Action A.2.03

Assessing the influence of forest management on biodiversity

METHODOLOGY REPORT

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1 Introduction

The removal of a significant part of biomass by timber harvesting has an enormous impact on the energy flux and the biogeochemical cycles of a forest ecosystem. Changes in structure and composition by forest management may have important effects on the availability of habitat structures in the forest. The presence of old, large trees and standing and laying dead wood of different tree species and dimensions are important for biodiversity but often scarce or absent in managed (Bütler et al., 2020a, 2020b, 2005; Eckelt et al., 2018; Lachat et al., 2019; Lorenz, 2012; Moning et al., 2010). Moreover, several studies are showing significant importance of so-called microhabitats (e.g. broken crowns, fungi on living and dead trunks, stem/branch cavities, bark-damages) on the biodiversity of forest habitats (Flade et al., 2004; Winter et al., 2016).

While species data for specific groups like plants, birds and mammals may be available from several studies, data assessment of other species-rich groups like fungi or invertebrates may be fragmentary due to high efforts and a low number of available experts. That is why exhausting biodiversity data for forests is uncommon in many forest ecosystems.

This is why proxy indicators like stand age, size of trees, gap-patterns or dead wood amounts are widely used to assess biodiversity (e.g. Geburek et al. 2010), while only a few studies are able to link structural forest data to empirical species numbers.

Under the proposed research, a wide-ranging literature survey on available studies in biodiversity and biodiversity indicators, focussed on beech forests will be implemented. The focus is to link species richness information to structural data, that can be used as a proxy indicator. The scope of studies will be widened from the data available from beech forest of the World Heritage network to other representative studies from other primary and old growth sites.

The analysis of European literature on biodiversity of beech forests and the linkage of rare species to specific micro habitats and structures of old growth forest will answer the following main questions:

- What are the important microhabitats and key structures in beech forests that indicate high biodiversity?
- Which quantity of these microhabitats and key structures are needed (average frequency per ha) to maintain a typical beech forest species biodiversity?
- What species can be used, to indicate the existence and long-term continuity of primary and old growth structures of the forest stand?

Based on this study, a list of structural indicators and microhabitats has been developed and implemented in a standardised field protocol and survey setup. This protocol was be applied for all test sites, to provide adequate data for the ecosystem services assessment.

For assessing biodiversity, the following proxy-indicators have been selected:

- Volume of standing deadwood and decay-stages
- Volume of lying deadwood and decay-stages
- Tree-Micro-Habitats (TREMs) at living and dead trees



2 Plot design of the dendrometric survey

Below, a set of parameters is listed that should be measured in every plot, using minimum standards of precision and threshold size. They are listed under 'REQUIRED'. Other parameters that can be useful and informative, but not essential for the project, are listed under 'ADDITIONAL'.

Many of these parameters are already registered in existing monitoring protocols. Field teams should check the requirements with their protocols and do additional measurements where needed to meet the requirements of the protocol.

Sampling strategy: use sample plots (preferably circular plots), located and selected according to the criteria described in chapter 5.

2.1 Plot size

REQUIRED : at least R=10m (314 m^2) (also 9m is accepted for existing plots) when already established as a standard)

Preferably: larger (500-1000 m^2); single or nested plot.

Plotless sampling (Bitterlich method) only allows for BA-assessment and does not allow for volume calculations or DBH-assessments, nor dead wood. They do not meet the requirements.

In case of nested plots, the radius of the plot to cover the minimum DBH trees (see below) should be 9m.

2.2 Living and dead standing trees - DBH threshold : 10 cm (preferably 7 cm), Height>130 cm

REQUIRED in all plots: all living and dead trees meeting the size threshold within the plot radius should be surveyed. For the assessment of whether a tree lies within the sampling circle or not, the distance from the plot centre to the tree axis is measured at DBH height. If the distance is less than the selected radius, the tree is recorded.

In the case of multi-stemmed trees with branching less than 1.3m in height, each individual stem is surveyed separately as single tree.

Diameter at Breast Height (DBH) always measured 130cm above ground surface; vertically for leaning trees. In steep terrain the measurement is always taken from the higher point (upslope). Measurement is performed with a diameter measuring tape or a calliper. When using calliper, to obtain more accurate results, 2 measurements are preferably taken at perpendicular angles.

