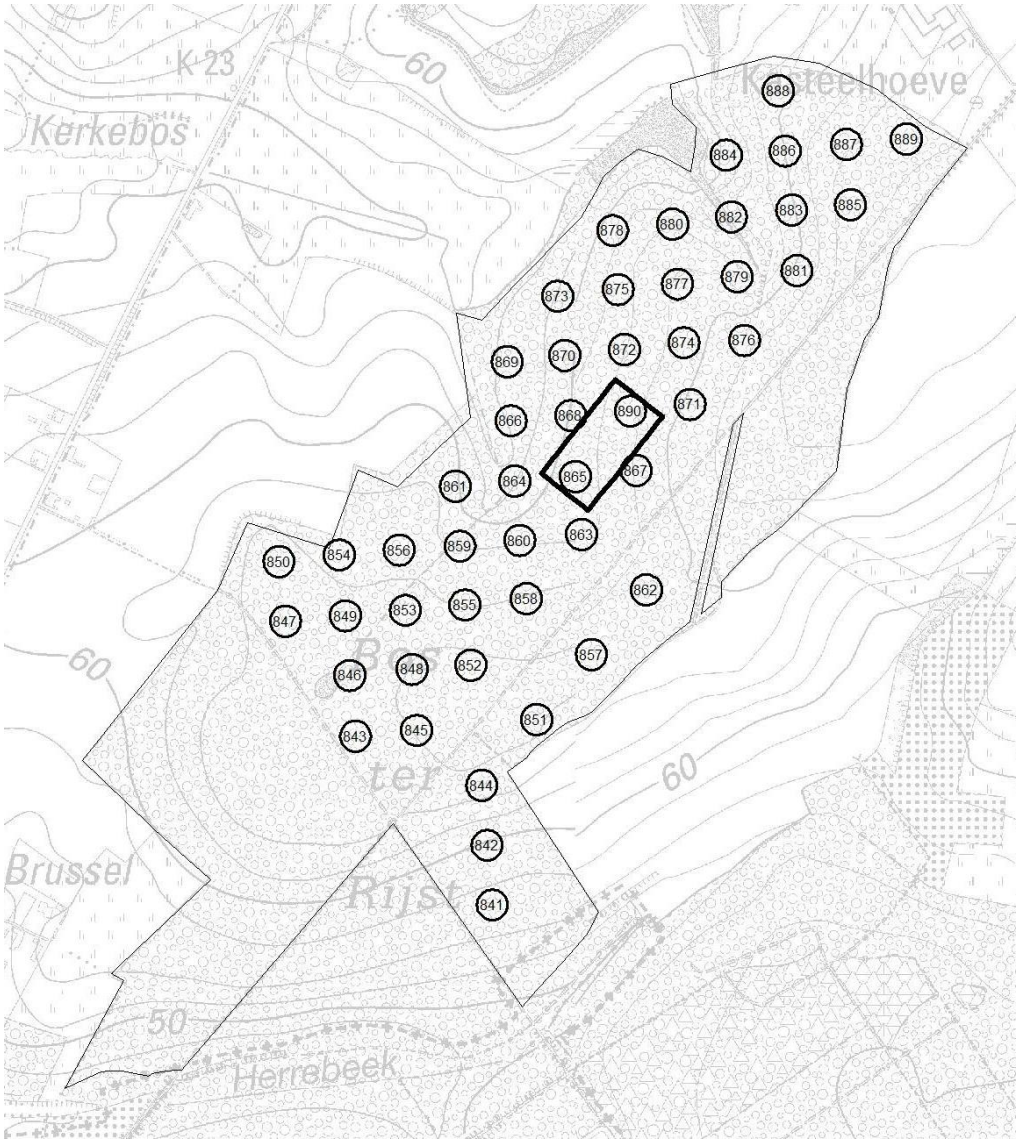
Survey years (up to 2020): 2004/2005 and 2014/15 - vegetation in 2005 and 2015

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area



 https://doi.org/10.21436/inbor.38677490

11.2 DE HEIRNISSE

Basic information on the site :

Surface area: total reserve : 76.39 ha Monitored area = 42 ha

Co-ordinates of the Centroid (WGS84-decimal): E 3,9986600846 N: 51,1683458770

Altitude : 4-5 m ASL

MAT : 10.2 °C **MAP:** 763 mm/y

Soil types : Sep (+ Zdp and Ufp) - Eutric Gleyic Cambisols (Loamic) (+ Fluvic gleyic Phaeozems)

Habitat-types: 91E0 (+9120)

Vegetation types: *Cirsio-Alnetum* -Base-rich variant of the *Filipendulo-Alnetum* with *Rubus caesius* and *Cirsium oleraceum*- EEA: 6.11.2; on sandy outcrop : Violo-Quercetum (atlantic Fago-Quercetum) - EEA 6.6.2

Official reserve status : 1996

Unmanaged since : 2008

Last commercial harvest/planting intervention: 1991

Mowing of paths until 2002, in 2003 some 20 poplars were girdled, cut of invasive non-native species (*Quercus rubra* and *Prunus serotina*) in 2003-2004, with glyphosate treatment of the stumps; control in 2008.

Hydrology of the wider area (thus also the reserve) is regulated outside of the reserve.

Specifications for this survey:

NONE – standard measurement protocol

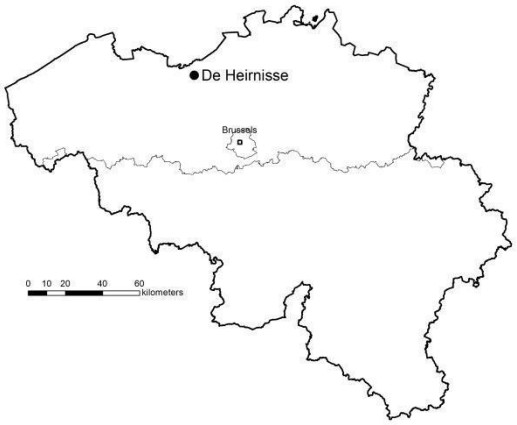
Number of circular plots : 68

Core Area : Yes (70x140m)

Survey years (up to 2020): 2003/2004 and 2013/14.

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area

 https://doi.org/10.21436/inbor.38677490

11.3 EVERZWIJNBAD (MEERDAALWOUD)

Basic information on the site :

Surface area: total reserve : 27.48 ha Monitored area = 27.48 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,6791368202 N: 50,7982678097

Altitude : 63-88 m ASL

MAT : 9.8 °C **MAP:** 820 mm/y

Soil types : Aba, Abc : Eutric Neocambic and Dystric Glossic Fragic Retisols (Siltic)

Habitat-types: 9160

Vegetation types: Stellario-Carpinetum, - EEA: 6.5.1

Official reserve status : 1995

Unmanaged since : 1995

Last commercial harvest/planting intervention: 1994 (commercial thinning)

In 1999-2000 a few *Quercus rubra* still present in the reserve were girdled (3-4 trees); hunting until 1998.

Specifications for this survey:

NONE – standard measurement protocol

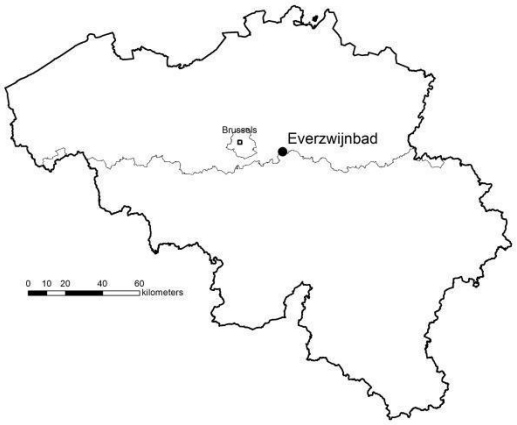
Number of circular plots : 48

Core Area : Yes (70x140m)

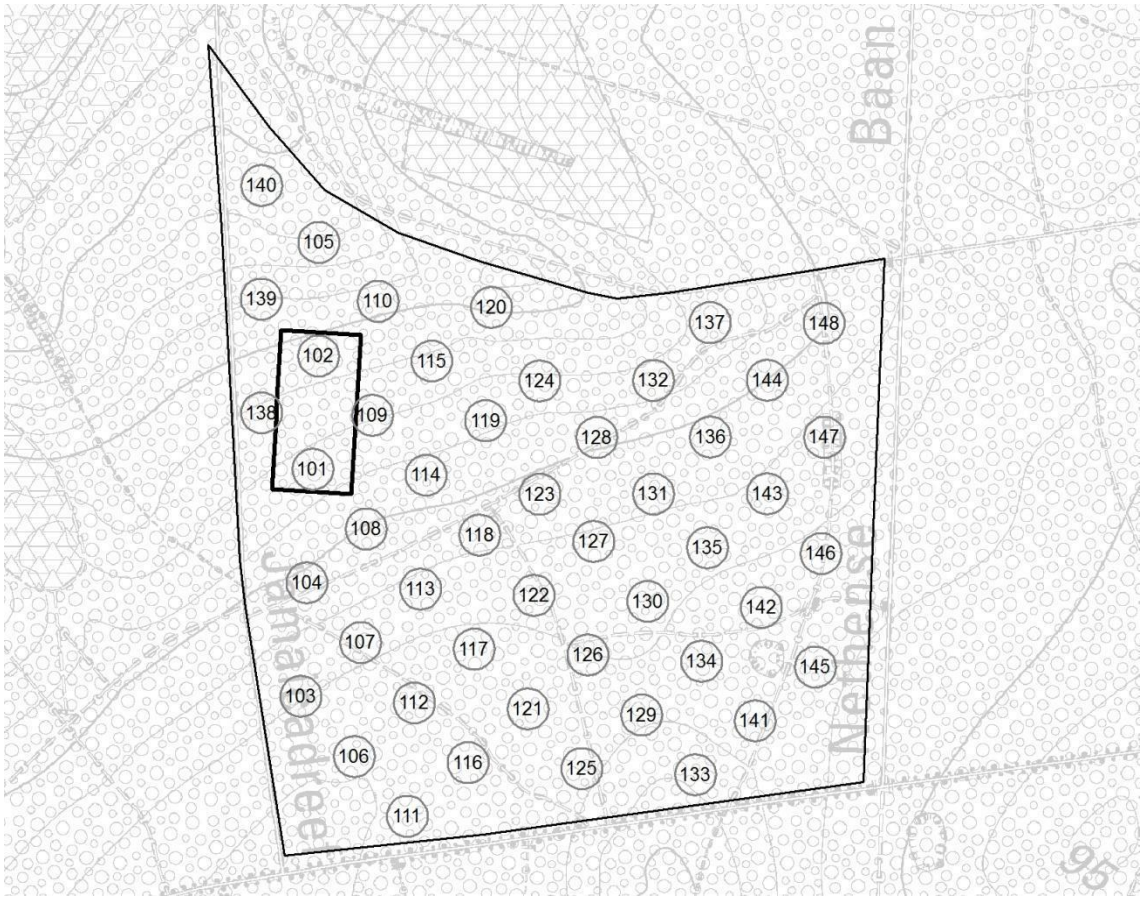
Survey years (up to 2020): 2002/2003 and 2012/13 - vegetation in 2003 and 2013.

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area



 https://doi.org/10.21436/inbor.38677490

11.4 PRUIKENMAKERS (MEERDAALWOUD)

Basic information on the site :

Surface area: total reserve : 38.69 ha Monitored area = 38.69 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,7152630115 N: 50,7986339669

Altitude : 59-89 m ASL

MAT : 9.8 °C **MAP:** 820 mm/y

Soil types : Aba (Abc) : Eutric Neocambic (and Dystric Glossic Fragic) Retisols (Siltic)

Habitat-types: 9160

Vegetation types: Stellario-Carpinetum/Primulo-Carpinetum - EEA: 6.5.1

Official reserve status : 1995

Unmanaged since : 2002

Last commercial harvest/planting intervention: 1993 (commercial thinning)

In 1998-2002 a few *Quercus rubra* still present in the reserve were girdled and *Prunus serotina* was cut all over the reserve (with glyphosate treatment of the stumps); last control in 2006. Young trees surrounding suppressed crab apple trees were felled in 2000. All in all, these interventions were limited.

In 2000 two small stands of Corsican pine and Douglas fir were felled and removed; adjoining stand of Scots pine was thinned as final introductory intervention. Also here, non-intervention was instituted since. Hunting until 1998 in the western half, until 2006 in eastern half of the reserve.

