Commonwealth Environment Research Facilities

Marine and Tropical Sciences Research Facility

Monitoring Revegetation Projects for Biodiversity in Rainforest Landscapes Toolkit Version 1, Revision 1

John Kanowski and Carla P. Catterall

Griffith UNIVERSITY

Australian Government

Department of the Environment and Water Resources

Monitoring Revegetation Projects for Biodiversity in Rainforest Landscapes

Toolkit Version 1, Revision 1

John Kanowski and Carla P. Catterall

Centre for Innovative Conservation Strategies and
School of Environment, Griffith University

Griffith
UNIVERSITY

Australian Government

**Department of the Environment
and Water Resources**

Contents

List of Figures

List of Tables

Acronyms Used In This Report

CRC............ Cooperative Research Centre
CSIRO........ Commonwealth Scientific and Industrial Research Organisation
EnviTE .... Environmental Training and Employment Inc.
FNQ NRM... Far North Queensland Natural Resource Management Limited
MTSRF .... Marine and Tropical Sciences Research Facility
NHT .... Natural Heritage Trust
RRRC .... Reef and Rainforest Research Centre Limited
TREAT .... Trees for the Evelyn and Atherton Tablelands
WTTPS....... Wet Tropics Tree Planting Scheme

Acknowledgements

1.　Introduction

Purpose of Toolkit

This toolkit has been written to assist landholders, community groups and restoration practitioners monitor the outcomes of revegetation projects for biodiversity in rainforest landscapes. By 'revegetation', we mean a range of on-ground works including the reforestation of cleared land and the enhancement or restoration of existing remnants. The toolkit protocols can also be used to track the recovery of rainforest from disturbance events, such as cyclones. The toolkit was developed from research conducted in tropical and subtropical Australia, with input from restoration practitioners and natural resource managers (see Acknowledgements).

Scope of Toolkit

This version of the monitoring toolkit includes protocols and proformas to monitor 'basic indicators' of the biodiversity outcomes of revegetation projects. Basic indicators are aspects of forest structure that provide information on the development of a revegetation project and are correlated with the use of sites by rainforest wildlife. This toolkit also contains proformas to record details of the on-ground works conducted in a revegetation project.

The monitoring protocols presented in this version of the toolkit do not require specialist botanical or zoological knowledge. However, users of the toolkit will need to have basic field survey skills including the ability to follow written survey protocols, lay out a transect with a tape measure and compass, describe environmental features of a site (soil, slope, aspect, etc), identify broad categories of ground cover (grass, herbs, ferns, leaf litter, etc.) and plant life forms characteristic of rainforest (vines, epiphytes, strangler figs, etc.), estimate tree height and canopy cover, and count trees and woody debris in various size classes. Clear instructions, illustrations and proformas are provided in the toolkit to assist with these tasks.

Future versions of the toolkit will provide information, protocols and proformas for monitoring 'advanced indicators' (e.g. flora, fauna and ecological processes) in revegetated sites.

Rainforest Revegetation: An Overview

Rainforest revegetation involves a number of on-ground activities including the restoration of existing remnants and the reforestation of cleared land. The relative importance of these activities varies with the scale and nature of degradation at a property and landscape scale. For example, techniques for rainforest enhancement have been particularly well developed in northern New South Wales, where widespread clearing has left only small patches of remnant forest, many threatened by weed invasion (Phillips 1991; Horton 1999; Harden *et al.* 2004; Big Scrub Rainforest Landcare Group 2005). In the tropics, there has been greater emphasis on the reforestation of cleared land, especially corridors linking remnant forests, partly because there are more patches of rainforest left in north Queensland (Goosem and Tucker 1995; Lamb *et al.* 1997).

Rainforest revegetation is a recent activity in Australia. A few remnant enhancement and reforestation projects were initiated by individuals and community groups in the 1970s, but most projects date from the 1990s as a result of regional or national revegetation schemes such as the Wet Tropics Tree Planting Scheme (WTTPS) and the Natural Heritage Trust (NHT). In total, these schemes have resulted in the reforestation of several thousand hectares of cleared land in rainforest landscapes at a cost of some tens of million of dollars and hundreds of thousands of hours of volunteer effort (Catterall and Harrison 2006).

Stages of a Revegetation Project

Revegetation is a long-term endeavour. It has been estimated that full recovery of the composition and structure typical of 'intact' rainforest (starting from cleared land) would take hundreds of years (Hopkins 1990). For this reason, careful planning, long-term commitment and a willingness to consider 'big picture' issues are essential ingredients in a successful revegetation project (Joseph 1999).

Remnant enhancement projects typically progress through two main phases of on-ground works: an initial intensive phase, when the primary weed control is conducted, followed by years to decades of maintenance work, during which time the structure and composition of the remnant return towards the target state (Joseph 1999; Harden *et al.* 2004; Big Scrub Rainforest Landcare Group 2005).

Reforestation projects also progress through two main stages: an initial 'establishment' phase and a longer-term 'building' phase. The 'establishment' phase is the period from when seeds or seedlings are planted until they have 'captured' the site, forming a relatively closed canopy and suppressing grasses and weeds. The establishment phase may last three to five years, depending on site conditions, planting design, maintenance, and so on. During the 'building' phase, the planted trees mature, reproduce and eventually die, and other species of plants and animals are recruited to the site.

The focus of a monitoring program will vary over the course of a restoration project. In a remnant enhancement project, practitioners will mostly be interested in the response of weeds to control measures. Later, the focus will shift to the recruitment of native plants and improvements in vegetation structure as the site is released from weed invasion (Harden *et al.* 2004; Big Scrub Rainforest Landcare Group 2005).

In the 'establishment' phase of a reforestation project, attributes such as the survival and growth of planted trees, weed control, the type of ground cover and the degree of canopy closure will be of particular interest to practitioners. Once 'site capture' has been achieved, the focus of attention is likely to switch to the development of forest structure, plant recruitment, and the value of revegetated sites to wildlife (Kooyman 1996).

The protocols presented in this toolkit are mainly relevant to the second phase of revegetation projects, i.e. for tracking the development of the vegetation structure as it moves away from the degraded state and returns, hopefully, towards the condition of intact forest.

Reasons for Monitoring Revegetation Projects

It is fair to say that most people involved in reforestation and restoration projects have focussed on 'getting trees in the ground' or 'getting rid of weeds', rather than on monitoring the outcomes of their work (Hunter 1999). Nevertheless, the design and management of revegetation projects have improved over time, because practitioners have kept track of outcomes such as the survival of planted trees or the recruitment of native plants, and how these have varied with site preparation, planting techniques, weed control measures, the matching of species to sites, and so on (Kooyman 1996; Joseph 1999).

To date, only a few practitioners have attempted to monitor the value of their revegetation projects for biodiversity (e.g. Tucker and Murphy 1997; Grundon *et al.* 2002). This is partly because most projects are still young, and the use of sites by wildlife is typically considered a long-term goal of revegetation projects. The lack of monitoring is also due to the fact that, under the NHT program, responsibility for restoration projects has been devolved to

landholders and community groups, many of who do not have the time, resources or expertise to design and conduct monitoring programs (Freeman 2004). The short-term and insecure funding available for revegetation projects has also made it difficult to develop long-term monitoring programs (Kanowski *et al.* 2007).

Furthermore, many people consider tree-planting and restoration projects to be inherently valuable for wildlife, such that monitoring revegetation is of academic interest rather than practical value (Freeman 2004). However, recent studies have shown that revegetated sites can vary widely in their value to biodiversity, according to factors such as the number and types of tree species planted, the structure of the vegetation, the availability of fruit and other resources, and the proximity of sites to remnant forest (Catterall *et al.* 2004, 2006; Kanowski *et al.* 2005, 2006). These factors can interact in complex ways, making it difficult to know the value of a revegetation project for biodiversity without site-specific monitoring.

Monitoring the biodiversity outcomes of revegetation projects is necessary if we want to improve our revegetation practices (Hunter 1999; Freudenberger and Harvey 2003a; Catterall and Harrison 2006; Kanowski *et al.* 2007). Without the information gained from a monitoring program, we won't know whether our revegetation projects are valuable for biodiversity, or how to improve their biodiversity value. Monitoring is also important if practitioners are to develop novel cost-effective methods of revegetation that are also valuable to rainforest wildlife. At present, there is a pressing need to develop such methods to enable the broadscale restoration of degraded land, not only in Australia but in cleared rainforest landscapes worldwide (Lugo 1997; Lamb *et al.* 2005). Even with the significant investment in reforestation that has occurred in Australia, only a small proportion of the area of cleared land has been revegetated using current practices (less than one percent in rainforest landscapes: Catterall and Harrison 2006).

Monitoring requires investment from funding bodies, as well as effort from restoration practitioners, community groups and landholders who are responsible for revegetation projects. The pay-off will be a greatly improved knowledge of the factors affecting the biodiversity value of restored sites, under a range of conditions. This knowledge should in turn increase the ability of restoration practitioners to design projects to meet biodiversity objectives, and the confidence of funding bodies to invest in revegetation projects.

What is Rainforest Biodiversity?

Biodiversity (or 'biological diversity') is a term used to describe the variety of life on the planet, in all its forms and levels of organisation. Rainforests support an exceptionally high proportion of Australia's biological diversity, despite occupying a small proportion (less than one percent) of the continent. This is because the present day rainforests of Australia are relicts of the ancient, diverse forests that once covered much of the continent. Over the past few million years, as Australia has become more arid, rainforests have contracted to moist refugia along the north and east margins of the continent. The main areas of rainforest in Australia today include the tropical rainforests of Cape York Peninsula, the Wet Tropics rainforests of northern Queensland, the subtropical rainforests of southeast Queensland and northern New South Wales, and the temperate rainforests of Tasmania.

Rainforests are characterised by a suite of physical, structural and floristic attributes that set them apart from other Australian vegetation types. These generally include a high diversity of plant species, a closed canopy, the presence of characteristic life forms such as vines, epiphytes, palms, strangler figs and trees with buttress roots (depending on the particular forest type), many plant species that bear fleshy fruit, and a humid microclimate without extreme temperatures.

In turn, the rainforest fauna includes many specialist animals that rely on the particular environments and resources of rainforests. The animals and plants interact to influence many aspects of rainforest dynamics. For example, most rainforest plants are pollinated by animals (especially insects, birds and bats), the seeds of most rainforest plants are dispersed by animals (especially birds and mammals), and the recruitment of seedlings is strongly influenced by rodents and other seed predators, ground birds which turn over the leaf litter, and herbivores such as wallabies.

These complex interactions between animals and plants are one of the reasons why rainforests support such a rich biodiversity. Other reasons include the long history of rainforests in Australia, the relatively productive environments they tend to occupy, and the disturbance regimes to which they are exposed (frequent, but scattered small-scale disturbances from tree-falls; occasional large-scale disturbances, e.g. from cyclones).

Humans have had profound and complex effects on the distribution of rainforests in Australia. For example, the use of fire by Aborigines may have reduced the overall extent of rainforest, but may also have protected particular rainforest patches. Since European settlement, the remaining rainforests have been extensively cleared for agriculture, especially forests on fertile soils. As a consequence, many rainforest plants and animals, and some rainforest types, are now considered threatened.

What is the future of rainforest biodiversity in Australia? While most of the remaining rainforests are in conservation reserves, many remnants are small, isolated by clearing and subject to a range of threats including the loss of key species, disruption of important animal-plant interactions, competition from introduced species and climate change.

There is a pressing need for the restoration of cleared rainforest landscapes. Restoration can improve habitat for rainforest wildlife, increase the connectivity between remnant forests and the amount of forest cover, and perhaps help mitigatesome of the impacts of climate change and other disturbances on rainforests and the ecosystem services they provide. The rich biodiversity of rainforests provides both the impetus for restoration projects, and a real challenge to practitioners in terms of the complexity of the task.

2.   Design of Monitoring Programs

Issues to Consider

Monitoring programs can range from simple surveys of a few key variables, such as plant survival and growth at a single site, through to detailed surveys of a range of biota and ecological processes on replicated treatment, control and reference sites. These different approaches to monitoring will give information of different value and rigour, but will also require different amounts of effort and expertise. For these reasons, monitoring programs need to be designed to meet the objectives and constraints of a particular situation.

In general, the first issue to consider in the design of a monitoring program is, **'What information is needed?'** For example, a monitoring program designed to track the progress of a revegetated site and evaluate its outcomes may require repeated surveys of the site over time, as well as 'one-off' surveys of forest reference sites. In contrast, a monitoring program designed to compare the outcomes of different revegetation techniques would need a different design, e.g. one that involved surveys of replicate 'treatment' and 'control' sites, and perhaps also a number of reference sites to provide a benchmark for evaluating results. Details of monitoring programs to meet each of these objectives are discussed below.

A second general issue to consider in the design of a monitoring program is, **'What time, skills and resources are available to conduct the monitoring?'** Monitoring programs require long-term commitment, good record-keeping and data management practices, and the use of well-documented and repeatable methodologies. This toolkit provides information and tools to assist in these tasks, but individuals and groups need to carefully assess their capacity to conduct a monitoring program. It would be a waste of time and money to embark on a monitoring program for which interest and funds could not be sustained over the long-term.

A third issue to consider is, **'What attributes will be monitored?'** Ideally, a range of attributes would be surveyed to provide information on the structure, composition and ecological function of a restored site (Society for Ecological Restoration 2004). In practice, though, most projects can only afford to monitor a few selected attributes. Then, for each attribute, an appropriate survey methodology (e.g. the number and size of survey plots) and survey regime (i.e. the number and frequency of surveys) need to be determined. This version of the monitoring toolkit presents protocols for surveying 'basic indicators' in restored sites. Basic indicators are aspects of forest structure that provide information on the development and habitat value of a restored site, and that can readily and rapidly be assessed by non-specialists (see Section 4).

The question of **'When and how often to monitor?'** restored sites (i.e. the 'survey regime') will be addressed at the end of this section.

Tracking the Progress of a Restoration Project

A major purpose of monitoring is to track the progress of a revegetation project over time and to evaluate its 'success' against suitable reference conditions. A monitoring program designed to meet this objective requires the repeated survey of a revegetated site, ideally starting from baseline conditions (before the commencement of on-ground works), as well as surveys of one or more reference sites (i.e. forests representing the 'target condition', such as remnant forests of the type that may have occurred on a site prior to clearing). Comparison of the monitoring results with baseline conditions will show how much a site has changed following revegetation, while comparison with forest reference site(s) will show

whether the revegetated site has achieved target conditions, and if not, what attributes need further development. Both types of comparison are worthwhile. Figure 1, below, illustrates the steps involved in a monitoring program aimed at tracking the performance of a revegetated site and evaluating its progress.