Dead hanging trees, with a deviation from the vertical axis of more than 45° are classified as ' lying deadwood' and recorded as such.

When using traditional analogue measuring devices and field forms, , we recommend to enumerate the trees in the sample at the beginning of the survey, in order to ensure that all tree related data are recorded are linked with the correct tree. Starting from North clockwise is one option.

The following parameters are **REQUIRED** for each tree:



- Tree species (if not assessable for deadwood at least conifer/broadleaf)
- DBH (cm)
- Status (living/dead)

ALSO **REQUIRED** for dead trees :

- Species (if still possible, at least conifer/broadleaved),
- DBH,
- Indication if tree is dead standing or broken (snag)
- Height for all snags
- decay stage in at least 3 classes (use characters for coding h,p,s; see table 5).

ADDITIONAL : Decay stage in 5 classes (use numbers for coding 1,2,3,4,5)

ADDITIONAL : cut stumps and snags< 1.3m :

A separate sheet is used for stumps and snags < 1.3 m with the following attributes: Tree species, decay stage, diameter, height

We use the term 'stump' for the remnant part of the tree after cutting. The term 'snag' is used for natural broken remnants of dead trees without sign of human interaction. The existence of cut stumps are an indication of human activity.

On plots selected for tree-coring (approximately 5-7 managed and 5-7 unmanaged/OGF forest plots, see details for tree-coring in chapter **Error! Reference source not found.**, p**Error! Bookmark not defined.**)

- Tree height (for 3 trees of the upper canopy for at least 10% of sample plots)
- Tree age (1 core for each 20 cm diameter class for beech and other dominating tree species for at least 3 old-growth and 3 managed forest plots; 30 cores in total)

Additional data :

Tree number (starting from North, clockwise)
Tree position: X/Y or Direction ° (azimuth, 360°)+ Distance (cm)
Relative height of the crown onset (l: lower third, m: middle third, u: upper third

By recording the tree number, tree species, angle and distance to the centre point, the tree can be clearly identified (for a possible repetition of the recordings).

Table 1: Decay stages of dead wood

Minimum (required)	Optional
h: hard	1 (freshly dead)
	2 (hard, bark still on the log)
p: partly decayed	3 (decayed, knife can penetrate deeply in direction of fibres but not transvers),



	4 (high decay, knife-blade can penetrate also in transverse direction to the fibres into the log, parts of original volume already lost)
s: Soft	5 (wood completely soft, mouldered log fall apart into fragments, can be separated easy by hand or foot)

2.3 Assessment of TREM

This report describes in the minimum requirements proposed for quantifying tree microhabitats (TreMs) in Life Prognoses study forests. Please refer to the Literature review "*Action A.2.03 - Assessing the influence of forest management on biodiversity*" (Di Filippo and Di Fiore, 2022) for further details justifying the selection of indicators and the suggested thresholds.

The suggested field approach is based on a list with synthesizes the minimum number of TreMs commonly considered in the most up-to-date scientific literature. In order to simplify the field approach, an effort has been made to homogenize thresholds among different TreMs.

The following indications consider the fact that tree microhabitats are often recorded in presence/absence (rarely counted), only on the tree trunk, and their frequency is calculated at the plot or stand scale. The crown is generally not considered since both TreMs and their size may be difficult to assess. A typical height limit is the tree canopy base, which is tree- and site-dependent.

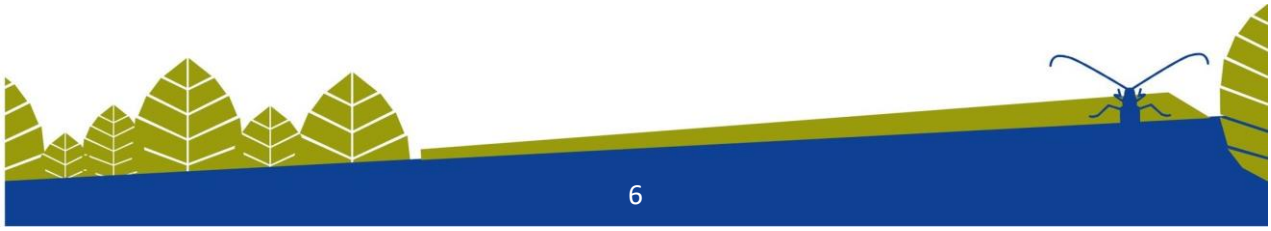
The occurrence and frequency of TreMs has often been analysed in relation to the characteristics of TreM-bearing tree, usually DBH and species. Among site-related features, forest management (including time since the last harvest) was the most frequently investigated factor.

