APPENDIX 3

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APPENDIX 3

SWIFTSYND METHODOLOGY

A methodology for measuring a minimum data set for calibrating pasture and soil parameters of the pasture growth model GRASP

Appendix 3 for Final Report DAQ-124A

EVALUATING THE RISKS OF PASTURE AND LAND DEGRADATION IN NATIVE PASTURES IN QUEENSLAND

Principal Investigators:- K A Day G M McKeon and J O Carter

Authorship and Acknowledgments

In deference to the needs of the bureaucracy and libraries, the authorship of this document is Day and Philp. However we acknowledge that the true author of this document is G.O. GUNSYNpD, a *nome de plume* for the large team that has produced the GRASP model, developed and refined the methodology described in this document and, most of all, collected data in the manner described in this preschedule for so many locations (>100 sites) since 1986.

This preschedule draws on previously unpublished documentation of the methodology known as GUNSYNpD: Grass Under Nutritional Stability: Yield, Nitrogen and phenological Development.

Updates to Methodology

Please forward any comments, amendments or additions to this document to:

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It is envisaged that this bibliography will become "active" on a new web site for NAGSNET (North Australia Grazing Systems Network) group.
Once constructed this web site will be linked to the Long Paddock web site:
http://www.dpi.qld.gov.au/longpdk

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SECTION 1: INTRODUCTION

The SWIFTSYND methodology is an abbreviation of methods used in the GUNSYNpD project. The GUNSYNpD project sought to collect detailed field information on native pasture growth from a wide variety of pasture communities across Queensland. The information collected provided parameters for the GRASP model, enabled testing of the model's generality and served as a basis to test modifications to the model.

The SWIFTSYND methodology is applicable to all northern Australian savanna communities. The primary aim of Swiftsynd is to derive parameters to run the model for the widest possible range of communities and soil/species combinations throughout northern Australia. The main parameter sought is the water-use-efficiency of the pasture, that is, the amount of above ground dry matter production per mm of transpiration. It is assumed that water-use-efficiency is related to soil fertility and species composition. The large number of sites studied in the SWIFTSYND project will enable us to broadly determine such relationships.

The objective of the SWIFTSYND methodology is to specify a minimum data set from which relationships can be drawn to simulate pasture growth at a site. However the methodologies presented in this document represent more than the minimum requirements to meet this objective. Extra tasks are included which fall into either of two categories. Firstly, certain tasks have been included because they provide cross checks on important data collected. Secondly, tasks have been included which may enable an operator to gain further insights on pasture growth which, at present, may not be included in the pasture growth model. An important example in this regard is the separation of pasture into various species groupings. In order to enable operators to better plan their study the bare minimum data set is outlined in the following section. It is hoped that operators build on this minimum data set to suit their own interests and objectives.

Field data sheets will help to streamline data collection from all sites. We urge operators to use these sheets and quickly report any problems to the authors. Many operators will prefer to construct spreadsheets according to their preferred software. Therefore a general spreadsheet is not provided but may be available on request. The calculation sheets attached will guide the design of spreadsheets. If you are willing to make your spreadsheets available for others to use, please inform the authors. In any case we request copies of the data sheets and calculations following each harvest. In this regard supply copies of field sheets and, if available, data in spreadsheet, database or ASCII format. If computing facilities are not available we are happy to make calculations from field sheets.

We urge operators to complete the few calculations on the field and laboratory sheets attached. These calculations will provide a quick check on more detailed calculations and should, ideally, be calculated by hand once data is collected.

This document will continue to be improved with your comments. The strength of SWIFTSYND comes through the combined effort and insight of many people.

SECTION 2: OUTLINE OF A MINIMUM DATA SET

The measurements outlined in this section are the minimum measurements required to determine pasture and soil parameters for the pasture growth model GRASP. A broad description of the model is provided in order to clarify the rational for taking measurements specified.

2.1 The water balance

The first stage of modelling pasture growth is to determine pasture water-use (transpiration). Inputs of water to a site include rainfall, run-on and irrigation. Water may be lost as run-off before entering the rooting zone. Water which reaches the rooting zone is stored for a period before being transpired, evaporated or drained beyond this zone. A certain amount of water remains in the soil being held too tightly for plants, the atmosphere or gravity to extract. GRASP accounts for these various pathways of water movement by calculating a water balance. Whilst it is difficult to physically measure some components of the water balance (e.g. transpiration) others are more easily measured (e.g. rainfall and stored water).

Rainfall and pan evaporation are the major climatic influences on the water balance. It is essential to measure rainfall at a SWIFTSYND site. If it is not possible to measure rainfall daily at a site then accumulated rainfall should be recorded. Accumulated rainfall should be partitioned to daily values according to the daily distribution of rainfall determined from local daily rainfall readings.

The influence of soil physical features and plant roots on the water balance can be described by measurements of PAWC (Plant Available Water Capacity). The minimum requirements in this regard are measurements of gravimetric water content at wilting point and at field capacity (FC). For swelling (cracking) soils FC can be estimated from the following equation:

$$FC \text{ (gravimetric in swelling soils)} = 0.124 - 0.265D + 0.160D^2 + 1.284 \times 15\text{bar moisture}$$

where D is depth (m) from surface .

Soil bulk density is required to convert gravimetric soil moisture content to volumetric moisture. Soil bulk density should be measured once for a site. In swelling (cracking) soils bulk density can be estimated from gravimetric moisture content as follows:

Bulk density (swelling soils) = 0.95 ¸ (1 ¸ 2.65 + gravimetric moisture content)

Plant cover influences the water balance by influencing run-off, transpiration and evaporation. The minimum data requirements in this regard are an estimate of total and green cover at each harvest.

Regular measurements of stored soil moisture provide a guide as to whether the model is calculating the water balance with reasonable accuracy. A minimum requirement is to measure gravimetric soil moisture content at each harvest. Moisture content should be determined at 10cm increments down the profile to 1m if possible. Measurements should be made initially after burning or mowing and at each subsequent harvest. Bulk density should be measured once (as above) to convert measurements of gravimetric moisture (g/g) to volumetric moisture (mm).

2.2 Pasture growth

The second stage of the modelling process is to calculate pasture growth. Pasture growth is calculated from a number of factors and in various ways according to factors limiting growth at a given time. Throughout the growing season water is often the most limiting factor. When water is limiting growth, plant growth is calculated from transpiration and the transpiration-use-efficiency (TUE) of the pasture. TUE specifies the potential rate of pasture growth per mm of water transpired. TUE is dependent on soil fertility and species composition. SWIFTSYND and GUNSYND measurements have established that TUE is also influenced by daytime vapour pressure deficit (VPD). Whilst it is not necessary to measure soil fertility or species composition in order to calculate TUE it is necessary to measure these factors in order to understand the underlying factors influencing TUE. Through providing combined measurements of TUE, soil fertility and species composition across a wide range of sites, SWIFTSYND will provides a means of assessing relationships between these factors.

Factors which limit pasture growth at other times include intercepted solar radiation, air temperature, pasture nutrient levels, pasture basal area and the degree to which soil moisture has been depleted. Minimum data requirements are:

- green cover measured at each harvest (to calculate intercepted solar radiation);
- total % nitrogen in grass and forbs at each harvest;

- pasture basal area (measured once); and
- dry matter yield of green grass, dead grass and forbs at each harvest.

SECTION 3: SUMMARY OF MINIMUM DATA REQUIREMENTS

3.1 Climate

- daily rainfall measured at the site or;
- accumulated rainfall measured at the site and daily rainfall measured nearby

3.2 Soils

- gravimetric moisture content (10cm increments in the profile) measured at the following times:

1. initially after burning/mowing;
2. at each harvest;
3. at wilting point;
4. at field capacity (FC) except for swelling (cracking) soils (below).

   FC (gravimetric in swelling soils) = 0.124-0.265D+0.160D^2+1.284 x 15bar moisture

   where D equals depth (m) from surface and 15 bar moisture (gravimetric: measured in a soils lab or estimated as the wilting point).

5. • soil bulk density measured once except in swelling (cracking) soils (below).

   Bulk density (swelling soils) = 0.95 ¸ (1 ¸ 2.65 + gravimetric moisture content)

3.3 Plants

- green and dead plant cover estimated at each harvest;
- dry matter yield of grass and forbs (measured at each harvest);
- dry matter yield of leaf, stem and inflorescence for each grass group sampled (measured at each harvest);
- total % nitrogen in grass and forbs (measured at each harvest)
- pasture basal area (measured once)
- tree basal area (measured once)

3.4 Other

- The best site description which can be made given the operators skills

- Sufficient information to allow others to relocate the site.