This type of monitoring was used by Jansen (2005) to evaluate the 'Donaghy's corridor' reforestation project on the Atherton Tablelands, north Queensland. In this study, several young replanted sites and rainforest reference sites were monitored annually for rainforest birds over three years. Some of the replanted sites were monitored from before establishment to provide baseline data. The results of the study showed that, even when young, the plantings provided habitat for a number of rainforest birds (although these were mostly generalist or 'edge' species). Over time, the composition of the bird assemblage in the replanted sites tended to become more similar that found in rainforest. On the basis of this monitoring program, Jansen was able to conclude that, "habitat restoration [at Donaghy's corridor] has good potential for success". Such a statement is likely to have considerable value in a project report or funding application.
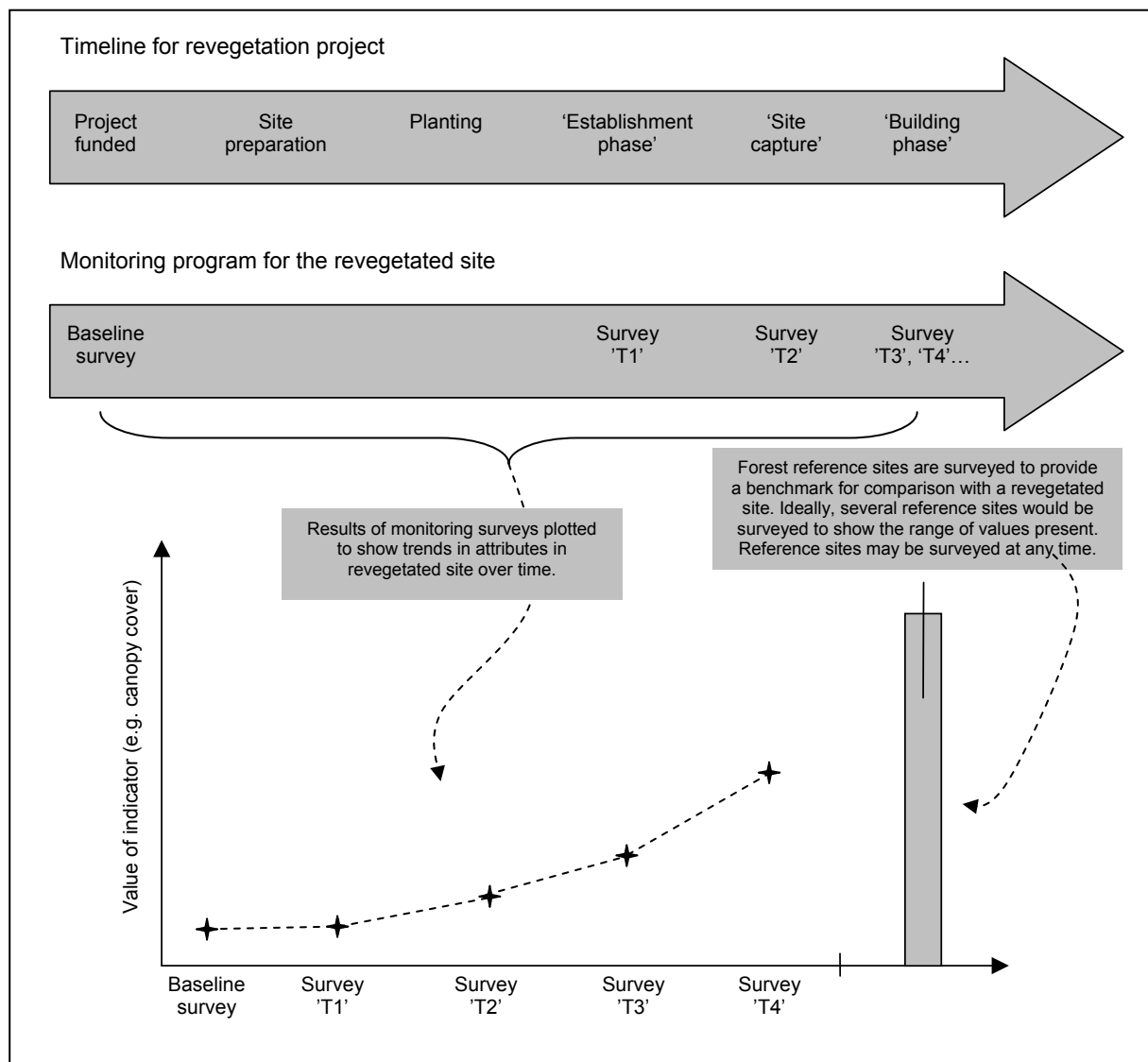
Figure 1: Monitoring the progress of a revegetated site over time.

Comparing Outcomes of Different Revegetation Methods

With a suitable design, the protocols and proformas presented in this toolkit can be used to compare the performance of different revegetation methods (e.g. comparison of a 'novel' low-cost method with current 'best practice'). A monitoring program for this type of project would require the survey of replicate plots or sites, some treated using the novel method and others with current methods, as well as the survey of baseline conditions and reference sites (Figure 2). Replicate sites are important for controlling for the effects of site-specific factors in an experiment (e.g. site history, disturbance, landscape context). They increase the effort required by a study, but also the confidence that can be placed in its results.

Timeline for project comparing 'current' and 'novel' revegetation methods:

Treatment 1 (e.g. 'current method')

| Project funded | Site preparation | Planting | 'Establishment phase' | 'Site capture' | 'Building phase' |

Replicate No. 2

Replicate No. 3

Treatment 2 (e.g. 'novel method')

| Site preparation | Planting | 'Establishment phase' | 'Site capture' | 'Building phase' |

Replicate No. 2

Replicate No. 3

Monitoring program for the revegetation treatments

| Baseline survey | Survey 'T1' | Survey 'T2' | Survey 'T3', 'T4'… |

Forest reference sites are surveyed for comparison with the two treatments.

Results of monitoring surveys plotted to compare trends in attributes of sites revegetated using 'current' and 'novel' methods.

Value of indicator (e.g. canopy cover)

'novel method'

'current method'

Baseline survey · Survey 'T1' · Survey 'T2' · Survey 'T3' · Survey 'T4'

Figure 2: Comparinig the outcomes of different revegetation methods.

An example of the this type of monitoring comes from northern New South Wales, where Harden *et al.* (2004) compared the costs and outcomes of two different restoration methods in the Wingham Brush rainforest remnant. The researchers set up a series of paired plots in the remnant: one plot in each pair was treated using the 'Bradley' method, and the other with the 'Wingham Brush' method (for details of the two methods, see Harden *et al.* 2004). The response of plant recruitment and growth to each method was monitored, and records kept of the effort required for each method. Harden *et al.* (2004) found that both methods produced similar outcomes for rainforest regeneration. However, the Wingham Brush method required just one-tenth of the effort of the Bradley method. The results of this study provided strong support for the use of the Wingham Brush method at that site, even though its use had initially been opposed by the organisation funding the restoration works. The Wingham Brush method has subsequently been adopted in other rainforest remnants in the region.

When and How Often to Monitor

An important question to consider in the design of a monitoring program is, **'When and how often to monitor?'** The answer to this question is, **'It depends'**: first, on the timescale over which changes in target variables are expected to occur (e.g. to monitor plant recruitment, annual surveys are probably sufficient); second, on the ecology of the target variables (e.g. to monitor birds, surveys may have to account for seasonal migration); third, on how much effort is needed to survey a variable with acceptable precision (e.g. for some variables, 'one-off' surveys may be strongly affected by chance events, such as the weather); and fourth, on the time and resources available for conducting the surveys.

Fortunately, the 'basic indicators' surveyed in this version of the monitoring toolkit are structural attributes which tend to change relatively slowly, can be surveyed at any time of year and in any (reasonable) weather, and with fair precision given the protocols presented. Experience suggests that it may take one to three hours to survey a site using the toolkit protocols, depending on the complexity of the site and the familiarity of the user with the toolkit.

A possible survey regime for monitoring basic indicators in a revegetated site might include:
- A baseline survey prior to on-ground works;
- One or more surveys until 'site capture' (typically, three to five years after establishment); and
- Less frequent surveys after site capture, perhaps every three to five years, depending on the interest and resources of the people conducting the surveys.
- In addition, surveys of one or more reference sites would generally be needed to evaluate the progress of the revegetated site towards target conditions. In most rainforests, these could be conducted at any time.

Note that if baseline data were not available (e.g. if an established site was being monitored), then 'control sites' could be surveyed to provide surrogate baseline data. Control sites are chosen to be similar to the condition of the revegetated site prior to on-ground works (e.g. a pasture or regrowth site).

A similar survey regime could be used for monitoring the outcomes of different restoration methods, although the exact design would depend on the aims of the experiment. For example, in an experiment comparing how quickly two different planting methods achieved canopy closure and suppressed grasses, monitoring would not need to proceed much beyond 'site capture'. However, in an experiment comparing the recruitment of rainforest plants under different planting models, monitoring might need to continue for a number of years or even decades after site capture. In most cases, it would be useful to seek the advice of a professional ecologist when designing such experiments.

3. Keeping Records of Projects

Why Bother?

Revegetation is inherently a long-term activity. Monitoring the value of a revegetated site for biodiversity may continue for years or decades after the site was established. In most cases, interpretation of the results of monitoring will be greatly assisted by records that describe the nature of the project, the on-ground works conducted in the project, and any subsequent maintenance activities, major disturbances and changes to land-use in the project area.

Unfortunately, good record-keeping practices have not been a feature of most revegetation projects in Australia to date. A review of approximately 13,000 revegetation projects funded by the Natural Heritage Trust found that "very few" had adequately documented their on-ground works (Freudenberger and Harvey 2003a). In response, Freudenberger and Harvey (2003b) proposed a minimum set of records that should be kept by revegetation projects in Australia, if the potential biodiversity benefits of those projects were to be assessed. We have drawn upon this list, as well as suggestions made by Kooyman (1996) and the Society for Ecological Restoration (2004) to compile a list of attributes that we suggest should be documented by rainforest revegetation projects.

What Information is Required?

Three sets of information are recorded to provide sufficient background data to facilitate subsequent monitoring and reporting of the results of revegetation projects. These are:

- A description of the type of project and the site(s) on which the project occurs;
- A description of the on-ground works done in a project ('establishment statistics'); and
- A project journal, which records subsequent maintenance activities and significant events in the life of a project, such as major disturbances or changes in land use over part of the project area.

Note that, where a project is conducted in stages, we recommend that records be kept separately for each stage. This is because many factors that can affect the outcomes of a revegetation project, such as the prevailing weather conditions, site preparation, planting stock and maintenance activities will often vary between different stages of a project.

Most of the information sought in the record-keeping proformas is self-explanatory. More details are provided below.

Project Description

An adequate description of a revegetation project would include: the name of the project, the number of stages involved; the names and location of project site(s), project objectives, the identification of reference condition and sites (if relevant), information about the proponent, land tenure and management, and details of key environmental factors that may affect the outcomes of the project. Some of the terms used in the proforma are defined below.

The **project name** is the name given to a particular revegetation project, which may take place on one or more **sites**, in one or more **stages**, over one or more **years**. The **project ID** and **site ID** are unique codes given to a project to facilitate the storage of information in a database. A project's **objectives** refer to the main aims or purposes of the project, in broad terms. Examples of objectives include biodiversity conservation, timber production and catchment protection. **Reference forests** are the type of forest that the project is trying to restore or create at a site. In many cases, this would be the forest type that occurred at a site

prior to clearing. However, the pre-clearing forest type may not be known, or may no longer be appropriate (e.g. if environmental conditions have changed significantly since clearing). In these cases, another forest type may be chosen as the reference, or if none is suitable, an appropriate reference condition may need to be described from scratch. **Reference sites** are examples of the reference condition (should they exist). For example, a revegetation project on the Atherton Tablelands, north Queensland, may wish to recreate complex notophyll vine forest (Type 5b: Tracey 1982), for which a reference site may be Curtain Fig National Park.

Establishment Statistics

The 'establishment statistics' record the on-ground works conducted in a project, including details of what, where, when and how much time, effort and money was expended on the project. This information is often very difficult to recover in later years if not recorded at the time the work was done. In many cases, keeping these records is usually just good 'housekeeping' on the part of a project. Nevertheless, it may not always be possible to record (or remember) this type of information in fine detail. In these cases, a 'ball park' figure will still be useful (e.g. were ten species planted, or fifty?).

For the purposes of this toolkit, we suggest that details of on-ground works be recorded separately for different types of activities. These are: **remnant protection** (e.g. fencing a remnant, or placing a remnant under a formal conservation agreement), **remnant enhancement** (e.g. weed control in an existing remnant), and **reforestation** (planting of cleared or degraded land). This is because these activities require very different inputs (effort, materials, funding), and their outcomes may need to be monitored separately. For example, in an enhancement project, it may be sufficient to record the weeds targeted, the control methods and the effort involved. In contrast, for a reforestation project, it would be useful to record the numbers, life forms and origin of species planted, the planting density or spacing, the planting technique, and the mix of species by successional stage, as well as any particular models of revegetation used to guide activities (e.g. the 'maximum diversity' model of Goosem and Tucker 1995). Likewise, GPS coordinates of the areas subject to on-ground works should also be recorded separately for the main types of project activities. To help interpret these data, it is useful to provide a 'mud-map' of the project, and to note whether particular areas contain one or more types of land-use (e.g. does an area mapped as 'reforestation' also include areas of remnant forest?).

Project Journal

The third set of information required is a record of (i) maintenance activities conducted at a site, and (ii) significant events in the life of a project, such as major disturbances or changes in land use over part of the area. This information is useful not only for interpreting the outcomes of a project (e.g. weed control may affect the success of a project), but also for documenting effort, both for reporting requirements or for planning future projects. For this reason, it may also be worth keeping a record of field days and similar events held to promote a project. The information we suggest be recorded includes the **date** of events, **a description of events** (e.g. maintenance activities, significant disturbance events, change in land use on part of project area, field days), and **who and what were involved** (e.g. number of people x hours, materials, costs) in the event.

Proformas for Recording Revegetation Projects

Proformas for Project Description, Establishment Statistics and the Project Journal are provided on the following pages.

PROJECT DESCRIPTION

Project name:	
Site name:	
Database Info:	Project ID: Site ID: Stage: Year:

OBJECTIVES, LOCATION AND LANDHOLDER DETAILS

Main objective of project (circle <u>one</u> from list):	• Biodiversity conservation • Erosion control • Timber production • Shelterbelt • Other forest products • Other (describe) • Stream bank stabilisation • Catchment protection
Other objectives of project (circle <u>any</u> from list):	• Biodiversity conservation • Erosion control • Timber production • Shelterbelt • Other forest products • Other (describe) • Stream bank stabilisation • Catchment protection

What **reference forest** type/s or conditions is the project trying to restore or create?

What are the names / locations of possible reference sites (if relevant)?

PROJECT LOCATION *Note: Record detailed location information on 'Establishment Statistics' proforma.*

1. Map / GPS reference (s) sufficient to locate project on a 1:25,000 or 1:50,000 map.

Datum:

2. Street address of project, or directions to locate it. Attach a 'mud-map' if necessary.

3. Sub-catchment and catchment details (*e.g. Peterson Creek, Barron River catchment*):

4. Local Government area:

PROPONENT AND LANDHOLDER DETAILS *Note: Treat landholder information in strict confidence in any database.*

Project **proponent** (*e.g. Malanda Landcare*)

Tenure of site/s (*e.g. private land, council reserve*):

Name of **Landholder** / Manager:

Postal **Address**:

Telephone:
Email:

11

Project name:				
Site name:				
Database Info:	Project ID:	Site ID:	Stage:	Year:

ENVIRONMENTAL DESCRIPTION OF PROJECT SITES

Landform (circle the relevant term):	e.g.	Ridge/ Crest	Upper slope	Mid slope	Lower slope
		Stream bank	Flat	Plateau	Other (describe):

Altitude:	
Geology / soils:	
Existing vegetation on project site/s (briefly describe):	
Pre-European vegetation on project site/s (if known):	
Land-use history (if known):	

Landscape context Proximity to waterway and type of waterway:	Is this a riparian project (i.e. adjacent to a waterway)? Yes / No
	
	   If *No*, how far is the project from a waterway (m *or* km)?
	
	Describe the type/s of waterway nearby (circle most relevant term):
	
	     Creek River Estuary Swamp Dam Lake Ocean

Proximity to remnant forest:	How far is the project from remnant forest (m *or* km)? What is the type of forest?
Surrounding land uses (describe):	
Disturbances Is the site prone to flooding, frost, fire, cattle browsing, pig rooting, etc? Describe.	

Project name:	
Site name:	

Database Info:	Project ID:	Site ID:	Stage:	Year:

OVERVIEW OF ON-GROUND WORKS

What are the dimensions of the project (this stage only)?

Length: m   **Width:**   m   **Area:**   ha

Specifically, over what area/s were the following actions conducted (this stage only)?