Plot number and size

The number of plots and their minimum size will be defined according to the general methods established in the Field Manual for describing old-growth attributes ((Vanderkerkhove et al., 2022) and quantifying carbon content (A2.02). In case there is an already existing plot network, microhabitat assessment can be performed on the plots already in place, provided that the sampling network has already been validated for structural/biomass studies in terms of statistical error. In alternative, it is suggested to implement a network based on the Field Manual (Kirchmeir et al., 2022): one circular plot within a regular grid with mesh size 100 m, either regularly or randomly placed.

2.3.1 TreMs assessment within each plot

Within each plot, assess the presence of TreMs after the following indications:



- Observation Unit: Tree or Standing Dead Tree with DBH ≥ 20 cm
- Observation Height: analyse the portion of the stem between the ground and the insertion of the first primary branch contributing to the sun-exposed tree crown (crown TreMs assessed independently from this definition).
- Recording TreMs: for each Observation Unit, record the presence of each TreM type according to the categories absent/present.
- TreM types and thresholds: see Table 1.

Table 2: Proposed TreMs and the corresponding thresholds. TreM Category

	TreM Type	Proposed Threshold				Notes
		Diameter / Width (cm)	Length (cm)	Depth (cm)	%	
REQUIRED						
Bark	Bark pocket	10	10	1		Loose bark, still attached to the stem
	Bark loss	10	30			Wood exposed, no cavity
Crack	Crack	1	30			Shows exposed or rotting wood inside the crack (not re-closed)
Trunk cavities	Woodpecker breeding cavity					breeding cavity, not foraging cavity or 'cavity attempts'
	Trunk rothole	10				
Tree base cavities (0-50cm above ground level)	Base rothole	10				Rot-hole below 50cm above ground; mostly with soil contact
	Root buttress concavity	10	10	10		Living wood; stem base deformation due to root buttressing, forming a shelter
	Dendrotelms	10				At least temporarily water-holding; can be in living wood or rotholes
Fungi	Perennial polypores	10				Living & dead fruit bodies of perennial species (=fruit body has woody texture and persistent for at least one year)
Crown damages	Dead crown				> 25	Over ¼ of the crown is dead
	Broken crown				> 25	at least ¼ of the crown has broken off (can be top-end or large limbs)



ADDITIONAL						
Bark	Exudates (sap, resin)		10			Crack/burst with active flow of sap or resin
Epiphytes	Mosses, lichens				30	At least 1/3 of the trunk up to 3m is covered
	Climbing plants/vascular plants				30	At least 1/3 of the trunk up to 3m is covered (ferns, Hedera, Clematis,…)
Cankers	Cankers	20				Deformations caused by an infection, dead or living (burrs),

REQUIRED:

record presence/absence per stem>20cm DBH (living and dead) for every of the required elements above. Always relate the recording to the individual tree (of which you also recorded at least its DBH, species, living/dead status).

ADDITIONAL sampling:

- also sample dead branches, branch base rot, ...or use the 47 types of Larrieu et al.,(2018);

- sample also tree crowns;

- sample also lying dead trees

ADDITIONAL recording:

for 'countable elements' : count the number of occurrences on every tree.

If additional elements are sampled, always make sure that you separate the results from the required protocol!

2.3.2 Additional TreMs to be measure on a voluntary basis

TreMs in Table 1b (exudates, epiphytes, climbing plants, cankers), as well as TreMs not reported in Table 3 in 2.03 Literature Review (Di Filippo & Di Fiore, 2022): e.g. insect galleries, nests, witch brooms, microsoils, pit-and-mound.

