**Monitoring Forest Restoration**

**Control and treatment sites**

To determine the effectiveness of forest restoration treatments, restoration plots should be paired with “control” plot nearby, where no restoration treatments are applied. The same sampling effort should be expended at both the restoration sites and the control sites and the measurements made in both should also be identical. Control sites should be close and as similar as possible to the restoration sites, in terms of original vegetation, elevation, slope, aspect, etc. Delineate the boundaries of both control and restoration sites with wrought iron metal poles, placed every 100 m. Wrap coloured sticky tape around the tops of the poles and write an identification number on each pole with an indelible pen. Record the GPS location of each pole and take a photograph looking towards the centre of the study site from each pole. Record site details on Data Sheet 1.

Circular sample units have become the international standard for monitoring vegetation recovery as a result of restoration activities. Position SU’s evenly across both the control and restoration sites. A minimum of 10 SU’s should be positioned across the restoration site and 10 more across the control site. Use a wrought iron pole (which will survive fire) to mark the centre of each circular SU and a 5-m-long piece of string (tied to the centre pole) to delineate the SU circumference. Use coloured tape and an indelible pen to apply an identification number to each pole. Record the GPS location of each pole and take four photographs.

**Photo monitoring procedure**

Take photos of the vegetation at all boundary and SU centre poles. At boundary poles, take photos looking towards the centre of the study site. At sample-unit poles, take 4 photos, looking out from the pole roughly N, W, S and E (in that order). Set the camera to the widest possible zoom setting and the highest resolution. Frame each picture to include the top of the pole (showing the pole i.d. number) in the lower right-hand corner. Use a compass to record the direction of the photo. Keeping the top of the pole in the lower right-hand corner of the picture, gradually tilt the camera down to minimized the amount of sky in the shot, so the horizon should be near the top edge of the picture. Repeat photo-monitoring in the mid dry and wet seasons and at annual intervals. Use the same camera with the same zoom and resolution settings for all photos. Transfer photos to a computer as soon as possible and rename the files as follows:

pole reference number\_date (yymmdd)

e.g. B08E\_120315 (boundary pole 8, facing east, taken on 15th March 2012).

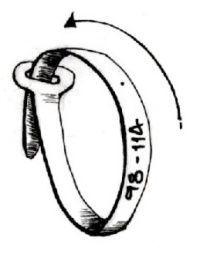
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Date:** | | | | | | | **Recorder:** | | | | | | |
|  | **Restoration** | | | | | | | **Control** | | | | | | |
| **Name** |  | | | | | | |  | | | | | | |
| **Location (Province District etc.)** |  | | | | | | |  | | | | | | |
| **Elevation range** |  | | | | | | |  | | | | | | |
| **Average slope** |  | | | | | | |  | | | | | | |
| **Average aspect** |  | | | | | | |  | | | | | | |
| **FACTORS AFFECTING REGENERATION** |  | |  |  | |  | |  | |  |  | |  | |
| **Fire History** |  | |  |  | |  | |  | |  |  | |  | |
| **Livestock usage** |  | |  |  | |  | |  | |  |  | |  | |
| **Erosion/landslides** |  | | | | | | |  | | | | | | |
| **BOUNDARY POLES** | **POLE ID #** | **GPS** | | | **PHOTO FILE I.D.** | | **PHOTO DIRECTION (DEGREES)** | **POLE ID #** | **GPS** | | | **PHOTO FILE I.D.** | | **PHOTO DIRECTION (DEGREES)** |
|  |  |  | | |  | |  |  |  | | |  | |  |
| **Etc. (add lines as needed)** |  |  | | |  | |  |  |  | | |  | |  |

