National Airborne Field Experiment 2005

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Experiment Plan

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1 Overview and Objectives

The purpose of this project is to map near-surface soil moisture at a range of resolutions making use of passive microwave airborne and spaceborne remote sensors. The ultimate goal is to be able to provide reliable near-surface soil moisture observations at the paddock scale globally. Specifically, this involves positioning ourselves to capitalise on future remote sensing missions such as ESA's Soil Moisture and Ocean Salinity (SMOS) satellite scheduled for launch in 2007 and NASA's Hydrospheric States (Hydros) scheduled for launch in 2010.

This project is complementary with others around the world, including the series of SGP (Southern Great Plains) and SMEX (Soil Moisture Experiment) campaigns in the United States (http://hydrolab.arsusda.gov) and coSMOS (Campaign for validating the Operation of SMOS) activities in Europe (http://www.esa.int/esaLP/LPsmos.html). Specifically, the coSMOS activities planned for Europe in summer of 2005 have been moved to Australia in cooperation with the NAFE (National Airborne Field Experiment) activities planned for November 2005, as described in this document. NAFE '05 has been made possible through recent infrastructure (LE0453434 and LE0560930) and research (DP0557543) funding from the Australian Research Council. Initial setup and ongoing maintenance of the study catchment was funded by research grants (DP0209724 and DP0556941) from the Australian Research Council and NASA.

1.1 Overview

Internationally there has been a significant decline in the number of gauged basins over recent years, yet the demand for hydrologic prediction is greater than ever, particularly as we enter an era of uncertainty due to global climate change. The potential for reliable hydrologic prediction in ungauged basins exists only through an increasing ability to remotely sense land surface states, fluxes, and parameters that impact on basin prediction. For instance, it is now possible to measure evapotranspiration rates that determine soil moisture and baseflow, near-surface soil moisture content that controls rainfall partitioning into infiltration and runoff, snow water equivalent of the snow pack that determines spring-time runoff, vegetation parameters such as leaf area index and greenness that control evapotranspiration, land surface elevation and canopy height that impact on runoff routing and evapotranspiration, and so on. However, there are still many unanswered questions that need to be addressed, including validation of data products from new sensors, maturing of retrieval algorithms, developing techniques for downscaling, and merging remote sensing data with model predictions through the process of data assimilation.

To answer these important questions it is essential that field campaigns with coordinated satellite, airborne and ground-based data collection be undertaken, giving careful consideration to the diverse data requirements for the range of questions to be addressed. Moreover, it must be recognized that such invaluable data sets do not come without considerable effort and cost. Thus it is increasingly important that scientists collaborate nationally and internationally on the collection and subsequent analysis of such data to share in the burden and reap the benefits of more extensive data sets than are possible on an individual basis. To this end two month-long National Airborne Field Experiments (NAFE; see http://www.nafe.unimelb.edu.au) have been planned in consultation with scientists from diverse backgrounds (soil moisture, runoff, evapotranspiration, carbon, forestry, bushfires, water quality, irrigation and salinity) and organizations (several divisions of CSIRO, State Agencies, CRC's, national and international universities, NASA and ESA).

While there is a clear emphasis on soil moisture remote sensing in the two planned NAFE experiments (a primary objective of the research project which provides core funding), the nature of the airborne and supporting data to be collected makes these campaigns applicable to a wide range of environmental remote sensing disciplines and applications.

These coordinated field experiments are open to collaboration from all interested parties. In November 2005 (NAFE ’05) there will be participants from the University of Melbourne, University of Newcastle, Airborne Research Australia, and several European universities and organizations including the European Space Agency (ESA), undertaking research on soil moisture, flood forecasting, carbon budgets and ecohydrology. In November 2006 (NAFE ’06) it is anticipated that participants will undertake research on soil moisture, evapotranspiration, bushfire prediction and precipitation measurement. This document describes in detail the core soil moisture component to the NAFE ‘05 field campaign.

1.2 Objectives

Information on soil moisture may be obtained from three sources. First, ground-based soil moisture profile measurements may be made continuously at individual points. Unfortunately, these are rarely representative of the spatial distribution, and so are unsuitable for mapping of large areas. Second, remote sensing may be used to give measurements of soil moisture in the top few centimetres for areas with low to moderate vegetation cover but do not provide any direct information on root zone soil moisture. Third, land surface models may be used to predict the spatial and temporal variation of soil moisture (near-surface and root zone) but those estimates suffer from inadequate model physics, parameter estimates, and atmospheric forcing data. Clearly these different approaches are complementary, and so one approach has been to utilise all three sources of data, by assimilation of the remotely sensed near-surface soil moisture measurements into a land surface model, and relying on the point measurements for verification. While current progress on this approach has been good, application has been confined to large scale estimates with little appropriate data available for assimilation and/or field verification. **Therefore appropriate observation and verification data needs to be collected to mature this technology.**

Over the past two decades there have been numerous near-surface soil moisture remote sensing studies, using visible, thermal infrared (surface temperature) and microwave (passive and active) electromagnetic radiation. Of these, passive microwave soil moisture measurement has been the most promising technique, due to its all-weather capability, its direct relationship with soil moisture through the soil’s dielectric constant, and a reduced sensitivity to land surface roughness and vegetation cover. Due to the long wavelengths required for soil moisture remote sensing, space-borne passive microwave radiometers (both current and planned) have a coarse spatial resolution, being on the order of 25 to 50km, but have a frequent temporal resolution of 1 to 2 days. While this spatial resolution is appropriate for some broad scale applications, it is not useful for small scale applications such as on-farm water management, flood prediction or meso-scale climate and weather prediction. Thus methods need to be developed for reducing these large scale measurements to a smaller scale. This may ultimately be possible using information from other types of higher resolution sensors (eg. thermal and visible imagery from the MODerate resolution Imaging Spectrometer (MODIS) or LANDSAT Thematic Mapper), but any **downscaling approaches must first be developed and validated with direct high resolution passive microwave measurements and such data must be collected**.

May 2002 saw the launch of NASA’s Advanced Microwave Scanning Radiometer for the Earth observing system (AMSR-E) on the Aqua satellite. This is the first passive microwave sensor in space with appropriate frequencies for measuring near-surface soil moisture content since the Scanning Multi-channel Microwave Radiometer (SMMR) ceased operations in 1987. During the SMMR mission, soil moisture remote sensing was in its infancy, and so there were no dedicated field campaigns for verification of remotely sensed and derived root zone soil moisture. This lack of concurrent data has made evaluation of SMMR-based studies effectively impossible. It is therefore imperative that research programs are designed and undertaken now, in order to fully exploit the potential for retrieving important information on the spatial and temporal variation of soil moisture content from AMSR-E data. The Aqua satellite has an operational design life of 6 years, so there is only a narrow window of opportunity to undertake ground-based research. **Verification of space-borne observations at these coarse resolutions** can only be undertaken using airborne data with a ground resolution fine enough to allow its own accurate verification from ground-based measurements. All airborne soil moisture remote sensing campaigns to date have had spatial resolutions on the order of 1km – an order of magnitude greater than what will be achieved in the NAFE campaigns. Moreover, surface rock covers a large proportion of the Earth's surface and this is not currently considered in retrieval algorithms, leading to a potential underestimation in soil moisture.

In addition there are two dedicated soil moisture missions planned with optimal frequencies for soil moisture measurement. These are the ESA Soil Moisture and Ocean Salinity (SMOS) and NASA Hydrospheric States (HYDROS) sensors to be launched in 2007 and 2010 respectively. These new sensors each will have their own novel approach to soil moisture measurement, requiring algorithms to be developed and results verified using field data. The SMOS sensor will collect data at a range of incidence angles potentially alleviating some of the current assumptions and ancillary data requirements for soil moisture retrieval. Hydros will collect both accurate low resolution passive microwave data together with noisy high resolution active microwave data to produce a 10km soil moisture product. However, both of these missions are planned for 6am/pm overpass times and it is likely that dew will impact on the 6am soil moisture retrievals, but this process is not well understood. Thus it is **important that we prepare now so as to obtain maximum benefit from these dedicated soil moisture sensors when they come online.**

1.3 Ground Requirements

To answer the science questions outlined there are a number of ground data requirements to be considered (Fig. 1):

- long-term observation of soil moisture profiles and associated meteorological data for evaluation of derived root zone soil moisture
- extensive ground-based near-surface soil moisture and temperature data at a range of spatial scales during airborne campaigns for scaling studies, aircraft and satellite verification and algorithm development
- continuous near-surface soil moisture, soil temperature, and thermal infrared point observation for relating air-to-ground measurements throughout the day
- vegetation biomass/water content and dew observation for determining vegetation and dew effects

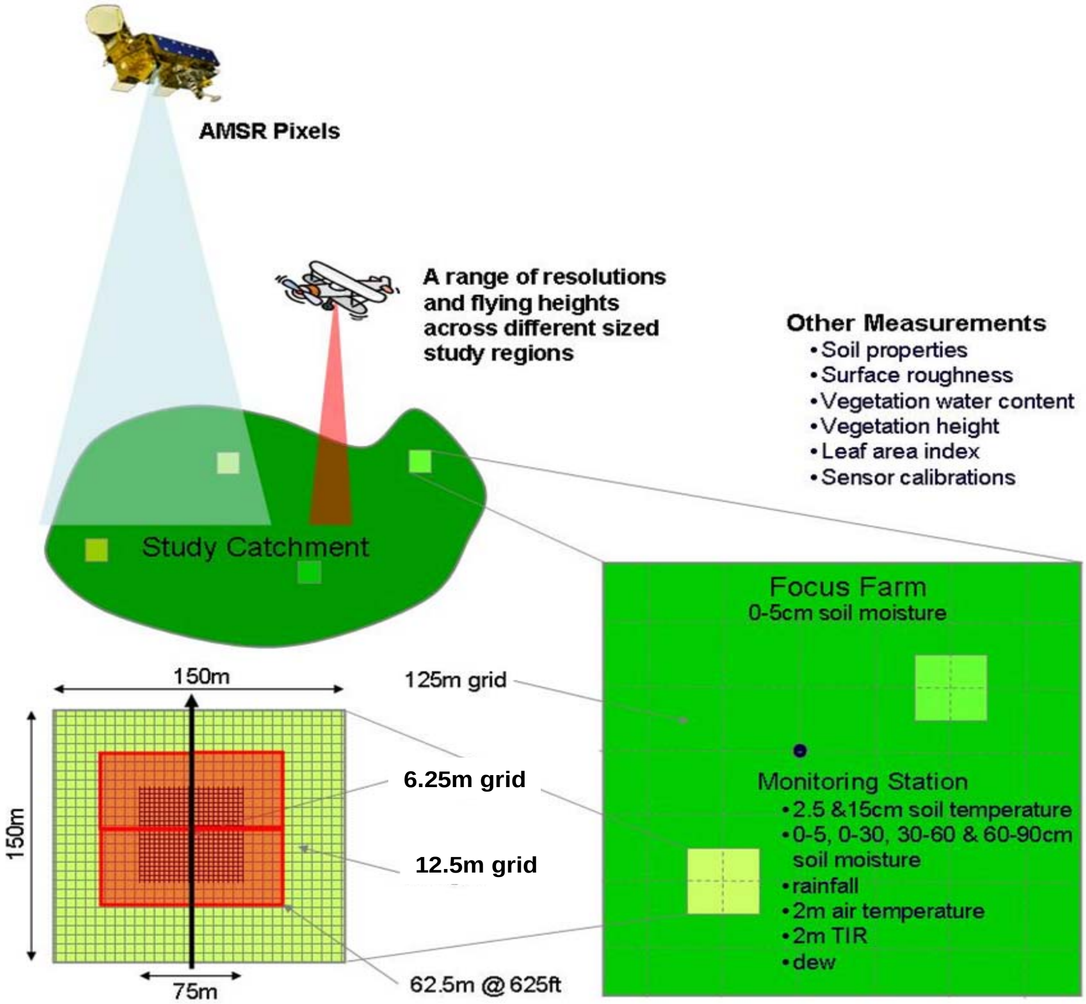


Figure 1. Schematic of the experimental design.

1.4 Air Requirements

To answer the science questions outlined there are also a number of airborne data requirements to be considered (Fig. 1):

- airborne passive microwave, thermal and NDVI data at a range of scales for algorithm development and satellite verification
- airborne lidar data for accurate topography and incidence angle information and vegetation height determination
- digital photography for land use and land cover information
- airborne observations coincident with ground observations and made as early in the morning as possible to ensure that soil and vegetation temperatures are more closely aligned, have a more uniform soil temperature profile, and to coincide more closely with AMSR-E (1:30am/pm) and SMOS/Hydros (6:00am/pm) overpass times
- airborne observations at a range of altitudes (625ft to 10,000ft) to achieve a range of ground resolutions (62.5m to 1,000m for passive microwave and 1m to 20m for thermal and NDVI) for scaling, algorithm development and satellite verification

- airborne observations with passive microwave radiometer in mapping and multi-incidence angle configurations for SMOS and HYDROS algorithm development

1.5 General Approach

The scientific objectives and data requirements of NAFE ’05 as addressed in the previous sections will be met by coordinating an aircraft remote sensing campaign with a ground data collection campaign. Furthermore, all collected data will support measurements taken from various spaceborne remote sensing platforms overpassing the study area. This is expected to provide appropriate and extensive datasets to address the scientific objectives of the project.

The aircraft remote sensing campaign will make use of a small environmental aircraft (see section 3) equipped with passive microwave, infrared and visible sensors to map the whole study area. The characteristics of such sensors in terms of spectral range, incidence angle and field of view are comparable with those onboard various existing and future satellite remote sensing missions. This will allow comparability between spaceborne and airborne measurements and therefore will ensure applicability of the outcomes of NAFE ’05 to future spaceborne missions. In order to address the scaling issues which are crucial to NAFE ’05, it is imperative to collect data at various resolutions and instrument configurations (in terms of incidence angle). This will be made possible by flying the aircraft at different altitudes, resulting in a variety of ground spatial resolutions ranging from satellite-footprint scale down to farm and paddock scale.

Airborne and spaceborne observations will be supported by ground data collected during the one-month long campaign. Ground measurements will include near-surface soil moisture for direct validation of the passive microwave remote sensors observations, as well as ancillary data such as vegetation biomass, land cover information, soil temperature and surface roughness. Ground sampling will be coordinated with aircraft and satellite overpasses times to minimise temporal lag between observations.

The study area of NAFE ’05 is the Goulburn River catchment, a subhumid to temperate area located in south-eastern Australian, approximately 300km north-west of the city of Sydney. A detailed description of the area is given in section 4. The area has been long monitored for hydrological and remote sensing purposes and thus constitutes a very suitable study site, in terms of both scientific requirements and logistical issues. An overview of the NAFE ’05 field campaign area is given in Fig. 2. The main study area includes a large portion of the northern part of the Goulburn Basin, approximately the size of a AMSR-E pixel. (these area will be hereby referred to as “AMSR sampling area” or alternatively “Regional sampling area”). Two focus areas delimited by the Merriwa River and Krui River catchment boundaries have been selected for more detailed analysis.. Within these areas eight farms have been chosen as the object of intensive farm-scale ground and aircraft monitoring (these areas will be hereby referred to as “Farm scale sampling areas”). The extent of mapping achieved by each flight altitude is also shown in the plot. The ground crew will be based in the township of Merriwa, located in the heart of the study area, and will set off from there for the daily sampling. The air crew will be based in Scone, near the airport used for the aircraft operations, approximately 1hour drive from Merriwa.

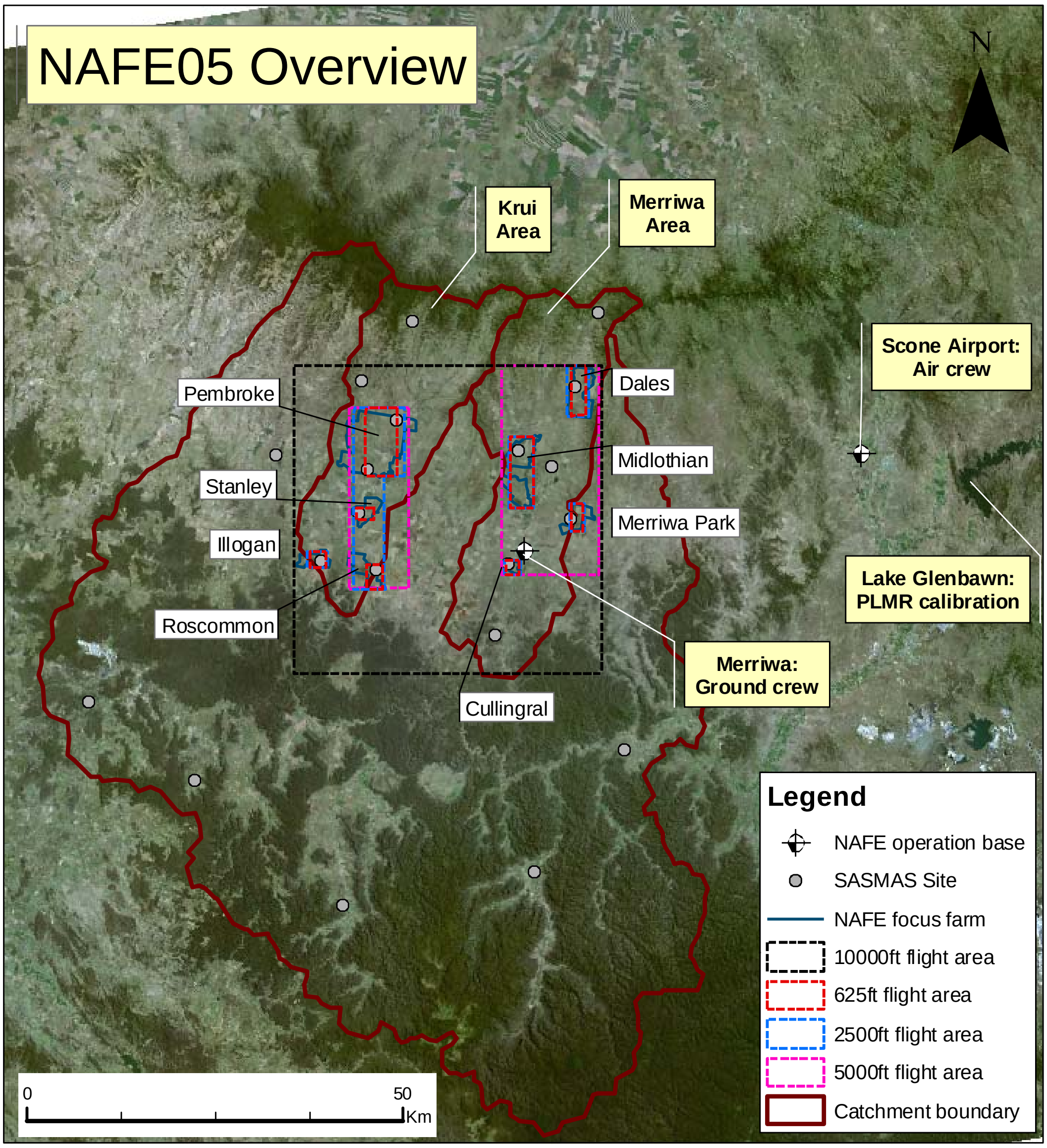


Figure 2. NAFE ‘05 overview. The map shows the location of the operation bases for the air and ground crews, the main study areas and the extents covered by the mapping from different altitudes. Permanent monitoring stations are also shown. The figure doesn’t specifically show the coverage at 10,000ft of the two sub-study area of Krui and Merriwa catchment, being these basically the same as the 5,000ft coverage’s for the two areas.

2 Satellite Observing Systems

The following summary of satellite observing systems is limited to those observing systems that provide data of potential relevance to soil moisture remote sensing and scaling. It covers not only a description of the observing systems but also the data collection and availability characteristics.

2.1 Advanced Microwave Scanning Radiometer for EOS (AMSR-E)

AMSR-E on Aqua (http://wwwghcc.msfc.nasa.gov/AMSR) is a multi-frequency dual polarisation microwave radiometer launched in May 2002, with frequencies of 6.925, 10.65, 18.7, 23.8, 36.5 and 89.0 GHz and spatial resolutions of 75, 48, 27, 31, 14 and 6km respectively. The most appropriate frequency for soil moisture measurement is the 6.925GHz or C-band channel, which does not show evidence of radio frequency interference in Australia as it does in the United States. The viewing angle of AMSR is a constant 55°. Aqua is in a 1:30am/pm equator crossing orbit with 1-2 day repeat coverage. Overpasses for the NAFE '05 region are summarized in Table 1. Fig 3. shows an example of global brigthness temperature data provided by AMSR-E

2.2 WindSat

WindSat (http://www.ipo.noaa.gov/Projects/windsat.html) is a multi-frequency polarimetric microwave radiometer with similar frequencies to the AMSR-E, with the addition of full polarisation for 10.7, 18.7 and 37.0 GHz channels and the lack of an 89.0 GHz channel. Developed by the Naval Research Laboratory, it is one of the two primary instruments on the Coriolis satellite launched on 6 January 2003 with an expected life cycle of three years. However, WindSat stopped responding earlier this year and is therefore not considered further in this experimental plan.

2.3 MODerate resolution Imaging Spectroradiometer (MODIS)

Another important instrument carried onboard Aqua is MODIS (http://modis.gsfc.nasa.gov), a passive imaging spectroradiometer with 36 discrete spectral bands between 0.41 (visible) and 14.2 micrometers (thermal infrared). These bands range in resolution from 250m to 1km, and are most useful for land cover and vegetation mapping. Details about MODIS bands are shown in Table 2. This instrument is also carried on the Terra (http://terra.nasa.gov) spacecraft. Aqua has a 1:30am/pm equator crossing time while Terra has a 10:30am/pm equator crossing time, meaning that MODIS data is typically available on a daily basis.

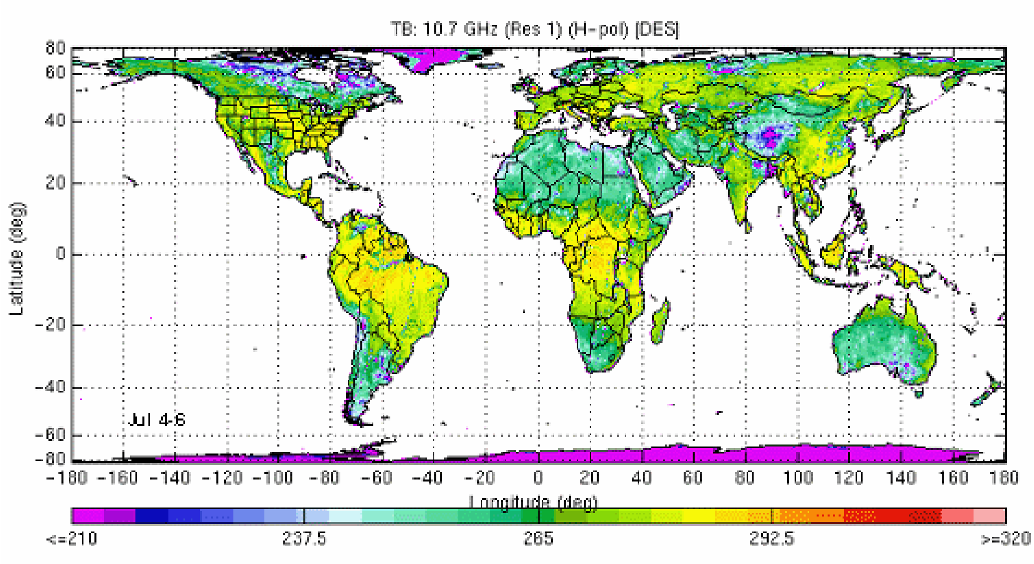


Figure 3. Example of AMSR-E brightness temperature image.at 10.7 GHz frequency, Horizontal polarization.

Table 1. Summary of Aqua overpasses for the Goulburn study area. Highlighted are the dates selected for regional sampling.

AQUA Overpasses			
Day of week	Date	Time of peak elevation (GMT + 10:00)	Peak spacecraft elevation above horizon
Sun	30-Oct-05	14:20:31	41.6
Mon	31-Oct-05	1:21:13	67.1
		13:25:40	46
Tue	1-Nov-05	14:08:20	57.4
Thu	3-Nov-05	13:56:08	79.4
Fri	4-Nov-05	0:56:49	64.7
Sat	5-Nov-05	1:39:36	40.9
		13:43:56	75.6
Sun	6-Nov-05	0:44:37	46.7
		13:31:44	54.3
Tue	8-Nov-05	14:14:23	48.8
Wed	9-Nov-05	1:15:04	79
Thu	10-Nov-05	14:02:11	67.7
Fri	11-Nov-05	1:02:52	76
Sun	13-Nov-05	0:50:41	54.9
Mon	14-Nov-05	1:33:20	48.2
		13:37:48	64.1
Tue	15-Nov-05	14:20:27	41.7
Wed	16-Nov-05	1:21:08	67.2
		13:25:28	46
Thu	17-Nov-05	14:08:15	57.5
Fri	18-Nov-05	1:08:56	87.7
Sat	19-Nov-05	13:56:03	79.4
Sun	20-Nov-05	0:56:44	64.5
Mon	21-Nov-05	1:39:24	41
		13:43:51	75.3
Tue	22-Nov-05	0:44:32	46.6
Wed	23-Nov-05	1:27:12	57
		13:31:31	54.2
Thu	24-Nov-05	14:14:11	48.9
Fri	25-Nov-05	1:14:52	78.9
Sat	26-Nov-05	14:01:59	67.8
Sun	27-Nov-05	1:02:40	75.8
Mon	28-Nov-05	13:49:47	87.4
Tue	29-Nov-05	0:50:28	54.7
Wed	30-Nov-05	1:33:15	48.3
		13:37:35	64

2.4 Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

ASTER, carried onboard Terra, provides high resolution visible (15m), near infrared (30m) and thermal infrared (90m) data on request, prioritized by project. In general the data coverage occurs on the same day as Landsat 7 for a 60 km swath, but trailing by approximately half an hour. Data for this sensor have bee requested and are awaiting approval.

Table 2. Modis Bands

Primary Use	Band(s)	Wavelength	Pixel Size
Vegetation Index	1	620-670 nm	250 m
Vegetation Index	2	841-876 nm	250 m
	3	459-479 nm	500 m
	4	545-565 nm	500 m
Vegetation H_2O	5	1230-1250 nm	500 m
Vegetation H_2O	6	1628-1652 nm	500 m
	7	2105-2155 nm	500 m
Ocean Color	8 - 16	405-877 nm	1000 m
Atmospheric H_2O	17 -19	890-965 nm	1000 m
Thermal	20 -36	3.660-14.385 :m	1000 m

2.5 Landsat

The Landsat (http://landsat7.usgs.gov/programdesc.html) satellites collect data in the visible (30m), panchromatic (15m), mid infrared (30m) and thermal infrared (60 to 120m) regions of the electromagnetic spectrum. These data have an approximately 15day repeat cycle with a 10:00am equator crossing time. This data is particularly valuable in land cover and vegetation parameter mapping. However, due to an instrument malfunction onboard Landsat 7 in May 2003, it is now only able to provide useful image data within the central ~20km of the swath. As Landsat 5 is still in operation it is being increasingly relied upon. The significance of this is a decrease in spatial resolution of thermal infrared data. The Goulburn River Catchment is located on path 90, row 82 of the descending node of both Landsat 5 and 7. Overpass details for Landat 5 and Landsat 7 are given in Table 3. This data needs to be purchased and is not currently included as part of the budget allocation.

2.6 Soil Moisture and Ocean Salinity (SMOS)

The SMOS (http://www.esa.int/esaLP/ESAMBA2VMOC_LPsmos_0.html) satellite is scheduled for launch in 2007 and seeks to provide 3-day repeat soil moisture at 50km. SMOS is a synthetically generated L-band microwave radiometer instrument yielding a range of incidence angles from 0° to 55° at both V and H polarisations, and a 1000km swath width. This satellite will have a 6:00am/pm equator overpass time. A novel feature of this system is its multi-incidence angle capability, expected to assist in determining ancillary data requirements, including vegetation attenuation, surface roughness, soil texture, surface temperature etc.

2.7 Hydrospheric States (Hydros)

The Hydros (http://hydros.gsfc.nasa.gov/mission) satellite is scheduled for launch in 2010 and seeks to provide 3-day repeat soil moisture at 10km. Hydros has a 40km rotating L-band radiometer with a constant 40° incidence angle at both V and H polarisations, and a 3km L-band radar at VV, VH, HV, and HH polarisations. This satellite will also have a 6:30am/pm equator overpass time. The novel features of this system is i) the combination of active and passive observations to alleviate the ancillary data requirements and ii) the combination of high resolution noisy data with low resolution accurate data to yield a high resolution reliable product.

2.8 Advanced Synthetic Aperture Radar (ASAR)

ASAR provides both continuity to the ERS-1 and ERS-2 mission SARs and next generation capabilities. This C-band SAR is carried on board the Envisat (http://envisat.esa.int) satellite, launched into a sun synchronous orbit in March 2002, also carrying a visible and near infrared imaging system called MERIS. The exact repeat cycle for a specific scene and sensor configuration is 35 days. ASAR can provide a range of incidence angles ranging from 15° to 45° and can operate in alternating polarisation mode, providing two polarisation combinations (VV and HH, HH and HV, or VV and VH). Swath width is nominally 100 km and the product pixel size is 30m. ASAR data for NAFE '05 have been requested and approved from ESA.

2.9 Advanced Along Track Scanning Radiometer (AATSR)

Also carried onboard Envisat, AATSR main objective is to establish continuity of the ATSR-1 and ATSR-2 data sets of precise sea surface temperature (SST). It makes use of four thermal infrared channels (centred on 1.6 microns, 3.7 microns, 10.7 microns, and 12 microns) for the SST. Additionally, with two visible channels (0.87 microns and 0.67 microns respectively) provides measurements of vegetation at 1 × 1km resolution at nadir. An additional visible channel at 0.55 microns indicates, from chlorophyll content, the growth stage and health of vegetation. AATSR data for NAFE '05 have been requested and approved from ESA.

2.10 Compact High Resolution Imaging Spectrometer (CHRIS)

CHRIS provides, for the first time, remotely-sensed Multi-View-Angle data at high spatial resolution, and in superspectral/hyperspectral wavelength resolutions. The sensor is onboard ESA's Project for On-Board Autonomy (Proba) launched on 22 October, 2001. CHRIS has a spectral range of 415-1050 nm, and provides observations at 19 spectral bands simultaneously, with a spatial resolution of 20m at nadir and a swath width of 14km. CHRIS data for NAFE'05 have been requested and proved from ESA.

3 Aircraft Observing System

Airborne measurements will be made using the small, low-cost, two-seater motor glider from

Table 3. Summary of Landsat 5 and Landsat 7 overpasses for the Goulburn study area.

Landsat 5

Day of week	Date	Time (GMT+10:00)
Fri	21-Oct-05	9:30:39
Sun	06-Nov-05	9:36:35
Tue	22-Nov-05	9:36:08
Thu	08-Dec-05	9:36:08

Landsat 7

Day of week	Date	Time (GMT+10:00)
Sut	29-Oct-05	9:25:33
Mon	14-Nov-05	9:37:27
Wed	30-Nov-05	9:30:39
Fri	16-Dec-05	9:36:35

Figure 4. The Diamond ECO-Dimona aircraft with PLMR mounted under the fuselage, and thermal imager, digital camera and NDVI scanner in an underwing pod.

the Airborne Research Australia national facility called Small Environmental Research Aircraft (SERA), shown in Fig. 4, together with the recently acquired Polarimetric L-band Multibeam Radiometer (PLMR; http://www.plmr.unimelb.edu.au) and thermal imager. This new infrastructure will allow for the first time, very high resolution passive microwave (~50m) and land surface skin temperature (~1m) observations to be made across large areas. There is no other capacity world-wide to make such high resolution measurements together with a range of other supporting data including a first-last return lidar, NDVI scanner and 11MegaPixel digital camera. An example of the data to be collected is given in Fig. 5..

The aircraft can carry a typical science payload of up to 120kg with cruising speed of 92-203km/h and range of 4-8hrs or 800-1500km. The aircraft ceiling is 3km or up to 7km with oxygen, under day or night VFR conditions. While the aircraft can take up to 2 crew (pilot/scientist + scientist), for maximum range and/or payload it is only possible to operate with 1 crew.

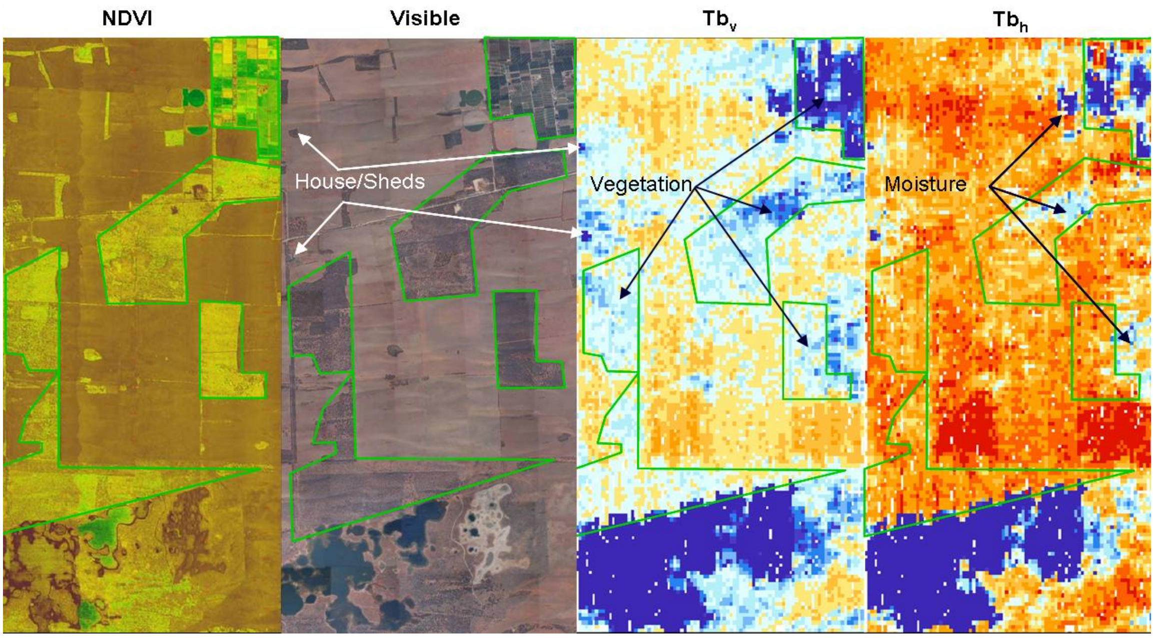


Figure 5. Example of airborne data collected from a trial campaign near Waikerie in South Australia. Note that the vertically (Tb_v) and horizontally (Tb_h) polarized passive microwave data are shown with a different colour scale.

Aircraft instruments are typically installed in one of the certified underwing pods (see Fig. 6) or the underbelly pod. Aircraft navigation for science is undertaken using a cockpit computer display that shows aircraft position relative to planned flight lines using the OziExplorer software. The aircraft has a Trimble TANS 4-way differential GPS system (antennae on each wing and both fore and aft on the fuselage) for position (georeferencing) and attitude (pitch, roll and heading at 0.1° resolution) interpretation. Additionally there is a Rockwell-Collins AHS-85 inertial navigation system yielding the more accurate attitude information required for interpretation of high resolution scanning instruments.