Remnant protection: ha	**Remnant enhancement:** ha
(e.g. fencing, conservation agreement: *give details next page*)	(e.g. weed control in remnants: *give details following pages*)
Reforestation: ha	**Other** (describe): ha
(i.e. planting cleared land: *give details following pages*)	

Have there been significant alterations to the area of the project since establishment? Yes / No If *Yes*, describe (what & when):

MAP   In the box below, draw a 'mud-map' of the project site/s, showing:

- Areas of remnant protection, enhancement and reforestation covered by this stage of the project, and where they are located with respect to the entire project area *(NOTE: mark any significant alterations in project area since establishment on map)*
- Location of other patches of remnant vegetation or revegetation on the site, and other relevant features of the site (e.g. property boundaries, roads, waterways, fences); and
- Approximate scale (include a scale bar, e.g. 0_____100 m) and north arrow.

Project name:	
Site name:	

Database Info:	Project ID:	Site ID:	Stage:	Year:

REMNANT PROTECTION

What was done?	
Remnant protection actions (briefly describe):	Was fencing installed as part of *this stage* of the project? Yes / No If *Yes*, what length of fencing was installed (m *or* km)? Was a formal conservation agreement concluded (provide details)? Provide details of any other remnant protection activities:
Where was it done?	
Provide a set of GPS coordinates that define where, *in this stage* of the project, **remnant protection** occurred:	Datum: Does the area of *remnant protection* (defined above) include any other land use? Yes / No If *Yes*, what type of land use? What percentage of the area?
When was it done?	
Date/s of on-ground works:	
How much did the on-ground works in *this stage* of the project cost (approximately)?	
Remnant protection:	Cash $ In-kind $
What was the source of funds (e.g. Natural Heritage Trust)? If several sources, give a percentage from each source:	

14

Project name:	
Site name:	

Database Info:	Project ID:	Site ID:	Stage:	Year:

REMNANT ENHANCEMENT

What was done?	
Remnant enhancement actions (briefly describe):	Weeding (describe main target weeds and control methods used): Provide details of any other remnant enhancement activities:
Where was it done?	
Provide a set of GPS coordinates that define where, *in this stage* of the project, **remnant enhancement** occurred:	Datum: Does the area of *remnant enhancement* (defined above) include any other land use? Yes / No If *Yes*, what type of land use? What percentage of the area?
When was it done?	
Date/s of on-ground works:	
How much did the on-ground works in *this stage* of the project cost (approximately)?	
Remnant enhancement:	Cash $	In-kind $
What was the source of funds (e.g. Natural Heritage Trust)? If several sources, give a percentage from each source:	

15

Project name:	
Site name:	
Database Info:	Project ID: Site ID: Stage: Year:

REFORESTATION

Reforestation actions Note: If some details are not known precisely, write 'approx.'.Record detailed planting information on following page.
Site preparation (briefly describe):
Number of species planted: Number of stems planted:
Planting stock (circle):   Seeds / Seedlings   If seedings, what age / size?
Stocking rate: stems/ ha   OR   Spacing of plants: m x   m
What type of life forms were planted (circle all relevant categories)? Tree   Shrub   Vine   Groundcover   Other (describe)
What was the biogeographical origin of the species planted (or provenances, if relevant)? Circle all relevant categories: Local region   Australian, but outside region   Exotic
Approximate mix of species by successional range (if known): Pioneers: %   Secondary phase spp.:   %   Mature phase spp.:   %
Was a particular planting model used (e.g. 'framework species': Goosem and Tucker 1995)? Name/ describe the model, if relevant:
Was fertilizer added to plants?   Yes / No If *Yes*, What product was used?   How much was used (approx.)?
Was mulch added to plants?   Yes / No If *Yes*, what product was used?   How much was used (approx.)?
Was the planting fenced?   Yes / No   If *Yes*, what length of fencing?   m
Where was it done?
Provide a set of GPS coordinates that define where **reforestation** occurred during *this stage* of the project.   Datum: Does the area of *reforestation* (defined above) include any other land use?   Yes / No If *Yes*, what type of land use? What percentage of the area?
When was it done?
Date/s of on-ground works:
How much did the on-ground works in *this stage* of the project cost (approximately)?
Reforestation: Cash $ In-kind $
What was the source of funds (e.g. Natural Heritage Trust)? If several sources, give a percentage from each source:

16

Project name:	
Site name:	
Database Info:	Project ID:	Site ID:	Stage:	Year:

DETAILED PLANTING INFORMATION

List of Species Used in Planting	Life form	Origin	Number of Stems
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
Note: If more than 30 species planted, tick here _____ and add extra page/s			

Notes: **Life form** = **T**ree / **V**ine / **S**hrub / **G**roundcover
        Origin   = species or provenances from: **L**ocal region / **A**ustralian, but outside region / **E**xotic

17

Project name:	
Site name:	

Database Info:	Project ID:	Site ID:	Stage:	Year:

Date(s)	**Description of events** (e.g. maintenance activities, significant disturbance events, changes in land use, field days)	**Who and what were involved?** (e.g. number of people x hours; materials, costs)

Tick here ☐ if journal continues. Add extra pages as needed.

18

4. Monitoring 'Basic Indicators'

What are 'Basic Indicators'?

This section of the toolkit presents information, protocols and proformas for monitoring 'basic indicators' at revegetated and reference sites. Basic indicators are various attributes of forest structure that have been selected for inclusion in this toolkit because they:

- Provide information on important stages of development of a revegetation project;
- Can be measured relatively easily and rapidly, without specialist knowledge; and
- Are correlated with the use of sites by rainforest wildlife.

Protocols for monitoring advanced indicators (plants, animals and ecological processes) will be presented in later versions of the toolkit.

The basic indicators used in this toolkit were identified from research conducted on the biodiversity values of reforested sites in tropical and subtropical Australia (see Table 1, below), and from other relevant work (Webb *et al.* 1976; McElhinny *et al.* 2005; Big Scrub Rainforest Landcare Group and EnviTE 2006; Gibbons and Freudenberger 2006). Where possible, indicators were chosen to be consistent with current state schemes (e.g. variants of the 'habitat hectares' scheme developed by Parkes *et al.* 2003, including 'BioMetric' in NSW and 'BioCondition' in Queensland: Gibbons *et al.* 2005; Eyre *et al.* 2006). However, the primary criterion used to select indicators was their relevance to monitoring revegetation in Australian rainforest landscapes.

Table 1:   The relationship between basic indicators and the occurrence of rainforest wildlife in reforested sites in tropical and subtropical Australia.

Structural attribute	Correlation with rainforest wildlife:				
	Plants	**Birds**	**Reptiles**	**Mites**	**Beetles**
Canopy cover	++++	+++	+++	+	+++
Canopy height	+++	+++	+	++	++
Tree density	++++	++++	+	+	+++
Basal area of trees	++++	++++	++	++	++
Shrubs density	++++	++++	+	+	++
Diameter diversity: trees and shrubs	+++	++++	++		++++
Special life forms	++	+++	+	++	++
(Lack of) grass cover	+++	++++	+	+	+++
Leaf litter cover	++	+			+
Woody debris	+	+	+	+	+

Note: The '+' symbols represent the number of significant positive correlations between structural attributes and wildlife from a total of four analyses, comprising: (i) all reforested sites, and (ii) young replanted sites only, for each of the (iii) tropics and (iv) subtropics. Data from 64 reforested sites aged 5-70 years old (Kanowski *et al.* 2003, 2006; Proctor *et al.* 2003; Catterall *et al.* 2004; Wardell-Johnson *et al.* 2005; Kanowski and Catterall 2006; Grimbacher *et al.* 2007).

Monitoring Basic Indicators: Standard Design

Basic indicators are monitored using a standard design (Figure 3). The same design is used for surveys of revegetated sites (including baseline studies) and reference sites. Ideally, the survey plots used to monitor basic indicators would be set up and permanently marked

during baseline surveys. The same plots would then be resurveyed each time the site was monitored. Use a metal peg or star-picket to permanently mark the location of the 0 m point on each transect (and perhaps the 50 m point). Record the location of the 0 m point with a GPS, record the compass bearing of each transect and mark the location of the transect on a 'mud-map' of the site. Space for recording these details is provided in the proforma for monitoring basic indicators.

Note that, in this toolkit, vegetation structure is assessed regardless of whether it is provided by native or exotic plants (weeds). The composition of the vegetation can be noted at the end of the proforma, along with any weed or maintenance issues at the site.

List of Attributes Surveyed

The basic indicators surveyed in this toolkit are based on structural attributes listed below.

Table 2: List of attributes to be surveyed for monitoring basic indicators.

Attributes	Definition
Canopy cover	Projective cover (%) of vegetation >2 m above ground (= shade cast by vegetation taller than 2 m, if the sun was directly overhead: includes both foliage and stems).
Canopy height	Height attained by the tallest tree in the canopy. The canopy is the layer of foliage forming the 'roof' of the forest; it may be broken by gaps or incomplete. In some sites and forest types, it may be necessary to distinguish canopy trees from emergents (i.e. trees projecting well above the canopy with crowns exposed on all sides).
Ground cover	Proportion of ground (%) covered by (a) vegetation <1 m high (grass, herbs, ferns, vines and scramblers, trees and shrubs, moss), (b) leaf litter and fine woody debris, (c) coarse woody debris, (d) rock, (e) soil, (f) other. Ground cover is assessed by looking down at the plot from 1 m above the ground, scoring what can be seen from this vantage point (as if looking at a photo). The total must add to 100%.
Trees	Live free-standing woody-stemmed plants >2 m high. Trees are tallied by dbh class (= stem diameter 1.3 m above ground) in the following categories: <2.5 cm, 2.5-10 cm, 10-20 cm, 20-50 cm, 50-100 cm, >100 cm. Where trees are multistemmed, tally each stem >2 m high by the appropriate dbh class (major stems only, not branches).
Structural damage to trees	Significant structural damage to live trees from storms or cyclones, recorded as: 1 = defoliation and smaller branches broken; 2 = larger branches broken, 3 = trunk broken; 4 = tree pushed over at >45° angle or uprooted. It may be difficult to assess minor damage (class 1) when some time has passed since the damage event. *Note: Assessment of structural damage is optional.*
Stags (dead trees)	Dead free-standing woody-stemmed plants >2 m high, tallied by dbh class: <2.5 cm, 2.5-10 cm, 10-20 cm, 20-50 cm, 50-100 cm, >100 cm.
Shrubs	Live free-standing woody stemmed plants 1-2 m high. May include saplings of trees.
Special life forms	Plant life forms characteristic of rainforest and/ or particular forest types (see illustrations). Includes: strangler figs, hemi-epiphytes, vines ('slender' <5 cm, 'robust' >5 cm diameter), vine towers, vine tangles, thorny scramblers, clumping epiphytic ferns, other epiphytes, tree ferns, ground ferns, palm trees, understorey palms, cordylines, herbs with long, wide leaves, herbs with strap leaves, cycads (with stems or on ground), pandanus, or any other life forms characteristic of a site (describe).
Woody debris	Fallen logs and branches, lying on or within 2 m of the ground. Coarse woody debris: >10 cm diameter. Fine woody debris: 2.5-10 cm diameter.

Note: "<" is the symbol for "less than", e.g. "stems <2.5 cm dbh" = stems less than 2.5 cm dbh.
"> " is the symbol for "greater than", e.g. "trees >2 m high" = trees greater than 2 m high.
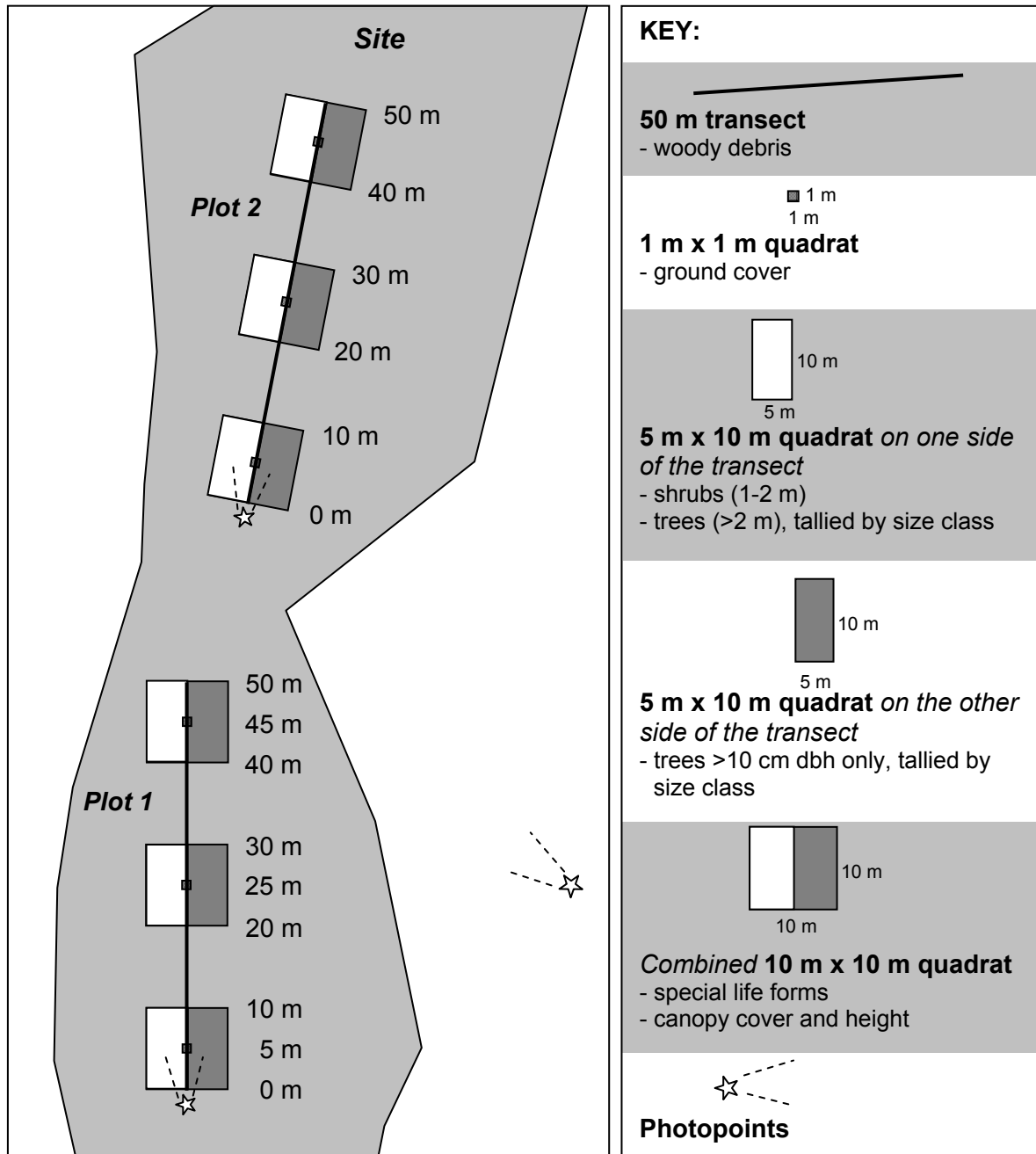
Figure 3: Standard layout of survey plots for monitoring basic indicators.

A **survey plot** is 50 m long by 10 m wide. Each plot consists of a 50 m **transect** with three sets of **quadrats** at the 5 m, 25 m and 45 m points. Where possible, two plots are surveyed per site.

Note: in some situations, it may be necessary to 'bend' or 'break' a transect at one or more points (e.g. in a narrow riparian site, or where a site is broken into several sections). However, the total length of each transect, and the size and number of quadrats, should remain unaltered. Any variations on the standard layout should be clearly documented and depicted on a map of the site.

Protocols For Monitoring Basic Indicators

Equipment required:

50 m tape, flagging tape, 2.5 m stick or PVC pipe marked at 1 m and 2 m, ruler or dbh tape, four 1 m sticks, clipboard and proforma, compass, digital camera (useful: GPS, clinometer, binoculars).