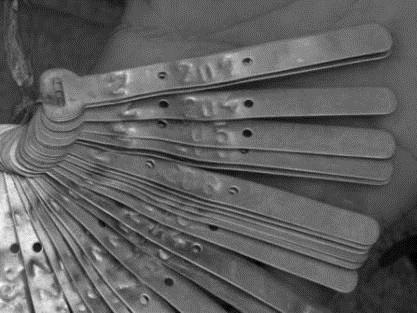
**Data Sheet 1 - Site Information**

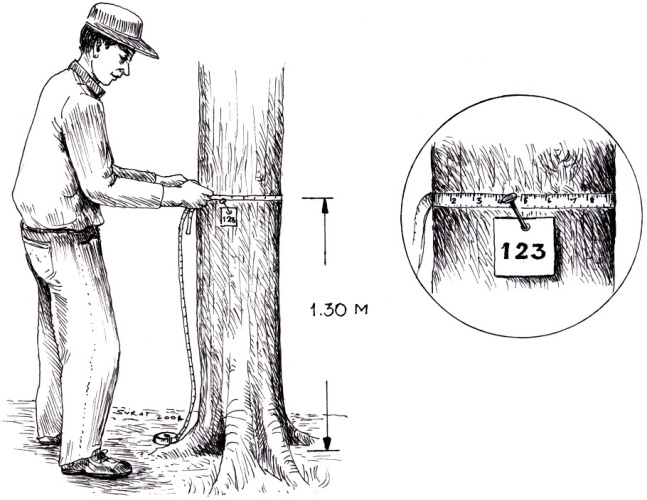
**Data Sheet 2 – Sample Unit Details**

|  |  |  |
| --- | --- | --- |
| **DATE:** | **RECORDER:** | **Sample Unit I.D. #:** |
| **STUDY SITE:** |  | **restoration or Control:** |
| **Slope:** | **Aspect:** | **Elevation:** |
| **GPS:** | **N** | **E** |
| **Signs of Fire:** |  |  |
| **Signs of livestock impact:** |  |  |
| **Signs of erosion:** |  |  |
| **Any other distinguishing features:** |  |  |
| **Photos** | **Compass direction (degrees)** | **Photo File I.D. #** |
| **N** |  |  |
| **E** |  |  |
| **S** |  |  |
| **W** |  |  |

**Labeling**

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****For seedlings and saplings use soft aluminium strips, used to bind electrical cables, available from builders’ supply stores. They can easily be formed into rings around tree stems. Use metal number punchers or a sharp nail to engrave an identification number on each label and bend them into a ring around the stem, above the lowest branch (if present) to prevent labels from becoming buried.

For larger trees and stumps, use square labels made from drinks cans. Cut off the top and bottom of the cans and slice up the length of the can to open out the metal foil sheet. Cut the sheet horizontally into 2-3 strips and then vertically to make squares. Place the labels on a pad of paper or rubber mat and then use a tough ball-point pen or nail to press identification numbers into these soft metal foil squares (on the inside can surface). On trees of girth 5 cm or more, nail labels to the trunk so that the upper edge of the label is at exactly 1.3 m above the ground, where girth at breast height (GBH) will be measured. Use 5 cm long, galvanized nails, with flat heads. Hammer only about 1/3 of the nail length into the trunk to allow plenty of room for tree growth.

**Measurements**

**Equipment**: metal labels, permanent marker or metal stylus, wire, nails, tape measures (1.5 m), Vernier calipers, Data Sheet #3, pencil, clip board, tree height measuring poles.

Within each SU, label every tree sapling taller than 50 cm and every live tree stump and then use Data Sheet 3 to record i) the label number, ii) the species name (both local name and scientific name), iii) height, iv) for small saplings, root collar diameter (RCD mm) or for larger trees (if girth at breast height (GBH) is more than 5 cm), record the GBH (cm), v) health score, vi) crown width and vii) for tree stumps, the number of coppicing stems. Ask local people for the name of each tree in the vernacular. Work with a botanist to obtain scientific names on-site, or collect specimens for identification at a herbarium later.

Use tape measures to measure the heights of small saplings (taller than 50 cm) (e.g. 1.5 m tape measures mounted on rigid PVC poles). Measure the tree height, from the root collar to the highest meristem (shoot tip). For taller trees, telescopic measuring poles can be used to measure trees up to 10 m tall.