Specifications for this survey:

NONE – standard measurement protocol

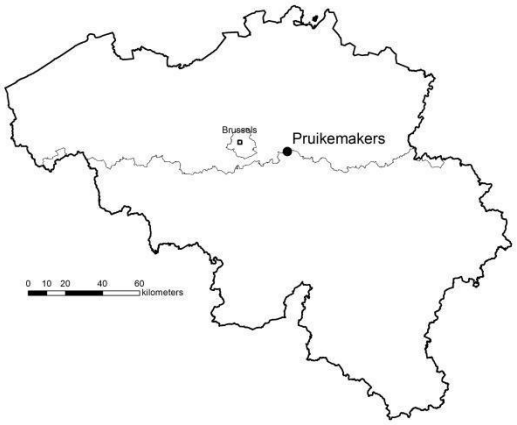
Number of circular plots : 66

Core Area : Yes (70x140m)

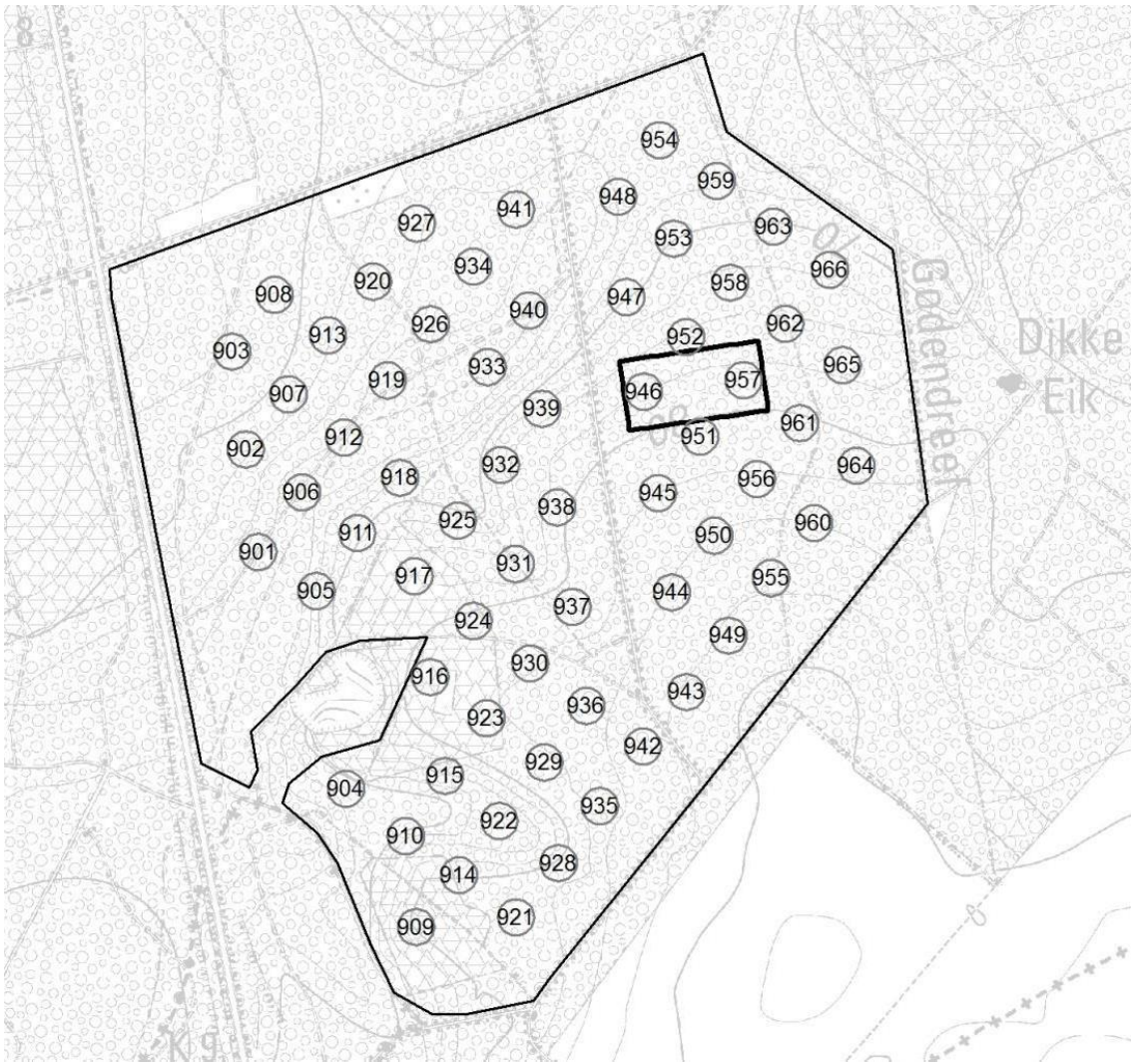
Survey years (up to 2020): 2005/2006 and 2015/16 - vegetation in 2006 and 2016.

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area



 https://doi.org/10.21436/inbor.38677490

11.5 DE HEIDE (MEERDAALWOUD)

Basic information on the site :

Surface area: total reserve : 32.60 ha Monitored area = ca. 20 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,7013401985 N:50,7971000671

Altitude : 64-79 m ASL

MAT : 9.9 °C **MAP:** 808 mm/y

Soil types : Abc - Dystric Glossic Fragic Retisols (Siltic)

Habitat-types: 9160

Vegetation types: Stellario-Carpinetum/Primulo-Carpinetum - EEA: 6.5.1

Official reserve status : 1999

Unmanaged since : none - this is a managed site: coppice with standards restoration

Last commercial harvest/planting intervention:

This is an experimental site where CwS management was reinstated. Area under study was subdivided in 8 blocks, one to be felled every second year at first cycle, one every 3 years from then onwards. Some delay in the realisation of the plans.

No planting of rejuvenation, but tending of oak seedlings possible.

First restoration fellings in 2001 : CwS cut in plot 5 (1433-1437), preparatory thinning in other plots; latest cut = plot 3 (1417-1426) in 2019.

Specifications for this survey:

Specific lay-out : stratified systematic plot lay-out : at least 5 sample plots per block; standard measurement protocol per plot

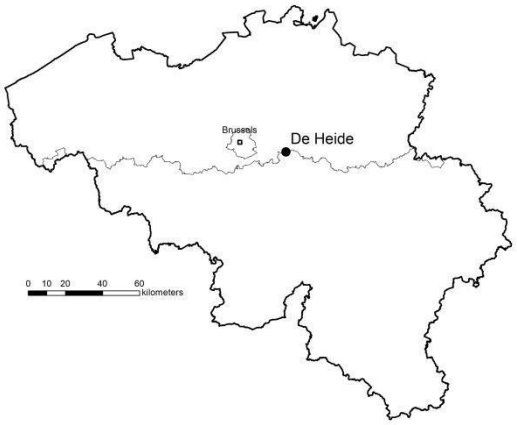
Number of circular plots : 52

Core Area : no

Survey years (up to 2020): 2016

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers)

 https://doi.org/10.21436/inbor.38677490

11.6 JANSHEIDEBERG (HALLERBOS)

Basic information on the site :

Surface area: total reserve : 26.50 ha Monitored area = 22 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,2772736527 N: 50,7058140471

Altitude : 80-118 m ASL

MAT : 9.8 °C **MAP:** 837 mm/y

Soil types : Aba - Eutric Neocambic Retisols (Siltic)

Habitat-types: 9130 Atlantic variant

Vegetation types: *Endymio-Carpinetum; Endymio-Fagetum - EEA:6.6.2 - Bohn: F5a*

Official reserve status : 1996

Unmanaged since : 1994

Last commercial harvest/planting intervention: 1994

Mowing of paths until 2000, in 2001 a small stand of Corsican pine (at plot 821) was harvested and the cut-over area left unmanaged since then

Specifications for this survey:

NONE – standard measurement protocol

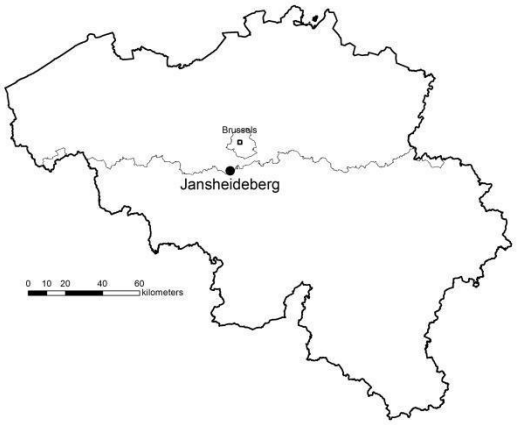
Number of circular plots : 33

Core Area : Yes (70x140m) - non-homogeneous core area : Northern half = mixed oak-hazel stand; Southern half = monospecific beech stand

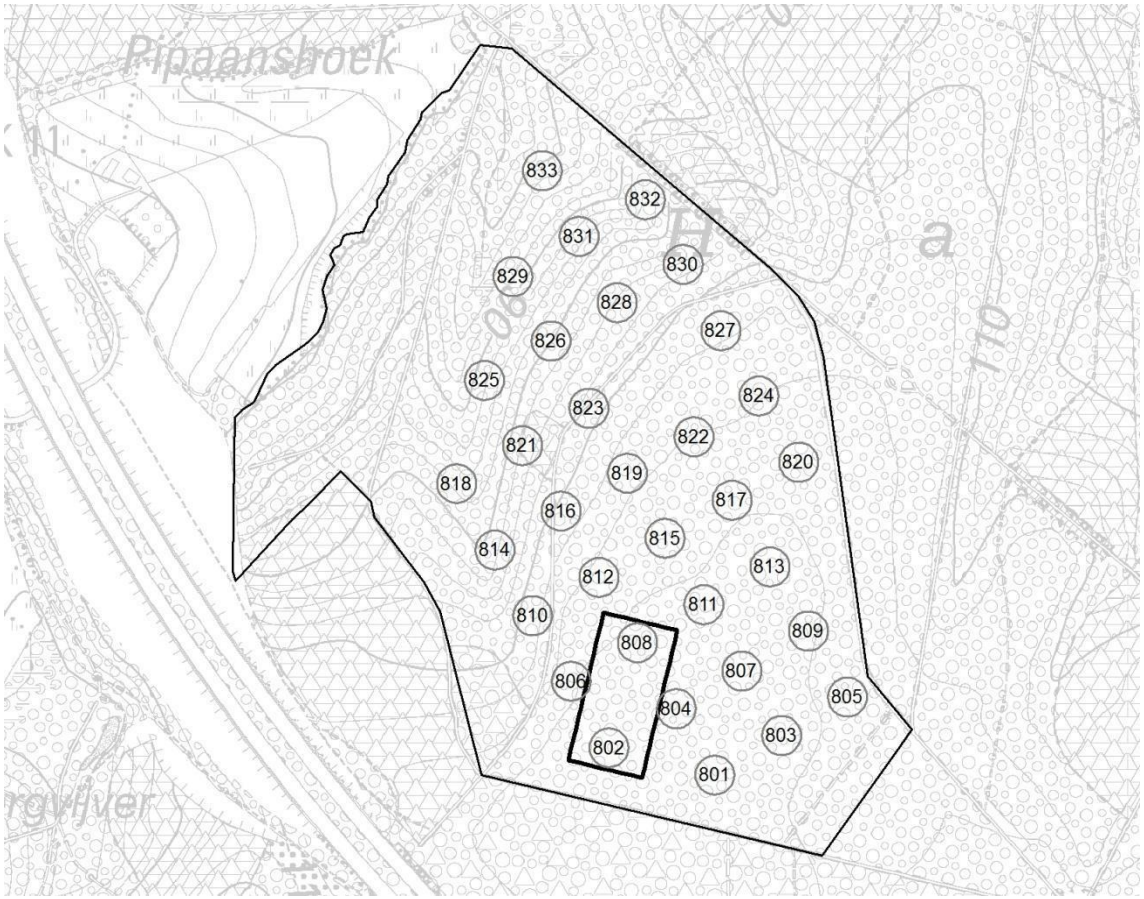
Survey years (up to 2020): 2004/2005 and 2014/15.

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area



 https://doi.org/10.21436/inbor.38677490

11.7 WIJNENDALEBOS

Basic information on the site :

Surface area: 91.60 ha, of which 65 ha strict reserve Monitored area = 64.15 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 3,0408827382 N: 51,0663101816

Altitude : 19-30 m ASL

MAT : 10.0 °C **MAP:** 705 mm/y

Soil types : Sdp - Eutric Stagnic Cambisols (Loamic, Abruptic) - Zdh - Terric Anthrosols (Arenic, Spodi-relocatic) -

Habitat-types: 9120

Vegetation types: *Fago-Quercetum - EEA:6.6.2*

Official reserve status : 1996

Unmanaged since : 2001

Last commercial harvest/planting intervention: 1984

In 1983-84, commercially valuable coppice was cut for the last time by private owner right before the sale of the forest; standards were not cut. Clear-cut of Pine stand (stand 21) on southern border of the reserve, with spontaneous regeneration of birch.

1987-1993 : removal of mainly windfall trees (in total about 250 trees); mowing of paths

2000-2001 : introductory management in the strict reserve : clearcut of small Douglas fir stand in the north, harvest (ca 500 trees in buffer zone) of intermixed larch trees; girdling of larch trees (345) and Am. Red oak trees (65 trees) in the rest of the strict reserve.

Specifications for this survey:

NONE – standard measurement protocol

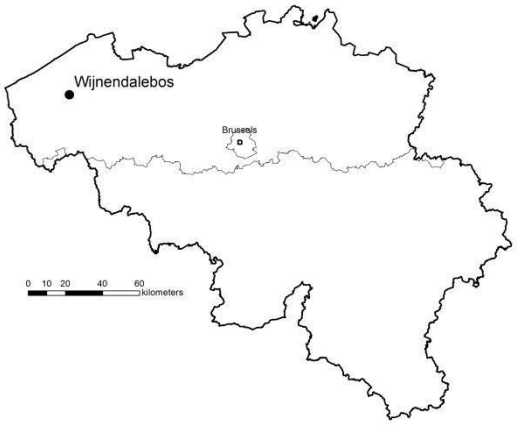
Number of circular plots : 123

Core Area : Yes (70x140m) - homogeneous core area : oak - beech - chestnut - sycamore