Step by step instructions:

Select the locations of two 50 m x 10 m plots to survey per site, if possible. *For each plot:*

Step 1: **Describe the survey area**: location, landform, slope, aspect, soils, proximity to waterways and to other land uses. Note any signficant disturbances. Draw the site and the location of each plot on a mud-map. Note any changes to the extent of the site since last survey.
Step 2: **Lay out a 50 m transect**. Record the compass bearing of the transect.
Step 3: Progressively **set out and survey the sets of quadrats** centred on the 5 m, 25 m and 45 m points (see Figure 3). Survey ground cover, forest structure, canopy cover and height, and special life forms in these quadrats (further details below).
Step 4: Survey **woody debris** by walking along the 50 m transect, and counting the number of times fallen logs cross the transect. Logs lying on or within 2 m of the ground are counted each time they cross the transect, tallied by diameter class. There are 2 diameter classes for fine woody debris (2.5-10 cm diam.) and 5 for coarse woody debris (>10 cm diam.).
Step 5: **Take a photo** of each monitoring plot from the 0 m point, along the transect.
Step 6: **Make general comments** on the structure and composition of the vegetation, and any variation across the site, in the: (i) overstorey, and (ii) understorey. Comment on the recruitment of species to the site. Note any weed problems or site maintenance issues.

Repeat Steps 1 to 6 for the second survey plot.

Step 7: Before leaving, take a **'landscape photo'** of the site, and record its location and direction. **Check** that the proforma has been completed.

Detailed instructions for ground cover, forest structure, canopy cover and canopy height:

At each plot, set out quadrats centred on the 5 m, 25 m and 45 m points. *At each point:*

- Survey **ground cover** on a 1 m x 1 m quadrat. Use four 1 m sticks to define the quadrat. Categories of ground cover include: (a) vegetation within 1 m of the ground, categorised by life form; (b) leaf litter and fine debris, (c) coarse woody debris; (d) rock, (e) bare soil; or (f) other.
- Survey **forest structure** on a 10 m x 10 m quadrat (comprised of two adjacent 5 m x 10 m quadrats: see Figure 3). Use a 2.5 m stick or length of pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.
- In one of the 5 m x 10 m quadrats, count all shrubs (1-2 m high) and tally trees (>2 m high) by dbh class (=stem diameter at 1.3 m). If trees have multiple trunks, tally each trunk >2 m high.
- In the other 5 m x 10 m quadrat, tally only larger trees (>10 cm dbh), by dbh class.
- Note: tally standing dead trees (**stags**) in the same way, but separately from live trees.
- *Optional: also score any **structural damage** (e.g. from cyclones) to living trees as follows:*
- *1 = minor damage, 2 = major branches broken, 3 = stem broken, 4 = pushed over or uprooted.*
- **Canopy cover** is assessed above the 10 m x 10 m quadrat. It can be estimated directly or calculated from a digital photo (see Appendices). We suggest using both methods.
- Assess **canopy height** above the 10 m x 10 m quadrat (the height of the tallest tree in the canopy). At some sites or forest types, it may be necessary to distinguish canopy trees from emergent trees (= trees projecting well above the canopy, with crowns exposed on all sides).
- **Special life forms** are recorded if present ('1') in the combined 10 m x 10 m quadrat. Note also if special life forms are present on the site, if not recorded on one of the plots. Illustrations of special life forms are provided on the page following the proforma.

  Note that vegetation structure is assessed without regard for whether plants are native or exotic.

Project name:	
Site name:	

Age of revegetation:		Assessed by:		Date assessed:	
Database Info:	Project ID:	Site ID:	Stage:	Year:

Description of Survey Plots	Plot 1	Plot 2
Location at 0 m point (map / GPS coordinates): **Datum:** _____		
Compass bearing of transect (from 0 m mark)		
Landform (e.g. plateau, crest, upper slope, mid-slope, lower slope, stream bank, flat)		
Slope (note: describe if not measured: e.g. very steep)	(°)	(°)
Aspect (compass direction or bearing)	(°)	(°)
Soil type / geology		
How close is the survey plot to a **waterway**? What type of waterway? (i.e. creek, river, lake, etc.)	m	m
How close is the survey plot to other land uses? What are the **adjacent land uses?**	m	m
Note any **significant disturbances** to the site: **what** (e.g. fire, cyclone) & **when** (e.g. 6 months ago)		

MAP   To help relocate the monitoring plots in future surveys, draw a map showing:
- Major features of the site (relevant property boundaries, roads, waterways, fences, landmarks);
- Location of remnant vegetation and/or revegetated sites;
- Location of monitoring plots (mark 0 m points) and landscape photopoint(s);
- Approximate scale (e.g. include a scale bar, e.g. 0 _____100 m) and North arrow.

Note on the map if there have been any changes to project area (e.g. due to changes in land use) since establishment

23

Site Name:	Date assessed:	Page 2 of 6

GROUND COVER, CANOPY COVER and CANOPY HEIGHT
For each survey plot, lay out a 50 m transect. Then, mark out and survey quadrats centred on the 5 m, 25 m and 45 m points (see Figure 3).

Ground Cover = proportion of ground covered by (a) vegetation within 1 m of ground (various categories), (b) leaf litter and fine woody debris, (c) coarse woody debris, d) rock, (e) soil, or (f) other. Note: total must add to 100%.

At the 5 m, 25 m and 45 m points, define a 1 m x 1 m quadrat, using four 1 m sticks. Looking down at the quadrat from 1 m, estimate the % of ground obscured by each cover type (i.e. as would be seen on a photo taken from 1 m).

Ground Cover	Plot 1			Plot 2		
Location of quadrat:	5 m	25 m	45 m	5 m	25 m	45 m
a) **Vegetation within 1 m of the ground**						
Grass (and sedges)	%	%	%	%	%	%
Herbs (soft-stemmed plants)	%	%	%	%	%	%
Ferns	%	%	%	%	%	%
Vines & thorny scramblers (e.g. lantana)	%	%	%	%	%	%
Tree seedlings & shrubs (foliage and stems)	%	%	%	%	%	%
Moss (and liverworts and lichens)	%	%	%	%	%	%
b) **Leaf litter** and fine woody debris <10 cm diameter	%	%	%	%	%	%
c) **Coarse woody debris** >10 cm diameter	%	%	%	%	%	%
d) **Rock**	%	%	%	%	%	%
e) **Soil**	%	%	%	%	%	%
f) **Other** (including tree trunks, roots, etc.)	%	%	%	%	%	%
TOTAL (must add up to 100%)	100%	100%	100%	100%	100%	100%

Canopy Cover = shade cast by all vegetation higher than 2 m above the ground, if the sun was overhead (foliage and stems). Canopy cover is estimated for the entire 10 m x 10 m quadrat around each point. It can be estimated by eye (although this can be very subjective) or from a photo. We suggest using both methods.

1. Estimate canopy cover visually, e.g. by reference to canopy photos (see Appendix 1).

2. Take a wide-angled digital photo of the canopy to calculate canopy cover (see Appendix 2). Record the number of each photo for later reference. Note: the photo is unlikely to capture the canopy above the entire quadrat.

Canopy Cover	Plot 1			Plot 2		
Location of quadrat:	5 m	25 m	45 m	5 m	25 m	45 m
Visual estimate of canopy cover	%	%	%	%	%	%
Canopy photograph (record number for reference)						
Canopy cover calculated from photograph	%	%	%	%	%	%

Canopy Height = the height of the tallest canopy tree in a 10 m x 10 m quadrat around each point. The canopy is the layer of foliage forming the 'roof' of the forest. It may be broken by gaps or incomplete.

In some sites and forest types, it may be necessary to distinguish canopy trees from emergent trees (i.e. trees projecting well above the canopy, with crowns exposed on all sides).

Note: Estimating height is difficult. Use a clinometer or range finder if available. Alternatively, place a 2.5 m stick or length of pipe against a tree, and standing at a distance, estimate height in multiples of 2.5 m.

Canopy Height	Plot 1			Plot 2		
Location of quadrat:	5 m	25 m	45 m	5 m	25 m	45 m
Height of tallest tree in canopy	m	m	m	m	m	m
Height of emergent trees (if present)	m	m	m	m	m	m

24

Site Name:	Date assessed:	Page 3 of 6

FOREST STRUCTURE: Plot 1

Trees and shrubs are counted on quadrats centred on the 5 m, 25m and 45 m points. At each point, set out a 10 m x 10 m quadrat (= two adjacent 5 m x 10 m quadrats, located either side of the transect: see Figure 3). Use a 2.5 m stick or length of PVC pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.

***In one 5 m x 10 m quadrat**, count all shrubs (1-2 m high) and tally trees (>2 m high) by dbh class (= stem diameter 1.3 m above ground). Use a 2.5 m stick or pipe (marked at 1 m and 2 m) to quickly assess if plants are within the height range of shrubs or trees (measure to the base of the highest leaf). If trees have multiple trunks, count each trunk >2 m high (major stems only, not branches). Tally dead trees (stags) by dbh class, separately from live trees.*

***In the other 5 m x 10 m quadrat**, tally only larger (>10 cm dbh) trees and stags, by dbh class.*

*OPTIONAL: Tally **damaged stems** of living trees by damage class: 1 = minor damage (may be difficult to determine some time after the damage event); 2 = larger branches broken; 3 = trunk broken; 4 = tree pushed over or uprooted.*

PLOT 1 @ 5 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
*Optional **Damage to living trees:** tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

Note: draw a line under the table when survey of plot has been completed

PLOT 1 @ 25 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
*Optional **Damage to living trees:** tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

Note: draw a line under the table when survey of plot has been completed

PLOT 1 @ 45 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
*Optional **Damage to living trees:** tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

25

Site Name:	Date assessed:	Page 4 of 6

FOREST STRUCTURE: Plot 2. A repeat of the methodology used to assess forest structure on Plot 1. Details below:
Trees and shrubs are counted on quadrats centred on the 5 m, 25m and 45 m points. At each point, set out a 10 m x 10 m quadrat (= two adjacent 5 m x 10 m quadrats, located either side of the transect: see Figure 3). Use a 2.5 m stick or length of PVC pipe (flipped end-over-end) to locate the corners of the quadrats and mark with flagging tape.

In one 5 m x 10 m quadrat, count all shrubs (1-2 m high) and tally trees (>2 m high) by dbh class (= stem diameter 1.3 m above ground). Use a 2.5 m stick or pipe (marked at 1 m and 2 m) to quickly assess if plants are within the height range of shrubs or trees (measure to the base of the highest leaf). If trees have multiple trunks, count each trunk >2 m high (major stems only, not branches). Tally dead trees (stags) by dbh class, separately from live trees.

In the other 5 m x 10 m quadrat, tally only larger (>10 cm dbh) trees and stags, by dbh class.

OPTIONAL: Tally damaged stems of living trees by damage class: 1 = minor damage (may be difficult to determine some time after the damage event); 2 = larger branches broken; 3 = trunk broken; 4 = tree pushed over or uprooted.

PLOT 2 @ 5 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
Optional **Damage to living trees:** *tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

Note: draw a line under the table when survey of plot has been completed

PLOT 2 @ 25 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
Optional **Damage to living trees:** *tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

Note: draw a line under the table when survey of plot has been completed

PLOT 2 @ 45 m	Shrubs (1-2 m high) Tally stems	Trees (>2 m high) Tally stems by dbh class					
		<2.5 cm dbh	2.5-10 cm dbh	10-20 cm dbh	20-50 cm	50-100 cm	>100 cm
First 5x10 m **quadrat**							
Second 5 x 10 m **quadrat**: Tally stems of larger trees (>10 cm dbh) only							
Optional **Damage to living trees:** *tally each damaged stem by damage class (1 – 4)*	class 1						
	class 2						
	class 3						
	class 4						
Tally stems of **dead trees** by dbh class	**First quadrat**						
	Second quadrat (stags >10 cm dbh only)						

Site Name:	Date assessed:	Page 5 of 6

SPECIAL LIFE FORMS *Record **presence** ('1') of life forms in 10 m x 10 m quadrats centred on the 5 m, 25 m and 45 m points (see Fig. 3). If a life form occurs on site, note presence ('1') in last column. Do not count abundance of life forms.*

Special Life Forms (see also diagrams following proforma)		Plot 1			Plot 2			**On site?**
	Location of quadrat:	**5 m**	**25 m**	**45 m**	**5 m**	**25 m**	**45 m**	
Strangler figs Figs with network of roots around stem of host tree, rooted in ground								
Hemi-epiphytes Climbing plants adhering to tree trunks, rooted in ground, e.g. *Pothos*, climbing pandanus								
Vines Climbing woody-stemmed plants dependent on trees for support, and rooted in the ground	**Slender** (stem <5 cm diam.)							
	Robust (stem >5 cm diam.)							
Vine towers Dense columns of vines growing over and smothering tree crowns and stems								
Vine tangles Dense masses of interwoven vine stems in understorey or midstorey								
Thorny scramblers Thicket-forming spiny vines or shrubs, e.g. *Calamus*, lantana, cockspur, raspberry	**Individual** plants present							
	Thickets present							
Palm trees Palms with stems >2 m high								
Understorey palms with stems <2 m high, e.g. walking stick palms (also includes juvenile palm trees)								
Tree ferns Ferns with stems usually >0.5 m high								
Ground ferns Ferns or fern-like plants without stems, growing on the ground								
Clumping epiphytic ferns Growing on trees, e.g. staghorns, elkhorns, basket ferns								
Other epiphytes Growing on trees, e.g. trailing ferns, orchids, not rooted on ground								
Cordylines 'Palm-lilies': shrubs to 5 m high, occasionally branched, with long leaves								
Herbs with long wide leaves e.g. gingers, cunjevoi, bananas								
Herbs with long strap-like leaves e.g. lilies, mat-rush (*Lomandra*)								
Cycads Plants with leathery palm-like foliage borne on stout stems or growing on ground (subterranean stems)	Stout stems, e.g. *Lepidozamia*							
	Ground cycads, e.g. *Bowenia*							
Pandanus ('screw-pine') shrub or small tree with prickly strap-like leaves in spirals on the end of trunks, often with prop roots								
Other life forms: describe… (note: record plant species or weeds on next page, <u>not</u> here)								

Woody debris = fallen logs and branches lying on or within 2 m of the ground.
Fine woody debris = logs 2.5 – 10 cm diameter.   **Coarse woody debris** (CWD) = logs > 10 cm diameter.

Tally the number of times logs are intercepted by each 50 m transect, by diameter class at point of intersection. If a log crosses the transect more than once, it is counted each time it crosses the transect, in the appropriate size class..

