COST Action E4

FOREST RESERVES RESEARCH NETWORK

WG2 "Recommendations for Data Collection in Forest Reserves, with an Emphasis on Regeneration and Stand Structure"

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CONTENTS

1 Introduction

The purpose of this paper is to present some recommendations on the methods to be used in the establishment and design of stand inventories, as a basis for research in forest reserves. This paper has been compiled as part of the output from COST Action E4: "Forest Reserves Research Network" (*COST Action E4, Forest Reserves Research Network: Final Report Summary*), and should be viewed in context with the other documents produced by COST Action E4.

Forest reserves encompass a wide range of forest types across Europe, all of which have a varied history in terms of anthropogenic influence and disturbance throughout the past. Truly natural forests are rare in Europe. Thus, there are many instances where forest reserves include degraded forests. Although these are not truly natural or "virgin" forests, they may be the most natural forests remaining in a particular geographic region. This report refers to research in all forests that are left to natural development.

There is much we can learn from observing natural stand development in an objective and scientific manner. The pattern of natural forest dynamics may hold valuable lessons for silviculture and forest management, while an understanding of natural processes is central to the effective conservation and protection of rare forest habitats. The combination of conservation and forestry objectives was a primary feature of COST Action E4, and is reflected in the methodology presented in this report. The principle of mimicking natural processes is at the root of current international moves to encourage sustainable forest management.

In order to achieve the aims of E4, three Working Groups (WG's) were established. The discussions that took place in these Working Groups highlighted the many difficulties that arise when attempting to create international networks. Each country has its own agenda, or programme, in relation to natural forests, their protection and management. The status and definition of "natural forests" varies widely between countries. It was the job of Working Group I to try to harmonise the terminology used and to facilitate an international understanding of the status of natural forests (*COST Action E4: Final Report, Working Group I*)[1]. The task of Working Group II was to standardise the methods used in scientific research in natural forests, in order to facilitate the comparison of data between countries (this report). Working Group III developed a database that provides an international link between research in natural forests (*COST E4: Final Report, Working Group III*). Data that have been collected according to the standards laid down in this report can therefore now be entered into a database that holds similar data for other European countries. This facilitates sharing of data, and comparison of results across a geographic range.

We would recommend that any group who are embarking on a programme of research in natural forests refer to the other COST Action E4 documents, to fully integrate their programme as much as possible into a European network. This maximises the potential return on an investment in research.

[1] NOTE: In this report of WGII, the term natural forest reserve (NFR) is used in a broad sense, to refer to any natural or semi-natural forest which is the focus of research on natural stand development. The actual nomenclature of forest reserves will vary for each country (see WGI Final Report).

2 Aims and Principles

2.1 Aims

It is very difficult to standardise the aims of research in forest reserves. The discussions that took place within WGII during its various meetings, for example, demonstrated the broad range of objectives that drive research in natural forests (Table 1).

Table 1. Range of Objectives and Applications of Research in Natural Forests

Research aims and objectives in forest reserves – some examples

- scientific research of natural/ecological processes
- long-term monitoring of natural development
- ecological inventories and biotope management
- assessment and maintenance of biodiversity (including genetic resources)
- response of forest dynamics to changing environmental factors

Main applications of research results

- conservation and/or restoration of representative or endangered forest ecosystems
- development of "close-to-nature" silvicultural management techniques
- afforestation (for example, the choice of tree species) and design of new forests
- recognise the ecological requirements of tree species and forest biotopes
- improved understanding of the processes at work in natural development
- observing forest stability in relation to environmental influences

It is recognised that individual research projects are generally aimed at addressing a clearly defined problem, and that the method of study used is largely determined by the research objectives. The aim of this report is to identify a minimum data set which should be collected from forest reserves. Adoption of a minimum, standard data-set will facilitate clearer interpretation of results and comparison of scientific data between different reserves and different countries (Table 2).

Table 2. Advantages of Standardised Data Collection Procedures

- Enables cross-comparisons of research data between reserves
- Provides comprehensive regional information
- Improves availability of information on:
    - a) distribution of tree species
    - b) growth rates of tree species
    - c) dynamic of forest change under different local or regional conditions
    - d) effects of different environmental influences based on tree species and/or forest communities

2.2 Principles

2.2.1 Parameters to be Measured in Natural Forests

There are many parameters that could be measured in order to describe the forest ecosystem. As mentioned above, the parameters measured often depend on the specific research objectives. However, of all possible features, the one that best characterises the condition of natural or semi-natural forests is vegetation.

Forest vegetation type determines the physical structure of the forest, and has a critical influence on the energy balance and food chain within the forest ecosystem. The dynamics of the forest ecosystem are driven by the processes of regeneration, competition between individuals, and senescence of tree species. In addition to the tree and shrub flora, the ground vegetation is also an important indicator of forest condition, in that it can indicate degree of human influence and regional patterns of variation. Furthermore, it is recognised that forest stand structure and vegetation are in close interaction with other components of the forest ecosystem (e.g. fauna).

For the reasons outlined above, it was decided among WGII to limit recommendations for forest reserve research to measurement of forest and ground vegetation:

The primary aims of the recommended research methodology are: to describe the forest stand structure (including dead wood), shrub layer, regeneration layer and ground vegetation, in such a way as to be able to repeat the measurements, and therefore to be able to observe, analyse and compare regeneration and stand structure development through time

What is essentially recommended is a forest inventory, focussing on a series of parameters which, in the experience of WGII members, are important in the context of forest development.

Long-term monitoring cannot answer all of the questions regarding forest ecology and development – research necessarily focuses on selected aspects of the forest. Also, the research methodologies in use are constantly being expanded and developed. Thus, the recommendations made here focus on the use of inventory methods which are well tried and readily available.

If it is possible to supplement the basic measurement of forest vegetation with other specific research methodologies, then this can enhance our understanding of natural forests. The following topics, for example, are important in forest reserves research, although specific recommendations on the methodologies to be adopted are beyond the scope of this report:

a) measurement of solar radiation
b) detailed ground vegetation monitoring (permanent plots, including lower plants)
c) measurements of physical and/or chemical parameters of site/soil
d) epiphytes (e.g. mosses, liverworts, lichens)
e) fauna inventory
f) litterfall
g) seed production

2.2.2 Planning a National Programme of Research in Natural Forests

Procedures for stand description vary widely between, and even within, countries. The approach used depends largely on the research objectives, the size of the forest reserve and the availability of funding. It is recognised by WGII that it may not be practical, from the point of view of the costs and labour required, to implement the approach described in this report in every forest reserve in the national network. Rather, the recommended procedures should be considered for implementation in selected "key" forest reserves. For example, it may be advantageous to target a suite of reserves that represent the full range of forest vegetation types which occur in the country.

In many countries, there are already procedures and experimental plots in place, which are focused on long-term monitoring of natural forests and which include stand descriptions. The protocol for existing recording schemes may differ from the recommendations presented in this report. It is not intended that existing experiments be significantly amended or abandoned if they don't conform to COST E4 recommendations. However, if new experiments are to be established, we would recommend that the COST E4 protocol be followed.

2.2.3 Summary

The principles underlying research in natural forests, as recommended by COST Action E4 are summarised in Table 3.

Table 3. Summary of Principles of Research in Natural Forests

- Stand description in permanently marked plots in natural and semi-natural forests (see *COST Action E4: Final Report, Working Group I*)
- Data collection using standardised procedures
- Comparison of data from within reserves, between reserves and between countries (see *COST Action E4: Final Report, Working Group III*)
- Replication of measurements or observations over time
- Establishment of a spatial and temporal network of forest reserves research
- Promoting the collection of quantifiable data, using an objective approach
- Application of clearer, more understandable methods and/or procedures
- Planning of forest reserves research at a practical level, in relation to the amount of work and costs involved

Two different levels of inventory within the forest are suggested. On the one hand is a representative description of the whole natural forest reserve (Section 3), while on the other hand are more detailed descriptions of selected parts of the forest (Section 4).

3 Description of Stand and Vegetation Characteristics in the Natural Forest Reserve (NFR)

3.1 Aims

A complete inventory of the whole natural forest reserve (NFR), while it would provide the greatest amount of information, is generally not feasible due to constraints of time and cost. Thus, the strategy recommended by COST E4 is: a) to establish a permanent network of Sample Plots over the NFR (see Section 3), and b) to supplement this with a number of larger permanent plots (Core Areas), in which complete inventories are made (see Section 4).

The methodology described here, in Section 3, is aimed at gathering data on site characteristics, forest vegetation and stand structure over the entire natural forest reserve (NFR). The aim is to gather data on the following parameters:

- general information (including mapping forest communities):
- site characteristics, e.g. topography, soils
- stand structure measurements, per hectare, for each species: number of stems; basal area; timber volume; volume of dead wood
- shrub structure: tree (shrub) species distribution and height (frequency classes)
- regeneration structure: tree (shrub) species distribution and height (frequency classes)
- ground vegetation: species lists; cover/abundance values; species distribution

3.2 General Information

As a preliminary step, the range of variation over the Reserve should be assessed by means of a survey to gather general information (Table 4). A general description of the NFR is helpful in choosing the inventory design.

Table 4. Summary of Principles of Research in Natural Forests

General information
name and number of the NFR
area of forest in NFR
protection status
date of the initial description of NFR
location (e.g. latitude/longitude, geographical region/district, forest area)
Site and soils
climate, altitude, exposure, slope, aspect, microclimate
geomorphology
geology
soil types
Mapping - site characteristics and soil types (Scale 1:5,000/10,000)
Forest vegetation community
vegetation relevés
Mapping – forest communities (Scale 1:5,000/10,000)

3.3 Inventory Design

Based on data from the general survey, above, decisions can be made regarding the design of the forest inventory, which forms the basis of recommended research in the NFR. The range of topographical variation in the NFR and the distribution of forest vegetation communities are important considerations. The inventory should be designed to ensure that the range of vegetation types present are sampled, while taking into consideration the amount of funding and time available for the research.

The basis of the recommended inventory design is the establishment of a systematic Grid Network, which covers the entire NFR, and which is permanently marked out on the ground. This is a fundamental element of the inventory design, and it ensures repeatability of the research. A series of circular Sample Plots are then located on the Grid Network (Fig. 1). The size and heterogeneity of the NFR will determine the scale and spacing of the grid, as well as the number and size of Sample Plots used. However, it is recommended that grid spacing and Sample Plot size should be chosen so that the total area sampled is 5-10% (preferably 10%) of the total NFR area. A recommended minimum Sample Plot density is 1 plot per hectare (ha), where 1 ha = 100m x 100m = 10,000m^2, with a Plot size of 500-1,000m^2, or greater. An important factor to consider when deciding Sample Plot size is tree density, i.e. no. trees/ha (Section 3.4.2).

