SEOSAW Field Manual

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1 Introduction

This field manual describes a method for establishing plots that is applicable for savannas, woodlands, and (dry) forests. It is focused on long term and large plots, but it is also useful for one-off and small plots. Following this manual and using the associated data sheets will ensure compatibility with others working in southern Africa, and it allows integration into global comparisons. The goal is to share experience about what works and what does not, to avoid mistakes being repeated. In many cases there will be more efficient and informative sampling designs possible, that could be used at any one site. However, in most cases, these will not work in the range of savannas, forests and woodlands present in southern Africa, and will have little overlap with global emergent standards. The methods suggested here are a good compromise, that should leave everyone (hopefully only a little) unhappy.

2 Summary

Here are the essentials to ensure your work fits with the SEOSAW protocols:

2.1 Plot design

a. Locate plots on homogenous areas, in terms of the soil type and the land use history.
b. Gain the informed consent of the landowners and informal land users before setting up a plot.
c. For long term monitoring, 0.25, 0.5 or 1.0 ha plots are recommended; 1.0 ha squares are preferred.
d. Measure the diameter of all stems above a diameter threshold e.g. >5 or 10 cm diameter. Measure diameter at 1.3 or 0.3 m height.
e. Mark permanent plots at the corners (or centre for circle plots) with concrete or iron bars.
f. Re-measure stems approx. every 3 years, with more frequent visits at the start.
g. Complete the required plot data fields for every plot. Example data sheets and data entry spreadsheets are available on the SEOSAW website. Also see sections 10 and 11 for a breakdown of these fields.

2.2 Tree stems

Table 1: The attributes of each stem that should be recorded (NB: stem, not tree – measure all stems, alive or dead, standing or fallen). These are considered the minimum needed to answer many of the key questions of the SEOSAW partnership. Many others could of course be added. Example data sheets and data entry spreadsheets are available on the SEOSAW website. Also see section 11 for a full breakdown of stem fields.

Attribute	Purpose	Key recommendations
Tag ID or Stem ID (if no tags)	Keep track of unique stems	Tag all stems that meet the inclusion criteria. Nail the tag 20 cm above the POM.
Stem diameter	Biomass estimation; growth rates	The Point of Measurement (POM) of diameter should be 1.3 or 0.3 m, along the stem in a straight line. (NOT vertical height). A diameter tape is preferred. Check POM is representative of the stem, and move upward if any issues with wounds, forks etc. Record the height of the POM if it had to be moved.

Point of diameter measurement (POM)	As above	Always record the height of the POM
Multiple stems	Biomass estimation, resprouting	Record the stem id / tag no. of other stems that start at the same base. Measure all stems that meet the inclusion criteria, even if they have the same base.
Species	Diversity studies, also needed for wood density lookup for biomass estimation	Bring a botanist if you can afford it, take vouchers if you can, use morpho-species or local names if not
Alive / Dead and cause(s) of mortality	Mortality and resprouting rates	Measure all stems even if they are dead. See 4.5 for the codes to use for damage and mortality.
Standing / fallen	Knowing if a tree is fallen helps explain its absence in subsequent censuses	Include stems that have fallen, as long as they are contiguous to the POM height and rooted in the soil.
Broken	Biomass estimation	Record the height at which a broken stem is severed
Damage	Predicting mortality and growth	Estimate the area of exposed cambium (missing bark) and note the presence of bracket fungus.
Other attributes	See section 4.4	These are quick to record and increase compatibility with global standards
Spatial position (optional)	Useful if tag lost, and for spatial analysis	Record distance in m from the SW corner of the plot (x and y coordinates). On large square plots divide the plot into 10 m strips to help with this. In circular plots record angle and distance from the plot centre.
Height (optional)	Improves biomass estimation; allometric traits	If there is a strong DBH-height relationship, measure height on a subset of 100 stems for each site. If relationship is weak, measure all heights. See section 4.7 for methods.
New recruits	Needed for net carbon balance, and for analysing population dynamics	In an existing plot, record new recruits (i.e. new stems that meet the inclusion criteria) on a separate sheet.
Stumps	Quantifying "missing biomass" and where possible the causes	Measure diameter of all stumps with a diameter >5 cm. Record height of diameter measurement. See section 7.
Small stems (optional)	Regeneration studies, diversity in small size classes	Count stems which are below the minimum size threshold of each species in transects that are 2 m wide and 50 m long.
Coarse woody debris (optional)	Quantifying fallen wood biomass for e.g. C stocks and fuelwood assessments	4 line intercept transects; measure all intersecting pieces >3 cm diameter and 0.5 m long. See section 8.
Soil (optional)	See separate protocol on the SEOSAW website.	
Grass, forbs, seedlings (optional)	See separate protocol on the SEOSAW website.	

3 Plot establishment

3.1 Engaging with local land users *and* owners

Engage with local land users *and* owners and be attentive that these may be different groups. e.g. the land may be privately or government owned, but local people may harvest wood fuel or NTFPs. At a minimum, engagement would typically involve a community-wide meeting both at the start and end of the plot setup and notifying local authorities of your work. Involving community members in the work on the plots can be beneficial for all and is a good way to ensure that the local community is fully informed of what is being done, and where. This can reduce the scope for misunderstandings about the purpose and nature of the work. Provide information to local land users in relevant local languages in written form so that they can be shared around the community. If possible, undergo ethics approval at your institution.

Report back to the local land users and owners about the key findings from the research is highly recommended, particularly for permanent sample plots where the stakeholders are being repeatedly engaged. At a minimum, this can take the form of disseminated reports together with a translator. However, in-person community meetings that facilitate dialogue between the researchers and the stakeholders are mutually beneficial, allowing for inclusion of indigenous and local knowledge, and discussion around the stakeholders' research priorities, as well as the researchers' further aims and plans.

3.2 Location and position

New plots should be located within areas that satisfy the following criteria:

a. Homogenous soil parent material and soil type
b. Homogeneous land use and land-use history
c. Landowners and informal land users have given informed consent for the plot to be established and accessed by researchers
d. Adequate access – although plots near to roads, tracks, paths, and settlements are more likely to be disturbed so care must be taken to avoid oversampling these areas, for example by locating plots at least 1 km from these features
e. Long term institutional support – increasing the likelihood that plots will be maintained and re-measured
f. Unlikely to be permanently converted to another land use – although new plots should **not** be specifically located in areas without human disturbance as such disturbances are ubiquitous and need to be understood. It is therefore useful to include plots used for shifting cultivation or harvested for timber, fuel, or construction materials.

When positioning plots there can be a tendency to select locations that seem easy work in or that fulfil pre-conceived ideas the about the area. To avoid potential for bias in plot locations, new plots should therefore be positioned randomly, or in a pre-determined pattern, within strata that meet the above criteria. Regularly spaced plots (e.g. on a grid) are advantageous for some analyses.

Determining random plot locations
To randomly locate plots, before going to the field use a GIS to randomly place points within the strata of interest and load these points onto the GPS. Place at least double the number of points, and use only the odd numbered points, saving the even numbered points as reserves in case the odd numbered point does not meet the criteria above.
A tablet with access to high resolution satellite imagery can help to determine whether potential plot locations meet the above criteria e.g. for identifying variation due to soil type and hydrological features, and signs of human use. Suitable software available in 2018 includes MotionXPro (iOS) or Gaia GPS (Android and iOS).