3.5 Saving time

The greatest time saving to be made in sampling SWIFTSYND is to limit the number of species groups separated to a bare minimum and thus minimising the number of samples cut in the field and sorted in the laboratory. The minimum requirement for SWIFTSYND is a grass and forb separation. However we strongly recommend at least separating the dominant grass at the site from other grasses. This information may provide insights into plant growth which will facilitate improvements to the GRASP model.

SECTION 4: SUMMARY OF TASKS AND TIMING

4.1: Tasks

1. Select and prepare site prior to burning/mowing
2. Report site description (community/species/soil/location) to Project Leader.
3. Burn or mow site (August, September, October).
4. Assess yield, cover and soil moisture immediately after burning/mowing (or as soon as possible after this time).
5. Conduct four harvests involving field and laboratory work (November through to September)
6. Measure grass basal area (December/January)
7. Measure soil field capacity and wilting point when opportune
8. Measure soil bulk density when soil moist
9. Describe site and soil as per McDonald *et al.* when local soil surveyor available

4.2: Timing of harvests

A minimum of four harvests are needed per year at each site. The first growth period (between burning and harvest 1) is dependant primarily on the ability of the pasture to regrow following defoliation. The second growth period (between harvest 1 and 2) is governed primarily by transpiration-use-efficiency and soil water limitations. The third growth period (between harvests 2 and 3) can be associated with cessation of growth associated with nitrogen limitations and flowering. Rate of detachment is determined in the final period between harvests 3 and 4. The timing of harvests are broadly as follows:

1. Some initial measurements and observations following mowing or burning;
2. 1st harvest after spring growth (November/December);
3. 2nd harvest near the end of summer growth (February/March);
4. 3rd harvest (May/June) as soon as possible following peak yield;
5. 4th harvest (August/September) prior to commencement of spring growth.

The timing of the first harvest is flexible and depends on rainfall. Later harvests should be conducted within the months suggested keeping harvests approximately three months apart. Harvest schedules for harvests 2 to 4 should be maintained despite lack of growth as such observations indicate conditions limiting growth.

SECTION 5: SITE SELECTION

5.1 Location

Sites are most useful if representative of soils and species within:

1. a grazing trial or other experiment
2. an important land system or pasture community (a priority list is available)

5.2: Position

Ideally a site should be positioned as follows:

- **Slope** - Mid-slope position preferable (run-on = run-off)
- **Soils** - Uniform with respect to type and depth (auger some holes to make sure).
- **Vegetation** - Uniform pasture with respect to species composition. If the effect of trees on pasture production is not of interest then avoid trees. As a general rule the area influenced by tree roots forms a circle from the trunk of which the radius is twice the height of the tree.
- **Met Station** - Proximity of meteorological data should be considered (see section: Meteorological Data Requirements)

As the exclosure is small, make sure that species composition and soil type at the site represent the broader region of interest.

SECTION 6: SITE PREPARATION

- determine dominant grass, sub-dominant grass
- determine exclosure design
- fence the exclosure
- mow or burn the exclosure
- install a rain gauge
- mark out quadrats
- take initial measurements of soil moisture, yield and cover

6.1 Determine species composition

For each quadrat harvested, separate pasture into the following groups:

1. dominant grass
2. sub-dominant grass
3. other grasses
4. forbs (dicots) including native legumes
5. sown legumes or naturalised legumes

Dominant and sub-dominant grasses are preferably identified at a species level. However identification at genera level is acceptable. This may be the case, for instance, where a number of species of the one genera together contribute significantly to pasture yield but, alone, form a minor component. The dominant and sub-dominant grasses should be determined during site selection.

6.2 Determine exclosure design

1. Choice of exclosure design depends on quadrat area selected and study duration

Quadrat area is largely dependant on pasture density and expected pasture yield. Generally a ½ m^2 quadrat is appropriate for dense to moderately dense pasture where expected peak yield is greater than 3000 kg/ha. For sparser pasture where expected peak yields is less than 3000 kg/ha then a 1 m^2 quadrat is more appropriate. Final choice of quadrat area is left to operator discretion.

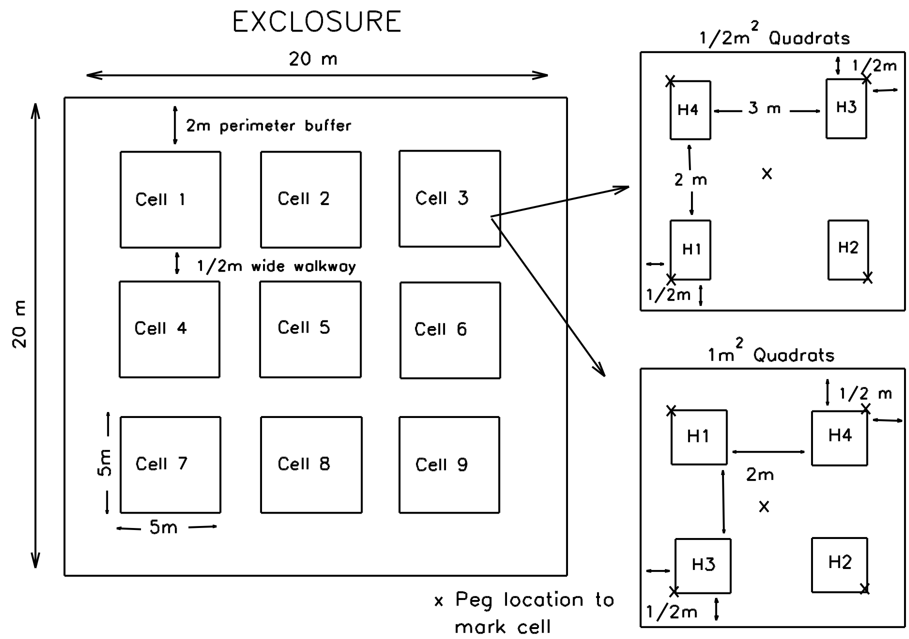
Studies are generally conducted for one or two years and appropriate exclosure designs are presented in Figure 1. The style of exclosure indicated in Figure 1 has a number of advantages. The exclosure is small thereby minimising cost and allowing a uniform area to be chosen. The design ensures uniform coverage of the exclosure at each harvest. Minimal pegging is required in preparation for sampling. Quadrats are easy to locate or relocate. Trampling is avoided through provision of walkways.

For each harvest a quadrat location is randomly chosen within each of the nine cells indicated in Figure 1. Figure 2 may be used to randomly allocate quadrats. At each harvest quadrats are numbered according to the cell (Figure 1) in which they are located (i.e. quadrat 1 in cell 1, quadrat 2 in cell 2 and so on).

The suggested design may allow some bias in pasture yields due to the potential effect a cut quadrat can have on neighbouring uncut quadrats (e.g. reduction in moisture and nutrient competition). This may introduce a progressive bias toward higher yields in later harvests as more surrounding quadrats are cut. In order to minimise potential bias the distance between quadrats should be made as wide as possible. A minimum distance of 1m should be left between quadrats.

One way to assess whether bias is occurring is to compare yield in the cells (Figure 1) with yields in a nearby undisturbed area. The designs presented in Figure 1 do not cater for such measurements. However if an adjacent undisturbed area is available then yield should be estimated in this area by measuring pasture height. At least 50 height measurements should be taken on the undisturbed area at each harvest. Take the measurements from the same points each time. At the completion of the trial these measurements will be compared with other height measurements (described later).