Figure 6. View of one of the underwing pod with the cover off, and view of the cockpit showing cockpit computer display.

Figure 7. View of PLMR with the cover off.

3.1 Polarimetric L-band Multibeam Radiometer

The PLMR (Fig. 7) measures both V and H polarisations using a single receiver with polarisation switch at incidence angles +/–7°, +/–21.5° and +/–38.5° in either across track (pushbroom) or along track configurations. The beamwidth is 17° resulting in an overall 90° field of view. The instrument has a frequency of 1.413GHz and bandwidth of 24MHz, with NEDT and accuracy better than 1K for an integration time of 0.5s and 1K repeatability over 4 hours. It weighs 46kg and has a size of 91.5cm × 91.5cm × 17.25cm.

3.2 Thermal Imager

The thermal imager is a FLIRTS ThermaCam S60 with spectral range 7.5 to 13μm, accuracy +/–2°C or +/–2% of reading and thermal sensitivity of 0.08°C. It has an 80° × 60° FOV lens with 1.3mrad IFOV, resulting in approximately 1m data from a 150m flying height. The thermal imager looks very similar to a digital video camera (Fig. 8), with a weight of 2kg and size of 10cm × 12cm × 22cm.

Figure 8. View of the S60 Thermal Imager.

3.3 Tri-spectral NDVI Scanner

The TSLS AWI/ARA Trispectral line scanner can operate in either of two modes - Visible (Red, Green and Blue) or Vegetation (Green, Red and Near-IR).The sensor offers a resolution of better than 0.5m. This is achieved using high pixel resolution of 2048 pixels per line, and an acquisition frequency of 50 lines per second (stored directly onto a hard disk). The scanner is a compact unit, measuring just 110mm x 110mm x 300mm. It has two lens option; a 28mm lens (45°) and a 50mm lens (24°). The 28mm lens will be used in this experiment to ensure maximum coverage, and flight lines will be planned to have a nominal 1/6th of a swath width overlap.

3.4 Digital Photography

The camera is a Canon EOS-1DS 11MegaPixel digital camera with two lens options; a 24mm lens (74° × 53°) and 50mm lens (40° × 27°). The 24mm lens will be used in this experiment to ensure maximum coverage.

3.5 Airborne Laser Scanner

The airborne laser (near infrared) scanner is a first pulse (vegetation) last pulse (ground) Riegl LMS-Q280i with range of 30m to 1500m, vertical accuracy of 30mm and resolution of 5mm. It has a maximum 60° FOV with 0.02° step width, yielding approximately 1m horizontal resolution when flown from a 150m flying height. The instrument is approximately 56cm × 20cm × 21cm and weighs approximately 20kg (Fig. 9).

Figure 9. View of the Riegl LMS-Q280i airborne laser scanner

4 Catchments

The 6,540km^2 Goulburn River experimental catchment (http://www.sasmas.unimelb.edu.au) is a tributary to the Hunter River in New South Wales, Australia (Fig. 10). This subhumid to temperate catchment extends from 31°46'S to 32°51'S and 149°40'E to 150°36'E, with elevations ranging from 106m in the floodplains to 1257m in the northern and southern mountain ranges. The catchment was chosen for i) its relative large area of predominantly low to moderate vegetation cover in the north of the catchment for satellite soil moisture remote sensing studies; ii) the lack of maritime effects in order to avoid mixed pixel responses from ocean and land data within satellite measurements; and iii) its relative proximity to the University of Newcastle.

Figure 10. Location of Goulburn River catchment.

The Goulburn River runs generally from west to east, with tributaries from the north and south, meaning the catchment is dominated by easterly and westerly aspects. The catchment has two more intensively monitored subcatchments, the Krui River (562km^2) and Merriwa River (651km^2) in the northern half of the catchment (Fig. 2). Additionally, a densely monitored 175ha micro-catchment is located on a property called "Stanley", located in the lower reach of the Krui River catchment.

4.1 Climate

The general climate within the region can be described as subhumid or temperate, with significant variation in the annual rainfall throughout the catchment. While the average annual rainfall in most of the catchments is approximately 700mm, it varies from 500mm to 1100mm depending on altitude (Fig. 11). Major rainfall events generally occur in October and November with an average precipitation of 50mm, while the monthly average precipitation in July is 40mm. The average annual Class A pan evaporation for the study region is about 1800mm. The minimum monthly pan evaporation is reached in July with an average of 75mm and the maximum can be observed in January reaching 250mm. Monthly mean maximum temperatures reach approximately 30°C in summer and 14°C in winter, with minimum values of 16°C and 2°C, respectively. Except for elevated areas, frost is unlikely to occur during daytime in winter, but night time minimum temperatures in winter are frequently less than 0°C.

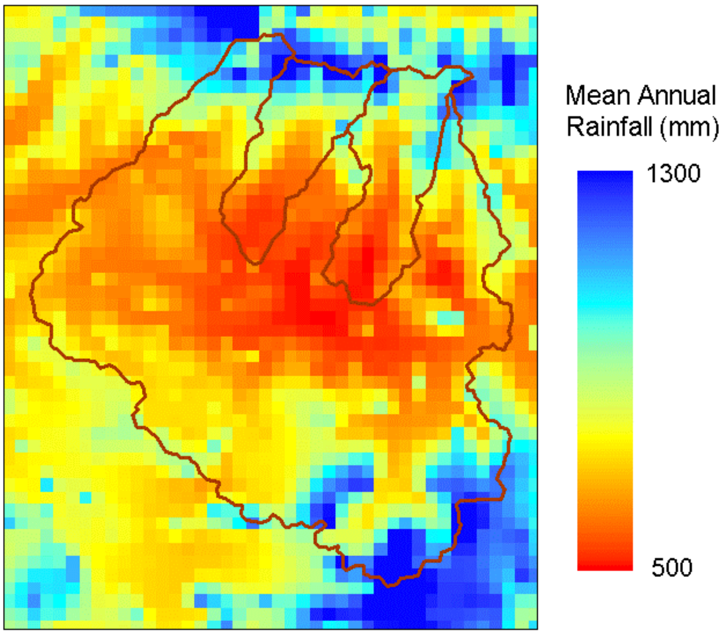


Figure 11 Map of mean annual rainfall for the Goulburn catchment.

4.2 Geology and Soils

The geology of the Goulburn River catchment can be distinguished into two types: the northern which is predominantly Tertiary basalt, a product of Cainozoic volcanism which took place throughout much of eastern Australia, and the southern which is dominated by rocks of the Triassic age laid down as sediments in lagoons and consisting of sandstone, conglomerate and shale. The regions geomorphology is largely dependent on its geological and climatic history with four main types of country identified; the Liverpool Range and Merriwa Plateau in the north and the Central Goulburn Valley and Southern Mountains in the south. The actual study area falls in the northern part of the Goulburn catchment, across the Liverpool Range and Merriwa Plateau. Situated at the northern extent, the Liverpool ranges are characterized by a rugged and basaltic landscape. The area rises over 1200m above sea-level, and localized plateaus exist despite the characteristic rugged topography. The Merriwa Plateau is located south of the Liverpool Range, presenting a rolling and hilly basaltic topography. Its elevation ranges between 450m to the north and 300m to the south.

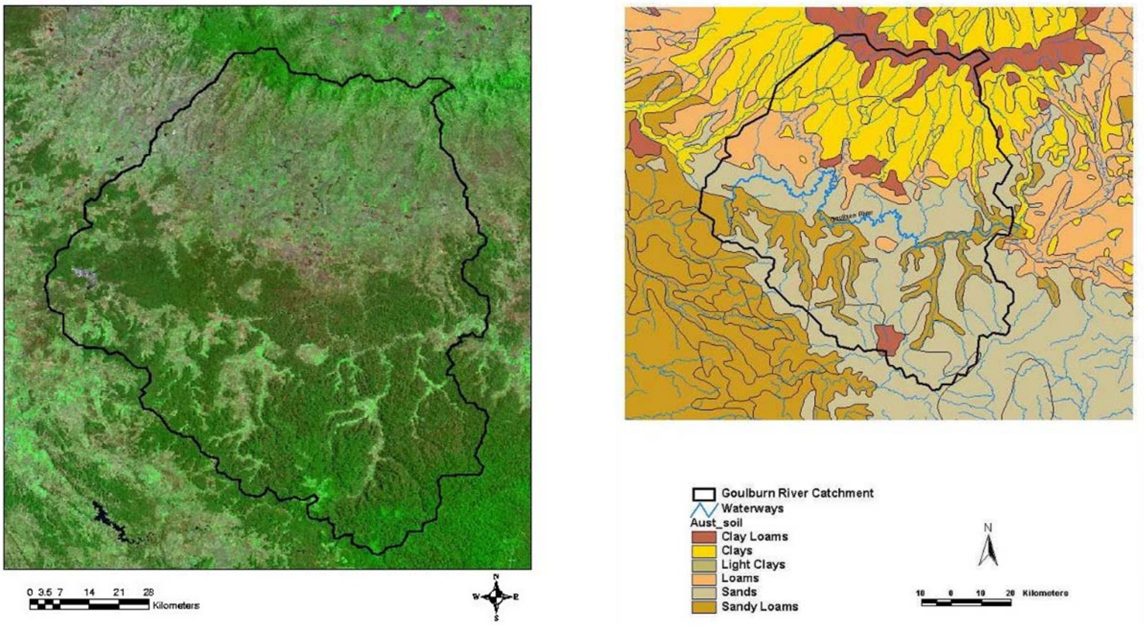


Figure 12. Vegetation (Landsat 5 false colour image) and soil characteristics of the Goulburn study area from the Atlas of Australian Soils.

The NAFE ’05 study area covers mainly the Merriwa Plateau and the southern fringes of the Liverpool Ranges. The northern part of the NAFE ’05 study area is therefore characterized by black basalt derived cracking clays, while the very southern part of the study area is characterized by sandstone derived soils (Fig. 12). Red basalt derived clays are also existent in southern regions of the study area.

4.3 Vegetation

Much of the original vegetation in the northern part of the Goulburn catchment has been cleared, the extent of which has largely been influenced by topography and soil type (Fig. 12). In the north where the terrain is rugged (the Liverpool Range), accessibility is restricted and the area has thus remained highly vegetated. To the south, clearing has been more extensive due to the rolling to hilly terrain ensuring greater accessibility (the Merriwa Plateau). Grazing and cropping activities dominate cleared areas, due to the high fertility of basaltic soils. The sandstone derived soils to the far south are largely uncleared as they are less fertile and productive.

4.4 Monitoring Infrastructure

The Goulburn River experimental catchment has been instrumented since September 2001 and will continue until at least January 2008. There have been several enhancements to the catchment instrumentation since its original installation and several more are planned and/or underway. The catchment monitoring includes surface and root zone soil moisture, soil temperature, meteorological and streamflow measurements.

A total of 26 soil moisture and temperature monitoring sites (Fig. 13) were chosen on the basis of being i) a representative monitoring site, ii) spatial distribution across the experimental catchment, and iii) accessibility. The representative monitoring site objective was addressed by choosing midslope locations with typical vegetation, soil, and aspect, so that they represented catchment average soil moisture locations. The spatial distribution was chosen to give a concentration of measurements in the open cropping and grazing land to the north for application to remote sensing measurements, while achieving a good distribution for model verification within the chosen focus catchments and the broader Goulburn catchment. The automatic weather stations were sited with regard to existing infrastructure and expected spatial variability, resulting in one at the centre of the Goulburn experimental catchment and a second in high terrain to the north of the catchment, supplementing sites to the south, east (Bureau of Meteorology) and west (Ulan Coal Mine). At the same time this resulted in having automatic weather stations located in both the upper and lower reaches of the Krui focus catchment and in the centre of the Stanley microcatchment. Five streamgauges were installed in the two focus catchments, adding to the 4 existing streamgauges operated by the New South Wales Department of Infrastructure, Planning and Natural Resources (DIPNR) allowing the main catchment to be subdivided into smaller modelling units. This included 3 subcatchments in the Krui, 3 subcatchments in the Merriwa, and a further 3 divisions in the Goulburn. Catchment runoff observations are also made at the Stanley microcatchment using a Parshall flume.

Each of the soil moisture sites have up to three vertically inserted Campbell Scientific CS616 water content reflectometers (http://www.campbellsci.com/cs616-l) over depths of 0-300mm, 300-600mm and 600-900mm, respectively (Fig. 14). The number of soil moisture sensors installed was determined by the depth to the bedrock, being less than 900mm in some cases. Sensors were installed by excavation and backfilling. These sensors ensured a continuous observation of the soil moisture profile, with sensors read and the values logged once every 20 minutes.

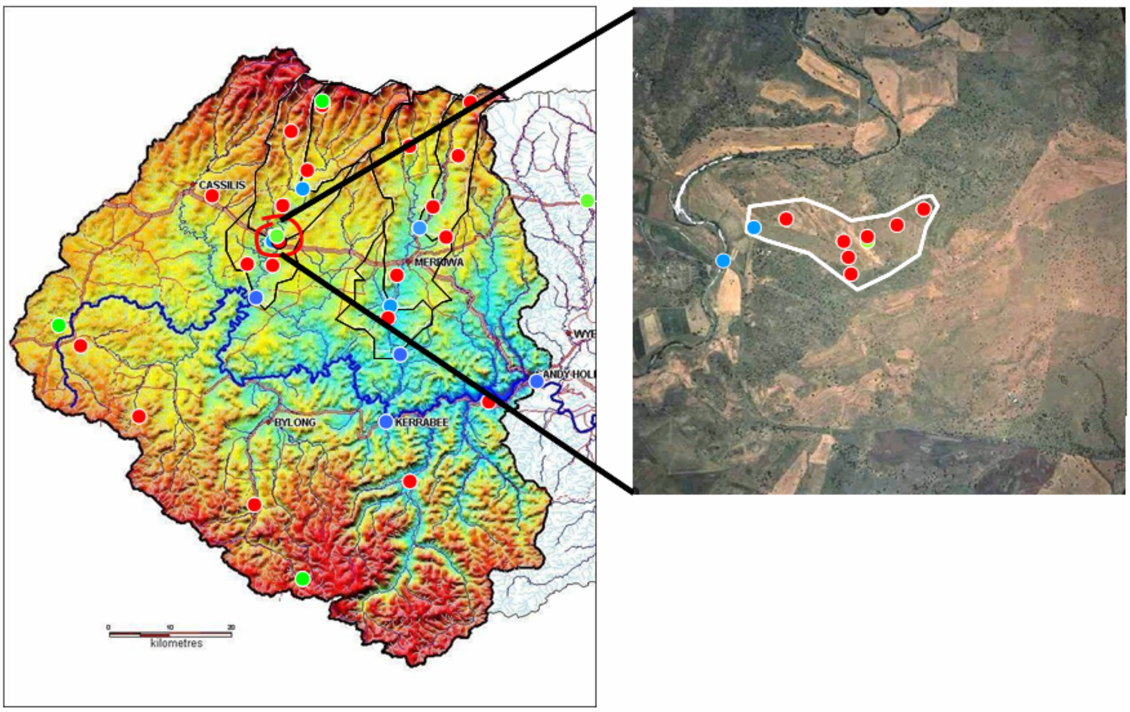


Figure 13. Soil moisture, climate and streamflow monitoring network in the Goulburn iver catchment, overlaying the elevation data. Inset shows the Stanley microcatchment.

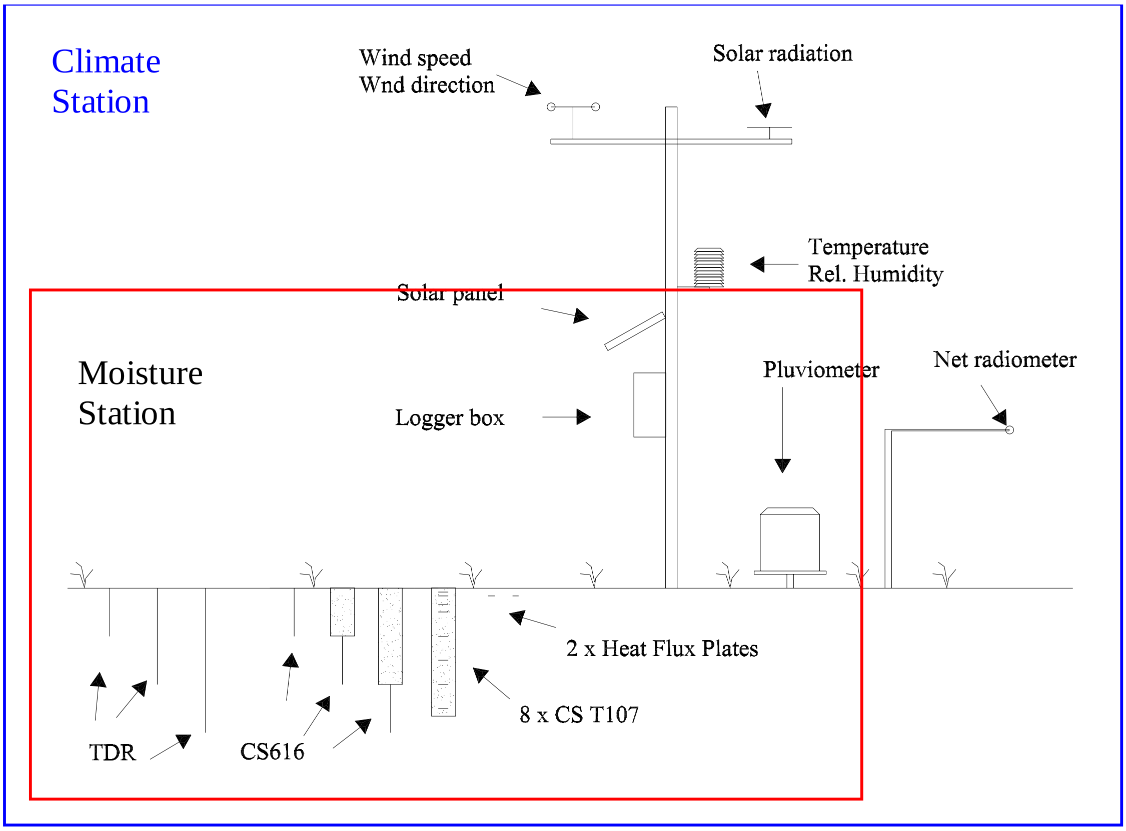


Figure 14. Schematic of monitoring stations.

Sensor response to soil moisture varies with salinity, density, soil type and temperature, so a detailed sensor calibration is being undertaken for each site using both laboratory and field measurements. As the CS616 sensors are particularly sensitive to soil temperature fluctuations Campbell Scientific T107 temperature sensors (http://www.campbellsci.com/107-l) were installed vertically with their midpoint at 15cm below the soil surface, providing a continuous record of soil temperature at a midpoint of the 0-30cm CS616 for each monitoring site. Deeper temperatures were assumed to have the same characteristics throughout the catchment and are therefore estimated from detailed soil temperature profile measurements made at the automatic weather station in the Stanley microcatchment, with a linear offset applied based on comparison of the two 15cm measurements. Fig. 15 displays an example of the collected datasets for years 2003 and 2004 at Spring Hill station, in the northern par of the study area.

Two focus catchments were created by establishing 7 soil moisture monitoring sites in each of the major subcatchments (6 individual sites in the Krui River catchment in addition to the Stanley microcatchment (with 7 sites) and 7 individual sites in the Merriwa Creek catchment), with a further 6 sites installed in the remaining Goulburn River catchment (Fig. 13). The intensively monitored Stanley microcatchment was designed to estimate the location of catchment average soil moisture sites within a catchment, as two groups of sites were located along lines at lower, mid and upper slope locations. Moreover, the higher density of soil moisture monitoring sites in the Krui and Merriwa catchments allows for work on the spatial organisation of soil moisture throughout the northern part of the catchment and supports work undertaken in the validation and scaling of satellite measurements and model simulation.

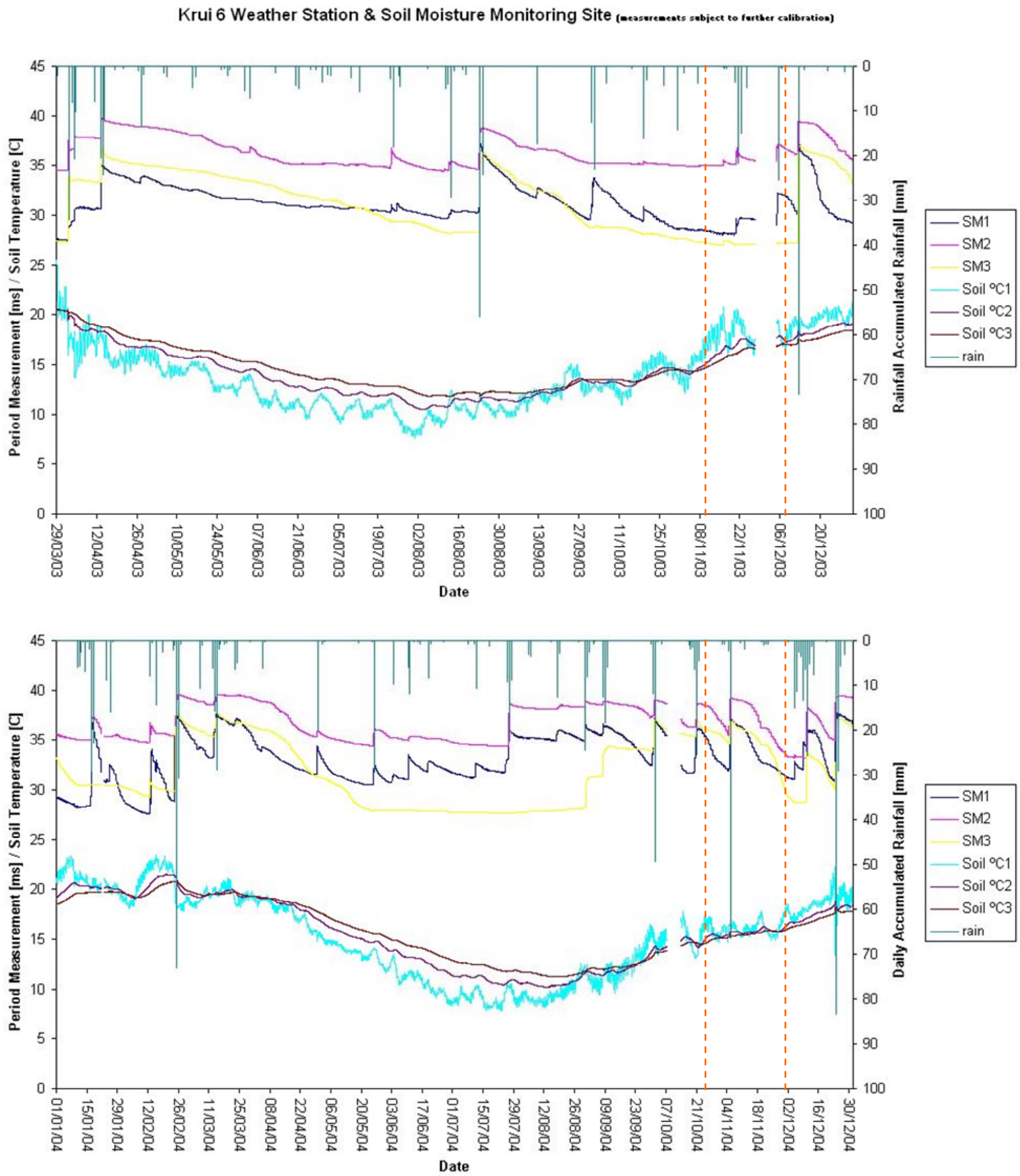


Figure 15. Example of data collected at SAMSAS sites. Plots show temporal variation of soil moisture and soil temperature at (1) 0-30cm (2) 30-60cm and (3) 60-90cm during 2003 (top panel) and 2004 (bottom panel). Daily rainfall is also indicated. Dashed red lines highlight the period in which NAFE'05 will take place.

NAFE'05 will take place in the period between October 31st and November 26th. The time frame was chosen in order to capture highly dynamic soil moisture stats. As evident in the panels of Fig. 15, storms are frequent in this period, at least in the upper part of the study area, resulting in a root-zone soil moisture content (0-30cm) variation within the month of about 7% (V/V). Given the buffer imposed by infiltration of water from the soil surface to these depths, the dynamics in the layer which affects remote sensing measurements (approximately 0-5cm), are expected to be even stronger.

5 Ground Monitoring

The ground component of the NAFE '05 field campaign consists of four aspects:

1. Network of continuous soil moisture profile monitoring stations;
2. Supplementary monitoring stations;
3. Spatial soil moisture mapping; and
4. Supporting data.

5.1 Soil moisture profile stations

The soil moisture and climate monitoring sites existing within the Goulburn River experimental catchment form the basis of all ground based monitoring activities. These monitoring sites have recently been upgraded with telemetry systems, Stevens Water

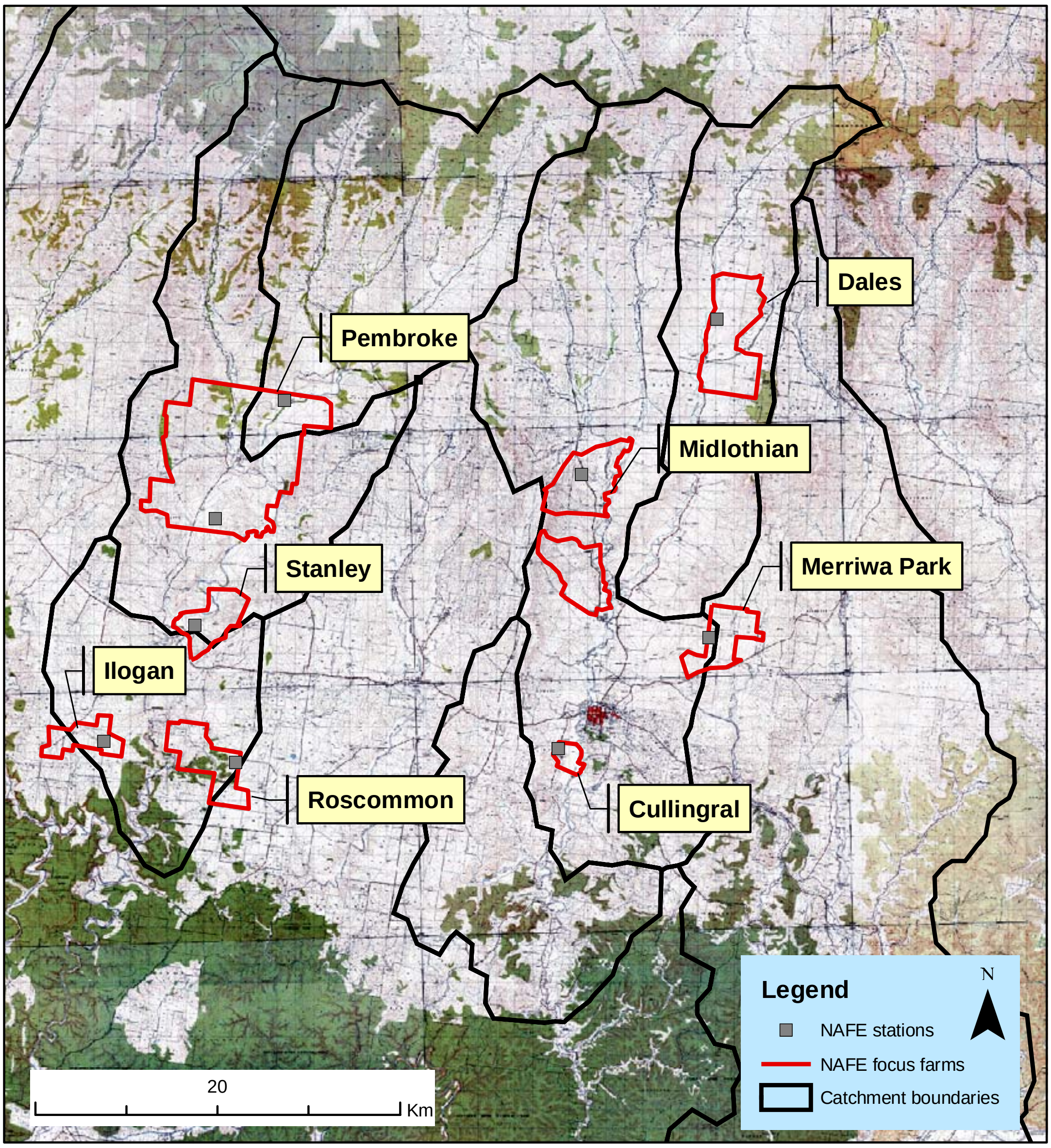


Figure 16. NAFE focus farms in the Northern Goulburn catchment area. NAFE mmonitoring stations are also indicated with squares.

Table 4. Main characteristics of target farms of the NAFE '05 campaign.

FARM NAME	AREA(ha)	TOPOGRAPHY	LANDUSES	SOILS
Pembroke	6400	Hilly/Gently rolling	• Grazing • Crop (wheat)	• Black basaltic clays
Stanley	720	Hilly	• Grazing	• Black basalts on flat; red basaltic clays on crests
Roscommon	940	Flat/Gently rolling	• Grazing	• Red basaltic clays and sandy soils
Ilogan	560	Flat/Gently rolling	• Crop (Barley, Oats, Wheat)	• Black basaltic clays with patches of red basaltc clays
Dales	1500	Flat/Hilly	• Grazing	• Black basaltic clays
Midlothian	2000	Flat/Hilly	• Grazing • Crop(Sorghum, Lucerne,Wheat)	• Black basaltic clays
Merriwa Park	750	Hilly	• Grazing • Crop (Wheat)	• Black basaltic clays
Cullingral	220	Flat	• Crop (Wheat, Lucerne)	• Black basaltic clays

HydraProbe® sensors (Stevens Water; http://www.stevenswater.com/catalog/stevensProduct.aspx?SKU='70030') for top 5cm soil moisture (inserted vertically from the soil surface) and tipping bucket raingauges. Because the HydraProbe temperature sensor is located in the exposed head of the probe, a supplementary temperature sensor has been installed at 2.5cm depth and temperature output from the HydraProbe discarded. Location of the NAFE '05 study area within the Goulburn River experimental catchment was chosen to encapsulate the majority of these stations, and eight focus farms for detailed measurements were chosen within the Krui and Merriwa sub-catchments according to spatial distribution and characteristics of farms hosting these stations (Fig. 16). As the dominant landuses are grazing and cropping, this region is very suitable for soil moisture remote sensing studies due to the moderate vegetation cover. Table 4 summarises the characteristics of each farm.

5.2 Supplementary monitoring stations

A total of eight of the existing monitoring stations (one at each of the eight focus farms) will be supplemented with additional sensors for the duration of NAFE '05 (hereafter referred to as NAFE stations). The primary purpose of this supplementary monitoring is to:

1. provide information on near-surface soil temperature profiles;
2. provide information on leaf wetness in response to dew and precipitation; and
3. develop relationships between thermal infrared observations and near-surface soil temperature

To capture the relevant information, there will be nominally:

- four stations that have thermal infrared radiometers (Two Ahlborn Thermalert TX® and two Everest Interscience Inc.® Infrared Temp Transducers, Model 4000), duplicate soil temperature sensors at 1cm, 2.5cm and 4cm (Unidata® 6507A/10 sensors), and leaf wetness sensors (Measurement Engineering Australia 2040®);

- two stations that have single soil temperature sensors at 1cm, 2.5cm and 4cm, and leaf wetness sensors;
- two stations that have single soil temperature sensors at 1cm, 2.5cm and 4cm; and
- one station that has 4 Unidata® 6507A/10 thermocouples attached to a rock (at Stanley farm)

This supplementary monitoring will in most cases be installed "within" the enclosure at existing monitoring station sites. In particular cases, they will be installed at nearby locations to capture land cover requirements not met at the existing sites; specifically for bare soil and at some crop sites. Fig. 17 shows the location of NAFE stations and the supplementary instrumentation to be installed at each. Fig. 18 shows a schematic of the instrumentation setup.

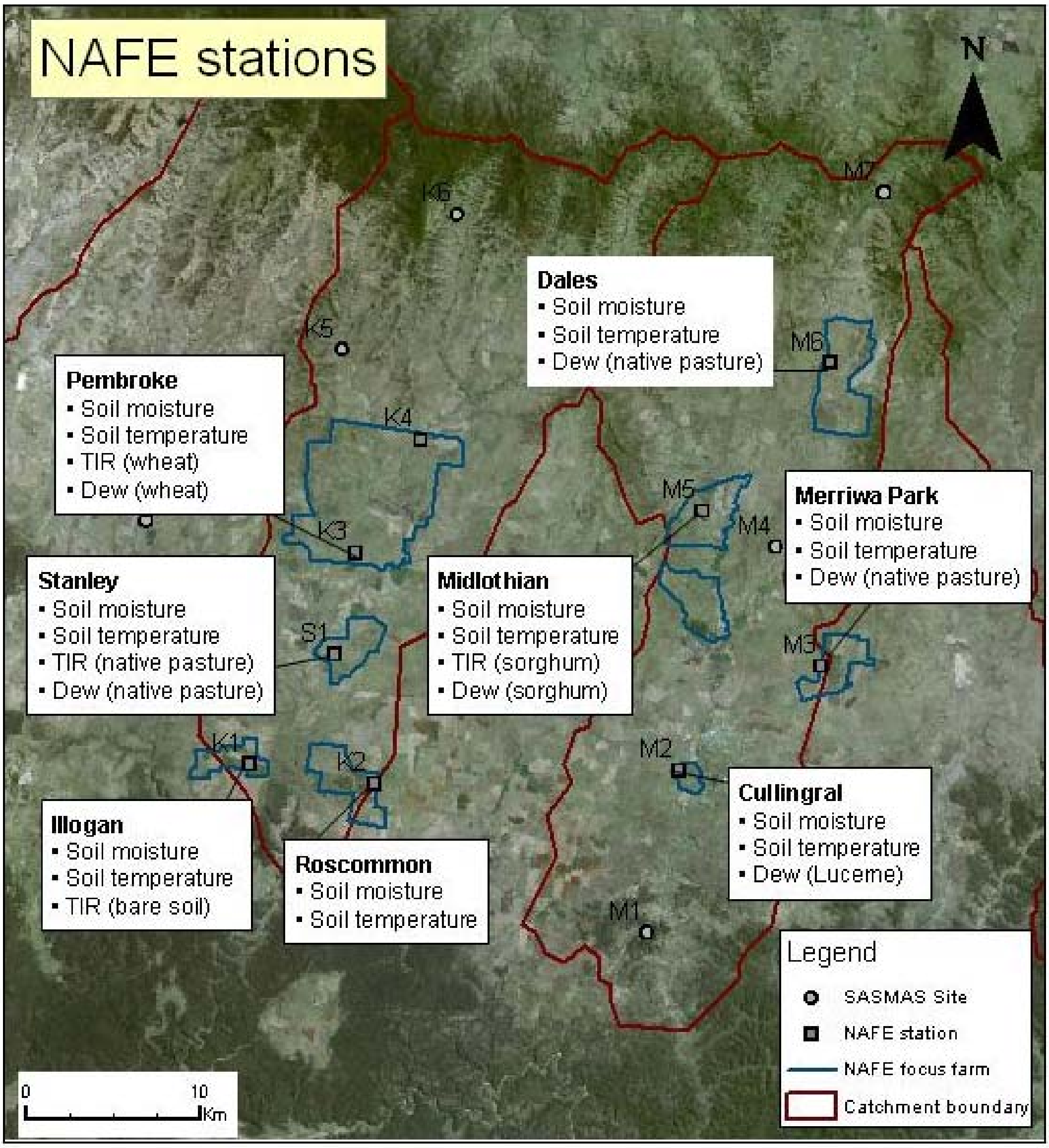


Figure 17. Location of additional ground instrumentations installed for the NAFE campaign. "TIR" stands for Thermal Infrared towers and "Dew" for Leaf wetness sensors.This figure doesn't display the rock surface temperature site at Stanley farm.