Using a drone to aid plot location
Using a drone can be of great benefit in assessing the suitability of possible plot location in terms of proximity to human disturbance and ephemeral drainage etc that might otherwise require significant field effort to detect or lead to inappropriate plot locations. See section 12.

3.3 Shape and orientation

Decisions over plot shape are influenced by the need to fit plots within homogenous strata, the perimeter:area ratio – which influences the number of trees on the boundary of the plot, and the ease of set up.

The SEOSAW network includes circular, square and rectangular plots. Circles have the smallest perimeter:area ratio and can be quick to set up, especially in open areas, but can become difficult to measure if they exceed around 20 m radius. For larger plots, squares or rectangles are easier to set up and are recommended for new plots of 0.2 ha or above. Where possible, square plots are preferable as they have a smaller perimeter:area ratio than rectangles, although rectangular plots may help to fit plots within homogenous strata.

Where possible, North/South and East/West should be used for the principal axes of square and rectangular plots, it may be necessary to adjust these however to enable a plot to be positioned within a homogenous stratum. The bearings of the main axes from the start point of the plot (the Southwest corner or equivalent) and the latitude, longitude and elevation of the start point should be recorded.

Accounting for slope when establishing plots
New plots should be set up to sample a given area of land surface, rather than a planar projection. This requires some flexibility with bearings and distances when closing the final side of square or rectangular plots.
To correct for slope and allow comparison to plots that sample a planar area, the average slope and aspect of the plot, and the altitude of each corner, should be recorded. The planar area can then be calculated later.

3.3.1 Estimating slope

Slope can be measured using different field instruments, such as clinometers and laser rangefinders. Slope should ideally be measured at multiple points on the plot and the mean reported. Try to measure slope over at least five points spread over the plot. As well as angle of slope, the orientation of the slope direction should also be reported, in degrees.

3.4 Size

Optimal plot size depends on the aims of the study and the characteristics of the stratum being sampled. Small plots have higher perimeter:area ratio and typically yield biomass estimates that have non-normal distributions, fit less well to remotely sensed observations, and have greater coefficients of variation than larger plots. One hectare has been adopted as the standard size used in many networks in the wet tropics and is recommended for long-term monitoring plots in the SEOSAW network. In open areas, larger plots may be needed to ensure there are >200 stems sampled as sampling fewer stems than this makes estimating mortality very inaccurate.

For non-permanent plots, and plots in areas with relatively homogeneous vegetation structure and high tree density plots of 0.75 ha, 0.5 ha and 0.25 ha are also acceptable. Plots with less than 25 stems inside them are not useful for estimating tree diversity and should be increased in size.

3.5 Timing

Variation in stem water content can affect diameter measurements, so if plots are going to be re-measured, it is best if measurements are made at the same time of year. Tree measurements are usually easier during the dry season when there is less understory vegetation, but it can also be useful to visit plots during the rainy season to collect herbarium vouchers of deciduous species and to increase the chances of finding species in flower or fruit, which increases identification accuracy.

3.6 Visibility

In plots that will be used for long-term monitoring, the corners of square or rectangular plots or the centre of circular plots, **must** be physically marked so that they can be relocated. In some areas, visibly marking the plot location can influence the way the plot is used by people, potentially introducing bias to the sampling. In these cases, trees should not be marked or visibly tagged (buried tags or detailed maps of tree locations can be used instead), and plot location should be marked with cryptic approaches. Materials used for marking plot locations must be durable enough to be maintained between measurement events and not be eroded by corrosion, fire, termites, etc. Adding additional markers, e.g. on a 20 m grid within the plot, and at 10 m intervals around the boundary, can help to reduce inclusion/exclusion errors on re-measurement, and to re-locate trees that lose their tags.

3.7 Stringing the plot

Once the start point of a square or rectangular plot has been determined the plot boundaries should be carefully measured out using a compass and tape measure, at least two people will be needed for this - one to hold the compass and another to measure the distance and lay string along the boundaries. Any cutting of vegetation within or adjacent to the plot should be kept to a minimum, and avoided whenever possible. Adding strings running the length of the plot at 10 or 20 m spacing can help with orientation while making measurements and mapping tree locations (see section 4.3.2).

Materials for marking plot locations:

- Treated wooden posts (15 cm diameter) last about 10 years, even with regular burning. These do need to be well dug in, however, which is hard work.
- Concrete posts with reinforcing bar inside them (40 x 10 x 10 cm) can often be fabricated locally and are more durable than wood. If buried with 2 cm protruding from the ground, they can be relatively cryptic and be relocated with a metal detector. If concrete is not available, iron bars alone can be used, but this is more prone to theft, and will rust.
- Treated steel fencing droppers (1.2 m in length) can be cemented in place to a depth of 0.5 m using holes bored with a soil auger.
- Feno Markers are a more expensive but potentially long-lasting option
- Differential GPS can be used instead of permanent posts, but this commits all subsequent users to using expensive equipment. Normal GPS units are not accurate enough to relocate corners – some kind of physical mark must be used.

3.8 Data recording

For each new plot, a full list of plot data (sometimes called meta data, but really a description of the plot) should be recorded (see Annex 1). This information is quick to record (most require a Yes/No answer) and will allow the plot data to be used for a variety of different analyses. This data is divided into sampling and disturbance data, which have separate data sheets available on the SEOSAW website.
Sampling data to record includes details of:

- Plot design – size, shape, what was sampled.
- Plot location – longitude, latitude of each corner/the centre. This should be recorded by a GPS set to average the GPS location over ~30 mins, and where possible should be repeated on multiple different days to improve accuracy.
- Altitude, slope, aspect
- Sampling carried out within the plot – taxa surveyed and other sampling or measurements made
- Environmental conditions – rainfall, canopy cover, catenal position, and presence of termites

Disturbance data to includes details of:

- Land use – legal status, user rights, occurrence of harvesting, and agriculture
- Fire – estimated fire return interval and/or time since last burn, fire management, etc.
- Natural disasters –cyclones, drought, floods, etc.
- Exposure to large herbivores – Elephants, Ruminants, Non-Ruminants, Livestock, etc.

4 Trees and their stems

4.1 What to measure

All stems of all trees (includes climbers, palms, and baobabs) should be tagged, measured and identified if:

a. More than 50% of the base of the stem is inside the plot; and
b. They have a diameter ≥ to a defined minimum diameter threshold at the appropriate point of measurement (including dead and fallen stems for which the stem is contiguous from the base to the appropriate point of measurement)

Minimum diameter threshold will be determined by the aims of the study, and the vegetation structure at the study site. Stem diameter ≥ 5 cm or ≥ 10 cm are commonly used thresholds. If the intention is to record recruitment (i.e. the number of new stems that have reached the minimum diameter threshold e.g. 5 cm), it is advisable to measure all stems with a diameter smaller than this (e.g. 4 cm or 9 cm). This ensures that errors made in determining diameter do not affect estimates of recruitment rates.

This protocol includes (optional) separate sections on measuring poles, saplings, and seedlings (stems smaller than the minimum diameter threshold) in sub subsamples of the main plot (section 0).

New plots established in the SEOSAW network should select a minimum diameter threshold for the main plot of either 10 cm, 5 cm, or 3 cm according to the aims of the study and the vegetation structure at the study site. The minimum diameter threshold selected should ensure that at least 200 stems are measured within the plot (not counting any measurements made in smaller sub-plots).