The inventory design should be flexible. For example, the General Description of the NFR (Section 3.2) may reveal that one area within the NFR is relatively heterogeneous, in terms of its topography or of the number of vegetation communities present. The density of sample plots on the grid can be increased within that particular area, in order to sample properly the range of variation. In some cases, it may be necessary to choose smaller plots, for example, 250-300m^2 , on a denser grid, if that is what is required to gain representative samples. On the other hand, over a large, homogeneous area, it is possible to locate sample plots on the grid through a process of random selection. Data collection in Sample Plots is described in Section 3.4. In some instances, the establishment of a Grid Network on the ground may be impractical. For example, it may not be feasible to establish a grid in forests on very steep slopes in alpine areas. Accepting practical limitations, the recommended inventory design should be adapted accordingly.

Recommendations by WGII on inventory design are summarised in Table 5.

The Working Group gave a “high priority” rating to the use of a Grid Network with Sample Plots (Table 5). In contrast, “Complete Data Recording” is given “low priority”, since it is viewed as impractical from the point of view of time and funding required. “Core Areas” are areas in which a more intensive study of stand characteristics is made in selected parts of the NFR (see Section 4). In general, “Core Areas”, which are square-shaped, are recommended over elongated “Transects” (Table 5).

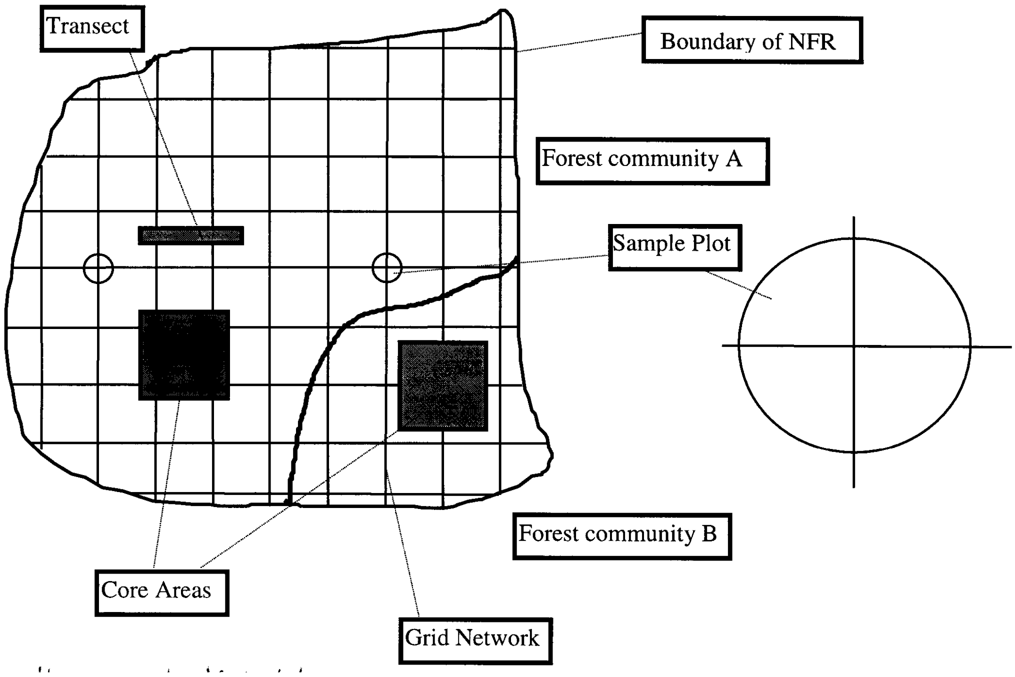

Figure 1. Sample Inventory Design for NFR Research Recommended by COST Action E4 Forest Community B is sampled as a Core Area, which is defined and discussed in Section 4 of this Report

Table 5. Recommended Priorities for Inventory Design in Natural Forest Reserves (+++ = high priority, ++ = medium priority, + = low priority)

	total Natural Forest Reserve
grid network	+++
core areas	++
transect	+
complete data recording	+

3.4 Minimum Data Set – Sample Plots

The purpose of Sample Plots is to derive data on forest vegetation and stand structure over the entire NFR. To describe the forest vegetation within each Sample Plot, it is recommended to take a structured approach to describing the woody vegetation, paying attention to all layers comprising the forest structure, i.e. canopy-forming trees; understorey or shrub layer; regeneration layer (i.e. regeneration of woody species); dead wood. These are referred to as "silvicultural parameters". Other important parameters are: Sample Plot location; soils;

vegetation. There is much variation in the range of attributes and in the level of detail recorded in different research programmes. Table 6 gives a list of attributes, which should be recorded as part of a minimum data set over the whole NFR.

While some of these parameters can be measured over the whole Sample Plot, this will often not be practical; for example where there are many saplings or shrubs present. For measurement of these, it may be more appropriate to mark out smaller observation areas, or Subplots, within the Sample Plots (Table 7).

Table 6. Systematic Data Collection in Sample Plots in Natural Forest Reserves: Parameters Recommended by COST Action E4 (see also Appendix 1A & 2)
* Note: These parameters may not always be required in a minimum data set, e.g. if using the data for modelling forest dynamics, these data will be required

- Site Characteristics
  - Location (latitude & longitude)
  - Slope, Aspect, Topography/Relief
  - Soil type, Vegetation Type
- **Stand Characteristics**
  - **Standing Live Trees (D.B.H. ≥ 5cm)**
    - Species
    - D.B.H.
    - Height
    - *X,Y (location in Sample Plot)* *****
    - *Height to living crown* *****
  - **Standing Dead Wood (D.B.H. ≥ 5cm)**
    - Species
    - D.B.H.
    - Height
    - Stage of decay
    - *X,Y (location in Sample Plot)* *****
  - **Shrub Layer (D.B.H. < 5cm; Height > 130cm)**
    - Species
    - Number of stems (Classes)
    - Height (Classes)
  - **Regeneration Layer (D.B.H. < 5cm; Height 30 - 130cm)**
    - Species
    - Number of stems (Classes)
    - Height (Classes)
    - Damage from herbivores
  - **Lying Dead Wood (Measure only Stems of Diameter ≥ 10 cm)**
    - Species
    - Component (whole tree/stump/stem/branch)
    - Diameter
    - Length
    - Stage of Decay
  - **Ground Vegetation**
    - Species
    - Cover/Abundance

Table 7. Recommended Observation Areas for Parameters measured in Sample Plots (see also Table 6)

Parameters	Observation Area
Site Characteristics	Whole Sample Plot
Standing Live Trees	Whole Sample Plot
Standing Dead Wood	Whole Sample Plot
Shrub Layer	Subplot (Shrub Layer Plot)
Regeneration Layer	Subplot (Regeneration Plot)
Lying Dead Wood	Whole Sample Plot
Ground Vegetation	Whole Sample Plot/Subplot (Relevé)

The recommended approach for measuring parameters in Sample Plots or associated Subplots is given in the following Sections. Details are also given in Appendix 1 & 2.

3.4.1 Site characteristics

A description of location, topography and soils in the study area should be made, if there is no detailed map of soils and topographical features already available for the NFR.

3.4.2 Standing Live Trees and Standing Dead Wood

All standing live or dead trees with stems[2] which are ≥ 5cm diameter at breast height (D.B.H.) should be recorded over the entire Sample Plot area. (Therefore, it is important to consider tree density when selecting sample plot size – see Section 3.3) For each stem in the Sample Plot, record: species, D.B.H. and height. For standing dead stems, the degree of decay should also be recorded. Depending on the data analysis to be carried out, it may be required to record also the position in the Sample Plot of live and dead standing trees. Also, for live trees, the height to the lowest live branches in the canopy (see Case Study, Section 5). It is of course possible to extend sampling to include stems smaller than 5cm D.B.H. For COST Action E4, 5cm is a recommended cut-off point.

3.4.3 Shrub Layer and Regeneration Layer

The shrub layer includes all stems with D.B.H. < 5cm and height > 130cm. Regeneration layer includes all stems for which: D.B.H. < 5cm and height = 30cm -130cm. Where shrubs or young trees are very abundant, it is recommended to measure both of these in permanently marked Subplots (Table 7), rather than over the entire Sample Plot. An example of a Subplot layout is given in Fig. 2. For each species present in both the shrub layer and the regeneration layer, count the number of stems present in the Subplot – this can be recorded in defined classes (see Appendix 2). Also record the number of stems, grouped into height classes. In

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[2] Note the emphasis on stems rather than on individuals, e.g. for coppice stems, record each one separately. This applies to the entire inventory procedure, including shrub and regeneration layers.

some programmes, the D.B.H. of stems <5cm is measured, but 5cm is chosen as a cut-off point in the COST E4 minimum data set.

The influence of herbivores on the regeneration layer is often an important feature of forest stands. The use of a simple damage classification system for each species is recommended.

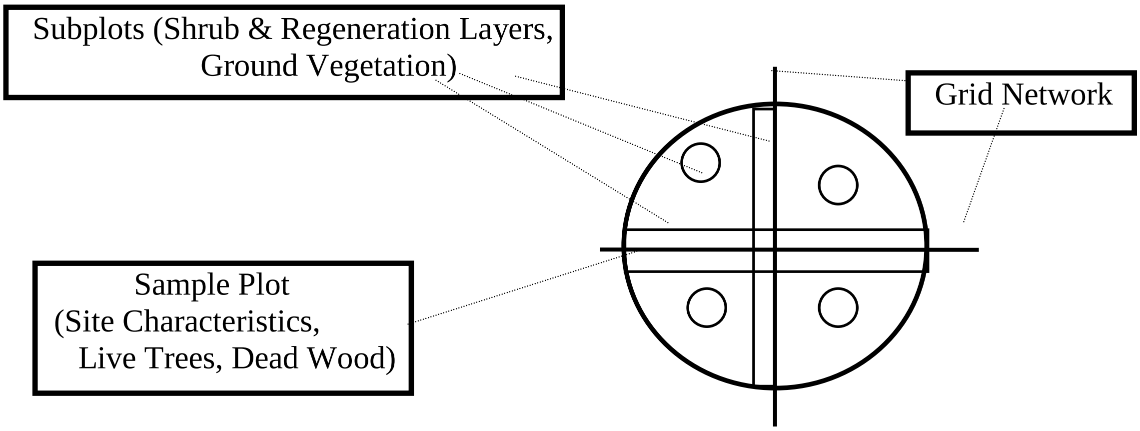

Figure 2. Sample layout of Sample Plot and supplementary Subplots. The size of Sample Plots and of Subplots depends on stand density. Subplots may be circular plots or transects, in which the Shrub Layer, Regeneration Layer and Ground Vegetation are recorded.

3.4.4 Lying Dead Wood

Lying dead wood should be quantified over the whole Sample Plot. Recording should include all components, i.e. stumps, lying trees, thick branches and stem parts, as well as newly broken trees, which have a diameter of at least 10 cm at their narrowest point. For all pieces of dead wood, record species (if possible) and component (i.e. whether stem, branch, stump, etc), diameter at widest point, length (or height of stump) and the degree of decomposition or decay. It is of course possible to extend sampling to include dead wood components smaller than 10cm diameter. For COST Action E4, 10cm is a recommended cut-off point.