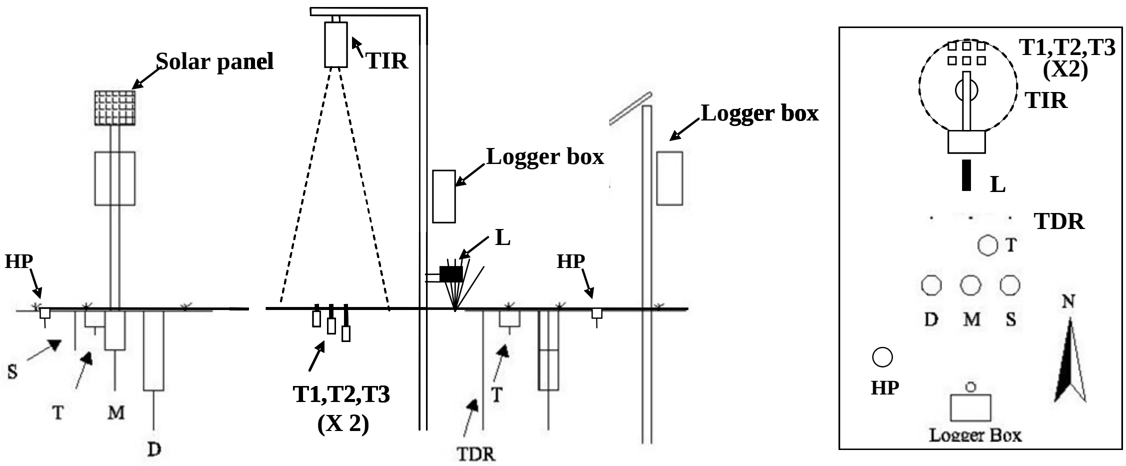


Figure 18. Typical set up of the supplementary monitoring site. (front view, side view and top view); showing shallow (S), medium (M), and deep (D) CS616 soil moisture sensors; 0-5cm Stevens HydraProbe (HP); CS T107 (T), 1 cm (T1), 2.5 cm (T2) and 4cm (T3) soil temperatures; Thermal infrared (TIR) and leaf wetness (L) sensors.

5.3 Spatial soil moisture mapping

Near-surface soil moisture will be measured across the NAFE study area at a range of spatial scales. This will provide an extensive multi-scale near-surface soil moisture dataset useful for addressing the objectives of the study as outlined in section 1.2. Specifically, there will be:

1. regional measurements for verification of airborne and satellite soil moisture retrieval;
2. farm wide measurements for:
    a. verification of scaling assumptions of radiobrightness equations;
    b. assessment of land cover impacts;
    c. development of multi-incidence angle algorithms;
    d. assessment of leaf water impact for 6:00am overpass times;
3. high resolution measurements across these farms for:
    a. understanding spatial variability and representativeness in individual ground measurements;
    b. developing downscaling techniques;
    c. understanding the impact of topography;
    d. understanding the importance of surface roughness;
    e. developing methods for vegetation water content assessment; and
    f. including the impact of surface rock.

Regional scale sampling will occupy an entire day once per week, while farm scale and high resolution area sampling will parallel in the same day on the same farm, four times a week, alternating between Krui and Merriwa area farms, as per the schedule in Table 5

During the 4 week experiment, ground crew will be organised into 4 teams of 3 people (with exception of the Pembroke farm which will have 4 people), each team acting independently within the daily schedule (apart from daily morning and evening briefings). Each team will be assigned 2 focus farms, one within the Krui and one within the Merriwa sub-catchments, and will be responsible for all sampling operations within the assigned areas, as well as general monitoring and reporting to the ground crew leader. Exact location of soil moisture sampling points will be provided – see section 7.

5.3.1 Regional scale sampling

One of the objectives of the NAFE '05 campaign is to provide ground verification data for the AMSR-E soil moisture retrieval algorithms. For this purpose, soil moisture measurements will be made at many locations within the focus farms and along the roadsides in the surrounding areas on days when there are both am and pm overpasses of AMSR-E for the study area. The main objectives are to:

1. Provide an estimate of the areal average and spatial variation of near-surface soil moisture content within an AMSR-E footprint (~50km) at the nominal time of satellite overpass.
2. Develop and verify approaches to downscaling low resolution near-surface soil moisture estimates such as those from AMSR-E to 1km or better resolution using higher resolution remotely sensed thermal and visible data.

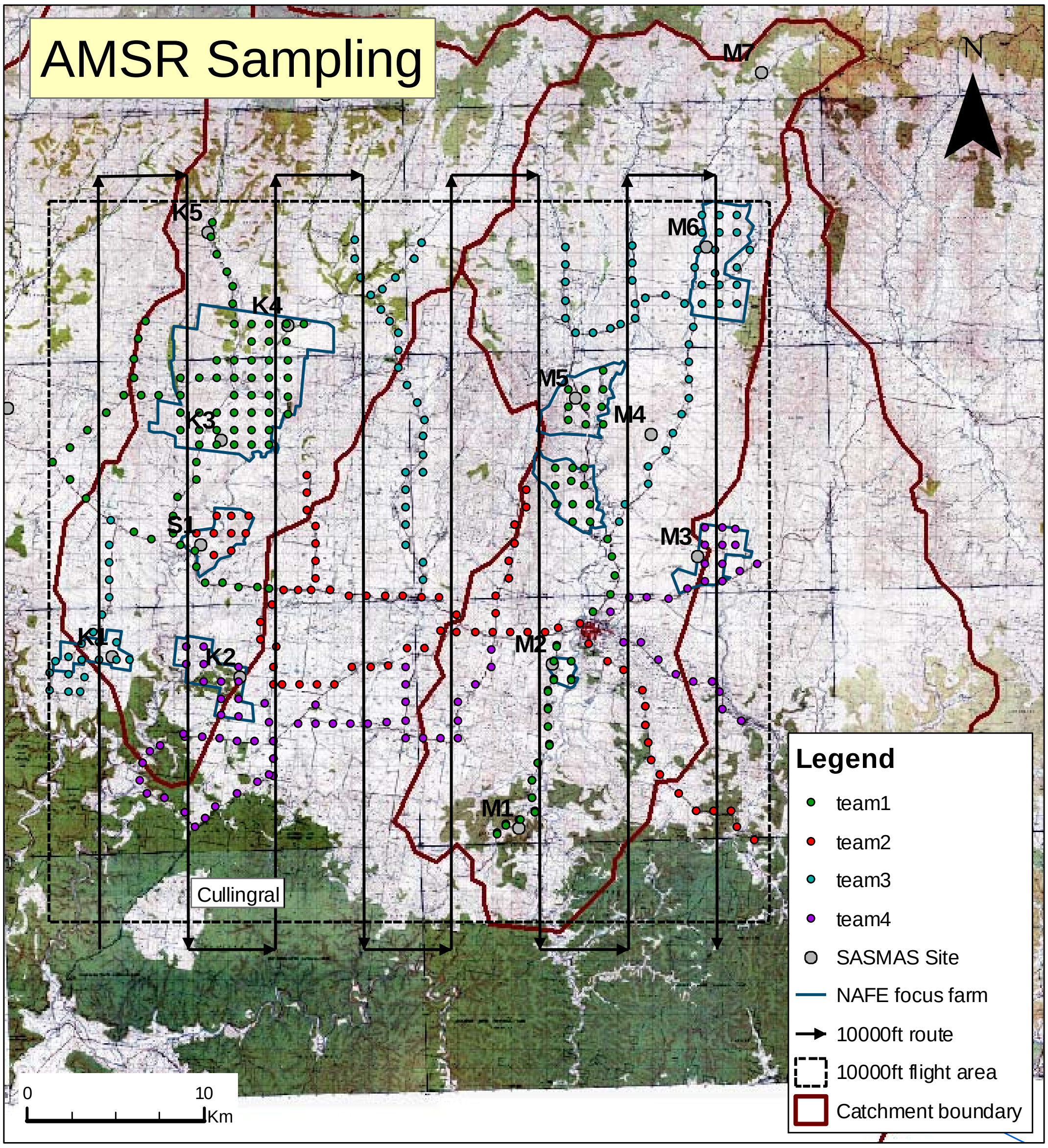


Figure 19. Planned sampling locations for regional scale soil moisture monitoring.

Table 6. Estimated regional sampling times. An average driving speed of 20 Km/h is assumed.

	Point N.	Distance (km)	Speed (Km/h)	Time (hrs)
team 1	122	121	20	6.1
team 2	116	115	20	5.8
team 3	130	129	20	6.5
team 4	99	98	20	4.9

Overpass dates and time are shown in Table 1. On these dates, PLMR flights with nominal 1km ground resolution will be undertaken concurrent with the regional ground sampling. Regional ground sampling of near-surface soil moisture will be undertaken by team leaders using iPAQ based HydraProbe systems (see section 7) at predefined GPS-located points approximately 1km apart. These points will be located in the respective two farms (one in each of the Krui and Merriwa sub-catchments) teams are responsible for and along the sides of main roads crossing the study area. The ground sampling grid according to team is shown in Fig. 19. Sampling will follow as closely as possible a regular 1km grid within the farm boundaries; sampling will occur mostly on the existent farm tracks in order to decrease the total sampling time. Outside the farm boundaries, sampling will be undertaken in the areas adjacent the road, at a distance from it sufficient to avoid localized moisture anomalies due to artefacts of the road. These sites would preferably be made “over the fence” to more closely represent the surrounding land use conditions, but without actually entering onto private land. The sampling illustrated in Fig. 19 is expected to take approximately 6 hours. See table 6 for detailed sampling times per each team.

Concurrently with soil moisture measurements, teams will collect the following supporting data across both focus farms in their responsibility during regional sampling days:

- Gravimetric soil moisture samples (also used for soil texture);
- Vegetation biomass samples;
- Vegetation type characterisation;
- Land use classification;
- Crop height measurements;
- Leaf wetness observations.

Table 5. Ground sampling calendar for NAFE.

	Monday 31/10	Tuesday 1/11	Wednesday 2/11	Thursday 3/11	Friday 4/11
AMSR area					
Krui Area					
Merriwa Area					
	Monday 7/11	Tuesday 8/11	Wednesday 9/11	Thursday 10/11	Friday 11/11
AMSR area					
Krui Area					
Merriwa Area					
	Monday 14/11	Tuesday 15/11	Wednesday 16/11	Thursday 17/11	Friday 18/11
AMSR area					
Krui Area					
Merriwa Area					
	Monday 21/11	Tuesday 22/11	Wednesday 23/11	Thursday 24/11	Friday 25/11
AMSR area					
Krui Area					
Merriwa Area					

AMSR sampling   Farm scale sampling   High resolution sampling

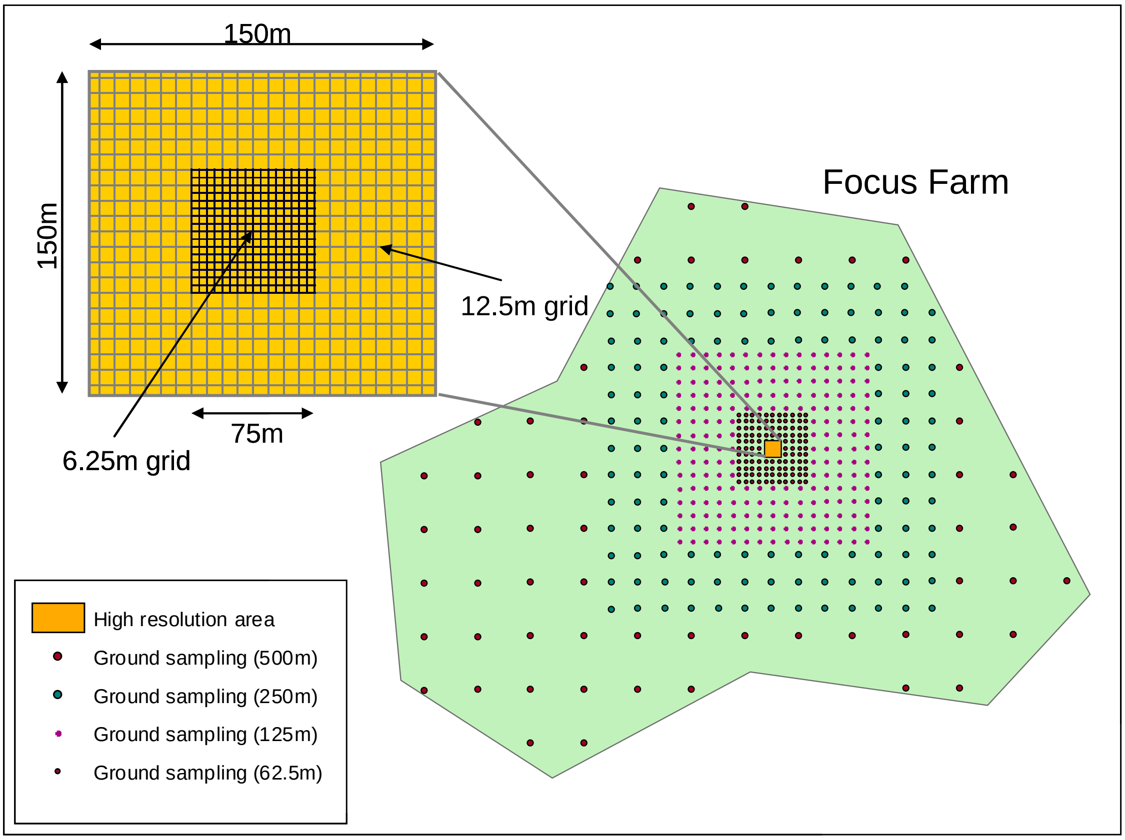


Figure 20. Schematic of farm scale soil moisture sampling strategy.

The following variables will be measured once only by each team for both farms, with instrumentation and/or personnel rotated between farms as necessary:

- Surface roughness measurements;
- LAI measurements;
- NDVI measurements;
- Surface rock cover estimation.

Detailed description of data sampling procedures can be found in sections 5.4 and 7. **For a summary of the daily measurements of each group refer to Tables B1 and B2 in Appendix B.**

5.3.2 Focus farms measurements

The purpose of farm scale sampling is to provide ground soil moisture and supporting data for verification of the aircraft soil moisture, soil temperature and vegetation mapping at different ground pixel resolutions. Near-surface soil moisture will therefore be measured across the focus farms concurrently with aircraft overpasses at a range of spatial scales. The objective is to cover as much of the farm extent and surface conditions present in the area as possible in a single day, with a combination of spatial resolutions. This will provide both direct ground and downscaling verification of the aircraft measurements with sufficient spatial detail to capture sub-pixel variability. The adopted sampling strategy (Fig. 20) is therefore a compromise between these objectives and logistic constraints such as number of ground personnel and time available.

Soil moisture measurements will be taken at many locations within the farm at various resolutions (500m, 250m, 125m and 62.5m), covering as much as possible of the range of land use, topographic, soil type and soil wetness conditions present across the farm. Furthermore, at each farm a small area of 150m by 150m size will be the focus of very intensive soil moisture sampling (12.5m and 6.25m). Each farm will be sampled in one day by one team, which will be divided into 2 groups:

- Group A (1 person) dedicated to the 500m, 250m and 125m sampling
- Group B (2 people) dedicated to the high resolution area sampling, in the morning, and the 62.5m sampling in the afternoon.

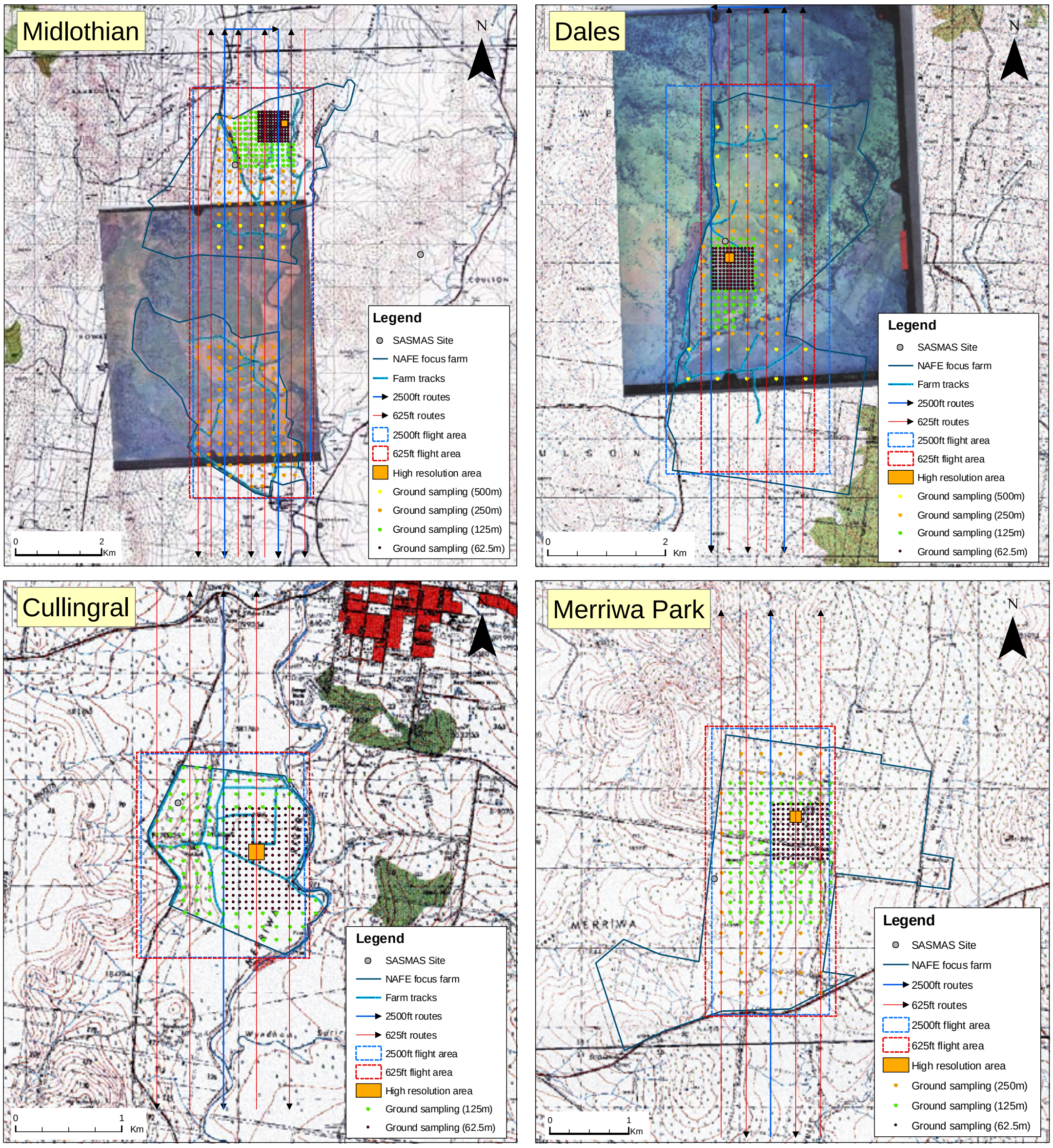
Exact sampling locations will be provided on the individual iPAQs. Group A will make use of the team vehicle to move across the farm, or walk to the sampling points in areas where driving is not feasible. Sampling points will be located by use of a GPS receiver link to the iPAQ. Similarly, Group B will identify the 62.5m sampling locations with the GPS and iPAQ system. As individual GPS receiver position accuracy is insufficient for the high resolution area, sampling locations will be clearly marked and labelled on the ground (see section 6.2). The farm scale sampling grid for all the focus farms are shown in Fig. 21 and 22.

The 150m x 150m areas herein referred to as "high resolution" areas will be sampled at very high resolution, down to 6.25m. This sampling approach has been chosen in order to (a) provide highly detailed ground information on the representativeness and variability expected from point soil moisture and vegetation biomass measurements used for accurate validation of the PLMR mapping and (b) validate the downscaling techniques with high

Table 7. Characteristics of the high resolution sampling areas

Farm	topography	vegetation cover	purpose	Soil type	Reference Lat(Deg)	Reference Long(Deg)
Pembroke	gently sloping/ contour bank	Native grass/ Wheat	vegetation cover variability	Black Basalt	150.1377	-32.0405
Stanley	slope	Native	topography	Red Basalt	150.1387	-32.0940
Roscommon	flat	Native	PLMR validation on native grass	Red Basalt	150.1460	-32.1754
Illogan	flat	Native grass/ Wheat	vegetation cover variability	Red Basalt	150.0572	-32.1454
Dales	sloping/creek	Native	topography	Black Basalt	150.4324	-31.9496
Midlothian	flat	Sorghum / Lucerne	vegetation cover variability	Black Basalt	150.3634	-32.0137
Merriwa Park	gently sloping	Wheat	PLMR validation on crop	Black Basalt	150.4335	-32.0979
Cullingral	flat	Lucerne	PLMR validation on crop	Black Basalt	150.3413	-32.1621

resolution ground data. For these reasons, the areas were selected in order to cover as many land cover conditions in the area as possible, while capturing detectable near surface



	Nr. Of Sampling points						Estimated sampling times (hrs)			
Farm	Hi-res area	62.5m	125m	250m	500m	1000m	person 1	person 2	person 3	person 4
Dales	289	140	58	41	21		6.5	6.5	6.8	none
Midlothian	289	140	86	157	8		6.5	6.5	6.5	6.7
Merriwa Park	289	140	138	41			6.5	6.5	6.8	none
Cullingral	289	197	89				7.1	7.1	5.5	none

Figure 21. Soil moisture sampling grids and estimated sampling times for all the four Merriwa area focus farms. High resolution PLMR flight lines are also indicated with the mapping coverage.

moisture patterns within the 150m x 150m area. The areas chosen represent microtopographic conditions and non-homogeneous vegetation covers and soil type which are expected to produce the desired soil moisture variability. Table 7 describes the characteristics of each high resolution area with the reference coordinate for their centre point. As shown, all predominant land cover types are included (with the exception of Barley and Oats crops, which will be generally very short or dead at this time of year and can therefore be considered as short native grasses), and various combinations of microtopography and non-uniform land cover are captured.

Teams will also collect the following supporting data at the focus farm on each farm sampling day:

- Gravimetric soil moisture samples;
- Vegetation water content samples;
- Leaf wetness observations and dew amount.

For a summary of the daily measurements of each group refer to Tables B1 and B2 in Appendix B.

The following section describes the methods use to sample these auxiliary data and their significance.

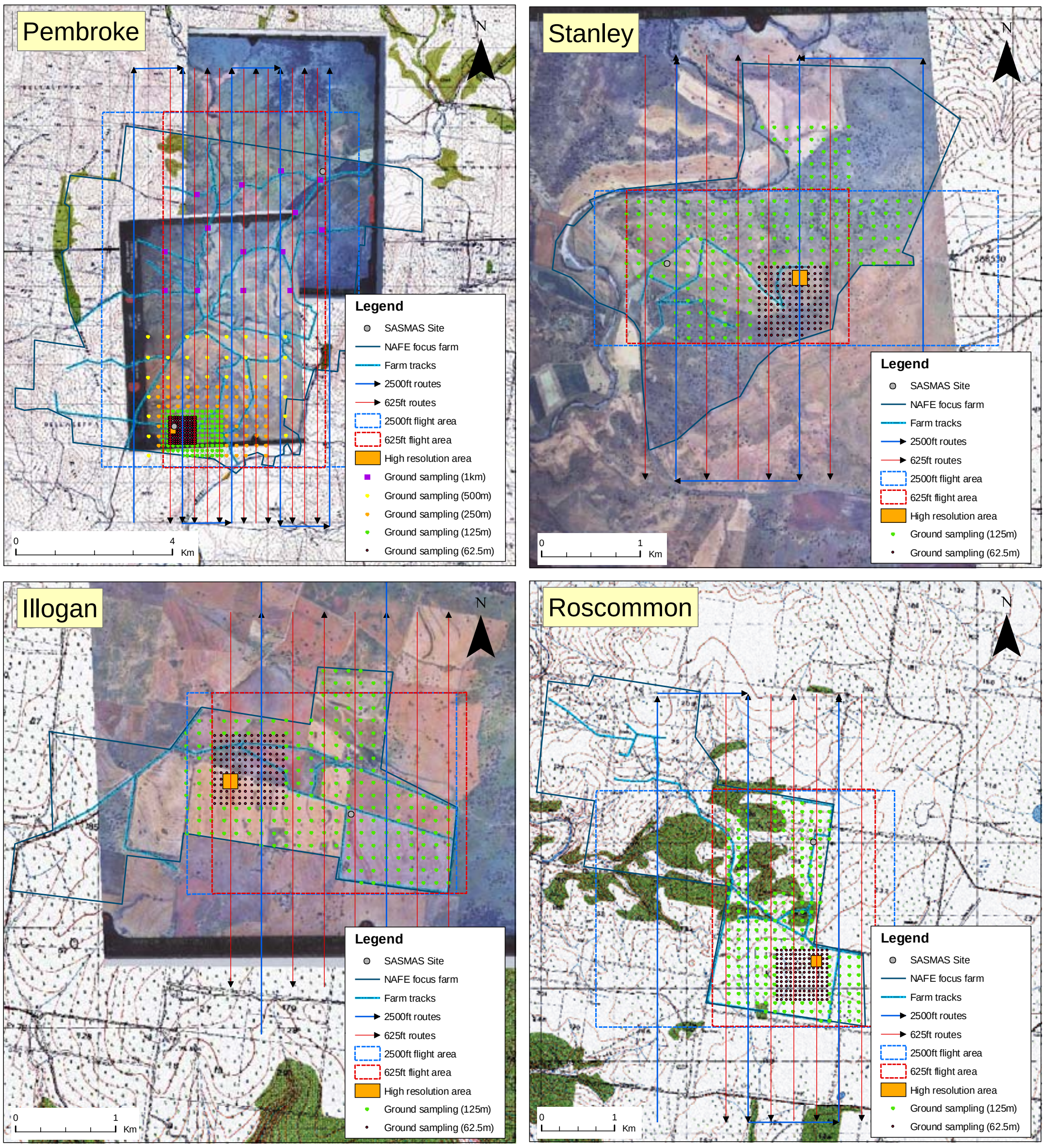
5.4 Supporting data

A number of auxiliary data sets are needed together with soil moisture in order to characterise the surface conditions within the study area. This information is necessary for various purposes:

- to provide auxiliary data required to model the soil microwave emission;
- to validate the observations from different remote sensors operating at different spectral bands which will be flown over the area;
- to calibrate the ground sensors that will be used during the campaign.

Supporting data that will be collected during the campaign include:

- Gravimetric soil moisture samples;
- Vegetation biomass and water content;
- Vegetation type;
- Landuse classification;
- Vegetation Leaf Area Index (LAI)
- Vegetation Normalized Difference Vegetation Index (NDVI)
- Surface roughness
- Soil textural properties
- Surface rock cover
- Leaf wetness



	Nr. Of Sampling points						Estimated sampling time (hrs)			
Farm	Hi-res area	62.5m	125m	250m	500m	1000m	person 1	person 2	person 3	person 4
Pembroke	289	140	101	64	31	14	6.5	6.5	7.1	7
Stanley	289	135	227				6.3	6.3	7.1	none
Roscommon	289	140	223				6.5	6.5	6.9	none
Illogan	289	140	228				6.5	6.5	7.1	none

Figure 22. Soil moisture sampling grids and estimated sampling times for the four Krui area focus farms. High resolution PLMR flight lines are also indicated with the mapping coverage.

The following sections discuss the significance of the above information and individual sampling strategies are described. **Details on how the measurement will be taken can be found in section 7.**

5.4.1 Thermogravimetric soil moisture samples

Volumetric samples of soil will be collected across the study area for both soil textural analysis and calibration of the Stevens Water HydraProbes®. Teams will collect soil samples both during both:

1. regional sampling days, requiring a minimum of 6 samples of different soil types and wetness condition combinations to be collected across each focus farm.
2. farm scale sampling, requiring a minimum of 2 samples of different soil types and wetness condition (1 dryish and 1 wetish) combinations to be collected across each focus farm.

In total, a minimum of 56 soil samples will be collected along the entire campaign. These volumetric samples (collected with a sampling ring for the same soil measured with the HydraProbe) will be dried in ovens at the end of each day to calculate the gravimetric water content and the bulk density. From there the volumetric water content will be compared with HydraProbe measurements taken at the same locations. These samples will cover a wide range of soil types and wetness conditions, providing a calibration equation for each farm if not the entire region.

5.4.2 Vegetation biomass and water content

The amount of vegetation biomass (Kg/m^2) and vegetation water content (g of water/g of biomass) present above the soil surface strongly affects the microwave emission observed. Information on the spatial and temporal variation of these two quantities is needed for microwave emission modelling and so that relationships with infrared and visible remote sensing observations can be established. An overview of the sampling approach is as follows, with detailed sampling procedures given in section 7:

1. During regional sampling days:
   - A total of 16 vegetation biomass "quadrant" samples will be collected on a grid across the high resolution area on both farms in weeks 1 and 4. These samples are intended to give an estimate of spatial variability in vegetation biomass and water content for a specific vegetation type.
   - A minimum of 6 vegetation biomass "quadrant" samples will be collected across each farm, with the aim of collecting at least one sample for every land cover class. Sampling locations should be the same for all four regional sampling days so they can be used to assess temporal variation in vegetation biomass and water content.
2. During farm scale sampling days:
   - A minimum of 2 vegetation water content "grab" samples will be collected for the farm reference vegetation at the end of the day. Sampling location and vegetation type will remain the same for all the sampling days. These samples are intended to give an estimate of temporal variability in vegetation water content for specific vegetation types.
   - Information about the plant height, using scale on HydraProbe pole.
   - Absence/presence of leaf wetness at start of day and time of burn off noted.

- During two of the Merriwa catchment sampling days there will also be an early morning “dew effect” flight (see Table 8). On these days 2 further vegetation water content “grab” samples will be collected for the farm reference vegetation at the beginning of the day. The purpose of these samples is to determine the amount of leaf water, so care must be taken not to shake the vegetation and loose this water.

5.4.3 Vegetation type

This information is important for the analysis of visual and infrared remote sensing observations, as well as general site characterisation. Dominant vegetation type will be recorded at each sampling site at least once during regional and/or farm scale sampling using the predefined list of vegetation types.

5.4.4 Land use classification

Land use is useful information that supports the interpretation of remotely sensed data of various nature. It is therefore important to characterize the main land uses in the study area, to complement land use mapping obtained from satellites like Landsat. Land uses will be characterized by visual observation during ragional sampling days, assigning every area sampled to one of the following subclasses (selected as the predominant land use classes in the region)

1. Native pasture
2. Improved pasture
3. Range land
4. Agricultural land: Fallow
5. Agricultural land: Wheat
6. Agricultural land: Sorghum
7. Agricultural land: Lucerne
8. Agricultural land: Canola
9. Agricultural land: Oats
10. Agricultural land: Barley
11. Forest land
12. Urban
13. Water body

5.4.5 Vegetation Leaf Area Index (LAI)

LAI assigns a quantifiable value to the amount of vegetation on the ground. Simply put, LAI is the leaf area per unit ground area as seen when looking down on vegetation. This parameter can be related to satellite and aircraft observations at infrared and visible wavelength to provide mapping of vegetation biomass over large areas. Given that the temporal variability of this parameter is expected to be moderate during the campaign, measurements of LAI will be undertaken across farms on only one occasion each, rotated between teams during regional sampling days (team 1 in week 1 through team 4 in week 4). Measurements will be made at 50m spacing at particular location in each farm, selected for high resolution LAI sampling. More extensive measurements will be made across the Stanley focus farm.

5.4.6 Vegetation Normalised Difference Vegetation Index (NDVI)

NDVI is a measure of the green, leafy vegetation density or the lushness of vegetation, and is a function of the difference between the visible and near-infrared sunlight that reflects off the vegetation. Ground measurements of this parameter can be used to verify satellite and aircraft observations, expected to provide vegetation biomass and downscaling information over large areas. Given that the temporal variability of this parameter is expected to be moderate during the campaign, measurements of NDVI will be taken together with the LAI measurements.

5.4.7 Surface roughness

Surface roughness affects the microwave emission from the soil by effectively increasing the surface area of electromagnetic wave emission. Although its effect on observations at L-band frequency has been shown to be very poor, it is important to characterise the spatial variation of this parameter across the different land cover types. As temporal variation in surface roughness is expected to be secondary to spatial variation, it will be estimated once only during the campaign at a minimum of 4 locations on each farm to capture the different roughness characteristics according to land cover type. Measurements will be made using a pin profiler which will be rotated between teams on regional sampling days (team 1 in week 1 through team 4 in week 4).

5.4.8 Soil textural properties

Information on soil textural properties is very important for modelling the microwave emission from the soil as it strongly affects the dielectric behaviour of the soil, a main factor in determining the microwave emission. Laboratory soil textural analysis will be performed on a subset of the soil samples for fraction of sand, clay and silt.

5.4.9 Surface rock cover

The effect of surface rock cover on microwave emission of the soil is still unclear and has not received special attention, despite the fact that large parts of the earth's surface has significant fractional surface rock coverage. One of the objectives of NAFE is to provide preliminary insight into this effect. This will be achieved by visually estimating the percentage of surface rock covered at all sampled sites on at least one occasion. Furthermore, rock temperature will be monitored by installing a set of sensors on a rock in the Stanley focus farm.

5.4.10 Leaf wetness

Passive microwave soil moisture retrieval algorithms generally rely on one fundamental assumption: that the temperature of the soil and the vegetation canopy are the same. This condition is more likely to be met early in the morning, when the effect of solar radiation is still minimal. For this reason, satellites missions are generally planned with local overpass times early in the morning and late in the evening (eg, 6:00am/pm for SMOS and Hydros). However, the presence of dew on vegetation at that time of day is likely to affect the accuracy of the passive microwave observation. One of the objectives of NAFE is to analyse the effect of dew on the microwave signal. This will be accomplished with two targeted "dew effect" aircraft flights during the campaign (see Table 8). On these days ground crew will additionally collect two vegetation samples at the start of the day when dew is still present (see section 7 for details). In order to support the leaf wetness measurement made by the permanent stations, ground crew will be required to provide a visual estimate of the leaf wetness conditions during the early hours of the day. This will be accomplished by assigning a value to the wetness state of the plants, ranging from 0= no dew, 1 = moderately wet, 3 = very wet.this values will be promted in the individual iPAQs

6 Airborne Monitoring

One of the major scientific components of the NAFE '05 field campaign is soil moisture mapping with the Polarimetric L-Band Multibeam Radiometer (PLMR) onboard the Small Environmental Research Aircraft (SERA). Technical details about the platform and scientific payload are presented in section 3.

