Protocol followed for establishing and monitoring the long-term transects

The following protocol can be best described as a trade-off between being too specific versus having broad guidelines. On one hand, being too specific might prove advantageous by reducing data variance, but might hamper the replicability across resource-limited institutes in India; on the other hand, keeping the protocol extremely broad and open ended might promote replicating, but can seriously hamper the scientific credibility. Such methodological challenges are common in ecological long-term data and we have tried to balance them by quantifying only the most critical variables (Magurran et al. 2010, Roman et al. 2013).

1. **Criteria for choosing study area:** Out of the several factors that one must consider while establishing long-term monitoring (Marthews et al. 2014), for campuses of educational institutes, it is important to have formal tie-ups with the college authorities and ensure that there will be sufficient logistical support. Securing this support of resources is very important for long-term research sustenance, given that the most important challenge for urban-tree inventories in countries like United States is resource-limitation (Roman et al. 2013).
2. **Criteria for choosing transect areas**: In order to ensure that the vegetation that will be sampled is representative of life stages spanning from saplings (smaller girth classes) to adult trees (larger girth classes), three types of areas should be preferred: 1) newly planted areas where saplings are present; 2) areas with mature, old trees (may include standing dead trees as well); 3) areas with trees representing a mixture of both 1 and 2 types of life stages, which also includes trees belonging to medium girth classes (Figure 1A, 1B, 1C).
   Distance between two transects should not be less than 5 meters. There should also be some easily recognizable landmark(s)/ objects near the transect (eg. pole, wall, road junction, sign boards, or even a peculiar well grown tree) which makes it easier to locate the transect (i-Tree Eco Field Manual, 2019).
3. **Habitat strata in campuses:**
   Common strata in educational institutes include roads, built up areas, gardens, play grounds, hills and water bodies. Using a map of the study area (and keeping the points 1,2,4 in mind), the total number of transects should be distributed equally in all parts (i-Tree Eco User's Manual, 2019). As far as possible, it is advised to randomise the choice of transect locations (but keeping the points 1,2,4 in mind). Transects should be used for vegetation along roads, built up areas, hills but not gardens. For gardens, a complete enumeration should be carried out wherever feasible, otherwise they should be sampled with adequate number of quadrats of appropriate dimensions (eg. 20m x 20m at least) following the methods provided in Magurran (2004).
4. **Access:** Trees that are easily accessible for measurement (usually roadside trees) should be preferred, except in some cases such as those on hills and gardens within the campus.
5. **Transect dimensions:** Since the vegetation that is being targeted is primarily found along paths, roads and along other linear infrastructure within a campus, a belt transect should be preferred with length 10m and width 2m.

6. **Sample size:** The minimum number of transects to be established and monitored each year should be determined based on species-area curve (Magurran, 2004) and, if the number is less than 30, the data might not be enough for robust statistical analyses. The maximum number should be limited by considering available work-force and logistics.
7. **A reconnaissance survey** must be done considering all the above points to decide possible locations.
8. **Establishing transects:** First/starting tree or nearest identifying object/ landmark (eg. pole/wall) must have the transect number written with yellow oil paint (eg. T10) and an arrow showing the transect direction. The rest of the trees should have a yellow line/mark on one stem per individual that is to be enumerated (Figure 1B, 1D). Length of the transect must be demarcated using a 10m long nylon rope stretched from the starting tree to 10m in the specified direction. Width must be kept 2 meters (one meter on both sides of rope). In order to avoid error during successive measurements, steel nails or pegs can be used to mark either the four corners, or ends of the central (rope) line (i-Tree Eco Field Manual, 2019, Marthews et al. 2014). All transects must be marked on a GPS unit with codes like 10A, 10B that denote start and end point of transects (i-Tree Eco Field Manual, 2019). A user-friendly map of these transects must be prepared for future monitoring (i-Tree Eco Field Manual, 2019, Appendix 1). All transects should also been given names based on prominent trees/ landmarks eg- 'IMDR Parking up'. Transect locations may also be drawn by hand for each transect along with photographs of the earlier sampling.