3.4.5 Ground Vegetation

A species inventory (species list) of the higher plants should be made over the entire Sample Plot. Estimates of cover/abundance of each species of higher plant should then be carried out in the Subplots (e.g. Regeneration Plot; Figure 2), and the data can therefore be analysed, if required, as vegetation relevés. Because of the definition of Regeneration Layer (Section 3.4.3), recording the Ground Vegetation here includes seedlings of tree and shrub species, with height <30cm. Efforts should be made to quantify the lower plants present, although identification of individual species may significantly increase the time involved in recording, depending on expertise of the recorder. At the very least, total cover of all bryophytes, all lichens and all fungi can be recorded quickly and easily, and so should be done. Extent or cover of litter layer, bare soil and bare rock in the Subplot should also be recorded.

3.4.6 Summary of Data Collection in Sample Plots

WHOLE FOREST NATURE RESERVE – SAMPLE PLOTS

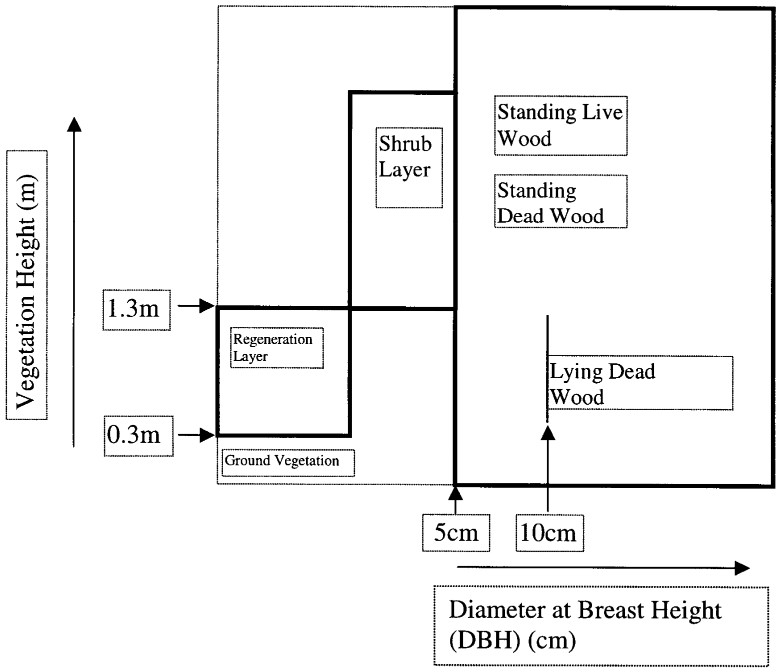

Figure 3. Schematic representation of the components of the recommended COST E4 inventory. See Section 3.4.2 – 3.4.5 for definitions of forest components.

4 Data Collection in Selected Core Areas (i.e. Intensive Study Plots)

4.1 Aims

A "Core Area" is an area selected within a NFR, in which a complete inventory of stand characteristics is carried out. It is similar to a Sample Plot (Section 3) in that it is permanently marked on the ground, but it is bigger than a Sample Plot. Also, there are more measurements to be made in a Core Area than in a Sample Plot.

There was some debate among members of WGII over the name – "Core Area". In some countries, plots such as these are already in use and are called "Intensive Study Plots". Whatever the nomenclature, such plots should form a central part of any research programme aimed at comprehensive monitoring of forest dynamics.

Core Areas should be selected to be representative of particular features of the NFR vegetation, for example, to represent a dominant, characteristic or widespread vegetation type, or alternatively to represent a rare forest vegetation type. On a European scale, it would be worthwhile considering what forest types are under-represented in forestry research, and selecting those types if possible, to make NFR research more comprehensive, on a regional scale.

Research aims in Core Areas can include:
- Detection of change in species composition of forest stand, i.e. forest dynamics
- Single-tree related research
- Vegetation dynamics

4.2 Minimum Data Set - Core Area

The recommended size of a Core Area is 0.25 ha to 1.0 ha (or 2.0ha if possible). [Note: recommended size for a Sample Plot is 0.05 ha to 0.1 ha, see Section 3.3.] It is recommended that Core Areas should be located so that there is a Buffer Zone around them. For example, a Core Area should not be located on the edge of the NFR, where it may be subject to processes operating outside the reserve (e.g. thinning or felling), which would affects ambient conditions (e.g. increased light penetration) within the Core Area. The establishment of a Buffer Zone around the Core Area is recommended. Table 8 lists the parameters that are recommended by WGII for measurement in a Core Area. In comparison with Table 6, which lists the same for Sample Plots, it will be seen that there are many similarities, but that a greater number of parameters is given "high priority" rating in Core Areas, and therefore that the "Minimum Data Set" for the Core Area is larger than that for a Sample Plot.

Table 8. Systematic Data Collection in Core Areas in Natural Forest Reserves: Parameters Recommended by COST Action E4 (see also Appendix 1B & 2)
* Note: These parameters may not always be required in a minimum data set. They could be viewed as "low priority" for inclusion in the data set, depending on research objectives.

Site Characteristics
- Location
- Slope, Aspect, Topography, Relief
- Soil Type, Vegetation Type

Stand Characteristics
- **Standing Live Trees (D.B.H. ≥ 5cm)**
  - Species
  - D.B.H.
  - Height
  - X,Y (location in Core Area)
  - Height to living crown *(see Section 4.2.2)*
  - Crown projection *(see Section 4.2.2)*
  - *Stem quality* *****
  - *Vitality* *****
- **Standing Dead Wood (D.B.H. ≥ 5cm)**
  - Species
  - D.B.H.
  - Height
  - X,Y (location in Core Area)
  - Stage of Decay
- **Shrub Layer (D.B.H. < 5cm; Height > 130cm)**
  - Species
  - Number of stems (Classes)
  - Height (Classes)
- **Regeneration Layer (D.B.H. < 5cm; Height < 130cm)**
  - Species
  - Number of stems (Classes)
  - Height (Classes)
  - Damage from herbivores
- **Lying Dead Wood (Measure only Stems of Diameter ≥ 10 cm)**
  - Species
  - Component (whole tree/stump/stem/branch)
  - Diameter
  - Length
  - X,Y (location in Core Area)
  - Stage of Decay
- **Ground Vegetation**
  - Species
  - Cover/Abundance

As in Sample Plots, it is recommended that the Shrub Layer, Regeneration Layer and Ground Vegetation be quantified in smaller subplots rather than over the entire Core Area (Table 9). The subplots should be laid out in a systematic grid system within the Core Area.

Table 9. Recommended Observation Areas for Parameters measured in Core Area (see also Table 8)

Parameters	Observation Area
Standing Live Trees	Whole Core Area
Standing Dead Wood	Whole Core Area
Shrub Layer	Core Area Subplot (Shrub Layer Plot)
Regeneration Layer	Core Area Subplot (Regeneration Plot)
Lying Dead Wood	Whole Core Area
Ground Vegetation	Core Area Subplot (e.g. Regeneration Plot)

The recommended methodologies for measurement of parameters in Cores Areas and associated Subplots are given below. Details are also given in Appendix 1 & 2.

4.2.1 Site Characteristics

Location of the Core Area (latitude and longitude) should be recorded, along with a description of topography and soils. Also important is the phytosociological name of the vegetation type.

4.2.2 Standing Live Trees and Standing Dead Wood

Measurements of all stems (live and dead) with D.B.H. ≥ 5cm should be carried out on the whole Core Area, exactly as described for Sample Plots (Section 3.4.2). The following should also be recorded: location of stem within the Core Area (using X,Y co-ordinates) and crown length (live trees only). Crown length should be calculated by subtracting {height to lowest live canopy branches} from {height to top of live canopy}. Crown projection should be recorded for live trees, by estimating on the ground the maximum spread of live canopy branches, and measuring this distance. NOTE: There were differences of opinion between WGII members regarding the priority rating of crown length and of crown projection measurements. These measurements should be included if it is intended to use computer programmes to model forest dynamics, e.g. the Silvistar programme that is in use in the Netherlands. Other characteristics such as stem quality and vitality should be recorded for live trees (these two parameters were not rated as high priority by WGII).

4.2.3 Shrub Layer

As in Sample Plots (Section 3.4.3), the shrub layer includes all stems with D.B.H. < 5cm and height > 130cm. Recording the Shrub Layer in the Core Area should be carried out as described for Sample Plots (Section 3.4.3). Depending on the number of shrub stems present in the Core Area, it is often more practical to use partial sample areas (i.e. subplots laid out in a systematic grid system, or sample strips; see Fig. 3) rather than measuring over the whole Core Area.

4.2.4 Regeneration Layer

The Regeneration Layer in the Core Area is defined as all stems with D.B.H. < 5cm <u>and</u> height < 130cm. <u>NOTE</u>: The definition of the Regeneration Layer is different in the Core Area than in the Sample Plots, where height is 30cm – 130cm (Section 3.4.3). The Core Area definition of Regeneration Layer means that all seedlings of tree and shrub species are to be included in a numerical count, rather than estimated in terms of their cover/abundance.

As with the Shrub Layer, above, it may be practical to measure the Regeneration Layer in partial sample areas (i.e. subplots laid out in a systematic grid system, or sample strips; see Fig. 3). For each species, record the number of stems, grouped according to classes, as well as stem heights (grouped into classes). Record damage from grazers on each stem, using a simple system of damage categories.

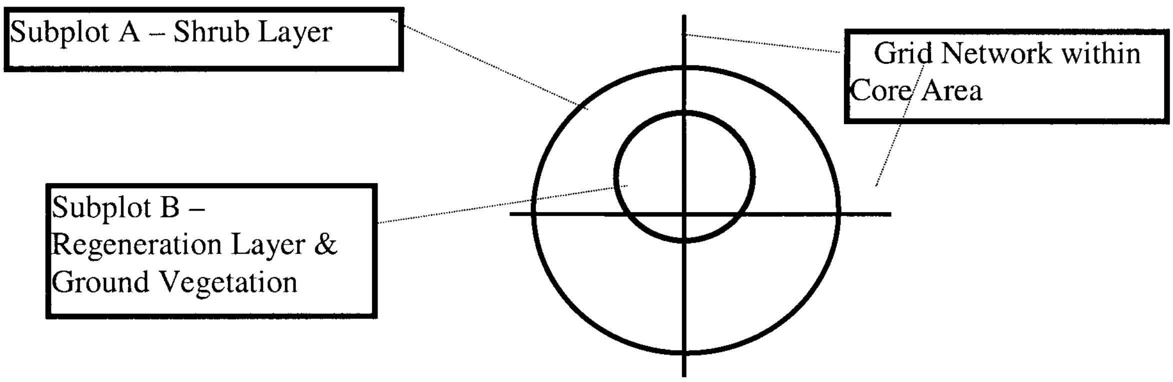

Figure 4. Sample layout of Subplots within Core Area. Subplots are used for recording the Shrub Layer, Regeneration Layer and Ground Vegetation in Core Areas. The size of Subplots depends on the density of stems in the Shrub and Regeneration Layers.

4.2.5 Lying Dead Wood

Recording of lying dead wood is exactly as for the Sample Plots (Section 3.4.4), and in addition, the location of dead wood components in the Core Area must also be recorded.