PLMR will be flown together with the thermal imager on all flights. Additionally, for the Krui and Merriwa regions there will be NDVI scanner flights at the start, middle and end of the campaign, there will be digital photography at the start of the campaign only, and there will be lidar coverage undertaken most likely in February. The PLMR flights will be made at a range of flying heights/resolutions across areas of different size throughout the northern half of the Goulburn River experimental catchment (see Figs. 23 and 24, and Table 6).

In parallel with the flights of SERA, the area will be the object of a study conducted by a team from the ESA's SMOS project. This group will be flying an aircraft carrying the EMIRAD system, The airborne, imaging, polarimetric EMIRAD system employs Ku (16 GHz) and Ka (34 GHz) band polarimetric radiometers at 2 different incidence angle (0° and 40°) to measure microwave britghtness temperatures.

The aircraft will be based at Scone airport (Fig. 2) and will operate daily from there. The air crew will be based in Scone and will be responsible for all pre-flight and post-flight activities.

The most important component of the campaign is the high resolution soil moisture mapping

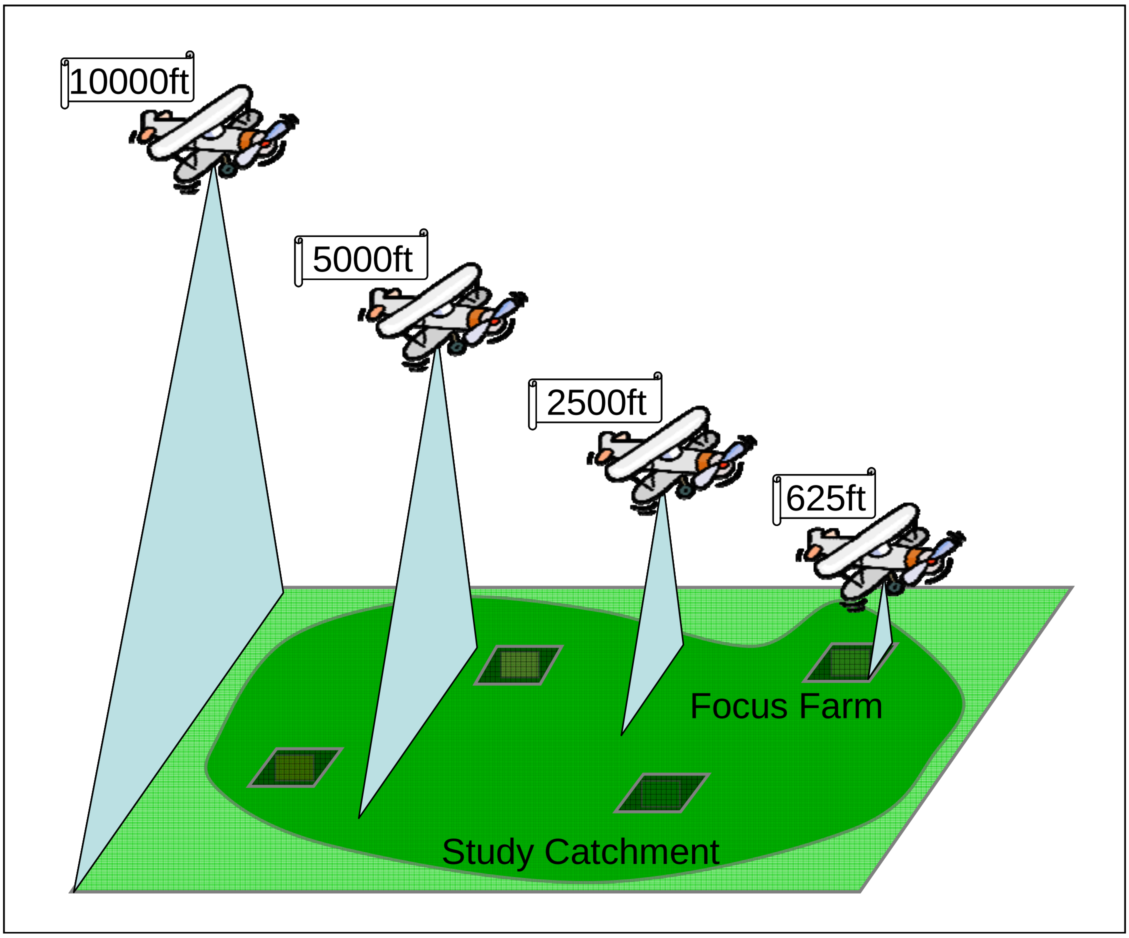


Figure 23. Schematic view of PLMR flights. Indicated flight heights are nominal mean altitudes above ground level.

Table 6. PLMR flight description. Labels for the flight lines naming convention are also indicated. See table C2 in Appendix C for details about Medium and high resolution actual flight altitudes ASL

FLIGHT NAME	FLIGHT ALTITUDE (AGL)	FLIGHT ALTITUDE (ASL)	NOMINAL GROUND RESOLUTION	SWATH	COVERAGE	LABEL
Low Resolution	10000ft	3430m	1000m	6000m	Regional plus Krui and Merriwa sub-areas	A
Intermediate Resolution	5000ft	1910m	500m	3000m	Krui and Merriwa sub-areas	B
Medium Resolution	2500ft	1050 - 1270m	250m	1500m	Farms	C
High resolution	625ft	480 -700m	62.5m	375m	Farms	D
Multi angle	2500ft	1210m	250m	1500m	Merriwa Park focus farm	E
Dew effect	5000ft	1910m	250m	1500m	Merriwa sub-area	F
NDVI	5000ft	1910m	2m	3000m	Krui and Merriwa sub-areas	G
Aerial photography	5000ft	1910m	0.5m	3000m	Krui and Merriwa sub-areas	G

over the focus farms. Such high ground resolution (62.5m) with an airborne passive microwave sensor is unprecedented (apart from a brief field trial). Therefore the scientific significance of this campaign will be outstanding. Intermediate, medium and low resolution flights will provide mapping of soil moisture at coarser scales but for larger areas, providing the linkage with satellite footprints, allowing the multiple scientific objectives of the NAFE '05 campaign to be addressed.

Before illustrating in detail the flight plans and schedules for NAFE '05, it is helpful to explain briefly the rationale behind the flight line planning.

6.1 Flight plans

Flight routes and coverage's at different altitudes have been carefully optimised in order to meet a number of objectives and logistic constraints. These objectives include:

- to cover as much of the study area at multiple ground resolutions during the campaign so as to obtain spatial soil moisture patterns at different scales for an extensive area;
- to map the same area at multiple ground resolutions within the same day to avoid so much as possible temporal differences between maps at different resolutions;

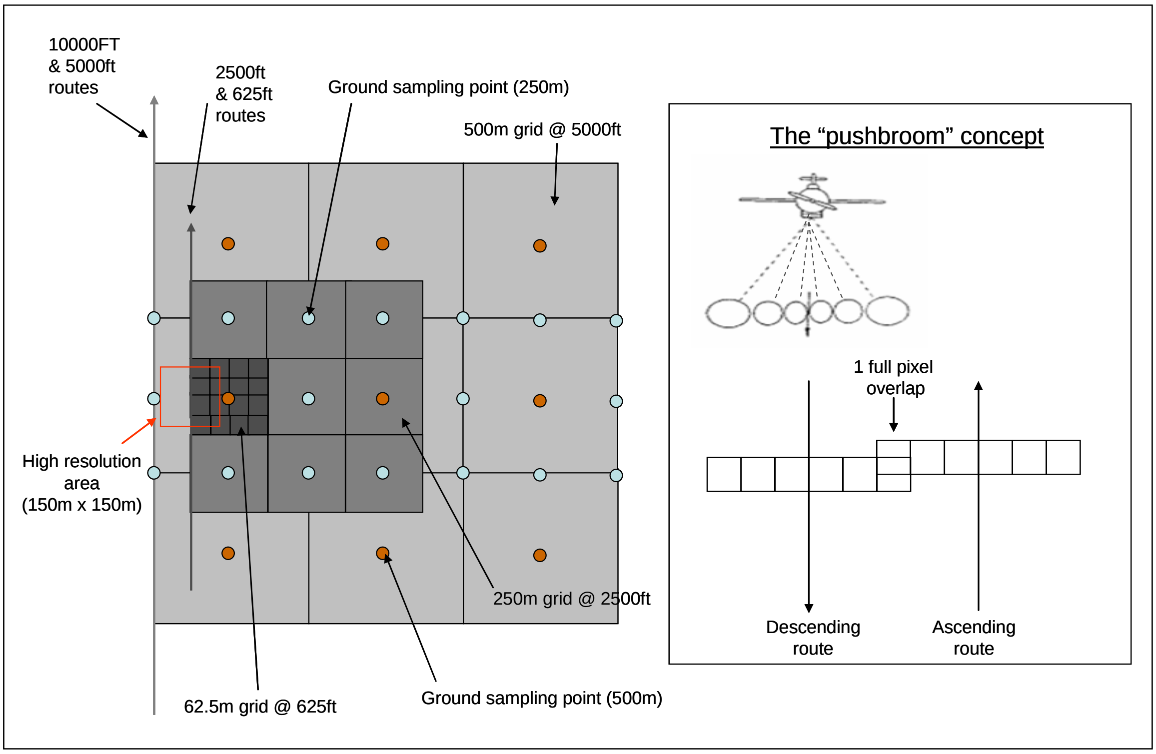


Figure 24. Schematic view of flight plan rationale.

- to obtain patterns of brightness temperature nested between different resolution for scaling purposes; and
- to have high resolution areas falling within the central pixels of the swath at each altitude (beam 1 or 2) to ensure they are not inadvertently missed due to diversions from planned flight paths and wing level attitude, or variations in ground elevation.

The main constraints include:

- to have sufficient overlap between adjacent flight lines in order to avoid areas of no data due to aircraft roll or variations in ground elevation;
- to have sufficient overlap to allow temporal correction of data back to a reference time;
- to have ground sampling points at the centre of aircraft pixels;
- to have a nested network of ground sampling grids linked between different ground sampling resolution (e.g. every second sampling point at 250m spacing is also a sampling point for 500m spacing);
- to keep the total number of mission flight hours for NAFE '05 below 92 hrs, due to legislative regulations; and
- to keep individual flights to not more than 4-5 hours and daily total flight hours below 6, to allow time for pre-flight and post-flight activities, avoid need for refuelling, and to allow the pilot to have a toilet break!!

Fig. 24 illustrates schematically the way flight lines at different altitudes and ground sampling points at different resolution are linked in order to meet the above criteria.

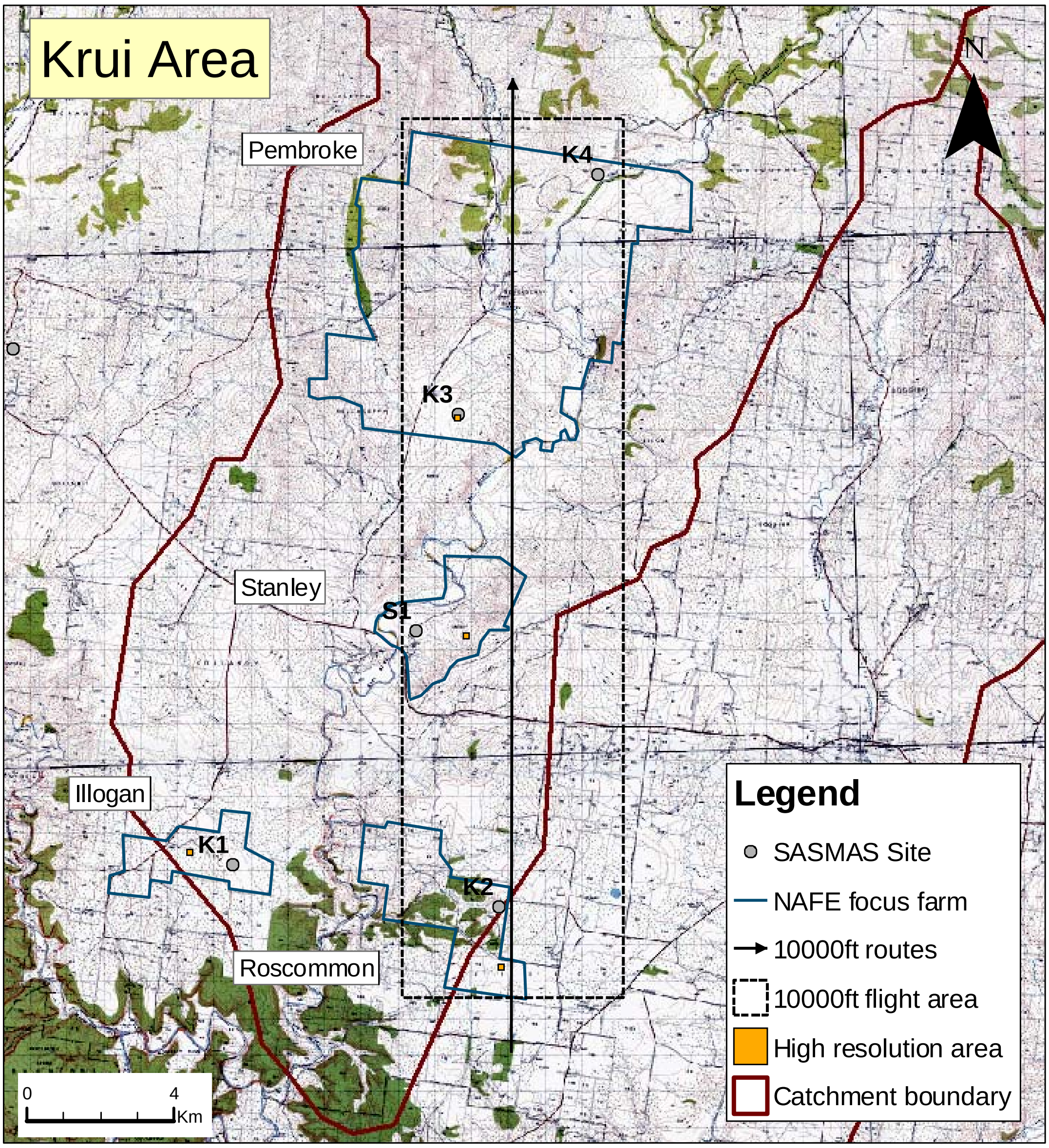


Figure 25. PLMR low resolution flightlines for farm scale days on Krui area. Black solid lines are the flight lines at 10,000ft altitude (AGL), dashed black lines are the areas covered by the mapping.

6.2 Low resolution mapping

One of the objectives of NAFE '05 is the mapping of soil moisture at satellite footprint scale from an airborne platform. This component of the airborne campaign will provide the necessary link between the passive microwave observations at high resolution and the equivalent spaceborne observation over large areas for scaling purposes. Furthermore, low resolution observations from the aircraft are easier to accurately validate than the satellite observations, due to the smaller ground pixel size achievable (1km against 50km). This will allow more accurate verification of the satellite-retrieved soil moisture over large areas by making use of the validated 1km product obtained with the aircraft. This will also provide invaluable data for verification of AMSR-E downscaling algorithms and exploring the scaleability of radiobrightness equations from tower to AMSR-E scales.

Low resolution mapping flights will be flown at a nominal altitude of 10,000ft AGL. Actual altitude above sea level will be of 3430m, which results from flying above the median

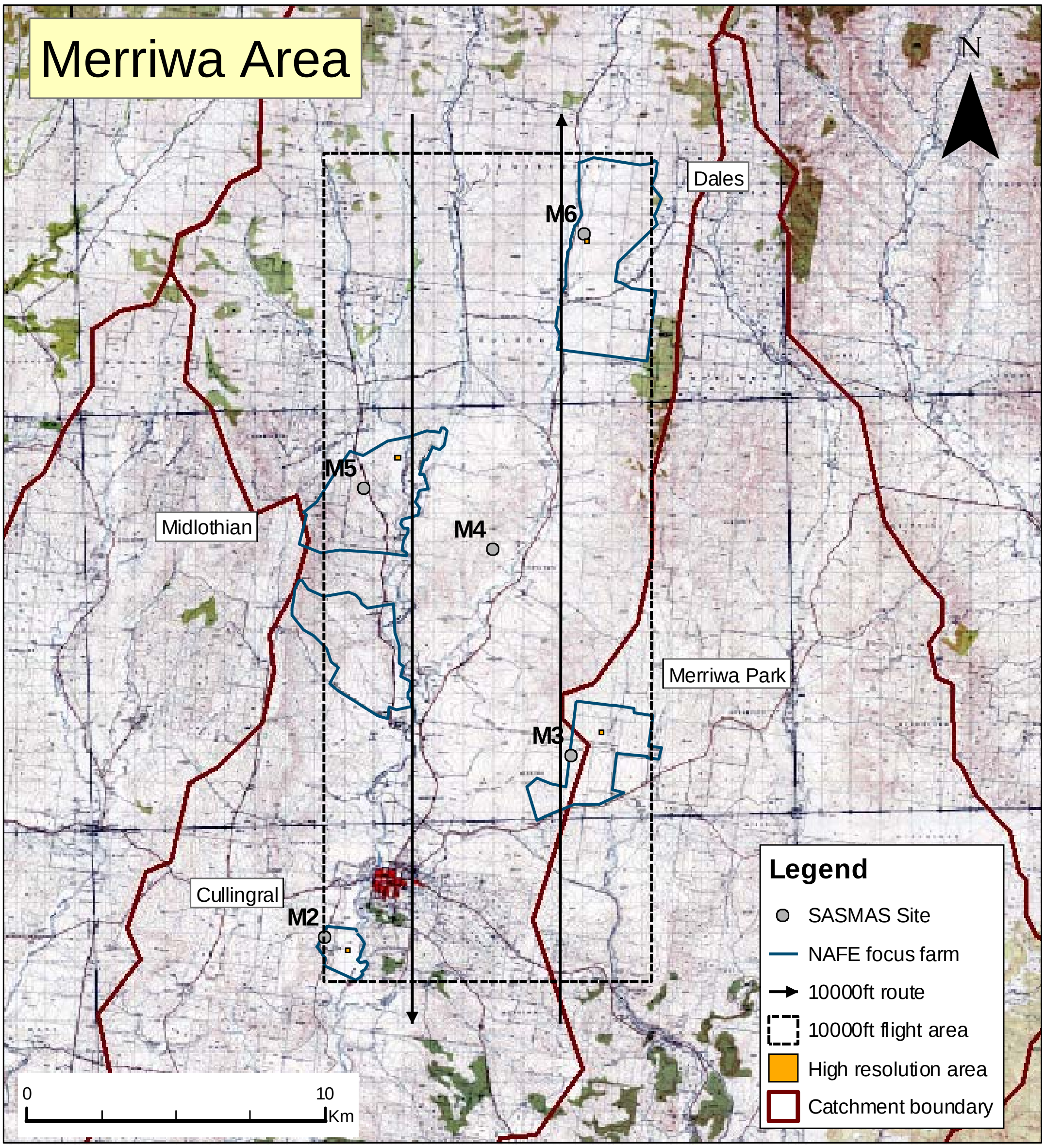


Figure 26. PLMR low resolution flight lines for farm scale days on Merriwa area. Black solid lines are the flight lines at 10,000ft altitude (AGL), dashed black lines are the areas covered by the mapping.

elevation of the terrain in the Northern Goulburn study area (see table C1 in Appendix C for details about terrain elevation and flight altitude). Ground pixel resolution will vary from approximately 861m to 1066m due to variable terrain elevation, with a mean resolution of 1km. Low resolution flights will be undertaken on various dates with different coverage's during the campaign:

- During regional days, low resolution flights will occupy the entire daily flying time and the coverage will be the area approximately covered by a satellite footprint (see Fig. 19 in section 5.3.1);
- During farm scale days, low resolution flight will be undertaken together with intermediate, medium and high resolution flights, with coverage being one of the two sub-catchment study areas, either Krui or Merriwa (see Figs. 25 and 26).

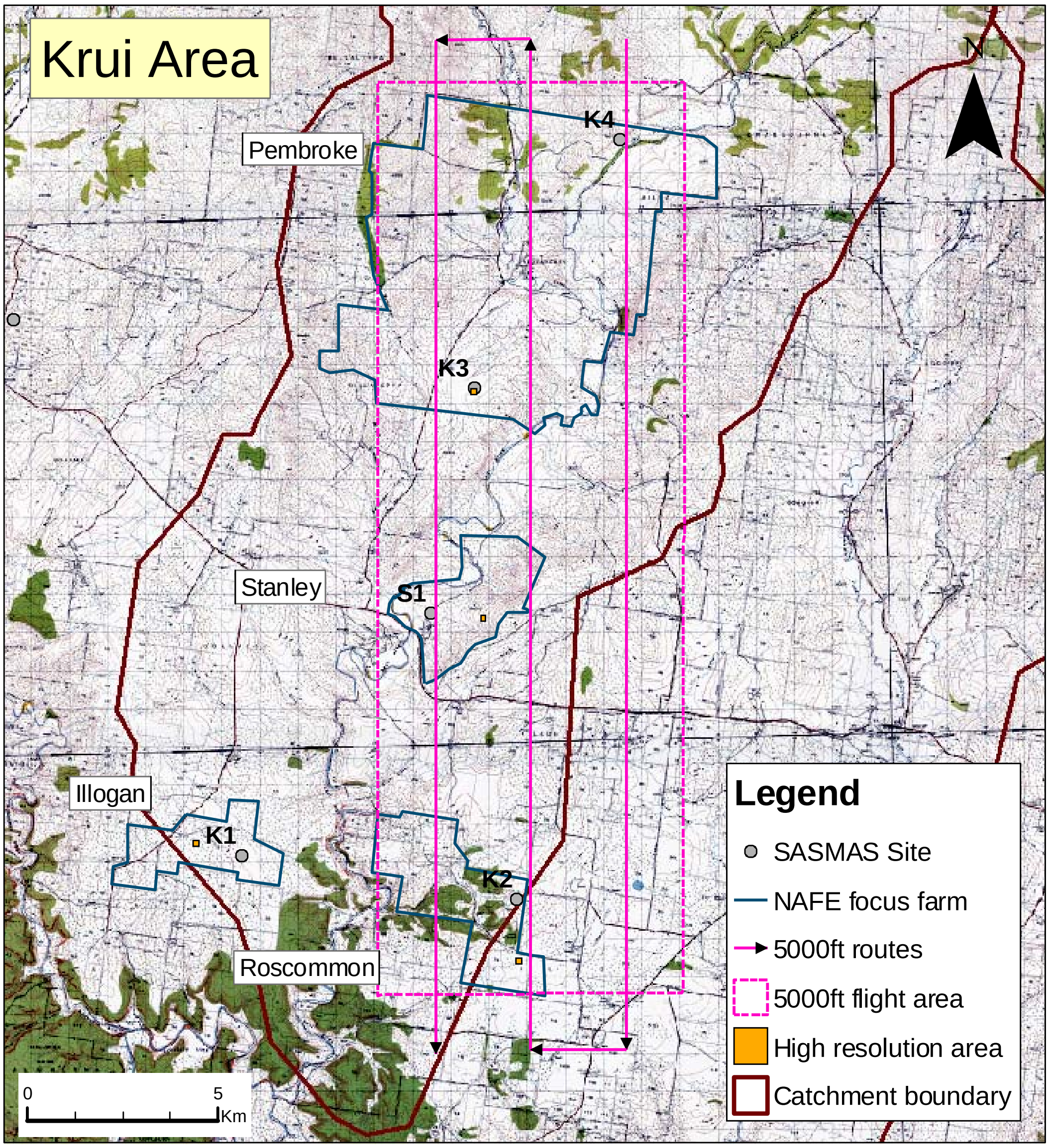


Figure 27. PLMR intermediate resolution flight lines over the Krui study area. Purple solid lines are the flight lines at 5,000ft altitude, dashed purple lines are the areas covered by the mapping.

A detailed flight schedule for NAFE05 is shown in Table 8. Coordinates for starting and ending points of all the sets of flight lines, together with reference coordinates for the mapping extents, are given in Appendix A. For low resolution flight lines refer to Table A1 (for regional days) and A2 (for farm scale days).

6.3 Intermediate resolution mapping

Flights at intermediate altitudes will allow investigation of the scaling nature of the microwave signature of soil moisture and will provide the link between regional scale microwave observations and the high resolution mapping, which is one main scientific objective of this campaign. The acquisition of microwave brightness temperatures at so many different resolutions is unprecedented. Investigation will focus on the relationship between brightness temperatures measured at different spatial resolution, down- and up-scaling issues.

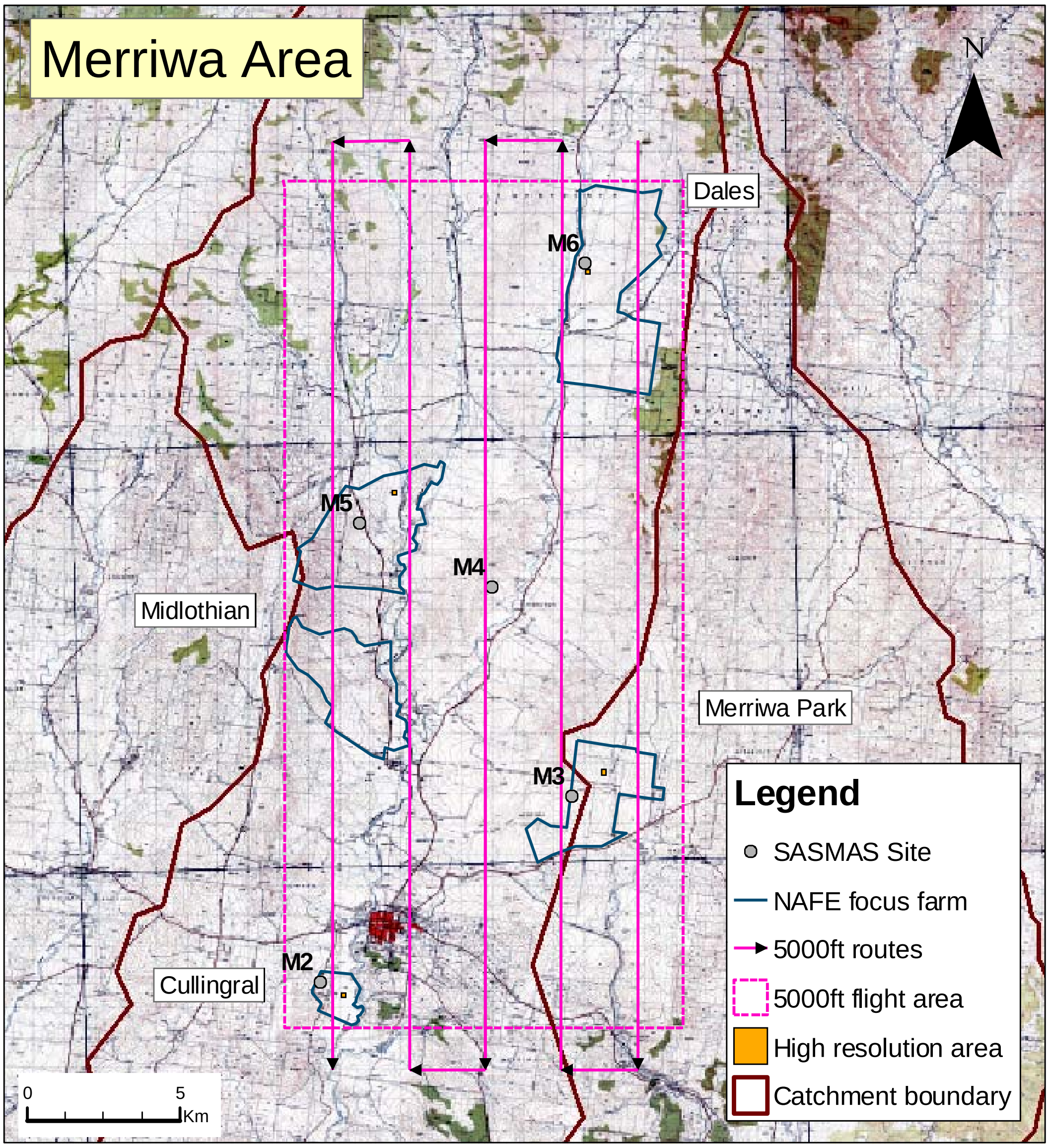


Figure 28. PLMR intermediate resolution flight lines over the Merriwa study area. Purple solid lines are the flight lines at 5,000ft altitude, dashed purple lines are the areas covered by the mapping.

Intermediate resolution mapping will include flights at a nominal 5,000ft AGL over 2 sub-areas in the northern half of the Goulburn River experimental study area, the Krui catchment and the Merriwa catchment. The actual planned flight altitude due to terrain elevation is 1910 ASL. This results from flying over the median terrain elevation of the Northern Goulburn study area. This reference elevation is the same for the low resolution and the intermediate resolution flights, and was chosen in order to maintain consistency between observations at different altitudes (i.e. linear scaling between ground pixels at different resolutions). These flights will entirely cover the NAFE focus farms and surrounding areas, and will therefore constitute an adequate medium resolution "frame" to the high resolution mapping of the individual farms. The only exception to this is the Illogan focus farm in the Krui study area. This farm is somewhat dislocated with respect to the other 4 farms in the area, being slightly isolated to the west. Given the restriction on the flight times, and the fact that the other 3 farms are aligned on a North-South corridor, a decision was made to exclude this farm from the 5,000ft and 10,000ft altitude flights. The farm is covered by the 2,500ft and 625ft flights.

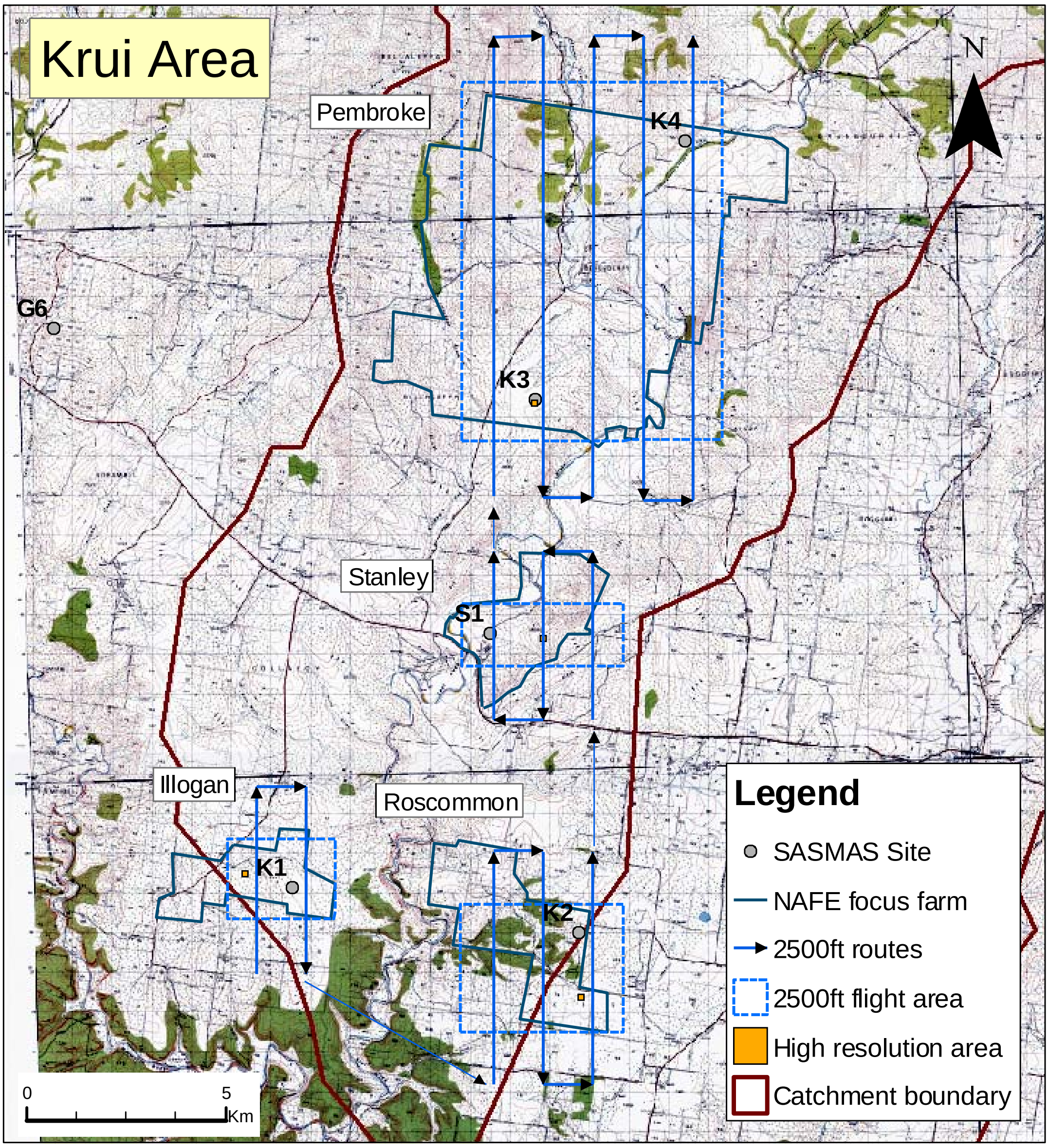


Figure 29. PLMR medium resolution flight lines over the Krui study area. Blue solid lines are the flight lines at 2,500ft altitude, dashed blue lines are the areas covered by the mapping**.**

Intermediate resolution flightlines will generally have different coordinates then those for low resolution flights. The lower altitude creates problems of a different nature which require dislocation of the flight paths (e.g, terrain elevation, matching with ground monitoring network and spatial sampling etc…). Tables A3 and A4 in Appendix A and Figs. 27 and 28

6.4 Medium resolution mapping

Flights at medium altitudes will allow investigation of the scaling nature of the microwave signature of soil moisture and will provide the link of the regional scale microwave observations with the high resolution mapping which is a main scientific objective of this campaign.

