National Airborne Field Experiment 2006 (NAFE'06)

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Experiment Plan

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Contents

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.

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). The NAFE (National Airborne Field Experiment) activities planned for November 2006, as described in this document, are the second of a series of intensive experiments being conducted in different parts of Australia (http://www.nafe.unimelb.edu.au).

The month-long NAFE'05 experiment was undertaken in the Goulburn River catchment during November 2005, with the objective to provide high resolution data for process level understanding of soil moisture retrieval, scaling and data assimilation. The 3-week long NAFE'06 experiment will be undertaken in the Murrumbidgee catchment during November 2006, with the objective to provide data for SMOS level soil moisture retrieval, downscaling and data assimilation. The details of this experiment plan are described in this paper.

The National Airborne Field Experiments have been made possible through recent infrastructure (LE0453434 and LE0560930) and research (DP0557543) funding from the Australian Research Council, and the collaboration of a large number of scientists from throughout Australia, United States and Europe. Initial setup and maintenance of the study catchments was funded by research grants (DP0209724 and DP0343778) from the Australian Research Council, the CRC for Catchment Hydrology, and NASA.

Fig. 1.1. Location of the study sites of the National Airborne Field Experiments: the Goulburn River (NAFE'05) and the Murrumbidgee catchment (NAFE'06).

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) participants from the University of Melbourne, University of Newcastle, Airborne Research Australia, and several European universities and organisations including the European Space Agency (ESA), undertook research on soil moisture, flood forecasting, carbon budgets and ecohydrology. In November 2006 (NAFE'06) participants from the University of Melbourne, Airborne Research Australia, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Department of Natural Resources (DNR), Department of Primary Industry (DPI), and several European and American universities and organisations will undertake research on soil moisture and evapotranspiration measurement. This document describes in detail the core soil moisture component to the NAFE06 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.

In addition there is the ESA Soil Moisture and Ocean Salinity (SMOS) sensor to be launched in 2007. SMOS is the first dedicated soil moisture mission planned with optimal frequencies for soil moisture measurement (see http://www.cesbio.ups-tlse.fr/us/indexsmos.html). SMOS relies on the use of a new instrument (2 D interferometer) to achieve both adequate spatial and temporal sampling. Over land, the multi-angular dual-polarised signal will be used to infer soil moisture, vegetation water content and equivalent temperature. The retrieval process of soil moisture must both account for the inhomogeneity of the land cover inside a SMOS pixel, and optimise the use of external information. Moreover this mission is planned for 6am/6pm overpass times and it is likely that dew will impact on the 6am soil moisture retrievals but this process is not well understood. Data collected during field campaigns are needed for the development of retrieval algorithms. Thus it is **important that we prepare now so as to obtain maximum benefit from this dedicated soil moisture sensor 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:

- 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

1.4 Air Requirements

To answer the science questions outlined there are also a number of airborne data requirements to be considered:

- 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 SMOS (6:00am/pm) overpass times

- airborne observations at a range of altitudes (500ft to 10,000ft) to achieve a range of ground resolutions (50m to 1,000m for passive microwave and 1m to 20m for thermal and NDVI) for scaling, algorithm development and satellite verification
- airborne observations at a temporal frequency consistent with SMOS (repeat cycle of 2-3 days) for data assimilation
- airborne observations with passive microwave radiometer in mapping and multi-incidence angle configurations for SMOS algorithm development

1.5 General Approach

The scientific objectives and data requirements of NAFE'06 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 2) 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 (see section 3). This will allow comparability between spaceborne and airborne measurements and therefore will ensure applicability of the outcomes of NAFE'06 to future spaceborne missions.

Airborne and spaceborne observations will be supported by ground data collected during the 3-week 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'06 is composed of three sites in the western part of the Murrumbidgee catchment, approximately 400km 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'06 field campaign area is given in Fig. 1.2. The study area includes the 60 by 60km Yanco area, the 600 km^2 Kyeamba catchment and the 26ha Yenda site. The extent of mapping achieved by the main flights is shown on the map. On the ground the main sampling effort will be undertaken in six farms of the Yanco area. NAFE'06 participants will be based in the Yanco Agricultural Institute, located in the north-east of the Yanco area, and will set off from there for the daily sampling. The Narrandera airport, located 10km from the town of Yanco, will be used for the aircraft operations. Ground sampling in the Kyeamba catchment and Yenda site will be undertaken by independent teams from DNR Wagga Wagga and CSIRO Griffith respectively.