4.2 Diameter measurement

4.2.1 Point of measurement

To enable repeat measurements at the same point on a stem, diameter should be measured at a defined point of measurement (POM). Plots in the SEOSAW network should adopt a default point of measurement for use in the entire plot of either 1.3 m or 0.3 m. The point of measurement (POM) is not the vertical height, but is the straight line distance from the ground at the base of the stems to the POM, even if the stem is leaning or bent.

A default POM of 1.3 m should be used unless few stems in the plot reach 1.3 m, in which case a default POM of 0.3 m can be used.

If a default POM of 0.3 m is used, a sub-sample of trees should be measured at both 1.3 m and 0.3 m to enable the use of a conversion factor for comparison with plots measured with a default POM of 1.3 m.

A stick with a mark at 1.3 m or 0.3 m placed at the base of the tree can be used to locate the default POM. Take note of the following circumstances:

- **Forked trees** – Trees that fork below the default POM are only included if the stems present above the fork exceed the minimum diameter threshold at the appropriate POM. These are measured as separate stems.
- **Resprouting trees** –A resprouted stem is only measured if it exceeds the minimum diameter threshold at the appropriate POM
- **Fluted trees** – Trees that are fluted for their entire length should be measured at the default POM.

The POM measurement should be made on a specific side of the tree. Exceptions should only be made the following circumstances:

- **Slopes** – If the stem is on a slope, POM height should be measured on the downhill side of the tree.
- **Leaning trees** – If the stem is leaning, POM height should be measured along the edge closest to the ground

Diameter should be measured at the default POM unless this does not provide a good representation of the diameter of the stem for one of the following reasons:

- **Deformities** – Stems that are deformed at the default POM, for example because of a wound, swelling, bark loss, or branch should be moved to a point 30 cm above the deformity.
- **Forked stems** – Trees that fork at the default POM should be measured at a point 30 cm below the bulge at the base of the fork
- **Buttresses and silt roots** – Trees that are buttressed or have stilt roots at the default POM should be measured 30 cm above the top of the buttress or the highest stilt root.
- **Climbers** – Climbers are included in the survey if they have a diameter greater than the minimum diameter threshold at any point within 2.5 m of the ground. Climbers that fulfil this criterion should be measured in 3 places; i) at 1.3 m measured along the stem from the last point of rooting; ii) at 1.3 m measured vertically above the ground; iii) at the largest diameter within 2.5 m of the ground, including any deformities. These three methods allow comparisons with other protocols.

If an adjusted POM does not give a good representation of stem diameter, then the POM should be moved further up until a good representation is found. Where a good POM is impossible or impractical because of damage to the whole stem, half diameter methods should be used (see section 4.2.2).

For all stems the height of the POM must be recorded. The POM can be painted to facilitate re-measuring - although oil-based paints can cause callus formation and should be avoided, and bark shedding and fire can degrade paint marks after a few years (see section 5.3.1). Tags can also be used to help relocate the POM. Tags should be located 20 cm above the POM, to speed remeasurement, and avoid the tag influencing the diameter.

4.2.2 Measuring diameter

Diameter at the default or adjusted POM(s) must be recorded for all stems. Diameter tapes should be used for measuring stems with diameter ≥ 5cm. Smaller stems should be measured with calipers. Diameter should be measured to the nearest 1 mm, and recorded in cm with 1 decimal place, even if this is zero, e.g. 17.0 cm, not 17 cm.

Large trees (10x the min. threshold and above) are very important for biomass estimation, and many aspects of ecology. To provide a double check on the existence of large trees, and guard against errors caused by a missing decimal place, write "large tree" in the notes of all stems > 10 x the diameter threshold e.g. 50 cm DBH for plots with a 5 cm threshold. This is particularly important.

Diameter measurements should be made under any small climbers, epiphytes or roots on the stem (by lifting away from the stem and not cutting), and after cleaning the POM of loose bark and debris. If climbers, epiphytes and roots cannot be lifted away from stem to allow a diameter tape to be passed underneath, half diameter methods should be used.

Half diameter methods
Half diameter methods should be used where it is impossible to measure all the way round the stem e.g. if it is fallen and lying on the ground, or if there are climbers or roots that cannot be lifted away from the stem, or deformities that cannot be avoided. Stem diameter can be estimated by measuring with calipers or using a diameter tape on only half the circumference of the stem and multiplying the value by two. If these approaches are used it should be noted in the data collection form.

4.2.3 Multiple stemmed trees

Stems can be connected above or below ground, and it will not always be possible to determine if stems are part of the same tree. When a new plot is established, all stems that meet the inclusion criteria should have the stem ID of the largest stem noted as the 'base ID' for all other stems that are part of the same tree as well as their own unique stem ID code.

4.3 Marking and mapping stems

4.3.1 Marking stems

Metal tags can be used to mark stems with their unique stem ID. If metal tags are used these should be attached to the tree so the nail is 20 cm above the exact POM to assist with locating the correct POM when the tree is re-measured, and to prevent any swelling caused by the nail from affecting diameter measurements. If tagging trees is expected to affect the way the plot is used by people or wildlife, an alternative to attaching tags to trees is to bury the tag at the base of the tree just below the mineral soil surface.

Marking trees with metal tags

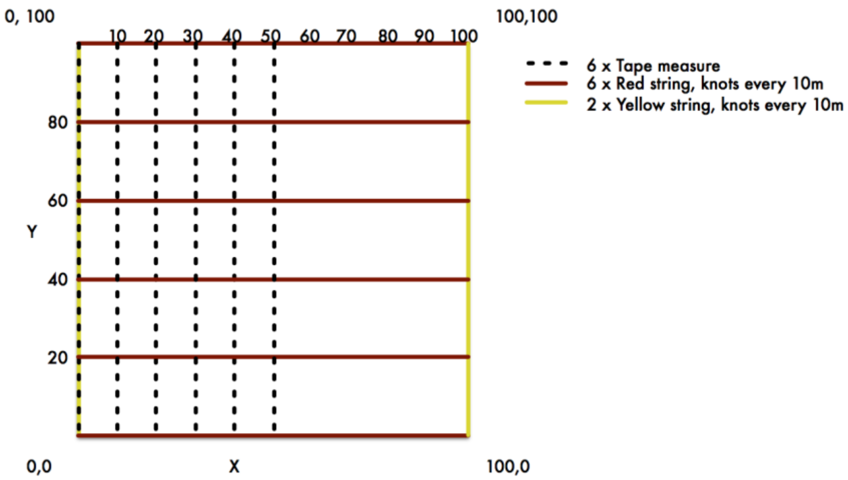
Small metal tags can be purchased or made from roofing zinc (approx. -5 x 5 cm) and numbered with a die stamp (positive indent stamp). Roofing zinc should be about 0.6mm in thickness. Tags that are too thin decay rapidly and require frequent replacing; tags that are too thick are difficult to stamp and may be illegible. Elephants may find the tags less offensive if they are made of non-reflective material or have been sprayed with paint. Tags should be securely attached to stems using a nail. It is best to use aluminium nails of around 5 cm in length. Aluminium causes less reaction from the tree as it does not rust but hammering an aluminium nail into hard wood is not always possible, so steel nails may need to be used in some cases. Nails should be hammered in at a slight downward angle just far enough so that it penetrates the bark and is secure, but has at least 2 cm free to allow space for the tree to grow.