4.2.6 Ground vegetation

Recording of Ground Vegetation is exactly as for the Sample Plots (Section 3.4.5). A species inventory (species list) should be made for the whole Core Area. Estimates of cover/abundance of each species should be carried out in partial areas or Subplots (Fig. 3).

4.2.7 Summary of Data Collection in Core Area

CORE AREA

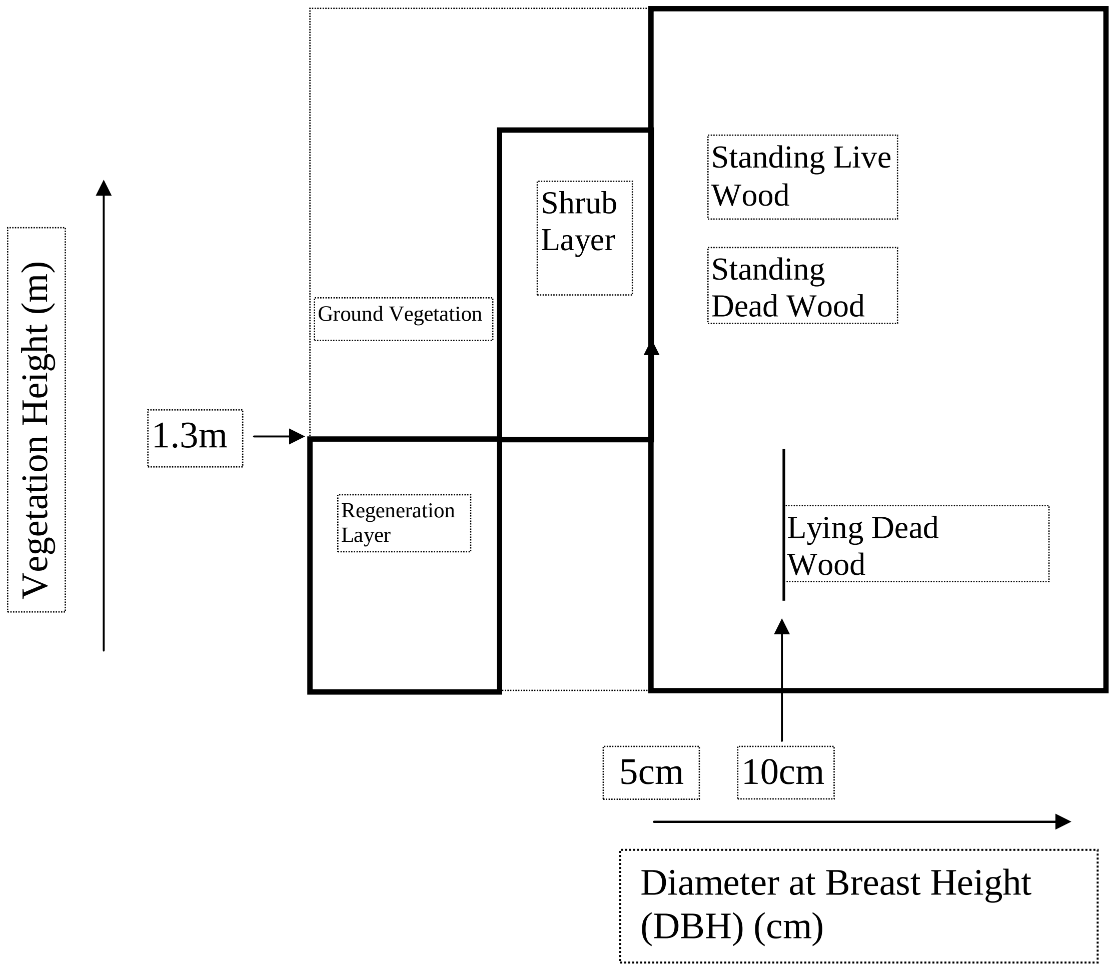

Figure 5. Schematic representation of the components to be measured in Core Areas, in the recommended COST E4 inventory of forest reserves. See Section 4.4.2 – 4.2.5 for definitions of forest components.

5 Case Study: Data Collection in A Forest Reserve in The Netherlands

Data collection in forest reserves: an impression of the costs.

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Introduction

Guidelines for data collection in forest reserves have been presented in the previous chapter. Countries that want to start with a study in forest reserves or want to adjust their data collection might find it useful to get an impression of the costs associated with the proposed data collection.

The Netherlands has a fifteen-year history in the study of forest reserves (Broekmeyer, 1999) and their data collection has many similarities with the data collection proposed in this publication (for details on the Dutch data collection see Stuurman & Clement, 1993 and Broekmeyer, 1999). The objective of this chapter is to present a Dutch case study which can act as a reference for estimating the costs of field work (including data storage) in other European countries. The reserve "Vijlnerbos" has been selected for this case study. The structure and composition of this forest reserve is representative for large areas of temperate broad-leaved forests in Europe.

Forest reserve "Vijlnerbos"

The forest reserve Het Vijlnerbos is situated in the most southern part of the Netherlands. The area of this forest reserve is approximately 21 ha. It lies on a northeast-facing slope at an altitude between 220 and 280 m. a.s.l. (i.e. above sea level). The forest reserve represents the Luzulo-Fagetum beech forest on the northern limit of its European distribution. At present the forest reserve primarily consists of a mixed pedunculate oak (*Quercus petraea*)-silver birch (*Betula pendula*)-beech (*Fagus sylvatica*) forest which has been managed as a coppice with standards. In addition, a young mixed plantation of pedunculate oak and sycamore (*Acer pseudoplatanus*) and an old mixed plantation of Japanese larch (*Larix decidua*) and Norway spruce (*Picea abies*) are included in the reserve as well. The vegetation is heterogeneous; patches dominated by bracken *(Pteridium aquilinum*) alternate with patches dominated by wavy hair grass (*Deschampsia flexuosa*) or patches without herbaceous vegetation. A general characterisation of the tree species composition of the forest reserve is given in Table 1.

Table 1. Tree species composition of the forest reserve Vijlnerbos in 1996.

	Mixed broad-leaved forest (17.9 ha)			Larch-spruce plantation (1.6 ha)			Sycamore-oak plantation (1.6 ha)		
	N [a)]	BA [b)] (m^2ha^{-1})	Dbh [c)] (cm)	N [a)]	BA [b)] (m^2ha^{-1})	Dbh [c)] (cm)	N [a)]	BA [b)] (m^2ha^{-1})	Dbh [c)] (cm)
beech	86	7.7	33.7	40	0.7	14.9			
oak	99	8.9	33.8	40	3.4	32.9	421	9.8	17.2
birch	160	9.5	27.5	20	0.8	22.6	60	1.5	17.8
sycamore							561	10.4	15.4
Other broadleaves	186	3.8	16.1	20	0.2	11.9	120	1.3	11.7
J. larch				221	16.6	30.4			
N. spruce	10	0.2	16.2	100	6.1	27.8			
Other conifers				20	1.6	31.9			
all species	542	30.1	26.6	461	28.9	28.3	1162	23.0	15.9

[a)] number of stems per hectare
[b)] basal area
[c)] mean diameter at breast height

Monitoring design

In this forest reserve a grid system with circular permanent plots and a rectangular core area has been established (Fig. 1). The spacing of the grid system is 50m by 50m. Eighteen intersections of this grid system were selected randomly as permanent plots. The area of a permanent plot is 500 m^2 (radius of 12.6 m). The core area has an area of 0.98 ha (70 by 140 m) and is selected to represent the pedunculate oak – silver birch – beech forest. In total 1.88 ha or 9% of the area is studied in detail (core area and permanent plots). In addition, a vegetation map and a soil and geological map is made for the whole reserve.
Recording will take place at intervals of 10 to 15 years. So far, the reserve has been recorded in 1987 and 1996.

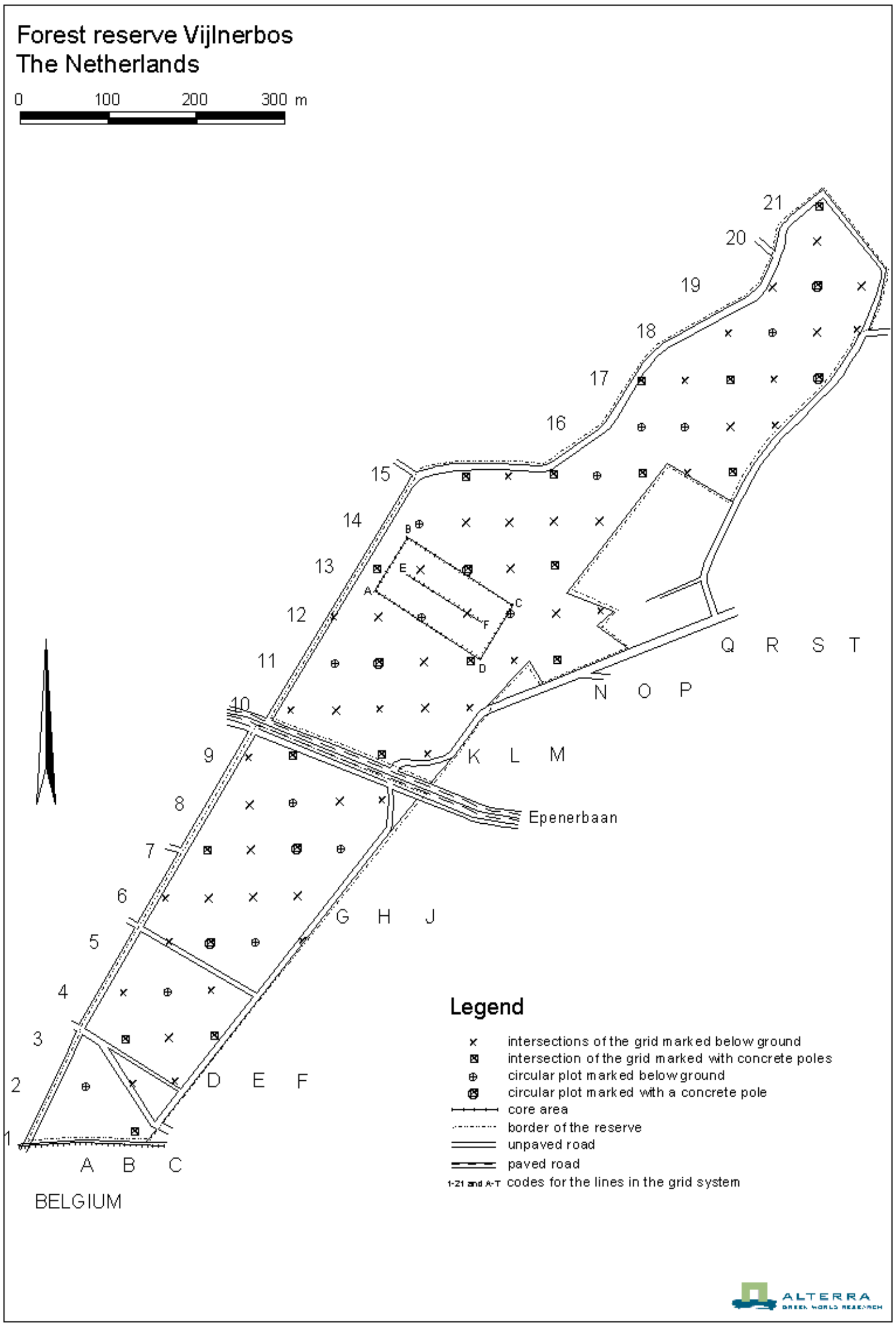

Figure 1. Schematic representation of the Forest Reserve at Vijlnerbos, The Netherlands.