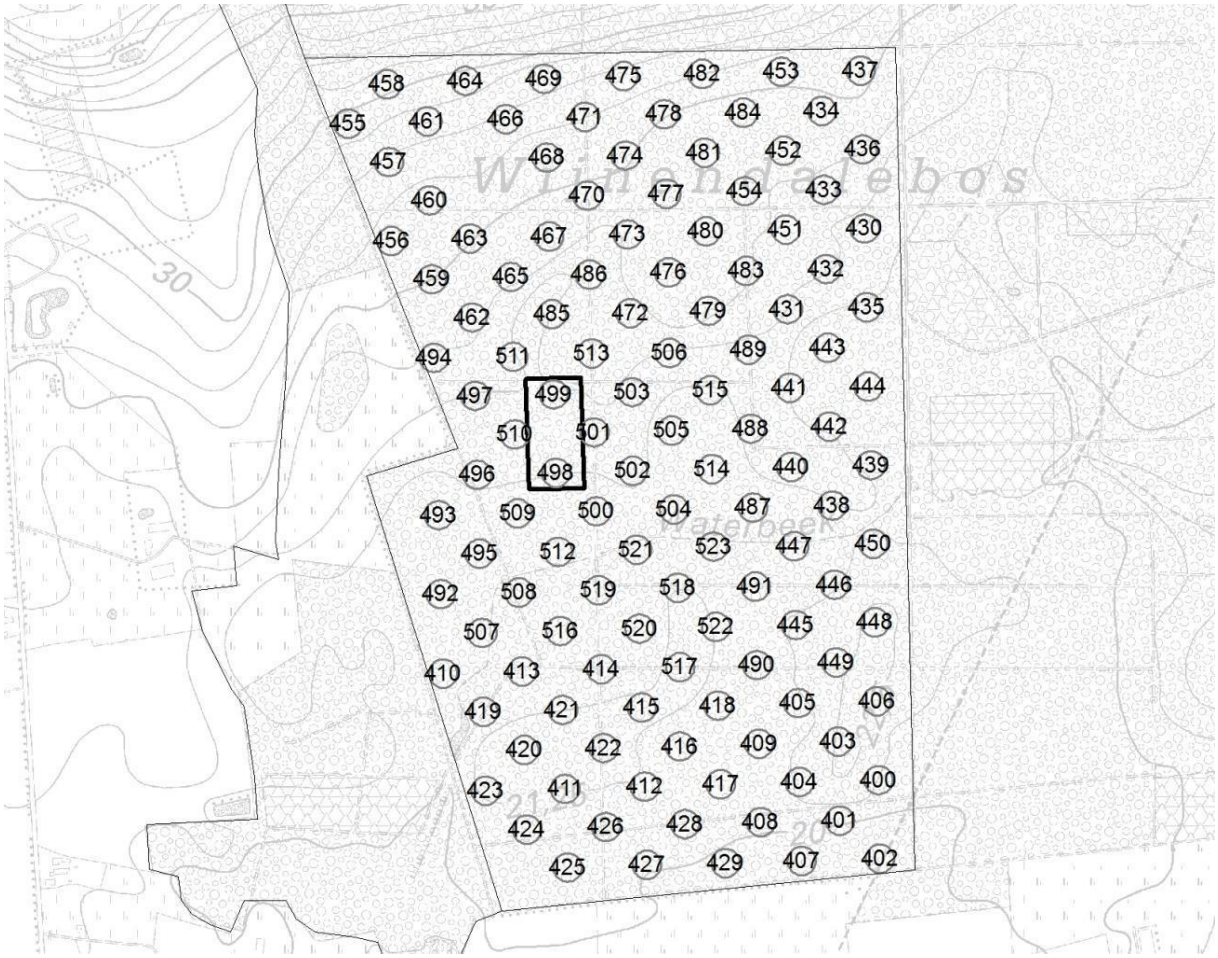
Survey years (up to 2020): 2002/2003+2004 and 2012/13+2014.

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area



 https://doi.org/10.21436/inbor.38677490

11.8 MUIZENBOS

Basic information on the site :

Surface area: 34.19 ha Monitored area = 34.19 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,5682529447 N: 51,1971862831

Altitude : 9-11 m ASL

MAT : 10.0 °C **MAP:** 781 mm/y

Soil types : w-Lep **-** Fluvic Gleyic Phaeozems (Loamic, Fluvic, Ruptic)-

Habitat-types: 91E0 - EEA : 6.5.9

Vegetation types:mostly *Alno-Padion ,*and some *Quercion* in the NE

Official reserve status : 1997

Unmanaged since : 1997

Last commercial harvest/planting intervention: 1997

In 1997 two last clearcuts of mature poplars were performed. One of the clearcut areas has been object of a separate monitoring with 5 year interval (see below). Between 1997 and 1999 some invasive non-native species (*Rhododendron, Quercus rubra, Quercus palustris*) were girdled. This was a limited number of trees.

Specifications for this survey:

NONE – standard measurement protocol

Number of circular plots : 46

Core Area : 70x150m : 70x70 in Ash stand (West) 70x70 in poplar stand (east), and 10x70 on the former unimproved path in between

Survey years (up to 2020): 2007-2008 and 2017-2018

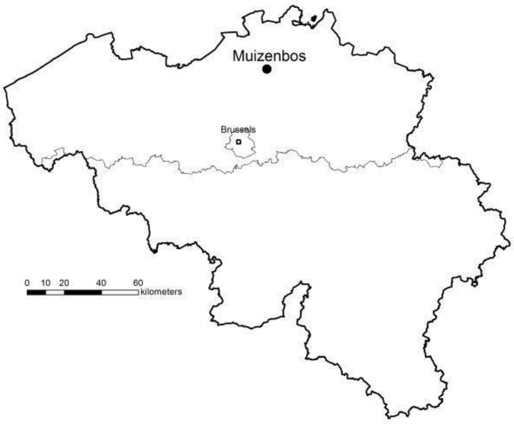
Additional plots :

- 3 parallel transects (10x 100) on managed path, CwS-strip and unmanaged forest: study of ground vegetation development (including *Colchicum autumnale, Dactylorhiza fuchsii, Valeriana dioica*) measured in 2002/3 and 2012/13.

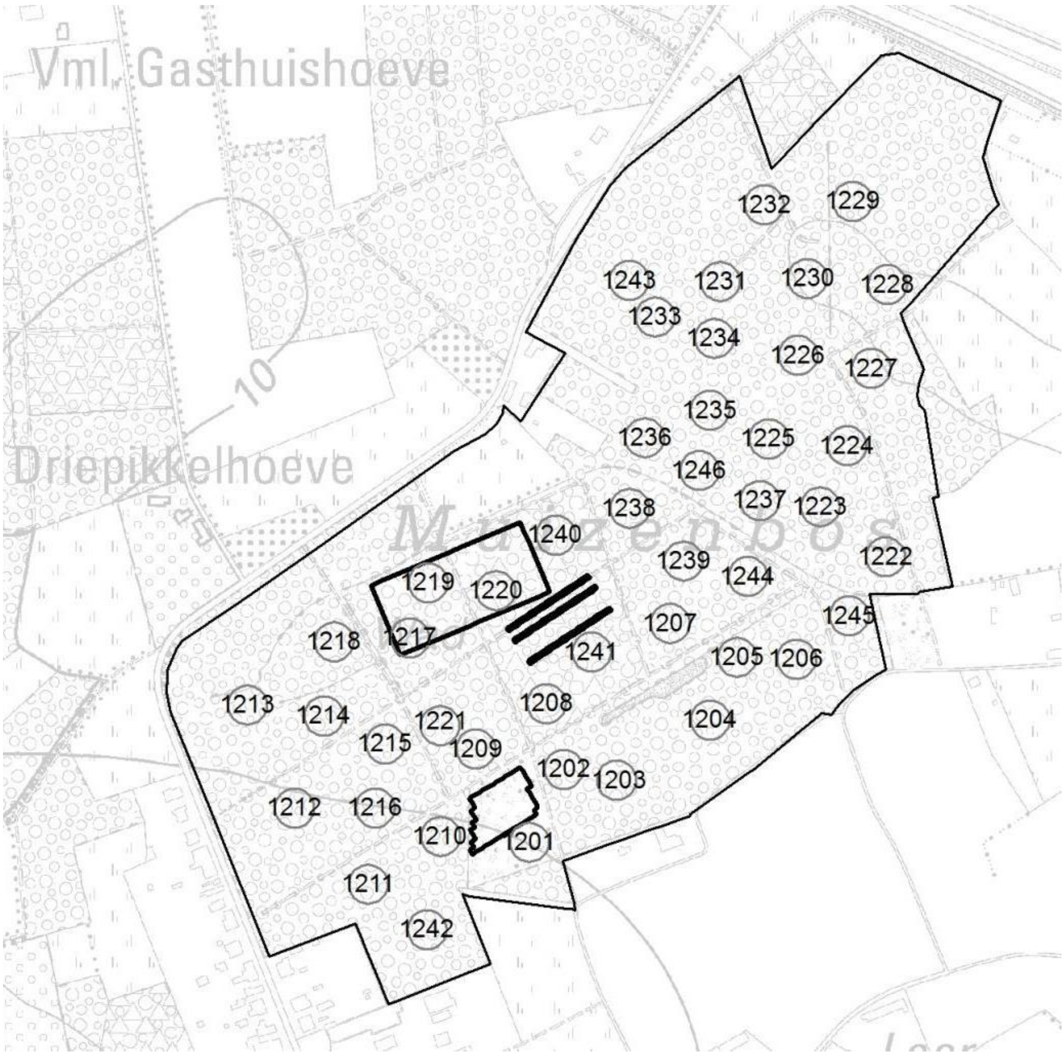
- full survey in grid 5x5m subplots on former clearcut (total area ca 0.25 ha) : development of tree and ground vegetation after clearcut : every 5 year remeasurement (1997-2002-2007-2012-2017)

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and Core area + clearcut plot and 3 parallel vegetation transects



 https://doi.org/10.21436/inbor.38677490

11.9 SEVENDONCK

Basic information on the site :

Surface area: 65 ha Monitored area = 51.40 ha

Co-ordinates of the Centroid (WGS84-decimal): E 4,9370821182 N:51,2738039617

Altitude : 17-20 m ASL

MAT : 9.8 °C **MAP:** 797 mm/y

Soil types : Zep, Sep (Plaggic Arenic Anthrosols) for Quercion; V (Dystric Rheic Sapric Histosols) Sep/Pfp (fluvic gleyic umbrisols) for Alnion

Habitat-types: 9190 and 91E0 - EEA : 6.4.1 and 6.11.2

Vegetation types: *Betulo-Quercetum (31.43 ha) + Carici elongatae - Alnetum (19.95 ha)*

Official reserve status : 1997

Unmanaged since : 1995

Last commercial harvest/planting intervention: 1994

In 1950-1975 very little management was done (military area); between 1975 and 1994 : until 1987: regular thinnings in the pine stands, selective thinnings to release oak trees. In 1991: salvation harvest of wind-felled trees. Last thinning in Pines: 1994; last cutting of coppice in the swamp forest: 1986-1987.

Specifications for this survey:

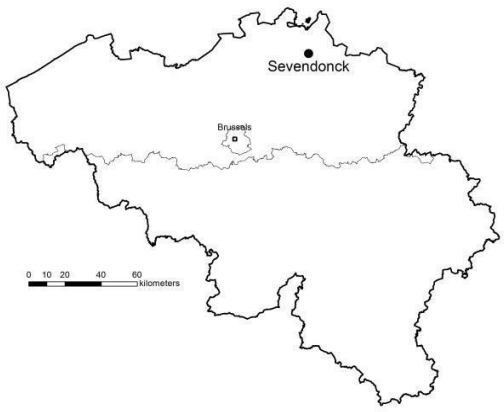
Number of circular plots : 78 of which 40 in Quercion, 38 in Alnion

Core Area : 2 small core-areas of 50x100 cm: one in Quercion, one in Alnion

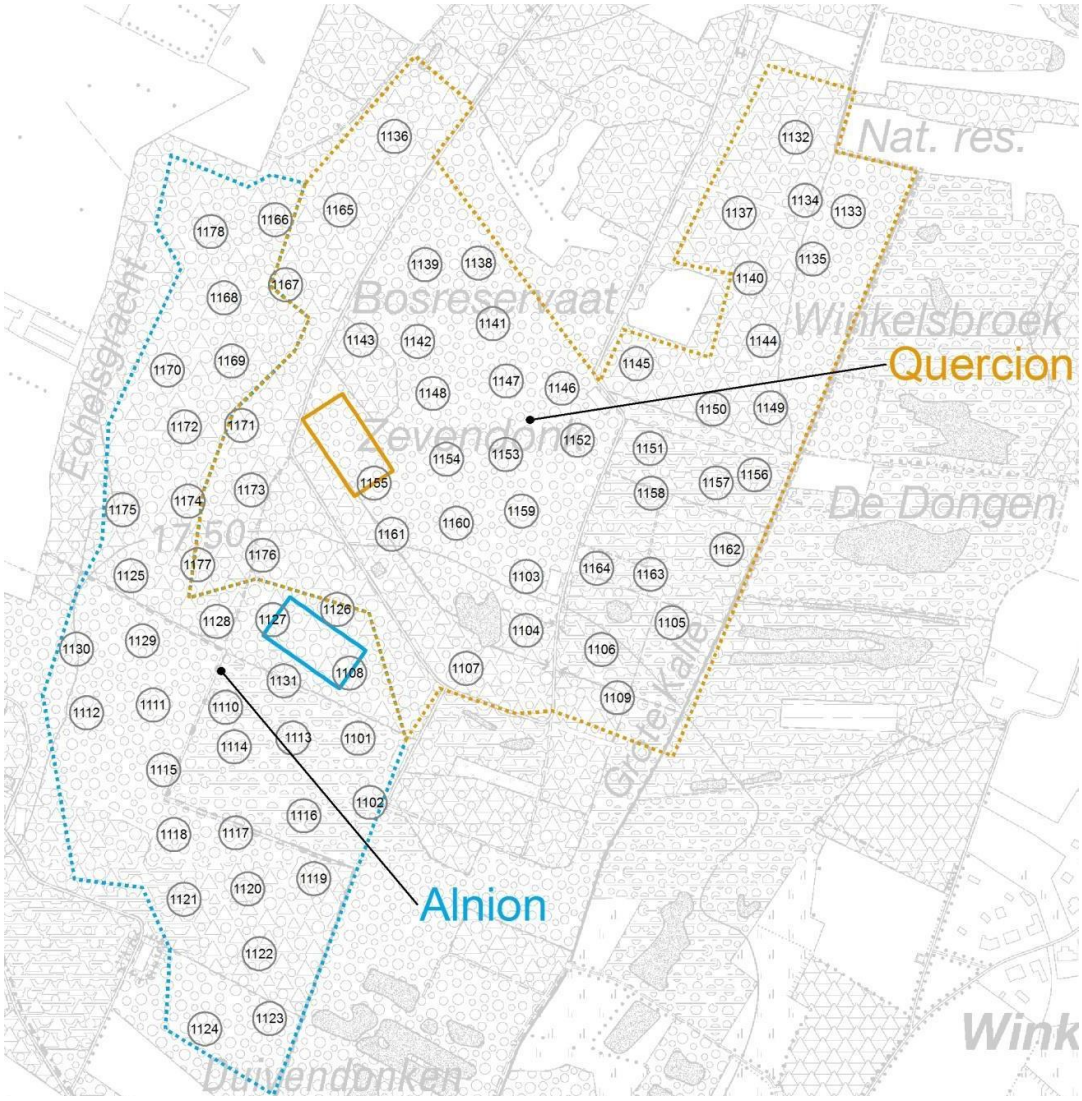
Survey years (up to 2020): 2007-2008 and 2017-2018

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and two Core areas; indication of the extent of the two contrasting forest types in the area.



 https://doi.org/10.21436/inbor.38677490

11.10 KLUISBOS

Basic information on the site :

Surface area: 50 ha reserve

Monitored area = 50 ha reserve, 60 ha managed forest

Co-ordinates of the Centroid (WGS84-decimal): E: 3,5030400753 N: 50,7629013062

Altitude : 40-122 m ASL

MAT : 9.6 °C **MAP:** 775 mm/y

Soil types : LbB - Eutric Leptic Cambisols (Loamic); Lcc - Eutric Retisols (Loamic)

Habitat-types: 9130 - Atlantic

Vegetation types: *Endymio-Fagetum*

Official reserve status : 2006

Unmanaged since : reserve: ca. 2000 (?)