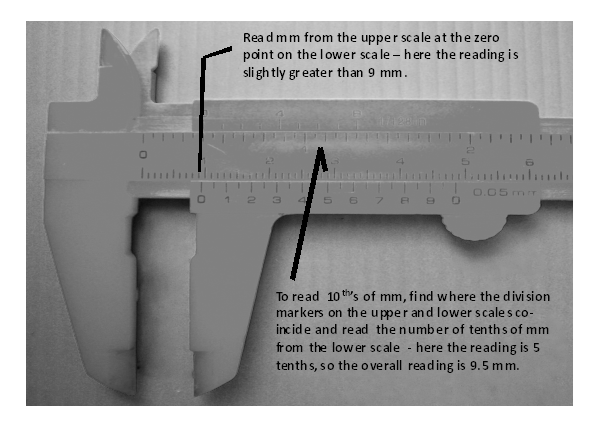
For small trees, measure RCD at the widest point with Vernier calipers. Once a tree has grown tall enough to develop a GBH of 5 cm or larger, measure both the RCD and the GBH (1.3 m from the ground), the first time and only GBH thereafter.

Assign a simple health score (0-3) to each tree and record descriptive notes about any particular health problems observed. Score zero if the tree appears to be dead. For deciduous tree species, don’t confuse a tree with no leaves in a dry season with a dead one. Do not stop monitoring trees just because they score zero on one occasion. Many trees, which appear dead above ground, may still have living roots, from which they may subsequently re-sprout new shoots. Score 1 if a tree is in poor condition (few leaves, most leaves discoloured, severe insect damage etc.). Score 2 for trees showing some signs of damage but retaining some healthy foliage. Score 3 for trees in perfect or nearly perfect health.

Measure the width of the tree crown (cm) at the widest part with a tape measure. Any tree seedlings or saplings shorter than 50 cm can be considered as part of the ground flora and need not be individually measured.

**Box 3 – Using Vernier Calipers**

Vernier scale calipers are available from most stationary stores. At the zero mark on the lower sliding scale, read number of millimetres diameter from the upper scale. For the decimal point, look for the point at which the division marks on the lower scale are exactly aligned with the division marks on the upper scale. Then, read the decimal point off the lower scale. For example, the Vernier scale here reads 9.5 mm. Because RCD is a small value, it must be measured with high accuracy. For best results, measure RCD twice by turning the calipers at right angles and then use the average reading.



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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SAMPLE UNIT ID #:** | | **RECORDER:** | |  | **restoration** | **OR CONTROL** | | **DATE:** |
| **Within 5 m radius circle** | | | | | | | | |
| **Label** | **Tree Species** | **Height** | **RCD** | **GBH (cm)** | **Health Score** | **Crown Width** | **No. Coppicing Shoots** | **Notes** |
|  |  | **(cm)** | **(mm)** | **if >5 cm** | **0-3** | **(cm)** | **(for tree stumps)** |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |
|  | Local |  |  |  |  |  |  |  |
|  | Sci. |  |  |  |  |  |  |  |

**Data Sheet 3 – Trees**

If restoration treatments are effective, the number/unit area of trees > 50 cm tall and their growth rates should increase more in the restoration site than in the control site. Furthermore, the mortality of small regenerants should be lower in the restoration site.

On the restoration site, more tree seedlings smaller than 50 cm tall (uncounted in the ground flora) should grow into the >50 cm size class (counted on Data Sheet 3) compared with the control site. From the data collected during the second monitoring, count the number of new regenerants, recorded in each SU, which are taller than 50 cm, but which were **not** labeled in the first survey (i.e. they were shorter than 50 cm in the first survey). Calculate the means (and SD’s) for the restoration and control sites and perform a t-test, to determine if the difference between the means is significant.

For each labeled regenerant, surviving in **both** surveys, calculate the relative growth rate (RGR) as follows:

ln H (2nd survey) - ln H (1st survey) x 36,500

No. days between measurements

...where ln H = natural logarithm of regenerant height (cm). RGR is an estimated annual percentage increase in size. It takes account of differences in the original sizes of the regenerants, so it can be used to compare regenerants that were larger at planting time with those that were smaller. The same formula can be used to calculate relative growth rates of root collar diameters and crown widths. To determine if RGR differs between the restoration and control sites, perform a t-test to compare the mean RGR values of each species with more than 5 surviving individuals on each site (over combined SU’s)

In each SU, count the number of regenerants recorded as dead in the second survey and express as a per cent of the number of live regenerants counted in the first survey. Exclude tree stumps and trees > 5 cm GBH from the count. Calculate the mean value and SD for the restoration and control sites and perform a t-test, to determine a significant difference in mortality between the means.

Steve Elliott

6/11/22