Tally number of intercepts with fallen logs by diameter class on each transect	**Fine woody debris 2.5-10 cm diam.**		**Coarse woody debris (CWD) > 10 cm diameter**				
	2.5-5 cm	**5-10 cm**	**10-25 cm**	**25-50 cm**	**50-75 cm**	**75-100 cm**	**>100 cm**
50 m transect, Plot 1							
50 m transect, Plot 2							

GENERAL COMMENTS *on structure and composition of vegetation, and variation across site.*

Overstorey (tree and canopy layer):

Understorey (shrub layer and ground cover):

Recruitment: *What type of plants are recruiting to the site (e.g. natives, weeds)? How abundant are they?*

WEED and MAINTENANCE ISSUES *(identify any weed problems and site maintenance issues*

Landscape photopoint information *(Note: mark locations of photopoints on 'mud-map', page 1 of proforma)*

Landscape photopoint location:	Direction of photo:
Map / GPS reference: Datum:	
Have photos been taken of **Plot 1**? Yes / No **Plot 2**? Yes / No	

Any other comments on the site?   Tick here _____ and add extra page.
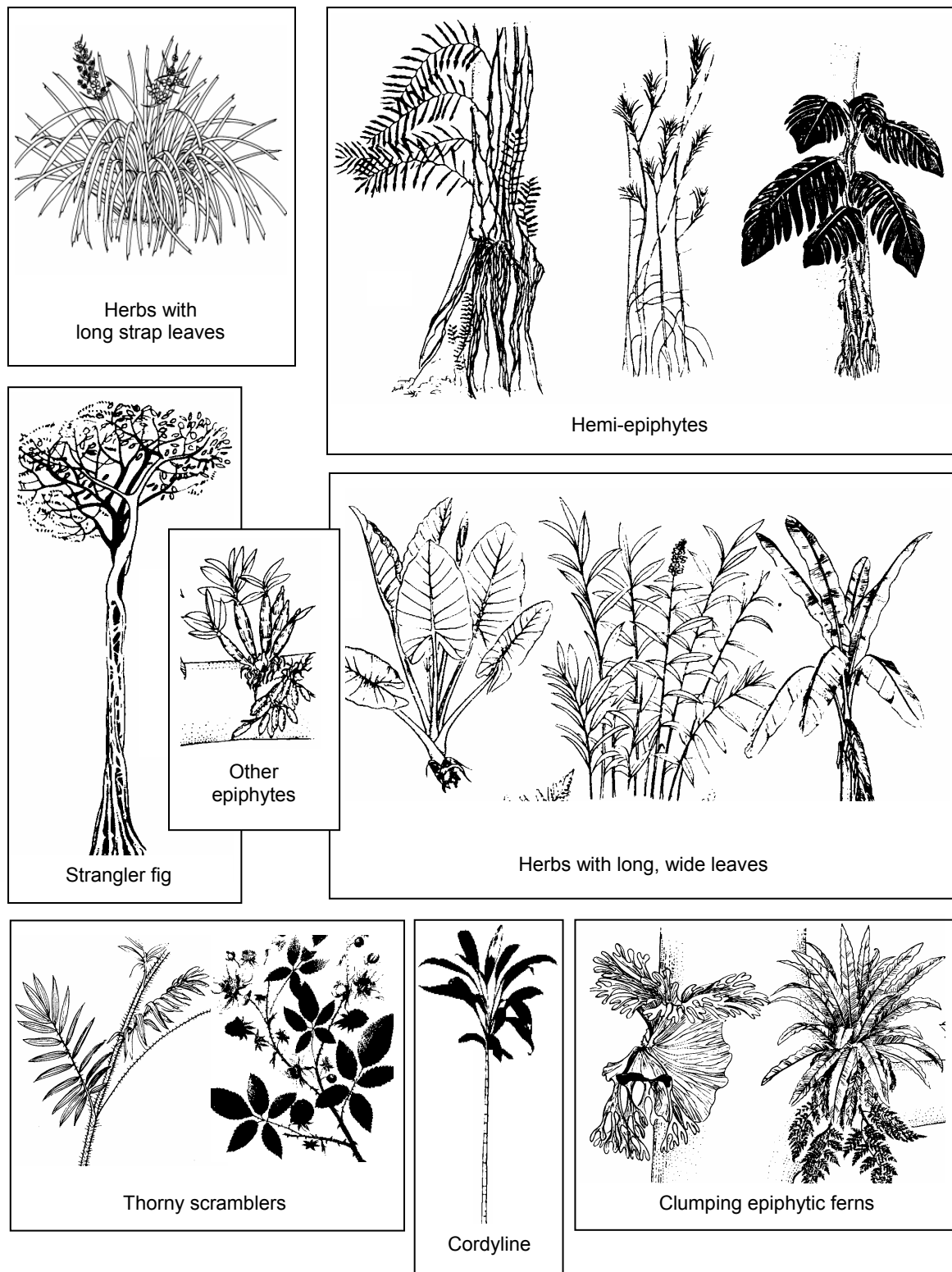
Figure 4. Illustrations of special life forms (mostly from Webb *et al.* 1976).

5. Data Management, Analysis and Evaluation

Data Management

A revegetated site may take three to five years to achieve 'site capture', decades to recruit a diverse range of native plants and wildlife, and centuries to approach the condition of 'intact' forest. Over that time, memories will fade, computers and software become obsolete, and volunteers come and go. Monitoring changes in a revegetation project therefore requires good data management. While the details will vary, some of the key elements of good data management include data integrity (checking and correcting errors), data security (storing data in a secure and accessible file system, making and storing backup copies, keeping original field sheets), and maintaining metadata (keeping a record of what the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc). A suggested approach to data management for information collected with this toolkit is as follows:

Data Integrity

The data in the proformas should be given a quick check while still in the field. Enter the data from the field proformas into a computer file as soon as possible after collection (same day or week, preferably), while the information is still fresh. A spreadsheet has been designed to store data from the monitoring proformas provided in this toolkit (see below). The data entered into spreadsheets should be checked for errors by comparison with the proformas.

Data Security

Make at least one backup copy of the data on a suitable long-lasting medium (e.g. CD). The original field proformas and a backup copy of the data should be stored in a secure and well-maintained filing system. For additional security, a second back-up copy of the data could be stored at another location.

Maintaining Metadata

Keep a description of the data and the methodology used to collect the data (e.g. a copy of the toolkit or relevant pages from it) with the field proformas and the backup data. Keep a written record of where the data are stored, the data format and the names of relevant computer files with the field proformas and backup data. An example of the type of metadata that might be stored with the results of a monitoring survey is given in Table 3.

Table 3: Example of metadata associated with monitoring basic indicators at a site.

Project Name:	*Victoria Park restoration project: revegetation site to north of remnant*			
Age of revegetation: *26* yrs	**Assessed by:** *John Kanowski*		**Date assessed:** *7/7/2006*	
Database info:	**Project ID:** QBVR	**Site ID:** *SE7*	**Stage:** north	**Year:** *1979*
Data Description:	*Results of survey of 'basic indicators' (vegetation structural attributes) on a revegetated site planted with a diverse range of rainforest trees and shrubs*			
Data Type:	*Spreadsheet in Excel 2000 format*			
Methodology:	*Data were collected using the protocol for monitoring 'basic indicators' provided in 'Monitoring Toolkit Version 1, Revision 1' (copy kept with this file).*			
Location of files:	*The data and the original hard copies are held by John Kanowski; a copy is stored on the computer at the Centre for Innovative Conservation Strategies, Griffith University*			

Data Entry and Analysis

We have written an Excel spreadsheet ('Basic_Indicator_data_file_Vers1_Rev1.xls') to store, analyse and summarise the data collected from monitoring revegetated sites using the protocols presented in this toolkit. The spreadsheet includes a number of worksheets including:

- A page of explanatory notes;
- A page to store details of the site and survey plots;
- A series of pages to store data from a baseline survey and up to eight repeat monitoring surveys of a revegetated site;
- Pages to record data from surveys of up to five reference sites;
- A page that automatically summaries data from these monitoring surveys; and
- A page that automatically graphs trends in selected data from repeat surveys of a revegetated site, alongside graphs of values recorded in reference sites for comparison.

The data entry pages have exactly the same format as the survey proformas. Data from repeat monitoring surveys are recorded on successive pages of the spreadsheet (e.g. data from the first monitoring survey after establishment are recorded in page 'T1', data from the second survey in page 'T2', etc.).

The spreadsheet automatically calculates the values of basic indicators from the monitoring data entered into it, using the formulae listed in Table 4. In most cases, these are simply the average values of attributes over the plots or quadrats surveyed, although some indicators require more complex calculations.

From these data, the spreadsheet automatically creates graphs of trends in basic indicators at a revegetated site over time. The graphs include data from a baseline survey, if available, for showing how much a site has changed following revegetation. The graphs also include data from reference sites (if surveyed), to show whether a site is approaching or has attained reference conditions. The average and range of values of reference sites are presented for these comparisons.

The latest version of the spreadsheet will be posted on the website of the Reef and Rainforest Research Centre: www.rrrc.org.au/publications. Examples of the spreadsheet and the graphs it produces are presented in Figures 5 and 6.

Note that while the spreadsheet will meet the needs of most users, there may be situations where formal statistical analyses of monitoring data are required (e.g. where there are legal requirements to restore sites to a particular condition). We assume that practitioners needing to conduct such analyses will seek competent advice from a professional ecologist early in the life of a monitoring program, as such requirements need a suitable design as well as appropriate analysis.

Table 4: Calculation of basic indicators from data collected using the toolkit. Calculations are made automatically when data are entered in the spreadsheet written for the toolkit.

Attribute	Derivation
Canopy cover	Average of cover estimates.
Canopy height	Average of height estimates.
Tree density	Number of tree stems per ha, calculated for each dbh class and for all tree stems.
Shrub density	Number of shrub stems per ha.
Stem diversity	Shannon-Wiener (H) index of the proportion of stems in each size class, calculated from counts of shrubs and trees in each dbh class: $H = -\Sigma\, p_i * \ln(p_i)$, where p_i is the proportion of stems in the ith size class.
Tree basal area	Cross-sectional area of trees, calculated from dbh classes: BA (m^2 per ha) = $\Sigma\, n_i\, \pi\,(dbh_i)^2/40000$, where n_i is the number of stems in the ith size class/ ha, and dbh_i is the notional diameter (cm) of the ith size class (= lower limit of class + 1/3 the class range, to account for the right-skewed distribution of stem sizes).
Stag basal area	Cross-sectional area of dead trees, calculated from dbh classes, as above.
Woody debris volume	Volume of woody debris calculated from the line intercept method (Van Wagner 1968): V (m^3 per ha) = $(\pi^2 / 8 L)\, \Sigma\, n_i d_i^2$ where L = transect length (m), n_i = number of logs in the ith diameter class, and d_i is the notional diameter (cm) of the ith size class (= lower limit of class + 1/3 the class range, to account for the right-skewed distribution of log sizes). Calculated for fine, coarse and total woody debris.
Ground cover	Average of cover estimates for each category.
Special life form frequency	For each life form, the proportion of quadrats where each life form was recorded (frequency index ranges from 0-1). If a life form was recorded on site, but not on any quadrats, it is given an arbitrary value of 0.1.
Ground cover index	Index of the similarity of ground cover in revegetated sites to forest reference sites, where cover types are weighted by their average value in reference sites. Index = $\Sigma\, p_i * u_i$, where p_i is the value of the ith ground cover as a proportion of the average of the ith ground cover in forest reference site(s), and u_i is the average of the i th ground cover in forest reference site(s). Note: the index does not include grass cover or rock cover. p_i is capped at 1. The index ranges from 0-100 %.
Special life form index	The frequency of special life forms relative to their occurrence in forest reference site(s). Index = $\Sigma\, p_i /n*100$, where p_i is the frequency of the ith life form, as a proportion of its average frequency in forest reference site(s), and n is the number of life forms encountered in forest reference site(s). Note: p_i is capped at 1. The index ranges from 0-100%. Life forms recorded in the revegetated site but not the reference site neither add to, nor detract from, the index score.
Forest structure index	Index of the abundance of shrubs and trees in each size class, relative to forest reference site(s). Index = average $(p_i)*100$, where p_i is the abundance of the i th size class, as a proportion of its average abundance in forest reference site(s). Note: p_i is capped at 1: i.e. if stem density in a dbh class is higher at a revegetated site than the average of reference sites, it does not score more, or less, than if it occurred at the same abundance. The index ranges from 0–100%.
Site 'structural condition index'	The average value of selected structural attributes relative to forest reference sites (attributes are: canopy cover, canopy height, total tree density, tree basal area, stag basal area, stem diversity, woody debris, ground cover index, special life form index, forest structure index). Index = average $p_i *100$, where p_i is the value of the ith attribute, as a proportion of its average value in forest reference site(s). Note: p_i is capped at 1. The index ranges from 0-100%. This index is a measure of the average development of structural attributes relative to forest reference sites: e.g. a score of 40% would indicate that, on average, the value of selected attributes at a site were at least 40% of values recorded in reference sites.

Enter data from field proforma into cells in tables below	
Site name	Victoria Park
Age of revegetation (yrs)	26
Assessed by:	J. Kanowski
Date of assessment:	7/06/2006

Ground cover	Plot 1			Plot 2		
Enter % cover for cover types present	5 m	25 m	45 m	5 m	25 m	45 m
a) Vegetation within 1m of ground						
Grass and sedges		5	10	30		5
Herbs = soft-stemmed plants		60		10		10
Ferns						10
Vines & scramblers inc. lantana					25	
Trees, shrubs, seedlings	1		1		10	15
Moss and other cryptograms (liverworts etc)						
b) Leaf litter and fine woody debris <10 cm diam	80	15	79	20	35	50
c) Coarse woody debris >10 cm diam					10	
d) Rock	1			10		
e) Soil	18	20	10	30	20	10
f) Other inc. tree trunks, roots						
TOTAL (note: must add up to 100%)	100	100	100	100	100	100

Canopy cover	Plot 1			Plot 2		
Enter % cover.	5 m	25 m	45 m	5 m	25 m	45 m
Visual estimate	95	82	70	65	70	90
Canopy cover calculated from photo	91	76	65	60	65	82

Canopy height	Plot 1			Plot 2		
Enter height in metres	5 m	25 m	45 m	5 m	25 m	45 m
Height of tallest tree in canopy (m)	12	15	17	11	9	18
Height of emergent trees (if present) (m)						

Summary data for 'basic indicators'		NOTE: DO NOT ENTER DATA INTO THE SUMMARY CELLS
		Values are calculated automatically
		The monitoring proforma is set up to accept data from 2 plots per site.
Number of plots surveyed	2	However, calculations will still be correct, even if only 1 plot was surveyed at a site
Number of quadrats surveyed	6	Note: calculations assume that ground cover was assessed on all 3 quadrats in each plot surve

| ATTRIBUTE	Result	Units
GROUND COVER		
a) Vegetation < 1m of ground		
Grass and sedges	8.3	%
Herbs	13.3	%
Ferns	1.7	%
Vines & scramblers	4.2	%
Trees, shrubs, seedlings	4.5	%
Moss and other cryptograms	0.0	%
b) Leaf litter & fine woody debris	46.5	%
c) Coarse woody debris	1.7	%
d) Rock	1.8	%
e) Soil	18.0	%
f) Other	0.0	%
CANOPY COVER		
Visual estimate	78.7	%
Canopy cover calc. from photo	73.2	%
CANOPY HEIGHT		
Height of tallest tree in canopy	13.7	m
Height of emergent trees (if presen		m

Figure 5: Example of the data entry worksheet.

The worksheet ('Basic_Indicator_data_file_Vers1_Rev1.xls') is used to enter data from monitoring surveys of revegetated sites (top panel).The values of basic indicators are automatically calculated from these data (lower panel).