(a)



(b)

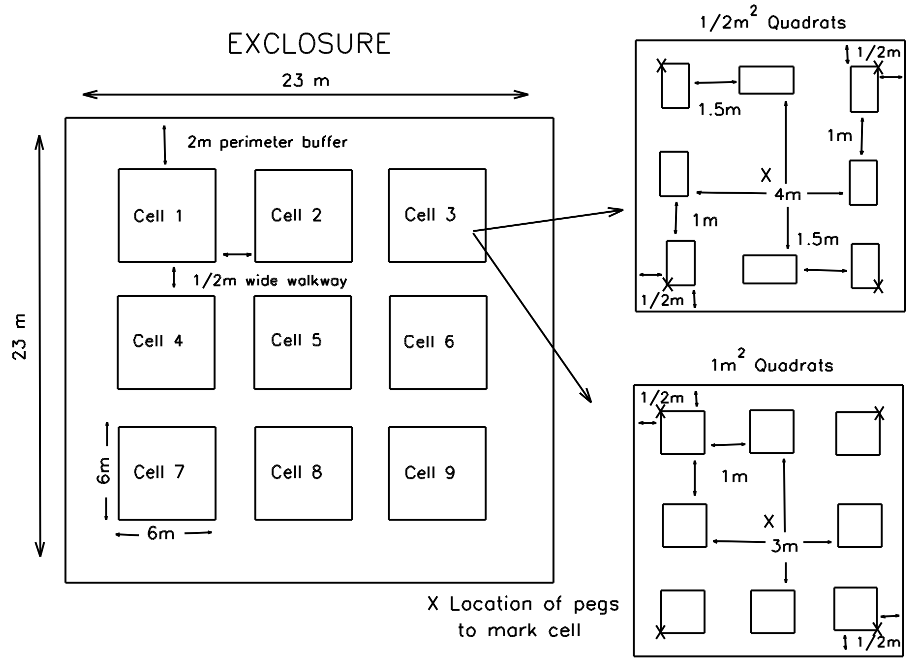
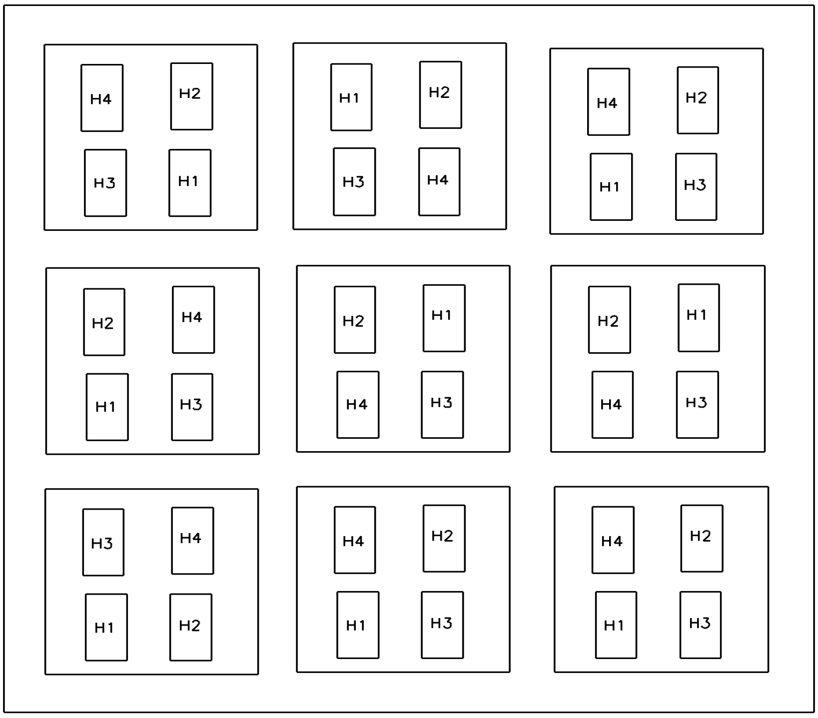


Figure 1 Exclosure design for 1 year (a) and 2 year sampling (b) with either ½m² or 1m² quadrats

(a)



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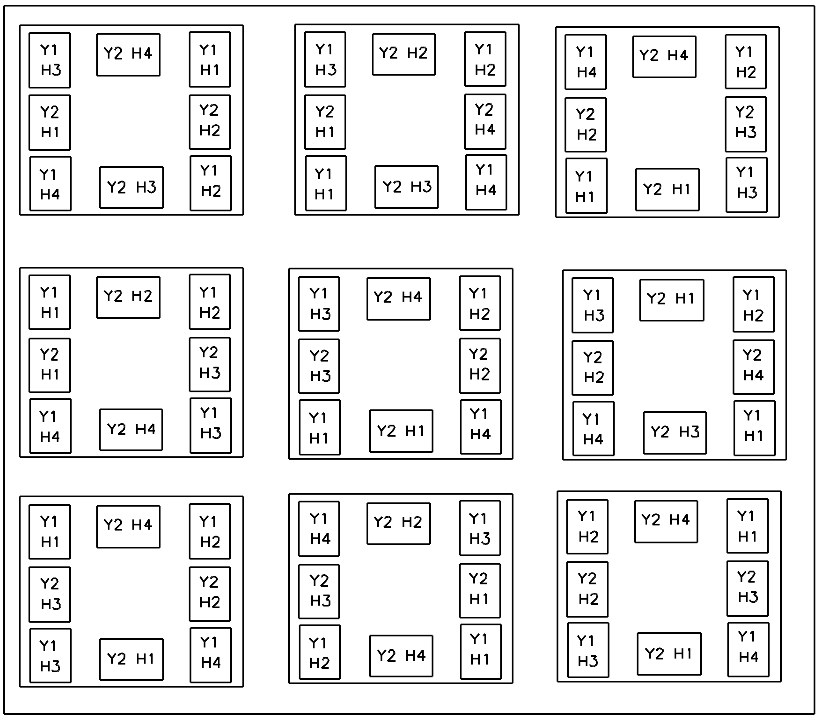

Figure 2 Harvests randomly allocated to quadrat positions for the 1 year (a) and 2 year (b) exclosure design.

6.3 Fencing

Fencing design is left to individual operators. The fence must **exclose all grazing animals** (within reason) for the period of the study. Exclosing small animals such as rabbits may require the use of chicken wire netting or the like. This should be placed such that a portion (not an edge) rests flat on the ground (facing outward). If rabbits are a real concern then wire netting should be partially buried. Cattle will lean over fences in dry times so the fence must be secure and an adequate distance left as a buffer inside the fence. Be sure to label the exclosure so people are aware of its purpose (e.g. exclosures have been previously used to camp sheep). Electric fencing is attractive to thieves (past experience) so should only be used where security is guaranteed. Consideration should be given as to whether such fencing is adequate for the purpose of exclosing small animals.

6.4 Installing a rain gauge

Daily rainfall should be measured on site or within 100 metres. If daily rainfall can not be read at the site then an accumulating rain gauge can be installed provided daily rainfall is measured within 5 kms. Accumulated rainfall at the site can then be partitioned according to the daily gauge. An accumulating gauge differs from a regular rain gauge in that a middle cylinder is not included and a layer of baby oil is placed in the gauge to minimise evaporation. An accumulating gauge is generally larger than a normal gauge. An example of a tried design is: 10cm PVC pipe sealed at the bottom end (PVC pipe cap) with a 10cm plastic funnel resting on a ring of silicon (seal) at the top end. The gauge is read by removing the funnel and inserting a thin dipstick with a tape measure attached. A tap can be placed on the bottom sealed end to make the gauge easier to empty. To avoid damage by stock attach the gauge to a star picket inside the fence.

6.5 Mowing or burning

The exclosure should be mown to 5 cm or burnt during spring to remove dead material. Decide whether you intend to mow or burn in August. Sites should be mown if burning is not feasible or not common practice in the region. Sites should be mown when the pasture is dry to minimise stress to the plants. Mowing should generally take place before Spring rains in late August, September or early October. The remaining litter should be removed from the site by raking. Although
raking may cause natural litter loads to be disturbed, raking is necessary to remove litter added by mowing.

Timing of burning should be in accordance with local practice, for example, after spring rainfall. Burnt litter should **not** be removed from the site. As non-uniform burning will create variation in harvested yields a light mowing may be required after burning to even up the pasture. A grass catcher should be used in such a case to avoid the need to rake.

6.6 Marking out quadrats

Insert pegs at four corners of the 9 cells (36 pegs) to mark the cells. These pegs are best placed at the outside corner of the four corner quadrats in each cell (see Figure1). After marking cells, mark the quadrats allocated to the first harvest by pegging the diagonally opposite corner to the corner already marked (9 pegs). After each harvest the nine pegs should be moved to new quadrat positions ready for the next harvest. Place one peg in the centre of each cell (9 pegs) to mark regular pasture height measurement positions.

6.7 Initial measurements

Estimates of yield and cover as well as measurements of soil moisture are required to describe the initial conditions at the site and, as such, to determine the rate of regrowth following burning or mowing. The model will be run from the date of these measurements. Measurements can be taken directly after burning or mowing or left to the earliest convenient time after this. If sites are burnt, yield and green cover will often be zero but whether this is the case will depend on the uniformity of the burn. Dead cover will rarely be zero due to the presence of tussock bases. If sites are mown to 5cm then yield will not be zero as 5cm is greater than the normal cutting height.