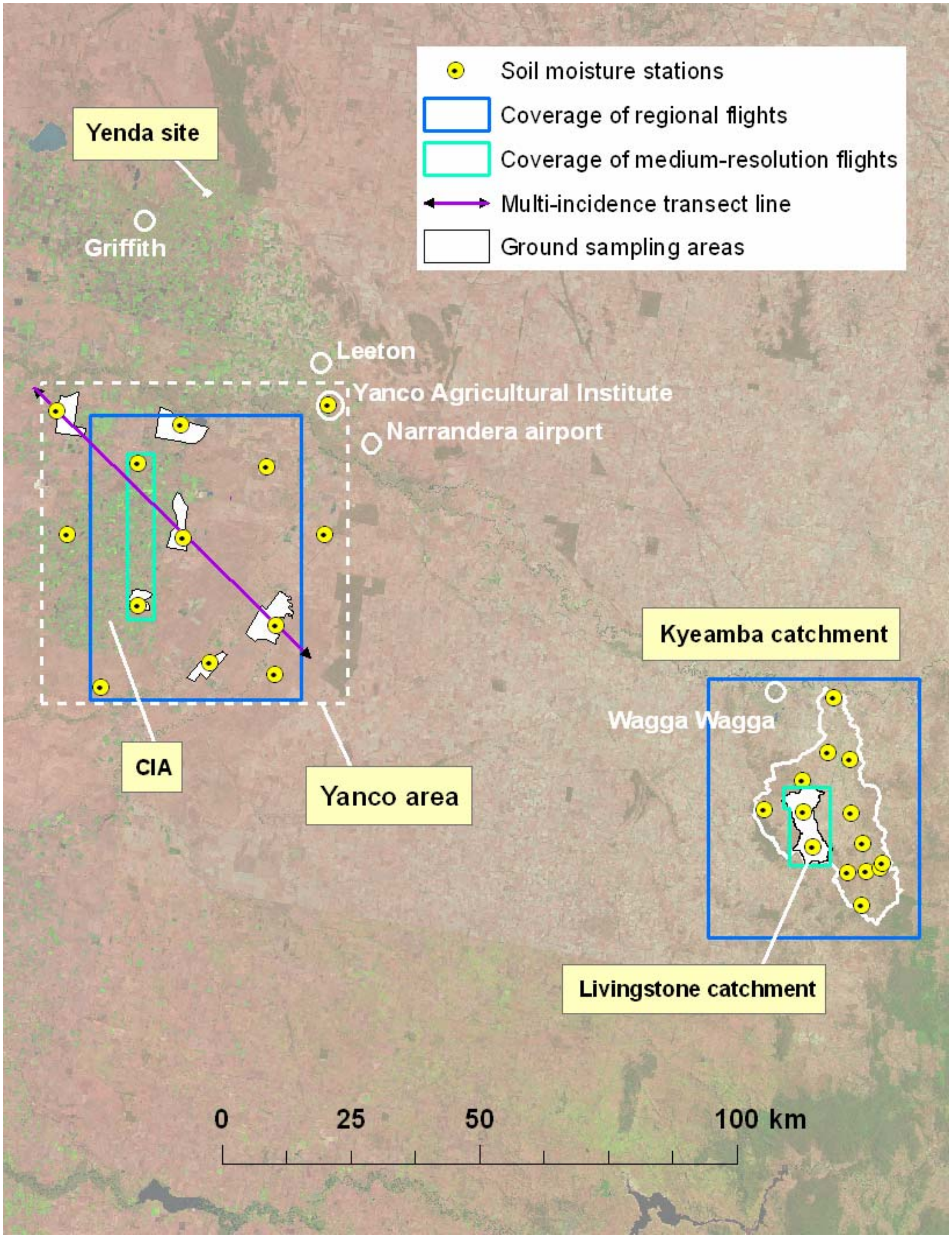

Fig. 1.2. NAFE'06 overview. The map shows the location of three study sites, the operation base for NAFE'06 participants, the coverage of the main flights over Yanco and Kyeamba and the six farms involved in the ground sampling in Yanco. The permanent soil moisture sites in Yanco and Kyeamba are also shown. Background is composed of Landsat 7 images acquired in 1999-2000.

2 Airborne Observing Systems

Airborne measurements will be made using the small, low-cost, two-seater motor glider from the Airborne Research Australia national facility called Small Environmental Research Aircraft (SERA), shown in Fig. 2.1, 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 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 full wave form lidar, NDVI scanner and 11MegaPixel digital camera.

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.

Aircraft instruments are typically installed in one of the certified underwing pods (see Fig. 2.2) 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.

Fig. 2.1. The Diamond ECO-Dimona aircraft with PLMR mounted under the fuselage, and thermal imager, digital camera and NDVI scanner in an underwing pod.

Fig. 2.2. View of one of the underwing pods with the cover off, and view of the cockpit showing cockpit computer display.

Fig. 2.3. View of PLMR with the cover off.

2.1 Polarimetric L-band Multibeam Radiometer

The PLMR (Fig. 2.3) 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 specified 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.

2.2 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. 2.4), with a weight of 2kg and size of 10cm × 12cm × 22cm.

Fig. 2.4. View of the S60 Thermal Imager.

2.3 Tri-spectral NDVI Scanner

The AWI/ARA Trispectral line scanner (TSLS) is an airborne sensor which can operate in either of two modes - Visible (Red, Green and Blue) or Vegetation (Green, Red and Near-IR). At an altitude of 1500m and a speed of 94 km/h (50 knots), 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 × 110mm × 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.

2.4 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.

2.5 Airborne Laser Scanner

Fig. 2.5. View of the Riegl LMS-Q560 airborne laser scanner (dimensions 560 × 200 × 217 mm).

The RIEGL LMS-Q560 is a new airborne laser scanner incorporating 2D laser scanner incorporating waveform digitising of the return laser pulses http://www.riegl.co.at/airborne_scannerss/lms_q560_/q560_all_.html). The LMS-Q560 gives access to the detailed target parameters by digitising the echo signal online during data acquisition, and subsequently through off-line waveform analysis. This method is especially valuable when dealing with difficult survey tasks, such as canopy height investigation or target classification. The LMS-Q560 instrument makes use of the time-of-flight distance measurement principle with nanosecond infrared pulses, and fast opto-mechanical beam scanning providing absolutely linear, unidirectional and parallel scan lines. This instrument is extremely rugged (see Fig 2.5) and is therefore ideally suited for the installation on aircraft. The LMS-Q560 key features are:

- Waveform analysis and recording of unlimited target returns
- High measurement rate of up to 50 kHz
- High range accuracy of up to ± 2cm
- Scan angle range: ± 22.5° = 45° total (up to 60° with 90% of maximum measurement range)
- Angle readout resolution: 0.001°.

3 Relevant Satellite Observing Systems

Satellite observing systems of relevance for soil moisture remote sensing are listed below. Two categories are distinguished according to whether sensors operate in the microwave or in the optical domain. While passive and active microwave sensors are able to provide direct estimates of near-surface soil moisture, optical data can be used in a synergy perspective for soil moisture algorithm development or scaling.

3.1 Microwave Sensors

3.1.1 Soil Moisture and Ocean Salinity (SMOS)

The SMOS (http://www.esa.int/esaLP/LPsmos.html) satellite is scheduled for launch in 2007 and will be the first satellite to make continuous multi angular L band (1.4 GHz) radiometric measurements over the globe. Over continental surfaces, SMOS will provide near-surface soil moisture data at 50km resolution with a repeat cycle of 2-3 days. The payload is a 2 D interferometer yielding a range of incidence angles from 0° to 55° at both V and H polarisations, and a 1000km swath width. Its multi-incidence angle capability is expected to assist in determining ancillary data requirements such as vegetation attenuation. This satellite will have a 6:00am/pm equator overpass time (6:00am local solar time at ascending node).

For the Yanco and Kyeamba sites, the overpass times (UTC+10 hrs) will be approximately 7:15am (ascending) and 5:45pm (descending).

3.1.2 Aquarius

Aquarius (http://aquarius.gsfc.nasa.gov/index.html) is a focused satellite to measure global sea surface salinity. It is planning to launch in 2009. The science instruments will include a set of three L-band radiometers and a scatterometer that corrects for the ocean's surface roughness. The goals of Aquarius are to provide global observations every 8 days and deliver monthly 150-kilometer resolution sea surface salinity maps over a 3-year mission lifetime.