Additional TreMs may be recorded on observation units or, alternatively, in the overall plot description as categorical variables, e.g. present in the plot on: < 10%, 10-50%, > 50% trees.



2.3.3 Analysing TreMs differences between old-growth and managed forests

The data collected in the field will be analyzed to match old-growth and managed stands considering the main TreM statistics summarized in the Table 1 of the in 2.03 Literature Review (Di Filippo and Di Fiore, 2022). For instance, possible statistics to compare and analyses to perform could be:

- Absolute and Relative Frequency, Density of TreMs on living or standing dead trees
- Distribution of stem according to tree species and size, and in general with respect to stand structure
- Differences in TreMs between old-growth and managed forests
- Relationship among TreMs and the main indicators of old-growthness
- Changes in TreMs along the environmental gradient covered by the network of sites.



3 Lying deadwood –lying [B, C]

Lying deadwood normally consists of trunks -or parts of it- and branches that fell to the ground. In managed forests, it may also consist of harvest residues (crown wood) or even forgotten and abandoned piles of wood or logs.

Freshly cut trees, that are obviously destined for extraction, are normally not registered.

Also excluded are wooded structures (benches, …) and dead branches that are still attached to living trees.

Hanging dead trees are considered as 'laying' if the deviation from the vertical axis is more than 45° (other is assessed as standing)

Lying deadwood is registered if it meets the minimum size requirements. The registration will depend on the applied method (below).

Two sampling methods are applied to lying deadwood : Line intersect sampling (LIS) or Full-area sampling (FAS). The required measurements are described below for both methods separately.

3.1 Line intersect method

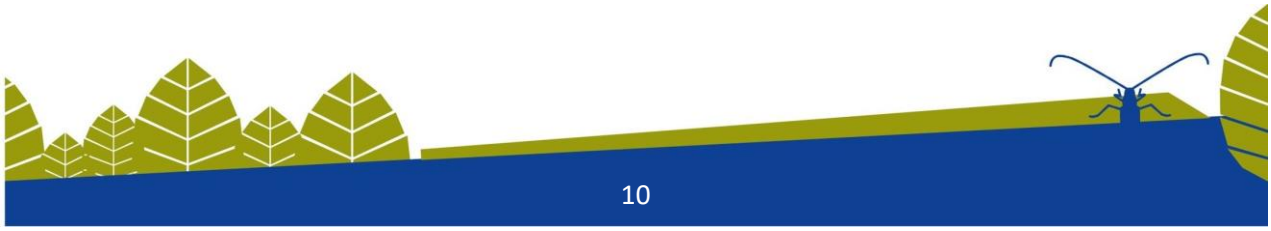
The line- intersect method is one option which is simple and time efficient (Ritter and Saborowski, 2012), but is not precise for local deadwood volume estimations (no local estimator). The result becomes stable and reliable when combining data from at least 10-20 plots combined.

The "line intersect" method was originally developed in North America for the assessment of the hazard potential posed by flammable undergrowth (WARREN & OLSEN 1964; VAN WAGNER 1968). In this method, all lying deadwood that crosses one of the 'intersect lines' and meets the diameter threshold at this point is recorded (independent of their length). Crossing does not require the fragment to touch the ground: it can cross the line at several meters high (e.g. branches of a fresh fallen crown that cross the line) . Dead hanging trees, with a deviation from the vertical axis of more than 45° are considered as 'lying deadwood' and recorded if they cross the intersect line.

If a deadwood fragment crosses the transect line more than once (or crosses several transect lines), it will be recorded at every crossing.

Not recorded are fragments of which the central axis coincides exactly with the transect line (very rare), or which touch the transect line but not cross it with their centre axis.

REQUIRED length and position of intersect lines : at least 2 intersect lines oriented perpendicular to each other, and centred at the plot centre are required. A design of three transects in orientation of 120° to each other and meeting in a central point is also applied (so-called 'fan-design'). Length of all transects together at one plot should be at least 80 m ((Fraver et al., 2018)).



On slopes, one transect is oriented parallel to the slope, the other one in direction of the slope, facing downhill and uphill. In flat sites, the transects are oriented North-South and East-West.