Estimate and record yield (green and dead). Yield estimates should exclude material below normal cutting height (1-2cm). If a reasonably confident estimate of yield cannot be made then it should be measured. In this case harvest material from three quadrats placed within the perimeter buffer of the exclosure. Quadrats should be selectively placed so as to best represent pasture yield within the exclosure. Bulk material from the three quadrats into the one bag to obtain average yield.

Estimate and record cover (green, dead, bare, litter, rocks). Cover should be estimated from quadrats marked for harvest 1.

Take three soil moisture cores mid-way along each of three sides of the exclosure (within the perimeter buffer: Figure 1).

Measure pasture height in the centre of each cell (four height placements per cell adjacent to centre peg).

Photograph site and quadrats as per a normal harvest.

Methodologies for the measurements outlined above are detailed in later sections.

6.8 Equipment summary for site preparation

- tape measure
- quadrat
- fencing materials
- 54 pegs (year 1) with an additional 9 pegs in year 2.
- rain gauge (normal or accumulating with baby oil)
- additional star picket and wire to support rain gauge
- mower, whipper snipper or matches
- rake
- fire control equipment
- recording sheets: initial measurement field sheet and soil moisture field sheet.

SECTION 7: FIELD SAMPLING TASKS (EACH HARVEST)

Tasks required at each harvest include:

- photograph site from each corner
- estimate for each quadrat
    1. pasture height
    2. pasture cover
    3. species composition
- photograph quadrats prior to cutting
- collect current seasons litter from each quadrat and bulk into 1 bag.
- cut quadrats to predetermined plant groups
- weigh fresh plant material in the field (optional)
- collect soil moisture profiles

7.1 Photographing site

Photograph site from each corner. Preferably photograph from as high as possible (e.g. stand on the back of a vehicle). Include an object or person in the photograph for scale.

7.2 Measuring pasture height

Pasture height measurements can offer an estimate of yield which can be taken between harvests or in extreme circumstances instead of harvesting. In order to estimate yield a regression between pasture yield and height is required. For this reason pasture height is measured before cutting each quadrat. Pasture height, in itself, is an important variable for the plant growth model.

To make a pasture height meter (Figure 3) flatten a beer carton and trim to 56 cm x 42 cm and a weight of 210 g. Cut a hole in the middle of the carton so that the carton slides freely down a metre rule. Calibrate the meter by recording the height when the carton rests on a concrete floor. Subtract this reading from subsequent pasture height measurements.

Pasture height should be measured at each harvest prior to quadrat placement. Take two measurements on each quadrat such that together they cover most of the quadrat. Pasture height measurements are taken by placing the end of the rule on the ground and lowering the carton gently onto the pasture. Record (on the pasture field sheet) the height at which the carton comes to rest. Average the two records for a quadrat. Round the average up for odds (eg. 49.5 = 50) and down for evens (48.5 = 48). Sum the nine average height records and divide by nine to determine the average pasture height for the site. Round this average to the nearest whole number.

Take four pasture height measurements from the centre of each cell. Take measurements adjacent to the centre peg. These measurements are taken at each harvest and as part of initial measurements during site preparation. Heights should be taken at the same points each harvest. These measurements can be repeated between harvests and can be used to calculate yields at these times. We suggest that such measurements be taken whenever possible. These measurements will also be used as a standard by which to compare height from the quadrats and thereby account for sample variability between harvests.

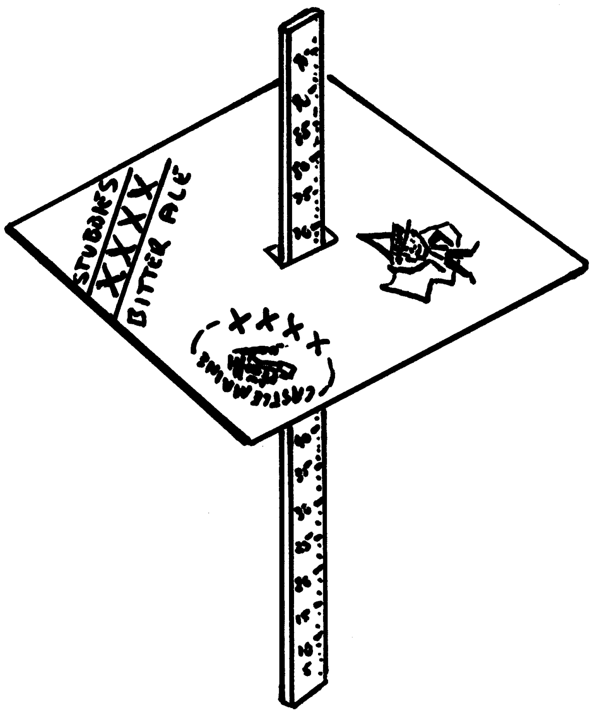

Figure 3 Pasture height meter

7.3 Estimating pasture cover

Estimate the percentage contribution of green and dead vegetation, bare ground, surface rocks and litter to total cover. Live stem and inflorescence is counted as green cover. Be sure that the operator is not colour blind (particularly red/green). The same person should estimate cover each harvest, if possible. Cover is defined as the *percent of the ground within a quadrat covered when viewing the quadrat from directly above.*

Therefore it is preferable to estimate cover whilst standing on a 20 litre drum (before or after photographing).

Record estimates on the pasture field sheet and ensure they sum to 100% for each quadrat. Average cover estimates for all quadrats (to one decimal place). Round the average to the nearest whole number. Minor adjustments may be required in rounding so that all cover groupings sum to 100%.

7.4 Estimating species composition

For each quadrat quickly estimate and record the contribution of each species group (determined during site preparation) to total dry matter yield. Estimate percent contribution to the nearest 5% and record on the pasture field sheet. Where a given component is present but makes less than 5% contribution, estimate contribution to the nearest one percent and adjust other numbers such that estimates for all groups sum to 100%. Record estimates on the pasture field sheet. The same person should estimate species composition each harvest, if possible.

The objectives of estimating the contribution of each species group to total yield are twofold:

1. to provide a measure of composition if this is not obtained by separating pasture into groups during harvesting. It may be planned at the outset to forego species separations or this may be forced due to time constraints.

2. to develop a relationship between estimated and observed composition if needed.

7.5 Photographing quadrats

Photograph individual quadrats prior to cutting using 35 mm colour slide film. Include a small sign in the photograph indicating date, site, and quadrat number. Photographs should be taken as close as possible to vertically above the quadrat. In order to do so, stand on an empty 20 litre drum (or a similar object 35cm or more high) to take photographs. This will also help to get the entire quadrat in the frame. Avoid shadows when photographing. Photographs are used to calibrate cover estimates of individual operators (see section Laboratory Tasks) and serve as a general reference.

7.6 Collecting litter

Collect litter prior to cutting. Bulk litter from all quadrats into one paper bag. This bag can be dried directly and contents weighed to determine litter dry matter yield (kg/ha).

Litter yield (kg/ha) = dry matter (g) ¸ total quadrat area (9 or 4.5 m^2) x 10 000 (m^2/ha) ¸ 1000 (g/kg).

Litter is very transient and, as such, dry matter dynamics of litter is difficult to study using the SWIFTSYND methodology. However the measurement is still useful. One circumstance where litter yield measurements are extremely useful is when a build up of litter has been observed in association with a loss of plant dry matter. Such instances confirm that detachment has occurred when otherwise, without litter measurements, this apparent decline in pasture yield may have been attributed to sampling variability. In this regard observations of litter build up or loss may prove as important, or more important, than a quantitative measure.

If collecting litter will prove too time consuming then make a general estimate of litter yield at the site at each harvest.

7.7 Cutting pasture

Clip each quadrat to 1.5-2.0 cm above ground level. Place species groups into separate, labelled plastic bags. We suggest the use of plastic as opposed to paper bags as they can be more easily re-used for latter harvests and thereby save a lot of relabelling. Keep these bags in the shade, when full, to avoid large differences in moisture content between the contents of each bag (e.g. place bags in a covered bin, fertiliser bag, esky etc.)

Species groups are decided on site selection (see previous section - "Selecting a Site"). The groupings and names decided during site selection should be adhered to from quadrat to quadrat and from harvest to harvest. So, for example, if it has been determined that speargrass is the dominant species at the site then it should be regarded as the dominant grass for every quadrat cut (even if in some quadrats it is not dominant).

