ForestGEO tree mortality and damage protocol

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Overview

The Annual Mortality Surveys (AMSs) aims to evaluate tree vigor, biomass loss, and factors likely to be associated with future tree death. The AMSs include a subset of stems with dbh ≥1 cm at the point of measure (POM) that were alive in the most recent full ForestGEO census. Stems included in the surveys are a stratified subset of trees representing dbh size classes and habitats within the plot. The most characteristic habitats of each plot are discussed a priori with principal investigators. At each habitat, there is a series of nested quadrats, with increasingly smaller trees in the smaller nested quadrats. Each individual is assessed for survival. Each stem is assessed for significant changes in standing biomass and other status metrics that may be related to future survival of the individual. Assessment on an annual basis enables more accurate evaluation of potential causes of mortality than the typical 5-year census interval used in the ForestGEO full censuses. After the full census of a ForestGEO plot, a population of individuals is selected and monitored over subsequent years. Recruitment is not assessed at each mortality survey, so this protocol is a cohort study during the time frame between full censuses. Although this protocol focuses on large forest plots, it can be easily applied to any forest plot. Specific details on sampling design, the rationale behind the variables collected as well as the statistical and practical issues considered in the AMSs are described in Arellano et al. (2021). The ForestGEO website contains this protocol, the link to the peer-reviewed paper, and example datasheets (https://forestgeo.si.edu/node/146527/).

Fieldwork procedure and operational definitions

A field team, usually consisting of two persons (one with a map, one with a form), visits every tree selected for the mortality survey. At each tree, both persons examine the tree while walking around it for ~30 seconds (or longer if the tree is big or otherwise difficult). Give a visual examination of the tree without binoculars. Look for "**immediately visible**" factors, those that can be seen while walking around the tree in ~30 seconds. For large trees, more time will be required to assess crown form, illumination status, liana infestation, etc. Keep in mind that we are looking for (1) things potentially bad for the tree, and (2) symptoms of bad things. The field form needs to be filled out completely for each selected stem of each tree (see following sections). Take time to carefully read and discuss the main operational definitions used throughout this protocol before and during data collection:

POM: Point of measurement of stem diameter, typically 1.3 m above ground. In buttressed trees, or in presence of deformities, it can be at a different height (Condit 1998).

Individual: An individual consists of all woody stems *and* anything else (e.g., non-woody resprouts) that arise from the same root system. Stems with a reasonably obvious aboveground or belowground connection are assigned to the same individual. In the case of clonal species, two stems within 1 m of each other are likely the same individual, but different rules exist depending on the biology of the species. In the ForestGEO AMS, we include individual trees with one or more stems ≥1 cm DBH at the *POM* in the previous full census of the plot.

Stem: Most individual trees are composed of a single stem. If there are multiple woody shoots bifurcating below the POM and reaching ≥1 cm DBH, each of them is considered a "stem" in our protocol. Note that, in some species, stems can be produced at or below ground level. Branches (including those arising horizontally from an obvious main trunk) are also treated as separate stems (not "branches"; see below), as long as they bifurcate below the POM and reach ≥1 cm DBH. In this protocol each stem is assessed separately, so rows in the data forms correspond to *stems*, not individuals.

Main axis: Not all woody plants have an obvious main trunk from base to tip. We use an operational definition to allow consistent measurements during the censuses. The goal is to split any given stem into a *main axis* and *branches* in a way that is repeatable. For any given stem, the *main axis* extends from the rooting point (height = 0) to the apex of the stem, passing through the POM (Figure 1a-c). From the POM to the top of the stem, follow the thickest part at each bifurcation or branching, no matter if it is alive (Figure 1b) or dead (Figure 1 c). If the bifurcation involves two parts of exactly the same size, follow the living one (Figure 1d). If both are alive, follow the most upright (Figure 1e). If both are equally upright, follow the longest (Figure 1f). From the POM to the rooting point, the stem is usually obvious. Only if in doubt, follow the shortest line connecting the POM with a rooting point through living tissues (see Figure 2 for main axis definitions in multi-stemmed individuals, and Figure 10 for examples of main axis definitions).

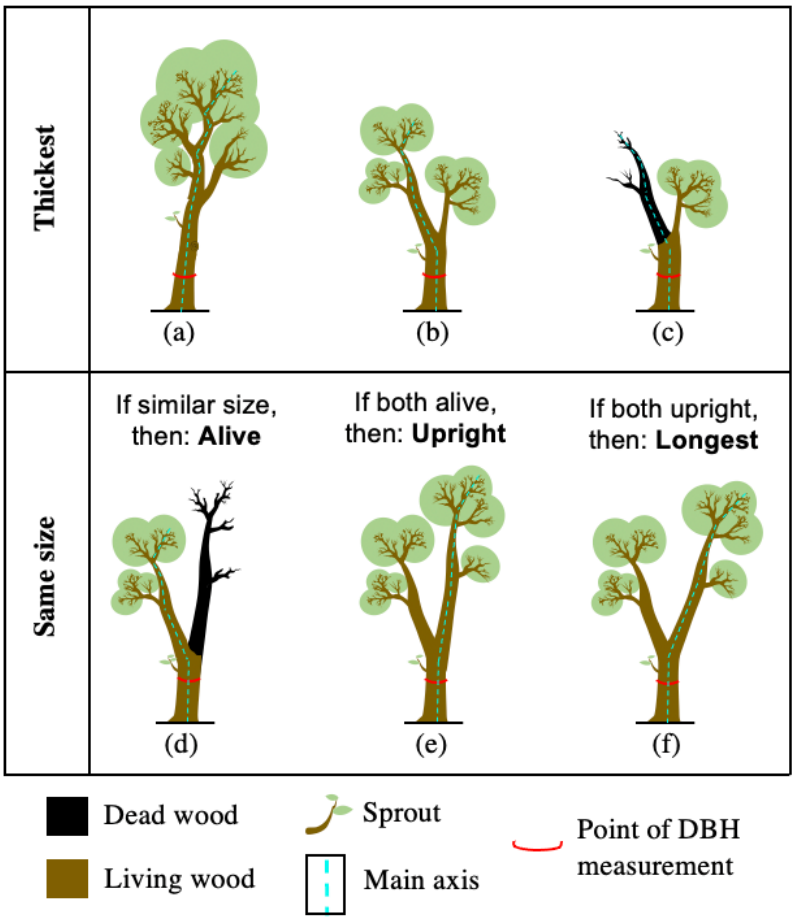


Figure 1. Main axis definition (light blue dashed line) in single-stemmed tree individuals (i.e. only one DBH) used in the annual mortality survey protocol. The main axis criteria are, in order of importance, the thickest, alive, upright and longest tree sections. The thickest part always takes priority (a) even when it is not the most upright (b) or the longest (c) part. Only when two parts in a bifurcation are of the same size, follow the alive part (d) or the most upright (e) or the longest (f). Main axis definitions for multi-stemmed tree individuals are presented in Figure 2.