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

The AMSR-E (http://www.ghcc.msfc.nasa.gov/AMSR/) is a passive microwave radiometer operating at 6 frequencies ranging from 6.925 to 89.0 GHz. Horizontally and vertically polarized radiation are measured at each frequency with an incidence angle of 55°. The ground spatial resolution at nadir is 75km × 45km for the 6.925 GHz channel (C-band). The AMSR-E is one of the six sensors onboard Aqua, which was launched in 2002 and has a 1:30am/pm equator crossing orbit with 1-2 day repeat coverage. A surface soil moisture product available globally is currently derived from level 2A AMSR-E brightness temperatures spatially resampled to a nominal 25-km equal area earth grid. AMSR-E data can be downloaded free of charge from NSIDC web site http://nsidc.org/data/amsre/order.html or other Distributed Active Archive Centers (DAAC). AMSR-E overpass times over Yanco and Kyeamba are provided in Tables 3.1 and 3.2 respectively.

3.1.4 Windsat

WindSat (http://www.nrl.navy.mil/WindSat/) 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. Windsat data are free of charge to scientists and can be accessed by contacting the Physical Oceanography DAAC (http://podaac.jpl.nasa.gov/about/). Windsat overpass times over Yanco and Kyeamba are provided in Tables 3.1 and 3.2 respectively.

Table 3.1. AMSR-E and WindSat overpass times over Yanco area.

AMSR-E		**WindSat**	
DATE	TIME (LOCAL=GMT+10)	DATE	TIME (LOCAL=GMT+10)
11/1/2006	1:37:58	10/31/2006	18:35:04
11/2/2006	14:23:32	11/1/2006	18:17:32
11/3/2006	1:25:45	11/1/2006	5:55:13
11/4/2006	14:11:20	11/2/2006	5:37:42
11/5/2006	1:13:33	11/3/2006	5:20:13
11/6/2006	13:59:07	11/5/2006	18:47:41
11/8/2006	1:44:04	11/6/2006	18:30:11
11/9/2006	14:29:36	11/7/2006	18:12:39
11/10/2006	1:31:50	11/7/2006	5:50:20
11/11/2006	14:17:25	11/8/2006	5:32:49
11/12/2006	1:19:37	11/11/2006	18:42:48
11/13/2006	14:05:12	11/12/2006	18:25:18
11/14/2006	1:07:26	11/12/2006	6:02:59
11/15/2006	13:52:58	11/13/2006	5:45:27
11/17/2006	1:37:55	11/14/2006	5:27:56
11/18/2006	14:23:29	11/17/2006	18:37:55
		11/18/2006	18:20:24
		11/18/2006	5:58:05

Table 3.2 AMSR-E and WindSat overpass times over Kyeamba watershed.

AMSR-E		**WindSat**	
DATE	TIME (LOCAL=GMT+10)	DATE	TIME (LOCAL=GMT+10)
10/30/2006	13:52:49	10/31/2006	18:34:51
11/1/2006	1:38:02	11/1/2006	5:55:17
11/2/2006	14:23:19	11/1/2006	18:17:21
11/3/2006	1:25:48	11/2/2006	5:37:45
11/4/2006	14:11:08	11/3/2006	5:20:15
11/5/2006	1:13:36	11/5/2006	18:47:28
11/6/2006	13:58:55	11/6/2006	18:29:59
11/7/2006	1:01:24	11/7/2006	5:50:24
11/8/2006	13:46:41	11/7/2006	18:12:27
11/10/2006	1:31:54	11/8/2006	5:32:52
11/11/2006	14:17:13	11/9/2006	5:15:23
11/12/2006	1:19:40	11/11/2006	18:42:35
11/13/2006	14:05:00	11/12/2006	18:25:06
11/14/2006	1:07:28	11/13/2006	5:45:30
11/15/2006	13:52:47	11/13/2006	18:07:33
11/17/2006	1:37:59	11/14/2006	5:27:59
11/18/2006	14:23:17	11/17/2006	18:37:42
11/19/2006	1:25:45	11/18/2006	18:20:12
11/20/2006	14:11:05	11/19/2006	5:40:36
		11/20/2006	5:23:05

3.1.5 Phased Array type L-band Synthetic Aperture Radar (PALSAR)

The PALSAR (http://www.eorc.jaxa.jp/ALOS/about/palsar.htm) is an active microwave sensor aboard the Advance Land Observing Satellite (ALOS, www.nasda.go.jp/projects/sat/alos/index_e.html). The sensor operates at L-band with HH and VV polarisation (HV and VH polarisations are optional). The sensor is beam steerable in elevation and the ScanSAR mode, which allows obtaining a wider swath than conventional SARs. ALOS was launched in 2004 into a sun-synchronous orbit at the altitude of 700km, providing a spatial resolution of 20m for the fine resolution mode (swath width of 70km) and 100m for the ScanSAR mode (swath width of 360km). The repeat cycle is 46 days and the local time at descending node is about 10:30am. ALOS PALSAR data have been requested over the Yanco area and the Kyeamba catchment. Note that the mode that will be operating is not known at the time when this experiment plan was written.

3.1.6 Advanced Synthetic Aperture Radar (ASAR)

The ASAR (http://envisat.esa.int/instruments/asar/) operating at C-band provides both continuity to the ERS-1 and ERS-2 mission SARs and next generation capabilities in terms of coverage, range of incidence angles, polarisation, and modes of operation. The resulting improvements in image and wave mode beam elevation steerage allow the selection of different swaths, providing a swath coverage of over 400-km wide using ScanSAR techniques. ScanSAR is a Synthetic Aperture Radar (SAR) technique that combines large-area coverage and short revisit periods with a degraded spatial resolution compared to conventional SAR imaging modes. 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). The ASAR is onboard the Envisat satellite, which was launched into a sun synchronous orbit in March 2002. The exact repeat cycle for a specific scene and sensor configuration is 35 days. ASAR Polarisation Mode PRI (product ASA_APP_1P) has been requested for NAFE'06.

