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Establishment of long-term vegetation monitoring plots in lowland and upland tropical rainforest, Fiji Islands

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Abstract— Long-Term Vegetation Monitoring Plots (LTVMP) provide vital information on the flora, vegetation ecology, ecosystem dynamics, climate change and anthropogenic impact on biodiversity. As part of the Pacific–Asia Biodiversity Transact (PABITRA) network, three long-term vegetation monitoring plots in lowland and upland tropical rain forest were established on the island of Viti Levu, Fiji Islands. The plots were established in the Wabu Forest Reserve and Sovi Basin, on the island of Viti Levu. Each monitoring plot consists of four 50m x 50m sub-plots. All trees greater than 10 cm in diameter at breast height were measured. The design of the LTVMPs and some of the ecological findings in the Wabu Forest Reserve are evaluated.

Introduction

In developing long term monitoring plots it is necessary to establish an accurate and permanent grid system that will allow trees (and also other plant forms) to be mapped precisely and easily relocated. The data collated will also serve as baseline information for the spatial distribution of plants in a given area, providing a better understanding of tree distribution, forest type, composition, densities and diversity and other vegetation dynamics. Species composition changes can also be monitored over time (Condit 1998). Following the Pacific Asia Biodiversity Transect (PABITRA) long-term biodiversity monitoring workshop Suva, Fiji (6-10 December 2004), it was decided that a series of monitoring plots would be set up at two PABITRA Gateway core sites which are recognized Key Biodiversity Areas (KBA) for Fiji, namely the Wabu Forest Reserve and Sovi Basin. This paper provides a description of the methodology used for site selection of the monitoring plots, establishment of the subplots, and alignment of gridlines for the mini-plots within each subplot. These plots are also part of a network of permanent plots set up at other PABITRA core sites in Fiji as described in Keppel (2005). Some preliminary results obtained from the LTVMP set up in the Wabu Forest Reserve will be discussed.

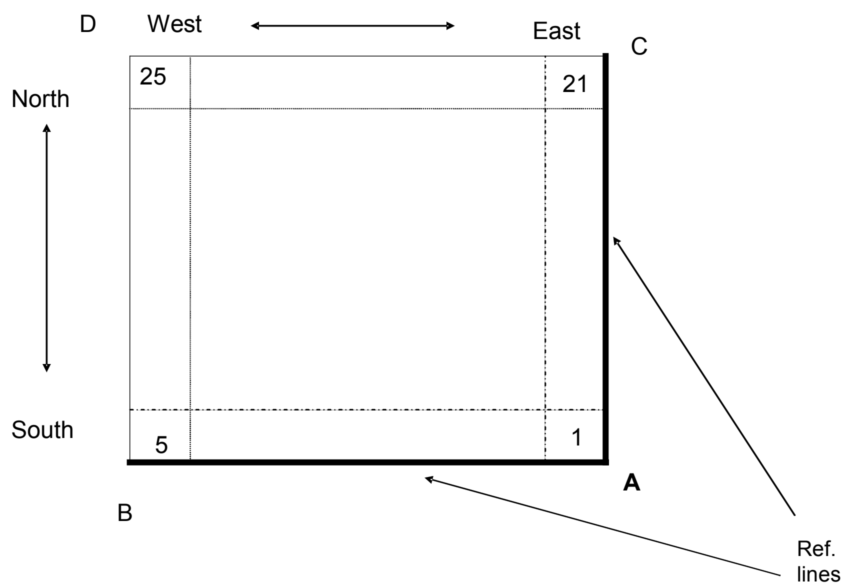

Figure 1. Layout plan of the long-term vegetation monitoring subplot and mini-plots.