If time does not allow separation of species into the above groups then adopt the following groupings:

1. all grasses

2. forbs (dicots)
3. sown/naturalised legumes

Operators should endeavour to separate grass into at least dominant and other grasses at either harvest 2 or 3 (close to peak yield). This will provide at least one estimate of pasture composition according to measured yield.

7.8 Measuring fresh weight of pasture in the field

Fresh weight is generally measured in the laboratory. However it may be useful to take these measurements in the field. This may be particularly useful when sampling some distance from a lab with a number of sites to be measured. The method has the advantage of enabling plastic bags to be reused for another site which can save bag labelling, bag losses etc. Fresh weight needs only to be measured to the nearest gram, or coarser, in this case. Protect the scales from wind influence as best as possible. Weights are recorded on Pasture Laboratory Sheet. Fresh material from each quadrat is bulked into a large plastic bag for each species group and taken back to the lab (see section: Laboratory Tasks).

7.9 Measuring soil water

Take soil samples from three randomly selected quadrats from the nine quadrats sampled for pasture yield. Use an auger to collect soil at 10cm intervals to 1m (if possible). Place the entire soil sample from each layer in a labelled container (e.g. air tight tin or sealed oven bag). Refill holes with soil of similar type to that removed to minimise disturbance to soil infiltration. Calculations for determining gravimetric and volumetric moisture content are described on the soil calculation sheet. Procedures for determining bulk density are described in a later section "Site Description".

An alternative to auguring is to take neutron probe counts. The neutron probe must be calibrated for each site and for different soil layers. Wet and dry readings should be used in the calibration. As neutron probes record volumetric soil moisture, calibrations should be made on volumetric measurements. Calibration of neutron probes requires a lot of work. Neutron probes should not be used for SWIFTSYND except where prior reliable calibration has been made or if other work on the site warrants the use of this equipment. Neutron probes be used to measure surface moisture content (to 20cm).

If a soil sampling rig is available then this may be used as an alternative to auguring. Samples will generally need to be taken in an exclosed area adjacent to the pasture sampling area. The exclosure should be designed in such a way as to enable the rig to take soil without disturbing the pasture sampling area.

A jackhammer with coring tubes can also be used for soil sampling. If available these may be worthwhile using on some soils. On hard soils tubes may bend making sampling difficult. Chrome molybdenum core tubes with strengthened tips do not bend or dent as easily as steel tubes. A lever device is needed to remove tubes from the soil.

7.10 Equipment summary for field tasks

- pasture and soil field data sheets
- camera
- 35mm colour slide film
- notepad
- photo labels
- 20 litre drum
- pasture height meter
- shears
- labelled plastic bags
- paper bag (for litter)
- quadrat
- soil tins (max. 30)
- auger

SECTION 8: LABORATORY TASKS (EACH HARVEST)

Laboratory tasks at each harvest include:

- Plant samples
    - ⇒ weigh fresh samples
    - ⇒ sub-sample fresh samples for 1) dry weight and 2) sorting
    - ⇒ dry sub-sample for dry weight
    - ⇒ weigh dry sub-sample
- sort sub-sample of fresh plant material
- grind plant material
- send ground samples for nutrient analysis
- Soil moisture samples
    - ⇒ weigh wet samples
    - ⇒ dry soil
    - ⇒ weigh dry samples
- Calibrate cover estimates using slides

8.1 Weighing fresh pasture samples

Fresh weight of plant samples for each quadrat can be measured either in the field or the laboratory. If a number of sites are to be sampled before getting back to the laboratory then it may be more convenient to measure fresh weight in the field (described under "Field Tasks"). If this has been done then the bulked samples for each species group are weighed fresh in the laboratory and recorded. Determine the total dry matter yield (all quadrats) for each species group (described below). The dry matter yield of each species group in each quadrat is determined as follows:

dry matter yld. (quad.) = fresh wt. (quad.) ¸ total fresh wt. (all quads.) x total dry matter yld. (all quads.)

If quadrat fresh weight is measured in the laboratory the following procedure should be followed:

- Sort bags into species groups and arrange in the order of quadrat number.
- Weigh each sample on a digital balance (to 0.1g)
- Record each weight on the laboratory pasture data sheet

- After weighing each grass group, bulk all samples of the same species group on a clean floor or bench
- Mix the bulk material thoroughly ready for sub-sampling.

For forb and legume groups bulk samples as above into a bucket but do not mix.

8.2 Sub-sampling pasture samples

A sub-sample is required from each grass species from which material is sorted later into components e.g. leaf, stem etc. For this sub-sample randomly select enough material from the bulked samples to half fill a small (approximately 30cm^2) plastic bag. Label the bag with: (1) site; (2) harvest; (3) species group and (4) the purpose of the bag e.g. "For Sorting". Leave the plastic bag open and place in a cold room for later sorting. If left in a cold room in this manner the samples should not be effected by mould. However keep an eye on them in case they start to deteriorate. It is best to sort this material as soon as possible but it can be stored in the cold room for a few weeks or even months if necessary.

For each species group, a sub-sample of fresh material is required to determine dry matter content and allow calculation of dry matter yield. Tare scales with an empty paper bag. Fill the bag with randomly selected material from the mixed bulk sample. Weigh the bag and contents and record the net weight of the sub-sample on the laboratory data sheet. Label the bag with: (1) site; (2) harvest; (3) species group and (4) the purpose of the bag e.g. "For Drying". Bulk dicot or legume groups for drying or, sub-sample only if necessary.

8.3 Drying plant material

Sub-samples (above), three empty bags and litter samples are dried in a dehydrator for 48 hours at 80°C. Dried samples should be weighed whilst still hot to minimise moisture uptake. Tare the scales with one of the three dried empty paper bags. Use the bag of median weight. For each species group weigh the bag and contents and record the net weight of each sub-sample on the laboratory data sheet. Calculate the dry matter proportion and dry matter yield of each species group according to the equations on the data sheet.

8.4 Sorting plant material

Sort all samples from the cold room (dominant grass, sub-dominant grass and other grass groups). Sort into the following components:

1. inflorescence;
2. dead leaf sheath;
3. dead leaf blade;
4. green leaf sheath;
5. green leaf blade;
6. dead stem;
7. green stem.

Be sure that the operator is not colour blind (particularly red/green). Rather than specify a required weight of a sorted sample we suggest that time spent sorting be used as the criteria for determining how much material is sorted. The time period we specify is *twenty minutes per sample (one person).* An operator will probably not sort all the sub-sample in this time. Operators will generally bias their sorting to certain components at a time. If sampling is stopped mid-way through a sample then the sorted material may reflect this bias. For this reason, sort the sample a portion at a time being careful to sort the entire portion. Don't stop sorting halfway through a portion. After twenty minutes finish sorting the current portion and place components into individual, labelled paper bags. Label each bag with: (1) site; (2) harvest; (3) species group and (4) plant component. Dehydrate for 48 hours at 80°C. Weigh dried samples out of the bag, while hot, to 0.01g or 0.001g. Return samples to their bags and store in a pest-free location for later grinding.

8.5 Nutrient analysis of plant material

Grind all oven dried sub-samples except for sorted samples (above). Ensure there is no dirt included in your litter sub-samples. Be careful to clean grinder (e.g. with compressed air) between grinding each sample. Take a sub-sample from the ground material and store in a sealed labelled container. Five to ten grams is more than an adequate sample (less than half a gram is required for nutrient analysis). Label the container with (1) site; (2) harvest; (3) species group. A code is preferable for this information but a record of the code must be kept.

Bulk sub-samples should be analysed for nutrient content (NPK) as these are essential for calculating total nutrient uptake and, on this basis, calibrating GRASP. Sorted material can also be ground and analysed if time and funds permit.

8.6 Processing soil water samples

Weigh wet soil samples in the tin (lid on). Record weight on the soil laboratory data sheet. Tin weights should have been recorded previously. Dry samples for 48 hours at 105°C (lid off). Replace the correct lid and weigh the dry soil in the tin immediately upon removal from the dehydrator. As soil cools moisture is absorbed from the atmosphere and the above procedures are aimed to minimise this problem. Record oven dry weight on the soil laboratory sheet. It may be more convenient to follow a slightly different procedure by taking the lid off before weighing and leaving the lid off from then on. Given the large volume of a SWIFTSYND soil sample differences in calculated moisture content between the above two methods (lids on verse lids off) will not be great. Other errors in the measurement process (e.g. in measuring bulk density, in sampling the soil etc.) will over-ride minor errors in this weighing phase.