Branch: Branches are woody shoots connected laterally to the *living length* of the main axis above the POM. Woody shoots connected to the main axis below the POM are by definition stems, not branches (e.g., Figure 4, Figures 9 and 10). If they are ≥1 cm DBH at the POM, they would carry a tag and would be evaluated independently, since we include all the stems ≥1 cm DBH of any included individual.

Crown: the set of all branches on a stem.

Damage: Damage includes any physical harm that leaves the inner wood exposed at the time of assessment. If the inner wood is hidden by sap or latex but you assume the wound is recent and still open, it is also considered damage (e.g., stem #25 in Figure 10). Previously damaged areas that are covered with bark (e.g., sealed wounds, case 1 in Figure 9, stem #1 in Figure 10) are no longer considered damage because they do not represent current risks for the tree. Scars of old branches are not considered damage or branch loss (*e.g.*, Figure 4). This definition of damage is used to decide whether the main axis is broken or not, to estimate crown damage, and to record wounds along the main axis. Note that the distinction between "there is inner wood exposed" and "there is not any inner wood exposed" is crucial for this protocol, since it represents the operational definition of "time". It is our criterion to determine whether something happened recently or too long ago to be considered.

Variables collected at each tree

The data forms are designed to be filled out completely for each stem. If it is not possible to assess a given aspect of a particular stem, use "?" (= "I can't tell in 30 seconds without binoculars."). Do not forget to record people and dates on each form page.

Survival status (OK / A / D / X / NF)

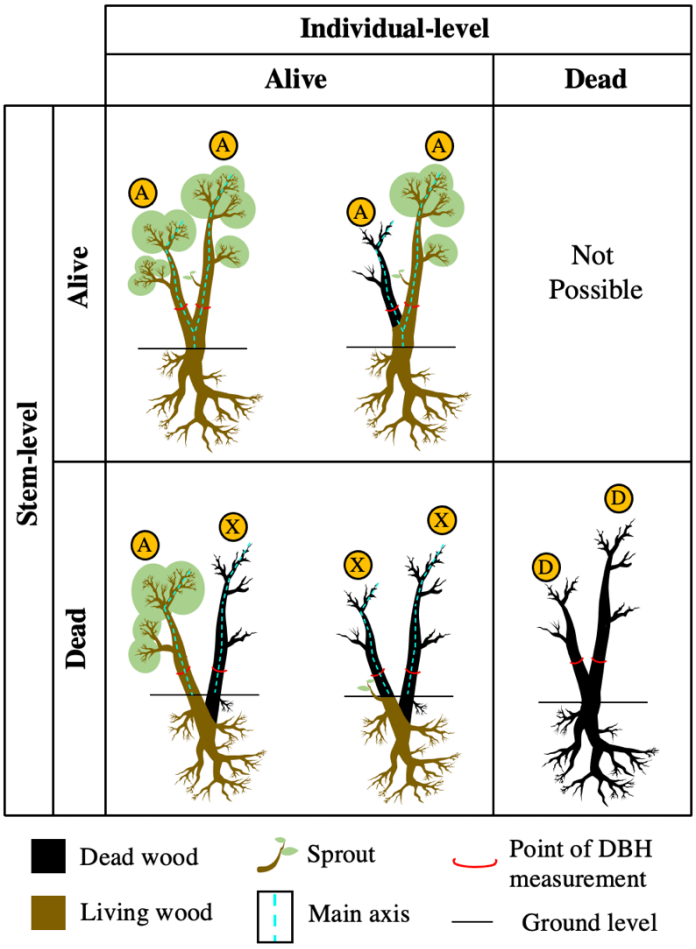


Figure 2. Three unique possibilities to encode the survival status of every *stem* in the mortality survey form: "A", "D", or "X". Note the sprout in the base of the tree in the second "Status = X" case: dead stems in living individuals. This figure additionally provides examples of the *main axis* definition (light blue dashed line) in multi-stemmed individuals.

A: *stem* alive, which necessarily implies *individual* alive. "A" should be registered when there is any living tissue on the *stem*. For example, a small segment of the stem or a resprout. Note that, even if there is no green shoot, a tree could be alive if the cambium is visibly green and the twigs flexible.

D: dead *individual*, which necessarily implies dead *stem(s)*. There is no sign of living tissues anywhere in the *individual*. Not in this stem, not in any other stem, not in anywhere else.

X: This case applies to stems composed of entirely dead tissues above ground ("living length = 0 m", see below) in a living individual (i.e., an individual that has living tissues somewhere else, but not on this stem). Given that this protocol only focuses on aboveground components and stems are defined from the ground level, the "X" case applies only for stems with a resprout at the ground level or for multi-stemmed trees that bifurcate at or below the ground level (Figure 2). An alternative way of coding a "X" stem is "status = A" along with "living length [of the stem] = 0 m" (see Figure 10).

NF: Stem not found and tag not found. This case can be interpreted as a dead stem in data analyses, unless the stem is found alive in subsequent surveys.

OK: Is a shortcut for a healthy and undamaged stem. "OK" means that the focal stem is alive, has a standing and complete main axis (not uprooted, not broken), has living tissues from the base to the tip of the main axis, and has a complete crown (90% of remaining crown or more). This code saves a lot of time.

Mode (S, B, U)

This field describes the mode of death (if status = "D") or damage (if status = "A" or "X"). If the tree is dead, the goal is to infer what may have killed the tree. If the tree is alive, the goal is to record damage that reduces total aboveground biomass and may impact future survival.

S: standing. The main axis is complete and retains physical continuity or integrity. It does *not* imply the stem is vertical. This code applies even if the main axis is composed of partially or entirely dead tissues (the length of dead tissue is estimated from the "living length"). Damaged or dead trees will always be incomplete to some degree as dead wood decays. In those potentially unclear cases, if you estimate that the tree died or decayed while standing, note "S".

B: broken. The main axis is snapped, incomplete, but some of it is still standing (may be meters or just centimeters). The broken section of the main axis typically has splinters. Unlike "S", "B" mode generally implies an external force acting on the stem.

U: uprooted. The tree has tipped over with the roots aboveground. This code means that roots that were belowground are now aboveground. Like "B", "U" implies an external force acting on the tree. Stilt or aerial roots, or roots exposed by soil erosion, do not qualify as "U". Uprooted does not necessarily mean that the main axis is on the ground. If Mode = "U", always fill out the "Leaning" field.