Materials and Methods

SITE SELECTION

Monitoring plots were to be placed in the Wabu Forest Reserve to represent Fijian upland rain forest, between 700 m and 850 m elevation, and for Sovi Basin to represent Fijian rain lowland forest, between 150 m and 250 m elevation (Mueller-Dombois & Fosberg 1998). Also important were the criteria that the monitoring plots were: i) close to areas where human impact is the greatest and for the longest period of time, ii) relatively accessible for trekking, air lift and drop-off or close to a traditional track and, iii) representative of the general or surrounding vegetation type under investigation. The placement of plots near areas of high human impacts was to allow for the assessment of invasive and recently introduced species and their influence on the biodiversity of the area. A series of 1:50000 Fiji Map Series (2002) were used to assist in site selection using the above selection criteria. Three sites (one in Wabu Forest Reserve and two in Sovi Basin) were selected. Later, a field surveillance survey was carried out to determine the exact placement for the monitoring plots. The monitored area consisted of four 50m x 50m subplots. The four subplots were positioned such that the forest types (based on the dominating topographical feature) within the 1 km^2 surrounding quadrant were represented proportionally.

MARKING OF THE SUBPLOTS AND GRIDLINES

Once the forest type(s) to be assessed had been identified, a hand-held compass was used to establish two reference lines aligned perpendicular to each other. Each line was 50 m long. The first reference line was aligned in the east–west direction and the second in the south–north direction.

The point where the two lines met was referred to as the "reference point" (indicated by the letter A in Figure 1). A wooden peg or stake was placed at this point with the upper end marked with two bands of yellow and orange paint. On each reference line a stake was placed every 10 m from the reference point. A third 50 m line was run parallel to one of the reference lines. The distance between the lines was 10 m. The whole process was repeated until a series of five parallel lines were placed in the north-south direction and likewise another five lines were laid out in the east-west direction. A total of 25 (10m x 10m) miniplots were established and each miniplot, was numbered from 1 to 25. Mini plot #1 was the first 100 m^2 quadrat immediately adjacent to the reference point and miniplot #25 was the furthest away (Figure 1).

Several Global Position System (GPS) readings were taken at the reference point to get an accurate coordinate for its position. At the respective corners of each subplot, GPS readings were taken over a 2-3 day period at different times of the day. Collated data comprised of waypoints, error, the South and East co-ordinates, and date.

DATA ENTRY AND COLLATION

GPS readings were taken when EPE (Estimated Position Error) was <10m with 3D coordinates. Despite holding the GPS above the canopy, poor GPS readings were a recurring obstacle in subplot corners residing in low lying valleys with dense canopy cover. Thus readings resorted to 2D co-ordinates. However, along the ridges and gentle slopes enclosed in thin and spreading canopy GPS readings still required a fair amount of time to obtain a constant EPE.

Personal Digital Assistants (PDAs) were used in the field for direct data entry. In each mini-plot, detailed assessment of all trees with diameter at breast height (dbh) (1.3m above ground) above 10 cm was carried out. For each tree either its scientific or local name was recorded, dbh measured to the nearest millimeter, crown width measured, and its health and phenology was assessed. The bole height and total tree height were calculated automatically when the clinometer angle and the distance of the observer to the tree was entered into the (PDA). Other variables such as rooting substrate, topography of the plot, time and site area, recorder name, and tree spotter name were also recorded.

These data were downloaded later in the day into a laptop. Data gathered were regularly checked to account for observer error (i.e. PDA data was crossed referenced against the manually entered field note data), which increase the accuracy and precision of large data sets like the Wabu tree plot data. Written records were also made in the field as a back-up for the digital data set, and they were especially helpful during rainfall, which hampered data entry on the PDAs. These records were also used to cross-check anomalous data during the preliminary analysis stage. For each tree assessed, an aluminum tag was attached by being either nailed or tied to the tree trunk at breast height with information on the tag is written as shown in Figure 2.

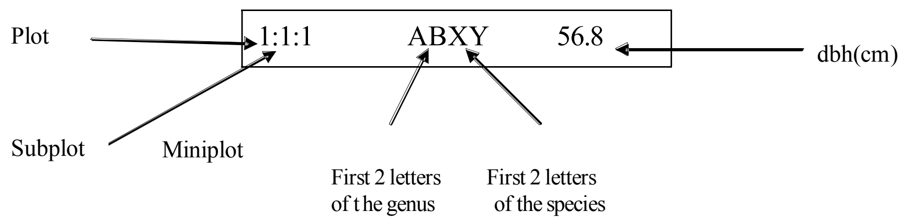

Figure 2. Labeling on aluminum tags. Where the botanical name was not known, the local name was used and written in full in its place.