After weighing, arrange tins in order of hole number and depth. Make a quick assessment of soil in each tin noting the depth at which significant changes in texture or colour occur. Make a quick visual estimate of root density relative to the surface 10cm interval (see soil field data sheet). This measurement is not vital but may prove useful, in conjunction with other measurements, to indicate rooting depth and pattern of root distribution. Clean tins so they are ready to re-use.

8.7 Calibration of cover estimates using slides

After processing, slides should be labelled on the rim with felt pen according to the quadrat label or, for general photos, according to the date and subject. Select at least three photographs at random and project to life size (or greater) on an appropriately marked sheet. Sheets are marked with 80 or more small circles (0.5cm diameter) or crosses which are arranged in a grid to cover the projected quadrat area. If circles are used, record the dominant feature (green material, dead material, bare ground, litter, rocks). If crosses are used record the feature at the centre of the cross. The advantage of using a circle is that the image is not obscured as it is with a cross. Record the percentage contribution of each group (data sheet not provided) and compare to those estimated in the field. Photographs can be difficult to interpret when quadrat yields are high (due to shadow). The comparison will help to calibrate field estimates between harvests or sites which will be necessary if large differences occur between field and slide estimates.

8.8 Equipment summary for laboratory tasks

The following equipment is required:

- laboratory data sheets (soil and pasture)
- weighing containers
- appropriate digital balance
- plastic bags
- paper bags of uniform weight (<10% weight difference between bags)
- marking pens
- cold room/fridge
- dehydrator
- grinder (or a range of grinders)
- containers for ground material

SECTION 9: SITE DESCRIPTION

The following is required:

- produce two site maps
- measure grass basal area
- measure tree basal area
- soil classification
- soil chemistry
- soil bulk density
- soil water holding capacity

9.1 Site maps

Mark the site location on a map (e.g. Natmap 1:100 000 regional topographic map). Additionally, if possible, take co-ordinates of the site using a GPS (satellite navigation) system. Sufficient records should be kept to enable others to relocate the site should further assessment be required.

Draw a map of the exclosure including general features such as quadrats and soil auger holes together with date sampled. The position of trees (if relevant) both inside and outside the exclosure should also be mapped where a tree outside the exclosure is within a distance from the exclosure equivalent to twice the height of the tree. Record the circumference of each tree at 30cm height and the species if known. The above information may prove a valuable record of pasture, soil and tree uniformity in relation to quadrat positions. If tree density is high, uniform and time consuming to measure, the Bitterlich method (see this section) will suffice in recording tree basal area.

9.2 Grass basal area (cover)

Grass basal area, in part, determines the potential growth rate of pasture after defoliation. Grass basal area should be measured when: (1) the pasture is green; (2) species are readily identified and (3) pasture yield is low enough to make the task easy. Usually December or January provide the best conditions to measure grass basal area.

For SWIFTSYND we have adopted a "frame" point measurement of basal area. A basal area frame (Figure 3) consists of five wire pins suspended vertically from a frame such that the pins can slide up and down but cannot move sideways. The pins are configured in one line and the distance between pins must be greater than the mean diameter of tussock bases. A frame can be borrowed from Brian Pastures but operators are encouraged to make their own if possible. Frames can be made from any suitable material (e.g. wood, steel aluminium).

Place the frame 20 times (ie. 100 point positions) in each cell covering the cell uniformly. Avoid previously cut quadrats. A strike is recorded when *the point of a wire strikes the base of a live tiller at ground level*. Each space on the recording sheet represents 1 placement of the frame and therefore 5 points. When a strike is made record the species code on the grass basal area data sheet (in the space reserved for that frame placement). As such, up to five species codes can appear in any one space on the data sheet. Tally the strikes for each cell and record the total strikes for that cell. As 100 points are taken per cell, the total number of strikes per cell is equivalent to the percent basal area of the cell. Record the mean basal of all cells (the site basal area). Tally the number of times each species (or species group) was scored in the site and calculate the percent basal area of each species for the site.

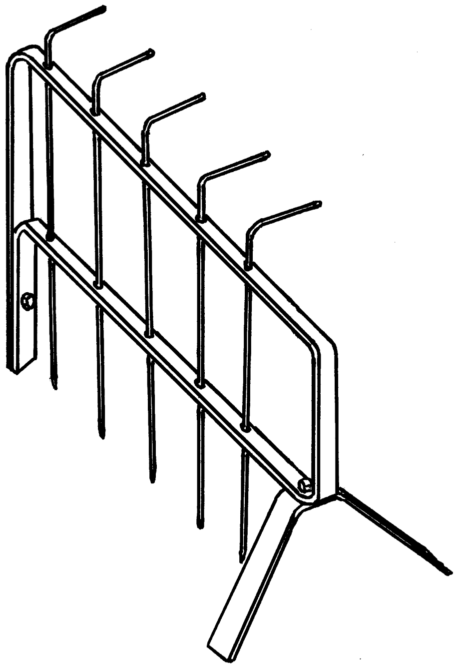

Figure 4 An example of a grass basal area frame

The objectivity of the measurement depends on the operators interpretation of a strike. The above definition is quite precise but we realise there can be some room for operator bias. For this reason we have previously suggested that one operator (David Orr) should do this measurement on all sites. David has agreed to continue making these measurements if practicable. If you believe it is feasible for David to visit your site make contact with him at the Tropical Beef Centre (TBC) in Rockhampton (Ph: (079) 360 134). However, in most cases, operators are encouraged to make their own assessment of basal area.

9.3 Tree basal area

Tree basal area can be quickly measured using a Bitterlich angle-gauge. The gauge consists of a 50 cm slat of wood with two nails forming a siting gauge at one end with a 1 cm space between the outside edges of the nails (Figure 4). To measure tree basal area, hold the gauge horizontally at eye level with the siting gauge furthest away and the other end on your cheekbone. Look through the siting gauge at all trees (30 cm from base) in a 360° arc. Give all trees which appear wider than the siting gauge a score of one. The sum point score is equal to the tree basal area expressed as m^2/ha. Repeat this measurement at the four corners and centre of the exclosure to provide some replication. Together with these measurements, make a note of the main tree species on the plant basal area field sheet. This measurement should be made regardless of whether a more detailed measure of tree basal area is made.

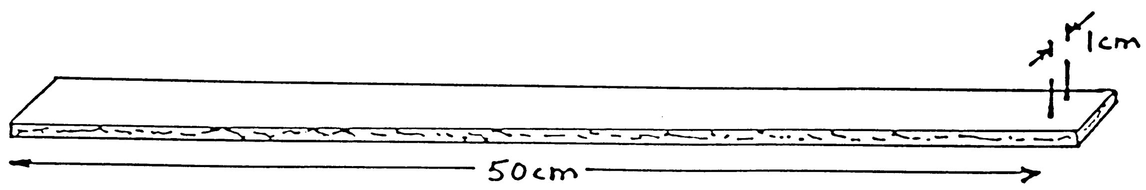

Figure 5 Bitterlich angle-gauge for measuring basal area by counting trees

9.4 Soil classification and chemistry

A profile description for each exclosure is required using the standard method and terms as outlined in McDonald et al. (1990). Given the specialised nature of this work it is best to call upon an experienced soil surveyor. In association with this classification, soil should be stored for chemical analysis. Contact the authors before organising such sampling in case other past study sites could be included in the survey. Procedures for preparing and submitting soil for analysis are yet to be documented (contact authors for details).

McDonald,R.C., Isbell,R.F., Speight,J.G., Walker,J. and Hopkins,M.S. (1990). Australian Soil and Land Survey Field Handbook, Second Edition. Inkata Press, Melbourne.

9.5 Soil bulk density

Soil bulk density is the weight of oven dry soil per volume of soil (g/cm^3). Soil bulk density is required for each 10cm soil increment to convert gravimetric soil moisture measurements to volumetric values.

One method of measuring bulk density is to dig a pit to 1 metre and inserting laterally a 10cm diameter tube to a depth of 10cm. This is done at 10cm intervals down the profile. Each core is carefully removed by removing soil from around the core. Follow standard procedures described in the section Laboratory Tasks to calculate soil dry weight. Calculate the volume of soil taken from the inside dimensions of the tube tip and the depth of the core.