All damaged or dead stems coded "S" will become "B" later (Figure 3). It is important to try to record the standing damage (if it happened) before wood decay hides it. A tip that has proven useful in the field to differentiate between an initially "B" tree and an initially "S" tree that later decayed is to examine splinters and woody debris on the forest floor (Figure 3). In the S→ B trajectory, the tree often starts to die and decompose from the top. In time, branch and trunk sections fall down in relatively small and non-continuous pieces. On the other hand, the B→ B trajectory implies an external, mechanical force acting on the stem (e.g., storms, other tree falls). When a tree breaks, the remaining stem has splinters, and the snapped part is generally found as continuous and more obvious sections that take longer to decompose. If still unclear, write "S/B?" or record the uncertainty in the "comments" field.

If the stem is uprooted (U) and broken (B), both codes can be used in the same field. "B" and "S" are not compatible. When the tree is dead and only the tag can be found, fill "Mode = ?".

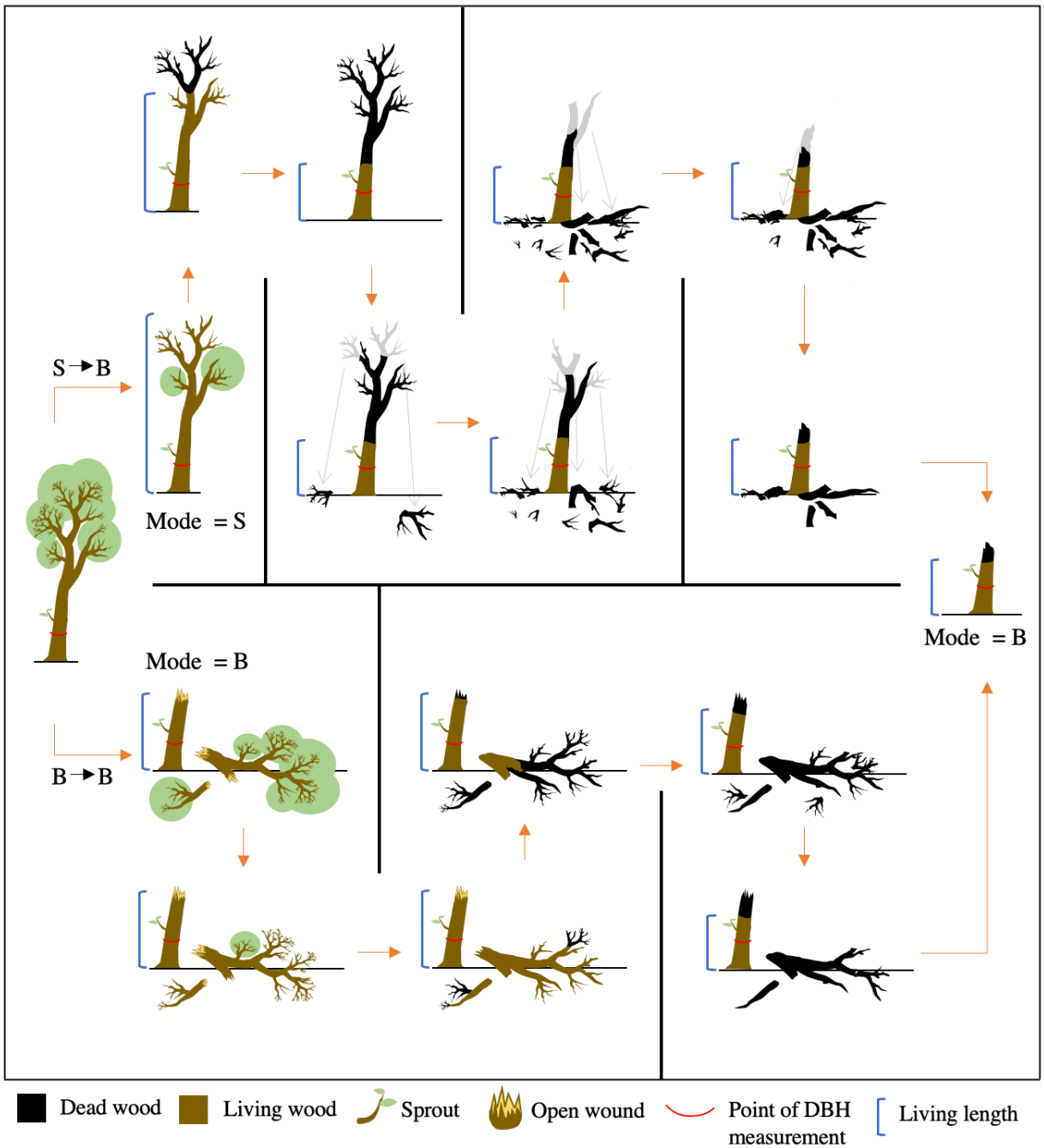


Figure 3. Two different causes may lead to the same recorded *mode* in a stem after some time: from a tree that was broken in the first place (B→B) to a tree that appear broken (B) only after a damage occurs and the wood decays (S→B). Note that, in these cases, splinters and woody debris can provide valuable clues on the mode of damage (or mortality if the tree finally dies). Specifically, the lack of prominent splinters in the stem as well as the presence of softer boles, smoothened segments in the forest floor may indicate that the transition was S→B.

Living length (m)

Record the length in m of the remaining living tissues in the *main axis* of the stem when the stem is alive but broken (mode = "B"), or in the process of dying standing (mode = "S") (Figure 3). Nothing is recorded when there are living tissues along the entire main axis of the stem. Usually the living length corresponds to the basal part of the stem. However, a tree may fall, resprout along its trunk, and survive and grow from there, and its original base could die (Figure 10, case #15) or stay alive (Figure 10, stem #26). In those cases, include the total, accumulated living length along the main axis. In most cases, you will be able to identify short living lengths, particularly if the tag remains attached. In some other cases the tag will not be there and you will not be sure about the former structure of the individual, in which case record "<POM" in this field.

Remaining crown within the living length (%)

Record the proportion of remaining crown (%) within the remaining living length. Branches below the POM are not considered branches in this protocol, so they play no role in the remaining crown assessment. The remaining crown assessment is based on evidence of dead branches still attached or broken branches leaving inner wood exposed (Figure 4). Fallen branches that disappeared so long ago that the scar does not leave inner wood exposed are not included in this estimate. In this field, 100% means that there is no evidence that branches have been lost within the living length, whereas 0% means a tree that lost all the crown within the living length (Figure 4). If there were no branches within the living length in the first place, write "NA", not "0%". It is sometimes difficult to distinguish dead branches from living branches without leaves. Often living branches show abundant twigs that are absent from dead branches (Figure 4). Do not assign low % to naturally sparse and open crowns with very few branches (e.g., *Cecropia*), or abnormal/asymmetrical crown growth that do not involve recent branch loss. For palms, you can assess the loss of leaves in this field, with caution during data analyses.