Field recording

The preparatory work for field recording encompassed the development of a field map (scale 1:5,000), the establishment of a grid system and the selection of the sample plots and the core area. The field map was based on forest maps on which the grid system, the intersections selected to be the centre of the permanent plots and the core area were projected. The researcher in charge selected the permanent plots (behind the desk) and the core area (in the field). A three-person field crew using tapes and a compass established the grid system, the permanent plots and the core area. For the grid system distances between parallel lines were checked regularly. The centres of the permanent plots and the corners of the core area were marked above ground using wooden poles and below ground using electro-magnetic spools.

The following field recording took place:
- Whole reserve
    - Vegetation mapping (scale of 1:5,000)
    - Soil- and geology mapping (scale of 1:5,000), only in 1987
- Core area
    - Vegetation mapping (scale 1:500 and transect 2 by 100 m)
    - Stand structure and composition (only trees and shrubs with a dbh > 5 cm; collected data: species, tree position (x-y co-ordinates), height, dbh, crown position and crown length (x-y-z co-ordinates) and vitality
    - Coarse woody debris (only for CWD with a minimum diameter of 10 cm at the base; collected data; species, standing/lying, decay stage, position (x-y co-ordinates top and base)
- Permanent plots
    - Vegetation relevés
    - Soil description (to a depth of 2.2 m), only in 1987
    - Stand structure and composition (only trees and shrubs with a dbh > 5 cm; collected data: species, tree position (x-y co-ordinates), height, dbh and vitality
    - Regeneration (trees and shrubs with a dbh <5 cm and a height> 0.5-m sampled on 36 subplots of 3 by 3 m: species and number per height class)

Vegetation maps and relevés were made by an experienced assistant vegetation scientist with intensive support by a vegetation scientist. An experienced assistant soil scientist made soil descriptions in the permanent plots and made the soil and geological map. The soil descriptions formed the basis for these maps. A well-trained two-person field crew collected data on stand structure and composition and on coarse woody debris. In the core area, positions of trees and their crowns and of coarse woody debris were assessed with tapes in 7 strips of 10 by 140 m (see Stuurman & Clement, 1993). In the permanent plots the position of trees and coarse woody debris was assessed with a compass and a tape; angle and distance to the plot centre were measured.

Costs for data collection and data storage

The data collection in 1987 took significantly more time than the data collection in 1996. Preparatory fieldwork was no longer necessary, and soil data were only collected during the first recording. Furthermore, at the second recording, maps with tree positions of the core area and of the permanent plots were available. So only the position of new trees and new pieces of coarse woody debris had to be measured.

All collected data were written on standard data forms or presented in sketch maps. These data were stored in a specific database, stored as digitized maps or redrawn as a final map. The time necessary for these activities is included in the estimated costs. However, time needed for the development and maintenance of the database is not included. An overview of the time necessary for the fieldwork is given in Table 2.

Table 2. Estimated time (in days) necessary for the recording of the reserve "Vijlnerbos" (21 ha, 1 core area, 18 permanent plots).

	field crew	**research assistant**	**scientist**
preparatory field work			
consultation			0.5
development field map		1	
selection core area			0.5
establishment grid system – core area – permanent plots (3-person field crew)	9		
First recording 1987			
stand structure and composition and coarse woody debris (2-person field crew)			
core area	18		
permanent plots	14		
data storage	7		
vegetation			
reserve (map)		1.5	1
core area (map & transect)		1.5	
permanent plots (relevés)		2	
data storage		1.5	
soil & geology			
reserve		1.5	
permanent plots		2	
data storage		2	
Second recording 1996			
stand structure and composition and coarse woody debris (2-person field crew)			
core area	12		
permanent plots	12		
data storage	5		
vegetation			
reserve (map)		1.5	1
core area (map & transect)		1.5	
permanent plots (relevés)		2	
data storage		1.5	

Experiences in other reserves

A total of 60 forest reserves are included in the Dutch forest reserve program. The size of these reserves ranges from 5 to 450 ha. So far 50 reserves have been recorded for the first time and already 10 of these reserves have been recorded for the second time. Based on our experiences in these reserves “Vijlnerbos” is an ordinary reserve for its size in terms of time needed for the fieldwork. Time-consuming reserves are either difficult to access (low thorny shrubby growth in the dune area, large number of small streams and ditches, large amounts of blown over trees) or have a low transparency (young stands, dense shrub layers). Under these circumstances especially the time needed for the establishment of the grid system might easily double.

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6 Summaries of Data Collected in Different Countries

An overview of existing methodologies for the monitoring of stand dynamics in Strict Forest Reserves

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Introduction

Strict Forest Reserves are important research areas, both for fundamental and applied scientific research. They allow us to study the principles and mechanisms of forest dynamics and are the basic reference tools for nature based silviculture. They provide information on how to manage our forests in a close-to-nature context and act as controls for the evaluation of management impacts on the ecosystem and its faunal and floral components.

Ideally, truly virgin forests best perform these functions; however near-natural or managed forests that have been left unmanaged for long periods provide a modest ‘ersatz’, i.e. the next best alternative (Leibundgut, 1966).

Historical development

The first Strict Forest Reserves were established during the 19th century for ‘aesthetic’ reasons. Very little research was carried out in them. However, the first studies of forest structure and dynamics in Strict Forest Reserves date back to the end of the 19th century. At that time the first full inventories were made of the last remnants of virgin forests in Central Europe, some of which had, by that time, received protection status.

Shortly after the Second World War, ideas on nature-based silviculture, which dated back to the beginning of the 20th century, received considerable interest, especially amongst the forestry universities in Central-Europe. This generated interest in strict reserves and more elaborate research programmes were established, using full inventories and line transects to study distribution and structure of different developmental stages (Leibundgut, 1959, 1981; Mayer, 1966, 1967, Mayer et al., 1988;Mlinsek, 1970; Korpel, 1995; Prusa, 1985)

From the 1970s onward, more attention was paid to the analysis of soil and ground vegetation; until then, measurements focused almost exclusively on trees, stand structure and tree mortality.

During the 1970s, interest in developing forest reserves increased in Germany, not only within forest science disciplines, but also for nature conservation purposes. In the absence of true virgin forests, well-structured managed forests were selected to become ‘natural’ forest reserves. Monitoring programmes applied here were initiated using a different approach, based on circular sampling plots within a grid system and detailed research in core areas (Albrecht, 1990; Bücking, 1990; Althoff et al., 1993). Within the Dutch forest reserves programme this methodology was further developed (Koop, 1989; Broekmeyer, 1995).

Even more recently, Strict Forest Reserves have become more important than ever, not only for their research potential, but also for nature conservation objectives. This is also reflected in modern research programmes. Not only do these programmes receive more attention, but also the scope of research has broadened to include important topics, which affect nature conservation. Inventories and monitoring of populations of fungi, birds, bats, saproxylic invertebrates and red-data book species are increasingly being integrated into monitoring programmes (Bücking, 1996; Rauh, 1993; Köhler, 1996).

In Scandinavian countries and in the British Isles, strict reserves have been established primarily for nature conservation, with nature-based silviculture being only of secondary interest. It is only very recently that there has been sufficient interest in developing forestry-related research in these areas. Nevertheless, there are important long-term studies of natural stand change and dynamics, with some transects in nature reserves dating back to the 1940s-50s (Peterken and Backmeroff 1988; Mountford et al., 1999).

Principal Results

The actual status and methodologies of monitoring programmes in the different member countries of COST-E4 are elaborated in Table 1 below. This information was largely derived from a questionnaire prepared by COST-E4 Working Group 2 and filled by the country representatives in this working group, combined with information derived from the country reports published in Parviainen et al., (eds.) (1999) and Diaci (ed.) (1999).

The principal findings confirm what might be expected as a result of historical developments in this field, i.e. although most of the countries have initiated monitoring programmes to study forest dynamics in Strict Forest Reserves, there are a wide variety of methodologies and parameters monitored in the different countries.

Methodologies can be split into two main groups :
- Many programmes, especially in Central European countries and a number in the UK have utilised long line transects, occasionally combined with mapping of the developmental stages for the whole reserve, based on full inventories or aerial photographs.
- Austria, the Netherlands Belgium and most German States have adopted grids of circular sampling plots,
- sometimes combined with detailed studies in a core area. Plot designs using clusters of circular plots are applied in Finland.

Moreover, there is considerable variation in plot sizes, plot densities, and parameters measured across Europe. Even for parameters that seem very obvious and clearcut, different recording methods exist :
- Dead wood degradation stages are given in most countries, however the number of identifiable stages varies; most countries use four stages, some have five and others only three stages of degradation.
- DBH is measured in all countries. However, the minimum threshold varies between 1 to 10 cm DBH.

Discussion

In many countries, monitoring programmes have existed for many decades. One of the basic rules in monitoring programmes that incorporate permanent plot systems is to adhere to the chosen system, design and methodology. Only then can comparable data sets be compiled and subsequently, reliable conclusions elucidated. The more repetitions of parameter measurements that are made, the more interesting and reliable are the results and conclusions. Thus, it would be most unlikely and inadvisable that countries change their existing sampling programmes and methodologies.

The original goal of Working Group 2, namely the development of a common sampling plot technique for all European countries, is almost certainly over ambitious. The Working Group can however, produce a number of suggestions and recommendations for countries where new programmes have yet to be established.

If different countries wish to co-operate and combine their data for analyses - which is strongly advisable - recommendations can be made on how to rationalise national monitoring programmes so that data comparisons can be made.

Conclusions

1. It is possible that general conclusions can be drawn where different methodologies are used. Existing methodologies can certainly be expanded; it is better to have a broad as opposed to a narrow focus, to keep records simple and archive details of the methodology used.
2. A standard approach is unlikely to prove suitable because the aims of forest dynamic studies differ between countries across Europe (dynamics of canopy trees, factors controlling regeneration, influence of soil, etc.). In addition, conditions vary between sites within countries and in different parts of Europe. Recorders may need to introduce new methods or temporarily abandon existing methods as new methods arise superseding existing practices.
3. Advice on the minimum threshold for measuring different parameters (e.g. minimum stem size) is desirable as this enables comparison.

4. Long-term studies are by their nature somewhat open-ended as we cannot foresee what may arise in the future and the influence new factors may have on individual sites.

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Table 1. Overview of research methodology systems for monitoring forest stand dynamics in the participating countries of COST E4.