3.2 Optical Sensors

3.2.1 MODerate resolution Imaging Spectroradiometer (MODIS)

The MODIS (http://modis.gsfc.nasa.gov) instrument is a highly sensitive radiometer operating in 36 spectral bands ranging from 0.4 µm to 14.4 µm. Two bands are imaged at a nominal resolution of 250 m at nadir, with five bands at 500 m, and the remaining 29 bands at 1 km. MODIS is operating onboard Terra and Aqua. Terra was launched in December 1999 and Aqua in May 2002. A ±55° scanning pattern at 705 km achieves a 2330-km swath and provides global coverage every one to two days. 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. MODIS data are free of charge and can be accessed online at http://lpdaac.usgs.gov/main.asp.

Tables 3.3 and 3.4 report the overpass times of Terra and Aqua forecasted at Y7 (Yanco) and K10 (Kyeamba) sites from October 30th to November 20th 2006 respectively. As orbit parameters change continuously, the exact overpass time has to be confirmed with further simulations. However, the overpasses with a peak elevation greater than 60-70° are expected to occur on the same days and at approximately the same time as indicated.

Table 3.3 Aqua overpass times predicted with the NASA overpass predictor from October 30th to November 20th 2006. The peak elevation and the time of peak are listed for peak elevations greater than 60° at Yanco (-34.85N; 146.12E) and Kyeamba (-35.32N; 147.53E). The peak elevation is the spacecraft elevation relative to the observing site. The larger the elevation angle, the closer the aircraft comes to flying directly over the observing site. The overpass times coinciding with aircraft flights are highlighted.

		Yanco area (34.85S; 146.12E)		Kyeamba area (-35.32S; 147.53E)	
Day of week	Date	Peak elevation (°)	Time (UTC+10:00)	Peak elevation (°)	Time (UTC+10:00)
Wed	01-Nov-06	79	01:33	68	01:33
Thu	02-Nov-06	80	14:19	71	14:19
Fri	03-Nov-06	76	01:21	87	01:21
Sat	04-Nov-06	75	14:07	83	14:07
Sun	05-Nov-06	-	-	65	01:09
Mon	06-Nov-06	-	-	62	13:54
Wed	08-Nov-06	69	01:39	-	-
Thu	09-Nov-06	70	14:25	61	14:24
Fri	10-Nov-06	85	01:27	80	01:27
Sat	11-Nov-06	85	14:13	82	14:12
Sun	12-Nov-06	64	01:15	75	01:15
Mon	13-Nov-06	63	14:00	72	14:00
Thu	16-Nov-06	72	14:23	-	-
Fri	17-Nov-06	80	01:33	70	01:33
Sat	18-Nov-06	81	14:18	73	14:18
Sun	19-Nov-06	74	01:21	85	01:20
Mon	20-Nov-06	73	14:06	81	14:06

Table 3.4 As for Table 3.3 but for Terra.

		Yanco area (34.85S; 146.12E)		Kyeamba area (35.32S; 147.53E)	
Day of week	Date	Peak elevation (°)	Time (UTC + 10:00)	Peak elevation (°)	Time (UTC + 10:00)
Mon	30-Oct-06	80	23:13	70	23:13
Tue	31-Oct-06	76	10:15	88	10:15
Wed	01-Nov-06	76	23:01	84	23:01
Thu	02-Nov-06	-	-	65	10:03
Fri	03-Nov-06	-	-	63	22:48
Sun	05-Nov-06	68	10:33	-	-
Mon	06-Nov-06	69	23:19	-	-
Tue	07-Nov-06	88	10:21	80	10:21
Wed	08-Nov-06	85	23:07	81	23:07
Thu	09-Nov-06	64	10:09	76	10:09
Fri	10-Nov-06	64	22:54	73	22:54
Tue	14-Nov-06	81	10:27	69	10:27
Wed	15-Nov-06	81	23:13	72	23:13
Thu	16-Nov-06	74	10:14	85	10:15
Fri	17-Nov-06	74	23:00	83	23:00
Sat	18-Nov-06	-	-	64	10:03

Fig. 3.1 shows eight images of the surface temperature acquired by MODIS on 4 dates in November 2005 over the study areas. In general, the range of surface temperature values is dependent on the time of acquisition and is greater for Aqua (the overpass time is about 10:15am local time for MODIS on Terra and 2:15pm local time for MODIS on Aqua). The downscaling approaches based on optical data requires a strong coupling between surface temperature and surface soil moisture, which commonly occurs in areas where surface evaporation is not energy limited (as in Yanco and Kyeamba) and when solar radiation is relatively high (usually between 11am and 3pm). Therefore MODIS on Aqua (1:30pm) is more relevant than MODIS on Terra for downscaling purposes.

3.2.2 Advanced Along Track Scanning Radiometer (AATSR)

AATSR (http://envisat.esa.int/instruments/aatsr/) is an optical radiometer aboard Envisat. The objectives of this instrument are to establish continuity of the ATSR-1 and ATSR-2 data sets of sea surface temperature (SST) and observe vegetation through the use of the improved visible-wavelength atmospheric correction that is achievable with AATSR's two-angle view. Four thermal infrared channels (centred on 1.6 µm, 3.7 µm, 10.7 µm and 12 µm) are dedicated to the SST and three visible channels (0.55 µm, 0.87 µm and 0.67 µm) to the vegetation. The spatial resolution of AATSR is 1km at nadir. AATSR Level 2 Gridded Surface Temperature (ATS_NR_2P) and AATSR Level 1 Gridded Brightness Temperature and Reflectance (ATS_TOA_1P) have been requested for NAFE'06.

3.2.3 Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

ASTER (http://asterweb.jpl.nasa.gov/) provides high resolution visible (15m), near infrared (30m) and thermal infrared (90m) data on request. ASTER is onboard Terra and has a swath width of about 60km. ASTER is being used to obtain detailed maps of land surface temperature, reflectance and elevation. An ASTER coverage has been requested over Yanco and Kyeamba for the possible collection times during NAFE'06 (see Table 3.5).

Table 3.5 Possible ASTER collection times at Yanco (34.85S; 146.12E) and Kyeamba (35.32S; 147.53E). Full mode (VNIR, SWIR, TIR) requires a peak elevation greater than 81.5 degrees while VNIR only requires a peak elevation greater than 64 degrees. The overpasses occurring on the regional flight days are highlighted. Note that these dates and times need confirmation.