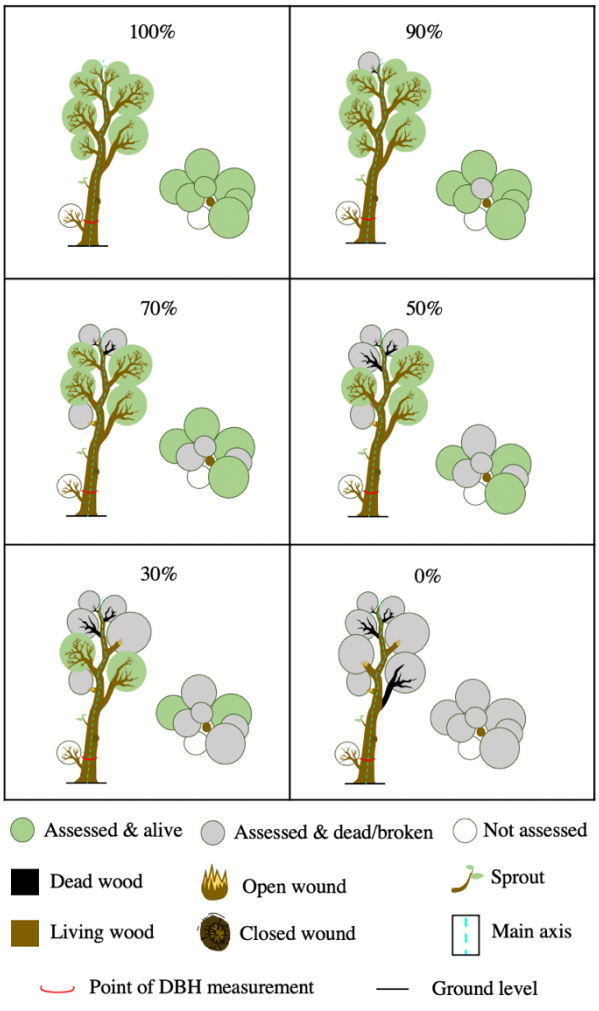


Figure 4. *Remaining crown (%)* assessment, with lateral and vertical projections of standard cases. Green circles correspond to alive branches that are assessed (i.e., they are connected to the living length of the main axis above the POM). Grey circles correspond to dead branches that can remain attached to the main axis (black branches) or that may have fallen recently (open wound). Empty circles refer to structures that are not assessed for "remaining crown" because they are connected below the POM (crown is defined above the POM). Structures larger than 1 cm DBH below POM would be assessed independently, as they would receive an independent tag in common forest inventories; however, they are included in the crown illumination, leaves (%), and leaf damage assessments (see next sections). Note that dead branches, even if not broken, are stripped from small twigs; this is a useful visual clue to detect them in many cases. See Figure 9 for a more complex case of remaining crown assessment with decreasing living length.

Crown illumination, CI (levels from 1 = no light to 5 = full light)

This field describes how much light the tree can access, including all leaves above or below the POM, regardless of whether they are covered with lianas or epiphytes (Figure 5):

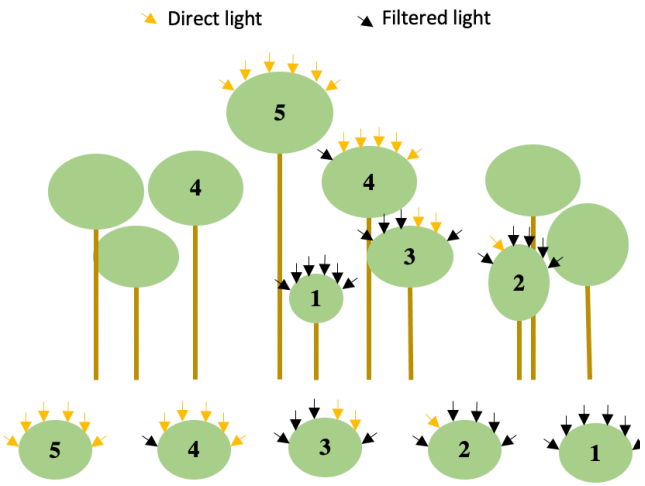


Figure 5. Schematic representation of the *crown illumination* (CI) index.

CI = 5: tree leaves completely exposed to vertical light and to lateral light within the 90 degrees inverted cone encompassing the crown.

CI = 4: full overhead light. ≥90% of the vertical projection of the crown exposed to vertical light.

CI = 3: some overhead light. 10-90% of the vertical projection of the crown exposed to vertical light.

CI = 2: lateral light. <10% of the vertical project of the crown exposed to vertical light, but the crown receives some light laterally.

CI = 1: no direct light. The crown receives only light filtered through the crowns of other trees.

Leaning (°)

This field records the deviation of the stem from vertical; the leaning angle measured in degrees from the base through the POM (Figure 6).

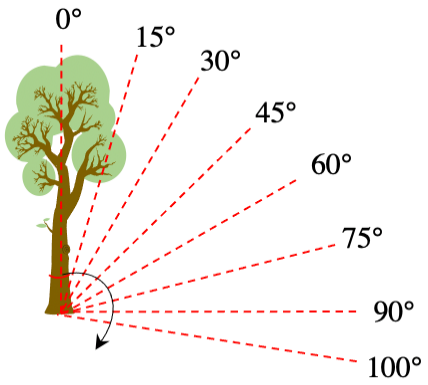


Figure 6. Tree inclination from the vertical, *leaning* (°). Note that for trees lying on slopes or creeks the leaning may be >90°. The inclination always refers to the straight line connecting the rooting points and the POM.

If the stem is curved, assess this attribute in the basal part of the main axis, between the rooting point and the POM (see case 27 in Figure 10).

Liana, stranglers (L, S)

Use "liana" in a broad sense, recording data on any liana, strangler fig or (hemi)epiphyte plant growing on the tree that may be affecting its vitality. If >50% of the crown is covered by a liana (s.l.), the tree is coded "L". If the liana or strangler appears to limit the diameter growth of the main axis, the tree is coded "S". Both codes are compatible.

Fungi (presence/absence)

Check (√) if there are visible fungi on the trunk that might affect the inner wood. Do not record the presence of fungi living superficially in the bark or of lichens on the bark or leaves.

Wounded main axis (levels: 1 = small, 2 = large, 3 = massive)

Record the presence and degree of damage to the wood or bark on the surface of the stem that leaves inner wood exposed. It is assessed within the living length of the main axis and it does not refer to the branches (Figure 7):

1 = small damage, smaller than an area of dimensions DBH × DBH.
2 = large damage, greater than an area of dimensions DBH × DBH but not affecting >50% of the basal area or living length.
3 = massive wound, affecting >50% of the basal area (i.e., a very deep and extensive wound; Figure 7c) or >50% of the living length (Figure 7d). These are cases of main stem breakage in which the breakage is not complete and the broken part is still connected and alive, and trunks that have been longitudinally split in two.