If the plot is divided into strips tagging all the stems in each strip on alternating sides of the stem can help to identify each strip and keep the stem measurements in sequence.

4.3.2 Mapping stems

On square plots, stem locations are recorded using the XY locations from the SW corner of the plot. This is optional, but very useful. X-Y coordinates reduce errors when tracing "vanished" stems or confirming missing tags during remeasurements. To be consistent, the southwest corner of the plot should be used as 0,0.

The simplest approach for a square plot is to string it as per the figure below and estimate the x coordinate from the distance between the two tapes, and the y coordinate from the reading on the tapes. The thing to watch for here is that you can easily lose track of which "strip" you are working in.



4.3.3 Cut, broken and fallen stems

For each stem note if:

- Cut, snapped, broken – record the height of the cut, break or snap, and optionally the estimated percentage of the stem remaining attached to the stem base. A snap is defined as where the stem above the snap is still attached, while a cut or break is defined as when the stem above the break is no longer contiguous with the stem base.
- Damaged – two metrics are used:

  - The percentage of cambium exposed, i.e. the bark missing. This should be estimated on 4 sides of the stem, from the ground to 2 m height.
  - If wounded, the size of the wound should be recorded along the greatest width and height in cm.
  - The presence / absence of bracket fungus should be recorded as in indicator of rottenness.
- Fallen - defined as no longer bearing its own weight.

NB If a stem is not rooted in the soil, it is not included in the stem inventory, but instead will be recorded as woody debris.

4.4 Other attributes of alive stems

The following attributes should also be noted with a simple Y/N:

- New recruit since last census (i.e. has grown to now exceed the threshold diameter)
- Located on a termite mound
- Presence of climbers/lianas in the canopy
- Presence of a strangler on the stem
- Stump. If the stem has been cut or broken lower than the POM, then it is called a stump.

4.5 Damage and death

Determining whether a tree stem is dead is a complex matter in savannas. It can be hard to see whether a stem is truly dead, and sometimes they "come back to life". Thus, it is important to record the alive / dead status for at least one more census after the initial declaration of death. Here, we avoid mention of "death" unless absolutely sure, referring instead to stems as "resprouting" if they appear dead. You should note the stem status, mode and any damage using the codes in Table 2.

4.5.1 Resprouting stems

A stem should be recorded as resprouting if there is no sap beneath the bark at the default POM, no signs of life in the canopy above the default POM, and has signs of life below the default POM. For instance, new stems emerging from the base of the stem.

Table 2: Details of stem status, stem mode, and cause of damage.

Status of stem	Mode of stem	Cause of damage*
A = stem alive R = stem dead, but signs of life elsewhere (base or other stems) D = stem dead, and whole plant dead	P = Snapped (still attached) U = Uprooted B = Broken/cut (stem detached) S = Standing L = Leaning (>15° from vertical) V = Vanished F = Fallen (not supporting itself) O = Other	N = Neighbouring tree E = Elephant F = Fire H = Human (cut or ringbarked) L = Lightning M = Termites W = Wind Q = Can't tell O = Other (describe in notes)

* Note, it will not usually be possible to determine the cause of death with any certainty and unless the cause is unambiguous "Q – Can't tell" code should be used. When cause of death = Human, add details to notes indicating method e.g. ringbarked, chainsaw, machete.

4.6 Species identification

Each stem measured should be assigned a species or morphospecies[1] name. A trained botanist and/or parataxonomist with knowledge of the local flora should be present for the establishment of the plot to identify species using scientific and/or local name. If possible, voucher specimens of all species and morphospecies present within the plot should be collected and duplicates stored in local, national, and international herbaria. Voucher specimens can then be used to confirm species names and assign scientific names to morphospecies. Species identifications can be verified and improved as plots are re-measured.

Collection and preparation of voucher specimens

In woodlands and savannas, voucher collection of leaf material can often be done by hand. However, some tall individuals and those with fruit or flowers in high places necessitate climbing or the use of clipper poles. In terms of collection protocols, it is important to collect several leaves attached to the stem, except in the case of large compound leaves where sometimes a single leaf (still attached to stem/twig) will suffice. If fruiting or flowering material is available, then effort should be expended to obtain it. In the dry season and/or arid areas, plant presses can dry in the sun (on a roof rack or otherwise). When humid, it is important to dry the specimens using a space heater or plant drying oven (can be constructed with a standard 1 or 2 burner gas stove and canvas or plywood) within several days of collection. Otherwise, the leaves fall off. In remote, humid areas where it is logistically infeasible to take a gas canister, specimens can be stored in plastic bags with alcohol.

Authorities

Exporting voucher specimens to at least one international herbarium allows species determinations to be standardised across countries. As per the Nagoya protocol, no international herbarium should accept specimens without associated paperwork and permissions.

Photographs

Definitive identification of trees by scientific name usually requires consultation of herbarium specimens. As most people are aware, plants look different when alive vs when pressed flat and glued to a sheet of paper. Thus, while photographs of living leaves, fruits, flowers, bark, and trunk slash are all very useful things (which we should endeavour to collect!), photographs of dried herbarium specimens are also very useful in cases where specimens cannot be readily exported to an international herbarium.

[1] Morphospecies are morphologically recognisable and distinguishable entities for which the scientific name is unknown. These can be 'local species names'. Alternatively, even when botanically-informed researchers are involved in plot set-up, there are often individual trees that cannot be identified (e.g. due to a lack of key diagnostic features present in fruits or flowers). In these cases, it is useful to determine which individuals across the plot seem to belong to the same species, even if a scientific name cannot be put on it (e.g. for purposes of calculating alpha diversity).

4.7 Height measurement

Accurately measuring the height of all stems in a plot is time consuming and will not usually be feasible. As an alternative, local height-diameter relationships can be developed to estimate height from diameter measurements, by measuring the height of all stems from a sub-sample of trees. The degree to which a diameter-height relationship can be built for a site that is suitable for prediction can be assessed by measuring around 50 trees from across the range of DBH values found in the site (e.g. 10 trees from each of the 5-10, 10-20, 20-30, 30-50 and >50 cm diameter brackets) and testing the r-squared of the resulting relationship. If the r-squared is less than 0.5, then individual height estimates for every tree may be necessary.

Note that height must be recorded for separate stems that meet the diameter threshold, not whole trees.

Estimating stem height with trigonometry

Stem height can be accurately estimated by measuring the angle from the bottom to the top of the stem from a known distance, and using trigonometry to estimate the stem height. For the most accurate height measurement, stand at a distance approximately equal to the stem's height (i.e. for a 20 m tall stem stand 20 m away), to give approximately a 45° angle when looking at the top of the stem. Move around the stem to get the clearest view of the stem base, stem and top. Avoid standing <10m from the stem unless the stem is very small, and be aware that some laser measuring instruments do not give accurate measurements at distances of <10m. On sloping ground avoid standing below the base of the stem. Clinometers, laser range finders (e.g. Nikon Forestry Pro) and ultrasound devices (e.g. Haglöf Vertex Hypsometer) can all be used to produce accurate estimates of tree height. The additional cost of more sophisticated devices generally provides quicker or easier measurements rather than improved accuracy.

