Standard Operating Procedure
Forest Litter-fall

September 2013

The Orangutan Tropical Peatland Project
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Aims and Background

The collection and measurement of forest litter-fall is a widely used method for assessing and monitoring forest productivity over both space and time (Proctor, 1983; Vitousek, 1984; van Schaik and Miranto, 1985; Burghouts et al., 1992; Barlow et al., 2007). Litter-fall data collection in Sabangau began in 2005 and is still underway at the time of writing. While researchers around the world collect and analyse litter-fall data for a variety of reasons, OuTrop’s particular aims in this area are to:

1. Provide a measure of overall forest productivity (weight of litter produced/unit time/unit area) as a component of our ecological monitoring programme (Harrison et al., 2012), for assessing and monitoring forest quality/condition in Sabangau over time and in relation to changes in human activities in the area.

2. Provide long-term litter-fall data for comparing forest condition with other research sites, to gain a better understanding into the causes behind spatial variations in forest condition and the impacts of human activities on this.

3. Provide supporting data for comparison with OuTrop’s other data sets on, for example, tree reproductive phenology data and butterfly emergence times, to better understand ecological interactions within the forest.

In this Standard Operating Procedure (SOP) we describe our methods for establishing litter-fall traps, and collecting and processing litter-fall data. These have worked well in OuTrop’s primary research site in Sabangau (Figure 1), yielding useful insights into the impacts of haze from human-induced forest fires on the ecosystem (Harrison et al., 2007), supporting analyses of orang-utan (Pongo pygmaeus wurmbii) feeding ecology (Harrison, 2009) and contributing to a variety of other previous (Sulistiyanto, 2004; Sulistiyanto et al., 2004) and ongoing research projects. Consequently, the protocols described herein are suggested as a standard for the region, particularly in tropical peat-swamp forest.
Figure 1. Map of Sabangau research site (bottom) in relation to Central Kalimantan (middle) and Indonesian Borneo (top), with the location of litter-fall trap transects shown in red.
Note that this SOP does not include methods for chemical or other laboratory analyses of litter collected, which may be desirable in some studies (e.g. Haase, 1999; Sulistiyanto, 2004; Sulistiyanto et al., 2004). Note also that, when comparing litter-fall data over space or time, it is important that methods are kept constant throughout. Any changes to trap design, litter collection or processing protocols — even if to accommodate methodological “improvements” — may result in erroneous impressions of actual changes in litter-fall in the forest that are in fact due simply to changes in methods. If it is necessary to change methods mid-way through a data collection, then it is imperative that these new methods are assessed and calibrated against the previous methods, such that any influence of method alterations can be accounted for in data analysis (Gardner, 2010).

Trap Design

Completed traps should resemble a table, with the frame made of piping and the top of sagging netting (Figure 2). The frames should be assembled and the nets cut at camp to ensure that everything fits, then dismantled to be carried out to the forest where they are to be erected.

Figure 2. Litter-fall trap frame. See text for details. Net not shown.
Equipment needed

- For each trap:
  - 8 m of plastic piping
  - 4 x “r” pipe joints
  - 4 x “T” pipe joints
  - 1.2 x 1.2 m fine-meshed fishing net

Other equipment:

- Saw
- Large sewing needles
- Lots of fishing line

Assembling the traps

1. Attach a “T” joint to the end of one of the pipes

2. Saw off a piece of piping roughly 4 cm, attach this to the already-attached “T” joint and attach an “r” joint on the end (so that the two joints are touching and there is no white piping visible, Figure 3).

3. Measure 1 m of pipe from the inside of the “r” joint and saw off the pipe at this point

4. Attach an “r” joint to the newly-cut end

5. Repeat until a 1-m square as measured from the inside of the square, with one “T” joint on each side at each corner, and an ‘r’ joint on each corner (Figure 4).
Figure 4. Aerial view of trap, showing 1-m squared inside trap measurement. Grey shade indicates the “r” joints and black shade the “T” joints.

6. Dismantle this top part and bundle it together with raffia.

7. Saw off four 1 m legs, tie together with raffia and then attach together with the top part, so that the completed trap frames are bundled together to be carried into the forest.