	Yanco area		**Kyeamba area**	
Date	Nadir time (UTC+10)	Telescope	Nadir time (UTC+10)	Telescope
Tue 31Oct06	10:15:06	VNIR only	10:15:14	Full mode
Wed 01Nov06	-	-	10:02:52	VNIR only
Sun 05Nov06	10:33:17	VNIR only	-	-
Tue 07Nov06	10:20:55	Full mode	10:20:55	VNIR only
Thu 09Nov06	10:08:41	VNIR only	10:08:41	VNIR only
Tue 14Nov06	10:26:45	VNIR Only	10:26:45	VNIR only
Thu 16Nov06	10:14:23	VNIR Only	10:14:23	Full mode

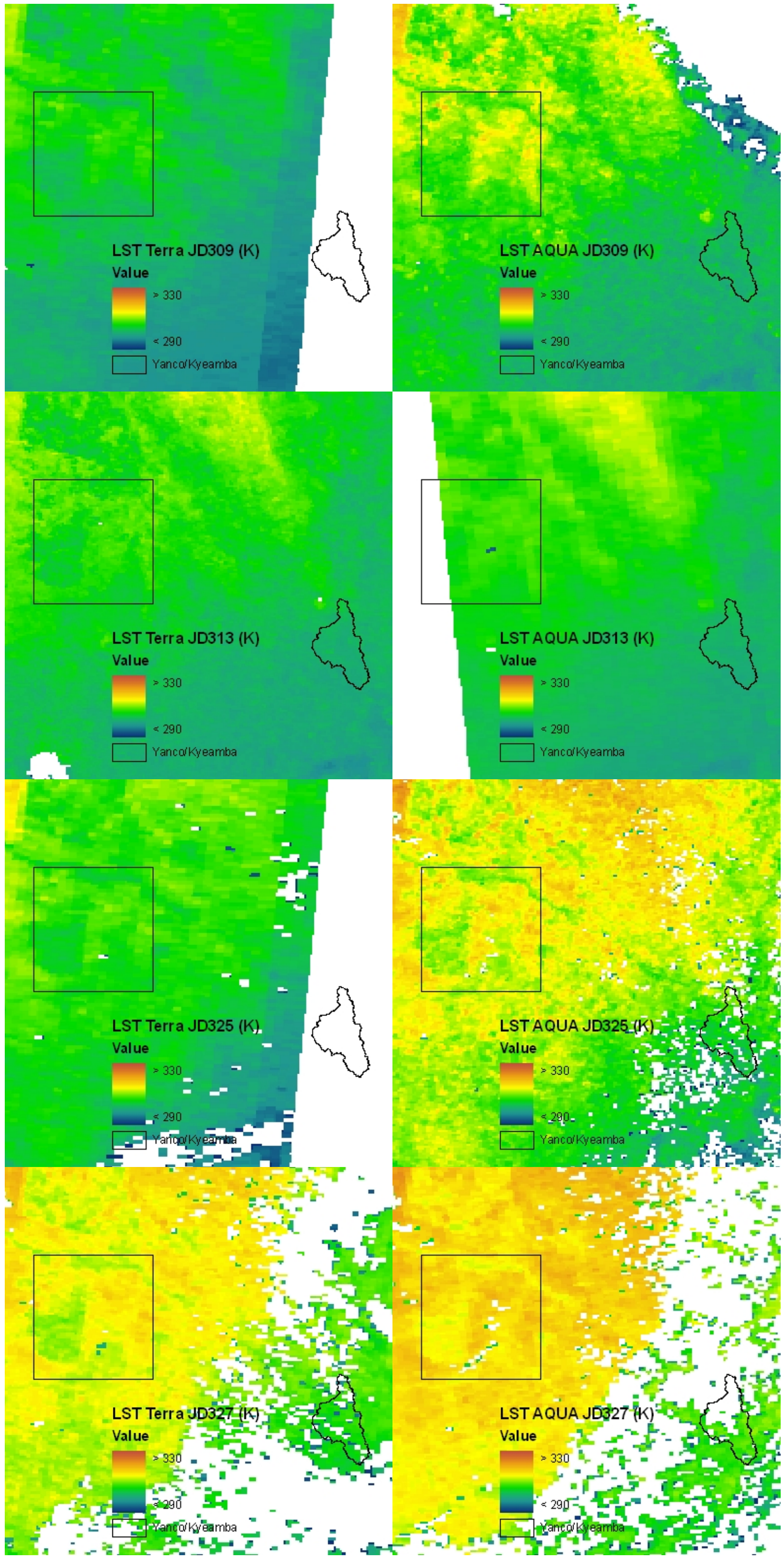

Fig. 3.1. Example of MODIS surface temperature images acquired in November 2005 over the study area of NAFE'06. On Julian days 309, 313, 325 and 327, MODIS images were acquired at approximately 10am on board Terra (left) and 2pm on board AQUA (right).

3.2.4 Landsat

Landsat (http://landsat.usgs.gov/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 16-day repeat cycle with a 10:00am equator crossing time. This data is particularly valuable in land cover and vegetation parameter mapping. Due to an instrument malfunction onboard Landsat 7 in May 2003, the Enhanced Thematic Mapper Plus (ETM+) is now only able to provide useful image data within the central ~20km of the swath. As Landsat 5 Thematic Mapper is still in operation it is being increasingly relied upon. The approximate scene size is 170 x 183 kilometers. The path and row numbers of the Landsat images covering the NAFE'06 sites are reported in Table 3.6. This data needs to be purchased and is not currently included as part of the budget allocation.

3.2.5 Compact High Resolution Imaging Spectrometer (CHRIS)

CHRIS (www.chris-proba.org.uk) provides remotely-sensed multi-angle data at high spatial resolution, and in superspectral/hyperspectral wavelength resolutions. The instrument 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 14 km. CHRIS is on board ESA's PRoject for On-Board Autonomy (PROBA). The PROBA satellite is on a sun-synchronous elliptical polar orbit since 2001 at a mean altitude of about 600km. A request for CHRIS/PROBA acquisitions over the NAFE'06 sites has been submitted to ESA.