If angle to base of stem (a), angle to the top of the crown (b), and horizontal distance to the centre of the tree (x) are measured, height can be estimated with the equation:

$$Height = x(\tan a + \tan b)$$

Estimating stem height by eye

A combination of a 2-meter stick with 10 cm increments marked, and eye, can be used to estimate stem heights. This method is clearly very accurate for stems <=2 m, and reasonably accurate up to 4 m if two people are present, one to hold the stick and one to stand far away. Estimation by eye is also possible for much larger stems (again with two people, one holding a stick of known length next to the stem), but accuracy decreases with height. If time or equipment is limited, estimation as described above is a valid option for many savanna trees, and certainly produces more useful data than collecting no height data at all.

5 Small stems

In general, it is recommended to set the diameter threshold to include all stem size classes of interest. If however, information on smaller size classes is required, a simple count of stems is normally sufficient.
Small stems with a dimeter at the POM of more than zero and less than the threshold should be counted in belt transects – no diameter measurements or tags are needed. The sub sampled area should be two transects per 0.25 ha of 2 m x 50 m. Counts recorded for each transect. Counts can be recorded for each species, if this extra information is needed. Studies with a particular focus on regeneration and the diversity of the understory will want to measure more attributes of the small stems, and they may sample more intensively to gain more precision; tagging (normally by attaching a tag around the stem with wire for saplings as nails will do too much damage to small stems) may also be needed. The method here is suggested as a minimum.

6 Stumps

Stumps that are cut above the appropriate POM are measured as stems. At the time of plot establishment all stems that are fully cut or broken below the POM should also be recorded on a separate data sheet. It is not necessary to tag these stumps.
For all stumps and cut stems measured, the following information should be recorded:

- diameter at top of the stem
- height of the top of the stem (where diameter measurement was taken)
- diameter at 0.3 m above the base (if possible)
- species (if possible)
- cause of break – see Table 2

7 Coarse woody debris

Coarse woody debris is defined as dead tree stems, large limbs, and other large wood pieces either lying on the ground or elevated off the ground, but not rooted in the ground. It does not include live material, standing dead trees still rooted in the ground (included in the stem inventory), stumps (which have their own protocol), dead foliage, separated bark, non-woody pieces, roots, or the part of the tree stem below the root collar.
Coarse woody debris should be measured along perpendicular transect lines forming an x or + across the plot to avoid piece-orientation bias. Each transect originates at the centre and radiates out, so that each plot has 4 transects if laid out in an + or x formation from the centre. Transect design can be flexible, but avoid parallel transects. A piece of debris is measured if:

a. the central longitudinal axis of the piece intersects the transect
b. the diameter at the point of intersection is > 3 cm, and the piece length is > 0.5 m
c. the piece is not decayed to the point of having no structural integrity (i.e. can be measured).
d. Other rules include:
    I. When a piece of wood is forked or has a very large branch attached to the main bole—and both segments intersect the transect—they are tallied as two separate pieces, if each meets the required minimum dimensions

II. A piece is tallied twice if it intersects two different transects or if it is nonlinear and intersects the same transect in two locations

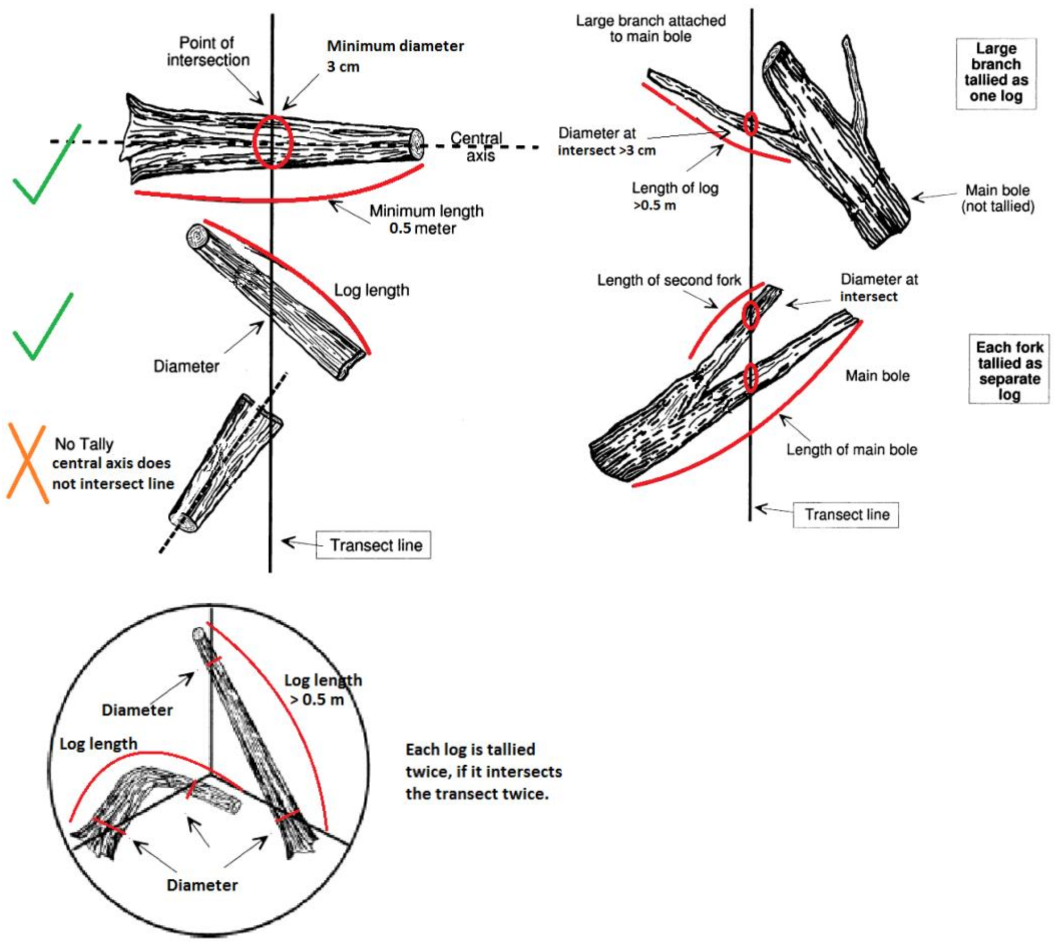


Figure 1: Coarse woody debris sampling diagrams, adapted from (Waddell, 2002).

Measurements taken on each piece are:

1. Diameter at the point of intersection (cm). This can be estimated if you cannot pass the tape around the piece. Callipers are very useful for smaller items; a diameter tape will be needed for larger items
2. Piece length (m)
3. Species of the piece, if possible.

Using the equations set out in (Waddell, 2002) you can thereby estimate total coarse woody debris density (logs/ha), volume (m3/ha), and biomass (t/ha) in the plot.

8 Plot re-measurement

Re-measure stems approx. every 3-5 years. Consider a shorter measurement period at the start which will help resolve errors in the first census, provide further opportunities for species identification, and it also maintains links with the local community.