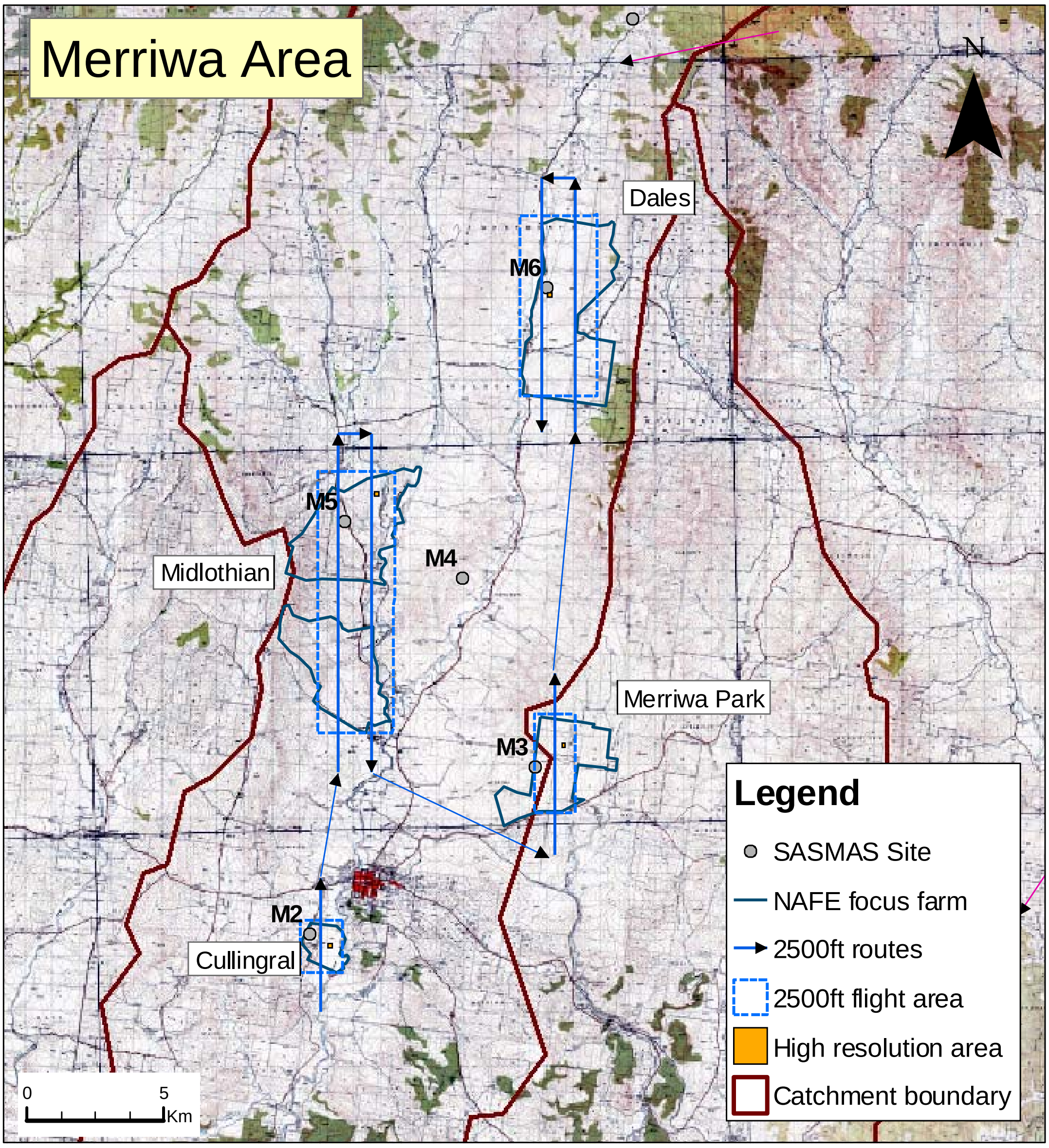


Figure 30. PLMR intermediate resolution flight lines over the Merriwa study area. Blue solid lines are the flight lines at 2,500ft altitude, dashed blue lines are the areas covered by the mapping.

Mapping at medium resolution will be undertaken at farm scale, at a nominal altitude of 2,500ft AGL, providing full coverage of all the NAFE focus farms at a ground resolution of approximately 250m. Actual flight altitude for these flights will be variable between farms, due to terrain elevation. Unlike for the low and intermediate flights, terrain elevation has a major impact on the ground resolution obtainable from these altitudes. In particular, due to the different mean elevations of the focus farms, it is not feasible to fly the whole medium resolution flight line set with constant altitude above sea level. This would in fact result in highly variable ground resolution. With the aim to maintain the highest possible consistency between the soil moisture maps, a decision was made to fly at 2,500ft (and 625ft for the high resolution flights) above the maximum elevation within each farm. This will guarantee greater uniformity in ground resolution as well as respect of the minimum flight altitude allowed without a low-level clearance, being 500ft. As for the medium resolution flight lines, flight altitude will vary between 1050m and 1270m ASL for the respective farms (see Appendix C),

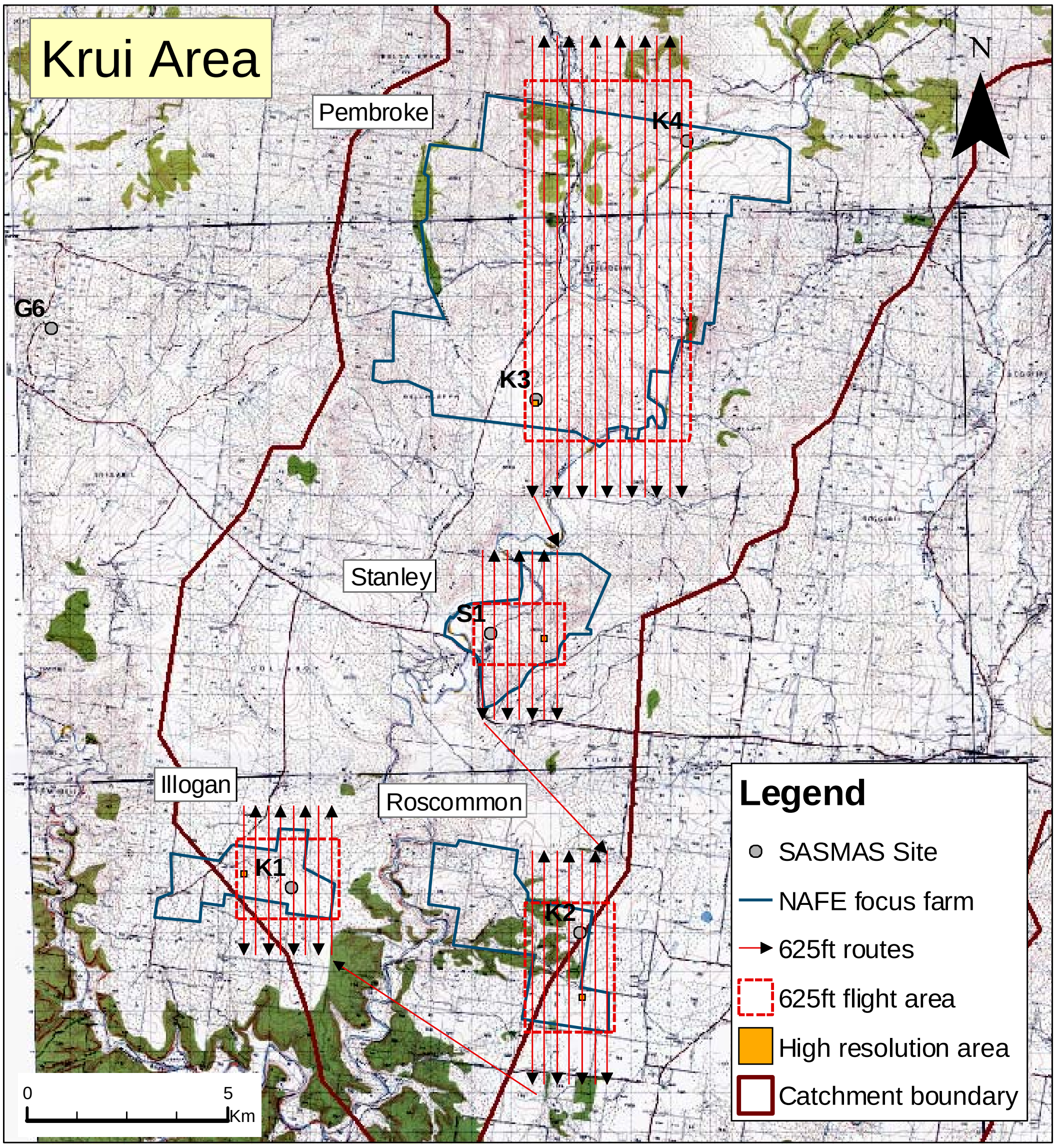


Figure 31. PLMR high resolution flight lines over the Krui study area. Red solid lines are the flight lines at 625ft altitude, dashed red lines are the areas covered by the mapping

resulting in a ground resolution between 240m and 308m.(see table C2 Appendix C for details) Medium resolution flight lines are described in Figs. 29 and 30 and Tables A5 and A6 in Appendix A.

6.5 High resolution mapping

The most important phase of the NAFE '05 campaign will be the monitoring of soil moisture at high resolution. PLMR will be flown at a nominal altitude of 625ft AGL to provide a nominal grid of 62.5m average near-surface soil moisture. Such a high resolution in passive microwave remote sensing is unprecedented, and will give the opportunity to study the microwave emission from the soil surface at very high detail. Together with the thermal-infrared, near-infrared and visible sensors onboard the SERA, the data provided by PLMR will allow development of downscaling techniques from coarser resolution measurement. The relatively small size of the ground pixels will also overcome one of the biggest problems faced by remote sensing validation campaigns in the past; relating ground point measurements

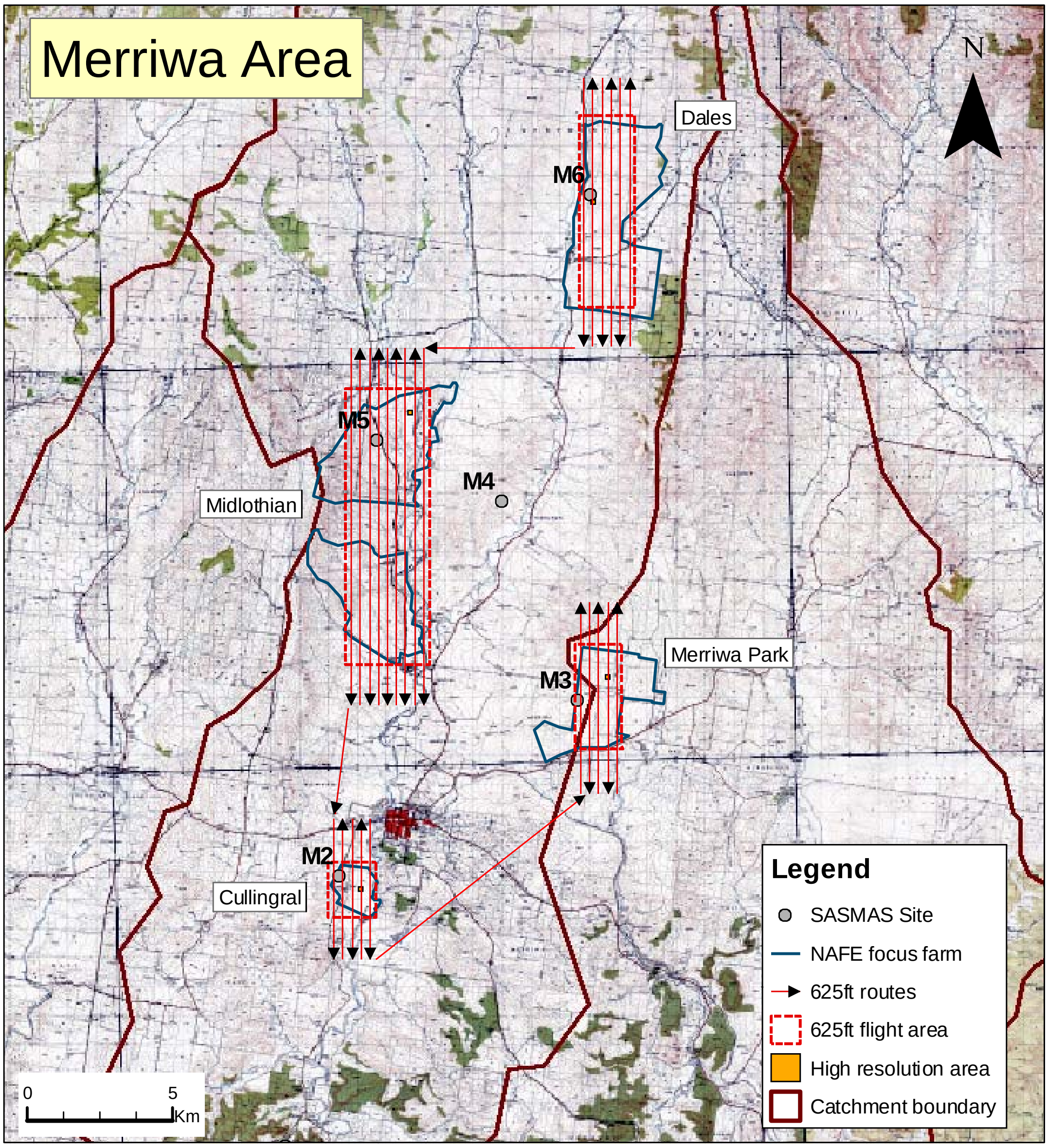


Figure 32. PLMR high resolution flight lines over the Merriwa study area. Red solid lines are the flight lines at 625ft altitude, dashed red lines are the areas covered by the mapping

as being representative of the soil moisture content for a much larger and non-uniform area for remote sensing validation. The validity of such an assumption is obviously weak and has been a constraint for accurate validation of satellite soil moisture products to date. During NAFE '05, intense ground sampling of soil moisture on the areas covered by high resolution aircraft mapping will provide highly detailed evaluation of the PLMR soil moisture product over a range of topographic and land cover conditions.

High resolution mapping flights will therefore be the core of the NAFE '05 aircraft campaign. Each farm will be mapped at 62.5m resolution twice a week (see Table 8) concurrently with intense ground monitoring of soil moisture as described in previous sections. The time to cover the single farm will be small (approximately 20 minutes) therefore there shouldn't be any appreciable time variation in soil moisture or temperature affecting the patterns. High resolution flight lines are described in tables A7 and A8 in Appendix A and illustrated in Figs. 31 and 32 for the Krui and Merriwa area focus farms. The actual flight altitude for this set of flights will vary between 480m and 700m ASL for the respective farms, resulting in a ground resolution between 51m and 121m (see table C3 Appendix C for details).

6.6 Multi-incidence mapping

A number of high resolution flights have been scheduled for the specific purpose of answering the important science question of multi-incidence angle retrieval of soil moisture. During these flights PLMR will be mounted on the SERA so as to have the 6 beams looking along the flight direction, 3 forward and 3 backward. In contrast to the "pushbroom" configuration, this set up will allow the same location on the ground to be remotely observed at three or more different incident angles. Given that every observation at a particular angle is bi-polarised, this will provide a set of six or more independent brightness temperature observations. The combination of these measurements potentially allows retrieval of auxiliary data in addition to soil moisture. Together with intensive ground sampling, these observations will provide a useful dataset to investigate multi-angle retrieval techniques.

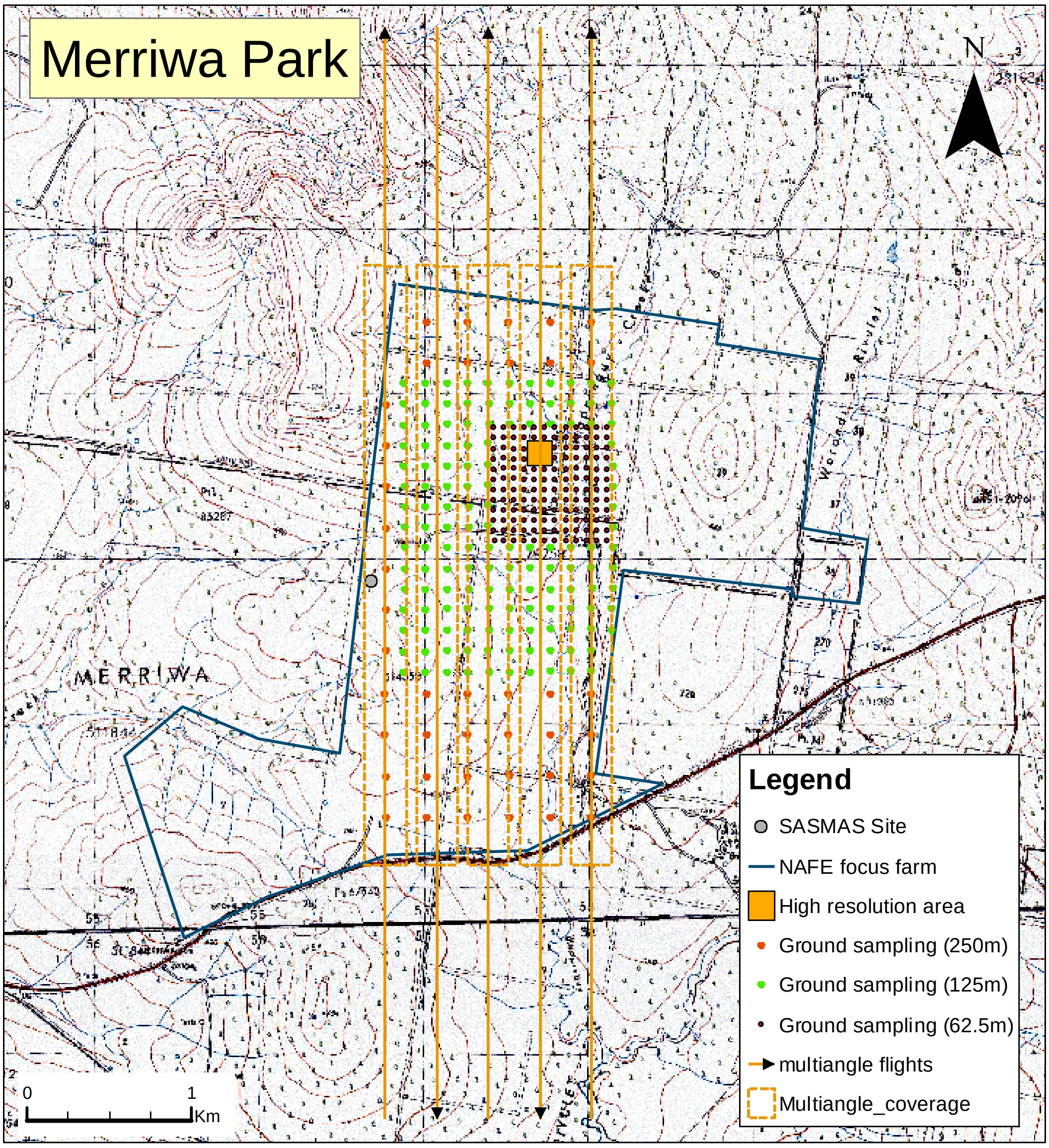


Figure 33. PLMR multi incidence angle flight lines over the Merriwa study area. Orange solid lines are the flight lines at 2,500ft altitude, dashed orange lines are the areas covered by the mapping in multi-angle configuration.

Multi-incidence observations will be undertaken at one particular farm, Merriwa Park in the Merriwa study area, on the same days when the area will be covered by multi-scale flights (see flight schedule in Table 8). Therefore, this experiment won't require extra ground sampling apart from the regular one. The Merriwa Park farm has been chosen for this experiment due to his smooth topography and easy accessibility, which makes it very suitable for the intensive farm scale ground sampling required for this experiment. Furthermore, due to is proximity to Scone Airport, this will make sure that multi-incidence angle flights won't interfere too much with the regular multi-scale flights held on the same day. For this experiment, PLMR will be flown following the high resolution routes over the farm, as described in previous sections, but at a nominal altitude of 2,500ft AGL.(1210m ASL) This will provide multi-angle coverage of the farm at a nominal resolution of 250m., with a range between 239m and 272m Fig. 33 illustrates this set of flight lines. As seen in the plot these flights are not expected to provide full coverage of the farm area, due to the distance between the flight lines being larger then the swath from that altitude. The start and end point coordinates are given in table A9 in Appendix A.

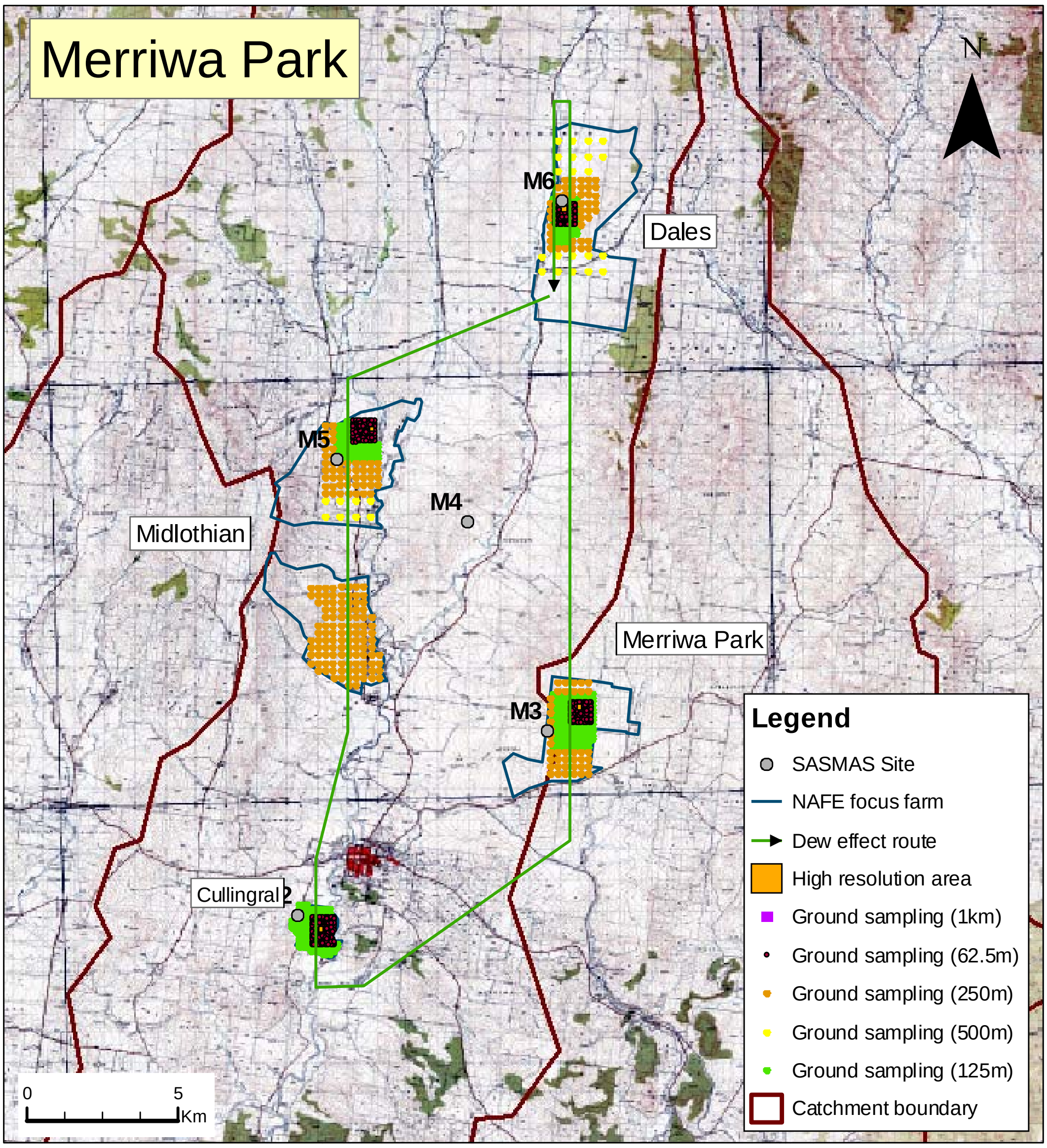


Figure 34. PLMR dew effect flight lines at 5,000ft over the Merriwa study area.

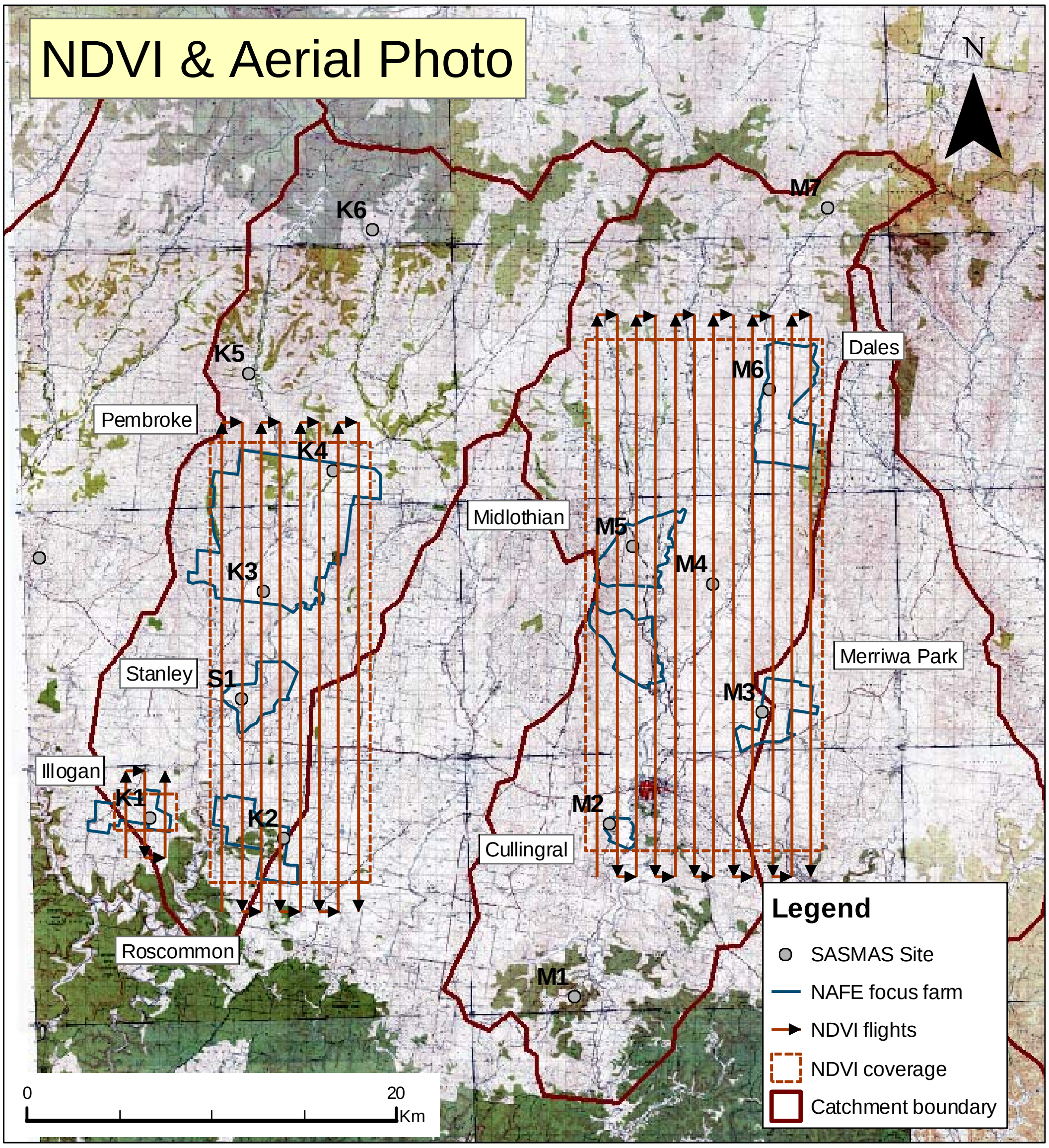


Figure 35. Flight lines for NDVI observations and aerial photography at 5,000ft over the Goulburn study area.

6.7 Dew effect

In order to analyse the effect of vegetation dew on the soil microwave signal, an early morning flight will be undertaken in the Merriwa area during some of Merriwa area sampling days. It is hypothesised that by comparison with the regular flights later in the day, this data will allow quantification of the role of vegetation dew on the microwave emission from the soil surface. Dew effect flights will include a loop covering the 4 focus farms in the Merrriwa area, as shown in Fig. 34. One single loop will be flown as early in the morning as possible. The nominal altitude for this flight will be 5,000ft AGL. This will allow direct comparison with the multi-scale 5,000ft flights over the area later on during the day. The actual flight altitude will be 1910m ASL, resulting from flying over the mean elevation of the Merriwa study area. This will result in a ground resolution between 405m and 554m. Subsequent to this loop the aircraft will return to Scone airport and take off for the regular multi-scale flights later in the day, when the dew has dried off. The coordinates of the main waypoints in the dew effect flight loop are listed in Table A10 of Appendix A.

6.8 NDVI

The Normalized Difference Vegetation Index, calculated from the visible and near-infrared radiation reflected by the vegetation, is a very useful parameter to characterise biomass density over large areas. For radiative transfer microwave modelling purposes, it is very important to collect information about the spatial and temporal variability of this quantity in order to properly quantify the masking of the microwave signal emitted from the soil by the vegetation canopy. For this purpose, the Tri-Spectral NDVI scanner onboard the SERA will be used to obtain high-resolution NDVI measurement for the study area. Given that NDVI is not expected to vary significantly over a 1 month time period, NDVI flights will be limited. On a date prior to commencement of the field campaign (~October 28th), a dedicated NDVI flight will be undertaken to cover the Krui and Merriwa sub-areas (see Fig. 35). This flight will have a nominal altitude of 5,000ft AGL, actual flight altitude 1910m ASL, resulting in a ground resolution of approximately 2m. Subsequently and depending upon instrument availability, two other full coverage flights are planned on two dates during and at the end of the campaign, to ensure temporal variation is captured. NDVI flight lines are described in Table A11 of Appendix A.

6.9 Aerial photography

High resolution aerial photo coverage of the Northern Goulburn study area will be undertaken concurrently with NDVI observations on the flight prior to the field campaign start only. Refer to section 6.8 for flight line details.

6.10 Calibration

The polarimetric L-band multibeam radiometer needs “warm” and “cold” calibration before, during and after each flight. The before and after flight calibrations are achieved by removing PLMR from the aircraft and making brightness temperature measurements of a calibration target and the sky (Fig. 36). The during flight calibration is accomplished by measuring the brightness temperature of the sky during a series of steep turns and of a water body. The water body is Lake Glenbawn, located approximately 100km east of the study area (Fig. 37). Ground requirement are the monitoring of the water temperature and salinity within the top 1cm layer of water. Both quantities will be monitored continuously during the campaign using a UNIDATA 6536B® temperature and salinity sensor connected to a logger, located at LAT & LONG to be defined. Furthermore, transects of water temperature and salinity in the top 1cm layer will be undertaken with a handheld temperature and salinity meter (Hydralab Quanta®) on four occasions. This will involve making 2km long north-south and east-west transects at 100m spacing once per week, centred on the monitoring station. The purpose of these measurements is to check for spatial variability. The air crew located at Scone airport will be responsible for these measurements.

Figure 36. Undertaking a sky cold point calibration with PLMR and the calibration box used for warm point calibration.

6.11 Flight schedule

All the flights described in the previous sections will be coordinated as per the calendar shown in Table 8. On regional days only low resolution flights will be undertaken covering the whole Northern Goulburn study area, concurrently with AMSR overpasses as described in section 2.1. The other days of the week will be occupied alternatively by multi-scale coverage of the two sub-areas, the Krui catchment and the Merriwa catchment. On these dates, flights will be undertaken at low, intermediate, medium and high resolution in this order. All the sub-area will be entirely covered at each altitude, before descending to the following altitude. In Table 8 tentative NDVI flights are also indicated.

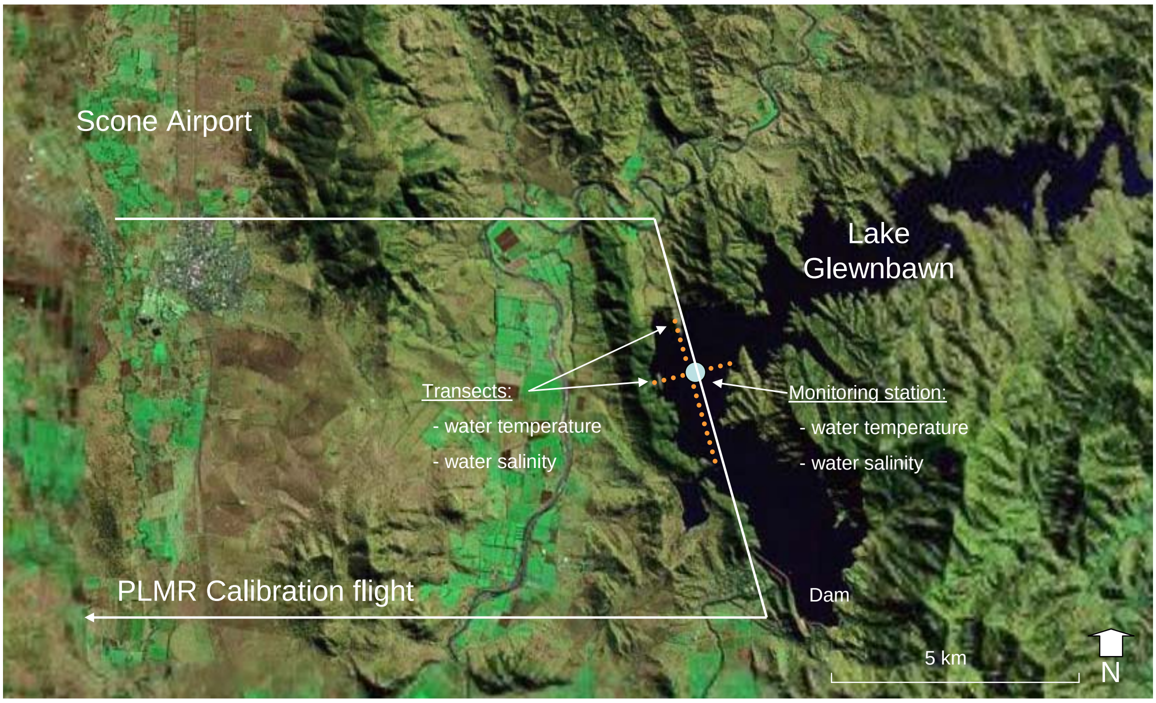


Figure 37. The location of Lake Glenbawn and Scone airport. The calibration flight line is schematically shown in solid white line. Dotted orange lines schematically indicate the planned water temperature and salinity transects. The approximate location of the permanent monitoring station is shown in blue.

Table 8. Schedule of flights during NAFE'05

	Mon 24/10	Tuey 25/10	Wed 26/10	Thur 27/10	Fri 28/10	Sat 29/10
Norhern Goulburn						
	Mon 31/10	Tue 1/11	Wed 2/11	Thur 3/11	Fri 4/11	Sat 5/11
Norhern Goulburn						
Krui Area						
Merriwa Area						
	Mon 7/11	Tue 8/11	Wed 9/11	Thur 10/11	Fri 11/11	Sat 12/11
Norhern Goulburn						
Krui Area						
Merriwa Area						
	Mon 14/11	Tue 15/11	Wed 16/11	Thur 17/11	Fri 18/11	Sat 19/11
Norhern Goulburn						
Krui Area						
Merriwa Area						
	Mon 21/11	Tue 22/11	Wed 23/11	Thur 24/11	Fri 25/11	Sat 26/11
Norhern Goulburn						
Krui Area						
Merriwa Area						

Low resolution   Intermediate res.   Medium res.   High resolution

Multi-angle   Dew effect   NDVI & Photo   NDVI (tentative)

This general schedule is likely to be affected by the weather conditions. In case of clouds, flights might be only partially completed, as per the following criteria

- On regional sampling days, flight altitude will be moved below the clouds. If clouds are lower than 5000ft no flights will be undertaken;
- On farm sampling days, only the flights with altitude lower then the clouds will be undertaken. If clouds are lower then the 2500ft no flights will be undertaken.