Do not record in this field anything associated with hollow trunks or hollow bases; use the "comments" field for this information.

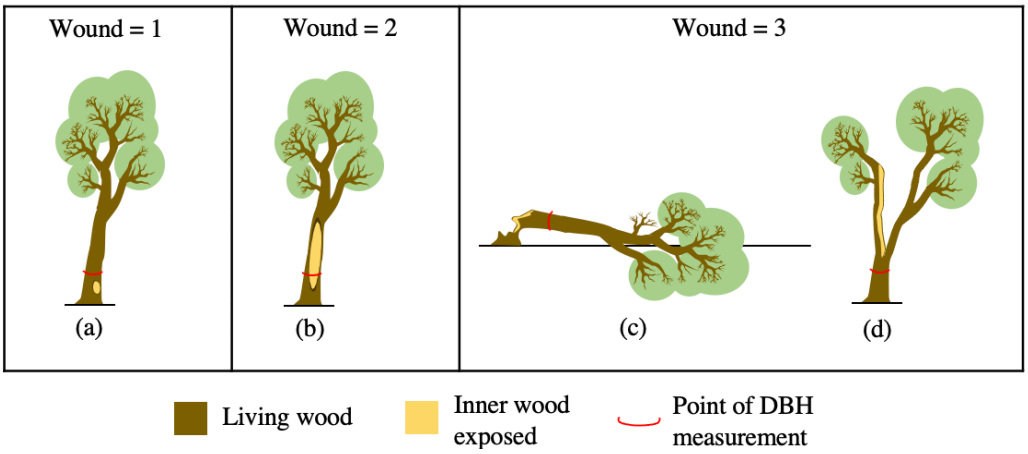


Figure 7. Levels of *wound* assessed on the main axis: (a) smaller in area than DBH × DBH; (b) larger in area than DBH × DBH; (c) massive damage affecting >50% of basal area; (d) massive damage affecting >50% of living length. Areas represented by inner wood can be used as examples when referring to tumors or rotting trunk explained below.

Canker, swelling, deformity (levels: 1 = small, 2 = large, 3 = massive)

The main axis has easily visible canker or deformity suggesting wood disease or abnormal growth of any kind. This may lead to failure of supporting tissues. In these cases, the inner wood is not exposed.

1 = small deformity area, smaller in area than a square of DBH × DBH in shape.
2 = big deformity, greater in area than a square of DBH × DBH in shape.
3 = massive deformity or canker, >50% of the basal area or >50% of the stem living length.

Rotting trunk (levels: 1 = small, 2 = large, 3 = massive)

Record this field when rotting wood is visible and the rotting is active by the time of the survey, but not if it happened in the past. If the wood was previously rotted and has disappeared, for example leaving a hole in the trunk, then that could be considered a "wounded main axis". Rotting precedes hollow trunks in most cases, but it is recorded as "rotting trunk" only if active rotting is taking place during the survey.

1 = small rotting area, smaller in area than a square of DBH × DBH in shape.
2 = big rotting area, greater in area than a square of DBH × DBH in shape.
3 = massive rotting, affecting >50% of the basal area or >50% of the main axis length.

Leaves (%)

If there is immediately visible defoliation, estimate the % of leaves that remain on the tree. This applies only to the living branches, not to the dead branches or parts of the main axis that are dead or gone. It is sometimes difficult to distinguish dead branches from living branches without leaves. Usually living branches show abundant twigs (small terminal branches) that are usually absent from dead branches (Figure 4 above). For palms, leaves (%) and remaining crown (%) correspond to the same assessment.

Leaf damage (presence/absence)

Check (√) this field is checked if, despite the retention of leaves, there is immediately visible leaf damage, including >25% lamina loss, obvious presence of abnormal leaf spots, blotch, etc. Do not record light leaf damage (which is ubiquitous in a natural forest), so this field should remain empty in a majority of cases. If branches have burnt tips this might be a symptom of a lightning strike (see "L" code in comments below).

Comments and other status indicators

In this last field, any additional information on factors likely to negatively affect or increase the risk of tree mortality are recorded. This might include specific comments such as gap size estimations or unique observations linked to the tree status. Each site/study can develop its own codes for fieldwork efficiency. Some codes are:

Animals. If there is immediately visible damage by animals, or animal structures (e.g. big ant or termite nests) that may damage the main axis or be a symptom of poor health, then this is recorded, e.g., "ant nest", "termites", "borer beetle".

L = Lightning. To identify lightning damage in trees, field crews should look for patterns of flashover as the primary diagnostic clue. This includes burnt tips of branches around the focal tree, burnt tips of branches from different trees facing each other, particular palms damaged around the focal tree (they seem to be more sensitive to lightning), or wilting, blackened epiphytes.