Last commercial harvest/planting intervention:

in reserve: thinning in 1990's (?)

Managed forest: thinning in 2016-17

Specifications for this survey:

Number of circular plots :

reserve : 67 (11 in poplar stand, 56 in beech forest);

managed forest: 55 thinned, 6 unthinned

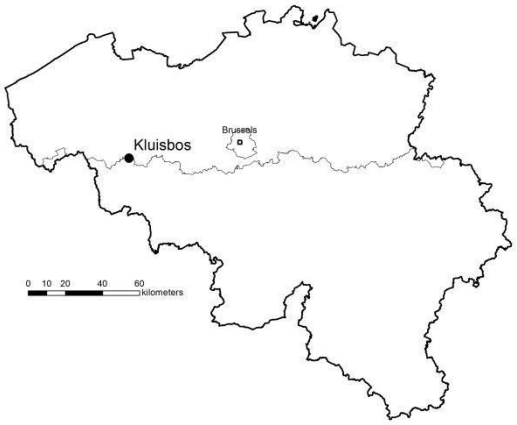
Core Area : NONE

Specific research topic for this site is the comparison of tree vitality and ground vegetation development between thinned and unmanaged beech stands.

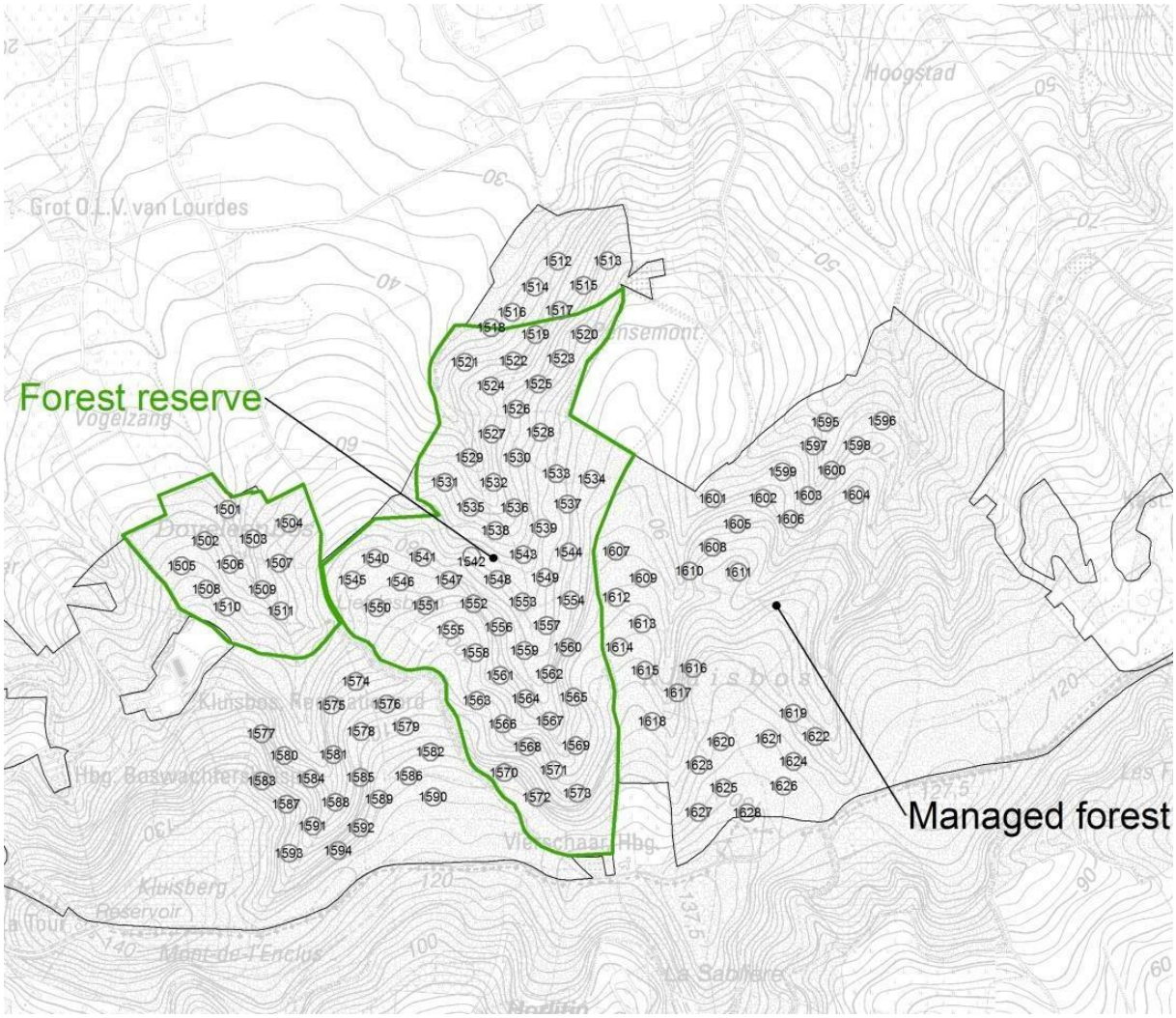
Survey years (up to 2020): 2017-18

Maps

Location within Belgium :



Map of the Site with grid of circular plots (plot numbers); indication of the strict reserve and the plots in the managed forest.



11.11 KOLMONTBOS

Basic information on the site :

Surface area: 16.70 ha reserve Monitored area = ca. 15 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 5,4249100685 N: 50,7990989685

Altitude : 67-104 m ASL

MAT : 9.7 °C **MAP:** 821 mm/y

Soil types : SAx/PAx (Eutric Cambisols (Loamic, Ruptic)) and UDx (Eutric Stagnic Cambisols)

Habitat-types: 9160 and 9120 - EEA: 6.5.1 and 6.6.2 (+91E0 - Alno-Padion)

Vegetation types: *Stellario-Carpinetum and Fago-Quercetum (+ Alno-Padion)*

Official reserve status : 1995

Unmanaged since : 1991

Last commercial harvest/planting intervention: no known harvests

No commercial harvest over at least the last 100 years, only removal of some dead trees and coppicing along the trails, mowing of trails.

Specifications for this survey:

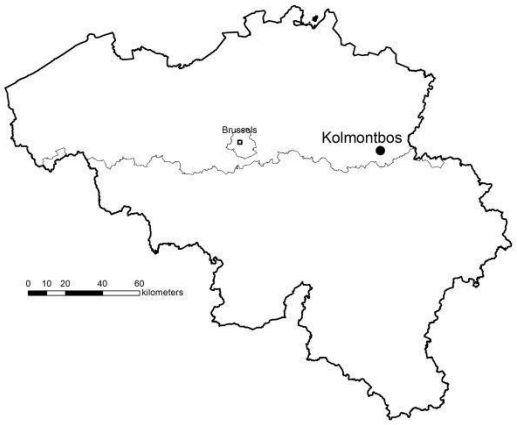
Number of circular plots : 32

Core Area : NONE

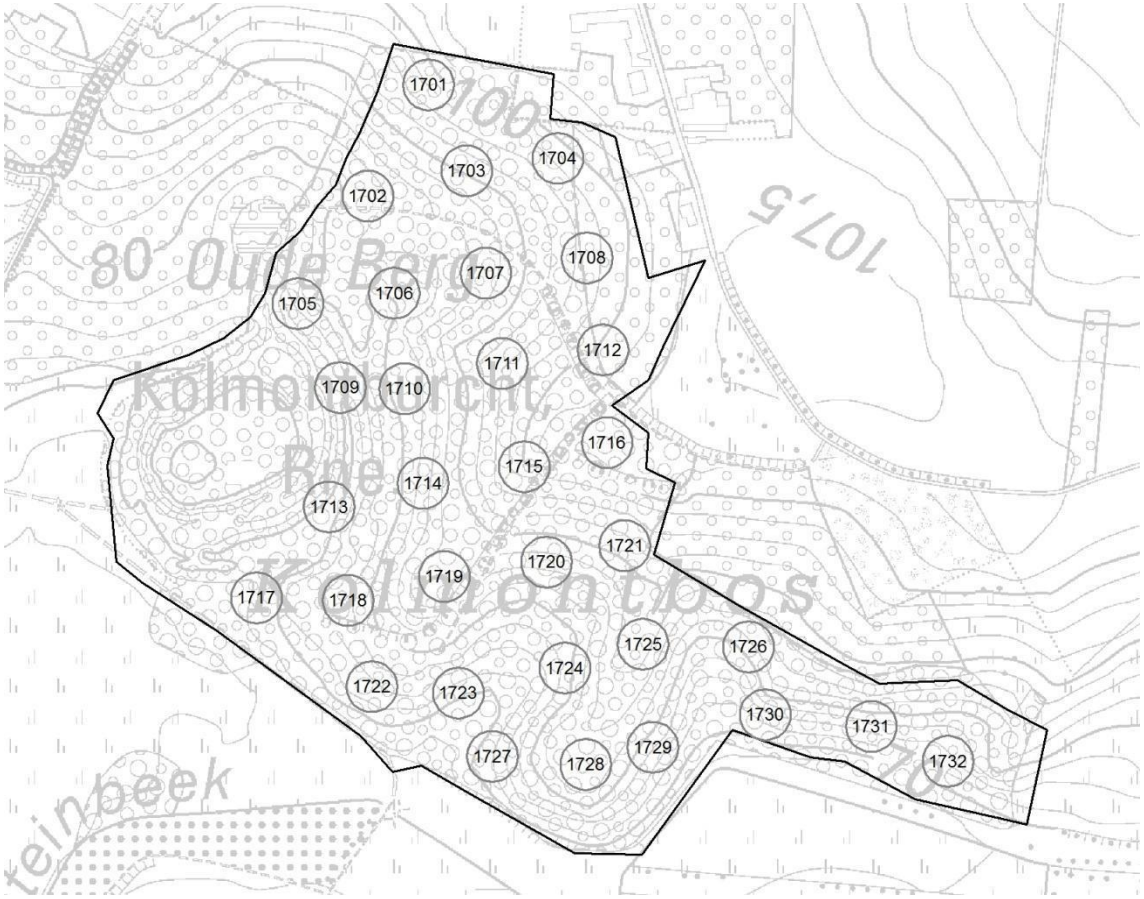
Survey years (up to 2020): 2019-2020

Maps

Location within Belgium :



Map of the Site with grid of circular plots (plot numbers)



 https://doi.org/10.21436/inbor.38677490

11.12 BOS T'ENAME

Basic information on the site :

Surface area: ca. 105 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 3,6453900337 N: 50,8558998108

Altitude : 13-70 m ASL

MAT : 10.0 °C **MAP:** 765 mm/y

Soil types : Ldc - Eutric Gleyic Retisols (Loamic); LDx and EDx - Eutric Stagnic Leptic Cambisols (Loamic, Ruptic) and Lhp - Eutric Fluvic Oxygleyic Gleysols (Loamic, Fluvic)

Habitat-types: 9130 Atlantic - EEA: 6.6.2 (+91E0 - Alno-Padion - EEA: 6.5.9)

Vegetation types: *Endymio-Fagetum (+ Alno-Padion)*

Official reserve status : early 1990's + regular extensions

Unmanaged since : area unmanaged forest = unmanaged since 1990's

Last commercial harvest/planting intervention:

No commercial harvest in the non-intervention zones since 1990's; CwS-areas : final cut of poplars with retention trees, re-instatement of CwS with rotation period of 12-16 years. Part of the reserve is extensively grazed (year-round) with cattle.