Depending on the applied correction for hillslope, the length of the transect will be 40 m exactly (when measuring along the slope) and corrected afterwards (for transformation to volumes per ha); or corrected in the field (for horizontal projection), resulting in slightly longer line length. In this case, it is **essential to record the precise length of the transect** that was recorded .

REQUIRED measurements : all lying deadwood fragments with Diameter >10cm at the point where the imaginary centre axis of the logs crosses the transect line are registered. Following parameters are measured:

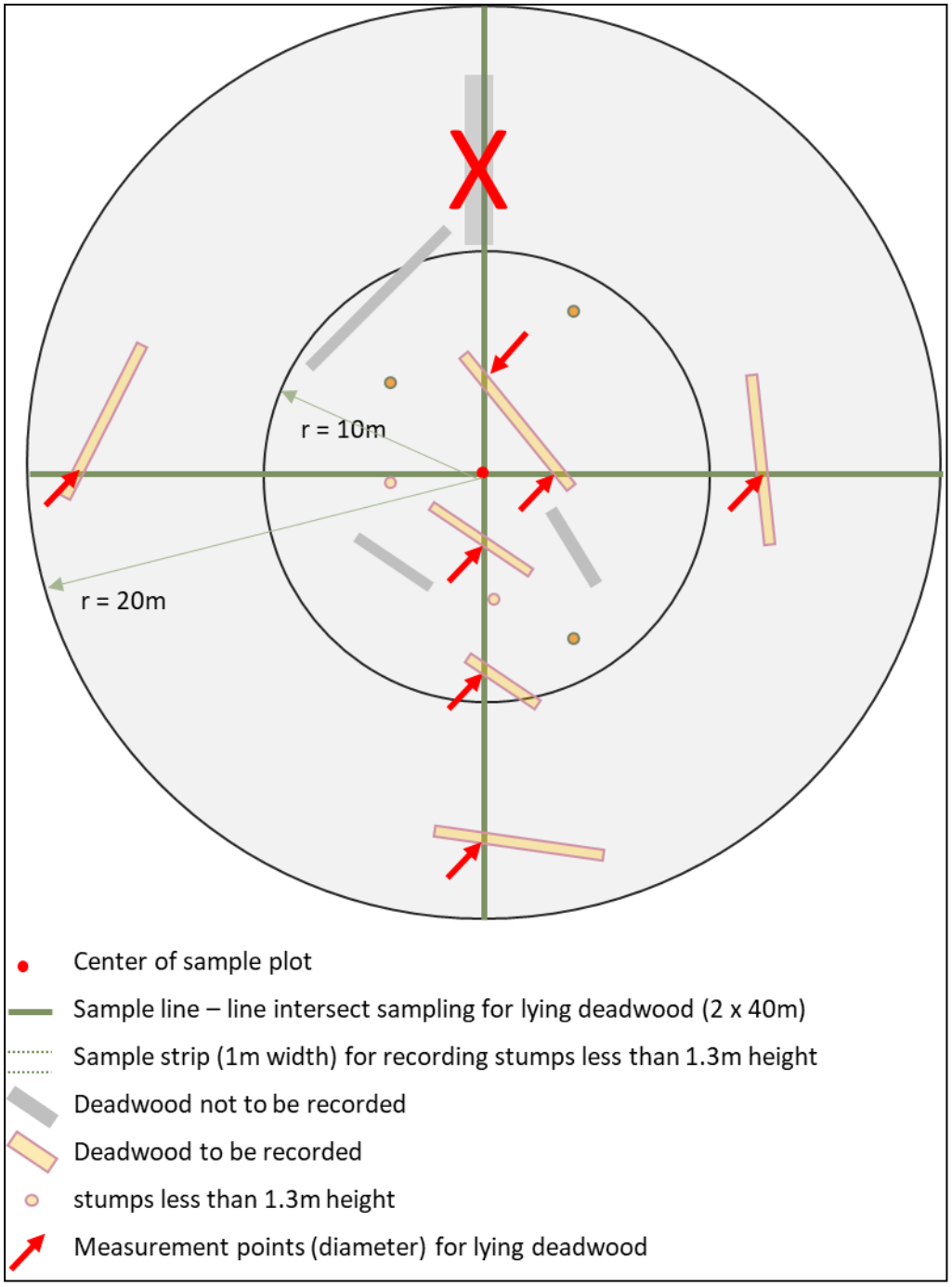
- Diameter (in cm) at the point of crossing (measured perpendicular to the stem axis)
- Decay stage in at least 3 classes
- Tree species (in higher decay stages: conifer, broadleaf, not assessable)