The flying time saved during these dates is expected to be used for extra NDVI mapping flights.

For logistic purposes, it is important to maintain the total number of hours flown in any single flight to around 4-5 hours and a daily total of not more than 6 hours, to allow time for pre-flight and post-flight activities on the PLMR and on the aircraft. This represented a major constraint in the planning of flight lines. Table 9 reports the estimated flight hours, including individual estimates for each set of flight lines and a summary of the daily total. As shown, the total number of hours is slightly higher then allowed (92 hours) for the whole field campaign. Nonetheless, the effective total is likely to be smaller due to possible adverse weather conditions resulting in cancelled flights and conservative flight time estimates. The estimates for NDVI/photography flights is not included in this total as the initial flight will be done on a separate aircraft, meaning that these hours do not count towards the aircraft maintenance requirement. While the second and third NDVI flights are planned for the same aircraft, it is expected that hours for this will become available due to cancellation of two or more days of flying as a result of poor weather conditions. The NDVI flights have been estimated at 4.4 hours.

Table 9. NAFE'05 flight times. Times have been calculated assuming the indicated aircraft speed.

Flight	Distance (Km)	Aircraft Speed (Km/h)	Flight Time (hrs)
Calibration	25.0	144	0.2
Ferry Scone airport-Krui area	143.1	180	0.8
Ferry Scone airport-Merriwa area	82.7	180	0.5
Ferry Scone airport-AMSR area	129.3	180	0.9
Low resolution regional area	385.4	144	2.7
Krui area			
Low resolution	26.5	144	0.2
Intermediate resolution	84.5	144	0.6
Medium resolution	129.8	144	0.9
High resolution	262.3	144	1.8
Merriwa area			
Low resolution	61.0	144	0.4
Intermediate resolution	162.5	144	1.1
Medium resolution	77.7	144	0.5
High resolution	250.0	144	1.7
Multiangle flights	35.0	144	0.9
Dew effect flights	64.4	144	1.1
Summary			
Regional days (Cal + Ferry + Low resolution)			**3.7**
Krui days (Cal+Ferry+Low+intermediate+medium+high)			**4.5**
Merriwa days (Cal+Ferry+Low+intermediate+medium+high)			**4.5**
Merriwa days + multiangle flights			**5.3**
Merriwa days + dew effect flights			**5.5**
TOTAL CAMPAIGN (4 weeks)			**93.8**

7 Field Work

7.1 General guidance

Sampling is conducted **every day**. It is canceled by the group leader if it is raining, there are severe weather warnings or a logistic issue arises.

- **Know your pace**. This helps greatly in locating sample points and gives you something to do while walking.
- All farmers in the area are aware of our presence on their property during the 4 weeks field campaign. However, if anyone questions your presence, politely answer identifying yourself as a scientist working on a University Of Melbourne soil moisture study with satellites. If you encounter any difficulties **just leave** and report the problem to the group leader.
- Although gravimetric and vegetation sampling are destructive, try to **minimise your impact** by filling holes. Leave nothing behind.
- When sampling on cropped areas, always sample or move through a field along the **row direction** to minimise impact on the canopy.
- Please be considerate of the landowners and our hosts. **Don't** block roads, gates, and driveways. Keep sites, labs and work areas clean of trash and dirt.

- Avoid driving through cropped areas.
- Beware of the possible presence of stocks in the sampling areas.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust.
- Drive carefully and maintain a low speed (~4 km/h) when going through tall grass fields. Hidden boulders, trunks or holes are always a danger.
- When parking in tall grass for prolongated periods of time, turn off the engine. The catalytic converters can be a **fire hazard**.
- **Close any gate** you open as soon as you pass.
- **For your own security, carry a cell phone or UHF transmitter. Check the mobile phonecoverage over your sampling area** and be aware of the local UHF securityfrequencies.
- In case of breakdown of any part of the sampling equipment, **report immediately** to the group leader.

7.2 Focus farms

Sampling of the farm area is intended to provide near-surface (0-5cm) hydra probe soil moisture measurement across the farm at the highest possible resolution, provided all the accessible areas on the property are covered by sampling. Together with soil moisture, supporting information are needed, for purposes of microwave emission modelling and the characterization of the land cover distribution in the area.

The person responsible for farm scale sampling (generally this will be each team's leader, see Table 12) will be required to measure or characterise the following quantities (**for detailed description on the sampling procedures, please refer to section 7.5**):

- 0-5cm soil moisture using the Stevens water Hydra Probe® instrument at each sampling location;
- 0-5 cm gravimetric soil moisture (also used for soil texture and soil bulk density): a minimum of two samples are required, 1 dry and 1 wet. Location of these samples should vary from day to day in order to cover different soil types;
- Dew present at the location. A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure. (this is only required until dew dries off completely);
- Vegetation type at each location
- GPS locations of all sample point locations

The soil moisture measurements will be taken on grids that will generally vary between farms (see section 4.7.2). The planned sampling locations for each farm will be loaded onto the iPAQ, and visible with the GIS software ArcPad. Sampling will involve navigating to the sampling location through the use of the GPS receiver, which displays the real-time position on the same ArcPAd screen where the sampling grid is visible, and then once located the point takes all the required measurements. All the measurements will be electronically stored in the iPAQ, by prompting the values into forms. For details see section 7.5.1.

Each person responsible for the farm scale sampling will be equipped with the items listed below. The person will be individually responsible for the use and care of the equipment throughout the campaign, and must report any damage to the group leader immediately so that actions can be taken to repair or substitute the damaged item.

- 1 4WD vehicle or quad bike
- 1 iPAQ pocket PC
- 1 wireless GPS receiver
- 1 Stevens Water Hydra Probe Stevens water Hydra Probe®
- 1 Bumpack
- 1 Gel cell battery
- 1 Gel cell battery connector
- 1 spare gel cell battery
- 1 soil sampling kit including: sampling ring (approximately 7.5cm diameter and 5cm depth), hammer, garden trowel, blade, gloves, plastic bags, rubber bands, permanent markers;
- 1 hardcopy of the farm sampling plan
- 1 fieldbook
- 1 UHF receiver.
- Pen

7.3 High resolution focus areas

High resolution areas are 150m x 150m in size and are intended to provide high resolution near-surface soil moisture measurements for the validation of the PLMR high resolution passive microwave observations. Within each farm, 1 such area has been selected as explained in section 4.7.2. In every team there will be 2 people specifically dedicated to the sampling of these areas (in the morning) and the surrounding 62.5m grid (in the afternoon).

The personnel responsible for the focus areas will be required to measure or characterise the following quantities (**For detailed description on the sampling procedures, please refer to section 7.5**):

- 0-5cm soil moisture using the Stevens water Hydra Probe® instrument at each sampling location;
- GPS locations of all sample point locations (only in the afternoon for 62.5m sampling , NOT for high resolution areas)
- Vegetation water content: 2 samples (“grab” type, see section 7.6.4) at the end of the day at two corners of the high resolution areas (farm reference vegetation). The location of these samples will remain the same throughout the campaign.
- Vegetation dew: 2 samples (“grab” type) at the beginning of the day at two corners of the high resolution areas (farm reference vegetation). The location of these samples will remain the same throughout the campaign. These samples will be required only when dew effect flights are scheduled for the day (see Table 8).

Each person responsible for the farm scale sampling will be equipped with the items listed below. The person will be individually responsible for the use and the care of the equipment throughout the day, and must report any damage to the group leader immediately so that actions can be taken to repair or substitute the damaged item.

- 1 iPAQ pocket PC
- 1 wireless GPS receiver
- 1 Stevens Water Hydra Probe Stevens water Hydra Probe®
- 1 Bumpack
- 1 Gel cell battery
- 1 Gel cell battery connector

- 1 spare gel cell battery
- 1 vegetation sampling kit including: quadrant (50cm x 50cm), vegetation clipper, scissor, gloves, plastic bags, rubber bands, permanent markers
- 1 hardcopy of the farm sampling plan
- 1 fieldbook
- Pen

Morning

The high resolution areas will be clearly marked prior to the field campaign with 4 pegs (1.5m high) in the 4 corners of the 150m x 150m grid. Given that some of these areas will be in paddocks with crops up to 1m high, the top of the pegs will be coloured white, ensuring that they will are clearly visible. Pegs will remain in place during the entire campaign and are not to be removed. The area within the grid is to be sampled at two different resolutions: the whole grid (150m x 150m) will be sampled on a 12.5m grid, while an inner sub-grid (75m x 75m) will be the object of a 6.25m intensive sampling. The sampling resolution chosen is intended to maintain consistency between the PLMR observations (aboard the aircraft) and the ground sampling for data upscaling and downscaling purposes. The sampling will be undertaken using Stevens water Hydra Probe® to take one 0-5cm soil moisture reading at each point of the 12.5m and 6.25m grids. The probe readings will be stored electronically in the

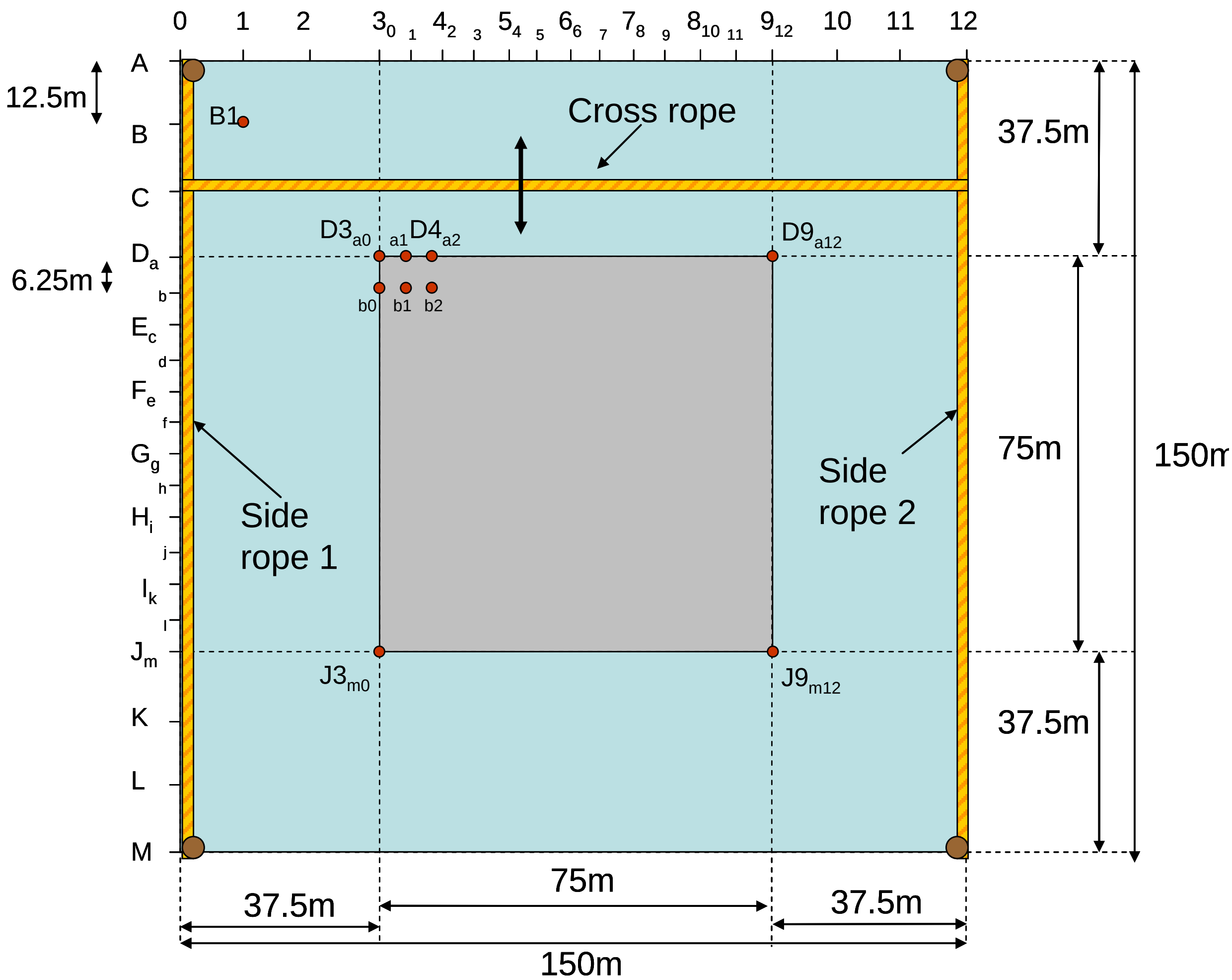


Figure 38. High resolution sampling scheme. In striped orange are indicated the ropes on the ground

iPAQ (see section 7.5.1).

The 12.5m and 6.25m sampling points will be marked by use of ropes labelled at 12.5m and 6.25m spacings. The system is explained hereby and illustrated schematically in Fig. 39. Two of the ropes (side rope 1 and side rope 2) will be laid prior to the field campaign and will remain in place for the entire four weeks. These ropes will be labelled with alphabetic characters; 12.5m points will be labelled with upper case, from "A" to "M", 6.25m points will be marked with lower case letters, from "a" to "m", starting at 37.5m from the edge of the high resolution area and forming an inner grid of 75m x 75m. The cross rope, will be removable, and will be laid at the beginning of each sampling day and collected at the end of the day, to be used on the other farm the next day. On this rope 12.5m points will be marked with large numbers from 0 to 12, while 6.25 m will be marked with small numbers from 0 to 12. Each point will therefore be uniquely identified by a letter/number combination (eg, B14). As shown in Fig.38, where a point belonging to the 12.5m grid will overlap a point belonging to the 6.25m grid, the point will be identified with both labels.

The sampling strategy for the two people dedicated to the high resolution areas will be the following:

- Upon arrival at the high resolution area in the morning, lay down the cross rope on row "A" between points A0 and A12.
- Sample row "A" converging to the middle from the side ropes (i.e. 1 person starts at A0, the other at A12, and meet in the middle)
- When finished the row, move the cross rope to next row "B" and repeat the sampling.
- When at row Da (beginning of 6.25m inner grid), sample all the points on the row in sequence
- When finished all the grid, remove the cross rope.

Some useful items on this sampling strategy are:

- Due to the length of the cross rope (150m) and the presence of vegetation (up to 1m high in places), the process of moving the rope sideways and tending it between the two side ropes can be difficult. It is suggested that the rope be moved in the following manner:
    1. When the two people sampling the hi-resolution grid meet in the middle of the rope, together, they should pick up the rope and walk approximately 12.5m (or 6.25m) in the direction the rope is to be moved
    2. Still holding the rope securely, each individual should walk back towards their respective side ropes
    3. Upon reaching the side rope untie the cross rope and move to the next sampling point along the side rope
    4. Pull the cross rope tight from each end so it clears the ground and then lay it down.
    5. Tie the cross rope to the side rope and begin sampling.
- In the inner 75m x 75m square, where the 12.5m grid is overlapped with the 6.25m grid, it is recommended to sample all the points in sequence as they appear on the rope, NOT the 12.5m before and the 6.25m after.

The planned sampling grids for each high resolution area will be loaded onto the iPAQ, and visible with the GIS software ArcPad. Sampling will involve navigating to the sampling location using the ropes and taking the measurements which will be electronically stored in the iPAQ, by prompting the values into forms. For details see section 7.5.1.

Afternoon

In the afternoon the people responsible for high resolution areas will be required to sample the 62.5m planned sampling grid, taking 0-5cm soil moisture sampling with Stevens water Hydra Probe® at each point. The 62.5m sampling grid will have to be divided between the two personnel by mutual agreement in order to optimise the sampling time.

The planned sampling locations for each farm will be loaded onto the iPAQ, and visible with the GIS software ArcPad. Sampling will involve navigating to the sampling location through the use of the GPS receiver, which displays the real-time position on the same ArcPAd screen where the sampling grid is visible, and then once located the point take all the required measurements. All the measurements will be electronically stored in the iPAQ, by prompting the values into forms. For details see section 7.5.1.

7.4 Regional sampling

Regional sampling will take place every monday and is intended to provide large scale (1km) near surface soil moisture measurements for validation of the PLMR and AMSR-E soil moisture product, as well as for scaling purposes as outlined in the objectives section of this work plan. On these dates, the sampling operations will be divided into 2 main phases:

- Soil moisture sampling across the region (including farms) at 1km resolution
- Vegetation sampling at the high resolution and surrounding areas

7.4.1 Soil moisture sampling at regional scale

Teams will sample at 1km spacing the two respective farms, one in the Merriwa and one in the Krui area (see Table 12), as well as the areas immediately adjacent to the main roads connecting the two farms. At each sampling location, teams will be required to measure or characterise the following quantities (**for detailed description on the sampling procedures, please refer to the section 7.6**):

- 0-5cm soil moisture using the Stevens water Hydra Probe® instrument at each sampling location;
- Landuse (on week 2 only);
- Vegetation type (on week 2 only);
- Dew present at the location. A numeric code will be used to represent the amount: 0 = no dew; 1=some dew; 2=a lot of dew. This is a purely qualitative measure. (this is only required until dew dries off completely);
- Percentage of surface rock cover: visual estimation and digital photography. This is to be done only on one occasion;
- GPS locations of all sample point locations

Furthermore, the following quantities will need to be measured throughout the day, following the indicated criteria.

- Vegetation Biomass: a minimum of 6 samples **per farm**, aiming at the dominant vegetation cover type in each farm;

- 0-5 cm gravimetric soil moisture (also used for soil texture and soil bulk density): a minimum of 6 samples **per farm** are required, aiming at different soil types and wetness conditions;
- Surface roughness using pin profiler: a minimum of 4 measurements per farm are required. This is to be done only on one occasion due to instrument availability

The soil moisture measurements will be taken on grids that will generally vary between farms (see section 4.7.2). The planned sampling locations for each farm will be loaded onto the iPAQ, and visible with the GIS software ArcPad. Sampling will involve navigating to the sampling location through the use of the GPS receiver, which displays the real-time position on the same ArcPAd screen where the sampling grid is visible, and then once located the point take all the required measurements. All the measurements, apart from the surface roughness, will be electronically stored in the iPAQ, by prompting the values into forms. For details see section 7.5.1.

Each person responsible for the soil moisture sampling during regional days will be equipped with the items listed below.

- 1 iPAQ pocket PC
- 1 wireless GPS receiver
- 1 Stevens water Hydra Probe®
- 1 Bumpack
- 1 Gel cell battery
- 1 Gel cell battery connector
- 1 spare gel cell battery
- 1 vegetation sampling kit including: quadrant (50cm x 50cm), vegetation clipper, scissor, gloves, plastic bags, rubber bands, permanent markers
- 1 soil sampling kit including: sampling ring (approximately 7.5cm diameter and 5cm depth), hammer, garden trowel, blade, gloves, plastic bags, rubber bands, permanent markers;
- 1 hardcopy of the farm sampling plan
- 1 fieldbook
- Pen

7.4.2 Vegetation sampling at the high resolution areas and surroundings

Intensive vegetation sampling will be undertaken at each farm's soil moisture high resolution area by at least 2 team members not involved in the soil moisture sampling. Every high resolution area will have to be sampled in half a day, one in the morning and one in the afternoon, accordingly with the farm visited by the team. Sampling will involve measurements of the following quantities: (**for detailed description on the sampling procedures, please refer to the section 7.6**):

- Vegetation biomass: a minimum of 16 samples ("quadrant" type, see section 6.6.4)
- Vegetation height at each vegetation sampling site. This will be done only on week1 and week 4
- Vegetation Leaf area index (LAI): at each vegetation sampling site. This will be done on one week only during the campaign due to instrument availability.

- Vegetation Normalised Difference Vegetation Index (NDVI) at each vegetation sampling site. This will be done on one week only during the campaign due to instrument availability.

There will be a specific ground crew member dedicated to the LAI and NDVI measurement, which will rotate through the teams on regional days (i.e. will make measurement of LAI and NDVI on each week on different farms).

All the above quantities will be initially measured on a 50m grid in the high resolution area, subsequently on two transects at 62.5m spacing (centred on the high resolution area) in the surrounding areas. These additional measurements will be depending on time availability. This sampling scheme is illustrated in Fig. 40. At each sampling location all the above quantities will be measured, with some repeats for the LAI and NDVI measurement as indicated in section 7.4.2.1 and 7.4.2.2 below. It is suggested to first sample the high resolution area, then transect 1 from west to east, followed by transect 2 from south to north.

The group responsible for vegetation sampling during regional days will be equipped with the items listed below (collectively):

- 1 iPAQ pocket PC
- 1 wireless GPS receiver
- 1 Bumpack
- 1 Gel cell battery
- 1 Gel cell battery connector
- 1 spare gel cell battery
- 1 vegetation sampling kit including: quadrant (50cm x 50cm), vegetation clipper, scissor, gloves, plastic bags, rubber bands, permanent markers
- 1 hardcopy of the farm sampling plan
- 1 fieldbook
- Pen

- 1 LAI 2000 device
- 1 Handheld radiometer device

Normalised Difference Vegetation Index (NDVI)

NDVI measurements will focus on the 150m x 150m high resolution grid. A measurement will be taken at each of the 16 vegetation biomass and water content sample points on the high resolution grid. Upon completion of these 16 measurements over the high resolution grid, time permitting, NDVI measurements will then be taken on two transects of the 62.5m farm scale grid.

One of the ground crew personnel (Jose Fenollar) will be specifically dedicated to the NDVI and LAI measurements. He will rotate through the teams spending one day with each team on regional sampling days (Mondays), this way covering the LAI/NDVI requirements once per each farm during the campaign.

Leaf Area Index (LAI)

LAI measurements will also focus on the 150m x 150m high resolution grid and be made at the same locations as for NDVI measurements.

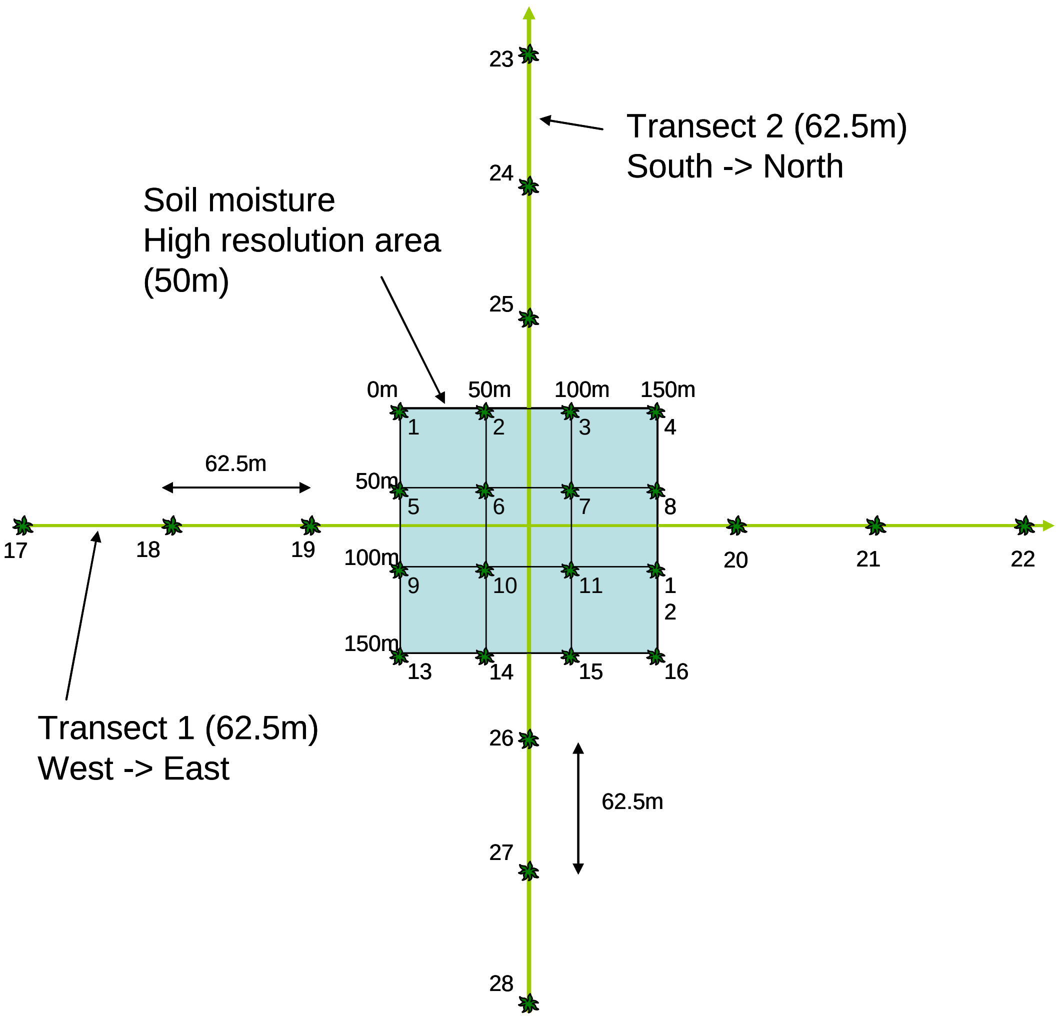


Figure 40. Vegetation sampling scheme for regional days

7.5 Sampling protocols

7.5.1 iPAQ procedures

Each person will be operating one of the iPAQs, for use with the Stevens water Hydra Probe®, both during regional and farm scale days. Every person will be responsible for their own iPAQ throughout the entire campaign. All iPAQs and accessories will be labelled with numbers, the same number indicating the accessories belonging to the same individual set. Basic items for the daily use of the iPAQ are the following:

Morning

- Check that the battery is at 100% recharge (Fig.41)

Start of sampling

- Take the iAPQ and GPS device out of the container. Install the iPAQ on the mount (see section 7.5.2)
- Ensure the gel cell battery, iPAQ, GPS receiver and hydra probe are all properly connected.
- Turn on the iPAQ by pressing the button at the top right corner of the device (Fig.41)

- Open ArcPad by tapping the program access icon on the top left corner of the iPAQ screen (Fig.41) and select "ArcPad".
- If working with GPS:
  - Turn on the GPS receiver
  - Establish a wireless connection between GPS and iPAQ (see below)
  - Activate the GPS in ArcPad, by tapping the "GPS" icon and selecting "GPS active"

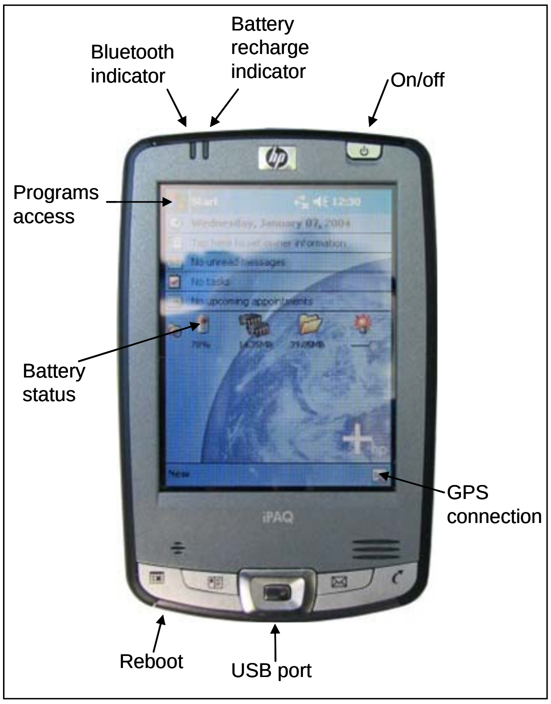


Figure 41. iPAQ basic features

During the day

- Ensure the iPAQ is constantly plugged into the gel cell battery. If so, the orange light on top of the device will be blinking (recharging) or still (fully recharged).
- Ensure the wireless connection with the GPS is active. If so the Bluetooth indicator on the iPAQ will be blinking blue.

Evening

- At the end of the sampling:
  - **Turn off** the iPAQ and the GPS device
  - Disconnect the iPAQ from the cables connected to its USB port
  - Disconnect the battery adaptor from the gel cell battery
  - Take the iPAQ off the mount and store it together with the GPS device in the iPAQ container. **DO NOT** leave the iPAQ on the mount, as it could get damaged during the car trip back to Merriwa.
- Download the data collected into the desktop computer in the right folders (see section 7.5.8 for detailed archiving procedures)
- Load into the iPAQ the blank files for the next day
- Plug the iPAQ for recharge and leave overnight

Connect the GPS to the iPAQ

A connection between iPAQ and the GPS device is required for (i) farm scale soil moisture sampling (1km, 500m, 250m or 125m resolution) (ii) high resolution area surroundings soil moisture sampling (62.5m resolution) and (iii) regional days soil moisture sampling.

The GPS device needs to be recognised by the iPAQ BEFORE activating the GPS from ArcPad, as explained in the previous section. To establish a wireless connection between iPAQ and the GPS device:

- Tap the "GPS connection" icon in the bottom right corner of the screen
- Activate Bluetooth by tapping the "Bluetooth" icon
- Select "Bluetooh Manager"

- Tap **and hold** the icon representing the GPS device you are connecting to, and select "connect". If this is successful, two horizontal green arrows will, be added to the GPS device icon
- Exit from Bluetooth manager

iPAQ Troubleshooting

The iPAQ doesn't respond to any input.
Perform a soft reboot of the device by GENTLY pressing the button on the bottom side of the device with the iPAQ pencil. The GPS connection will then have to be re-established and ArcPad started again. No data will be lost.

The iPAQ is dead, the battery indicator doesn't blink despite the battery being properly connected.
The iPAQ battery is too low. Extract the battery, leave it disconnected from the device for 5 minutes, re-insert the battery and leave charging for at least 30 minutes, until the battery indicator starts blinking again.

The iPAQ doesn't connect with the GPS device
Make sure the GPS device in turned on and charged

GPS Troubleshooting

There's no GPS icon in the Bluetooth manager
The GPS device hasn't been bonded with the iPAQ. Make sure the GPS device is turned on and charged. To bond the GPS device, tap "new" and select "explore a Bluetooth device". When the GPS device is detected, tap the serial port option "SPP serial port". When the bond is confirmed, tap "finish" and connect to the GPS device as explained above in "Connect the GPS to the iPAQ connection**"**

ArcPad Error: no fix GPS position
The GPS device is unable to determine a fix position. Stay in place and wait for a few minutes until a fix position is achieved.

ArcPad Error: too many data are received from your GPS device
Press ok and Ignore

7.5.2 HydraProbe sampling procedure

System set-up

The soil moisture measuring system will be set up as follows (see Fig. 42):

- Stevens water Hydra Probe® firmly attached at the bottom of a PVC pole
- iPAQ mounted on top of the pole. The Hydra probe cable is directly connected to the USB port at the bottom of the iPAQ (see Fig. 41), through a sequence of converters which will be firmly attached to the pole.
- The gel cell battery necessary to provide power to the iPAQ, the GPS device and the Hydra probe will be carried in a bumpack around the waist, together with the GPS device

- The gel cell battery will be connected to all the devices through a single cable running from the bumpack to the pole, firmly attached to the pole at waist height.
- Disconnection from the pole will be possible by unplugging the gel cell battery adaptor in the bumpack

The iPAQ has been programmed in order to automatically read the Hydra probe at the desired sampling location when a specific command is sent from the iPAQ, and storing the probe readings in a file together with the GPS coordinates provided by the GPS device. This is achieved with the software "ArcPad", a Geographic Information System for Handheld devices. Hereby the ArcPAd sampling procedures are described:

The ArcPad program developed for NAFE'05 to read the Hydra probe has essentially two functions:

Figure 42. Typical set up of a soil moisture measuring unit, with hydra probe communicating directly to an iPAQ and a wireless GPS receiver. Everything is powered by a battery carried by the user.

1. GPS mode: Stores the readings of the probe with the coordinates given by the GPS device. This will be used during the soil moisture sampling at farm scale and regional scale and will be active when the GPS is made active in ArcPad
2. GRID mode: Stores the readings of the probe with the coordinates of the points visited by the user on a predefined grid. This will be used for the sampling of the high resolution areas, where the predefined grid is that illustrated in section 7.3. This mode will be active when the GPS is deactivated.

In both cases, all the necessary commands will be given through the ArcPad screen, with basically no need to access any ArcPAd menu items. On the ArcPad screen there will be 4 visible layers:

- Topographic map of the area
- Grid of planned sampling locations
- Grid of effective sampling locations: this is the file that will be edited every time a soil moisture reading is taken.
- GPS position indicator

Sampling procedure

The procedure for taking a soil moisture reading with this system is:

1. Navigate to the sampling point:
    - If in GPS mode, the exact location will be indicated by the overlapping of the GPS position indicator and the sampling point on the planned sampling grid

- If in GRID mode, point will be identified on the ground, as explained in section 7.3

2. Insert the probe vertically in the ground, until the probe head base is in intimate contact with the ground surface.
3. Take a hydra probe reading:
   - If in GPS mode: tap the question mark icon on the bottom left corner of the ArcPad menu. This will activate the program that reads the hydra probe values. To take a reading, tap ANYWHERE on the screen and wait.
   - If in GRID mode: tap the question mark icon on the bottom left corner of the ArcPad menu. To take a reading, tap on the point labelled as the point you navigated to on the ground (e.g. B17) and wait
4. The process of reading the hydra probe takes some 4-5 seconds. During this time wait and DO NOT tap anything on the iPAQ screen
5. After 4-5 seconds, a form appears in ArcPad containing several text boxes:
   - The point sequential number (for GPS mode) or the point label (for GRID mode)
   - The Hydra probe soil moisture reading (in volumetric water content fraction)
   - The Hydra probe soil temperature reading (in Celsius degrees)
   - A comment text box
   - A vegetation type text box, to be chosen from a drop down list
   - A landuse text box, to be chosen from a drop down list
   - A surface rock cover text box, to be chosen from a drop down list
   - A dew estimation text box, to be chosen from a drop down list
   - A text box for the vegetation sample sequential ID
   - A text box for the soil sample sequential ID
6. After checking on the form that all the values have been properly inserted, the user can:
   - Accept the point by tapping "ok" on the top right corner of the form. This will store the point and measurement taken.
   - Cancel the point by tapping "cancel", next to the "ok" button. This will erase the current record permanently. You will then need to repeat the above process to retake the readings.

ArcPad troubleshooting

Error windows might appear while interrogating the probe through ArcPad. Error messages are generally vague and of the kind "error, line 89, source text unavailable". Usually, these are associated with lack of power to the probe or disconnection of one of the many component of the iPAQ-Hydra probe system. The general rule is to press "ok" on the error window, wait a few seconds and retry the command. If the error persists, please do the following:

- Check that all the connections are firm
- Check that the battery adaptor is firmly connected to the battery
- Check that the iPAQ USB serial port is firmly connected
- Check that the iPAQ is not low in battery

If the problem persists, change the gel cell battery with the spare one.

7.5.3 Gravimetric sampling procedure

- Remove vegetation and litter.