3.2.6 Medium Resolution Imaging Spectrometer (MERIS)

MERIS (http://envisat.esa.int/instruments/meris/) is a wide field-of-view (68.5°) pushbroom imaging spectrometer that measures the solar radiation reflected by the Earth. The instrument provides a ground spatial resolution of 300m in 15 spectral bands in the visible and near infra-red (from 0.4 µm to 0.9 µm) with a swath width of 1150km. MERIS is aboard Envisat and allows global coverage of the Earth in 3 days. The objectives of MERIS are to provide quantitative information about the state and evolution of the ocean, the atmosphere and land surfaces. MERIS Level 1B Full Resolution (650 km) (MER_FR_1P), MERIS Level 2 Full Resolution (650 km) (MER_FR_2P) and MERIS Level 2 Reduced Resolution Extracted Vegetation have been requested for NAFE'06.

Table 3.6 Landsat overpass dates (UTC +10 hours) for Yanco (Path 92, Row 84) and Kyeamba area (Path 91, Row 85) in the period October-December 2006. The dates when airborne data will be collected are highlighted.

Yanco (92/84)		**Kyeamba (91/85)**	
Landsat 5	Landsat 7	Landsat 5	Landsat 7
Sat Oct 7	Sun Oct 15	Mon Oct 16	Sun Oct 8
Mon Oct 23	Tue Oct 31	Wed Nov 1	Tue Oct 24
Wed Nov 8	Thu Nov 16	Fri Nov 17	Thu Nov 9
Fri Nov 24	Sat Dec 2	Sun Dec 3	Sat Nov 25
Sun Dec 10	Mon Dec 18	Tue Dec 19	Mon Dec 11

3.2.7 Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2)

AVNIR-2 (http://www.eorc.jaxa.jp/ALOS/about/avnir2.htm) is a visible and near infrared radiometer onboard ALOS. AVNIR-2 is a successor to AVNIR that was on board the ADvanced Earth Observing Satellite (ADEOS), which was launched in August 1996. Its instantaneous field-of-view is the main improvement over AVNIR. AVNIR-2 also provides 10m spatial resolution images, an improvement over the 16m resolution of AVNIR in the multi-spectral region. Improved CCD detectors (AVNIR has 5,000 pixels per CCD; AVNIR-2 7,000 pixels per CCD) and electronics enable this higher resolution. The pointing angle of AVNIR-2 is +44° and -44°. AVNIR-2 data have been requested for Yanco and Kyeamba (period 20 Oct to 4 Dec 2006).

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4 Study Area

NAFE'06 will take place in two well instrumented areas of the Murrumbidgee catchment: the 3600km^2 Yanco area and the 600km^2 Kyeamba catchment. As illustrated in Fig. 4.1, there are 38 soil moisture stations distributed in the whole Murrumbidgee catchment with 13 in the Yanco site and 14 in the Kyeamba site (see http://www.oznetunimelb.edu.au/).

The air and ground plans for NAFE'06 have been determined based on the location of the permanent soil moisture stations. The 27 soil moisture sites in Yanco and Kyeamba represent therefore the core of the airborne experiment. This section gives a general presentation of the study area and provides a detailed description of the ground instrumentation that will be used during the field campaign.

4.1 Murrumbidgee Catchment

The Murrumbidgee is a 100,000 km^2 catchment located in southeast of Australia with a latitude ranging from 33S to 37S and a longitude from 143E to 150E. There is significant spatial variability in climate (alpine to semi-arid), soils, vegetation and land use. Fig. 4.1 shows the catchment topography with elevation varying from 50m in the west of the catchment to in excess of 2000m in the east.

Climate variations are primarily associated with elevation, varying from semi-arid in the west, where the average annual precipitation is 300mm, to temperate in the east, where average annual precipitation reaches 1900mm in the Snowy Mountains. The evapotranspiration (ET) in the Murrumbidgee is compared to rainfall data in Fig. 4.2. It is indicated that the actual ET is about the same as precipitation in the west but represents only half of the precipitation in the east.

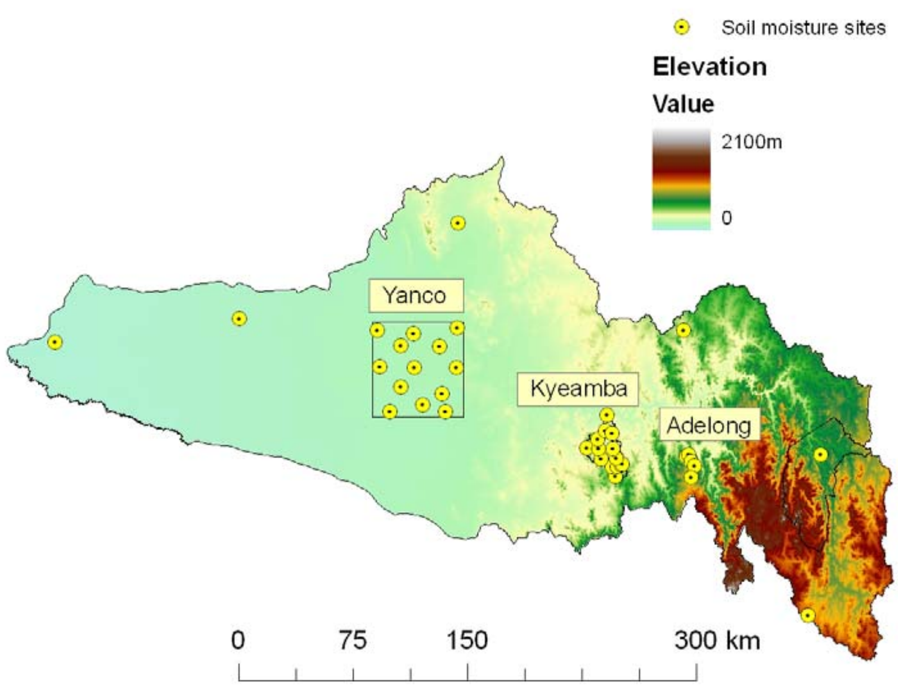


Fig. 4.1 The Murrumbidgee monitoring network is structured to target two scales: the whole catchment and three focus areas (Yanco, Kyeamba and Adelong).

Soils in the Murrumbidgee vary from sandy to clayey, with the western plains being dominated by finer-textured soils and the eastern half of the catchment being dominated by medium-to-coarse textured soils.

Landuse in the catchment is predominantly agricultural with exception of steeper parts of the catchment, which are a mixture of native eucalypt forests and exotic forestry plantations. Agricultural landuse varies greatly in intensity and includes pastoral, more intensive grazing, broad-acre cropping, and intensive agriculture in irrigation areas along the mid-lower Murrumbidgee. The NDVI images derived from MODIS/Terra data in Fig. 4.3 illustrate the gradient east-west of vegetation in the Murrumbidgee and the change in vegetation cover during November 2005.