Data collection (core variables):

9. **Investigators, date, plot codes:** It is extremely important to note this information (see Appendix 2 for our data sheet template).
10. **Botanical identification**: Each tree should be identified up to the species level using its scientific name. Species codes (acronyms of the genus and species names) may be used if convenient (Vogt et al. 2014). Relevant regional and local floristic literature should be followed for plant identification followed by field validation by experts, if needed. See Appendix 3 for a list of some useful resources for field identification of urban trees in India.
11. **What groups to measure**: It is important to measure all standing vegetation in the transects, both live and dead. All plant groups including Palms, Cycads, woody Pteridophytes, Bamboos and lianas. Non-woody groups (eg. *Dracaena* spp., *Musa* spp.) may be excluded.
12. **Measuring Girth**: Girth at breast height (GBH) must be measured at 1.3m above ground of all woody species with a diameter greater than 1cm (approximately greater than our index finger) that are present at that height. The investigators should determine the point of measurement ideally using a stick with a mark at 1.3m height (Marthews et al. 2014), but can also standardise it according to ones height. Measurement must be done using a correctly calibrated measuring tape. Measure girth to the nearest millimetre (eg- 30.8 cm instead of 31). For trees smaller than 10cm

diameter, a digital Vernier calliper can also be used instead of the tape [however, note that the measurement is of diameter here instead of girth (circumference) by the tape]. Care should be taken to identify stems of the same tree, and for such multi-stemmed trees, girth must be entered as '10.2+20+29.5+5'. If the stems are not joint at the base as observed, they should be considered different trees (ramets) (as seen frequently in the case of *Leucaena leucocephala*). For more details about measuring irregular trees and special cases, see Marthews et al. (2014) and Vogt et al. (2014). Note down newly planted saplings that do not reach 1.3m height above ground separately in 'remarks' column and not in 'species' column.

For Bamboos: Measure a few representative stems for each girth class (say 3 to 4) and note down the number of stems for each such class instead of measuring each stem manually (Marthews et al. 2014). Same can be followed for dense clumps of species like *Lantana camara.*

13. **Height**: can be recorded using visual estimation or with the help of Rangefinders. If using visual estimate, it is recommended that the investigators standardize their height estimate at the beginning of each session using the transect rope (see an alternative method here: https://gubbilabs.github.io/tree-map/method-1.html). The decision of accuracy level followed for measurement depends eventually upon the questions.
14. **Transect photograph**- This will serve as a reference for further monitoring (i-Tree Eco Field Manual, 2019). Should be clicked as follows: Keep the transect rope, click a photo in the zoomed out/ wide angle standing next to/ behind the start point so as to include first tree, rope and last tree with all trees in between preferably visible (Figure 1D).

Note: The present protocol outlines description of variables that are needed to answer questions described in Nerlekar et al. (2019). Additional variables may be added for site-specific questions. A list of some useful additional variables and methods to record them can be found in Vogt et al. (2014), (i-Tree Eco Field Manual (2019).

15. **Re-monitoring:** After the initial setup and enumeration, transects should be monitored before the onset of dry season (for seasonal regions with large proportion of deciduous trees) since leaves are retained till then-which helps in correct botanical identification. The frequency of monitoring should approximately be one year, and the same month of the year if possible. The entire monitoring must be completed within a short span (about 10 days) to avoid any sampling-duration bias.
16. **Data entry, management and archiving**: Data sheets should be scanned and the hard copies should be stored securely. A metadata (description about the data) abstract file must be maintained that describes each variable measured (see https://portal.lternet.edu/nis/metadataviewer?packageid=knb-lter-bes.3300.110 for example). Over time, with increasing volume of the data, it is essential to follow good management practices (see https://www.britishecologicalsociety.org/wp-content/uploads/Publ_Data-Management-Booklet.pdf for details). Once data entry and curation are complete, the data must be archived and all files should be uploaded on an institutional portal or on data portals such as GitHub (https://github.com/), Open