Also, in each mini-plot the Braun-Blanquet scale was used to estimate the percentage ground cover of the following plant groups: ground ferns, woody dicots, woody monocots, herbaceous plants and bryophytes. A checklist of plants with dbh <10cm was compiled. Additionally, the spatial distribution of all trees with dbh >10cm was recorded (mapped) manually into field notebooks. For at least five of the largest trees in each subplot their position were recorded using a GPS and their relative position from the reference point or the nearest corner stake was manually measured and a compass was used to record the direction of the measurement. Herbarium specimens of tagged plants were collected and those that could not be identified in the field, especially those that were either flowering or fruiting, were collected for later verification of their identity and processed as herbarium vouchers at the South Pacific Regional Herbarium (SPRH).

Results

DESCRIPTION OF THE SUBPLOTS

Subplot 1 was on a creek-flat that extended from the edge of the Wabu creek to the beginning of a gentle slope. The position of the subplot using the Fiji Grid Line Coordinates of the reference point or stake was 1925072 3932604. The dominant tree in the plot was *Ficus* cf. *tinctoria* Forst. (151cm dbh) and this was the largest tree encountered in any of the subplots assessed. Other large trees noticed in the subplot included *Myristica* spp., *Calophyllum vitiense* Turrill and *Endospermum macrophyllum* (Muell. Arg.) Pax & Hoffm.. The most common tree species was *Gironniera celtidifolia* Gaud. Amongst the shrubs *Psychotria* spp. was most common.

Subplot 2 was on a relatively steep slope and extended upslope to include the edge of a ridge-top or flat. Also included is part of a riparian system where several large exposed rocks were found. The position of the subplot using the Fiji Grid Line Coordinates of the reference point or stake was 1925034 3932495. The dominant tree was *Agathis macrophyllum* (Lindl.) Mast. with a dbh of 133 cm. It was growing on the side of the ridge. Other large trees (dbh > 50cm) observed in the subplot included *Parinari insularum* A. Gray, *Dysoxyllum* sp., *Degeneria vitiensis* I.W. Bailey & A.C. Sm., *Calophyllum* spp. and *Trichospermum richii* (A. Gray) Seem. The most common tree species was *G. celtidifolia*. Two species of palms were observed in the subplots and these included the *Veitchia* sp. and *Physokentia petiolata* (Burret) D.Fuller. Bryophytes were plentiful on exposed rock surfaces and stems of trees in and around the riparian system.

Subplot 3 was on a ridge flat area and extended about a meter into the adjacent gentle slope. The position of the subplot using the Fiji Grid Line Coordinates of the reference point or stake was 1925081 3932316. The dominant tree was *A. macrophyllum* which had a dbh of 129 cm. Other large trees (>50 cm dbh) included *P. insularum*, *T. richii*, *Syzygium* sp. and *E. macrophyllum*. The most common tree species was *G. celtidifolia*.

Subplot 4 was on a long gentle slope and extended onto a ridge. The position of the subplot using the Fiji Grid Line Coordinates of the reference point or stake was 1924639 3932972. *A. macrophyllum* was the dominant tree with a dbh of 97cm. Other large trees in the subplot included *P. insularum* and *T. richii*. Like the three other subplots *G. celtidifolia* was the most common tree species.

For the four subplots assessed, preliminary results indicated a total of 79 tree taxa (some were based on Fijian names), with three as yet unidentified. The dominant tree was *A. macrophyllum*. On subplot 3 a stand of three large *Agathis individuals* were growing 3 m from each other. This is not an uncommon phenomenon as this was also noticed in other similar forest types nearby. *G. celtidifolia* was the most common tree species found in all the subplots. This was followed by trees in the *Syzygium* and *Endiandra* genera. In total, 869 trees with

Table 1. Summary of the average measurement of trees found in each of the four subplots at Wabu.