8. Cut a piece of netting 1.2 x 1.2 m, roll up and tie together with raffia.

9. Repeat for each trap.

**Setting up Traps**

In line with general recommendations (Proctor, 1983; Morrogh-Bernard et al., 2002; Finotti et al., 2003), OuTrop currently use eight litter-fall traps to assess forest productivity on each of our sampling transects. These sampling transects cover areas of forest representing different disturbance levels and ecological conditions, allowing us to further our understanding how these factors influence forest productivity and condition. Researchers at other sites are advised to conduct trials first to establish the minimum number of traps needed to ensure acceptable levels of accuracy and precision at their site (Finotti et al., 2003).

Traps may be positioned either systematically or randomly, but a distance of at least 50 m between traps should normally always be maintained. Stratification will be needed if more than one habitat type/condition is to be compared. On occasions, large tree falls or other obstacles may prevent establishment of traps at the exact pre-defined positions, in which case traps should be positioned as near to this position as possible.
Overall, the most important consideration is that traps within a particular sample area are not positioned by the researcher in reflection of any habitat characteristics (e.g. in “good” or tall forest patches, because this might produce the “best” data), as this will introduce bias into the data set.

**Equipment Needed**

- Disassembled traps, net and fishing wire, as described in the previous section.
- 1 x densitometer
- Tree tags
- Nails
- Hammer
- Wire or plastic string (raffia)
- Tape measure
- Special DBH tape measure (optional)
- Permanent pen
- Tagging material

**Procedure**

A team of at least two people is required to set up a trap. Traps should be set up as follows to resemble the trap illustrated in Figure 5 (steps preceded by an asterisk * are optional steps that we have found to be helpful):

1. A 1 m² area free of living/dead/fallen trees and excessive amounts of undergrowth (small amounts can be chopped down) should be selected to erect the trap as close as possible to the pre-specified trap location.

2. Assemble the trap frame and push the legs down into the peat until the top of the trap (i.e. net frame) is approximately 60 cm above the ground. Traps established at lower heights than this will be at increased risk of rain splattering soil up into the traps. In areas with harder soils in which trap legs cannot be inserted, trap legs may need to be cut using a saw on site (Muller-Landau and Wright, 2010). If the intention is specifically to collect and assess larger leaves and branches, then a ground-level trap may be preferable, as very large leaves, palm fronds and larger branches may slide/bounce off above-ground traps.
3. Ensure that the top of the trap is level and that no one side is higher than any of the others. This is important, because if the top of the trap is not level, then the effective surface area of the trap net is reduced, influencing the data.

![Litter-fall trap at the Sabangau study site.](image)

Figure 5. A litter-fall trap at the Sabangau study site. Note in particular the slack in the net, which helps prevent falling litter from bouncing or blowing out of the trap. In this trap, the far right leg is not 100% vertical due to roots/wood below the peat surface, which required a slight re-positioning of the leg. Such slight deviations are acceptable where necessary and providing that they do not result in an unlevel net frame.

4. Record the height of the trap top from the ground (useful to ensure that all traps are indeed set up in a standard fashion).

5. * One person should stand in the centre of the trap and record canopy cover (either overall and/or in different height bands) using a densitometer. This measurement can be repeated at intervals to establish how canopy cover (a measure of forest structure/condition) and litter-fall are related.

6. * This person should then look directly above them and find all the trees that have branches with the potential to drop litter into the traps. Tree trunks etc. that could not contribute litter should be ignored.

7. * If these trees have a tag number (from any reproductive phenology plots, etc.), this should be recorded, and if not then a special litter-fall tree tag can be made and attached using either a nail for larger trees, or wire or plastic string (raffia) for smaller trees.
8. * Measure the diameter at breast height (DBH) of these overhanging trees using either the standard tape measure or special DBH tape measure and record the species (local or scientific name).

9. Climb out of the trap and attach the net to the frame using the fishing wire. Ensure that the net is firmly attached and that there is sufficient slack (the net should not be taught across the frame, this may lead to falling items bouncing out of the net).

10. Assign each trap a unique number (we suggest a combination of the transect number/designation and a unique number for each trap) for each trap. Using a permanent pen, write this trap number onto an appropriate durable material or plastic tag and attach this to the side of the top frame closest to the transect with fishing wire, so that the trap number can be easily seen from the transect.