ADDITIONAL:

- Lower diameter threshold
- Decay stages in 5 classes (**Error! Reference source not found.**)
- Origin : sawn, broken or windthrown

Windthrown is if the tree where the fragment originates from was uprooted (check for the presence of a root plate or exposed roots

A visualisation of a possible plot design, when applying line intersects is given below.


r = 10m
r = 20m
Center of sample plot
Sample line – line intersect sampling for lying deadwood (2 x 40m)
Sample strip (1m width) for recording stumps less than 1.3m height
Deadwood not to be recorded
Deadwood to be recorded
stumps less than 1.3m height
Measurement points (diameter) for lying deadwood

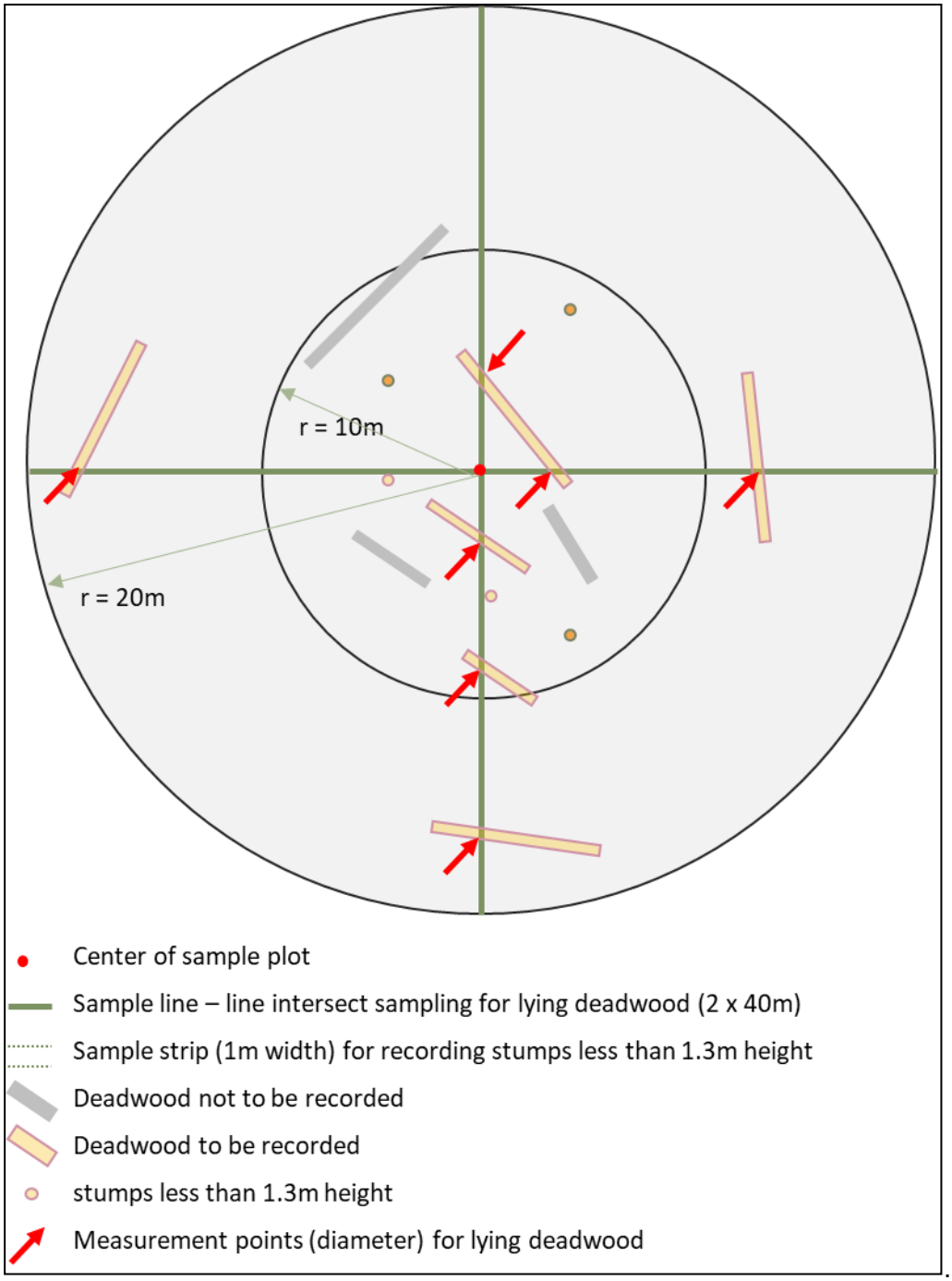


Figure 1: Proposed plot design for field teams who have no existent plot network. It shows the basic unit (circle with 10m and 20m radius), the sample lines (2 x 40m).