Subplot	Average DBH (cm)	Average bole height (m)	Average Tree height (m)
1	21.4	5.87	10.42
2	19.4	4.82	9.41
3	18.4	5.28	9.72
4	20.5	5.85	10.78
Plot mean	19.7	5.43	10.04

diameters greater than 10 cm were tagged and recorded (Subplot 1, 188; Subplot 2,195; Subplot 3, 292, Subplot 4, 194). Average dbh, bole height, and tree heights are shown in Table 1.

GROUND COVER

The average percentage of plant forms making up the ground cover for each sub-plot is summarized in Table 2. Overall, the ground ferns and their allies comprised the greatest percentage of ground cover throughout the four (50 m x 50 m) sub-plots. These mostly comprised fern ally species in the genus *Selaginella*, and ferns in the *Marattia*, *Trichomanes*, *Asplenium* and *Tectaria* genera which made up to 45% of the ground cover. *Clidemia hirta* (L.) D. Don, and species in the *Macropiper*, *Psychotria* and *Ficus* genera formed the woody dicots that grew extensively within the sub-plots ensuing the second largest percentage ground cover in any of the sub-plots.

Some of the more common woody monocots included species in the *Freycinetia* and *Alpinia* genera, and *Scleria polycarpa* Boeck., and they made up the third largest group. The fourth group was bryophytes which were often observed along the trunks, roots of trees and rotting barks. Herbs, on the contrary, frequently comprised <10% of ground cover the most common herbs being species in the genus *Cyrtandra* and Orchids.

Table 2. Summary of the average percentage of plants forming the ground cover for each subplot at Wabu.

Growth form	Average percent cover			
	Subplot 1	Subplot 2	Subplot 3	Subplot 4
Ground ferns	26	29	20	27
Tree ferns	19	18	24	15
Woody dicots	18	16	16	17
Woody monocots	16	15	14	14
Bryophytes	14	14	13	14
Herbs	8	8	12	13

Conclusions and Recommendations

Some of Fiji's largest forest trees have been observed inside the Wabu Forest Reserve. The largest tree encountered in the subplots was *Ficus* cf. *tinctoria*. Other large trees encountered and observed within the 1 km^2 vicinity of the subplots and not already mentioned included *Hernandia olivacea* Gillespie, *Myristica castaneifolia* A. Gray, *Gonystylus punctatus* A.C. Sm., *Astronidium* sp. and *Dacrycarpus imbricatus* var. *patulus* de Laubenfels. All these tree species are important timber trees for Fiji and as such, Wabu is considered an important germplasm bank or source for these timber species.

During this survey the sighting of the rare orchid *Macodes* sp. in the area of study has resulted in the extension of its distribution range within the Wabu Forest Reserve. The orchid was first recorded in Fiji from the same vicinity during a similar survey in 2003.

Permanent PVC stakes should be used to replace the temporary wooden stakes currently used to mark out the boundary line of the subplots and miniplots, as the wooden stakes are likely to decay. Trees assessed should be marked with paints as the use of nails and aluminum wire to fix the tags to the tree will usually result in either the damaged part of the trunk growing over the nails and tags or both being dislodged from the trunk, and allocated a number where dbh measurements were taken. The plots will be resurveyed once every three to five years to monitor growth rate, recruitment and phenology.

A brief trek into the adjacent forest towards Balesere village in the Ra province revealed an intact primary forest similar to that which was found in the forest reserve. From discussions with landowners who were part of the survey team, we found out that there are plans to log the area. Negotiations by some landowners with potential logging companies are in progress. Logging activities occurring on these adjacent hills could have a very devastating effect on wildlife in the whole Wabu reserve. As such, preventative measures should be put into place immediately to avoid such catastrophic activities. Relevant authorities should begin a process where this set back will be avoided.

Education and awareness for the local resource owners with regards to the impacts of invasive flora and fauna are vital to maintain the unique biodiversity of the area. Also, alternative sources for income generation should be put into place to reduce desires to log in the area. Most importantly the "true" value of Wabu's rich and unique biological diversity and that this is a truly intact primary forest should be made known to the resource owners, their neighbors and those in high authority in the managements of Fiji's natural resources.

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