11. * In areas where high winds occur, it may be desirable to use either side netting (ca. 20 cm height suggested; L. L. B. Graham, pers. comm..), or even plastic window screens (Muller-Landau and Wright, 2010) to help ensure that litter falling into the trap is not blown out. This is likely to be less of an issue in forests where wind speeds are generally very low and thick undergrowth acts to slow wind speeds close to ground level.

**Trap Maintenance**

Over time, all parts of the trap may suffer from wear and tear, as a result of falling branches and other heavy litter, forest animals and weather. Litter may not be collected properly in broken traps and so it is important that traps are checked regularly (at minimum on scheduled litter-fall collection dates or once a month, whichever is shorter) and ongoing repairs are made as soon as problems are detected. It is therefore advisable to carry some basic repairing kit (fishing line, sewing needles, tag material, permanent markers) on each litter collection exercise and to ensure that major replacement items (e.g. piping) are always kept in stock in the main research camp.

Particular attention should be paid to:

- Holes in nets – holes frequently develop in nets and these can typically be repaired by sewing holes up using fishing line and a needle. If a hole is very large or the net has suffered from numerous holes, then it may be necessary to replace the net.
• Nets coming detached from the frame – frequently as a result of broken fishing lines. This is normally easily repaired by simply attaching a new line using a needle.

• Trap tag/marker deterioration/loss – easily repaired through either re-writing the trap number in the case of faded writing, or replacing tags in the case of more serious deterioration/loss.

• Tilted frame – tree/branch falls, forest animals, flooding or peat/soil subsidence may cause the height of one or more trap legs to drop, tilting the traps and reducing the effective trap area. In peat swamps, this can normally be corrected on site by pulling/pushing the trap legs to level the trap.

• Broken frames – may occur as a result of heavy branch or tree falls. Depending on the severity and location of damage, it may be possible to repair the trap using a ‘splint’, but otherwise replacing the broken piping will be necessary.

• Aerial blocks above traps – in some cases (very rarely in tropical peat-swamp forests), single large leaves or other obstacles may move to block the area above traps, preventing litter from dropping into the trap. Such obstacles will need to be removed.

• Damage from large tree falls – in extreme cases where a large tree has fallen on the trap, the trap may be too broken to repair and require complete replacement and/or it may become unfeasible to retain and access the trap in its current location. In such an instance, the trap should be relocated to the nearest accessible location, and the new location and date of relocation recorded.

Litter-fall Collection Schedule

The exact schedule for litter-fall data collection will depend upon the aims and needs of any particular study, with shorter intervals providing increased insight into shorter-term processes, but requiring increased survey effort and hence cost. Schedules must therefore be a balance of these considerations. Typical schedules operate on either a twice monthly or monthly cycle, and both have been used by OuTrop and other researchers in Sabangau (Sulistiyanto et al., 2004; Harrison et al., 2007; Harrison, 2009). Regardless of the exact schedule chosen, it is important to ensure that either there are equal intervals between sampling times (preferable), or that data are analysed such that litter-fall can be expressed in a standardised time unit (i.e. mean weight of litter collected/day).
Litter-fall Collection in the Forest

Equipment Needed

- Equipment for maintaining traps (see above).
- Cloth bags for collecting litter (suggested two bags are carried per trap in case needed – more may be necessary in periods of exceptionally high litter-fall). These bags should be numbered using permanent pen to ensure that litter collected from different traps does not get confused upon processing.
- Large backpack for carrying litter collected back to camp.
- A notebook or data sheets/clipboard to record any trap repair or relocation details. Depending on survey routes, it may also be helpful to include check boxes to record whether individual traps have already been visited during that collection.
- Heavy-duty clippers for cutting large leaves and branches.
- Tape measure or DBH tape.
- Use of gardening gloves is optional and may help reduce the risk of stings or pricks through handling litter in traps.

Procedure

1. Visit each trap on the route in sequence. Ideally, all traps should be visited within one day to minimise any temporal differences between traps. In cases where large numbers of traps are present or traps/groups of traps are located far apart, this may not be possible, in which case collections should be completed over the minimum feasible time.