Bulk density can be measured from cores taken from a hydraulic rig. In this case a 10cm diameter sampling tube is required as smaller tubes may cause too much compression of the sample. The soil is most easily sampled when moist. The core is laid out and sectioned carefully (slicing with wire) into 10cm increments. Soil is placed in an air-tight container until processed to determine dry weight. Volume of soil is determined as above.

If it is not possible to measure bulk density by the above methods we suggest the following "sure but steady" method. Tap a metal ring (20-30cm diameter) into the surface soil (0-10cm) and dig surrounding soil away. Slice the tin and contents off using a wire. Progressively take soil down the profile. With increasing depth use rings of smaller diameter if necessary. Volume and weight of soil is calculated as above. For deep layers the following method can be used if necessary. This technique is adequate for SWIFTSYND.

A crude measure of soil bulk density can be obtained by backfilling soil moisture holes with sand of known bulk density. Determine the sand bulk density (average weight (grams) of a litre of sand divided by 1000 (cm^3/litre) equals bulk density (g/cm^3)). Weigh the sand in an accurate measuring beaker or cylinder. A steel tape measure or stick is used to determine the depth of each sampling interval as soil is removed. After the hole is augured, the hole is progressively backfilled to the measured intervals. Once each interval is reached weigh the sand container and determine the weight of sand used (difference in weights between each interval). The volume (cm^3) of each interval is calculated as: weight of sand (g) ¸ sand bulk density (g/cm^3). This method will provide only a rough measure but can be made once in conjunction with normal sampling procedures until a better measure can be made.

On cracking clay soils an equation can be used to calculate bulk density from gravimetric moisture content (see section: Summary of Minimum Data Requirements).

9.6 Soil water holding capacity

Soil water holding capacity involves measures of air dry and saturated moisture content (surface 10cm), wilting point moisture content, field capacity and drained upper limits (10cm increments down profile). Whilst techniques are available to measure each of these features, specialist equipment is required. We are reluctant to suggest that these measures be made routinely. However we do recommend that opportunistic measures of soil moisture be made at the following two times to provide an approximate measure of field capacity and wilting point:

- shortly following a period of rainfall sufficient to wet the entire profile. (this opportunity may not occur during the study period);

- when the pasture has high green cover and leaves are continuously wilted throughout the day.

9.7 Equipment summary for site description

- basal area frame
- Bitterlich stick and probably tape measure
- 1:100 000 topographic map
- GPS unit (contact authors if not available locally)
- local soil classification specialist
- appropriate equipment for soil sampling

SECTION 10: METEOROLOGICAL DATA REQUIREMENTS

The order of priority for climate data required is as follows:

Absolutely necessary:

- daily rainfall to 9 a.m. (record on Daily Rainfall Sheet).

If possible:

- maximum and minimum screen temperature to 9 a.m.
- wet and dry bulb temperature (or relative humidity and a dry bulb temperature) at 9 a.m.
- solar radiation (daily total to 9 a.m.)

If you are really serious:

- pan evaporation (daily total to 9 a.m.)
- wind run (daily total to 9 a.m.)

Apart from daily rainfall the other climate elements can be measured within 20 km providing there are no likely gradients due to change in land form or use. If it is not possible to have a full climate set on site, then any measurements that can be taken (eg. thermo-hydrograph) will at least provide a check with the regional climate station.

If it is not possible to obtain a daily measure of rainfall at the site then it is possible to partition an accumulated total against a local daily gauge (see section Site Preparation).

SECTION 11:. DATA FILES FOR GRASP

Special data formats (currently under revision) are required to run the GRASP model. These new file formats will be documented separately and made available upon request. The production of GRASP input files by SWIFTSYND operators is encouraged. Most importantly the production of these files will help the operator become familiar with the modelling process and one end-point of the field research.

The document produced will also contain suggested relationships to be calculated from SWIFTSYND data. These relationships provide summaries of the field records and, in most cases, are directly used by GRASP.

SECTION 12: REPORTING REQUIREMENTS

The data collected in SWIFTSYND should be used to calibrate the pasture growth model GRASP for your study site. The data from your study site will be more meaningful when compared to data from other sites especially if this is done by comparing calibrated GRASP parameters. For this reason considerable effort has gone in to maintaining a central repository for pasture production data and promoting the standard method of data collection as outlined in this preschedule. Please contact Ken Day for further information in this regard.

Ken Day,
4th floor Forestry Building
80 Meiers Road, INDOOROOPILLY Qld 4068.

Phone: (07) 3896 9576, Fax: (07) 3896 9606, Email dayka@dpi.qld.gov.au

APPENDIX 1: RAW DATA SHEETS AND CALCULATION SHEETS

Raw Data Sheets

Sheet 1: Initial Pasture Measurements Field Sheet

Sheet 1required after mowing or burning

Observations:

- whether site was burnt, mown or both and date when this occurred
- measurement or estimate of yield (kg/ha)
- estimate of cover (%) in quadrats marked for harvest 1
- measurement of pasture height (cm) in centre of cells

Calculations (by hand):

- Average cover and pasture height.
- Calculate dry matter yield if measured.

INITIAL PASTURE MEASUREMENTS FIELD SHEET
(after burning or mowing)

Site	Operator	Date of measurements	Quadrat area
Dominant grass	Subdominant grass	Sown legume	

SITE BURNT OR MOWN: **DATE BURNT OR MOWN:**

TOTAL YIELD ESTIMATE (kg/ha): **GREEN YIELD ESTIMATE (kg/ha):**

Either measure 3 quadrats or estimate across site to determine above yields.
Estimates of yield should not include material below 2 cm height.

	Cover Estimate (% of Total Cover)				
Quad	**Green**	**Dead**	**Bare**	**Litter**	**Rocks**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
	↓	↓	↓	↓	↓
Mean	•	•	•	•	•

	Pasture height (cm) centre of cell				
Cell	**Height 1**	**Height 2**	**Height 3**	**Height 4**	**Mean**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
				Mean →	

Sheet 2: *Pasture Field Sheet*

Sheet 2 required for harvests 1-4

Observations:

- measurement of pasture height (cm)
- estimate of cover (%)
- estimate of species composition (% of total yield)

Calculations (by hand):

- average cover and pasture height

PASTURE FIELD SHEET

Site	Operator	Harvest No.	Date	Quadrat area
Dominant grass	**Sub-dominant grass**	**Sown legume**		

	Pasture height (cm)			Cover Estimate (% of Total Cover)					Species Composition Estimate (% of total yield)				
Quad.	**Height 1**	**Height 2**	**Mean** *	**Green**	**Dead**	**Bare**	**Litter**	**Rocks**	**Dom. grass**	**Sub-dom. grass**	**Other grasses**	**Dicots**	**Sown legumes**
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													

* or mean height of each quadrat round odd up and even down.. For mean height of all quadrats round to the earest whole number.

	Mean	Green	Dead	Bare	Litter	Rocks
Mean of quads. ** →		•	•	•	•	•
Round and adjust to nearest whole						

Pasture height (cm) around centre peg of each cell

CELL	HEIGHT 1	HEIGHT 2	HEIGHT 3	HEIGHT 4	MEAN	CELL	HEIGHT 1	HEIGHT 2	HEIGHT 3	HEIGHT 4	MEAN
1						7					
2						8					
3						9					
4						10					
5						11					
6						12					

Average of 12 cells →

Sheet 3: Soil Field/Lab Sheet

Sheet 3 required after burning/mowing and for harvests 1-4

Observations:

- texture and/or colour change with depth
- root distribution
- variables for calculation of gravimetric moisture content

SOIL FIELD/LAB SHEET

SITE	HARVEST	DATE	OPERATOR

Hole No.	Texture/Colour* Changes	Roots**	Depth (cm)	Tin No.	Tin weight(g)	Tin + soil MOIST (g)	Tin + soil OVEN DRY (g)
		=	0-10				
			10-20				
			20-30				
			30-40				
			40-50				
			50-60				
			60-70				
			70-80				
			80-90				
			90-100				
		=	0-10				
			10-20				
			20-30				
			30-40				
			40-50				
			50-60				
			60-70				
			70-80				
			80-90				
			90-100				
		=	0-10				
			10-20				
			20-30				
			30-40				
			40-50				
			50-60				
			60-70				
			70-80				
			80-90				
			90-100				

* Describe in own terms features of the profile noting depth at which these features change

** Roots (amount relative layer 0-10): **(=)** same; **(<=)** almost as much; **(>½)** more than half; **(≈½)** approx. half; **(<½)** less than half; **(0+)** almost none; **(0)** none