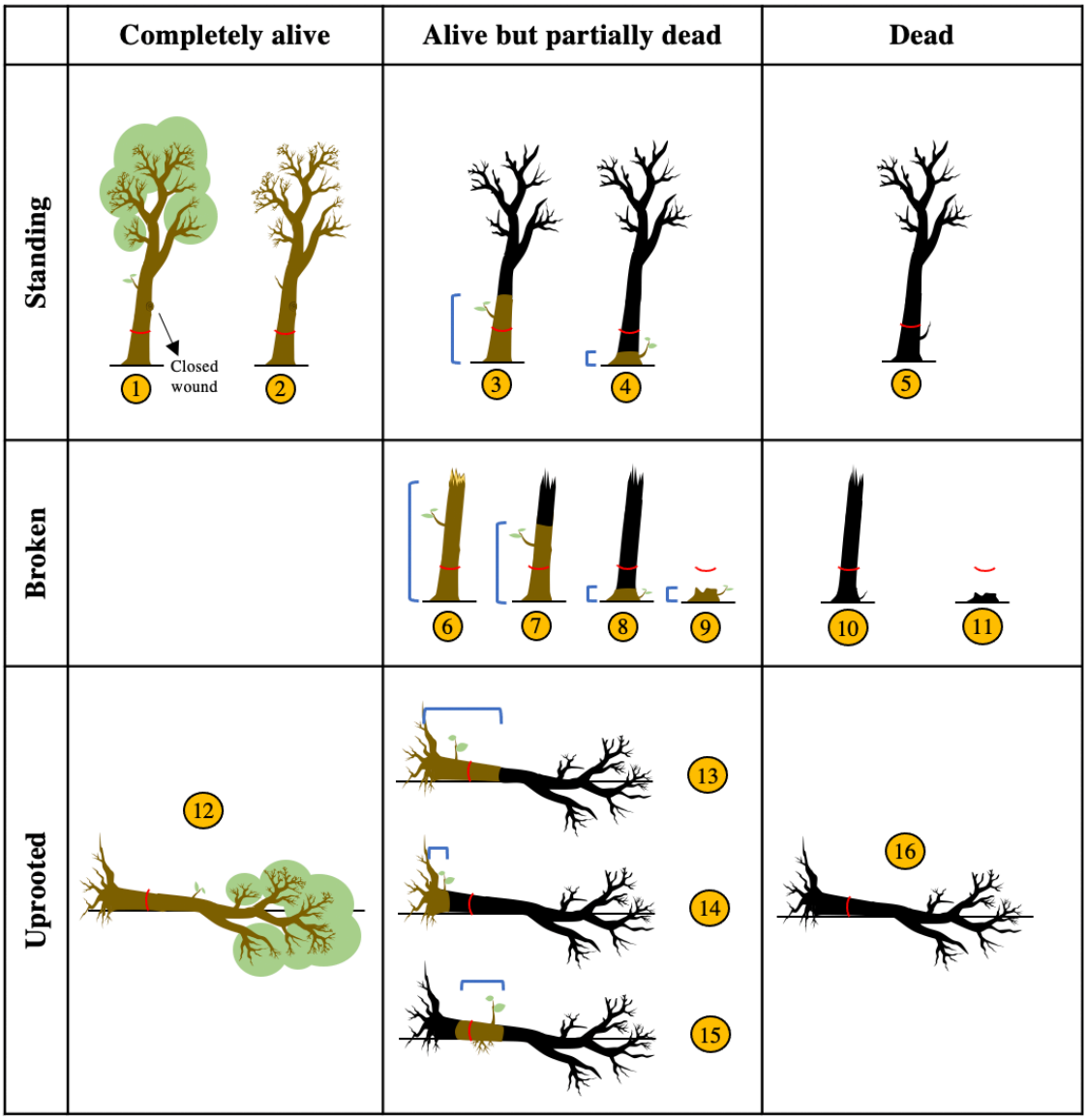
G = Gaps (record the estimated disturbance driver and impact if possible).
F = Fire (stem charred, fire scars on bark).
H = Hollow trunk.
HB = Hollow base of the stem.
R = Root damage.
S = Slope failure, evident landslide even if small.
W = Wind-throw.

Examples with common and rare cases

Figure 8 summarizes the most common cases and provides examples on how to encode them in order to improve understanding of the most main variables in the protocol. Figure 9 shows how to assess the remaining crown when the living length changes. **Figure 10** shows examples and explanations on how to encode particular cases of tree damage and death assessment.

References

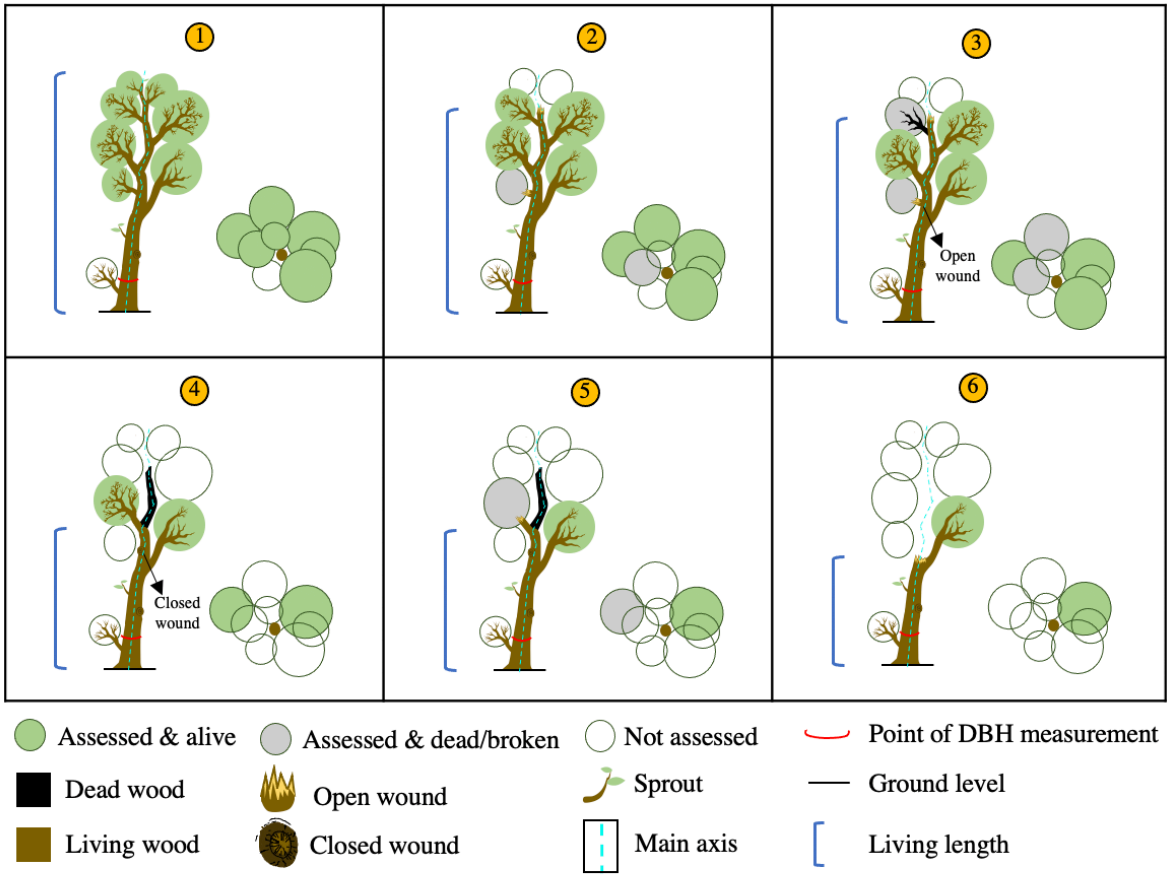
Arellano G., Zuleta D., & Davies S.J. 2021. Tree death and damage: a standardized protocol for frequent surveys in tropical forests. J. Veg. Sci. https://doi.org/10.1111/jvs.12981



Case	Survival Status	Mode	Living length
1	A	S	-
2	A	S	-
3	A	S	3
4	A	S	0.4
5	D	S	-
6	A	B	5
7	A	B	3
8	A	B	0.4

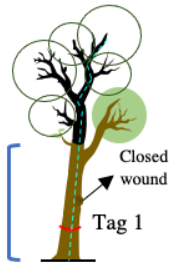
Case	Survival Status	Mode	Living length
9	A	B	0.4
10	D	B	-
11	D	B	-
12	A	U	-
13	A	U	5
14	A	U	0.4
15	A	U	1.5
16	D	U	-

Figure 8. Common cases recorded in the annual mortality surveys. Note that the length of the living length in a stem (blue open bracket '[') can be greater than the height of the last sprout (e.g. in case 2, for a completely defoliated tree). Living length in 'completely' alive trees is assumed to be the total height of the tree; in these cases, we rely on allometric models to avoid estimating heights of every tree in the field. The numeric value in the "living length" column is hypothetical, just an example of a possible living length expressed in meters.