2. For each trap, empty all the trap contents into the cloth bag labelled with that trap’s number. Do not mix litter from multiple traps in same bag.

3. Large leaves may need to be folded or snapped in half to fit inside bags; similarly, large branches or other debris may need to be broken or cut to fit inside bags.
4. Very large branches (≥ 5 cm diameter is used as the cut-off in Sabangau, following Proctor, 1983) should be discarded from above-ground traps and a note made on the data sheet to this effect (these can be retained for ground traps). For tapering branches, the portion of the branch < 5 cm diameter should be retained and the remaining larger portion of the branch discarded.

5. Secure the bag(s) to ensure that no litter can come out of the bag during the rest of the circuit.

6. Record whether each trap has been damaged since the last visit and any repairs that were conducted. If the trap is not in good/usable condition, then the litter from that trap should be discarded for that collection period.

7. Take the litter back to camp for processing; usually either later that day or the next day.

Litter-fall Processing at Camp

**Equipment Needed**

- Weighing scales, accurate to at least 0.01 g. In field stations, these must be carefully packed away after each use (ideally in a sealed plastic box including dehumidifying agents in humid sites) and regularly recalibrated.

- Tape measure or DBH tape.

- Callipers.

- Old newspapers, on which to sort litter-fall.

- Data sheets, clip boards/folders and pencil.

- Drying oven with inbuilt or external thermometer. In Sabangau, a large wardrobe-like kerosene drying oven with holes in the roof to allow air circulation and moisture escape, and standard air temperature thermometer, is used for drying litter-fall (and other) samples, but smaller ovens may be appropriate in many circumstances. If using an external power source, such as kerosene in a remote site, it is important to make sure that the oven remains continually fuelled to ensure effective drying.
Procedure

The exact procedure used for processing litter-fall will clearly depend upon the aims of the study and, particularly what, if any, subsequent laboratory analysis of litter-fall might be required. As described above, OuTrop’s long-term litter-fall data collection in Sabangau is focused on assessing and monitoring trends in forest productivity (i.e. temporal differences in the weight of litter-fall recorded/trap), which is likely to be useful and feasible for the majority of long-term ecological monitoring projects in the region. The procedure below therefore does not account for laboratory analysis for chemical composition of litter or other variables; recommendations regarding processing for laboratory samples can be found elsewhere (e.g. Haase, 1999; Sulistiyanto, 2004; Sulistiyanto et al., 2004; Muller-Landau and Wright, 2010). Our long-term litter-fall monitoring research is based on the procedure described by Proctor (1983) and is detailed below.

1. Record the date of collection (i.e. from the forest), the date of weighing and the observers that performed the weighing on the Litter Processing Data Sheet (see below).

2. Sort the litter from each trap into its constituent parts (see list below and Figure 6). Some researchers may prefer to sort litter after drying, which is also acceptable.

3. After sorting, dry in the oven in unsealed brown paper envelopes with the open-end facing upwards to allow moisture to escape and to facilitate drying. The envelopes should be labelled with the trap number, litter fraction and date collected. Codes used for the litter fractions in Sabangau are below:
- Leaves = daun
- Fruit = buah (not including stalks; these go under other)
- Flowers = bunga (not including stalks; these go under other)
- Large branches (less than 5cm diam., tapered branches should be broken/cut at the 5cm diam. point) = dahan besar
- Small branches (less than 2cm diam., tapered branches should be broken/cut at the 2cm diam. point) = dahan kecil
- Bark fragments = kulit pohon
- Debris (minor/unidentifiable components, e.g. leaf bracts, petioles, fine and broken leaf fragments, bryophytes etc. Light brushing is required here to remove fine fragments adhering to larger fragments) = lain

So, e.g., the label “0.4D daun” = leaves from trap D on transect 0.4.
Figure 6. Sorting forest leaf litter into its constituent parts in Sabangau.

4. Very wet samples will not dry effectively in the oven and so may be left to dry for a period of time (e.g. overnight) before being put in the oven. If pre-drying samples in this way, it is imperative to ensure that drying is performed under circumstances where litter can neither be lost (e.g. through being blown away if left unprotected/uncovered outside) or mixed from different traps (i.e. good labelling and seclusion from drafts is needed).