(a)
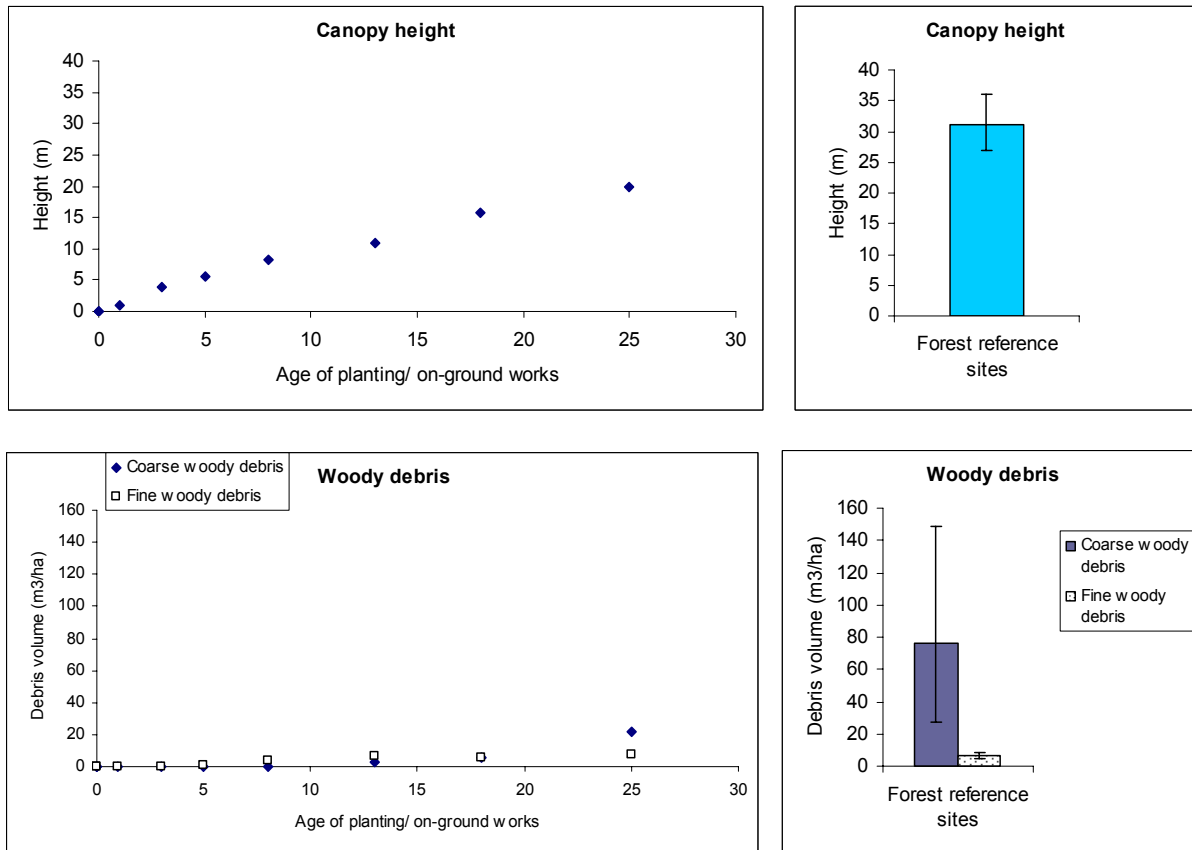
(b)
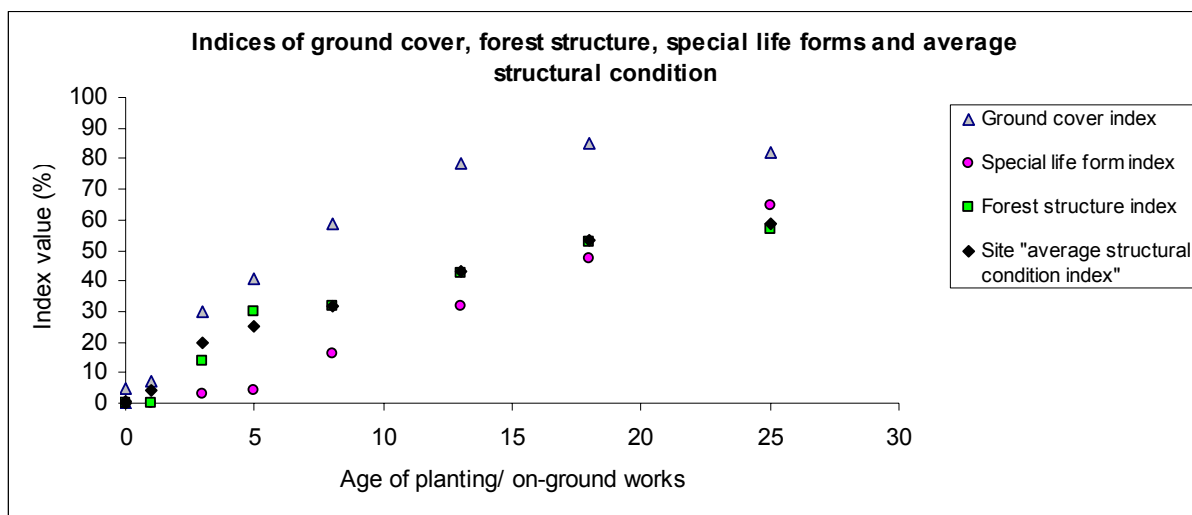
Figure 6: Graphs of trends in basic indicators in a revegetated site.

(a) Comparison of values of basic indicators in a revegetated site with mean (and range) of values in reference sites using the worksheet, 'Basic_Indicator_data_file_Vers1_Rev1.xls'

(b) indices of ground cover, special life forms, forest structure and 'site structural condition' in a revegetated site. The indices internalise comparisons with reference sites. The 'site structural condition index' is the average value of selected structural attributes in a revegetated site, relative to reference sites (see Table 4).

Evaluating Revegetation Projects

Tracking the Progress of a Revegetation Project

When a revegetated site has been monitored on several occasions, the results of surveys can be graphed to show changes or trends in basic indicators at that site over time. Examination of trends in indicators can show whether, and how fast, a site is progressing away from baseline conditions and towards reference conditions. If a project is not progressing as swiftly as planned, or in the intended direction, changes could perhaps be made to the management of the project, or the design of future projects.

A useful way of evaluating the progress of a revegetated site is to compare the monitoring results with (i) baseline data (describing the condition of a site before the revegetation was established) and (ii) with data from surveys of one or more reference sites (i.e. forests representing the 'target condition', such as remnant forests of the type that may have occurred on a site prior to clearing). Comparison with baseline data will show how much a site has changed following revegetation, while comparison with forest reference site(s) can show whether the revegetated site has achieved the target condition, and if not, what attributes require further development. Appropriate reference sites should be selected for a revegetated site (e.g. matching soils and climate) because many structural attributes of rainforest vary between forest types and regions (Webb *et al.* 1976).

Figure 5 shows an example of how trends in monitoring results can be compared with baseline data and reference sites. Trends can be examined for particular indicators (e.g. canopy height and woody debris, in panel (a) of Figure 6), or for indices which summarise a number of attributes (e.g. panel (b) in Figure 6). Indices for ground cover, the occurrence of special life forms, forest structure (density of trees and shrubs) and an overall index of 'site structural condition are calculated by the 'Basic_Indicator_data_file_Vers1_Rev1.xls' file (see definitions in Table 4). These indices incorporate a comparison with reference sites in their calculation, and range from 0 (unlike reference conditions) to 100 (resembling reference conditions). While indices can greatly simplify the presentation of data from monitoring surveys, it is important not to lose sight of the underlying trends. For example, if an increasing trend in one attribute is cancelled out by a decreasing trend in another, a summary index may fail to reveal changes in a monitored site.

It should also be pointed out that reference sites are likely to vary in values for basic indicators. Consequently, a revegetated site may come to closely resemble reference sites without achieving 'perfect scores' for index values. Determining how close a revegetated site needs to approach reference sites to be considered 'successful' is a matter of judgement which partly depends on the inherent variation in reference sites.

Comparing Different Revegetation Methods

Monitoring programs aimed at comparing the performance of different revegetation methods require a suitable experimental design, typically the survey of different 'treatments' on replicate plots or sites over time (see Section 2). This type of monitoring is essentially ecological research. A detailed discussion of this topic is beyond the scope of this toolkit, and practitioners wanting to conduct this type of monitoring program should seek competent ecological and statistical advice at both the design and analysis stages.

An example of this type of analysis is presented in Figure 7, concerning the development of structural attributes in different types of reforestation in northern Queensland. The reforested sites were compared with baseline sites (pasture) and reference sites (rainforest). Five to ten replicate sites were surveyed in each 'treatment'. The results were analysed using ANOVA.

The results show that (1) restoration plantings had a more 'rainforest-like' structure than timber plantations, and (2) there were some differences in structure between monoculture and mixed species plantations. While all types of reforested sites had acquired some forest attributes, they still lacked some characteristic structural features of rainforest, particularly special life forms and woody debris.
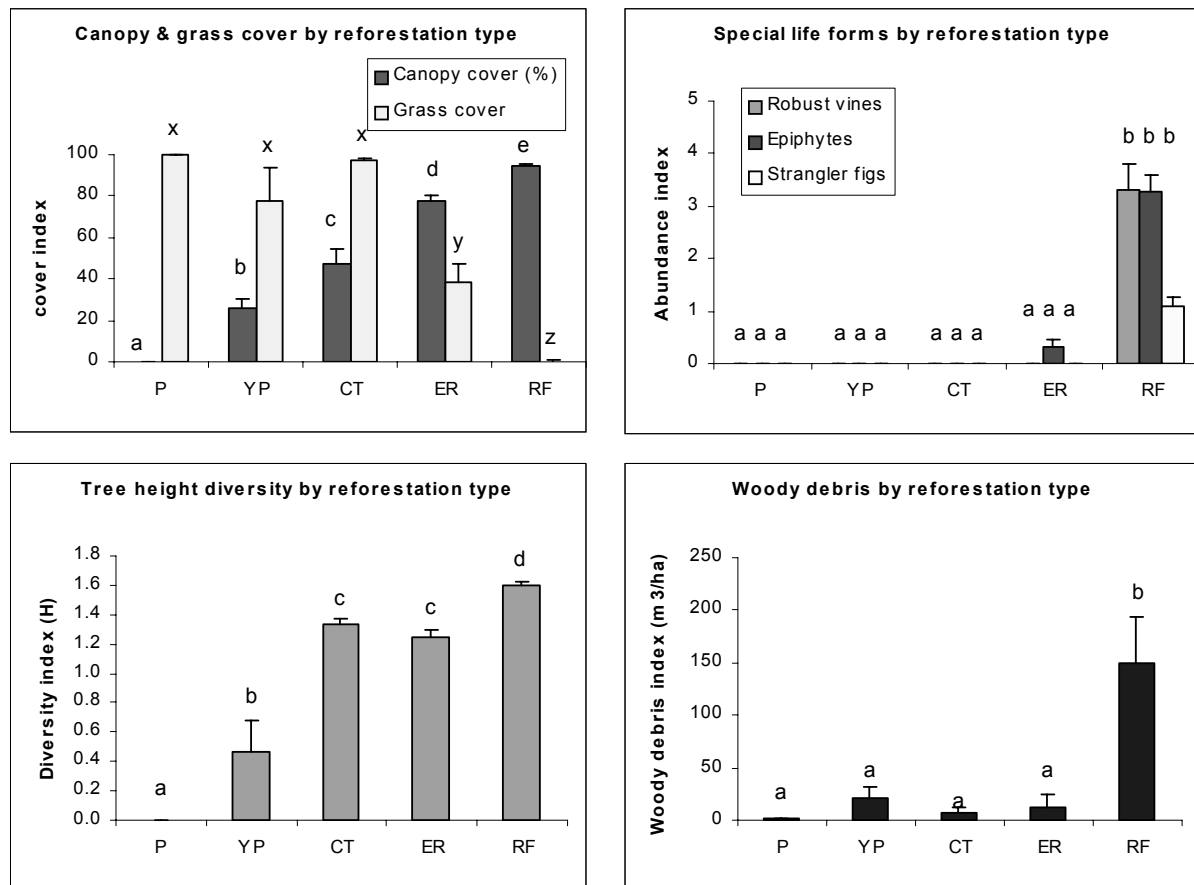
Figure 7: Use of monitoring results to compare different types of reforestation.

Site types: P = pasture; YP = monoculture plantations; CT = mixed species cabinet timber plantations; ER = ecological restoration plantings; RF = rainforest. Bars show average values ± standard errors. For all analyses, values differ significantly overall among different site types. Site types with different letters have significantly different values for each attribute. The data are from surveys of sites on the Atherton Tableland, north Queensland (Kanowski *et al.* 2003; Catterall *et al.* 2004).

Other Issues to Consider

Rigorous Assessments of 'Success'

The comparison of monitoring results from revegetated sites with baseline data and reference sites, as discussed above, will provide useful information on the progress of a site towards target conditions. However, in some cases, a more rigorous assessment of 'success' may be required: for example, when a restoration project has to meet legal or contractual obligations. One of the main features of a robust design would be the survey of replicate plots within the revegetated site, to properly account for the variability in a site and to facilitate statistical analysis of the results. Another feature might be the nomination of performance criteria by which 'success' might be judged: e.g. within the range of reference conditions, or within twenty percent of the mean of reference conditions. Again, a detailed discussion of these matters is beyond the scope of this toolkit.

Assessing a 'Recovery Trajectory'

The comparison of revegetated sites with reference sites might be considered an interesting but largely academic exercise, given that most revegetation projects are still relatively young and would not be expected to resemble mature rainforest for many decades, perhaps centuries. In these circumstances, it may be more useful to determine whether trends in the attributes of a young revegetated site are tending to converge on the attributes of reference site(s), and whether the rate of convergence is acceptable. This approach has been termed 'trajectory analysis' by the Society for Restoration Ecology (2004). When combined with ecological knowledge, this approach may be useful in identifying which attributes need intervention to 'move' them towards target conditions, and which can be left to develop by natural processes. The graphs produced by the 'Basic_Indicator_data_file_Vers1_Rev1.xls' worksheet (see Figure 6) are an informal kind of 'trajectory analysis' for basic indicators in revegetated sites.

Again, a robust formal assessment of the trajectory of a revegetated site would require the survey of replicate plots or sites, and suitable statistical analyses. Several authors have used multivariate analysis to argue that particular restoration sites are (Jansen 2005) or are not (Wilkins *et al.* 2003) progressing towards reference conditions. The Society for Restoration Ecology (2004) considers that trajectory analysis is "still under development". A proper assessment of whether a revegetated site is trending towards target conditions will probably require long-term data on the developmental trajectories of many sites, representing a range of ecological conditions, and we are still a long way off having such data for rainforest. For example, an analysis of successional trajectories in jarrah (*Eucalyptus marginata*) forests rehabilitated after bauxite mining required data from several hundred plots, some of which had been monitored for decades (Grant 2006). It is hoped that the production of this toolkit will facililate the collection of data to advance our knowledge of the ecological development of revegetated sites in rainforest landscapes.

References

Big Scrub Rainforest Landcare Group (2005) *Subtropical Rainforest Restoration: A Practical Manual and Data Source for Landcare Groups, Land Managers and Rainforest Regenerators.* Second Edition. Big Scrub Rainforest Landcare Group, Bangalow NSW.

Big Scrub Rainforest Landcare Group and EnviTE (2006) *Monitoring and Evaluation Database.* Lismore, NSW. Available online at http://www.envite.org.au/index2.html

Catterall, C. P. and Harrison, D. A. (2006) *Rainforest Restoration Activities in Australia's Tropics and Subtropics.* Cooperative Research Centre for Tropical Rainforest Ecology and Management. Rainforest CRC, Cairns. Available online at http://www.rainforest-crc.jcu.edu.au

Catterall, C. P., Kanowski, J. and Wardell-Johnson, G. W. (2006) Biodiversity and new forests: interacting processes, prospects and pitfalls of rainforest restoration. In: *Living in a Dynamic Tropical Forest Landscape.* Stork, N. E. and Turton, S. M. (eds.). Blackwell Publishing Ltd, in press.

Catterall, C. P., Kanowski, J., Wardell-Johnson, G. W., Proctor, H., Reis, T., Harrison, D. and Tucker, N. I. J. (2004) Quantifying the biodiversity values of reforestation: perspectives, design issues and outcomes in Australian rainforest landscapes. In: *Conservation of Australia's Forest Fauna Vol 2.* Lunney, D. (ed.) pp. 359-393. Royal Zoological Society of New South Wales, Sydney.

Eyre, T. J., Kelly, A. L. and Neldner, V. J. (2006) *BioCondition: A Terrestrial Vegetation Condition Assessment Tool for Biodiversity in Queensland.* Field Assessment Manual Version 1.5. Environmental Protection Agency, Brisbane. Available online as "BioCondition Manual" at http://www.epa.qld.gov.au/nature_conservation/biodiversity/

Freeman, A. (2004) Constraints to community groups monitoring plants and animals in rainforest revegetation sites on the Atherton Tablelands of far north Queensland. *Ecological Management and Restoration* 5: 199-204.

Freudenberger, D. and Harvey, J. (2003a) *Assessing the Benefits of Vegetation Enhancement for Biodiversity: A Framework.* Report for Environment Australia. Available online at http://www.ea.gov.au

Freudenberger, D. and Harvey, J. (2003b) *Case Study Applications of a Draft Framework for Assessing the Biodiversity Benefits of Vegetation Enhancement Activities.* Report for Environment Australia. Available online at http://www.ea.gov.au

Gibbons, P., Ayers, D., Seddon, J., Doyle, S. and Briggs, S. 2005. *BioMetric Version 1.8.* NSW Department of Environment and Conservation. available on the web at: http://www.nationalparks.nsw.gov.au/npws.nsf/Content/biometric_tool

Gibbons, P. and Freudenberger, D. (2006) An overview of methods used to assess vegetation condition at the scale of the site. *Ecological Management and Restoration* 7: S10-S17.