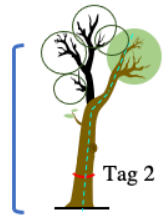
Case	Survival Status	Mode	Living length (m)	Remaining crown (%)	Explanation for the codes
1	A	S	-	100	Typically encoded as 'Ok'.
2	A	B	9	80	Branches that were in the top are not assessed because they are not within the living length and the loss is considered in the reduction of living length.
3	A	B	9	60	Only the remaining crown decreased compared to Case 2.
4	A	B	6	100	The remaining crown is complete because the only branch that is missing within the living length has its wound closed.
5	A	B	6	50	One out of the two branches of similar size is broken.
6	A	B	3	100	The living length decreased, but all branches (i.e., only one) within it are alive.

Figure 9. Assessment of remaining crown within (decreased) living length. We present both lateral and vertical projections in each case. Green circles correspond to alive branches that are assessed (i.e., connected to the living length of the main axis above the POM). Grey circles correspond to dead branches that are assessed and may either remain attached to the main axis (black branches) or have fallen recently (open wound). Empty circles refer to structures that are not assessed because: (1) are not connected to the living length of the main axis (top branches in cases 2-6), (2) are connected below the POM (basal sprout connected to the base of the bole in cases 1-6), or (3) were broken in the past but have closed their wounds (this does not exist to us because it does not comply with our definition of "damage"; cases 4 and 5). In cases 2-6, branches above the living length are not assessed because they are already discounted by the decrease in the living length. Structures larger than 1 cm DBH below POM would be assessed independently, as they would receive an independent tag in ForestGEO plots. Note that dead branches (in black) are stripped from small twigs, even if not broken, which is a useful visual clue to detect them in the field. A sample of the field form encoding for the first four variables of the protocol is shown at the bottom of the figure including a short explanation. The figures represent trees of similar size (~10 m height, as a mere example).



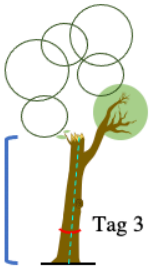
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
1	A	S	3	100

Main axis is defined following the 'thickest' criterion and is Standing (S). Branches within the living length are alive (only one on the right). The closed wound is not considered in the remaining crown assessment. The sprout is a good clue to identify the living length.



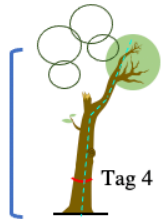
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
2	A	S	-	40

Main axis is defined following the 'thickest' criterion and is Standing (S). The living length is complete; and is filled as '-' because it will be assumed as the total height of the tree (estimated from an allometric model based on DBH). The stem lost an important branch (~60% of existing branches). The closed wound below the sprout height is not a lost branch (it happened long ago).



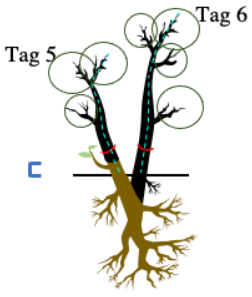
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
3	A	B	3	100

Main axis is defined following the 'thickest' criterion and is broken (B). All branches connected within the living length are alive. The closed wound is not considered in the remaining crown assessment.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
4	A	S	-	40

Main axis is defined following the 'thickest' criterion and is Standing (S). Living length is complete, not broken as in stem #3. The stem lost an important branch (~60% of existing branches). The closed wound is not considered for remaining crown assessment.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
5	A	S	0.5	-
6	X	S	0	-

The sprout is a good sign to define the living length in stem #5. Stem #6 is a dead stem in an alive individual. X cases by definition have living length = 0 m, so that '0' is redundant, in a strict sense. Both living lengths are <POM, so "remaining crown" does not apply.

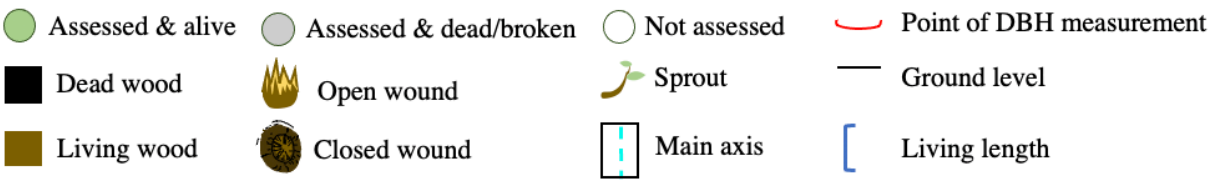
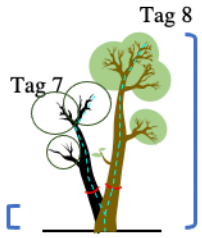
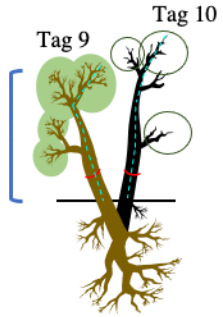


Figure 10. Encoding and explanation for particular cases of tree damage and death assessment. Each tag refers to one stem in the field and one row in the form.



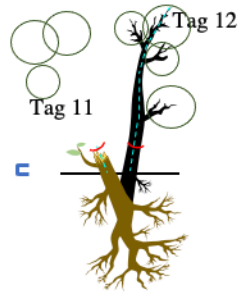
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
7	A	S	0.7	-
8	A	S	-	100

Stem #7 is not 'a dead stem in an alive tree' (status 'X'), because it still has living length > 0 (the proportion shared with the stem #8). The living length of stem #8 is complete. Stem #8 is typically filled as status 'OK'.



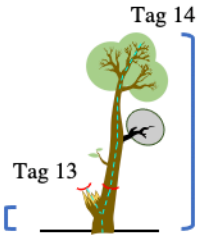
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
9	OK	-	-	-
10	X	S	0	-

Stem #9 is exactly equal in the main four variables to stem #8; but here, we are using 'OK' as a shortcut to indicate that the stem is alive, the main axis is standing (not 'U' or 'B'), it has complete living length, and 90% or more of its remaining crown. Note that '-' in 'remaining crown' means 'complete' in #9 and 'does not apply' in #10.