Specifications for this survey:

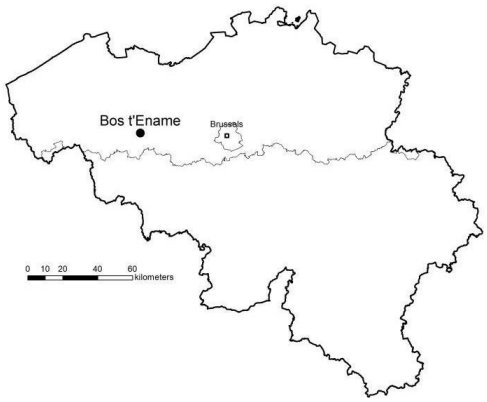
Number of circular plots : 73 plots spread over the different management types (for numbers per management type: see figure below)

Core Area : NONE

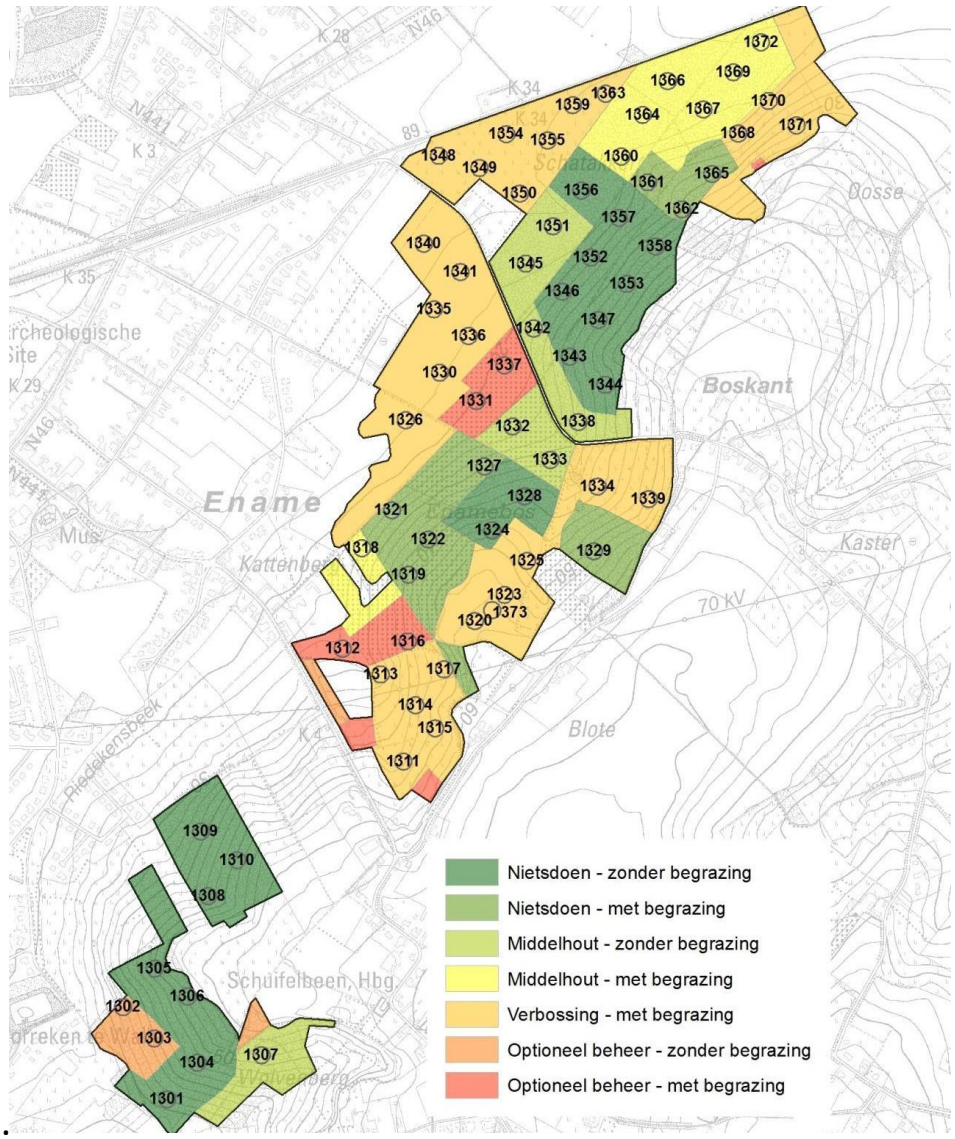
Survey years (up to 2020): 2014-2015 (vegetation: 2016)

Maps

Location within Belgium :



Map of the Site with grid of circular plots (plot numbers) in the different management categories



.

https://doi.org/10.21436/inbor.38677490

11.13 LIEDEKERKEBOS

Basic information on the site :

Surface area: ca. 21 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,1143071489 N:50,8660778098

Altitude : 26-34 m ASL

MAT : 10.2 °C **MAP:** 785 mm/y

Soil types : Lda and Ada - Gleyic Luvisols (Loamic)

Habitat-types: 9120 - EEA: 6.6.2 (+91E0 - Alno-Padion - EEA: 6.5.9)

Vegetation types: *Fago-Quercetum (+ Alno-Padion)*

Official reserve status : 2003

Unmanaged since : 1972

Area was used as transcontinental radio transmission station until 1972. Intensive coppicing of the forest stands and mowing of the lanes with the pylons was done to keep vegetation low. No interventions in the forest stands since 1972. In 2006-2007, however, (immediately after the 2006 inventory) the intermixed *Prunu* atment of the stumps) as an introductory measur

Non-intervention (18)

Non-intervention + extensive grazing (8)

Mowing of some of the lanes between the a 2000 m²) cut and sod-cutted for experimental r a

Coppice-with-standards (7)

Last commercial harvest/planting interve

CwS + extensive grazing (7)

Intensive harvest of coppice to keep vege smission function.

Spontaneous afforestation + ext. grazing (27)

Specifications for this survey:

Number of circular plots : 30 plots - divergent plot size and threshold due to earlier measurements - plot radius 15m: living tree threshold DBH 5 cm; dead wood DBH 10 cm for the whole plot; regeneration and vegetation in 2006 and 2016 using standard method (Circle A1 and A2; vegetation plot 16x16m).

Additional : Strip-transect 10x340m (34 subplots starting at south-west end) - surveyed in 1986, 1996,2006 and 2016. Subplot measurements as in core area subplots.
Core Area : NONE

Survey years (up to 2020):

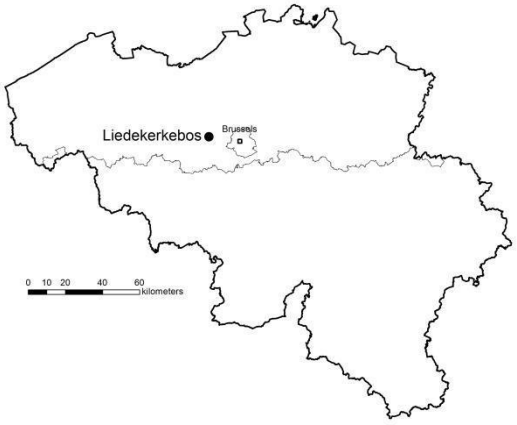
Dendrometrics circular plots : living trees : 1986 -1996 - 2006 - 2016; dead wood 2006, 2016

Dendrometrics transect : living trees : 1986 -1996 - 2006 - 2016; dead wood 2006, 2016

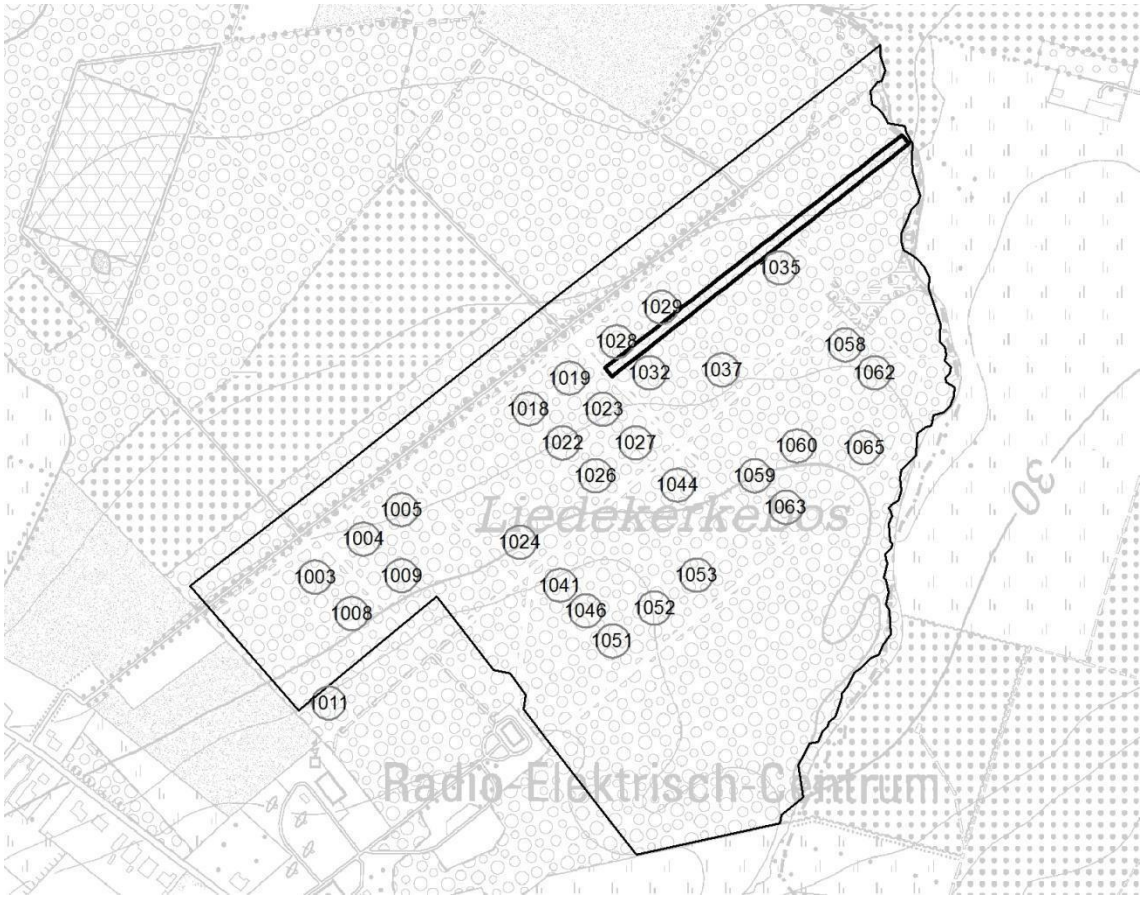
Vegetation circular plots and transect : 2006 - 2016

Maps

Location within Belgium :



Map of the site with grid of circular plots (plot numbers) and transect



 https://doi.org/10.21436/inbor.38677490

11.14 WITHOEFSE HEIDE

Basic information on the site :

Surface area: ca. 18 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,4493598938 N: 51,3708992004

Altitude : 24-26 m ASL

MAT : 9.9 °C **MAP:** 792 mm/y

Soil types : Zcgb and Zdgb : Albic and Gleyic Podzols (Arenic)

Habitat-types: Rbb Ppm (spontaneous Pine-birch forest)- EEA: 6.14.1 (+9190 EEA: 6.4.1)

Vegetation types: *Pinetum; Betulo-Quercetum*

Official reserve status : 1994 (Nature reserve) - non-official reserve status since 1984

Unmanaged since : 1943

Spontaneous afforestation after forest fire - no harvest interventions (some firewood collection in the 1960's and 1970's) - mowing of pathways until 1980'ies. Around 2000: removal and stump treatment of *Prunus serotina* (very limited in the reserve).

Last commercial harvest/planting intervention: none

Specifications for this survey:

Number of circular plots : 29 plots - divergent plot size and threshold due to earlier measurements (S. Vandewiele) - plot radius 20 m

Trees:

2002 : living tree threshold DBH 10 cm; dead wood S&L : DBH 10 cm for the whole plot;

2012 : living trees threshold DBH 10 cm; dead wood S&L : 10 cm

Regeneration : R=20m: count per species in 3 height classes : 0-50 cm, 50-130 cm and >130cm

Vegetation plot : standard plot 16x16m : 2003

Core Area : NONE - one transect 10x100m ('mycotransect') measured only in 2006 (10 subplots according to standard measurements in core area subplots)

Survey years (up to 2020):

First survey of dendrometrics (non-permanent plots): 1976.

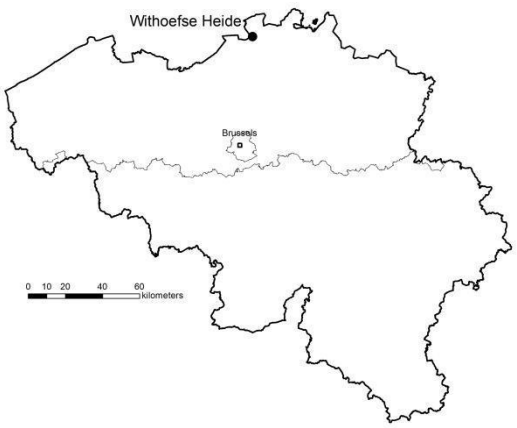
Dendrometrics circular plots : 2002; 2012

Dendrometrics transect : 2006

Vegetation : 2003 (not repeated in 2013)

Maps

Location within Belgium :



Map of the Site with grid of circular plots (plot numbers) and transect

 https://doi.org/10.21436/inbor.38677490

11.15 COOLHEMBOS

Basic information on the site :

Surface area: ca. 78 ha, 50 ha unmanaged

Co-ordinates of the Centroid (WGS84-decimal): E: 4.314138 N:51.075599

Altitude : 2-5 m ASL

MAT : 9.8 °C **MAP:** 780 mm/y

Soil types : vLgp - Fluvic Reductigleyic Mollic Gleysols (Loamic, Thaptohistic)

Habitat-types: 91E0 - EEA: 6.14.1 (+9190 EEA: 6.4.1)

Vegetation types: *Carici elongatae - Alnetum*

Official reserve status : 1995

Unmanaged since : 1993

Coppice management; after WWII only coppicing for hunting purposes; after acquisition by the Flemish Government (1991), one commercial harvest of 94 poplar trees (and a little coppice) was performed.