Goosem, S. and Tucker, N. I. J. (1995) *Repairing the Rainforest: Theory and Practice of Rainforest Reestablishment in north Queensland's Wet Tropics.* Wet Tropics Management Authority, Cairns.

Grant, C. D. (2006) State-and-transition successional model for bauxite mining rehabilitation in the Jarrah forest of Western Australia. *Restoration Ecology* 14: 28-37.

Grimbacher, P.S., Catterall, C.P., Kanowski, J. and Proctor, H.C. (2007) Responses of ground-active beetle assemblages to different styles of reforestation on cleared rainforest land. *Biodiversity and Conservation*, in press.

Grundon, N., Wright, J. and Irvine, T. (2002) *Pelican Point Revegetation, Atherton Tableland: an example of a community participatory project – establishment and measuring post-development success.* TREAT, Atherton.

Harden, G. J., Fox, M. D. and Fox, B. J. (2004) Monitoring and assessment of restoration of a rainforest remnant at Wingham Brush, New South Wales. *Austral Ecology* 19: 489-507.

Hopkins, M.S. (1990) Disturbance - the forest transformer. In: *Australian Tropical Rainforests – Science, Values, Meaning*. Webb, L.J. and Kikkawa, J. (eds). pp. 40-52. CSIRO, Melbourne.

Horton, S. (1999) *Rainforest Remnants: A Decade of Growth*. NSW NPWS, Sydney.

Hunter, J. (1999) Monitoring – why and how? In: *Rainforest Remnants: A Decade of Growth*. Horton, S. (ed). pp. 181-187. NSW NPWS, Sydney.

Jansen, A. (2005) Avian use of restoration plantings along a creek linking rainforest patches on the Atherton Tablelands, north Queensland. *Restoration Ecology* 13: 275-283.

Joseph, R. (1999) An integrated, systematic approach to rainforest remnant restoration. In: *Rainforest Remnants: A Decade of Growth*. Horton, S. (ed). pp. 168-180. NSW NPWS, Sydney.

Kanowski, J., Catterall, C. P. and Harrison, D. H. (2007) Monitoring the outcomes of reforestation for biodiversity conservation. In: *Living in a Dynamic Tropical Forest Landscape.* Stork, N. E. and Turton, S. M. (eds). Blackwell Publishing Ltd, in press.

Kanowski, J., Catterall, C. P., Wardell-Johnson, G. W., Proctor, H. and Reis, T. (2003) Development of forest structure on cleared rainforest land in eastern Australia under different styles of reforestation. *Forest Ecology and Management* 183: 265-280.

Kanowski, J., Catterall, C. P., Proctor, H., Reis, T., Tucker, N. I. J., and Wardell-Johnson, G. W. (2005) Rainforest timber plantations and animal biodiversity in tropical and subtropical Australia. In: *Reforestation in the Tropics and Subtropics of Australia Using Rainforest Tree Species.* Erskine, P. D., Lamb, D. and Bristow, M. (eds). pp. 183-205. RIRDC, Canberra and Rainforest CRC, Cairns.

Kanowski, J., Reis, T., Catterall, C. P. and Piper, S. (2006) Factors affecting the use of reforested sites by reptiles in cleared rainforest landscapes in tropical and subtropical Australia. *Restoration Ecology* 14: 67-76.

Kooyman, R. (1996) *Growing Rainforest: Rainforest Restoration and Regeneration. Recommendations for the humid subtropical region of northern New South Wales and southeast Queensland.* Greening Australia, Brisbane and NSW State Forests, Sydney.

Lamb, D., Erskine, P. D. and Parrotta, J. A. (2005) Restoration of degraded tropical forest landscapes. *Science* 310: 1628-1632.

Lamb, D., Parrotta, J. A., Keenan, R. and Tucker, N. I. J. (1997) Rejoining habitat remnants: restoring degraded rainforest lands. In: *Tropical Forest Remnants* Laurance, W. F., Bierregaard, R. O. (eds). pp. 366-385. University of Chicago Press, Chicago.

Lugo, A. E. (1997) The apparent paradox of re-establishing species richness on degraded lands with tree monocultures. *Forest Ecology and Management* 99: 9-19.

McElhinny, C., Gibbons, P., Brack, C. and Bauhus, J. (2005) Forest and woodland stand structural complexity:Its definition and measurement. *Forest Ecology and Management* 218: 1-24.

Parkes, D., Newell, G. and Cheal, D. (2003) Assessing the quality of native vegetation: the 'habitat hectares' approach. *Ecological Management and Restoration* 4: S29-38.

Phillips, S. (1991) *Rainforest Remnants.* NSW NPWS, Sydney.

Proctor H. C., Kanowski, J., Reis, T., Catterall, C. P., and Wardell-Johnson, G. (2003) Does diversity beget diversity? A comparison between plant and leaf-litter invertebrate richness from pasture to rainforest. *Records of the South Australian Museum Monograph Series* 7: 267-274.

Society for Ecological Restoration International Science and Policy Working Group (2004) *The SER International Primer on Ecological Restoration*. Available online at http://www.ser.org/

Tracey, J. G. (1982) *The Vegetation of the Humid Tropical Region of North Queensland*. CSIRO, Melbourne.

Tucker, N. I. J. and Murphy, T. (1997) The effect of ecological rehabilitation on vegetation recruitment: some observations from the Wet Tropics of north Queensland. *Forest Ecology and Management* 99: 133-152.

Walker, J. and Hopkins, M. S. (1990) Vegetation. In: *Australian Soil and Land Survey Field Handbook*. McDonald, R. C., Isbell, R. F., Speight, J. G., Walker, J. and Hopkins, M. S. (eds). pp. 58-86. Inkata, Melbourne.

van Wagner, C.E. (1968) The line intersect method in forest fuel sampling. *Forest Science* 14, 20-26.

Wardell-Johnson, G. W., Kanowski, J., Catterall, C. P., McKenna, S., Piper, S., and Lamb, D. (2005) Rainforest timber plantations and the restoration of plant biodiversity in tropical and subtropical Australia. In: *Reforestation in the Tropics and Subtropics of Australia Using Rainforest Tree Species*. Erskine, P. D., Lamb, D. and Bristow, M. (eds). pp. 162-182. RIRDC, Canberra and Rainforest CRC, Cairns.

Webb, L. J., Tracey, J. G., and Williams, W. T. (1976) The value of structural features in tropical forest typology. *Australian Journal of Ecology* 1: 3–28.

Wilkins, S., Keith, D. A. and Adam, P. (2003) Measuring success: evaluating the restoration of a grassy eucalypt woodland on the Cumberland Plain, Sydney, Australia. *Restoration Ecology* 11: 489-503.

Glossary

Term	Definition
Actions	The activities and on-ground works undertaken to achieve the project objectives, in broad terms. For the purpose of this toolkit, these actions are likely to include remnant protection, remnant enhancement and reforestation.
Advanced indicators	Measures of plant and animal composition or ecological processes of a site, which may require specialist knowledge and training. Protocols for monitoring advanced indicators will be presented in later versions of the toolkit.
Aspect	The compass direction you face when you stand on a slope and look in the direction of the steepest fall of land
Basal area	Cross-sectional area of trees, calculated from counts of stems in dbh classes.
Baseline data	Information on the condition of a site prior to revegetation. The comparison of monitoring results with baseline data can show how much a site has changed following revegetation. Where baseline data are not collected, it is difficult to make strong claims about the effects of revegetation on target variables.
Basic indicators	Aspects of forest structure that reflect the development of a revegetation project, can be measured easily and rapidly in the field, without specialist knowledge, and are correlated with the use of sites by rainforest wildlife.
Building phase of revegetation	The stage of revegetation after 'site capture', during which the planted trees mature, reproduce and die, and other species of plants and animals are recruited to the site. In a restoration project, the aim of this phase is typically the development of a floristically and structurally diverse forest that provides habitat for native wildlife. It may take decades or even centuries for a revegetated site to come to resemble mature rainforest.
Canopy cover	Projective cover (percentage) of vegetation >2 m above ground (= shade cast by vegetation >2 m above ground, if sun was directly overhead).
Canopy height	Height attained by the crown of the tallest tree in the canopy. The canopy is the layer of foliage forming the 'roof' of the forest; it may be broken by gaps or incomplete. In some sites, it may be necessary to distinguish canopy trees from emergent trees.
Coarse woody debris	Fallen logs and branches >10 cm diameter, lying on or within 2 m of the ground. Where present, coarse woody debris usually comprises most of the volume of woody debris. Provides habitat for organisms dependent on rotting wood, as the core remains moist.
Control sites	Sites not revegetated but included in the monitoring program to represent examples of the 'do nothing' option. Monitoring control sites can help to identify what outcomes were due to revegetation and what to other factors (e.g. natural regrowth). Control sites can also be used to provide surrogate baseline data, if baseline data were not collected from sites prior to revegetation.
Correlation	A term describing the statistical relationship between two variables. Two variables can be positively correlated if their trends run in the same direction (e.g. tree height and dbh), or negatively correlated if their trends run in opposite directions (e.g. canopy cover and grass cover). When variables are correlated, one can be used as a surrogate for the other in monitoring surveys.
Datum	The horizontal reference system used to draw up a map grid (e.g. WGS84, GDA94). For any set of GPS or map coordinates, the datum should be specified; both the coordinates and datum are needed to specify a location.
Dbh (diameter at breast height)	The diameter of a tree, measured at 1.3 m above the ground, or above the buttress (if present).
Emergent trees	Trees projecting well above canopy, with crowns exposed on all sides.
Establishment phase of revegetation	The period from when seeds or seedlings are planted until they have 'captured' the site, forming a relatively closed canopy and suppressing competing grasses and other weeds. The establishment phase may last three to five years, depending on site conditions, planting design, maintenance, etc.

Term	Definition
Establishment statistics	Details of the on-ground works done in a project.
Fine woody debris	Fallen logs and branches 2.5-10 cm diameter, lying within 2 m of the ground. It usually adds little to woody debris volume and can dry out, making it poor habitat for many organisms. However, it may be the only type of woody debris present on young revegetated sites.
Forest structure	The arrangement of trees and shrubs at a site, assessed by surveying stem density in a range of size classes (shrubs, and trees by dbh class).
Floristic composition	The assemblage of plants present at a site.
Ground cover	The proportion of ground obscured by (a) vegetation <1 m high (scored separately for each of: grass, herbs, ferns, vines and scramblers, trees and shrubs, moss and cryptograms); (b) leaf litter and fine woody debris; (c) coarse woody debris; (d) rock; (e) soil; and (f) other (including tree trunks, roots).
Herbs	Soft-stemmed plants (other than ferns, moss, etc.).
Landform	A description of the topographical location of a site, e.g. plateau, crest, upper slope, mid-slope, lower slope, stream bank, flat.
Leaf litter	Fallen leaves and branches <2.5 cm dbh.
Metadata	A description of a collection of data: usually includes a description of what attributes the data are about, the methodology used to collect the data, where the data are stored and in what format, the names of relevant computer files, etc. The recording of metadata allows someone else to access and understand a datafile.
Monitoring	For the purposes of this toolkit, monitoring is defined as the repeated survey of selected attributes to track and evaluate the progress of revegetation at a site, or to compare the outcomes of different revegetation techniques.
Objectives	The main purposes of the project, in broad terms. Examples include improved biodiversity outcomes (e.g. conservation, habitat restoration), timber production, other forest products (e.g. bush tucker), stream bank stabilisation, catchment protection, erosion control, shelterbelts.
Photopoint	A place from which photos are taken for monitoring changes at a site. In this toolkit, photopoints are to be located at the start of each transect, as well as at a point looking across the revegetated site.
Project ID	Unique code given to a project, for example by a funding body, to simplify the storage of information in a database.
Quadrat	A survey plot of defined dimensions (e.g. 5 m x 10 m).
Recruitment	The process that describes the regeneration of plants at a site. Recruitment can be from plants which already grow at a site ('in-situ') or from dispersal from plants outside a site ('ex-situ').
Reference forest type or condition	A description or example of the type of forest that a project is trying to restore or create at a site. In many cases, this is the forest type that occurred at a site prior to clearing. However, the pre-clearing forest type may not be known, or may no longer be appropriate (e.g. if environmental conditions at the site have changed significantly since clearing). In these cases, another forest type may be chosen as the reference, or the reference condition may need to be described from scratch.
Reference sites	Examples of the reference condition (e.g. sites in remnant forests of the type that occurred on a site prior to clearing). Comparison with reference sites can show the extent to which revegetated sites have reached target conditions, and what attributes need further development.
Remnant enhancement	Actions undertaken to improve remnant condition, e.g. weed control.
Remnant protection	Actions undertaken to protect a remnant forest, e.g. fencing from stock.
Replicate sites (or plots)	Two or more sites or plots where a treatment or survey is repeated to help control for site-specific factors (e.g. history). They increase effort but also the generality of results. Replicate plots within a site are useful when attributes are patchy (e.g. woody debris). If a monitoring program does not include replicate sites, the results may not apply beyond the site studied.

Term	Definition
Revegetation	Planting of cleared or degraded land.
Shrub	For the purposes of this toolkit, a woody-stemmed free-standing plant 1-2 m high. May include tree saplings as defined here.
Site capture	The stage of development reached by a revegetated site when it will continue to develop on its own towards the reference condition, without large management inputs. In rainforest, site capture occurs when the planted trees form a relatively closed canopy and suppress competing grasses and other light-dependent weeds.
Special life forms	Plant life forms characteristic of rainforest and/ or particular forest types. Includes: strangler figs, hemi-epiphytes, vines ('slender' <5 cm diameter, 'robust' >5 cm diameter), vine towers, vine tangles, thorny scramblers, epiphytic ferns, tree ferns, ground ferns, palm trees, understorey palms, cordylines, herbs with long, wide leaves, herbs with strap leaves, cycads, and any other characteristic life form. See illustrations on page 21 for selected examples of these life forms.
Species richness	The number of species in a defined group of animals or plants.
Stag	Dead standing tree.
Stratification	Selection of sites based on particular criteria, e.g. soil, aspect, rainfall. When monitoring replicate sites, stratification can help control for the effects of environmental factors on target variables. Otherwise, natural variation ('noise') may swamp the 'signal' that is being monitored.
Structural damage to trees	Damage to trees resulting from storm or cyclone damage. In this toolkit, structural damage is assessed as: 1 = defoliation and smaller branches broken; 2 = larger branches broken, 3 = trunk broken; 4 = tree pushed over at >45° angle or uprooted.
Surrogate	A variable (often relatively easy to survey) that is monitored in place of another, with which it is correlated. For example, the volume of woody debris might be monitored as a surrogate for the richness of beetles that live in rotting logs.
Survey regime	A term that describes the number and frequency of monitoring surveys. The survey regime should address the timescale over which changes to target variables are expected to occur and the ecology of the target variables (e.g. a monitoring program which targets birds may need to account for seasonal migration). 'One-off' surveys may be strongly affected by chance events (e.g. prevailing weather) or systematic bias (e.g. seasonal variation).
Target variables	Attributes surveyed in a monitoring program (e.g. survival, canopy cover, bird species composition). They should be relevant to the objectives of the project: e.g. a project that aims to provide habitat for birds should ideally monitor use of the site by birds, or at least attributes associated with birds (e.g. forest structure). Target variables vary widely in the effort, skills, permits, etc., required to survey them.
Transect	A survey line of defined length (e.g. 50 m).
Tree	Woody-stemmed free-standing plants >2 m high.
Tree density	Number of tree stems per ha.
Woody debris	Fallen logs and branches, lying on or within 2 m of the ground.