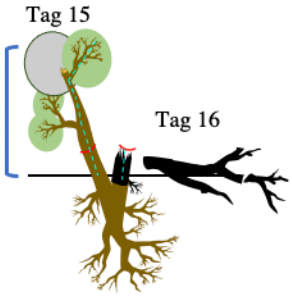
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
11	A	B	0.75	-
12	X	S	0	-

The only difference between stem #11 and stem #5 is the mode.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
13	A	B	0.75	-
14	A	S	-	75

Stem #13 is not a 'dead stem in an alive tree' (status 'X'), because it still has living length > 0 (the proportion shared with the stem #14). The difference between stem #13 and stem #7 is the mode. Stems #14 and #8 differ in their remaining crowns.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
15	A	S	-	60
16	X	B	0	-

Compared to stem #9, stem #15 is not considered 'OK' because it lost an important branch that represented >10% of its crown (~40%). Stem #16 is assessed with mode 'B' because the dead wood has splinters and the woody debris is still on the forest floor (valuable clues to identify external disturbance).

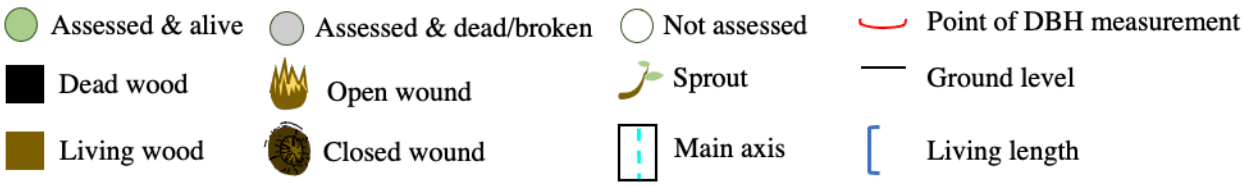
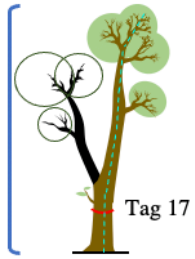
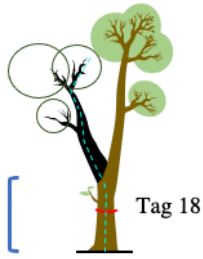


Figure 10. Continued…



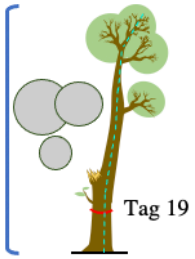
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
17	A	S	-	30

Main axis is defined following the 'thickest' criterion, which in this case is the alive section in the first bifurcation. The living length is complete. The stem lost its biggest branch (~70% of existing branches).



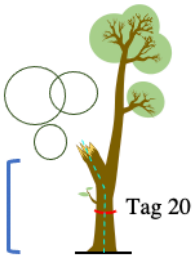
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
18	A	S	2	100

Main axis is defined following the 'thickest' criterion, which in this case is the dead section in the first bifurcation. So the living length is smaller than the living length of the stem #17. Despite the crown is complete (i.e., there is no sign of branch lost within the living length above the POM), this stem cannot be considered 'OK' because of its incomplete living length.



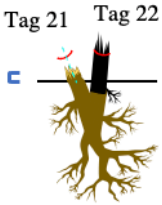
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
19	A	S	-	30

Stem #19 is exactly equal to stem #17; the branch lost represents the same proportion no matter whether branches are found dead on the tree (stem #17) or broken (stem #19).



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
20	A	B	3	100

The stem #20 only differs from stem #18 in the mode and in the living length.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
21	A	B	0.3	-
22	X	B	0	-

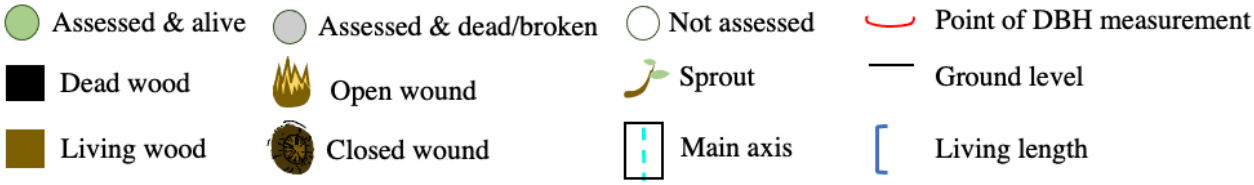
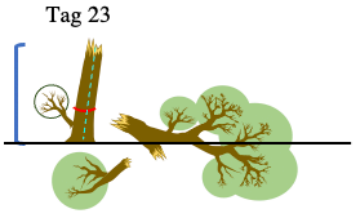
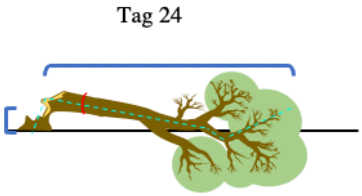


Figure 10. Continued…



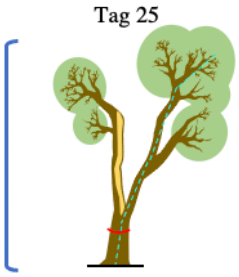
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
23	A	B	3	-

Remaining crown is '-' because there are not branches within the living length above the POM. Branches fallen on the forest floor will be taken into account by the reduction in the living length. Branches below the POM are not considered for remaining crown evaluation, but for crown illumination, leaves (%), and leaf damage.



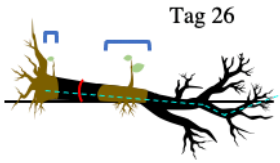
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)	Wounded main axis
24	A	S	-	-	3

The mode is 'S' because the living length is complete. This massive damage is generally caused by another tree or large branch that falls right at the base of the tree trunk. If the cause is known, it should be recorded in 'comments'.



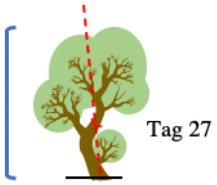
Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)	Wounded main axis
25	A	S	-	-	3

Similar case to stem #24. This massive damage is generally caused by another tree or large branch or lightning strikes.



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)
26	A	U	0.3 + 1.5	-

The living length is assessed as the accumulated sections regardless of its distribution along the stem along the main axis. In this case, the living length is estimated as 0.3m (at the base) + 1.5m (at the middle).



Stem tag	Survival Status	Mode	Living length (m)	Remaining crown (%)	Leaning (°)
27	A	S	-	100	5

The deviation of the stem from the vertical (leaning) is assessed based on the a projected line between the base of the stem and the POM (red line). Thus, in this curved stem, the leaning is just 5°. The main axis is not showed to improve visibility of leaning line.

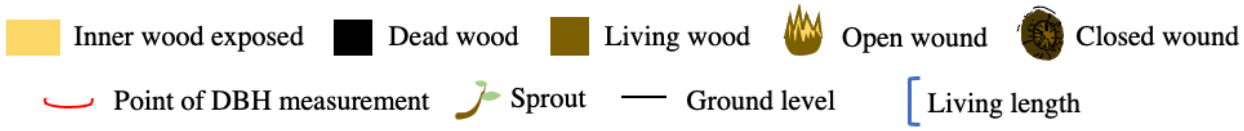


Figure 10. Continued…