Last commercial harvest/planting intervention: 1993

Specifications for this survey:

Number of circular plots : NONE

Core Area : two smaller core areas (50x100m) -

Western Core Area = typical mesotrophic swamp forest (Carici elongatae Alnetum)

Eastern Core Area = dryer form with oak, alder and Osmunda regalis

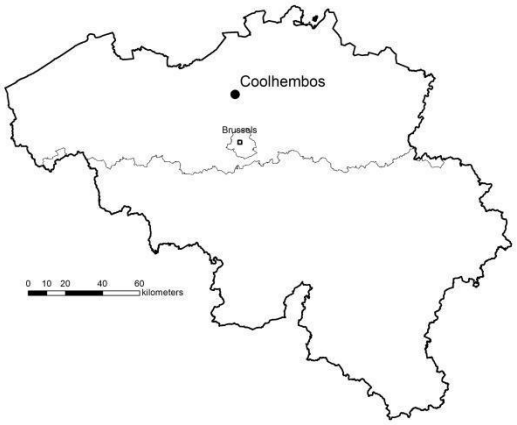
Survey years (up to 2020):

Dendrometrics : 2004/05, 2014/15

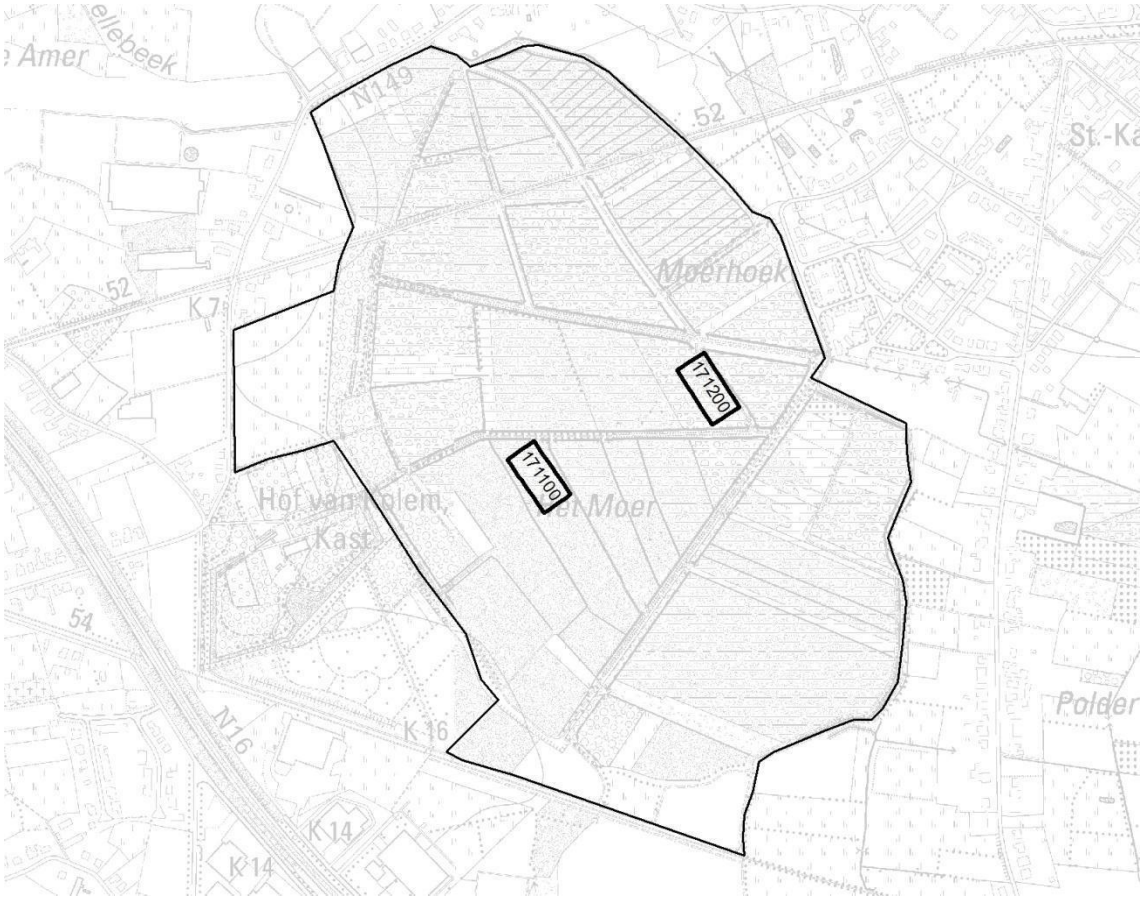
Vegetation : 2004, 2014

Maps

Location within Belgium :



Map of the site with the two Core areas



https://doi.org/10.21436/inbor.38677490

11.16 RODEBOS

Basic information on the site :

Surface area: full area ca. 90 ha, survey area = ca. 15 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4.314138 N:51.075599

Altitude : 50-70 m ASL

MAT : 10.0 °C **MAP:** 764 mm/y

Official reserve status : 1989

Unmanaged since : halfway 1980's

Specifications for this survey:

Number of circular plots : NONE

Core Areas : two sampling areas, originating from previous surveys by Koop et al (1991).

Large Core Area '41000' (70x140m):

Soil type : A/L; Ada - Gleyic Luvisols (Siltic);

vegetation = 9120; Fago-Quercetum

Measurements : First measured by Koop in 1991; trees >5 cm DBH, dead wood, vegetation in central transect 2x100m

Measurement in 2001 and 2011/12 : full core-area according to standard measurements (dendrometrics and vegetation in 98 subplots 10x10m) (DBH threshold 5 cm)

Vegetation: 50 subplots 2x2m (1991), 10 subplots 2x10m and 10x10m (2001); 98 subplots 10x10m (2012)

Regeneration: only cover estimated in 1991 and 2001; standard survey core area in 2011.

Small Core Area '43000' (50x100m) :

Soil type : LDp - Eutric Gleyic Cambisols (Loamic, Colluvic)+ luvisols;

vegetation = gradient Alno-Padion (91E0 - EEA 6.14.1) to Fago-Quercetum (9120 - EEA: 6.6.2)

Originally only a transect of 10x100m, measured by Koop (1991) (DBH threshold 5 cm)

Re-measured in 2001 (10x100m).

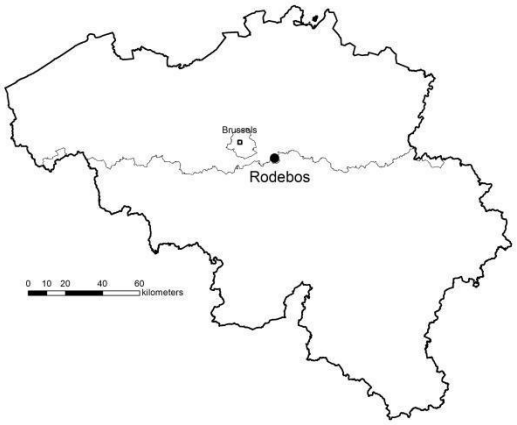
For the resurvey in 2011, it was decided to enlarge the transect to a 50x100m core area with 50 subplots (10x10m). Subplots surveyed as in a standard core area (dendrometry+ regeneration + vegetation).

Vegetation: 50 subplots 2x2m (1991), 10 subplots 2x10m and 10x10m (2001); 50 subplots 10x10m (2012)

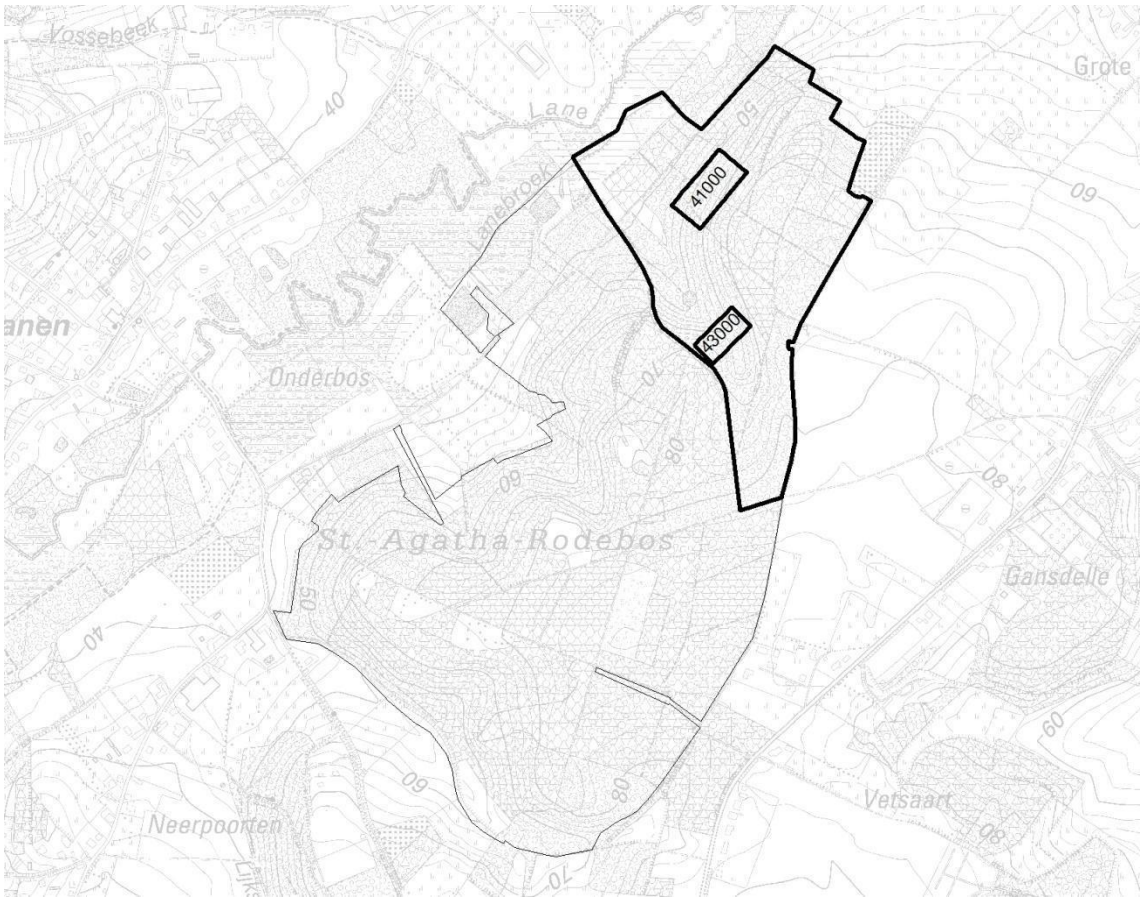
Regeneration: only cover estimated in 1991 and 2001; standard survey core area subplots in 2011.

Maps

Location within Belgium :



Map of the site with large and small Core area



 https://doi.org/10.21436/inbor.38677490

11.17 WALENBOS

Basic information on the site :

Surface area: full area ca. 300 ha, surveyed area = 1 core and 1 transect

Co-ordinates of the Centroid of the core area (WGS84-decimal): E: 4.865944 **N**: 50.928474
Altitude : 25-30 m ASL

MAT : 10.0 °C **MAP:** 800 mm/y

Official reserve status : 1989

Unmanaged since : halfway 1980's

Specifications for this survey:

Number of circular plots : NONE

Core Areas :

Large Core Area '41000' (70x140m):

Soil type : V - Dystric Rheic Sapric Histosols

vegetation = 91E0 - mesotrophic swamp forest and Alno-Padion

Dendrometrics : First measured by Koop in 1991; trees >5 cm DBH, dead wood; re-measured in 2001 and 2011/12 : full core-area according to standard measurements (DBH threshold 5 cm)

Vegetation: 50 subplots 2x2m (1991), 10 subplots 2x10m and 10x10m (2001); 98 subplots 10x10m (2012)

Regeneration: only cover estimated in 1991 and 2001; standard survey core area in 2011.

Transect (10x100m) : 'Oligotrophic transect'

Soil type : Edb - Gleyic Umbrisols (Loamic)

vegetation = 91E0 - oligotrophic swamp forest

Transect of 10x100m, measured by Koop (1991) (DBH threshold 5 cm), remeasured in 2001 and 2011(10x100m). For the resurvey in 2011, it was checked if there was a possibility to enlarge the transect to a 50x100m core area with 50 subplots (10x10m), but due to limited accessibility and homogeneity, this was not possible. Subplots in 2011 surveyed as in a standard core area (dendrometry+ regeneration + vegetation).

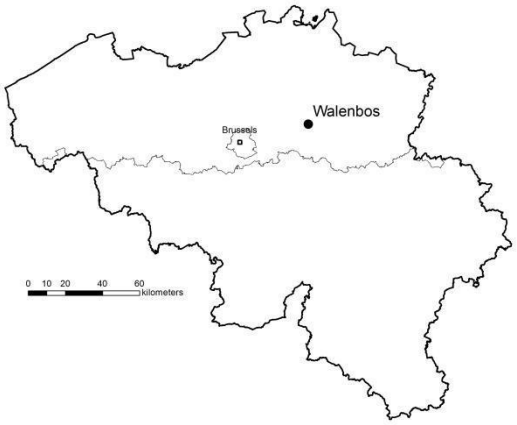
Vegetation: 50 subplots 2x2m (1991), 10 subplots 2x10m and 10x10m (2001); 50 subplots 10x10m (2012)

Regeneration: only cover estimated in 1991 and 2001; standard survey core area subplots in 2011.

Remark: In 1991 and 2001 an additional 'Mesotrophic transect' (10x100m) was monitored, located west of the Core Area. This transect was no longer measured in 2011-2012.

Maps

Location within Belgium :



Map of the site with large Core area and transect

https://doi.org/10.21436/inbor.38677490

11.18 HANNECARTBOS

Basic information on the site :

Surface area: full area ca. 40 ha, surveyed area = 1 small core area of 50x100m

Co-ordinates of the Centroid of the core area (WGS84-decimal): E: 2.700425 N: 51.130789,

Altitude : 25-30 m ASL

MAT : 10.0 °C **MAP:** 600 mm/y

Official reserve status : 1989

Unmanaged since : halfway 1980's

Specifications for this survey:

Number of circular plots : NONE

Core Areas :

Small Core Area '31000' (50x100m):

Soil type : d.Db - Calcaric Planosols (Arenic, Ruptic)

vegetation = wet dune forest 2180 and 91E0 - mesotrophic swamp forest

Dendrometrics : First measured by Koop in 1991; trees >5 cm DBH, dead wood,

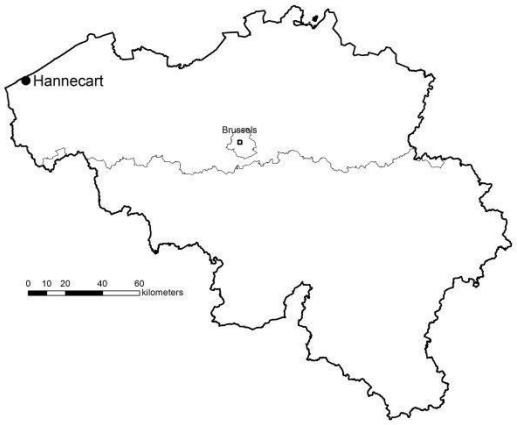
Re-measured in 2001 (10x100m). In 2011, this transect was enlarged to a core area of 50x100m; standard measurements for core-area subplots.

Vegetation: 50 subplots 2x2m (1991), 10 subplots 2x10m and 10x10m (2001); 50 subplots 10x10m (2012)

Regeneration: only cover estimated in 1991 and 2001; standard survey core area in 2011.