Country	Methodology for monitoring stand dynamics	**Additional information and research / specification/differentiation**
Austria Standard monitoring programme started in 1995	Guidelines for the establishment of monitoring plots, including a mandatory, detailed field manual under the new **National Forest Reserve Programme**. **Sampling method** : Circular plots (150-100 m²) in grids (50*50 or 100*100) and/or transects (10(20)*30(50)m or full inventory (small reserves). Regeneration in small sub-plots (1-4 m²) Ground-vegetation : 100-500 m² (Braun-Blanquet) resulting in forest communities – maps (based on relevés), Mapping scale : 1/1000 to 1/10.000 Mapping of developmental stages The new **National Forest Reserves Programme** includes a standard monitoring programme based on a permanent grid system, i.e. BITTERLICH sampling plot techniques. All trees <1.3 m are recorded using polar co-ordinates for periodical measurement: species. DBH in mm using girth band, tree height, stem quality and occasionally age. Monitoring frequency: dependant on forest community type.	**Global information :** Name, area, size, short description (height, slope, climate factors, geological substrate, soil type) **Specific description** : forest history (pollen analysis), stand structure Under the **National Forest Reserve Programme**, which was initiated in 1995,a minimal programme was developed for standard reserves and an ‘enlarged programme’ for key reserves. The minimal programme includes key parameters that should be monitored at the very least while the ‘enlarged programme’ contains extra parameters. Vegetation relevés measured using the Braun Blanquet method, where possible, within the grid system. Detailed soil mapping and description, and mapping of forest communities are obligatory. Specific monitoring programmes carried out in key reserves, i.e. burned areas or virgin forest remnants. Remote sensing using aerial photography in key reserves and additional faunistic research at selected sites.
Belgium (Flanders) Standard monitoring programme to commence in 2000	**Sampling method** : Standard : circular plots in grid (50*50-100*100) + core area (1ha). <u>Nested circular plots</u> : 1000 m² : position, species and DBH of trees (DBH>40cm) 500 m² : position, species and DBH of trees (DBH> 8 cm) 100 m² : regeneration / 16*16m square : vegetation relevés Light measurements and soil sampling <u>Core area</u> : full inventory with crown projections.	 Standard programme for 30 reserves Minimum programme for all others: transects 10*100 m (1 transect every 3-4 ha) Additional faunistic research in selected reserves : - xylobiontic organisms - bird inventories - mosses, lichens and fungi.

Denmark No standard monitoring programme to date	**Sampling method :** A basic research programme for natural forests was developed in 1995 (Nielsen *et al*., 1995) but has yet to be implemented. It is planned that permanent plots will be established where tree positioning, DBH and tree height will be measured. Biogeochemical and climatic measurements, as well as inventories of flora, fungi and selected groups of insects are envisaged. Approximately 6 to 8 strict reserves are presently monitored at regular intervals by a number of institutions in Denmark. However, this is not done using a standardised methodology.	Minor strict reserves were established by the Geological Survey in 1948 in stands dominated by native species. The purpose was to use long term monitoring of forest dynamics for in order to obtaining better tools for interpreting pollen diagrams. (Pollen analysis is a major topic of research). Some specific research on structure, dynamics and light-conditions is carried out at some reserves In Draved skov, 2 stands of 4-6 hectares each, have been monitored intensively since1948, while the geological Survey of Denmark have been monitoring in Eldrup Skov 1 stand of 9 hectares since 1968. Monitoring includes canopy trees (position (mapping), diameter, crown health, etc., for all trees with dbh > 10 cm) on single tree level and understory at grid level (25 m^2). Soil and herb vegetation are assessed on a 10*10 meter grid. Pollen deposition is monitored using traps (Møller 1987, 1988).
Finland Monitoring programme started in 1993	**Sampling method :** 400-500 permanent sample plots established in strictly protected areas spread across all forest types in Finland (some plots in Russia) Typically a plot consists of 1 central circle (circle size : 900-2500 m² depending on stem number) and 8 satellite circles (circle size: 180-500 m² depending on stem number). All trees (living and dead, DBH>5cm) are recorded in the central plot and 4 of the 8 satellite plots (species location, DBH, understorey, health, shape; (Height and bole length for designated individuals). Small trees (DBH<5cm are recorded in all 9 plots (circle size: 100m²). Monitoring frequency : 10 years	Vegetation relevés, vegetation mapping, fauna, humus soil and nutrient cycling are optional depending on the availability of experts, i.e. optional -not included in the standard programme.
France No systematic monitoring programme to date	Monitoring and research carried out in Fontainebleau. In 1999, a monitoring programme of Strict Forest Reserves was launched in public forests, based on the COST - guidelines (e.g. the strict forest reserve of Guebwiller in the "Vosges" mountains, ca. 110 ha).	

Germany Every 'State' has its own system. Some programmes initiated as early as 1975, but most were initiated between 1985 and 1990.	**Sampling method : (*based on Balcar (s.d.)*)** In 13 Länder, monitoring programmes are performed. In 4 cases, a grid of circular sample plots is used, in 1 State, a core area is used, while in 7 States, a combination of both is used. Full inventories are only used in the monitoring programme of one State. Sample plots vary in size between 0.05 and 0.5 ha (mostly 0.1 ha), while core areas vary between 0.21 to 2 ha (generally 1 ha). Measurements : Living trees (DBH >4 –7 cm (in most cases > 7 cm): species, DBH, height (all), x,y co-ordinates (11 out of 13), crown-parameters (5), bole-length (5), IUFRO-classification (8) Regeneration : in small subplots, including shrubs < 7 cm DBH Dead wood : considerable variation on minimum diameter for lying dead wood ; DBH, length, degradation stage (4 classes), species (where possible)	In almost all States, ground flora is studied using vegetation relevés in the sample plots. A great deal of additional research is done on fungi, xylobiontic beetles, birds, and other ecosystem components. Also reserve areas are often compared with managed areas located nearby. This research however is, as a rule, limited to case studies, and is not systematically included in the monitoring programme.
Greece No systematic monitoring programme to date	Only a few experimental plots designed according to COST guidelines. **Sampling method :** Single circular plots of 500-1000 m². Tree species, position, DBH. Minimum size DBH = 5 cm	Vegetation relevés optional
Hungary First monitoring/ research initiated in 1986; systematic monitoring/ research started in 1997	An official programme, focussing on ten so-called 'sample and demonstration reserves' was initiated in 1997, however the monitoring programme is still being developed. After mapping of developmental stages and forest-types, permanent plots are installed in each of the ten reserves. Until recently, vegetation and soil surveys were generally the norm. **Sampling method :** Mainly transects (20*20 m) (also sample plots on a 50*50 m grid; variable size using relascope Measurements : Tree species, position, DBH, height and crown dimensions	Other data is now being collected in the ten study areas including : Geological description, historical data, detailed soil-mapping (1/5000) and soil-profile analysis, meteorological observations, microclimatic studies, tree ring analyses on dead wood, vegetation mapping, mosses, fungi, data processing of aerial photographs and faunal inventories

Ireland No systematic monitoring programme to date	Isolated monitoring projects with permanent plots since 1975; no standard methodology **Sampling method :** sample plots of 25-15000 m² Major emphasis on vegetation description and assessment of regeneration – published data on stand structure is scarce	The sites with longest data sets include those at Killarney and Glendalough. Roughly ten years of data collected at Brackloon Wood, i.e. forest health, radioisotopes, soil fauna, flora (ground and arboreal), bats, birds – all using approved methodology, i.e. UN-ECE and ECN protocols. Soil research, pollen analyses and site history combined in order to interpret future monitoring data more accurately
Italy No systematic monitoring programme to date	**Sampling method :** 24 permanent plots, 1-6 ha each (84 ha in total) are left unmanaged and have been studied since 1952. Dendrometric and floristic analysis	Dendrochronology
Netherlands Systematic monitoring started in 1988.	**Sampling method :** Combination of circular plots and core areas 50-70 <u>circular plots</u> (500m²) stratified randomly selected on a 50*50 m grid. Living trees : DBH (>5cm), co-ordinates, species; Small trees (DBH>5cm) counted and height >0.5 m; dead wood (DBH>10 cm) : species, DBH, degradation phase vegetation relevés (18*18 m, 36 subplots), <u>1 core-area</u> (70*140 m = 1 ha) : vegetation mapping, living trees (DBH>5cm) : species, DBH, co-ordinates, crown-parameters; dead wood : cfr. Circular plots; vegetation and regeneration studies in central strip (10*140 m) Monitoring frequency : 10 years	Additional research in all monitoring sites : Soil profiles (every circular plot), geological mapping, aerial photography Mapping of indicator species denoting old-growth forests Additional research on fungi, birds and beetles at some sites
Norway No systematic monitoring programme to date	Some studies and inventories are carried out when reserves are being established. The Norwegian Monitoring Programme for Terrestrial Ecosystems, established in 1990, includes research on stand structure, ground vegetation and epiphytic lichens in some protected forest areas. The ground vegetation is monitored in permanent plots at different scales, using 0.25*0.25m, 1*1m and 5*10m sample plots in selected core areas.	An inventory of red data book species is carried out. Mapping of indicator species. Integrated studies of chemical and biological monitoring, including precipitation, soil, vegetation and faunal parameters.
Portugal No systematic monitoring programme to date	No monitoring programme on protected areas; only plant inventories, vegetation mapping and phytosociological studies	Additional faunistic inventories are performed in places

Slovakia **Very long tradition of monitoring in strict reserves**	Long-term research : main results published in Korpel (1993) **Sampling method :** Permanent experimental plots of variable size (occasionally whole reserves) : living trees DBH>8 cm : species, DBH, height, sociological (age) class, stem and crown quality, degree of sucker formation, damage; necromass (3 degradation phases) Transects : living trees DBH >1cm : species, DBH, height, position, crown parameters, regeneration (using 4 height classes) Monitoring frequency : 5-10 years	Biogeochemistry
Slovenia Very long tradition in monitoring of strict reserves	**Sampling method :** 1882-1950 : full inventory of stand structure in the old-growth forest reserves (up to 100 ha) 1951-1980 : in 25-30 reserves : additional new network of permanent plots in all typical identifiable developmental phases of the woodland : transects mainly of 1-2 ha measurements : living trees (>5cm DBH) : species, species co-ordinates, DBH, height, sociological (age) class, stem and crown quality, damage, health condition; necromass : species, level of degradation, co-ordinates; shrub, ground-vegetation and mosses; subplots for regeneration patterns Monitoring frequency : 5-10 years	Some reserves have very valuable data sets, i.e. repeated measurements at regular intervals over 100 years. Additional research : Phytocoenology, zoology, birds, fungi Recent developments : emphasis on inter-disciplinary and comparative research in reserves and managed areas
Spain No systematic monitoring programme	Structural, dynamic and functional studies on natural forests are very scarce, permanent plots almost non-existent. A detailed monitoring programme occurs at only one location, i.e.: in Garajonay N.P. (Started in 1995) **Sampling method :** Global vegetation level : information on structure, growth, regeneration, mortality in all forest communities : circular plots of 250-900 m² in a 500*500 grid (62 plots) Living trees DBH>7 cm : species, DBH, height, vitality, regeneration : in subplots; vegetation relevee in 10*10m subplot Gaps and necromass (DBH>10 cm) measured and positioned; Monitoring frequency : 10 years Additional necromass studies in transects (DBH>40 cm) : measured annually Intensive vegetation monitoring : 6 circular plots out of 900-2500 m² Monitoring frequency : 5 years	Inventories made for the EU Habitats Directive and for the inventory of National and Natural Parks of Spain. Additional research in Garajonay : hydrology, climatology, inventories of autochthonous and introduced fauna, endangered species, qualitative erosion, fuel accumulation and aerial photography