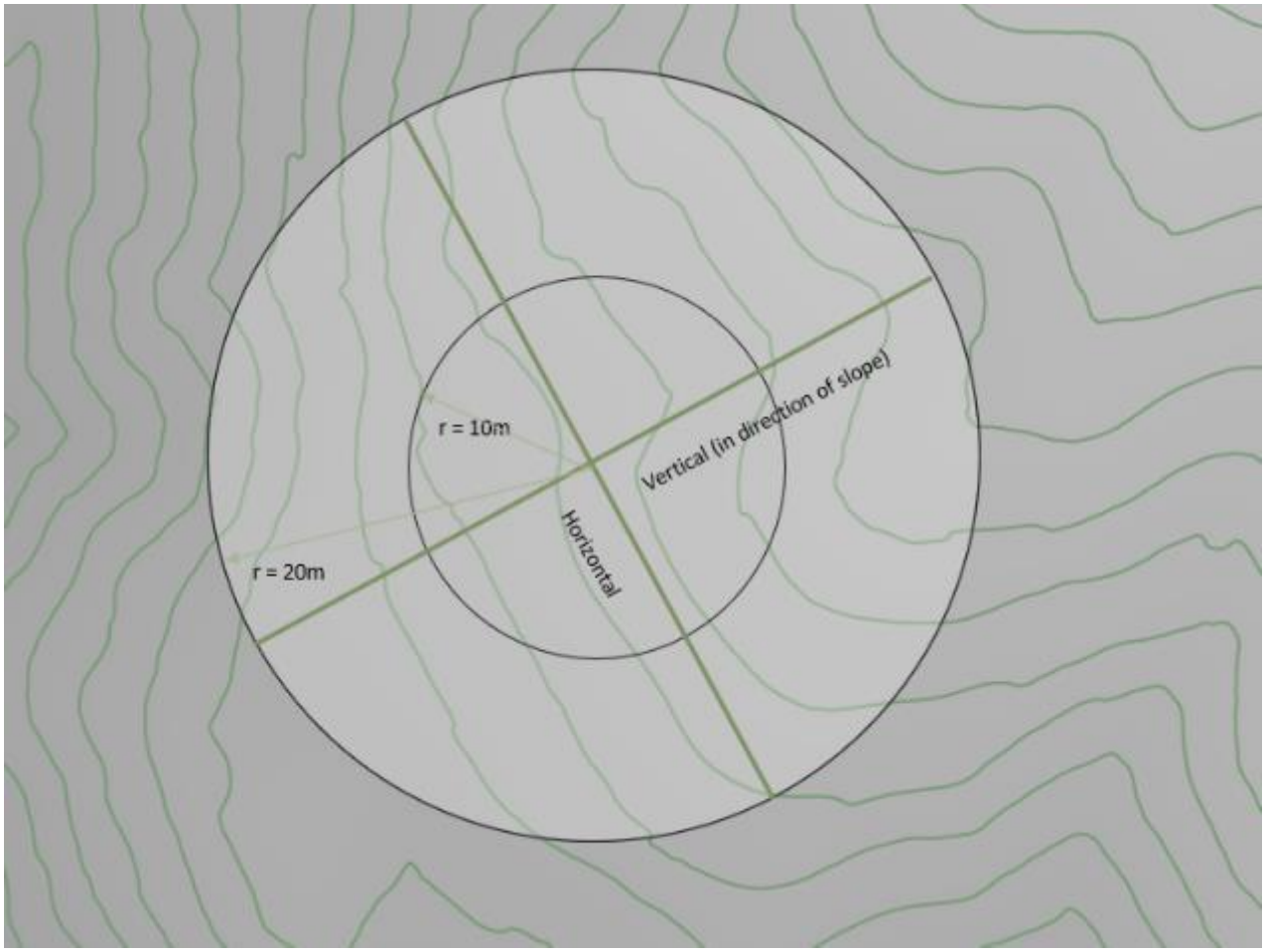


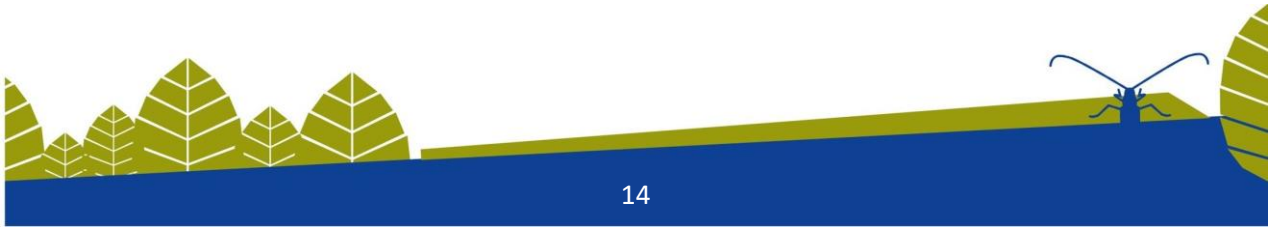
Figure 2: In sloped terrain, the transect are oriented in slope direction (vertical) and parallel to isohypses (horizontal).

3.2 3Dead wood: full sampling

In this method, all lying deadwood units meeting the size requirements are measured. Also parts (e.g. crowns) not touching the ground are measured and considered lying deadwood if attached/part of a fragment or tree that is lying on the ground. Dead hanging trees, with a deviation from the vertical axis of more than 45° are classified as 'lying deadwood' and also recorded as such. Dead branches that are still attached to living trees are not recorded.

REQUIRED : all fragments or dead lying tree sections with a diameter at the largest end of >10 cm and more than 1m length within the 10m plot are recorded. For every fragment, following parameters are recorded :