Maps

Location within Belgium :



Map of the site with Core area

https://doi.org/10.21436/inbor.38677490

11.19 SONIAN FOREST : SFR JOSEPH ZWAENEPOEL (INCLUDING HARRAS AND KERSSELAERSPLEYN)

Basic information on the site :

Surface area: 230 ha

Co-ordinates of the Centroid (WGS84-decimal): E: 4,4137201309 N: 50,7569007874,

Altitude : 88-125 m ASL

MAT : 9.8 °C **MAP:** 840 mm/y

Soil type : Abc - Dystric Glossic Fragic Retisols (Siltic) (+ Acp - Eutric Cambisols (Siltic))

Official reserve status : 1995 - extension: 2010

Unmanaged since :

- 'core area' unmanaged since 1983.
- Official reserve 'Kersselaerspleyn' (100ha) unmanaged since 1993.
- Reserve part 'Harras' (30ha) also mainly unmanaged since 1993, except small area with Cws restoration experiment (1995-2000), abandonded and since then unmanaged
- Extension area (2010) last intervention (thinning) in 2005-2008.

Previous management : originally managed as 'tire-et-aire' (= can be compared with Coppice with standards, but with rotation of 80-100 years - no coppice with resprouts but natural reforestation mainly with beech) until beginning of 20th century. Since that time, until establishment of non-intervention: selective thinnings and group final fellings with replanting (until 1980's). Salvation harvest of wind-felled trees (mainly storms of 1991).

Southern part of 'Kersselaerspleyn' was the last 'tire-et-aire' cut in 1908, replanted with mixed tree species.

Reserve consists of a mixture of overmature beech stands (200-250 year old), oak stands (Harras : ca. 200 year old) intermixed with younger stands after final harvest of the old beeches during 19th and first half of 20th century.

Specifications for this survey:

This is our 'master site' with a very wide range of measurements

Circular plots : 150 plots (64+86)

Circular plots are larger than standard plots, and use different threshold size (due to extraordinary size of the trees) - Base Grid = 100x100m

Circle A4 : (2000, 2010, 2020) : radius 30m (= 2827m²), threshold DBH = 30 cm
Circle A3 : (2010, 2020) : radius 12m (= 452.4m²), threshold DBH = 5 cm
Circle A1 and A2 (2010, 2020): radius 3m and 6m

Circle A1-A3 at first survey (2000; only Kersselaerspleyn): A1 = 2.25m, A2= 4.5m, A3 = 9m

Dendrometrics in CP :
- Kersselaerspleyn (excluding 'core area') : A1-A4 in 2000/01, 2010/11 and 2020/21
- Core Area : A1-A4 in 2010/11 and 2020/21; in 2000/01 only data on Circle A4 (threshold DBH=30 cm) generated by GIS from the core-area full survey
'extension' and 'Harras' : A1-A4 only in 2020/21.

Vegetation plots in these circles = standard 16x16m, similar recording periods as dendrometrics (spring and summer 2011 and 2021; in 2001 only summer vegetation recording). Additional: vernal flora in circular plots of 'Kersselaerspleyn' (incl. core area) may-2015.

Large Core Area : 10.75 ha

Dendrometrics : Full survey of all trees (L+D) with DBH>30cm in 1986-87; revisited in 1991 to record windthrown trees due to windstorms of february 1991 (Vivian & Wiebke). Volume calculations with tariffs (Van den Berge et al. 1990; 1992).

In 2000/01 : re-survey of full area, with DBH threshold of 30 cm, trees of 10-30 cm counted, not positioned; smaller trees not surveyed in full area but in subsamples (see regeneration).

2010 and 2020 : full survey of all trees (L+D) with DBH>5cm.

Regeneration: counted in standard height classes in subplots: 750 plots of 10x10m in 2001; selection of 140 subplots (every 5th row) of 10x10m in 2010/11 and 2020/21 (see transects on map)

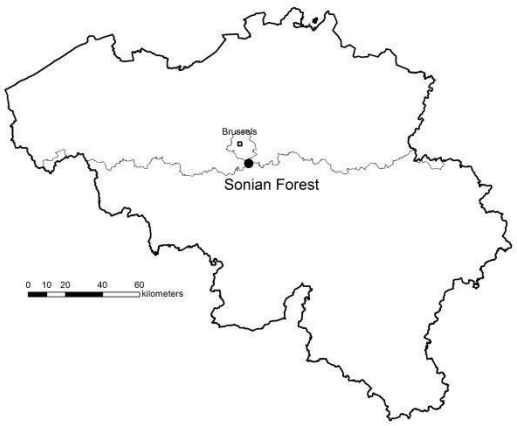
Vegetation : standard relevé on 10x10m subplots: 750 plots, only summer survey in 2001; 140 plots in 2011 and 2021 - spring and summer survey; additional survey in spring 2015 (vernal flora).

Standard Core Area 'Harras' : 70x140m

Standard measuring protocols of core-area subplots for dendrometrics, vegetation and regeneration in 2008/09 and 2018/19.

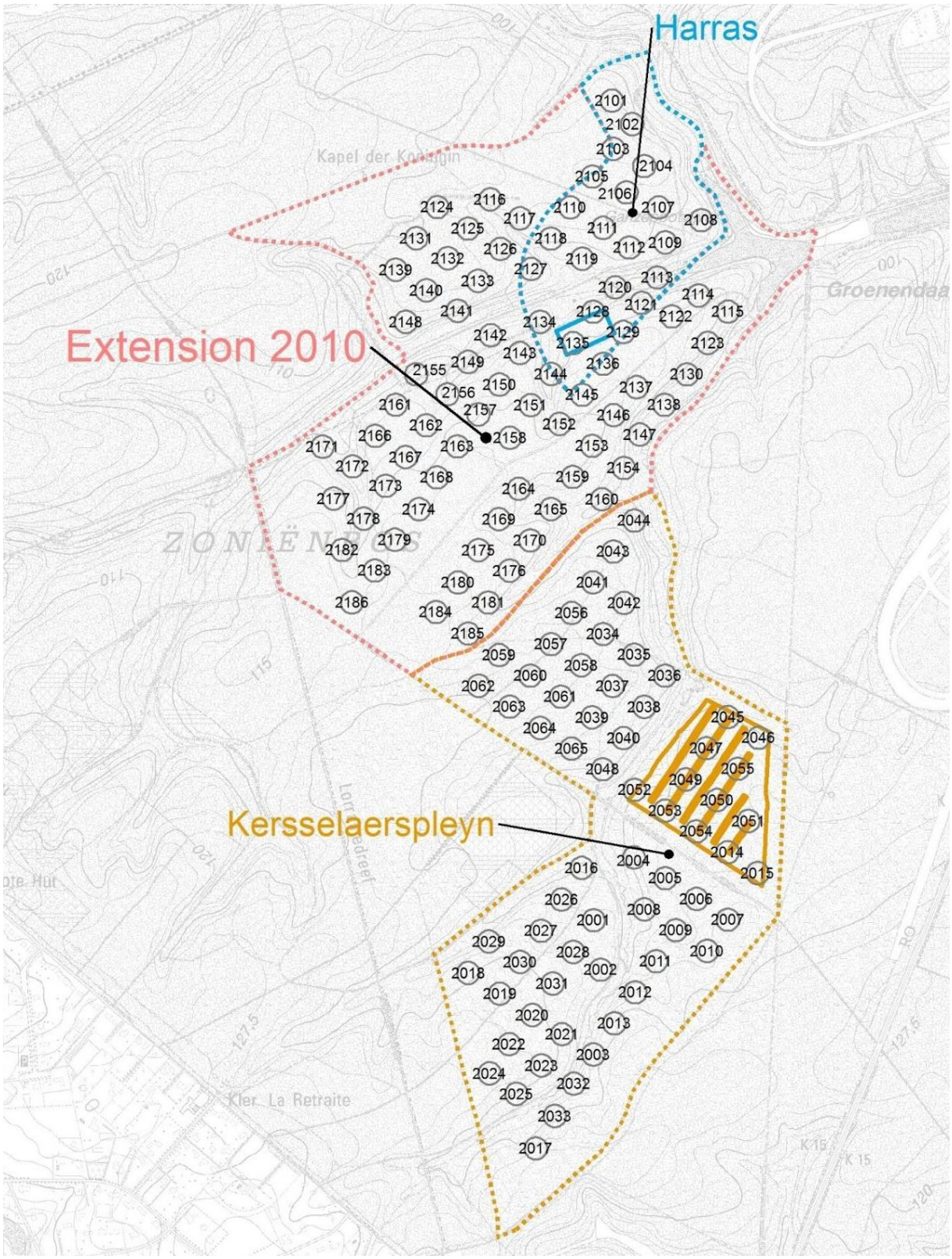
Additional standardised surveys of vascular plants, fungi, bryophytes and lichens on dead wood in 2001 and 2016-2021 on selected trees over the full extent of the reserve, but mainly in the core area.

Maps - Location within Belgium :



 https://doi.org/10.21436/inbor.38677490

Map of the Site showing the different sub-areas, grid of circular plots (with plot numbers), large core area (trapezium shape) and Harras standard core area



11.20 *EXTRA* : PEERDSBOS- RESEARCH SITE 'BOSWACHTER'

Basic information on the site : research plot of University of Antwerp (Evolutionary Ecology Group, Department of Biology)

Surface area: research plot full area ca. 10 ha

Co-ordinates of the Centroid of the core area (WGS84-decimal): E: 51.272681, N: 4.488357

Altitude : 8-9 m ASL

MAT : 10.0 °C **MAP:** 785 mm/y

Official reserve status : none

Unmanaged since : NA - no interventions over the last decade

Specifications for this survey:

Number of circular plots : NONE

Core Areas :

One large 'core-area' of approximately 10 ha

Soil type : Sep - Dystric Fluvic Gleyic Cambisols; - Calcaric Planosols (Arenic, Ruptic)

vegetation = acidophyllous oak-beech forest (9120)

Dendrometrics : tree positioning, species, DBH and tree code of all trees with DBH>20 cm (dominant tree layer -mainly oaks and beeches), in total 1558 trees in sept/oct 2017.

Tree DBH was already measured once before in 2010 and linked to tree ID-code (by Univ. Antwerp).

Budburst data were collected by Univ. Antwerp for all deciduous trees in 2010, and for a selection of trees in 2009 and 2017. In 2010, all trees were visited 5–6 times between 23 March and 19 May, with most frequent observations (three visits per tree) between 22 April and 6 May. One overall score was given per tree, on a scale from 0 to 6.

Breeding success of *Parus major* and *Parus caeruleus* in nest boxes attached to a selection of trees is performed yearly from 1997 to 2017. For this purpose, a constant set of 118 nestboxes were operational in the study plot, linked to a specific tree ID. A third of the boxes had small (26 mm) entrances (evenly spaced across the plot) allowing access to Blue Tits only.

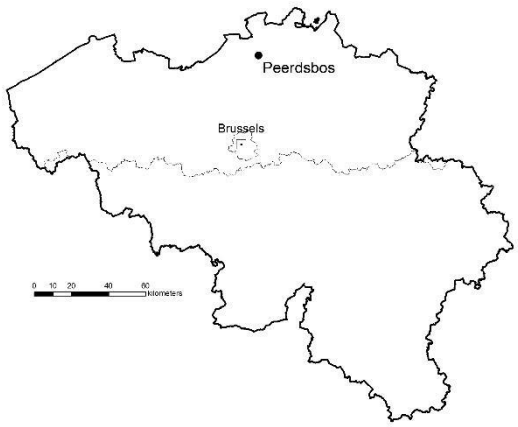
More information: see:

Adriaensen & Van de Kerckhove (2019) Fenologie in onze bossen, … over bomen en mezen. Bosreservatennieuws 16, 24-27.

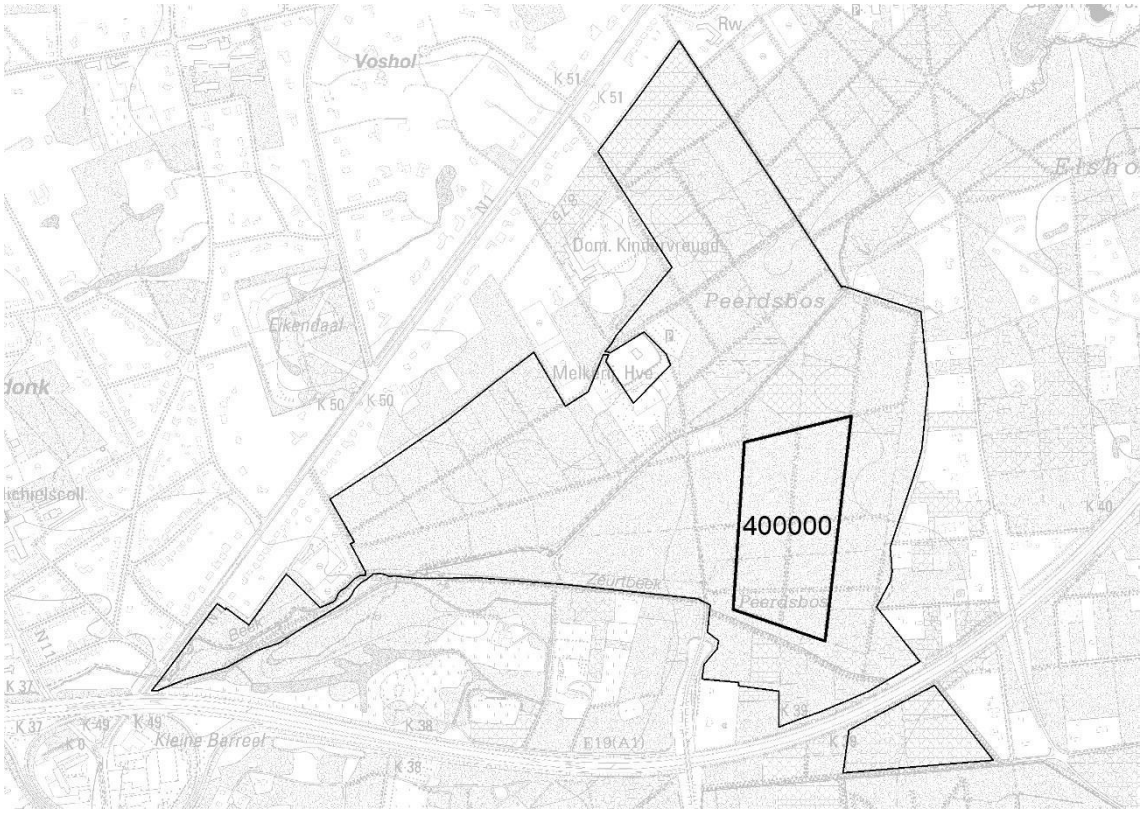
Matthysen E., Adriaensen F., Vandekerkhove K. & Van de Kerckhove P. (2021) Great and blue tit laying dates vary with fine-scale variation in local tree composition but not tree budburst. Journal of Ornithology.