5. In Sabangau, the oven is kept at 40-50 C, as this is the drying temperature originally employed for the oven when drying orangutan/gibbon food samples for a related research project (Harrison et al., 2010) and adjusting this now would impact the long-term integrity of the data set. Other researchers may wish to use higher temperatures (e.g. 65°C, Muller-Landau and Wright, 2010), but the most important consideration is that field dry weights are being reached and maintained from the time spent in the oven (see next point).

6. Litter should be kept in the oven for at least as long as is required until all samples achieve field dry weight. The length of time taken to reach this point will vary depending on the oven temperature and design, and the moisture content of the litter. This length of time can be assessed through weighing samples on a daily basis to record the time needed to achieve a constant weight whereby no further weight reductions are recorded (i.e. where all water that can be lost under field drying conditions has been lost).
7. After the litter is dry, remove it from the oven. This can be either immediately after the litter is dry or a period of time after, provided that the drying conditions in the oven have been maintained such that moisture has not been reabsorbed by the litter.

8. Weigh each litter fraction from each trap, ensuring that all of the litter is removed from the envelope. Record in the appropriate column on the Litter Processing Data Sheet.

9. Dispose of the litter appropriately (this will obviously not be the case in studies wishing to perform laboratory or other further analysis!).

10. Clean the collection bags and pack them away, so they are ready to be used again for the next collection.

Data Storage and Analysis

Data are generally most easily stored in an Access or similar database, which helps keep data more neatly organised and reduces the probability of data input errors, compared to Excel or similar spreadsheets. An Access database allows litter-fall data to be linked to specific traps and related to habitat variables measured for these traps, in addition to facilitating extraction of data on a trap or temporal basis. OuTrop would be happy to discuss database needs with any researchers interested in developing litter-fall research at their site.

Data analysis needs will differ from project to project, and so we do not attempt to provide guidelines on specific data analysis techniques herein. It is, however, pertinent to highlight that litter-fall data are generally presented in such a way as to standardise by both unit area and unit time. This means that litter-fall production rates can be easily compared between different sites employing potentially different total trap areas. The most typical measure used is kg-1 ha-1 unit time-1 (frequently either a month or a year). Litter-fall trap data are easily converted into such a standardised measure using formulae in Excel, following extraction from the Access database.
# Sabangau Field Data Sheets

## Trap set-up data sheet

<table>
<thead>
<tr>
<th>Date</th>
<th>Observer</th>
<th>Transect</th>
<th>Trap No.</th>
<th>Height from ground (cm)</th>
<th>Canopy Cover (%)</th>
<th>Notes</th>
</tr>
</thead>
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**OUTrop Standard Operating Procedure: Litter-fall**
Litter Processing Data Sheet
N.B. Any damage and repairs to traps are recorded in the notes column.

<table>
<thead>
<tr>
<th>Trap No. No. Trap</th>
<th>Leaves Daun</th>
<th>Fruit Buah</th>
<th>Flowers Bunga</th>
<th>L. branch Dhn bsr</th>
<th>S. branch Dhn kecil</th>
<th>Bark Kit phn</th>
<th>Other Lain</th>
<th>Notes Catatan</th>
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Litterfall Data Sheets / Lembaran Data Penangkap Daun

Month/Bulan:

Collection Date/Tanggal dikumpul:

Name/Nama:
Acknowledgements

The methods described in this report were developed in the Natural Laboratory for the Study of Peat-swamp Forest (NLPSF) by the researchers, staff and volunteers of OuTrop and CIMTROP, whom we thank for their hard work and dedication. We would like to thank the people and administrations of Kereng Bangkerai, Kecamatan Sabangau and Kotamadya Palangka Raya for ongoing support; the University of Palangka Raya; the State Ministry of Research and Technology (RISTEK); TSA-KALTENG; and The Orangutan Project, Arcus Foundation, Rufford Foundation, US Fish and Wildlife Service Great Apes Conservation Fund, Wallace Global Fund, Primate Conservation Inc., Conservation International Primate Action Fund, Wingate Foundation, Cambridge Philosophical Society and Columbus Zoo for financial support of our litter-fall research. Laura Graham provided comments that helped improve this SOP, in addition to contributing towards field data collection during 2006-2008.
References