Tree Map initiative (https://gubbilabs.github.io/tree-map/index.html), Dryad digital repository (https://datadryad.org/) with appropriate licencing. See more about data archiving in Whitlock (2011). As an example of an effective data management system for urban long-term monitoring, see the Baltimore LTER portal (http://beslter.org/dm_policy.html) and the LTER portal (https://portal.lternet.edu/nis/mapbrowse?packageid=knb-lter-bes.3300.110).

References:

1. i-Tree Eco Field manual. (2019). Tools for assessing and managing Community Forests. Software Suite v6.0. Available online at: https://www.itreetools.org/resources/manuals/Ecov6_ManualsGuides/Ecov6_FieldManual.pdf.
2. i-Tree Eco User's manual. (2019). Tools for assessing and managing Community Forests. Software Suite v6.0. Available online at: https://www.itreetools.org/resources/manuals/Ecov6_ManualsGuides/Ecov6_UsersManual.pdf
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8. Vogt JM, Mincey SK, Fischer BC, Patterson M (2014) Planted Tree Re-Inventory Protocol. Version 1.1. Bloomington, IN: Bloomington Urban Forest Research Group at the Center for the Study of Institutions, Population and Environmental Change, Indiana University. 96 pp. Available online at: https://urbanforestry.indiana.edu/doc/publications/2014-planted-protocol.pdf
9. Whitlock, M. C. (2011). Data archiving in ecology and evolution: best practices. *Trends in Ecology & Evolution*, *26*(2), 61-65.