Sheet 4: Pasture Laboratory Sheet

Sheet 4 required for harvests 1-4

Observations:

- species group fresh weights
- variables for calculation of dry matter proportion
- litter dry weight
- dry weight of sorted components (e.g. leaf, stem, etc)

Calculations (by hand):

- total fresh weight for each species group
- dry matter proportion for each species group
- dry matter yield for each species group

PASTURE LAB SHEET

Site	Operator	Harvest No.	Date	Quadrat area
Dominant grass	Subdominant grass		Sown legume	

	Dom. grass	Sub-dom. grass	Other grass	Dicots	Sown legume
Quadrat 1	•	•	•	•	•
Quadrat 2	•	•	•	•	•
Quadrat 3	•	•	•	•	•
Quadrat 4	•	•	•	•	•
Quadrat 5	•	•	•	•	•
Quadrat 6	•	•	•	•	•
Quadrat 7	•	•	•	•	•
Quadrat 8	•	•	•	•	•
Quadrat 9	•	•	•	•	•
Quadrat 10	•	•	•	•	•
Quadrat 11	•	•	•	•	•
Quadrat 12	•	•	•	•	•
Sum	•	•	•	•	•
Sub-sample net fresh weight (g)	•	•	•	•	•
Sub-sample net dry weight (g)	•	•	•	•	•
Dry matter (proportion)*					
Species groups (kg/ha)**					
Grass/Forb (kg/ha)					
TOTAL					

* Plant dry matter (proportion) = sub-sample net dry weight ÷ sub-sample net fresh weight

** Plant dry matter (kg/ha) = sum fresh weight (g) ÷ sum quadrat area (m^2) x 10 000 (m^2/ha) ÷ 1000 (g/kg) x plant dry matter (proportion)

= sum fresh weight ÷ sum quadrat area x 10 x plant dry matter proportion

Total Litter	DRY WEIGHT (g)	DRY WEIGHT (kg/ha)

Litter dry weight (kg/ha) = dry weight (g) ÷ sum quadrat area x 10

	LEAF BLADE		LEAF SHEATH		STEM		INFLOR.
	Green	Dead	Green	Dead	Green	Dead	
Dry weight Dominant grass (g)							
Dry weight Sub-dominant grass (g)							
Dry weight Other grass (g)							

Sheet 5: Grass and Tree Basal Area Field Sheet.

Sheet 5 required once only during the year.

Observations:

- strikes per basal area frame placement
- Bitterlich angle gauge counts

Calculations (by hand):

- percent grass basal area
- tree basal area (m^2/ha)

GRASS AND TREE BASAL AREA FIELD SHEET

SITE:	DATE:	OPERATOR:

GRASS BASAL AREA

Each cell represents one placement of a five pin frame. Record number of strikes per frame placement or, if possible, record strikes according to species code.

1	2	3	4	5	6	7	8	9	10	No. of strikes

↓

TOTAL → STRIKES	

SPECIES	CODE	STRIKES	%BA
	TOTAL →		

%BA = total strikes ÷ 1000 x 100%

TREE BASAL AREA

Location	Score
Centre	
Corner 1	
Corner 2	
Corner 3	
Corner 4	
MEAN →	

Dominant tree species

Sub-dominant tree species

Other tree species

NOTES:

Calculation Sheets

Calculation sheets are to be filled in or used as a guide to spreadsheet design.

Sheet 6: Soil Moisture Calculation Sheet

Observations:

- Bulk density profile

Calculations:

- Gravimetric moisture content
- Volumetric moisture content (each profile and average profile)

. SOIL MOISTURE (CALCULATION SHEET)

SITE	HARVEST	DATE	OPERATOR

Hole No.	Depth (cm)	Gravimetric * moisture (g/g)	Bulk density (g/cm³)	Volumetric moisture ** (mm/10cm)
	0-10			
	10-20			
	20-30			
	30-40			
	40-50			
	50-60			
	60-70			
	70-80			
	80-90			
	90-100			
	0-10			
	10-20			
	20-30			
	30-40			
	40-50			
	50-60			
	60-70			
	70-80			
	80-90			
	90-100			
	0-10			
	10-20			
	20-30			
	30-40			
	40-50			
	50-60			
	60-70			
	70-80			
	80-90			
	90-100			

Average volumetric moisture (mm/10cm) (all holes)	
0-10	
10-20	
20-30	
30-40	
40-50	
50-60	
60-70	
70-80	
80-90	
90-100	
TOTAL →	

* Gravimetric (g/g) = ([tin+soil moist] - [tin+soil dry]) / ([tin+soil dry] - tin weight)
** Volumetric (mm/10cm) = Gravimetric (g/g) x Bulk density (g/cm³) / 1 (g/cm³) x 100mm
= Gravimetric x Bulk density x 100

Sheet 7: *Dry Matter Yield Separation Calculation Sheet*

Observations:

- dry weight of sorted components for each species group (from lab sheet)

Calculations:

- dry matter yield of sorted components for each grass species group
- percent contribution of sorted components for each grass species group

DRY MATTER YIELD (SEPARATION CALCULATION SHEET)

Site	Operator	Harvest No.	Date	Quadrat area
Dominant grass	Subdominant grass		Sown legume	

RAW DATA FROM PASTURE LAB SHEET	LEAF BLADE		LEAF SHEATH		STEM		INFLOR.		SUM
	Green	Dead	Green	Dead	Green	Dead			
Dry weight Dominant grass (g)								→	
Dry weight Sub-dominant grass (g)								→	
Dry weight Other grass (g)								→	

↓ ↓ ↓ ↓ ↓ ↓ ↓

Percentage contribution* Dominant grass							
Percent contribution Sub-dominant grass							
Percent contribution Other grass							

From Pasture Lab Sheet
↓

Total dry matter yield (kg/ha)

Dry matter yield** (kg/ha) Dominant grass							
Dry matter yield (kg/ha) Sub-dominant grass							
Dry matter yield (kg/ha) Other grass							

Sum (kg/ha)							

* Percent contribution = Dry weight for each component expressed as a percentage of the sum dry weight.
** Dry matter yield (kg/ha) = Percentage contribution for each component x sum dry weight.
*** Dry matter yield (kg/ha) = The sum dry matter yield of various groupings of components (see figure below)

	DRY MATTER *** (kg/ha)								
	Blade	Sheath	Leaf	Stem	Stem+inflor.	Green	Dead	Green leaf	Dead leaf
Dominant grass									
Sub-dom. grass									
Other grass									

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

SUM (kg/ha)									

Sheet 8: Dry Matter Yield Quadrat Calculation Sheet

Calculations as for sheet 7 but for individual quadrats

DRY MATTER YIELD (QUADRAT CALCULATION SHEET)

Site	Operator	Harvest No.	Date	Quadrat area
Dominant grass	Subdominant grass	Sown legume		

	Measured Dry Matter Yield * (kg/ha)							Measured Percent Dry Matter **					Estimated Dry Matter Yield *** (kg/ha)				
Quadrat	Dominant grass	Sub-dom. grass	Other grass	Dicots	Sown legumes	Total		Dom. grass	Sub-dom. grass	Other grass	Dicots	Sown legumes	Dom. grass	Sub-dom. grass	Other grass	Dicots	Sown legumes
1						→	→										
2						→	→										
3						→	→										
4						→	→										
5						→	→										
6						→	→										
7						→	→										
8						→	→										
9						→	→										
10						→	→										
11						→	→										
12						→	→										
	↓	↓	↓	↓	↓	↓							↓	↓	↓	↓	↓
Total DM yield (kg/ha)					→		←	Check the totals equal those calculated in Pasture Lab Sheet									
Total DM yield (kg/ha)	Grass			Dicot									Grass			Dicot	
% ****																	
%	Grass			Dicot									Grass			Dicot	

*	Measured Dry Matter (kg/ha)	= Fresh weight (g) x Plant dry matter (proportion) x 10 000 (m^2/ha) ÷ Quadrat area (m^2)
		= Fresh weight (g) x Plant dry matter (proportion) (both from Pasture Lab Sheet) x 10 ÷ Quadrat area
**	Measured Percent Dry Matter	= Percent contribution of each species group to total yield per quadrat
***	Estimated Dry Matter (kg/ha)	= Total measured dry matter (kg/ha) x Species composition estimate (Pasture Field Sheet) for each quadrat and species group
****	%	= Percent contribution of each species group total to total dry matter production