Appendix 1: Reference Canopy Cover Photographs
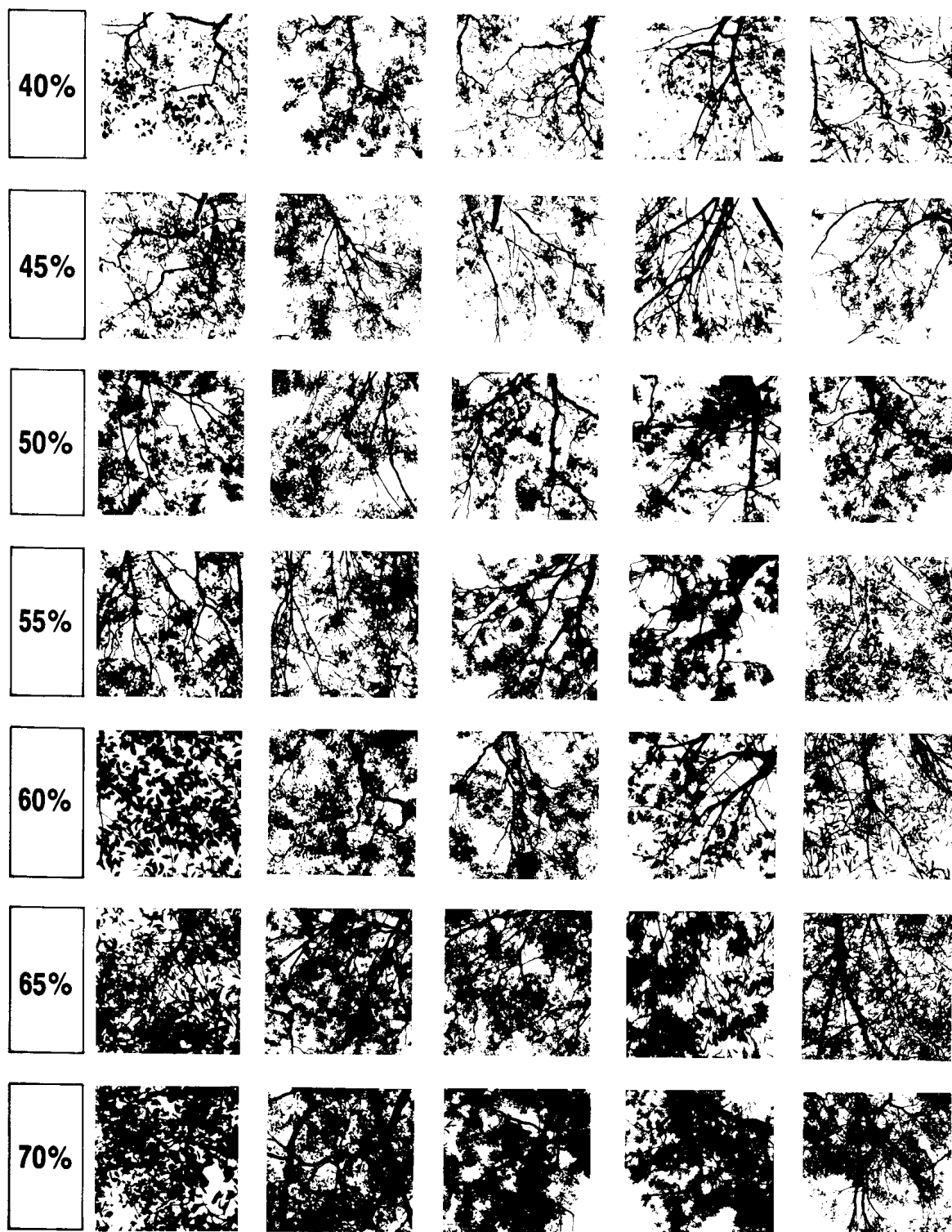
Source: Walker and Hopkins (1990).

Note: Canopy cover in rainforest is often greater than 70%.

Appendix 2

How to Calculate Canopy Cover from Digital Photographs

Visual estimates of canopy cover can be very subjective, and it may often be desirable to use a more objective, repeatable method. One such method uses digital photographs to estimate canopy cover. This method has the additional advantage that the photos can be stored for later reference or used for showing changes in cover over time.

The method presented below estimates canopy cover from digital photos using Microsoft Word. It is based on superimposing a 10 x 10 grid (the internal gridline intersections of a 11 x 11 table) over a digital image of the canopy. Canopy cover (percentage) is estimated by counting the number of grid intersections with vegetation (or by counting grid intersections with the sky, and subtracting this number from 100).

Two versions of the method are given. The first version, below, is intended for users who are familiar with manipulating images and tables in Microsoft Word. The second version, on the following pages, is intended for users with a more basic knowledge of the program.

Short Description: Method for Estimating Canopy Cover from a Digital Image

Start Microsoft Word and open a new document.
Create an 11 row x 11 column table with closely spaced (e.g. 0.7 cm) columns and rows.
Insert a picture of the canopy into the document.
Format the picture so that it sits behind the text.
Move the picture so that it sits just inside the top left edges of the table.
Resize the table, so that its right and lower boundaries extend just outside the edges of the picture.
Resize the columns and rows so that they form a regularly spaced grid over the picture.
Count the number of grid intersections with vegetation to calculate the percentage of canopy cover, or count intersections with the sky, and subtract from 100 to determine canopy cover (see example, below).

Note: To more accurately determine whether the grid intersects with vegetation or the sky, view the document at 200% zoom.
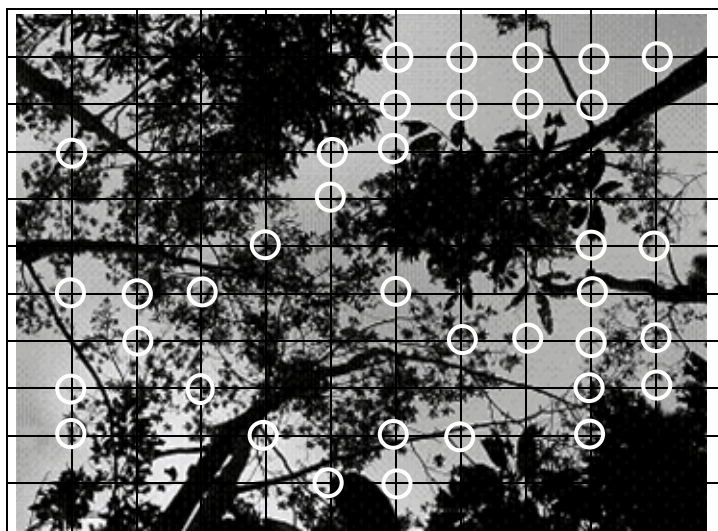
A similar method could be used to estimate canopy cover from photos taken with print film, if necessary, by using a 10 x 10 grid drawn on clear plastic.

Detailed Description: Method for Estimating Canopy Cover from a Digital Image

Note: These instructions have been written for versions of Microsoft Office 2000 and 2003. Where necessary, separate instructions are given for users of Microsoft Office 97.

1. Start Microsoft Word and open a new document.
2. Create an 11 x 11 table with closely spaced (e.g. 0.7 cm) columns and rows.
   - *From the menu* Table*, go to* Insert*, then* Table*.*
   - *A new window will appear. In this window, under* Table size*, specify 11 columns and 11 rows. In the same window, under* Autofit behaviour*, specify* Fixed column width *and click the top arrow of the adjacent panel so that* 0.7 cm *appears (this ensures that the table is initially smaller than the picture).*
   - *Click* OK *when finished. The table should appear within the new document, as shown below.*

Microsoft Office 97 Users:
- *From the menu* Table*, go to* Insert*, then* Table*.*
- *A new window will appear. In this window, under* Table size*, specify 11 columns and 11 rows. In the same window, for* Column width*, click the top arrow of the adjacent panel so that* 0.7 cm *appears (two clicks).*
- *Click* OK *when finished. The table should appear within the new document, as shown to the left.*

3. Insert a picture of the canopy into the document under the table.
   - *Place the cursor below the table.*
   - *From the menu* Insert*, go to* Picture*, then* From file*. A new window will appear. Locate and select the appropriate image and click* Insert*.*


4. Format the picture so that it sits behind the text.
   - *Place the cursor over the picture and right click your mouse. A menu will appear.*
   - *Select* Format picture*. A window with several tabs will appear. Select the* Layout *tab, then select* Behind text*. Click on* OK*. It may be necessary to repeat this step in some versions.*

Microsoft Office 97 Users:
- *Place the cursor over the picture and right click your mouse. A menu will appear.*
- *Select* Format picture*. A window with several tabs will appear. Select* Position *and then* Float over text*. Next, select* Wrapping*, and then* None*. Click on* OK*.*
- *Place the cursor over the picture and right click your mouse again. A menu will appear. Select* Order*, then* Send behind text*.*

5. Move the picture so that it sits just inside the top left edges of the table.
   - *Place the cursor over the picture, left click your mouse, and drag the picture to the desired position.*
   - *The gridlines of the table should appear in front of the picture. If not, repeat Step 4, above.*
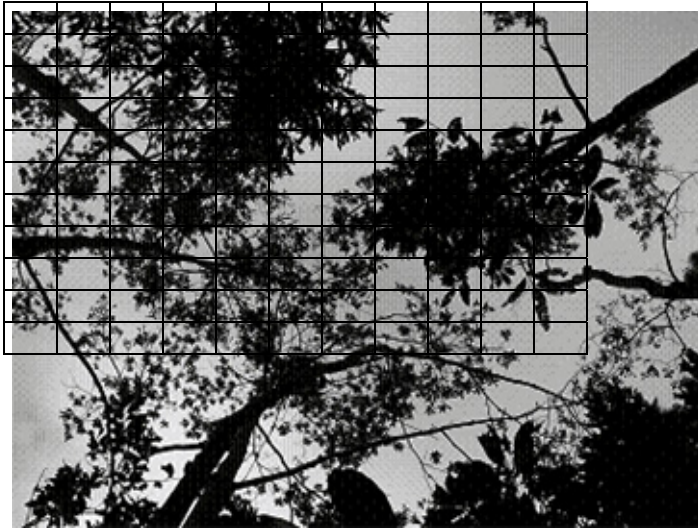
6. Resize the table so that its right and lower boundaries extend just outside the edges of the picture.
   - *Place the cursor over the right edge of the table. The cursor should change to two parallel lines. Left click your mouse and drag so that the edge of the table lies just outside the picture.*
   - *Then place the cursor over the lower edge of the table. The cursor should change to two parallel lines. Left click your mouse, and drag so that the edge of the table lies just below the picture.*
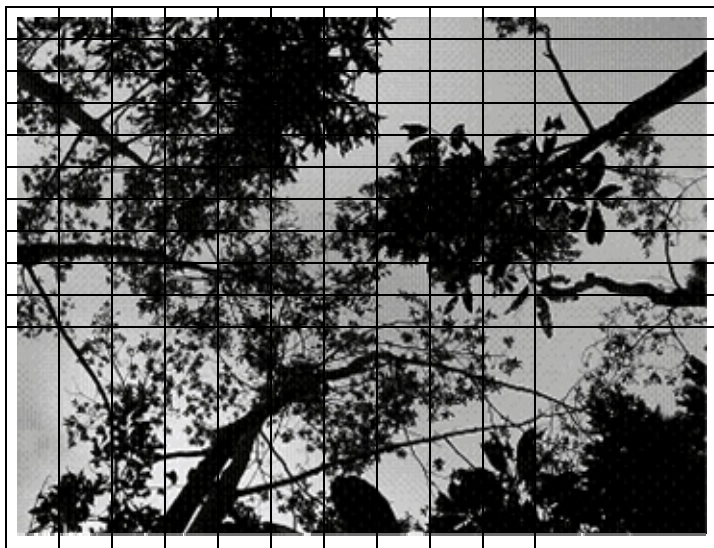
7. Resize the columns and rows so that they form a regularly spaced grid over the picture.

    – *Place the cursor to the left of the table; it should change into an arrow. Left click your mouse and drag down so that all the rows of the table are highlighted.*
    – *From the menu* Table*, go to* Autofit*, then click on* Distribute rows evenly*.*
    – *Then, while the table is still highlighted, go to the* Table *menu, select* Autofit*, then click on* Distribute columns evenly*.*
    – *The table should now form a regularly spaced grid over the picture.*
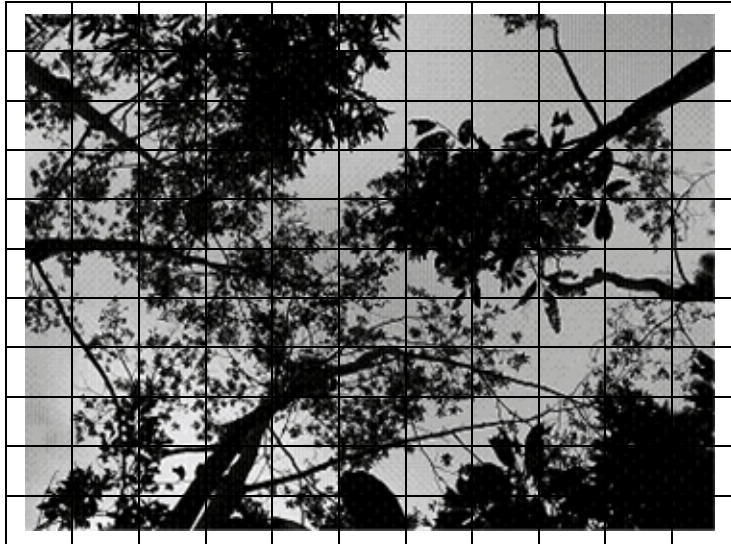

Microsoft Office 97 users:

As above, except Autofit does not occur in the menu.

Instead, click on Distribute rows evenly*. Visit the* Table menu *again to* Distribute columns evenly*.*

8. Count the number of grid intersections with vegetation to calculate the percentage of canopy cover (or count intersections with the sky, and subtract from 100 to determine canopy cover).

    – *Carefully count the number of grid intersections that coincide exactly with vegetation cover. This number is the percentage of canopy cover. For example, if 25 grid intersections coincide with vegetation in a photo, then canopy cover is 25%. Note: If canopy cover is dense, it will be easier to count intersections with the sky, and subtract this number from 100 to determine canopy cover. In the example below, there are 36 intersections of the grid with the sky, so canopy cover is 100 - 36 = 64%*
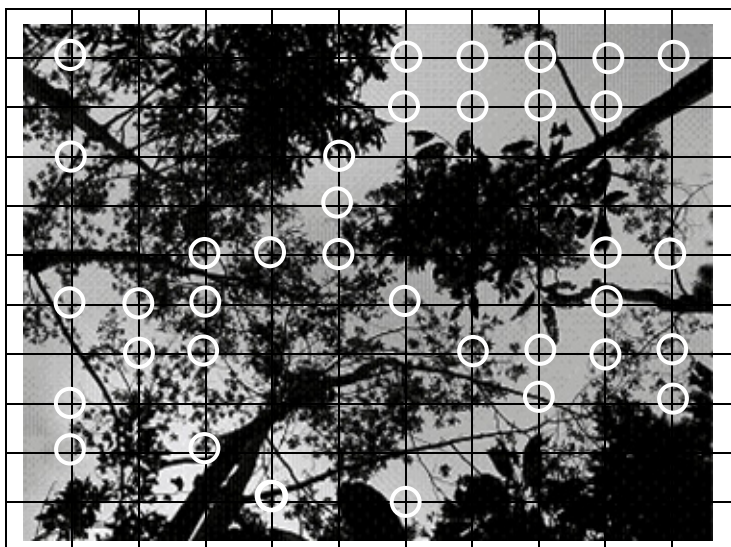
Note: To more accurately determine whether the grid intersects with vegetation or the sky, view the document at 200% zoom.

Further information

Marine and Tropical Sciences Research Facility
PO Box 1762
CAIRNS QLD 4870

or

Marine and Tropical Sciences Research Facility
PO Box 772
TOWNSVILLE QLD 4810

This document is available for download at http://www.rrrc.org.au/publications