Re-record the locations of the plot corners at every remeasurement to improve accuracy and update the plot data sheet with any changes in e.g. human use. And replace any missing plot corner markers.
Make sure that previous census data are consulted when recording remeasurement data. This helps identify errors. For this reason, it is recommended that for each stem originally measured, a new row is inserted into the re-survey datasheet below previous records (completed example shown in grey in the example below). This allows all data to be maintained on the datasheet without adding columns, ensures consistent recording methodology between surveys and creates data that is formatted ideally for easy data cleaning and analysis (every row is a record, every column is a variable). Recruits should, if possible, be recorded on a separate datasheet that is clearly marked as a recruit sheet and dated with time of survey (but is otherwise identical). A sample datasheet is included Annex 2, Table 1.

The recorder should not use previous measurements to "correct" or even recheck the new measurement unless they indicate a gross error, e.g. a diameter change of more than 2 cm. Adjusting the new measurement with the old one in mind will create biases and must be avoided.

Table 3: Illustrative example of how to record remeasurement data. Note that stems 2 and 3 have the same base (multiple stems), and that stem 3 died between census years. Grey rows indicate the new data from a second census conducted in 2020.

Tag id	Year	Species	Diameter	POM	Base ID	Alive/Dead	Standing/Fallen	Notes
1	2015	*B. boehmii*	10.0	1.3	1	A	S	
1	2020	*As above*	11.5	1.3	1	A	S	
2	2015	*B. spiciformis*	55.1	1.3	2	A	S	Large tree
2	2020	*As above*	55.2	1.3	2	A	S	
3	2015	*B. spiciformis*	10.8	1.3	2	A	S	
3	2020	*B.spiciformis*	10.5	1.3	2	D	S	Elephant damage
4	etc							

To record demographic process (recruitment, resprouting and mortality), the SEOSAW approach for long term plots is to:

a. Tag all stems where possible
b. Also keep track of all bases that have stem(s). This allows for studies of resprouting.
c. In the simplest case, a base with one stem, the id of the base is the same as the id of the stem (see tag id 1 above)
d. In cases of multiple stems, the base id is the id of the first stem to be tagged. This is maintained, even if the first stem dies. For this reason, tag numbers should never be reused. If the first stem (lowest numbered stem) is very clearly dead (no probability of "coming back

to life") and the tag can be recovered, place the first tag on the base below the POM to keep track of the base ID.

e. The base id of recruits should be recorded so that resprouting can be assessed

Because of the extra care needed to calculate mortality rates, it is well worth taking extra time over dead stems. Their alive / dead status should be recorded in at least one census after they are first marked as dead. Stems do "come back to life" – either because they weren't dead in the first place, or because of recording errors. Once a stem has been recorded dead in two censuses, it can be removed from the field sheets used in subsequent censuses.

8.1 Stem measurements

It is necessary to restring the plot before remeasurement, to reduce errors in relocating stems (which may have lost tags etc). Restringing the plot also aids in confirming "vanished stems" and recording the XY location of new recruits.

All measurements should be repeated, except the XY coordinates. The species determination should be quickly double checked for gross errors. Remeasuring height is optional.

Locate the POM by measuring from the tag if possible (the POM is always 20 cm below the tag). On untagged plots measure the height of the POM from the ground. Trees often shrink and shed bark, so do not worry if the diameter measurement is smaller than the previous one. Anything that might explain large changes should be noted in the comments.
If a POM becomes bad between censuses (e.g. a deformity has appeared), measure diameter at both the bad, old POM, and a new, good one. This allows for a correction to be made for the biomass increment.

8.2 New recruits

Stems that attain the threshold diameter (recruits) should be tagged and measured and with the data entered onto the "recruit" sheet, or at the end of the stem remeasurement form. The tag number should simply be the next tag number in the sequence for that plot. Whatever else you do, do not reuse a tag that has **ever** been used on that plot. To maintain the spatial continuity of the new recruits relative to the previous stem tags, we suggest using the first number of the nearest living stem and adding a letter and sequence number (see section 13). The base id of the recruit needs to be recorded, taking particular care to ascertain if the base is shared with another stem in the current or previous census. If it is not shared, then the base id is the same as the new stem id.

8.3 Missing trees

Take particular care to understand the fate of missing stems and confirm topkill rather than measurement error. For stems that are no longer present, search for the tag in the soil, and try and locate the remains of the roots, or the hole where the roots have been burned out. This helps confirm that the tree is really dead, and not just mis located in a previous census. Any doubts should be recorded in the comments.

9 Severely damaged or otherwise compromised plots

Occasionally, a permanent plot may be transformed in such a way that it is no longer possible to relate future censuses to previous censuses on a stem-by-stem basis. For example, a plot may have been clear-felled for agriculture, heavily impacted by timber harvesting/charcoal production, or the majority of tags may have been stolen. It is also possible that there may be impending land tenure changes which preclude future censuses.

In some cases, the plot may never be remeasured whilst in other cases the plot may be monitored for other purposes or even tagged again at some point in the future. Even if the plot is to be abandoned completely, and there are no trees left on the plot, effort should be made to document one final census. This final census provides information on why the plot is to be abandoned or the stem growth data cannot be carried over to future censuses, assesses the condition and structure of the plot and assures the quality of associated plot metadata.

This final census is referred to here as a “compromised plot survey”.

9.1 Why surveys on compromised plots are valuable

From a practical perspective, when designing studies and planning field campaigns it is important to record in the plot database when a plot is no longer suitable for phyto-demographic analysis. It may also be important to know which plots are in the process of regenerating from a known large disturbance, as these can form a basis for independent study. It may also be useful to know the date of clearance to study tree and soil recovery rates following heavy disturbance. These plots may also be targeted for focussed studies of processes such as and species turnover and seedling and suckering rates. Studies of land cover change which utilise remote sensing techniques often want to establish the extent to which a plot was transformed, and an approximate date window for this transformation, to validate their methodology.
Collecting data from disturbed plots where possible is therefore crucial for our understanding of the resilience of these ecosystems to disturbance processes at local and regional scales and the potential carbon/biodiversity benefits of restoration projects.

9.2 How to conduct a compromised plot survey

Depending on how the plot has been transformed, this may be the last chance to collect valuable data about the plot. Try to conduct a thorough plot level survey, following the guidance in section 3 in this manual. In addition, the compromised plot survey should collect some metadata related to the cause and extent of the plot transformation, or otherwise the reason that the plot is deemed to be compromised. The table below lists the minimum questions which should be answered. The more detail the better.

If possible, the locations of plot corners should be recorded with GPS, with the GPS unit set to average the GPS location over ~30 minutes. Finally, if possible, the plot corner markers should be secured by hammering them into the ground until only 5 cm is showing above the surface. If corner markers are badly degraded or missing, reasonable efforts should be made to replace them.