- Lay the ring on the ground
- Put the wooden base horizontal on top of the ring and use the hammer to insert the ring in the ground, until its upper edge is levelled with the ground surface.
- Use the garden trowel to dig the side of the ring. The hole should reach the bottom of the ring (5cm) and sufficiently large to fit the spatula
- Use the spatula to cut the 0-5cm soil sample at the bottom of the ring
- Place the 0-5cm soil sample in the plastic bag and seal with the rubber band provided
- Label the external plastic bag as **farm/team/date(dd-mm-yy)/time(hh:mm)/Sample ID**

7.5.4 Gravimetric soil moisture sample processing

All gravimetric soil moisture samples are processed to obtain a wet and dry weight. It is the sampling teams responsibility to deliver the samples, fill out a sample set sheet, one sheet per day per team, and record a wet weight at the field headquarters. All gravimetric soil moisture samples taken on one day will be put to dry in the ovens at 105^{o}C in the evening and will remain in the ovens until the following evening (approximately 24 hours).

Wet Weight Procedure

1. Turn on balance.
2. Tare.
3. Obtain wet weight to two decimal places and record on sheet.
4. Process your samples in numeric order, carefully emptying contents in the trays provided.
5. Place the used bags in order. The labelled bags will be needed for permanently storing the samples after the drying procedure is finished.

Dry Weight Procedure

1. All samples should remain in the oven for a minimum of 20-22 hours at 105^{o}C.
2. Turn off oven and remove samples for a single data sheet and place on heat mat. These samples will be hot. Wear the gloves provided
3. Turn on balance.
4. Tare.
5. Obtain dry weight to two decimal places and record on sheet.
6. Process your samples in sample numeric order, returning samples to the original plastic bags and store in the assigned locations.
7. Load new samples into oven.
8. Turn oven on.

7.5.5 Vegetation sampling procedure

Vegetation biomass ("quadrant" type sample)

A 0.5m x 0.5m quadrant will be used to obtain vegetation samples. The procedure for vegetation biomass sampling is as follows:

1. Note and record type of vegetation to be sampled (e.g. crop, native grass, improved pasture)

2. Randomly place 0.5m x 0.5m quadrant on ground near area to be sampled
3. Label bag provided using a permanent marker with the following information: **farm/team/date(dd-mm-yy)/time(hh:mm)/Sample ID**
4. Take photo of area to be sampled prior to removal of vegetation
5. Record sample location with GPS and/or sample location reference number
6. Remove all aboveground biomass within the 0.5m x 0.5m quadrant using vegetation clipper and scissors provided
7. Place vegetation sample into labelled bag provided
8. Close bag with sample using rubber bands provided
9. Take photo of sample plot following removal of aboveground biomass.

Vegetation water content ("grab" type sample)

The purpose of the grab sample is to characterise the ratio between vegetation dry biomass and vegetation water content, and monitor its evolution in time. Therefore a grab type vegetation samples is taken simply cutting off the part of a reference plant that sticks out of the ground. These g/g measurements can later be scaled to g/m^2 using the reference vegetation biomass measurements from quadrants.

Vegetation dew sample

This kind of sampling is done in a very similar way to the "grab" vegetation water content. Please refer to previous sections for sampling procedures. Particular attention will have to be paid in order to make sure that all the water present on the plant is collected in the sample bag. It is suggested to cover the entire plant with the sample bag before cutting it at ground level.

LAI measurements

Measurements of Leaf Area Index will be taken with an Exotech Inc. LAI-2000® device, operated exclusively by one team member. Sampling procedures for this instrument therefore will not be included in this work plan.

NDVI measurements

Measurements of Normalised Difference Vegetation Index will be taken with an Exotech Inc. Hand Held Radiometer 100BX® device, operated exclusively by one team member. Sampling procedures for this instrument won't therefore be included in this work plan.

7.5.6 Oven drying procedure – vegetation

Vegetation samples collected will be processed either in Merriwa or at The University of Newcastle. It is the responsibility of the teams to deliver the vegetation samples to NAFE headquarters at the end of the day, weigh and store them in the appropriate place. The procedure for vegetation biomass processing will be as follows:

1. Weigh samples before drying in ovens and record green biomass
2. Weigh the plastic bag and tag and record weight and subtract from sample green biomass
3. Dry samples in oven at 40^{o}C until constant weight is reached
4. Weigh dry vegetation samples and determine dry biomass.
5. Vegetation water content will be determined by subtracting the sample dry biomass to the sample green biomass

7.5.7 Surface roughness procedure

Surface roughness measurements will be taken a using a 1 m long drop pin profiler with a pin separation of 25 mm (see Fig. 43). At each surface roughness sampling location, 2 measurements will be taken with respectively North-South and East-West orientation. The procedure for one measurement is a s follows:

1. Note on the field book the position of the roughness measurements.
2. Position the profiler making sure that all the pins touch the soil surface. The pins MUST NOT be inserted into the ground or resting on top of vegetation.
3. Note on the field book the height reached by each pin, as read on the background grid. Pins has to be read from left to right, and indicated on the field book with sequential numbers from 1 to 41.

In the evenings, all readings will then be transcribed into an appropriate excel file named "Surface roughness", into the folder named as the farm of interest.

7.5.8 Data archiving procedures

All data collected during the day will be downloaded and backed up upon return to the NAFE headquarters on desktop PCs. There will be 2 desktop computers available for the downloading operations. It will be the responsibility of the teams to download all data collected with the iPAQs onto the appropriate folders (see "downloading" section below) and to insert into an excel worksheet all the data collected in the fieldbooks.

Figure 43. Pin profiler for surface roughness measurements

File structure

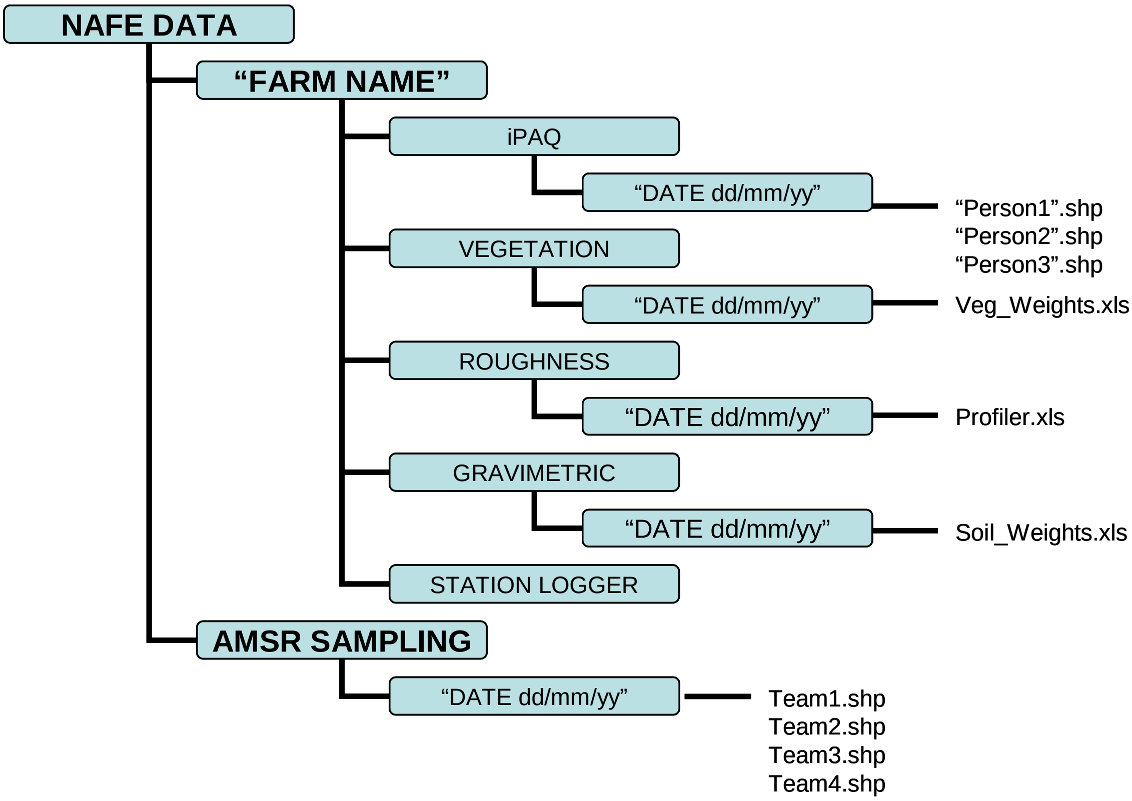


Figure 44. Tree diagram of the NAFE file structure

Downloading

- iPAQ data: Each person will download the iPAQ shapefile “hydra.shp” into the folder “Farm name”/iPAQ/”date”/.**The file hydra.shp MUST be renamed with the person name BEFORE downloading, when the file is still on the iPAQ.** Downloading will be done with the software Microsoft ActiveSync installed on the desktop computers. To download:
    - Connect the iPAQ to the desktop computer through the iPAQ USB cable
    - Start Microsoft ActiveSync
    - Establish a “Guest” partnership between the iPAQ and the desktop computer
    - Navigate to the /SD card/Goulburn folder on the iPAQ
    - Rename the file hydra.shp with your name
    - Copy the file and past it into the appropriate folder on the desktop computer (see Fig. 44)
- Vegetation data: Each team will insert into a excel worksheet named “Veg_weights.xls” contained in the folder “Farm name”/VEGETATION/”date”/ ,the samples ID of the vegetation samples taken, as a reference for the subsequent drying operations.
- Gravimetric data: Each team will insert into a excel worksheet named “Soil_weights.xls” contained in the folder “Farm name”/GRAVIMETRIC/”date”/ ,the samples ID and wet weight of the soil samples taken.
- Surface roughness data: The readings of the pin profiler will be inserted be each team into a excel worksheet named “Profiler.xls”

- AMSR sampling data: Each team will download the the iPAQ shapefile "AMSR_teamX.shp" into the folder AMSR SAMPLING/"date"/

Downloading

Daily data will be backed up on both DVD's and external hard disk drive. It will be the responsibility of the project leader to do the back up.

8 Logistics

8.1 Operation bases

Ground crew will be based in the town of Merriwa, located in the heart of the study area. The NAFE '05 headquarters will be at the local Anglican Church Hall (Fig. 45 and 46). The hall will be equipped with all the equipment needed for pre-sampling and post-sampling operations, including scales for sample weighing, ovens for soil and vegetation sample drying, computers for data downloading and processing, storage spaces for processed samples and equipment. It will be the responsibility of each team to make sure instruments and tools are stored properly overnight. The hall kitchen provides all sorts of facilities that can be used for breakfast. It is left to the individuals to arrange their own breakfast supplies, through the local bakery or supermarket (see Fig. 46).

One of the ground crew members, Rodger Young, will be based at the hall and will be dedicated to instrument repair and general technical support. Breakdowns and instrument faults must be reported to him at the end of each day.

Air crew will be based in Scone and operate both the SERA and the EMIRAD aircraft out of the Scone Airport (see Fig 47 and 48).

Figure 45. NAFE'05 headquarters

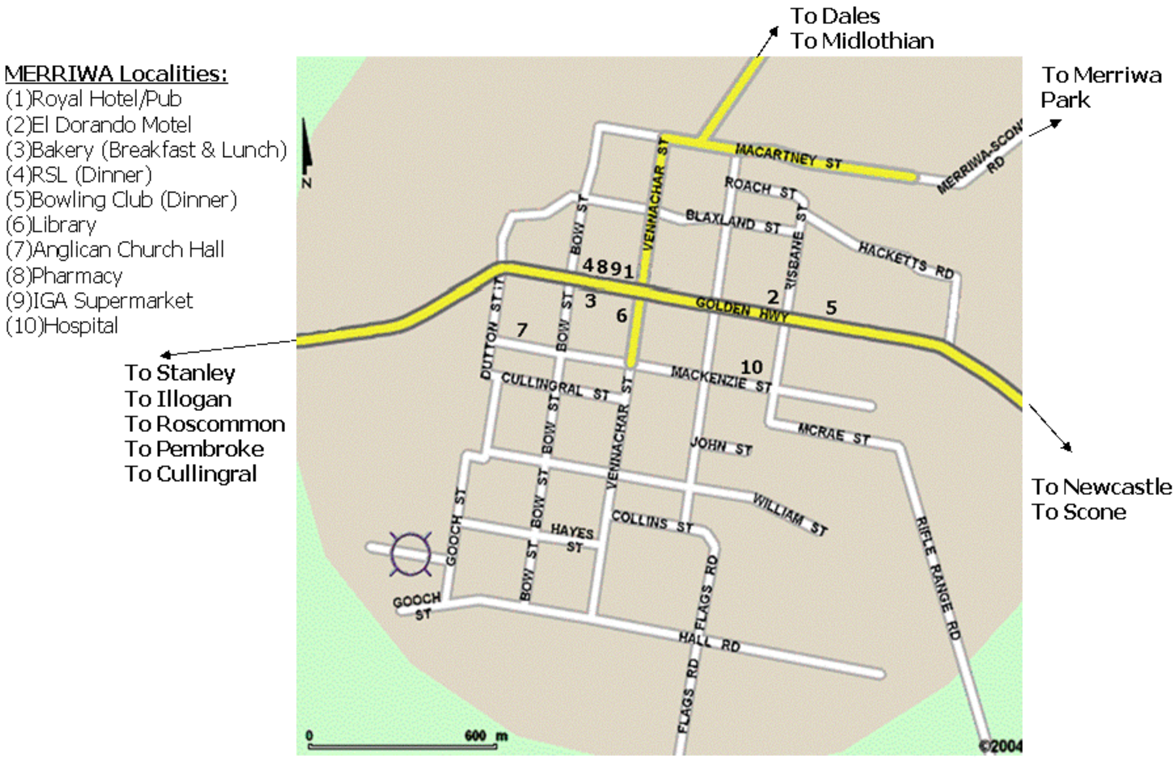


Figure 46. Map of Merriwa town centre map with NAFE '05 logistic locations.

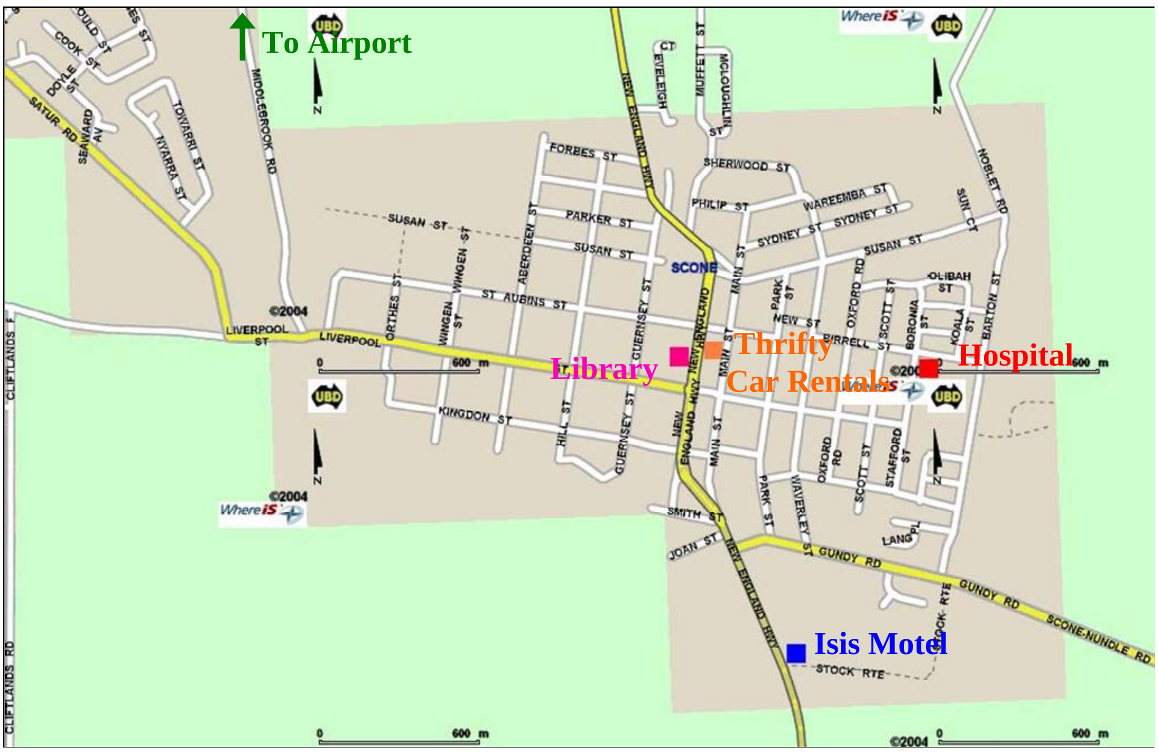


Figure 47. Map of Scone town centre

8.2 Accommodation

A block of rooms has been reserved for ground crew participants at the only motel in Merriwa, the "El Dorado" motel (see details below and Merriwa map in Fig. 46). Participants have been pre-assigned to rooms (Table 10), depending on the period of stay and the institution of origin, to facilitate check-in and check-out operations and payment. The rooms are single, double, triple or family rooms, and mostly they will be shared between participants (on a male/female basis). At your arrival, check in at the reception and make sure you provide your details. At departure, payment will be done on an individual basis. A number of the participants from Newcastle University have elected to be accommodated at one of the pubs in town, the Royal Hotel, and are responsible for their own arrangements.

The air crew will be accommodated at the Isis Motel in Scone. A block of rooms have been already booked and details are given in Table 11.

8.3 Meals

Meals arrangements are left to individuals to organise. However, following are some suggestions to facilitate organisation of the ground crew:

- Breakfast: supplies can be bought at the local supermarket (see Fig. 46) and prepared/eaten at the NAFE'05 headquarters' kitchen;
- Lunch: can be bought at the local supermarket or at the Merriwa bakery (see Fig. 46). To facilitate this, Rodger Young will take orders for the sandwiches the day before, and collect them at the bakery every morning. Expenses will be billed to your tab.
- Dinner: apart from the supermarket (if you want to do this make sure you buy your supplies in advance, as the supermarket might be close by the time you get back from your sampling), the only options for dinner are the Royal Hotel (only on the weekends, see Fig. 46), the Returned Services League Club, and the Bowling Club, which serves some Chinese food as well as regular meals (Fig. 46).

Figure 48. PLMR hangar at Scone airport and a view of the airstrip

Table 10. Accommodation logistics for the ground crew at Merriwa "El Dorado" motel

Room N.	People	Start date	End date	N. days	Price ($/night)	Total room
5	Viviana Maggioni* Jennifer Grant	29/10/2005	26/11/2005	28	69	1932
13	Jetse Kalma**	29/10/2005	26/11/2005	28	38	1064
10	Patricia De Rosnay Gilles Boulet (Kauzer Saleh)	29/10/2005	12/11/2005	14	80	1120
10	Rob Pipunic* Chris Rüdiger* Stuart Jones*	12/11/2005	26/11/2005	14	80	1120
7	Rodger Young* Olivier Merlin*	24/10/2005	26/11/2005	33	69	2277
8	Rocco Panciera* Marco Rinaldi*	24/10/2005	2/12/2005	40	69	2760
14	Jose Fenollar Daniele Biasioni*	24/10/2005	26/11/2005	33	55	1815
15	Michael Berger	24/10/2005	5/11/2005	13	45	585

Table 11. Accommodation details for air crew at Scone "Isis" Motel

Room N.	People	Start date	End date	N. days	Price ($/night)	Total room
1	Jon Johanson	27/10/2005	26/11/2005	30	60	1560
2	Helmut Thompson	4/11/2005	26/11/2005	30	60	1200
4	Sten Schmidl Soebjaerg	4/10/2005	12/11/2005	16	60	480
6	Jorg Hacker (+Shakti)	27/10/2005	2/11/2005	6	68	408
14	Jeff Walker	27/10/2005	26/11/2005	30	60	1560
15	Ed Kim	29/10/2005	26/11/2005	28	60	1440
16	Valerio Paruscio	29/10/2005	26/11/2005	28	60	1440
17	Patrick Wurstein	28/10/2005	28/11/2005	31	60	1620
18	Jan Balling	9/11/2005	26/11/2005	17	60	900

8.4 Internet

Due to the remoteness of the area, internet service will be very limited. The only option in town is the local library (see Fig 46). As per an agreement reached with the library management, access for NAFE'05 participants will be available between 8-9pm, only on Monday, Wednesday and Thursday. There will be 10 computers available and the hourly fee will be $2.50 per user, to be paid individually.

In Scone, Internet will be available at the Upper Hunter regional library. Refer to the section 7 for contact details.

8.5 Maps and directions

8.5.1 Getting there

Airport shuttle

There will be three "Airport Shuttle" runs provided by NAFE, **Saturday 29th October**, **Saturday 12th November** and **Saturday 26th November.** Please make sure we have your arrival and departure details if you require this service.

By car

<u>From Sydney Airport (Mascot) to Maitland (New England Highway)</u>

1	*Start at	Elizabeth Avenue		Mascot	0 metres	0 Seconds
2		Botany Road	S	Mascot	747 metres	1:06 Minutes
3		Eastern Distributor on ramp	E	Mascot	143 metres	6 Seconds
4		Eastern Distributor	E	Botany	8.86 kms	6:37 Minutes
5		Cahill Expressway	N	Woolloomooloo	1.13 kms	57 Seconds
6		Sydney Harbour Tunnel	N	Sydney	2.45 kms	1:52 Minutes
7		Warringah Freeway	N	North Sydney	4.28 kms	3:12 Minutes
8		Gore Hill Freeway	W	Artarmon	925 metres	53 Seconds
9		Pacific Highway exit	W	Artarmon	635 metres	38 Seconds
10		Pacific Highway	NE	Lane Cove North	13.51 kms	18:12 Minutes
11		Sydney Newcastle Freeway on ramp	NE	Wahroonga	27 metres	1 Second
12		Sydney Newcastle Freeway	N	Wahroonga	126.95 kms	1:19 Hours
13		John Renshaw Drive	E	Beresfield	561 metres	1:20 Minutes
14		New England Highway on ramp	E	Beresfield	624 metres	1:29 Minutes
15		New England Highway	NW	Beresfield	13.97 kms	18:37 Minutes
16		New England Highway		Maitland	0 metres	0 Seconds
					174.90 kms	2:14 Hours

From Newcastle Airport (Williamtown) to Merriwa

Driving Directions

Driving Directions from Williamtown NSW to Merriwa NSW Reverse Route

ID		Road	Direction	Town	Distance	Time
1	*Start at	Slades Road		Williamtown	0 metres	0 Seconds
2		Unnamed	W	Williamtown	237 metres	17 Seconds
3		Williamtown Drive	SE	Williamtown	674 metres	40 Seconds
4		Unnamed	SE	Williamtown	10 metres	0 Seconds
5		Nelson Bay Road	SW	Williamtown	683 metres	30 Seconds
6		Cabbage Tree Road	W	Williamtown	6.63 kms	4:57 Minutes
7		Tomago Road	W	Tomago	8.50 kms	6:22 Minutes
8		Pacific Highway	SW	Tomago	1.41 kms	56 Seconds
9		New England Highway exit	SW	Hexham	109 metres	4 Seconds
10		New England Highway	N	Hexham	22.37 kms	28:18 Minutes
11		New England Highway	NW	Rutherford	29.78 kms	27:12 Minutes
12		Golden Highway	SW	Whittingham	25.88 kms	23:54 Minutes
13		Long Point Road	NW	Warkworth	18 metres	0 Seconds
14		Golden Highway	NW	Warkworth	13.90 kms	11:08 Minutes
15		Golden Highway		Jerrys Plains	0 metres	0 Seconds
16		Golden Highway		Jerrys Plains	27.59 kms	22:48 Minutes
17		Jerdan Street	SW	Denman	55 metres	5 Seconds
18		Golden Highway	W	Denman	51.20 kms	41:15 Minutes
19		Vennacher Street		Merriwa	0 metres	0 Seconds
20		Vennacher Street		Merriwa	0 metres	0 Seconds
					189.09 kms	2:48 Hours

<u>From Newcastle Airport (Williamtown) to Scone</u>

Driving Directions

Driving Directions from Williamtown NSW to Scone NSW Reverse Route

ID		Road	Direction	Town	Distance	Time
1	*Start at	Slades Road		Williamtown	0 metres	0 Seconds
2		Unnamed	W	Williamtown	237 metres	17 Seconds
3		Williamtown Drive	SE	Williamtown	674 metres	40 Seconds
4		Unnamed	SE	Williamtown	10 metres	0 Seconds
5		Nelson Bay Road	SW	Williamtown	683 metres	30 Seconds
6		Cabbage Tree Road	W	Williamtown	6.63 kms	4:57 Minutes
7		Tomago Road	W	Tomago	8.50 kms	6:22 Minutes
8		Pacific Highway	SW	Tomago	1.41 kms	56 Seconds
9		New England Highway exit	SW	Hexham	109 metres	4 Seconds
10		New England Highway	N	Hexham	22.37 kms	28:18 Minutes
11		New England Highway	NW	Rutherford	113.56 kms	1:41 Hours
12		New England Highway		Scone	0 metres	0 Seconds
					154.24 kms	2:23 Hours

8.5.2 Getting around

Krui Farms:

ILLOGAN:

- Travel approximately 28 km west along Golden Hwy
- Turn left onto Comiala Road
- Travel approximately 7km south down Comiala Road & 'Illogan' property marked on left

STANLEY:

- Travel approximately 24km west along Golden Hwy
- On right hand side of Golden Hwy

ROSSCOMMON:

- Travel approximately 20km west along Golden Hwy
- Turn left onto Redwell Road
- Travel approximately 7km south down Redwell Road (sampling site on right hand side of road);

PEMBROKE:

- Travel approximately 25km west along Golden Hwy
- Turn right onto Pembroke Road
- Travel approximately 11km north along Pembroke Road

Merriwa Farms:

MERRIWA PARK:

- Turn right off Golden Hwy onto Venacher St (Royal Pub corner)
- Turn right onto Macartney St
- Travel approximately 6km along Merriwa-Scone Road
- Turn off to left to access property

CULLINGRAL:

- Travel approximately 500m west along Golden Hwy
- Turn left onto Cullingral Road
- Travel approximately 1km south along Cullingrat Road. Cullingral homestead is marked on left

MIDLOTHIAN:

- Turn right off Golden Hwy onto Venacher St (Royal Pub corner)
- Turn right onto Macartney St
- Turn left onto Coulsons Creek Road (i.e. follow Willow Tree signage)
- Travel approximately 4.5km north along Coulsons Creek Road
- Turn left onto Mountain Station Road. The Midlothian property is on left of road (approximately 1km)

DALES:

- Turn right off Golden Hwy onto Venacher St (Royal Pub corner)
- Turn right onto Macartney St

- Turn left onto Coulsons Creek Road (i.e. follow Willow Tree signage)
- Travel approximately 19km north along Coulsons Creek Road
- Dales property on right hand side of road

8.6 Groups

The ground crew segment will be based in Merriwa and coordinated by Prof. Jetse Kalma. This group will be responsible for all the soil moisture and supporting data measurement in the Northern Goulburn study area. The sampling operations will be undertaken by 4 teams acting independently. Each team will be assigned two of the eight focus farms, one in the Merriwa sub-catchment and one in the Krui sub-catchment. Each team will sample the same two farms for the entire field campaign. Table 12 indicates the composition of each team and the focus farm assigned to each group. The air segment will operate from the Scone airport and will be coordinated by Jeff Walker (Table 13).

Table 12. NAFE '05 ground crew segment. Group leaders are indicated in red.

	Weeks 1,2	Weeks 3,4	Vehicles	Krui area	Merriwa area
Team 1	**Rocco Panciera** Marco Rinaldi Patricia DeRosney Gilles Boulet	**Rocco Panciera** Marco Rinaldi Rob Pipunic TBD	White Rodeo 4WD (STT 296) Melb Uni + 1 Quad bike	Pembroke	Midlothian
Team 2	**Greg Hancock** Cristina Martinez Jose' Fenollar Viviana Maggioni Mark Thyer	**Greg Hancock** Cristina Martinez Jose' Fenollar Viviana Maggioni	White Toyota Prado 4WD (UNI 211) Newcastle Uni	Stanley	Cullingral
Team 3	**Jetse Kalma** Jennifer Grant Patricia Saco Daniele Biasioni	**Jetse Kalma** Jennifer Grant Daniele Biasioni	Silver Toyota Prado 4WD (UNI 033) Newcastle Uni	Roscommon	Dales
Team 4	**Tony Wells** Olivier Merlin Kauzeer Saleh	**Chris Rüdiger** Olivier Merlin Stuart Jones	Newcastle Uni	Illogan	Merriwa Park

Table 13. NAFE'05 Air crew members

PLMR		EMIRAD	
Jeff Walker	27-Oct 26-Nov	Helmut Thompson	4-Nov 26-Nov
Jorg Hacker + Shakti	27-Oct 2-Nov	Michael Berger	24-Oct 5-Nov
Valerio Paruscio	29-Oct 26-Nov	Patrick Wurstein	28-Oct 28-Nov
Ed Kim	29-Oct 26-Nov	Sten Schmidl Soebjaerg	4-Nov 12-Nov
Garry Willgoose	29-Oct 26-Nov	Jan Balling	9-Nov 26-Nov
Chris Dever	only day trips		
Jon Johanson	27-Oct 26-Nov		

Table 14. Schedule of training sessions

Time	Place	Activities	Coordinators
8.00am - 8.30am	NAFE headquarter	Presentation of NAFE'05	Jetse Kalma
8.30am - 9.30am	NAFE headquarter	Presentation of NAFE'05 sampling strategy	Rocco Panciera
9.30am - 10.30am	Example focus farm	Instrument use explanation (all together)	Rocco Panciera Cristina Martinez
10.30am - 12.30pm	Example focus farm	Instrument use practice (in teams)	Team leaders
12.30pm - 1.30pm		Lunch	
1.30pm - 6.00pm	Team farms	Study areas recognition(2 farms): *Farm scale sampling points survey *High resolution areas survey *High	Team leaders

8.7 Training sessions

Two training sections have been scheduled to ensure all the participants to NAFE are familiar with the project objectives, the sampling strategy and the use of all the instruments involved in the sampling. Training sessions will take the whole day and are scheduled for Sunday 30th October and Sunday 13th October, to match the arrival of new participants to the second two weeks of the campaign. Training session will be held at the NAFE's headquarters (morning), and at the respective farms (afternoon), with the schedule and activities indicated in table 13

Training on instrument use will include:

- iPAQ basics
- Soil moisture sampling with Stevens Hydra Probe®
- Soil moisture sampling on high resolution areas
- Gravimetric soil sampling
- Vegetation biomass sampling
- Vegetation water content sampling
- Vegetation dew sampling
- Vegetation dew estimation
- Vegetation height estimation
- Vegetation type estimation
- Surface roughness measurements
- Surface rock cover estimation

8.8 Daily activities

The Hall will be the meeting point for the morning group assembly, breakfast and sampling preparation. At the end of the day, group will report to the hall, download the data collected, put the samples in the oven for drying, control the instruments, ensure electronic devices are recharged overnight and report to the project leaders. Daily operations will proceed as per the following schedule:

- **7.00am:** Gathering of the teams at the NAFE headquarters.
  Breakfast
  Morning briefing
  Review of the activity of the day on the notice board
  Preparation of the instruments and tool for the sampling
- **7.30am:** Teams departure for the sampling locations
- **7-30am – 12.30pm:** Sampling operations
- **12.30pm – 1.30pm:** Lunch
- **1.30pm – 5.30pm**: Sampling operations
- **6.00pm:** Teams return to the hall
  Report to the project leaders
  Data downloading on the desktop/laptop computers
  Soil and vegetation samples in ovens for drying
  Recharge of electronic devices

8.9 Farm access and mobility

Farms will be accessed every day for the sampling operations. Transport from Merriwa to the farm and across the farm for sampling will be done on the team 4WD vehicle. Please note that 4WD driving on off-road areas and farm tracks can lead to injury and death and requires extreme attention and care. Sampling of the farm area will require driving along tracks and through paddocks, while walking will be necessary where driving is unfeasible, due to particular topographic or vegetation. In particular, driving through cultivated areas should be avoided at all times, due to the serious damage the transit could cause to crops.

The sampling locations have been organised so that only reasonably accessible areas will be object of the sampling. Project and team leaders have good knowledge of the areas, and in most cases they will be responsible for the farm scale sampling. The planned sampling locations will not be numbered, and no specific indication will be given as to the order to follow in covering the points. Due to logistic constraints, it will be left to the individuals to plan their own preferred sampling routes. However, following are some recommendations to make the sampling as uniform and consistent as possible between different farms and different days:

- Plan ahead: decide your sampling route and **be consistent** with it between sampling days.. This will ensure consistency between the soil moisture maps produced during the campaign.
- Sample from the big scale to the small scale: It is recommended to start from the coarse scale points, then sample the smallest scale points, then increase depending on the time left.
- Sample on a “paddock” base: we are interested in spatial patterns, so groups of points are preferred to long lines of points. If you get to a fence, make sure you sampled all the points within the paddock before getting to the next one (provided this doesn’t conflict with the previous note).

- Take the sample exactly at the location indicated on the map: exception to this rule might be the case of a sampling point falling to close to an undesirable location which might create local soil moisture condition not representative of the site (e.g. an isolated tree in a vast short grass area or creek). In the case, shift the sampling far enough to capture the average site conditions (up to 30m depending on grid resolution)
- Always sample in the same locations as the previous days to ensure consistency.

Remember that NAFE’05 activities are allowed by the property owners in the agreement that no damage will be caused to the properties. In particular:

- Be aware of the presence of stock on most of the farms during the sampling activities. Most of the animals are inoffensive cows and sheep, which will generally keep distant. However, in some cases cows could be inquisitive. A particular case is the Merriwa Park farm; Bulls are present on one of the paddocks. Although they shouldn’t represent particular risk, always check the position and movement of the stock. Team members assigned to Merriwa Park will be advised properly of the conditions.
- Many farm in the area adopt the so called “intensive cell grazing” technique. This results in a dense network of interconnected single electric wires, all converging into a certain number of “nodes”, where transit between paddocks is made easy through electrically isolated holds. Generally, it will be possible to crawl below or step over the wires without risk. When driving through these areas, locate the nearest node to transit into the next paddock.
- In the case of heavy rain, stop sampling and wait for better weather conditions: this is both to avoid damage to the electronic instrumentation used for the sampling and also to prevent excessive “digging” of the muddy farm tracks by the vehicle wheels.

8.10 Communications

Communications between team members and team and project leaders is important both from a logistic and safety point of view. In every team there will be at least two mobile phones and a UHF transmitter. One mobile phone will stay with the team leader, who will be sampling at farm scale, while the other will stay with the team members who will be sampling the high resolution areas. This will provide contact within the individual teams. On most farms the mobile phone coverage is extensive, while on some it is poor. On the farms with only partial coverage, team members should agree on some “check times” (at least 1 every hour) during the morning and the afternoon, for the farm scale sampler to report to the high resolution areas and indicate the areas he/she will be sampling next. In case a check time is missed by the farm scale sampler, actions should be taken by the team members to ensure his/her safety. In particular:

- Contact with the missing team member should be immediately attempted with the mobile phone.
- If that fails, contact should be made with the project leaders with mobile phone. The project leaders should attempt contact with UHF. The local emergency channel is **Channel 8 Duplex. To connect to this channel via the UHF receiver:**

  (1) press the DUP (i.e. duplex) button on the UHF
  (2) then dial channel 8

- If that failed, the project leader should immediately bring a vehicle to the farm and start searching in the areas indicated by the other team members

Team leaders should make themselves familiar with the use of the UHF transmitter and the emergency frequency indicated above.