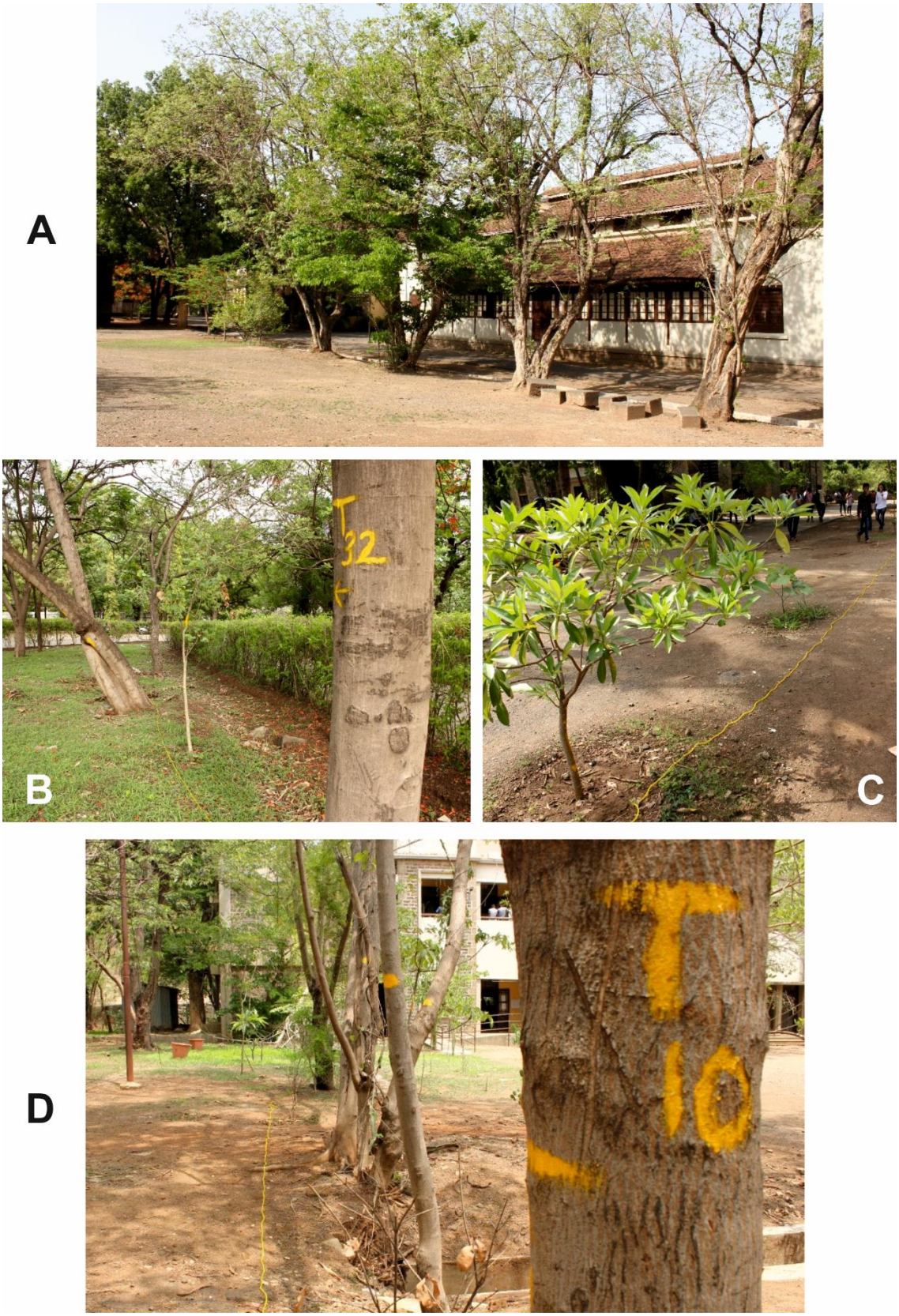
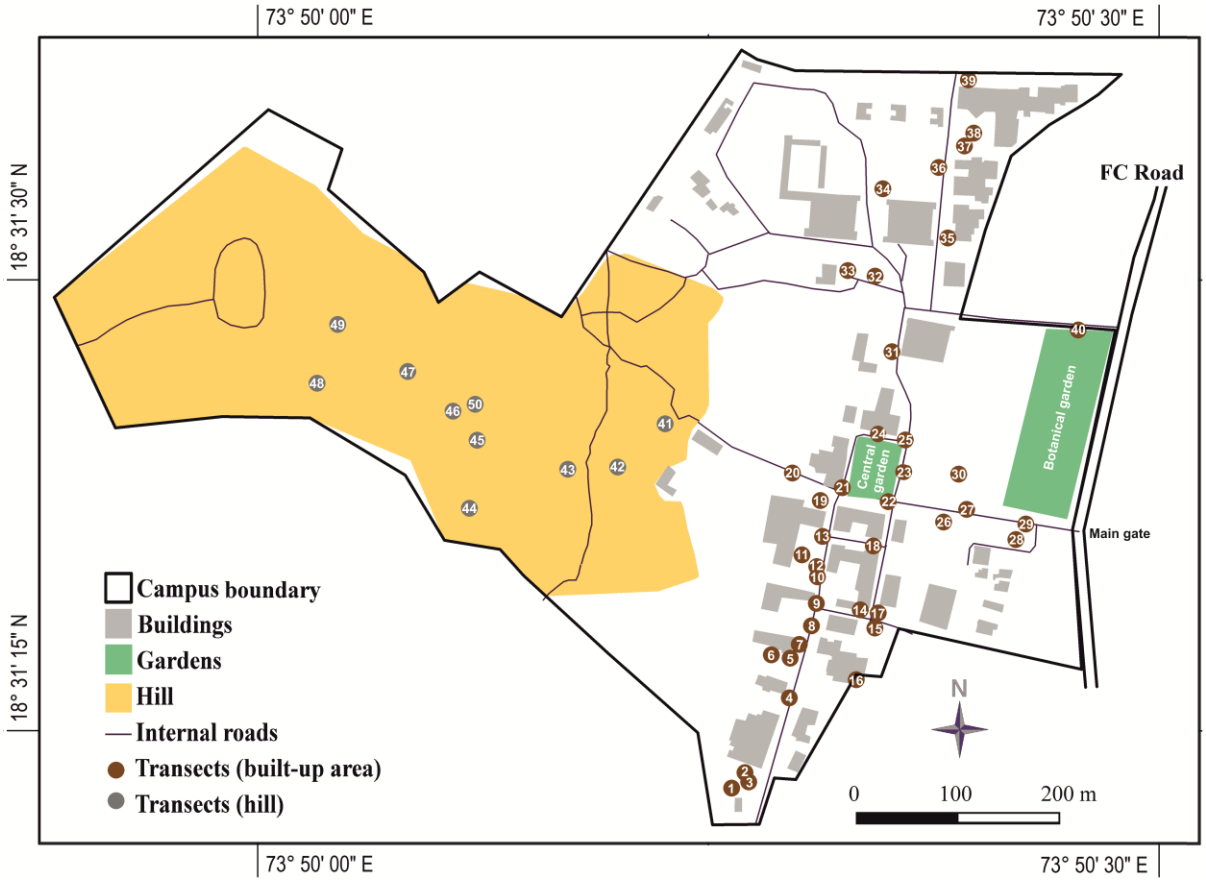