Question	Notes
Why is the plot damaged/compromised for future census work?	Land use conversion, extensive tree cutting, extensive damage to plot materials, community sentiment, changing land tenure etc. Be as detailed as possible. Multiple causes of change can occur simultaneously. Consider the expected changes in plot land use in the next 10 years based on nearby activities and dialogue with the community/landowners, as well as the immediate effects inside the plot.
Has the plot been clear-cut, i.e. all or nearly all trees removed?	Approximately what year did the clear-cutting occur? How large an area was cleared (including outside the plot)? <10 ha, >10 ha, >50 ha, >100 ha? Why was it cleared? Agriculture, settlement, infrastructure (e.g. roads), timber harvesting, fire, mining, other
Has the plot been converted to agriculture?	What kind of farming? Shifting cultivation (slash and burn), subsistence, commercial. How is the farming conducted? Mechanized, manual.
Has the plot been converted for livestock grazing?	What kind of livestock farming is practiced in the plot? Nomadic herding, livestock ranching What animals are being grazed? Goats, cattle, sheep
Are trees being harvested for human use?	What products are being harvested? Timber, fuelwood, charcoal, poles, other What is the intensity of the harvesting? Clear-cut, selective, other

9.2.1 How to collect stem level data

A final stem census should be conducted in the plot, according to section 4 in this manual. Basic measurements include stem location on the plot, stem species, stem diameter, and the point of measurement (POM), i.e. the height of the diameter measurement. Particular attention should be paid to recording causes of damage, snapped/broken/fallen stems, and the mortality status of stems. Stem tags should be recorded where they are still present on the stem, or if they can be reliably identified as having belonged to a particular stem. If the tag cannot be found, the stem should still be measured. Stumps should also be measured according to section 4 in this manual.

New recruits that have grown into the stem size threshold since the previous census should still be measured but should not be tagged during a compromised plot survey; simply record these individuals as untagged and note that they are recruits. In cases where a recruited or resprouting stem that meets the minimum diameter threshold originates from a reliably identified stem from previous surveys, record the tag number of the origin tree as the tree ID, as in a normal stem census.

If stem XY coordinates have not yet been recorded in previous censuses, record these during this census.

10 Annex: Plot data fields

Table 4: Minimal plot level data to be recorded. Find blank data sheets using these columns on the SEOSAW website (https://seosaw.github.io/manuals), or create your own data sheets using these fields as a guide.

Name	Unit or valid options	Instructions	Notes
Plot administration			
1. Plot name	Text	A unique name or code.	Also note any spatial clusters of plots
2. Date of plot establishment or re-measurement	YYYY-MM-DD	Date that initial tree measurements were finalised.	
3. Principal investigator	Text	The data owner's name.	Include institution and email address.
4. Other authors	Text	Other people who have ownership rights to the data (i.e. who would need to be consulted before it were used).	Include institution and email address.
5. People to be acknowledged	Text	Names of people who helped create the data, but who would not normally be included as authors to papers, e.g. field technicians.	
Plot design			
6. Shape of plot	Rectangle, circle		Also note any un-nested subplots
7. Length of x-axis	Metres		If nested, the largest plot.
8. Bearing of x-axis	Degrees	If a rectangle plot, the bearing of the x-axis measured from the south-western corner.	
9. Length of y-axis	Metres		If nested, the largest plot.
10. Bearing of y-axis	Degrees	If a rectangle plot, the bearing of the y-axis measured from the south-western corner.	
11. Plot radius	Meters	If a circle plot.	
12. Minimum stem diameter	Centimetres	What was the threshold of stem diameter that was measured, e.g. >5 cm DBH.	If nested, the largest minimum stem diameter threshold.

13. Minimum stem height	Meters	As above but for height. Leave blank if there was no height criteria.	If nested, the largest minimum stem height threshold.
14. Height method	Text	"eye" - estimated by eye. "rangefinder" - estimated using laser or ultrasonic apparatus with an electronic tilt sensor e.g. Nikon Forestry Pro. "clinometer" - estimated using a mechanical clinometer. "hypsometer" - estimated using a laser vertex hypsometer from below the tree using last return. "direct" - estimated by climbing the tree or adjacent tower and measuring the height with tape or stick.	
15. Nested?	Y/N	If you used a nested plot design, then Y	Repeat fields 7 to 15 for each nested subplot.
What was sampled?			
16. Dead stems	Y/N	Were dead stems sampled?	
17. Lianas sampled	Y/N	Were lianas (climbers or scramblers, i.e. woody plants that cannot support their own weight) measured?	
18. Soil sampled	Y/N	Did you collect soil samples? See the SEOSAW soil manual for more details.	
19. Saplings and poles sampled	Y/N	Did you count woody stems that were smaller than the minimum size thresholds?	
20. Understory sampled	Y/N	Did you measure grasses, forbs and shrubs? Y/N.	
21. Stumps sampled	Y/N	Did you measure tree stumps that remained after felling or other forms of tree death?	
22. Coarse woody debris sampled	Y/N	Did you measure coarse woody debris?	
23. Land use history timeline	Text	Do you have information on the land use history of the plot?	
24. Protocol	Text	File name of document containing description of methods for data collection, provided to SEOSAW, or a reference to a document. If not documented then NA.	

Plot location			
25. Latitude of centre / corners and accuracy	Decimal Degrees, accuracy in metres	Use WGS84 projection system.	Repeat over multiple days if possible to reduce errors. Report mean of multiple days. If plot is rectangular, measure corners, if circular, the plot centre.
26. Longitude of centre / corners and accuracy	Decimal Degrees, accuracy in metres	Use WGS84 projection system.	Repeat over multiple days if possible to reduce errors. Report mean of multiple days. If plot is rectangular, measure corners, if circular, the plot centre.
27. Elevation	Metres above sea level, accuracy in metres		
28. Mean plot slope	Degrees		
29. Slope method	"rangefinder" if a laser or sonic rangefinder was used, "trigonometry" if slope was estimated with tape measures and-or a clinometer, "eye" if estimated by eye, "other" if another method.	Provide extended description of the method elsewhere.	
30. Aspect	Degrees	Aspect of mean plot slope	
Environmental conditions			
31. Catenal position	Ridge crest, concave slope, midslope, convex slope, valley floor, flat	Estimate at what position on the catena the plot lies. This can be very scale dependant, so estimate in relation to the nearest river that is at least 2 m wide.	
32. Termites	Count	How many termite mounds in the plot?	
33. Canopy cover	Percent	What percentage of ground is directly beneath tree canopy	Optional
34. Canopy cover method	Periscope densitometer, mirror densitometer, hemispherical photo, aerial photo, canopy dimensions, other	How did you measure canopy cover? Provide extended description of sampling strategy.	Optional
Current land use			

35. Manipulation experiment?	Y/N	Is any aspect of the plot's land use or env conditions manipulated by scientists?	
36. Protected Area status	Name of protected area.	Leave blank if not in protected area. Search protected areas at: https://www.protectedplanet.net/	Include WDPA (Protected Planet) designation and code if known.
37. Local community rights	to harvest trees, to harvest NTFPs, both	What are the local community allowed to harvest (for non-commercial use)?	This is the legal (de jure) rights for own use
38. Other usufruct rights	Text	Do other people (i.e. outsiders) have rights to harvest trees; NTFPs or both?	
39. Timber harvesting occurring	Y/N	Is there any evidence of trees being harvested for timber - i.e. for making into planks, or industrial wood products (not including poles)?	
40. Fuel wood harvesting	Y/N	Is there evidence of fuel wood collection (excludes charcoal production).	
41. Charcoal harvesting	Y/N	Evidence of charcoal makers harvesting trees in the plot?	
42. Other woody product harvesting	Y/N	Other evidence of people harvesting woody material or felling trees for e.g. string, beehives, canoes, etc	Includes hives, bark for string etc
43. NTFP harvesting	Y/N	Is there evidence of people harvesting non-wood products, e.g. mushrooms, honey, fruit, etc?	
44. Used for farming in last 30 years?	Y/N	Is it likely that the plot was used for farming (or cleared for another reason) in the last 30 years?	
45. High-graded in last 100 years.	Y/N	Is it likely that high quality timber trees were removed from the plot the last 100 years?	