8.11 Safety

There are a number of potential hazards in doing field work. The following has some good suggestions. Common sense can avoid most problems. Remember to:

- When possible, work in teams of two
- Carry a phone or UHF receiver
- Know where you are. Keep track of your position on the provided farm map.
- Do not touch or approach any unidentified objects in the field.
- Notify your NAFE supervisor after returning to the field headquarters
- Dress correctly; long pants, long sleeves, boots, hat
- Use sunscreen.
- Carry plenty of water for hydration.
- Notify your teammate and supervisors of any preexisting conditions or allergies before going into the field.

Australian Red Cross

First aid for snake bite.

Use the pressure immobilisation technique for a bite on a limb.
-apply firm pressure over the bite site
-apply broad bandage to keep pressure on bite site.
-immobilise limb
(for bites on the head or trunk do not use this technique but keep thepatient still and get medical aid asap)

Monitor the airways, breathing and circulation of the patient. Be ready to give Expired Air Resuscitation (mouth to mouth)or CPR.
Keep the patient very still and reassure.
Start transport to the nearest medical centre or call and meet an ambulance.
Do not cut the bite
Do not suck the bite.
Do not wash the bite.
Do not apply a tourniquet

- Beware of harvesting machinery. Several crops will be harvested during November. When sampling on crop, always make sure your presence is noted and watch out for the moving harvesting machines.
- Beware of Snakes. Always wear sturdy boots to avoid bites. refer to http://www.australianfauna.com/australiansnakes.php for detailed info about the most common of australian snakes species.

The temperature used for the soil drying ovens is 105 ^{o}C. Touching the metal sample cans or the inside of the oven may result in burns. Use the safety gloves provided when placing cans in or removing cans from a hot oven. Vegetation drying is conducted at lower temperatures that pose no hazard.

9 Contacts

Field work

Name	Team	Mobile
Jeffrey Walker	Air crew coordinator	0413 023 915
Panciera Rocco	Team 1	0431 688 696
Greg Hancock	Team 2	0409 328 942
Jetse Kalma	Team 3/Ground crew coordinator	0427 426 217
Tony Wells	Team 4 - weeks 1,2	n/a
Chris Rüdiger	Team 4 - weeks 3,4	0410 131 407
Rodger young	technical support	0417 504 593

Emergency

local UHF	Channel 8 Duplex	
Ambulance	12 1233	
Merriwa Hospital	6548 2006	6532 5000
Merriwa Police	6548 2203	0408 293 423
Poison information center	13 1126	
Merriwa Rescue Quad	6548 2538	

Farmers

Farm	Farmer Name	Home Phone	Mobile Phone
Illogan	Robert & Maree Goodear	(02) 63761129	n/a
Stanley	Doc & Fiona Strahan	(02) 65485154	n/a
Roscommon	Tony & Joanna O'Brien	(02) 65485161	n/a
Pembroke	Matthew & Marion Dowd	(02) 65487233	0428 233 891
Cullingral	Peter McNamara	n/a	0407 257 154
Merriwa Park	Martin Nixon	(02) 65482225	n/a
Midlothian	Mike Gilder	(02) 65482219	0429 482 219
Dales	James & Judy Bettington	(02) 65488563	n/a

Accommodation & logistics

El Dorado Motel
50 Bettington Street
Merriwa NSW 2329
Telephone: (02) 6548 2273
Facsimile: (02) 65482208
Rating: **1/2

Royal Hotel
Bettington Street
Merriwa NSW 2329
Telephone: (02) 6548 2235

NAFE headquarters
@ Anglican Church Hall
Pat Kirkby
(H): (02) 65482424
(M): 0407132436

Medical

Merriwa Community Hospital
Mackenzie Street
Merriwa NSW 2329
Telephone: (02) 6532 5000
Facsimile: (02) 6532 5005
http://www.hnehealth.nsw.gov.au/docs/transport_merriwa.pdf

Merriwa Pharmacy
106 Bettington Street
Merriwa NSW 2329
Tekephone: (02) 6548 2213

Car rentals

Off Road Rentals
1370 North Road
Huntingdale VIC 3166
Phone (03) 9543 7111
Fax (03) 9562 9205
Email: manager@offroadrentals.com.au

Scone

Isis Motel
250 New England Hwy Scone NSW 2337
ph: (02) 6545 1100

Upper Hunter Regional Library (with internet access)
214 Kelly St Scone NSW 2337
ph: (02) 6545 1451

NAFE'05

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10 Equipment List

The following tables list all the equipments that will be required for NAFE'05, grouped per person, team and operation base

PERSONAL EQUIPMENT		TOTAL (15 PEOPLE)
hx2110 iPaq	1	15
ipaq container box	1	15
postpack	1	15
ipaq storage card	1	15
hydra probe	1	15
sampling pole	1	15
ipaq mount	1	15
bumpack	1	15
foam (4 hydra probe)	1	15
ipaq split sync cable	1	15
ipaq power cable	1	15
ipaq AC adaptor	1	15
GPS receiver	1	15
GPS battery recharge kit	1	15
GPS power jack	1	15
coinverter CONV485	1	15
battery connector	1	15
gel cell battery	2	30
electrial isolating gloves (pair)	1	15
hat	3	45
sunscreen bottle	1	15
insect repellent	1	15

TEAM EQUIPMENT		TOTAL (4 TEAMS)
4WD vehicle	1	4
UHF receiver	1	4
rope (150m)	3	12
hi-res area pegs	8	32
rope pegs	32	128
plier	1	4
light hammer	2	8
duck tape roll	4	16
screwdriver	1	4
tool container box	1	4
hardcopy farm map	3	12
hardcopy whole area map	1	4
copy of workplan	1	4
pencil	6	24
field book	3	12
first aid kit	1	4
water jerry can	1	4
flags/colored stripes	10	40
Vegetation sampling kit	2	8
* 1 veg clipper		8
* 1 pair of scissors		8
* 1 vegetation quadrant		8
* 304 plastic bags		1216
* 304 rubber bands		1216
Soil sampling kit	2	8
* 1 soil sample ring		8
* 1 garden trowel		8
* 1 blade		8
* 1 spatula		8
* 1 wooden base		8
* 604 plastic bags		2560
* 604 rubber bands		2560
* 4 markers for bags		16

GENERAL EQUIPMENT - Merriwa	
NAFE'05 headquarters	
ovens	2
scales	2
alluminium tray	300
weight recording form	4
samples container boxes	4
desktop computer	2
field laptop	1
backup dvd	50
backup hard drive	1
color printer	1
laptop wall projector	1
cd's with data	1
multi plug base	5
gel cell battery charger	4
plug extension	5
notice board	1
board pencils	10
Monitoring stations	
TIR sensor	4
dew sensor	6
stands	4
soil temp sensor	31
starlogger	8
starlogger download cable	2
gel cell battery	22
rock temp sensor	
instruments	
pin profiler	1
hand-held temp sesnor	1
Licor LAI sensor	1
NDVI sensor	1
handheld IR radiometer	1
quad	1
quad helmet	1
theta probes	7
repairing kit	
starlogger screwdriver	2
terminal strip screwdriver	2
duck tape roll	4
wire stripper	2
wire cutter	2
solder	1
hammer	1
spare gel cell/wire multi connectors	
spare wires	
mutlimeter	

GENERAL EQUIPMENT - Scone	
UNIDATA salinity/temp sensor unit	1
gell cell battery	3
floating station	1
backup dvd	10
backup hard drive	1
field book	2
gps unit	1
handheld sal/temp sensor	1
boat	1
laptop for lake station	1

11 Appendix A: Flight Line Coordinates

Table A1. PLMR low resolution mapping flight lines and coverage reference coordinates for AMSR sampling days. The corners are counted clock-wise starting from North-West.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
A1	10000	11265	43	150.0568	-32.2981	150.0688	-31.9033
A2	10000	11265	43	150.1216	-31.9044	150.1098	-32.2993
A3	10000	11265	43	150.1629	-32.3004	150.1744	-31.9056
A4	10000	11265	43	150.2273	-31.9067	150.2159	-32.3016
A5	10000	11265	43	150.2684	-32.3026	150.2795	-31.9078
A6	10000	11265	43	150.3323	-31.9089	150.3214	-32.3037
A7	10000	11265	43	150.3744	-32.3048	150.3851	-31.9100
A8	10000	11265	43	150.4379	-31.9111	150.4275	-32.3058

corner	Longitude (Deg)	Latitude (Deg)
1	150.0376	-31.9141
2	150.4690	-31.9241
3	150.4580	-32.2914
4	150.0257	-32.2820

Table A2. PLMR low resolution mapping flight lines and coverage reference coordinates for farm scale sampling days.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
A9	10000	11265	26	150.1485	-32.1965	150.1561	-31.9574
A10	10000	11265	30	150.3715	-31.9098	150.3635	-32.1846
A11	10000	11265	30	150.4165	-32.1857	150.4243	-31.9109

Krui

	Longitude (Deg)	Latitude (Deg)
crn 1	150.1173	-32.1825
crn 2	150.1243	-31.9668
crn 3	150.1875	-31.9682
crn 4	150.1809	-32.1839

Merriwa

	Longitude (Deg)	Latitude (Deg)
crn 1	150.3325	-32.1713
crn 2	150.3397	-31.9210
crn 3	150.4560	-31.9233
crn 4	150.4490	-32.1737

Table A3. PLMR intermediate resolution mapping flight lines and coverage reference coordinates for the Krui area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
B1	5000	6265	26	150.1825	-31.9580	150.1750	-32.1971
B2	5000	6265	26	150.1485	-32.1965	150.1561	-31.9574
B3	5000	6265	26	150.1297	-31.9569	150.1220	-32.1967

	Longitude (Deg)	Latitude (Deg)
crn 1	150.0376	-31.9141
crn 2	150.4690	-31.9241
crn 3	150.4580	-32.2914
crn 4	150.0257	-32.2820

Table A4. PLMR intermediate resolution mapping flight lines and coverage reference coordinates for the Merriwa area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
B4	5000	6265	30	150.4507	-31.9114	150.4430	-32.1861
B5	5000	6265	30	150.4165	-32.1857	150.4243	-31.9108
B6	5000	6265	30	150.3980	-31.9097	150.3900	-32.1851
B7	5000	6265	30	150.3635	-32.1846	150.3715	-31.9098
B8	5000	6265	30	150.3448	-31.9094	150.3370	-32.1840

	Longitude (Deg)	Latitude (Deg)
crn 1	150.3276	-31.9208
crn 2	150.4658	-31.9232
crn 3	150.4591	-32.1739
crn 4	150.3205	-32.1710

Table A5. PLMR medium resolution mapping flight lines for the Krui area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
C1	2500	3778	4	150.0598	-32.1683	150.0612	-32.1259
C2	2500	3778	4	150.0744	-32.1262	150.0730	-32.1686
C3	2500	3876	6	150.1221	-32.1949	150.1238	-32.1420
C4	2500	3876	6	150.1371	-32.1423	150.1354	-32.1952
C5	2500	3876	6	150.1486	-32.1954	150.1503	-32.1426
C6	2500	3855	4	150.1512	-32.1127	150.1524	-32.0742
C7	2500	3855	4	150.1392	-32.0739	150.1378	-32.1124
C8	2500	3855	4	150.1248	-32.1120	150.1260	-32.0736
C9	2500	4073	11	150.1264	-32.0614	150.1297	-31.9569
C10	2500	4073	11	150.1429	-31.9572	150.1396	-32.0617
C11	2500	4073	11	150.1526	-32.0620	150.1561	-31.9574
C12	2500	4073	11	150.1693	-31.9577	150.1660	-32.0630
C13	2500	4073	11	150.1793	-32.0633	150.1825	-31.9580

Stanley	Longitude (Deg)	Latitude (Deg)
crn 1	150.1169	-32.0855
crn 2	150.1601	-32.0865
crn 3	150.1597	-32.1005
crn 4	150.1164	-32.0996

Illogan	Longitude (Deg)	Latitude (Deg)
crn 1	150.0528	-32.1373
crn 2	150.0815	-32.1380
crn 3	150.0808	-32.1561
crn 4	150.0523	-32.1555

Roscommon	Longitude (Deg)	Latitude (Deg)
crn 1	150.1145	-32.1536
crn 2	150.1581	-32.1545
crn 3	150.1572	-32.1838
crn 4	150.1135	-32.1828

Pembroke	Longitude (Deg)	Latitude (Deg)
crn 1	150.1210	-31.9669
crn 2	150.1901	-31.9684
crn 3	150.1876	-32.0499
crn 4	150.1182	-32.0485

Table A6. PLMR medium resolution mapping flight lines and coverage reference coordinates for the Merriwa area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
C14	2500	3448	4	150.3373	-32.1839	150.3386	-32.1399
C15	2500	3774	12	150.3460	-32.1049	150.3493	-31.9937
C16	2500	3774	12	150.3625	-31.9939	150.3593	-32.1052
C17	2500	3984	6	150.4292	-32.1342	150.4309	-32.0744
C18	2500	4175	9	150.4410	-31.9949	150.4433	-31.9112
C19	2500	4175	9	150.4301	-31.9109	150.4277	-31.9946

Cullingral	Longitude (Deg)	Latitude (Deg)
crn 1	150.3300	-32.1536
crn 2	150.3462	-32.1539
crn 3	150.3459	-32.1712
crn 4	150.3294	-32.1709

Midlothian	Longitude (Deg)	Latitude (Deg)
crn 1	150.3300	-32.1536
crn 2	150.3462	-32.1539
crn 3	150.3459	-32.1712
crn 4	150.3294	-32.1709

Merriwa P.	Longitude (Deg)	Latitude (Deg)
crn 1	150.4226	-32.0876
crn 2	150.4383	-32.0879
crn 3	150.4373	-32.1205
crn 4	150.4217	-32.1201

Dales	Longitude (Deg)	Latitude (Deg)
crn 1	150.4216	-31.9229
crn 2	150.4511	-31.9234
crn 3	150.4496	-31.9832
crn 4	150.4200	-31.9825

Table A7. PLMR high resolution mapping flight lines for the Krui area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
D1	625	2198	11	150.1792	-31.9580	150.1760	-32.0626
D2	625	2198	11	150.1727	-32.0625	150.1759	-31.9579
D3	625	2198	11	150.1726	-31.9578	150.1694	-32.0624
D4	625	2198	11	150.1661	-32.0624	150.1693	-31.9577
D5	625	2198	11	150.1660	-31.9577	150.1627	-32.0623
D6	625	2198	11	150.1594	-32.0622	150.1627	-31.9576
D7	625	2198	11	150.1594	-31.9575	150.1561	-32.0621
D8	625	2198	11	150.1528	-32.0621	150.1561	-31.9574
D9	625	2198	11	150.1528	-31.9574	150.1495	-32.0620
D10	625	2198	11	150.1462	-32.0619	150.1495	-31.9573
D11	625	2198	11	150.1461	-31.9572	150.1429	-32.0618
D12	625	2198	11	150.1396	-32.0618	150.1428	-31.9571
D13	625	2198	11	150.1395	-31.9571	150.1363	-32.0617
D14	625	1980	4	150.1425	-32.0737	150.1413	-32.1123
D15	625	1980	4	150.1380	-32.1123	150.1392	-32.0736
D16	625	1980	4	150.1359	-32.0735	150.1347	-32.1122
D17	625	1980	4	150.1314	-32.1121	150.1326	-32.0735
D18	625	1980	4	150.1293	-32.0734	150.1281	-32.1120
D19	625	1980	4	150.1248	-32.1120	150.1260	-32.0733
D20	625	1980	4	150.1227	-32.0732	150.1214	-32.1119
D21	625	2001	6	150.1536	-32.1424	150.1520	-32.1954
D22	625	2001	6	150.1487	-32.1953	150.1504	-32.1424
D23	625	2001	6	150.1470	-32.1423	150.1454	-32.1952
D24	625	2001	6	150.1421	-32.1952	150.1437	-32.1422
D25	625	2001	6	150.1404	-32.1421	150.1387	-32.1951
D26	625	2001	6	150.1354	-32.1952	150.1371	-32.1421
D27	625	2001	6	150.1338	-32.1420	150.1321	-32.1951
D28	625	1903	4	150.0798	-32.1645	150.0809	-32.1306
D29	625	1903	4	150.0776	-32.1306	150.0765	-32.1645
D30	625	1903	4	150.0732	-32.1644	150.0743	-32.1305
D31	625	1903	4	150.0710	-32.1304	150.0699	-32.1643
D32	625	1903	4	150.0666	-32.1642	150.0676	-32.1303
D33	625	1903	4	150.0643	-32.1303	150.0632	-32.1641
D34	625	1903	4	150.0599	-32.1641	150.0610	-32.1302
D35	625	1903	4	150.0577	-32.1301	150.0566	-32.1640

Pembroke	Longitude (Deg)	Latitude (Deg)
crn 1	150.1374	-31.9671
crn 2	150.1811	-31.9681
crn 3	150.1783	-32.0499
crn 4	150.1347	-32.0489

Stanley	Longitude (Deg)	Latitude (Deg)
crn 1	150.1203	-32.0855
crn 2	150.1441	-32.0859
crn 3	150.1437	-32.1000
crn 4	150.1198	-32.0994

Roscomm	Longitude (Deg)	Latitude (Deg)
crn 1	150.1315	-32.1538
crn 2	150.1552	-32.1544
crn 3	150.1543	-32.1837
crn 4	150.1306	-32.1831

Illogan	Longitude (Deg)	Latitude (Deg)
crn 1	150.0555	-32.1374
crn 2	150.0826	-32.1380
crn 3	150.0820	-32.1561
crn 4	150.0549	-32.1555

Table A8. PLMR high resolution mapping flight lines for the Merriwa area.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
D36	625	2300	9	150.4444	-31.9952	150.4467	-31.9113
D37	625	2300	9	150.4434	-31.9112	150.4410	-31.9951
D38	625	2300	9	150.4377	-31.9951	150.4400	-31.9111
D39	625	2300	9	150.4367	-31.9111	150.4343	-31.9950
D40	625	2300	9	150.4310	-31.9949	150.4334	-31.9110
D41	625	2300	12	150.4301	-31.9109	150.4277	-31.9949
D42	625	1899	12	150.3691	-31.9941	150.3659	-32.1052
D43	625	1899	12	150.3626	-32.1051	150.3658	-31.9940
D44	625	1899	12	150.3625	-31.9939	150.3593	-32.1050
D45	625	1899	12	150.3560	-32.1050	150.3592	-31.9939
D46	625	1899	12	150.3559	-31.9938	150.3527	-32.1049
D47	625	1899	12	150.3494	-32.1048	150.3526	-31.9937
D48	625	1899	12	150.3493	-31.9937	150.3460	-32.1048
D49	625	1899	12	150.3427	-32.1047	150.3459	-31.9936
D50	625	1899	12	150.3426	-31.9935	150.3394	-32.1046
D51	625	1573	4	150.3320	-32.1398	150.3307	-32.1838
D52	625	1573	4	150.3340	-32.1839	150.3353	-32.1398
D53	625	1573	4	150.3386	-32.1399	150.3373	-32.1839
D54	625	1573	4	150.3406	-32.1840	150.3419	-32.1400
D55	625	1573	4	150.3452	-32.1401	150.3439	-32.1841
D56	625	2109	6	150.4226	-32.1341	150.4243	-32.0743
D57	625	2109	6	150.4276	-32.0743	150.4259	-32.1342
D58	625	2109	6	150.4292	-32.1342	150.4309	-32.0744
D59	625	2109	6	150.4342	-32.0745	150.4325	-32.1343
D60	625	2109	6	150.4358	-32.1344	150.4375	-32.0745

Cullingral	Longitude (Deg)	Latitude (Deg)
crn 1	150.3296	-32.1534
crn 2	150.3468	-32.1538
crn 3	150.3463	-32.1713
crn 4	150.3290	-32.1709

Midlothian	Longitude (Deg)	Latitude (Deg)
crn 1	150.3401	-32.0058
crn 2	150.3708	-32.0064
crn 3	150.3683	-32.0927
crn 4	150.3376	-32.0921

Cullingral	Longitude (Deg)	Latitude (Deg)
crn 1	150.3296	-32.1534
crn 2	150.3468	-32.1538
crn 3	150.3463	-32.1713
crn 4	150.3290	-32.1709

Merriwa P.	Longitude (Deg)	Latitude (Deg)
crn 1	150.4216	-32.0874
crn 2	150.4391	-32.0878
crn 3	150.4383	-32.1206
crn 4	150.4208	-32.1204

Table A9. PLMR multi-angle mapping flight lines over the Merriwa Park farm.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
E1	2500	3984	6	150.4226	-32.1342	150.4243	-32.0744
E2	2500	3984	6	150.4276	-32.0745	150.4259	-32.1343
E3	2500	3984	6	150.4292	-32.1344	150.4309	-32.0745
E4	2500	3984	6	150.4342	-32.0746	150.4325	-32.1344
E5	2500	3984	6	150.4358	-32.1345	150.4375	-32.0747

	Longitude (Deg)	Latitude (Deg)
crn 1	150.4226	-32.0874
crn 2	150.4385	-32.0878
crn 3	150.4375	-32.1206
crn 4	150.4216	-32.1203

Table A10. PLMR dew effect flight lines waypoints

Waypoint No.	Altitude AGL (ft)	Altitude ASL (ft)	Longitude (Deg)	Latitude (Deg.)
F1	5000	6265	150.4291	-32.1374
F2	5000	6265	150.4297	-31.9174
F3	5000	6265	150.4297	-31.9174
F4	5000	6265	150.4265	-31.9752
F5	5000	6265	150.3553	-31.9985
F6	5000	6265	150.3523	-32.1034
F7	5000	6265	150.3403	-32.1412
F8	5000	6265	150.3392	-32.1793
F9	5000	6265	150.3556	-32.1791

Table A11. Flight lines coordinates and coverage reference coordinates for NDVI observations.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
G1	5000	6265	4	150.0549	-32.1682	150.0563	-32.1257
G2	5000	6265	4	150.0674	-32.1260	150.0661	-32.1685
G3	5000	6265	4	150.0772	-32.1687	150.0786	-32.1262
G4	5000	6265	26	150.1093	-32.1963	150.1169	-31.9566
G5	5000	6265	26	150.1280	-31.9568	150.1208	-32.1963
G6	5000	6265	26	150.1319	-32.1966	150.1391	-31.9571
G7	5000	6265	26	150.1501	-31.9574	150.1428	-32.1972
G8	5000	6265	26	150.1539	-32.1974	150.1615	-31.9575
G9	5000	6265	26	150.1726	-31.9577	150.1654	-32.1973
G10	5000	6265	26	150.1765	-32.1976	150.1836	-31.9581
G11	5000	6265	26	150.1947	-31.9583	150.1873	-32.1982
G12	5000	6265	30	150.3256	-32.1835	150.3334	-31.9090
G13	5000	6265	30	150.3447	-31.9094	150.3368	-32.1838
G14	5000	6265	30	150.3479	-32.1840	150.3558	-31.9096
G15	5000	6265	30	150.3669	-31.9098	150.3590	-32.1842
G16	5000	6265	30	150.3702	-32.1845	150.3780	-31.9100
G17	5000	6265	30	150.3891	-31.9102	150.3813	-32.1847
G18	5000	6265	30	150.3925	-32.1849	150.4002	-31.9105
G19	5000	6265	30	150.4114	-31.9107	150.4036	-32.1852
G20	5000	6265	30	150.4148	-32.1854	150.4225	-31.9110
G21	5000	6265	30	150.4336	-31.9112	150.4259	-32.1856
G22	5000	6265	30	150.4371	-32.1858	150.4448	-31.9111
G23	5000	6265	30	150.4559	-31.9114	150.4482	-32.1861

Illogan

	Longitude (Deg)	Latitude (Deg)
crn 1	150.0492	-32.1372
crn 2	150.0849	-32.1380
crn 3	150.0843	-32.1560
crn 4	150.0485	-32.1552

Krui

	Longitude (Deg)	Latitude (Deg)
crn 1	150.1099	-31.9665
crn 2	150.2011	-31.9686
crn 3	150.1945	-32.1840
crn 4	150.1031	-32.1820

Merriwa

	Longitude (Deg)	Latitude (Deg)
crn 1	150.3266	-31.9205
crn 2	150.4622	-31.9233
crn 3	150.4553	-32.1736
crn 4	150.3193	-32.1708

12 Appendix B: Team Task Sheets

Table B1. Task sheet for Team 1. All activities to be done by all members of the team over the four week campaign unless specified otherwise. "FL","VL" stands for fixed or variable sampling locations between days.Tasks in red are for team leaders, in blue for other members.

Team Members	Rocco Panciera, Marco Rinaldi Patricia DeRosney, Gilles Boulet , Rob Pipunic
Farm Sites	Pembroke (Krui) Midlothian (Merriwa)

Farm scale sampling: Pembroke (Krui days), Cullingral (Merriwa days)

Measurement	Extent	Spacing	N. of Samples	Comments
Soil moisture (hydra probe)	High resolution grid /FL	12.5/6.25m	289	morning
Soil moisture (hydra probe)	Farm scale/FL	62.5m	Pemb: 140 Mid: 140	afternoon
Vegetation water content samples(grab type)	Farm scale/FL	-	2	End of day
Dew vegetation samples	Farm scale/FL	-	2	On dew flight days (early morning)
Soil moisture (hydra probe)	Farm scale/FL	1000/500/250/125m	Pemb: 210 Mid: 251	
Gravimetric soil samples	Farm scale/VL	-	>2	1 dry/1 wet
Vegetation type	Farm scale	1000/500/250/125m		Week 1 only
Dew visual observation	Farm scale	-		Until drying

Regional sampling: Pembroke (morning), Midlothian (afternoon), connecting roads

Measurements	Extent	Spacing	N. of Samples	Comments
Vegetation biomass samples (quadrant type)	High resolution areas/FL	50m/62.5m	16 p/farm	Week 1,4 only
Vegetation height	Farm/ FL	50m/62.5m	-	Week 1,4 only
Soil moisture (hydra probe)	Regional/FL	1 km	122	
Gravimetric soil samples	Farm/VL	-	>6 p/farm	Different soil type/wetness
Vegetation biomass samples (quadrant type)	Farm/FL	-	>6 p/farm	1 each land cover
Vegetation type	Farm	1km	-	Week 2 only
Landuse	Regional	1km	-	Week 2 only
Surface roughness	Farm		>4 p/farm	Week 2 only
Surface rock cover	Farm	1km	-	Week 2 only
LAI (Jose Fenollar)	Farm	62.5m	-	Week 1 only
NDVI (Jose Fenollar)	Farm	62.5m	-	Week 1 only

Table B2. Task sheet for Team 2. All activities to be done by all members of the team over the four week campaign unless specified otherwise. "FL","VL" stands for fixed or variable sampling locations between days. Tasks in red are for team leaders, in blue for other members

Team Members	Greg Hancock, Cristina Martinez, Jose Fenollar & Vivianna Maggioni, Mark Thyer
Farm Sites	Stanley (Krui) Cullingral (Merriwa)

Farm scale sampling: Stanley (Krui days), Cullingral (Merriwa days)

Measurement	Extent	Spacing	N. of Samples	Comments
Soil moisture (hydra probe)	High resolution grid /FL	12.5/6.25m	289	morning
Soil moisture (hydra probe)	Farm scale/FL	62.5m	Sta: 135 Cull: 197	afternoon
Vegetation water content samples(grab type)	Farm scale/FL	-	2	End of day
Dew vegetation samples	Farm scale/FL	-	2	On dew flight days (early morning)
Soil moisture (hydra probe)	Farm scale/FL	125m	Sta: 227 Cull: 89	
Gravimetric soil samples	Farm scale/VL	-	>2	1 dry/1 wet
Vegetation type	Farm scale	125m		Week 1 only
Dew visual observation	Farm scale	-		Until drying

Regional sampling: Stanley (morning), Cullingral (afternoon), connecting roads

Measurements	Extent	Spacing	N. of Samples	Comments
Vegetation biomass samples (quadrant type)	High resolution areas/FL	50m/62.5m	16 p/farm	Week 1,4 only
Vegetation height	Farm/ FL	50m/62.5m	-	Week 1,4 only
Soil moisture (hydra probe)	Regional/FL	1 km	116	
Gravimetric soil samples	Farm/VL	-	>6 p/farm	Different soil type/wetness
Vegetation biomass samples (quadrant type)	Farm/FL	-	>6 p/farm	1 each land cover
Vegetation type	Farm	1km	-	Week 2 only
Landuse	Regional	1km	-	Week 2 only
Surface roughness	Farm		>4 p/farm	Week 3 only
Surface rock cover	Farm	1km	-	Week 2only
LAI (Jose Fenollar)	Farm	62.5m	-	Week 2 only
NDVI (Jose Fenollar)	Farm	62.5m	-	Week 2 only

Table B3. Task sheet for Team 3. All activities to be done by all members of the team over the four week campaign unless specified otherwise. "FL","VL" stands for fixed or variable sampling locations between days. Tasks in red are for team leaders, in blue for other members

Team Members	Jetse Kalma, Jennifer Grant, Patricia Saco, Daniele Biasioni
Farm Sites	Roscommon (Krui) Dales (Merriwa)

Farm scale sampling: Roscommon (Krui days), Dales (Merriwa days)

Measurement	Extent	Spacing	N. of Samples	Comments
Soil moisture (hydra probe)	High resolution grid /FL	12.5/6.25m	289	morning
Soil moisture (hydra probe)	Farm scale/FL	62.5m	Ros: 140 Dales: 140	afternoon
Vegetation water content samples(grab type)	Farm scale/FL	-	2	End of day
Dew vegetation samples	Farm scale/FL	-	2	On dew flight days (early morning)
Soil moisture (hydra probe)	Farm scale/FL	500/250/125m	Ros: 223 Dales: 120	
Gravimetric soil samples	Farm scale/VL	-	>2	1 dry/1 wet
Vegetation type	Farm scale	500/250/125m		Week 1 only
Dew visual observation	Farm scale	-		Until drying

Regional sampling: Roscommon (morning), Dales (afternoon), connecting roads

Measurements	Extent	Spacing	N. of Samples	Comments
Vegetation biomass samples (quadrant type)	High resolution areas/FL	50m/62.5m	16 p/farm	Week 1,4 only
Vegetation height	Farm/ FL	50m/62.5m	-	Week 1,4 only
Soil moisture (hydra probe)	Regional/FL	1 km	130	
Gravimetric soil samples	Farm/VL	-	>6 p/farm	Different soil type/wetness
Vegetation biomass samples (quadrant type)	Farm/FL	-	>6 p/farm	1 each land cover
Vegetation type	Farm	1km	-	Week 2 only
Landuse	Regional	1km	-	Week 2 only
Surface roughness	Farm		>4 p/farm	Week 4 only
Surface rock cover	Farm	1km	-	Week 2 only
LAI (Jose Fenollar)	Farm	62.5m	-	Week 3 only
NDVI (Jose Fenollar)	Farm	62.5m	-	Week 3 only

Table B4. Task sheet for Team 4. All activities to be done by all members of the team over the four week campaign unless specified otherwise. "FL","VL" stands for fixed or variable sampling locations between days. Tasks in red are for team leaders, in blue for other members

Team Members	Tony Wells, Chris Rüdiger, Olivier Merlin, Kauzeer Saleh, Stuart Jones
Farm Sites	Illogan (Krui) Merriwa Park (Merriwa)

Farm scale sampling: Illogan (Krui days), Merriwa Park (Merriwa days)

Measurement	Extent	Spacing	N. of Samples	Comments
Soil moisture (hydra probe)	High resolution grid /FL	12.5/6.25m	289	morning
Soil moisture (hydra probe)	Farm scale/FL	62.5m	Illo: 140 Merr: 140	afternoon
Vegetation water content samples(grab type)	Farm scale/FL	-	2	End of day
Dew vegetation samples	Farm scale/FL	-	2	On dew flight days (early morning)
Soil moisture (hydra probe)	Farm scale/FL	250/125m	Illo: 228 Merr: 179	
Gravimetric soil samples	Farm scale/VL	-	>2	1 dry/1 wet
Vegetation type	Farm scale	250/125m		Week 1 only
Dew visual observation	Farm scale	-		Until drying

Regional sampling: Illogan (morning), Merriwa Park (afternoon), connecting roads

Measurements	Extent	Spacing	N. of Samples	Comments
Vegetation biomass samples (quadrant type)	High resolution areas/FL	50m/62.5m	16 p/farm	Week 1,4 only
Vegetation height	Farm/ FL	50m/62.5m	-	Week 1,4 only
Soil moisture (hydra probe)	Regional/FL	1 km	99	
Gravimetric soil samples	Farm/VL	-	>6 p/farm	Different soil type/wetness
Vegetation biomass samples (quadrant type)	Farm/FL	-	>6 p/farm	1 each land cover
Vegetation type	Farm	1km	-	Week 2 only
Landuse	Regional	1km	-	Week 2 only
Surface roughness	Farm		>4 p/farm	Week 1 only
Surface rock cover	Farm	1km	-	Week 2 only
LAI (Jose Fenollar)	Farm	62.5m	-	Week 4 only
NDVI (Jose Fenollar)	Farm	62.5m	-	Week 4 only

13 Appendix C: Flight Elevations

Table C1. Elevation statistics for the study area and the focus farm

	MIN (m)	MAX (m)	RANGE (m)	MEDIAN(m)	MEAN (m)
Norther Goulburn	180	807	627	375	384
Krui area	273	686	414	396	399
Merriwa area	220	676	456	365	372
Pembroke	346	510	204	394	399
Stanley	316	443	127	358	355
Roscommon	344	450	106	392	393
Illogan	348	420	72	381	384
Dales	330	541	211	398	404
Midlothian	259	419	159	310	312
Merriwa Park	380	483	102	413	416
Cullingral	222	319	98	233	244

Table C2. Flight altitude and ground resolution for PLMR medium resolution flights

	Flight Altitude over local maximum elevation (ft AGL)	FINAL FLIGHT ALTITUDE m(ASL)	Minimum ground pixel sixe(m)	Maximum ground pixel size (m)
Pembroke	2400	1240	240.0	293.8
Stanley	2400	1170	240.0	281.8
Roscommon	2400	1180	240.0	274.6
Illogan	2400	1150	240.0	263.5
Dales	2400	1270	240.0	309.3
Merriwa Park	2400	1210	240.0	273.6
Midlothian	2400	1150	240.0	292.3
Cullingral	2400	1050	240.0	272.1

Table C3. Flight altitude and ground resolution for PLMR high resolution flights.

	Flight Altitude over local maximum elevation (ft AGL)	FINAL FLIGHT ALTITUDE m(ASL)	Minimum ground pixel sixe(m)	Maximum ground pixel size (m)
Pembroke	525	670	52.5	106.3
Stanley	525	600	52.5	94.3
Roscommon	525	610	52.5	87.1
Illogan	525	580	52.5	76.0
Dales	525	700	52.5	121.8
Midlothian	525	580	52.5	104.8
Merriwa Park	525	640	52.5	86.1
Cullingral	525	480	52.5	84.6