Sweden No systematic monitoring programme	Strict reserves are especially selected for protection purposes, <u>not</u> for research An 'Integrated environmental monitoring' programme is performed at 18 locations : measurements of a wide range of ecosystem variables in small catchment areas	Many independent research activities in National parks and reserves, which mainly focus on conservation biology : - inventory of fauna and flora in remnant biotopes - biodiversity indicators in the forest landscape - bird and xylobiont beetle inventories
United Kingdom **No systematic monitoring programme**	No nationally co-ordinated research programme on forest dynamics, but the statutory nature conservation body in England (English Nature) is initiating a programme in a representative series of semi-natural reserves managed under a minimum intervention policy. Part of the Environmental Change Network (ECN) monitors forest dynamics and there are several existing baselines and some important long-term studies in unmanaged woodland reserves (Peterken and Backmeroff 1988) **Sampling method** : 20 m wide transects (some are up to 1 km long), small plots based on a 50-100m grid system or individual plots: all living trees over 1.3 m height and all stems over 1-5cm DBH: position, species, DBH, crown position (5 classes), crown parameters (in rough classes), crown dieback, trunk damage, description of stem form Necromass and canopy gap estimation : line transect method or measurement and plotting of large dead wood pieces DBH >10 cm; length > 1m), plotting of gaps onto transect/plot diagrams Ground vegetation : established coverage of each species per block Monitoring frequency : approximately every 10 years	Some UK environmental change network sites include forest reserves: integrated monitoring of a wide range of variables, including climate, hydrology, air pollution, vegetation, soils and animal populations Forest vegetation and tree measurements: Up to 50 square permanent plots, 10 m*10 m, randomly selected from a grid. In each plot up to 10 trees are marked and recorded for DBH every three years and for height, every nine years. Ground vegetation is recorded every nine years in these plots; other plots are used to record ground vegetation every three years (Sykes & Lane, 1996). There are also grid systems elsewhere, e.g. at Wytham Woods (established in 1976 – Kirby *et al*., 1996)

Table 2. Differences in criteria measured and monitoring methodologies used in Strict Forest Reserves in fifteen European countries

Country	**grid based**	**line transects**	**core area (ha)**	**circular plot size (m2)**	**ground vegetation**	**mapping scale**	**min. Tree height (cm)**	**min. DBH (cm)**	**dead wood classes**	**Monitoring frequency (yr)**
Austria	50(100) * 50(100)	10(20) * 30(100)		1-4	BB 100-500 m2	1:1000 / 1:10000	130	-		
Belgium	50(100) * 50(100)		1	1000 (500) {100}				40 (8) {-}		
Finland				1*[900-2500] + 8*[180-500]				<5 / >5		10
Germany	50(100) * 50(100)		0,2-2,0	500-5000	100-500			4-7	yes / 4	10
Greece				500-1000				5		
Hungary										
Ireland				25-15000						
Italy										
Netherlands	50*50		1 (70*140 m)	500			50	5	yes / 4	10
Norway										
Slovakia								8 (1)		5-10
Slovenia			1-2					5		
Spain	500*500			250-900 (900-2500)				7		10 (5)
Sweden										
UK										

7 Broader Recommendations of Working Group II (7/5/99 – Thessaloniki, Greece)

In addition to the function of WGII (i.e. to make recommendations on design and methodologies for use in research in Natural Forest Reserves), the Group discussed a range of wider recommendations, which are presented below. These recommendations refer to important broader issues that need to be addressed, in order to further the applicability and relevance of research in natural forests.

NOTE: These recommendations are not listed in order of priority

Recommendations to Policy Makers

SECTION 1 - Management of Forests based on knowledge from Forest Reserves and Silvicultural Experiments

1. The area of forests in nature reserves should be increased and there is also a need for research on whether these new reserves should be managed or simply left to nature, for example, some restoration work may be needed.

2. Research and monitoring programmes should be established in as many forest reserves as possible.

3. Research is needed to develop tools with which to evaluate forest management.

4. Experimental plots should be established, in which different silvicultural techniques can be practically tested. This type of research, together with that from forest reserves research, would help in the development of guidelines for "close-to-nature" silviculture.

5. If management of a forest is changed from one management regime to another, there is a need to research the changes, which occur in the stand.

SECTION 2 - Networking in Europe

1. There is a need to expand the network of forest reserves in Europe, to include all of the important forest types. Some forest types may be under-represented or absent from reserves.

2. Promote the exchange of information between scientists and the public. There should be a platform for the exchange of results.

3. Working Group II has produced a common methodology for use in a network of reserves, for the exchange of scientific data. Each State should select key reserves to participate in this network, probably choosing forest types, which also occur in other European countries.

SECTION 3 - Research on Forest Disturbance

1. Establish a network to evaluate the impact of herbivores on forest dynamics.

2. Monitoring of forests after major disturbances is recommended, to observe the post-disturbance succession in the forest.

3. Resource allocation for forest research programmes should reflect the erratic nature of major disturbances, and the consequent need for more intensive research.

SECTION 4 - Ecosystem Approach

1. There should be a multi-disciplinary approach to forest reserves research. We should encourage researchers of many different disciplines to visit and work in the forest reserves, e.g. invertebrates, palynology.

2. Need more integrated co-operation between foresters and ecologists/biologists in developing forest reserves research.

Recommendations to Working Group II and Scientists

1. WGII have recommended a "minimum data set" which should be gathered in forest reserves research. There is a need for researchers now to evaluate this minimum data set, to see how applicable it is.

2. There is a need for research to improve the methodologies for quantifying regeneration and dead wood in monitoring programmes.

3. It should be borne in mind that the approach taken in scientific research is site specific and depends also on the particular questions being addressed. Scientists should be flexible in their use of this methodology (but incorporate the "minimum data set").

8 Appendices

Appendix 1. List of attributes to be assessed in forest reserves research

<u>NOTE – Appendix 1</u>
mm = millimetres; cm = centimetres; dm = decimetres (=0.1m)
“categories” = you are required to devise categories or incremental classes for these attributes, rather than reporting individual values
The Appendix is laid out in four columns:

1. Name of attribute
2. Source of data collection
3. Target of data collection
4. Recording units

Attributes in italics are not part of the COST E4 Minimum dataset for forest reserves research

1A List of Attributes to be measured in Sample Plots over whole NFR (see Section 3)

SITE CHARACTERISTICS

Location	field assessment	sample plot	latitude/longitude
Slope	field assessment	sample plot	%
Aspect	field assessment	sample plot	^{o} (degrees)
Topography/Relief	field assessment	sample plot	categories
Soil type	field assessment	sample plot	categories
Vegetation type	field assessment	sample plot	categories (phytosociology)

STAND CHARACTERISTICS

<u>Standing Live Trees</u> – each measurement to be made for each stem in Sample Plot

Species	field assessment	each stem	Latin name
Diameter at breast height (D.B.H.)	field assessment	each stem	cm
Height (to top of crown)	field assessment	each stem	dm
Location	*field assessment*	*each stem*	*X,Y co-ordinates*
Height to base of living crown	*field assessment*	*each stem*	*dm*
Estimate of Timber Volume	*functions, tables*	*each stem*	*m³*

<u>Standing Dead Trees</u> – each measurement to be made for each stem in Sample Plot

Species	field assessment	each stem	Latin name
D.B.H.	field assessment	each stem	cm
Height (to top of tree)	field assessment	each stem	dm
Stage of decay	field assessment	each stem	categories

Location	*field assessment*	*each stem*	*X,Y co-ordinates*
Estimate of Timber Volume	*functions, tables*	*each stem*	*m³*

<u>Shrub Layer</u> – if shrub layer abundant, measurements can be made in subplots within Sample Plot

Species	field assessment	subplot area	Latin name
Number of stems	field assessment	subplot area	categories
Height of stems	field assessment	subplot area	categories

<u>Regeneration Layer</u> - if regeneration layer abundant, measurements can be made in subplots within Sample Plot

Species	field assessment	subplot area	Latin name
Number of stems	field assessment	subplot area	categories
Height of stems	field assessment	subplot area	categories
Damage from herbivores	field assessment	subplot area	categories
Regeneration origin (seedlings, sprouts, etc.)	*field assessment*	*subplot area*	*categories*

<u>Lying Dead Wood</u> – each measurement to be made for each component in Sample Plot

Species	field assessment	each component	Latin name
Component (whole tree/stump/stem/branch/etc.)	field assessment	each component	categories
Diameter at Breast Height (D.B.H.)	field assessment	each component	cm
Length/Height	field assessment	each component	dm
Stage of decay	field assessment	each component	categories
Estimate of Timber Volume	*functions, tables*	*each tree*	*m³*

<u>Ground Vegetation</u>

Species list (higher plants)	field assessment	sample plot	Latin names
Cover/abundance of species (higher plants)	field assessment	subplot area	%, or categories
Total Cover of Bryophytes, Lichens, Fungi	*field assessment*	*subplot area*	*%, or categories*

1B List of Attributes to be measured in Core Areas within NFR (see Section 4)

SITE CHARACTERISTICS

Location	field assessment	core area	latitude/longitude
Slope	field assessment	core area	%
Aspect	field assessment	core area	° (degrees)
Topography/Relief	field assessment	core area	categories
Soil type	field assessment	core area	categories
Vegetation type	field assessment	core area	categories (phytosociology)

STAND CHARACTERISTICS

Standing Live Trees – each measurement to be made for each stem in Core Area

Species	field assessment	each stem	Latin name
Diameter at breast height (D.B.H.)	field assessment	each stem	cm
Height (to top of crown)	field assessment	each stem	dm
Location	field assessment	each stem	X,Y co-ordinates
Height to base of living crown	field assessment	each stem	dm
Crown Projection	field assessment	each tree	dm
Stem Quality	*field assessment*	*each stem*	*categories*
Vitality	*field assessment*	*each stem*	*categories*
Estimate of Timber Volume	*functions, tables*	*each stem*	*m³*

Standing Dead Trees – each measurement to be made for each stem in Core Area

Species	field assessment	each stem	Latin name
D.B.H.	field assessment	each stem	cm
Height (to top of tree)	field assessment	each stem	dm
Location	field assessment	each stem	X,Y co-ordinates
Stage of decay	field assessment	each stem	categories
Estimate of Timber Volume	*functions, tables*	*each stem*	*m³*