Fire			
46. Estimated fire return interval (years)l	0-Inf	E.g. 1 for annual burning; 2 for every two years, 3 for every three years	Inf =no burn.
47. Fire managed?	Text	Is there any attempt to protect the plot from fire or deliberately burn it? Protected / deliberately burned: very effectively / somewhat / not at all	
Large herbivores			
48. Herbivore exclosure	No / large / small / large + small	Are browsers excluded from the plot by a fence?	
49. Elephants	Y/N	Are elephants present on the plot?	
50. Elephant density	Elephants km^{-2}	If elephants are present, at what density?	
51. Elephant data source	Text	Source of elephant density data	
52. Small non-social browsers	Y/N	E.g. dik-diks, duikers and grysbok, steenbok	Herbivore categories based on (Hempson, Archibald, & Bond, 2015)
53. Medium-sized social mixed diets	Y/N	E.g. gazelles and oryx	
54. Large browsers	Y/N	E.g. giraffe, okapi, eland, nyala, kudu	
55. Water-dependent grazers	Y/N	E.g. roan, sable, bluebuck, waterbuck, lechwe	
56. Nonruminants, excluding suids/pigs	Y/N	E.g. zebra, hippos, rhinos	
57. Cattle graze here	Y/N	Do domestic cattle feed in the plot?	
58. Goats graze here	Y/N	Do goats feed in the plot?	

11 Annex: Stem data fields

Table 5: Minimal stem level data to be recorded. Find blank data sheets using these columns on the SEOSAW website (https://seosaw.github.io/manuals), or create your own data sheets using these fields as a guide.

Name	Unit or valid options	Instructions	Notes

Date of measurement	YYYY-MM-DD		
Plot name	Text	To match with plot data.	
Subplot	Text	If the plot is divided into multiple subplots, whether nested or not, the ID of the subplot.	
Tree ID	Text	A unique identifier for each tree to which multiple stems may be attached. Usually the tag ID of one of the stems on the tree.	
Stem ID	Text	A unique identifier for each stem. Usually the tag ID on the stem.	
Species	Text	Either the local name or preferably the binomial name (e.g. *Burkea africana*)	
Point of measurement (POM)	Metres to nearest 10 cm	The height on the stem at which the diameter measurement was taken.	
Diameter (DBH)	cm to nearest mm	The diameter of the stem at the POM.	
Height	Metres to nearest 10 cm	The height vertically from the ground of the stem, to the highest stem material, either branch or leaf. May also include bole height from the ground to the base of the crown.	
Crown dimensions	Metres to nearest 10 cm	May include any number of crown diameter measurements, and crown depth.	
Status	A R D	A = stem alive R = stem dead, but signs of life elsewhere (base or other stems) D = stem dead, and whole plant dead	
Mode	U P B S L V F O	P = Snapped (still attached) U = Uprooted B = Broken/cut (stem detached) S = Standing L = Leaning (>15° from vertical) V = Vanished F = Fallen (not supporting itself)	

		O = Other	
Damage	N E F H L M W Q O	N = Neighbouring tree E = Elephant F = Fire H = Human (cut or ringbarked) L = Lightning M = Termites W = Wind Q = Can't tell O = Other (describe in notes)	If damage caused by humans, describe in more detail elsewhere.
Cambium exposed	Percent	The proportion of trunk surface area with exposed vascular cambium, between the ground and 2 m.	
Bracket fungi	Y/N	Are bracket fungi present on the surface of the tree?	
Coordinates	Metres to nearest 10 cm	Coordinates of stem within plot, either X-Y, or angle and distance from plot centre if a circular plot.	
Notes	Text	Any other notes about the stem. Describe damage, stem mode, decay in more detail here.	

12 Annex: Using a drone to locate new plots (Thom Brade)

A consumer drone carrying a basic RGB camera can be deployed to great effect when establishing new plots, and these are relatively affordable (~£1000 will buy a very effective drone) and readily available. Quadcopter designs are stable and easy to operate (wind conditions permitting) and are available in compact folding designs easily transportable as hand luggage (which both the drone and the drone batteries should be due to flight checked baggage restrictions). We recommend DJI drones due to wide availability, proven performance and compatibility with several open source software packages that facilitate accurate automated survey.

12.1 Drone field operation – iOS or Android device

Free software can be downloaded onto your mobile iOS / Android tablet or phone and deployed by plugging said mobile device into the drone remote control. This allows fully automated survey in which the mission can be uploaded to the drone which will then take off, fly the planned mission taking photos at specified points and return to the mission starting point (assuming the mission has been designed within the limitations of drone battery and within the maximum contact range with the controller). Examples of free software used for this purpose are:

- Pix4d Capture (iOS and Android)
- DJI GS Pro (iOS only)

Single batteries on a compact quadcopter can be expected to comfortably perform surveys of areas of 5 ha depending on requirements of imagery (which will determine flight altitude, image overlap extent, drone speed etc.). If a bigger area is required, missions can be paused, battery changed, and mission resumed with both of these software packages.

12.2 Drone post processing

If you have planned missions appropriately (mission photo overlap and altitude settings) and have access to photographic processing software and relatively high performance computing facilities (recommend machines with 64 GB RAM and SSD write facilities) mission photo outputs can be mosaicked into single large area images for creating areal statistics or for other forms of analysis. Examples of commercial software (require licence) used for this purpose are:

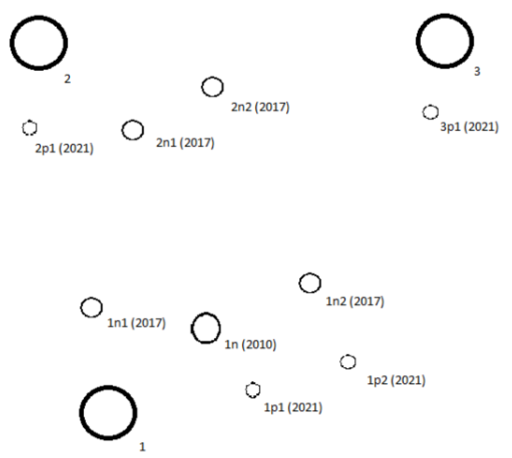
- Pix4d
- Agisoft (Metashape / Photoscan)

Read software manuals before planning any missions. Inappropriate specification of parameters such as photo overlap and altitude of flight for your given purpose and woodland / forest will inevitably lead to issues with output data quality or lead to failure of processing. See for example: https://support.pix4d.com/hc/en-us/categories/200300675-Pix4Dcapture for information on recommended mission settings.

13 Annex: Tagging new stem recruits during plot remeasurement

When remeasuring a plot that has existing stem tags, new recruits should be named relative to the closest living stem to maintain the spatial continuity of the tag numbers. We suggest using the first number of the nearest living stem and adding a letter and sequence number for multiple recruits in that location.

For example, a new recruit near the nearest living stem “1” can be recorded as “1n1” and an adjacent stem as “1n2”. In the next campaign a new letter can be used, such that a new recruit near “1n1” can be tagged as “1p1”, “1p2”, “1p3” etc. Note in this case we omitted letters “O” and “Q” as being too similar to “0” (zero) on the die stamps.



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