Figure 1: **A**: a row of adult (old) trees along the campus road; **B**: transect showing two trees of greater girth and one newly planted sapling; **C**: transect with all newly planted trees with smaller girths; **D**: transect with the first tree marked with transect code (T10) along with the 10m rope visible on the ground

Appendix 1: A map of the long-term transects and gardens sampled in the Fergusson College campus. Transects are numbered and colour coded based on habitat strata (Built up area, n= 40 and hill, n= 10). Campus boundaries are as depicted in Limaye, P. M. (1935). *The History of the Deccan Education Society Parts I–III*. Deccan Education Society, Poona-4.



Appendix 2: The data sheet template used by us. Researchers aiming to replicate the monitoring should consider modifying the template for specific questions if necessary

Fergusson College Long-term vegetation monitoring – Data sheet template

Investigators: …… Date: …… Page ----/----

Transect no & name	Species	GBH (cm)	Height (m)	Remarks
No. : **T**___ Name: _____ _____ _____	1)			
	2)			
	3)			
	4)			
	5)			
	6)			
	7)			
	8)			
	9)			
	10)			
	11)			
	12)			
No. : **T**___ Name: _____ _____ _____	1)			
	2)			
	3)			
	4)			
	5)			
	6)			
	7)			
	8)			
	9)			
	10)			
	11)			
	12)			

Appendix 3: A non-exhaustive list of resources that can be useful to identify trees in most Indian cities:

1. Almeida, M. and N. Chaturvedi (2006). *Trees of Mumbai.* Bombay Natural History Society, Mumbai.
2. Ingalhalikar, S. and S. Barve (2010). *Trees of Pune -Including Palms, Conifers, Cycads& Bamboos*. Corolla Publications, Pune.
3. Krishen, P. (2006). *Trees of Delhi: a field guide*. Penguin Books India.
4. Prasanna, P. V., Reddy, N. C. M., Venkat Ramana, M. and P. Venu (2012). *Trees of Hyderabad: a pictorial guide.* Botanical Survey of India, Kolkata.
5. Randhawa, M. S. (1996). *Flowering Trees*. National Book Trust, New Delhi.
6. Rao, K. S. and S. Champanerkar (2009). *Flowering plants of Indian Institute of Science: a field guide* (2 volumes). Indian Institute of Science, Bangalore.
7. Sahni, K. C. (1998). *The Book of Indian Trees*. Bombay Natural History Society, Mumbai.
8. http://www.flowersofindia.net/
9. http://flora-peninsula-indica.ces.iisc.ac.in/index.php
10. https://sites.google.com/site/efloraofindia/