Maps

Location within Belgium :



Location of the research plot 'Boswachter' (code 400000) within Peerdsbos



12 REFERENCES

Albrecht, L. 1990. Naturwaldreservate in Bayern - Schriftenreihe, Band 1 - Grundlagen, Ziele und Methodik der waldökologischen Forschung in Naturwaldreservaten. Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten

Althoff, B., Hocke, R. & Willig, J., 1993. Naturwaldreservate in Hessen. Waldkundliche Untersuchungen, Grundlagen und Konzept. Mitteillungen der Hessischen Landesforstverwaltung, Band 25. Wiesbaden, Hessische Landesforstverwaltung.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2004a. Bosreservaat Everzwijnbad : basisrapport: situering, standplaats, vegetatie, historiek en onderzoek. Rapport IBW.Bb.R.2004.006, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2004b. Bosreservaat Wijnendalebos : basisrapport: situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2004.009, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2004c. Bosreservaat De Heirnisse : basisrapport: situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2004.18, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2006a. Bosreservaat Jansheideberg (Hallerbos): basisrapport: situering, standplaats, historiek en onderzoek. Rapport INBO.R.2006.13, Instituut voor Natuur- en Bosonderzoek.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2006b. Bosreservaat Bos Ter Rijst (Heikruis): basisrapport: situering, standplaats, historiek en onderzoek. Rapport INBO.R.2006.15, Instituut voor Natuur- en Bosonderzoek.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K. & Walleyn, R., 2007. Bosreservaat Pruikenmakers (meerdaalwoud): basisrapport: situering, standplaats, historiek en onderzoek. Rapport INBO.R.2007.44, Instituut voor Natuur- en Bosonderzoek.

Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Vandekerkhove, K., 2002. Bosreservaat Kersselaerspleyn: basisrapport: algemene situering, standplaatsbeschrijving, historische kadering en overzicht: wetenschappelijk onderzoek. Rapport IBW.Bb.R.2002.005, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., De Keersmaeker, L., Walleyn, R., Van de Kerckhove, P., Christiaens, B., Esprit, M. & Vandekerkhove, K., 2003a. Monitoring van een transect in het Vlaams natuurreservaat Hannecartbos: basisrapport: situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2003.012, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., De Keersmaeker, L., Walleyn, R., Van de Kerckhove, P., Christiaens, B., Esprit, M. & Vandekerkhove, K., 2003b. Monitoring van kernvlakte en transecten in het Vlaams natuurreservaat Rodebos en Laanvallei: basisrapport: situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2003.013, Instituut voor Bosbouw en Wildbeheer.

Baeté, H., De Keersmaeker, L., Walleyn, R., Van de Kerckhove, P., Christiaens, B., Esprit, M. & Vandekerkhove, K., 2003c. Monitoring van kernvlakte en transecten in het Vlaams natuurreservaat Walenbos: basisrapport: situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2003.014, Instituut voor Bosbouw en Wildbeheer.

Berben, J., 1983. Dendrometrische studie van de Corsikaanse den, LISEC, Genk.

Bijlsma, R.J. & Clerkx A.P.P.M., 2019. The Dutch forest reserves network: Documentation of monitoring design and databases. Wageningen Environmental Research Report 2940.

Bücking, W., 1989. Bericht des Landes Baden-Württemberg über den Stand den Einrichtung, Sicherung, Bestandserfassung und Dauerbeobachtungen von Naturwaldreservaten. Natur und Landschaft 64(12): 550-553

Christensen, M. & Vesterdal, L., 2003. Physical and chemical properties of decaying beech wood in two Danish forest reserves. Nat-Man Working Report 25. University of Copenhagen, Denmark.

Cools, N. & De Vos. B., 2016. Part X: Sampling and Analysis of Soil. In: UNECE ICP Forests Programme Coordinating Centre (ed.) Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany.

Cools, N., Verstraeten, A., Sioen, G., Neirynck, J., Roskams, P., Louette, G.& Hoffmann, M., 2016. LTER-Belgium - Results of long-term, large-scale and intensive monitoring at the Flemish forest condition monitoring sites within the LTER-Belgium network. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2016 (INBO.R.2016.11433903). Instituut voor

Natuur- en Bosonderzoek, Brussel.

Dagnélie, P., Palm, R., Rondeux, J., Thill, A., 1985. Tables de cubage des arbres et des peuplements forestiers. Les presses agronomiques de Gembloux, Gembloux, Belgium.

De Keersmaeker, L., Van de Kerckhove, P., Baeté, H., Walleyn, R., Christiaens, B., Esprit, M. & Vandekerkhove, K., 2005. Monitoringprogramma integrale bosreservaten: inhoudelijk programma en basishandleiding. Rapport IBW Bb.R.2005.003. IBW, Geraardsbergen, Belgium.

Dhiedt, E., De Keersmaeker, L., Vandekerkhove, K., Verheyen, K., 2019. Effects of decomposing beech (*Fagus sylvatica*) logs on the chemistry of acidified sand and loam soils in two forest reserves in Flanders (northern Belgium). Forest Ecology and Management 445, 70–81

Dik, E.J., 1990. De schatting van volumes en werkhoutlengten bij populier. De Dorschkamp, rapport nr 590, Wageningen, 52p.

Govaere, L. & Vandekerkhove, K., 2005. Biotoopkartering. Specifiek biotoop- en soortenbeheer in bossen : methodologische ondersteuning. Deel I : Methodiek en Deel II: Biotoopfiches, soortenliJsten en invulformulieren.

Hammond, W., Stone M., Stone P., 2020. Picture worth a thousand words: Updating repeat photography for 21st century ecologists. Ecology & Evolution 10: 14113–14121.

Hendrick, L. & Copenheaver C., 2009. Using repeat landscape photography to assess vegetation changes in rural communities of the Southern Appalachian mountains in Virginia, USA. Mountain Research and Development 29, 21-29.

Hochbichler, E., O'Sullivan, A., van Hees, A. & Vandekerkhove, K., 2000. Recommendations for data collection in forest reserves, with an emphasis on regeneration and stand structure. In : European Community, Directorate General for Research (2000) Forest Reserves Research Network COST-action E4. EUR19550. Brussels, European Communities.

Kärcher, R. & Förster, M., 1994. Waldschutzgebiete Baden-Württemberg: Anweisung für Vermessung und Aufnahme. Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Abteilung Botanik und Standortskunde, Freiburg, 61pp.

Kätzler, W., 1984. Zur forstlichen Aufname der Bannwälder in Baden-Württemberg. Mitteilungen der Forstlichen Versuchs- und Forschungsanstalt Baden-Württemberg, 108, 123-130.

Keller, M. (Red), 2005. Schweizerisches Landesforstinventar. Anleitung für die Feldaufnahmen der Erhebung 2004-2007. Birmensdorf, Eidg. Forschungsanstalt WSL, 393pp.

Koop, H., 1989. Forest Dynamics, SILVI-STAR: A comprehensive Monitoring System. Springer Verlag, Berlin

Koop, H., Leten, M., Boddez, P., Tielens, T.& Hermy, M., 1992a. Bosstructuur en soortensamenstelling van het Hannecartbos. Rapport IN A92.71. Instituut voor Natuurbehoud (Hasselt)

Koop, H., Leten, M., Boddez, P., Tielens, T.& Hermy, M., 1992b. Bosstructuur en soortensamenstelling van het Walenbos - monitoring van bosstaatsnatuurreservaten in Vlaanderen. Instituut voor Natuurbehoud, Hasselt

Koop, H., Leten, M., Boddez, P., Tielens, T.& Hermy, M., 1992c. Bosstructuur en soortensamenstelling van het Rodebos – monitoring van bosstaatsnatuurreservaten in Vlaanderen. RIN-rapport 92/27 (NL), IN-rapport A92/71a (B.

Korpel', S., 1995. Die Urwalder der Westkarpaten. Gustav Fischer Verlag, Stuttgart, Germany

Kramer, H. & Akça, A., 1982. Leitfaden für Dendrometrie und Bestandsinventur. Frankfurt, 251pp.

Lambinon, J., De Langhe, J.-E., Delvosalle, L. & Duvigneaud, J., 1998. Flora van België, het Groothertogdom Luxemburg, Noord-Frankrijk en de aangrenzende gebieden - derde druk. Belgian Botanical Garden, Meise, Belgium.

Leibundgut, H., 1956. Empfehlungen für die Baunklassenbildung und Methodik bei Versuchen über die Wirkung von Waldpflegemassnahmen. IUFRO section 23, report 10.

Leibundgut, H., 1982. Europäische Urwälder der Bergstufe. Verlag Paul Haupt, Bern, Switzerland and Stuttgart, Germany.

Londo, G., 1984. The decimal scale for relevés of permanent quadrats. In: Knapp R (ed) Sampling methods and taxon analysis in vegetation science. Dr. W. Junk Publishers, The Hague, The Netherlands, pp 45-49

Mayer, H., 1976. Richtlinien für die schaffung von Waldreservaten. Oslo, IUFRO-world congress 1976, proceedings of working group nr 1, ecosystems, 100-105.

Mountford, E.P., Peterken, G.F., Edwards, P.J. & Manners, J.G., 1999. Long-term change in growth, mortality and regeneration of trees in Denny Wood, an old-growth wood-pasture in the New Forest (UK). Perspectives in Plant Ecology, Evolution and Systematics 2(2), 223-272.

Parviainen, J., Bücking, W., Vandekerkhove, K., Päivinen, R. & Schuck, A., 2000. Strict Forest Reserves in Europe : efforts to enhance biodiversity and research on forests left for free development in Europe (EU-COST-action E4) Forestry 73, 107-118

Peterken, G.F. and Backmeroff, C.E., 1988. Long-term monitoring in unmanaged woodland nature reserves. Research and Survey in Nature Conservation No. 9. Peterborough, Nature Conservancy Council.

Projektgruppe Naturwaldreservate, 1993. Empfehlungen für die Einrichtung und Betreuung von Naturwaldreservaten in Deutschland. Forstarchiv 64, 122-129

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).

Richter, A. & Grossmann, H., 1959. Untersuchungen über Probekreisgrösse und Netzpunktdichte bei Holzvorratsinventuren. Arch. Forstwes. 8, 976-1016.

Smets, K., Baeté, H., Christiaens, B., De Keersmaeker, L., Esprit, M., Van de Kerckhove, P., Walleyn, R. & Vandekerkhove, K., 2005. Bosreservaat Coolhembos : basisrapport : situering, standplaats, historiek en onderzoek. Rapport IBW.Bb.R.2005.014, Instituut voor Bosbouw en Wildbeheer

Spurr, S.H., 1952. Forest Inventory. New York, The Ronald Press Company, 476 p.

Van Den Berge, K., Roskams, P., Verlinden, A., Quataert, P., Muys, B., Maddelein, D., Zwaenepoel, J., 1990. Analyse van een bosreservaat in een 215-Jarig bestand in het Zoniënwoud. Rapport Werkgroep Sociale en Economische Betekenis van het Bos 17. Ministerie van de Vlaamse Gemeenschap

Van Den Berge, K., Maddelein, D. & Muys, B., 1992. Recent structural changes in the beech forest reserve of Groenendaal (Belgium). In: Broekmeyer M, Vos W., & Koop, H. (Eds) European Forest reserves Proceedings of the European Forest Reserves Workshop 6-8 May 1992, 195-198. Wageningen, Pudoc.

Van Den Meersschaut, D. & Lust, N., 1997a. Ontwikkeling van een methodiek voor de monitoring van de bosreservaten in Vlaanderen : Vergelijking van de monitoringsmethodiek voor bosreservaten in Nederland en Beieren (Duitsland) – Literatuurstudie. Gent, Laboratory for Forestry, University Ghent.

Van Den Meersschaut, D. & Lust, N., 1997b. Monitoring van de bosstructuur en de bossamenstelling in het RTT-domein van Liedekerke. Methodologische studie. Gent, Laboratory for Forestry, University Ghent.

Van Den Meersschaut, D., De Cuyper, B., Vandekerkhove, K. & Lust, N., 1999. Monitoring natural stand change in the forest reserve of Liedekerke, Flanders (Belgium). Silva gandavensis 64, 1-16.

Van Den Meersschaut, D., De Cuyper, B., Vandekerkhove, K. & Lust, N., 2000. Required sample size for the monitoring of stand dynamics in strict forest reserves : a case study. In : Hansen & Burk (Eds). Integrated tools for natural resources inventories in the 21st century. Proceedings of the IUFRO conference, August 16-20, 1998 - Boise, Idaho, USA USDA Forest Service North-Central Research Station – General Technical Report NC212, 185-191.

Vandekerkhove, K., 1998. Criteria voor de selectie van bosreservaten in functie van een betere kadering van de Vlaamse bosreservaten in een Europees netwerk. Mededelingen IBW 1998/3, 113pp.

Vandekerkhove, K., De Keersmaeker, L., Christiaens, B., Esprit, M., Leyman, A. & Van de Kerckhove, P., 2012. Bosreservaat Sevendonk: eerste inventarisatie van de dendrometrische gegevens en de vegetatie in steekproefcirkels en twee kernvlaktes in het onbeheerde reservaatsdeel. Rapport INBO.R.2012.29, Instituut voor Natuur- en Bosonderzoek.

 https://doi.org/10.21436/inbor.38677490