<u>Shrub Layer</u> – if shrub layer abundant, measurements can be made in subplots within Core Area

Species	field assessment	subplot area	Latin name
Number of stems	field assessment	subplot area	categories
Height of stems	field assessment	subplot area	categories

<u>Regeneration Layer</u> - if regeneration layer abundant, measurements can be made in subplots within Core Area

Species	field assessment	subplot area	Latin name
Number of stems	field assessment	subplot area	categories
Height of stems	field assessment	subplot area	categories
Damage from herbivores	field assessment	subplot area	categories
Regeneration origin (seedlings, sprouts, etc.)	*field assessment*	*subplot area*	*categories*

<u>Lying Dead Wood</u> – each measurement to be made for each component in Sample Plot

Species	field assessment	each component	Latin name
Component (whole tree/stump/stem/branch/etc.)	field assessment	each component	categories
Diameter at Breast Height (D.B.H.)	field assessment	each component	cm
Length/Height	field assessment	each component	dm
Location	field assessment	each component	X,Y co-ordinates
Stage of decay	field assessment	each component	categories
Estimate of Timber Volume	*functions, tables*	*each tree*	*m^3*

<u>Ground Vegetation</u>

Species list (higher plants)	field assessment	sample plot	Latin names
Cover/abundance of species (higher plants)	field assessment	subplot area	%, or categories
Total Cover of Bryophytes, Lichens, Fungi	*field assessment*	*subplot area*	*%, or categories*

Appendix 2. Guidelines for measurement of attributes in forest reserves research

NOTE – Appendix 2
mm = millimetres; cm = centimetres; dm = decimetres(=0.1m)
"categories" = you are required to devise categories or incremental classes for these attributes, rather than reporting individual values
Four aspects of each attribute are presented:

a) measurement rule – brief definition of attribute
b) threshold – smallest measurement to include
c) measurement scale – unit of measurement to be used
d) data source

Site Characteristics

Slope (Gradient)

a) Average slope/gradient
b) -
c) %-classes
d) field assessment

Aspect

a) The exposure of a slope is the direction in which it faces
b) -
c) degrees
d) field assessment

Relief

a) Topography of sample plot area
b) -
c) categories
d) field assessment

Description of Humus Layer

a) Name of humus type
b) -
c) categories
d) field assessment

Description of Soil Type

a) Name of soil type
b) -
c) categories
d) field assessment

Stand Characteristics

Standing Live Trees

Definition: Living, standing trees (incl. shrubs) with a D.B.H. of 5 cm or greater

Position (X,Y)

D.B.H.

a) Measured at 1.3m height above ground; on slope measured from uphill side. One reading, calliper (right leg) pointing to plot centre, on slope calliper pointing downhill. Measured point marked by drawing pin; paint. Or: use a tape measure to measure tree girth at 1.3m above ground, and calculate diameter from girth measurement.
b) minimum d.b.h.: 5 cm
c) cm
d) field assessment

Tree height

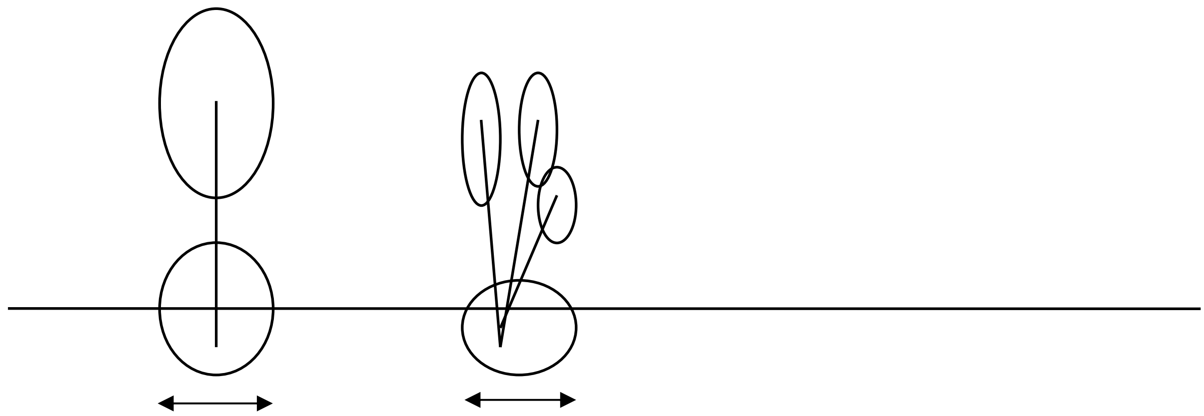
a) Height of tree from ground level to top of tree.
b) minimum d.b.h.: 5cm
c) 0.5m
d) field assessment

Height to the living crown

a) Length of stem from ground level to first living branch of crown
b) minimum D.B.H.: 5cm
c) 0.5m
d) field assessment

Crown projection

a) measurement of 8 radii (in the sky direction). By missing crown areas, the whole crown projection is averaged
b) minimum DBH: 5cm
c) 0.5m
d) field assessment



Stem quality

a) Stem quality according to given categories
b) - categories
c) -
d) field assessment

Vitality (Needle/Leaf loss extent)

a) Needle/Leaf loss extent and type of loss for the whole crown
b) Categories
c) assessment only on predominant and dominant sample trees
d) field assessment

Estimate of Timber Volume

a) Volume of growing stock estimated by functions and/or tables
b) minimum d.b.h.: 5cm
c) m^3
d) calculation

Standing dead trees
Definition: Dead, standing trees with a d.b.h. of 5 cm or greater

Position (X,Y)

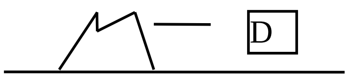
D.B.H.
a) Measured at 1.3m height above ground; on slope measured from uphill side. One reading, calliper (right leg)pointing to plot centre, on slope calliper pointing downhill. Measured point marked by drawing pin.
b) minimum d.b.h.: 50 mm
c) mm
d) field assessment

(Tree) Height
a) Height of tree (stem) from ground level to top of tree (stem).
b) minimum D.b.h.: 5cm
c) dm
d) field assessment

Stage of decay
a) -
b) -
c) Level of decay
   1) recently dead (1-2) years
   2) early phase: Bark loosens, timber is still solid, starting to rot in the middle <1/3 diameter
   3) Advanced decomposition: splint soft, timber only partial hard, centre rotten >1/3 diameter
   4) Badly decomposed: timber completely soft, surrounding completely loosened
d) field assessment

Estimate of Timber Volume
a) Volume of standing dead tree estimated by functions and/or tables
b) minimum d.b.h.: 5cm
c) m^3
d) calculation

Stumps
Definition: Stumps up to a height of 130cm and a minimum diameter of 10cm



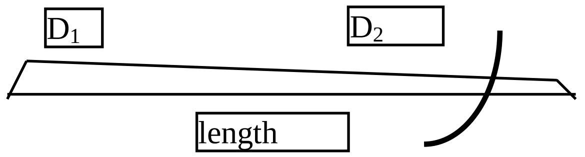
Position (X,Y)

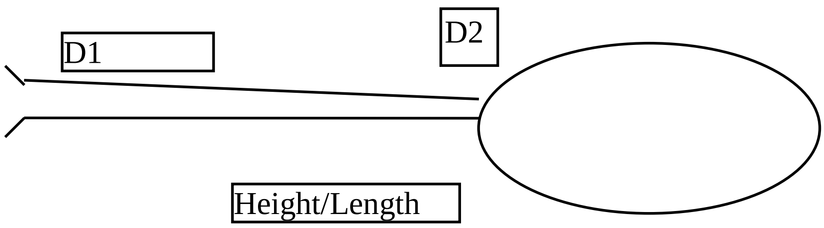
Diameter
a) Diameter at the break point
b) minimum diameter : 10cm
c) cm
d) field assessment

Height
a)
b)cm
c) cm
d) field assessment

Estimate of Timber Volume
a) Volume estimated by functions and/or tables
b) minimum d.b.h.: 5cm
c) m^3
d) calculation

Lying dead stems and/or dead thick branches and/or trunk parts
Definition: Dead, lying pieces, diameter of at least 10 cm at the lowest end





Position (X,Y)

Diameter
a) Diameter (D1) at widest point and diameter (D2) at the top/narrowest point or at the sample plot border
b) D2 must be ≥10 cm
c) cm
d) field assessment

Length
a) Length between D_1 and D_2
b) -
c) dm
d) field assessment

Estimate of Timber Volume

a) Volume estimated by functions and/or tables
b) minimum diameter 10 cm
c) m^3
d) calculation

Stage of decay

a) -
b) -
c) Level of decay
   1) Freshly dead (1-2) years
   2) Decay starting: Bark loosens, timber is still solid, starting to rot in the middle <1/3 diameter
   3) Advanced decomposition: splint soft, timber only partially hard, centre rotten >1/3 diameter
   4) Badly decomposed: timber completely soft, surrounding completely loosened
d) field assessment

Shrub layer

Definition: Living, standing woody plants (trees, shrubs) up to a d.b.h. of 5 cm and higher than 130cm

Number of individuals of each tree and shrub species

a) Frequency classes of tree and shrub species in subplot area
b) -
c) Frequency classes

Code	n/m²	n/ha
0	0	0
1	= 1	10.000
2	>1 - 3	10.001-30.000
3	> 3	≥30.001

d) field assessment

Number of plants per species

a) Number of plants counted and recorded per species in regeneration plot (B), divided into height classes
b) –
c) number
d) field assessment

Height of shrub layer

a) -
b) minimum height = 130cm; max. D.B.H. = 5cm
c) height classes
   1.3m – 4.0m
   4.0m – 6.0m
   6.0m – 8.0m ………
d) field assessment

Regeneration Layer

Definition: Living young plants (trees, shrubs) higher than 30cm up to a height of 130 cm

Frequency classes of tree and shrub species

a) Frequency classes tree and shrub species in subplot area
b) -
c) Frequency classes

Code	n/m²	n/ha
0	0	0
1	= 1	10.000
2	1 -3	10.001 - 30.000
3	> 3	≥30.001

d) field assessment

Browsing and/or grazing

a) Damage class (browsing/grazing) of each tree species
b)
c) Categories

Code	Visible Damage
0	none
1	some damage, which does not inhibit further development
2	heavy damage, likely to inhibit further development
3	severe damage, stunted development („bonsai“ like)

d) field assessment

Ground Vegetation

Definition: Ground vegetation (includes all higher plants, i.e. ferns, grasses, herbs (no mosses))

Species Lists

a) Species in subplot area
b)-
c) categories
d) field assessment

Cover/Abundance of Ground Vegetation

a) Coverage of ground vegetation on subplot area. Considered are all ferns, grasses, herbs (no mosses)
b) -
c) %; %-categories

Braun-Blanquet

Code	Definition
+	very scarce, scattered, very little cover
1	sparse, little cover (less than 5% cover)
2	5-25% cover
3	25-50% cover
4	50-75% cover
5	75-100% cover

d) field assessment

Appendix 3. A list of WG 2 members.

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RI = Research Institute, UN = University, AM = Administration