4.2 Soil Moisture Sites

Each soil moisture site of the Murrumbidgee monitoring network measures the soil moisture at 0-30cm, 30-60cm and 60-90cm with water content reflectometers (Campbell Scientific). Reflectometers consists of a printed circuit board connected to two parallel stainless steel rods that act as wave guides. They measure the travel time of an output pulse to estimate changes in the bulk soil dielectric constant. The period is converted to volumetric water content with a calibration equation parameterised with soil type and soil temperature. Such sensors operate in a lower range of frequencies (10-100 MHz) than Time Domain Reflectometers TDR (700-1000 MHz).

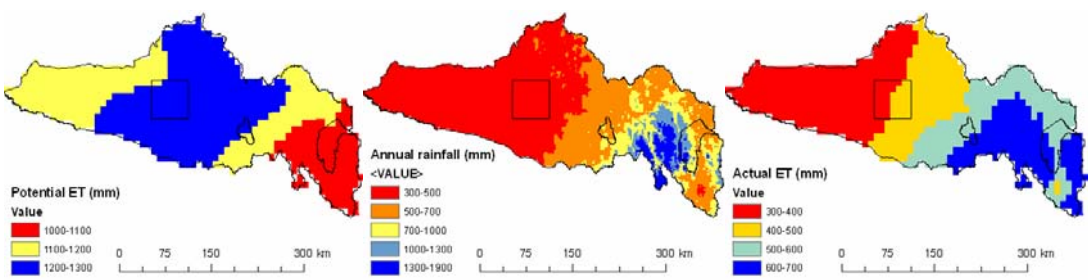


Fig. 4.2. 30-year average (in the period 1961-1990) of potential evapotranspiration (ET), annual rainfall and actual ET in the Murrumbidgee catchment (source: Bureau of Meteorology).

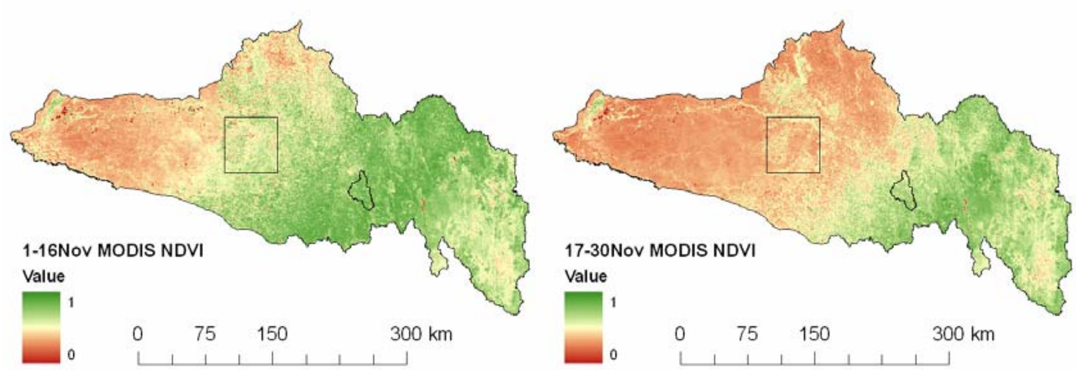


Fig. 4.3. MODIS NDVI images of the first and second two weeks of November 2005. Significant spatial and temporal variations of vegetation index are observed in the western Murrumbidgee.

Soil moisture sites also monitor continuously precipitation (using the tipping bucket raingauge TB4-L) and soil temperature. Moreover Time Domain Reflectometry (TDR) sensors are installed and are monitored when sites are visited to provide additional calibration information and ongoing checks on the reflectometers.

All the stations except for one in Yanco and seven stations in Kyeamba were installed throughout late 2003 and early 2004 (new sites) while the eighteen other stations have operated since late 2001 (original sites). Fig. 4.4 illustrates the differences between the original and new sites. The original sites use the Water content reflectometer CS615 (Campbell, http://www.campbellsci.com/cs615-l) while the new sites use the updated version CS616 (Campbell, http://www.campbellsci.com/cs616-l), which operates at a somewhat higher measurement frequency (175MHz compared with 44MHz). The original sites monitor soil temperature and soil suction (in the 60-600kPa range) at the midpoint of the four layers 0-7cm, 0-30cm, 30-60cm and 60-90cm, whereas the new sites only monitor 15cm soil temperature from T-107 thermistors (Campbell, http://www.campbellsci.com/107-l). All new sites have been upgraded since April 2006 to include a 0-5cm soil moisture from a HydraProbe (Stevens Water; http://www.stevenswater.com/catalog/stevensProduct.aspx?SKU='70030'), 2.5cm soil temperature from thermistors (Campbell Scientific model T-107) and telemetry.

Sensor response to soil moisture varies with salinity, density, soil type and temperature, so a site-specific sensor calibration is being undertaken using both laboratory and field measurements. The on-site calibration consists of comparing reflectometer measurements with both field gravimetric samples and occasional TDR readings. As the CS615 and CS616 sensors are particularly sensitive to soil temperature fluctuations the T-107 temperature sensors were installed to provide a continuous record of soil temperature at midway along the reflectometers. Deeper temperatures are assumed to have the same characteristics across the Yanco and Kyeamba sites and are therefore estimated from detailed soil temperature profile measurements made at the original soil moisture sites.