- Diameter at both ends (in cm) and length of the fragment (in cm) Fragments or trees that cross the border of the plot are virtually 'cut-off' at this border: their diameter and length is measured at this point (or automatically generated if using specialized equipment).
- Decay stage in at least 3 classes

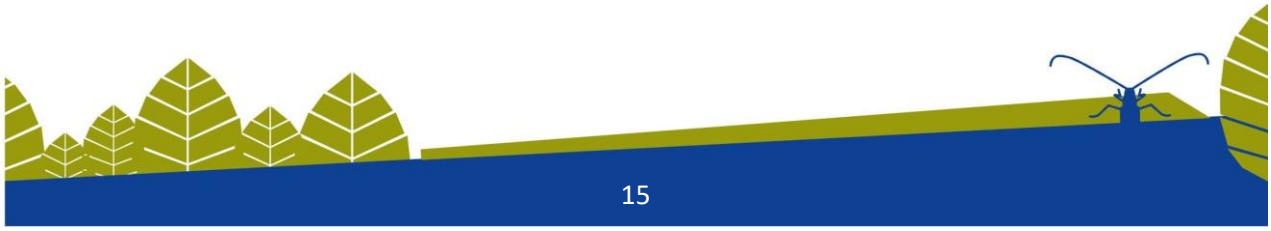


- Tree species (in higher decay stages: conifer, broadleaf, not assessable)

ADDITIONAL:

- Lower diameter threshold
- Decay stages in 5 classes (**Error! Reference source not found.**)
- Positioning of the fragments
- Origin (sawn, windthrown or broken)

Windthrown: tree was uprooted (check for root plate or exposed roots on the tree it originates from.



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