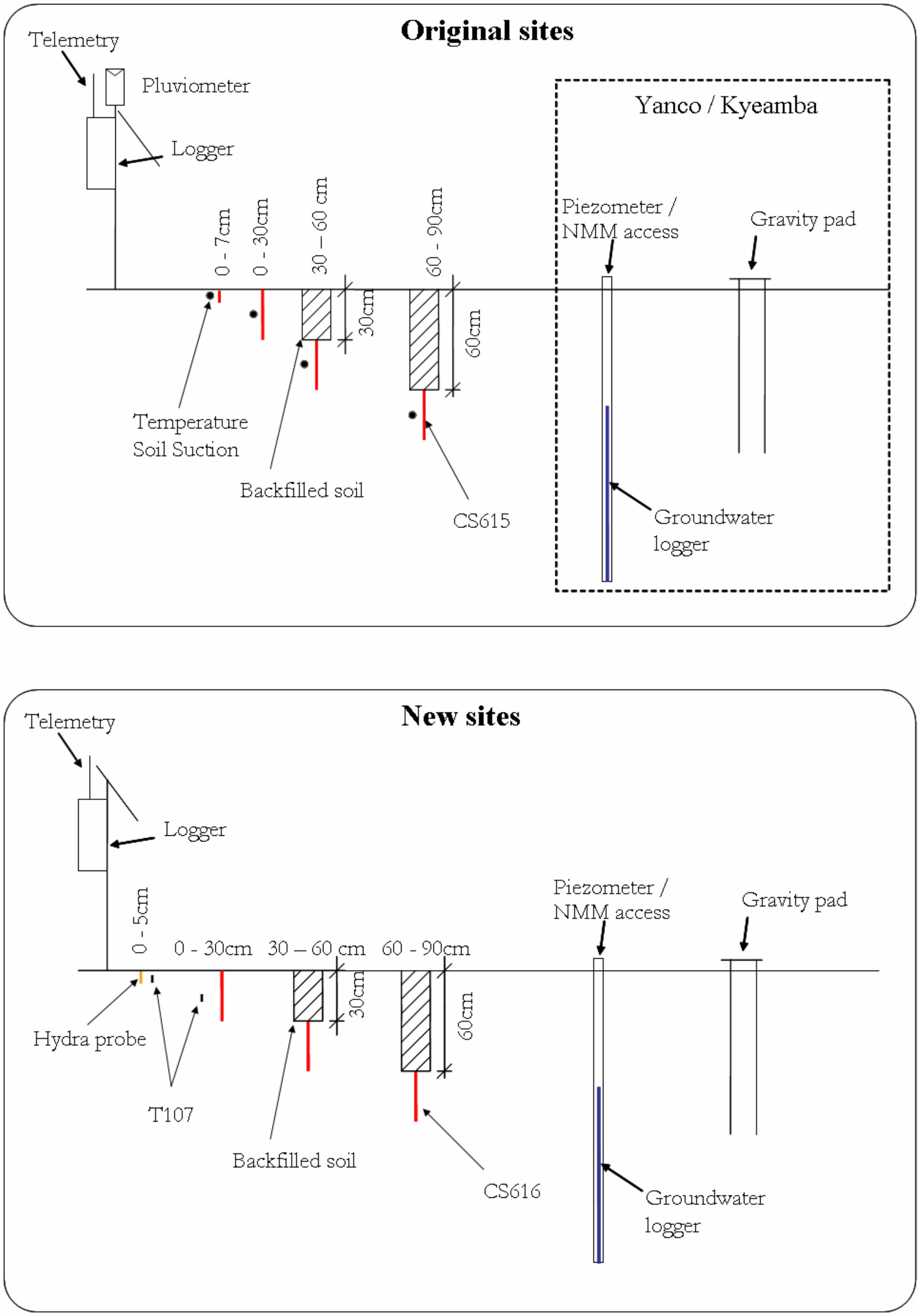


Fig. 4.4. Typical equipment at the original (2001) and new (2004) soil moisture sites in the Murrumbidgee catchment. Each site provides continuous data of rainfall, soil moisture at 0-5cm (or 0-7cm), 0-30cm, 30-60cm and 60-90cm and soil temperature and accommodates periodic measurements of gravity, groundwater and TDR soil moisture measurements.

4.3 Yanco area

4.3.1 Yanco area description

The Yanco area is a 60 by 60km area located in the broad western plains of the Murrumbidgee where the topography is flat with very few geological outcroppings. Soil types are predominantly clays, red brown earths, transitional red brown earth, sands over clay, and deep sands. According to the Digital Atlas of Australian Soils, dominant soil is characterised by "plains with domes, lunettes, and swampy depressions, and divided by continuous or discontinuous low river ridges associated with prior stream systems--the whole traversed by present stream valleys; layered soil or sedimentary materials common at fairly shallow depths: chief soils are hard alkaline red soils, grey and brown cracking clays" (see Fig. 4.5).

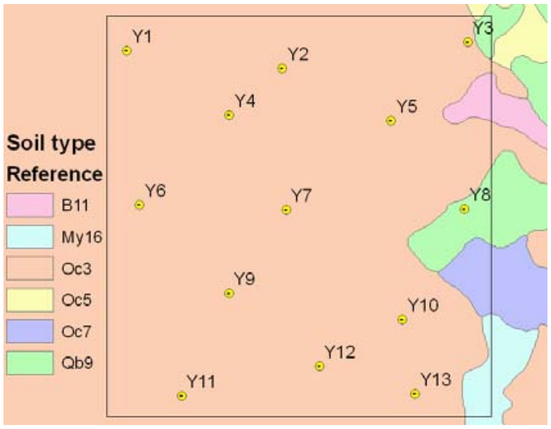


Fig. 4.5. Dominant soil type in the Yanco area according to Northcote's classification (Bureau of Rural Sciences, 1992).

Approximately one third of the Yanco area is irrigated. The Coleambally Irrigation Area (CIA) is a flat agricultural area of approximately 95,000 hectares (ha) that contains more than 500 farms. Fig. 4.6 illustrates the extension of the CIA within the Yanco area, as well as the farm boundaries. The principal summer crops grown in the CIA are rice, maize, and soybeans, while winter crops include wheat, barley, oats, and canola. The average CIA cropping areas are listed in Table 4.1.

Table 4.1. Average CIA cropping areas from 1998 to 2002 (source: Coleambally Environmental report).

Crop	Total area (ha)
Rice	23,374
Maize	2,411
Soybean	4,116
Lucerne	-
Wheat	18,207
Canola	2,592
Pasture	10,238
Dry pasture	8,600
Dry wheat	8,057
Fallow	8,600
All	86,195

In November, rice crops are usually flooded by about 30cm of irrigation water, and the presence of this standing water is expected to have a significant impact on the brightness temperature of a microwave pixel. Assuming that the microwave emission of a mixed water-land pixel can be aggregated linearly, a rough computation indicates that 5% areal coverage by water will have the effect of underestimating the microwave emission by about 4 to 8K depending on the surface conditions of the emerged land. Fig. 4.7 illustrates the effect of standing water on observed brightness temperature for assumed land values in the range 180-260K, suggesting that as little as 2.5% submerged land may result in greater than 4%v/v error in retrieved soil moisture.

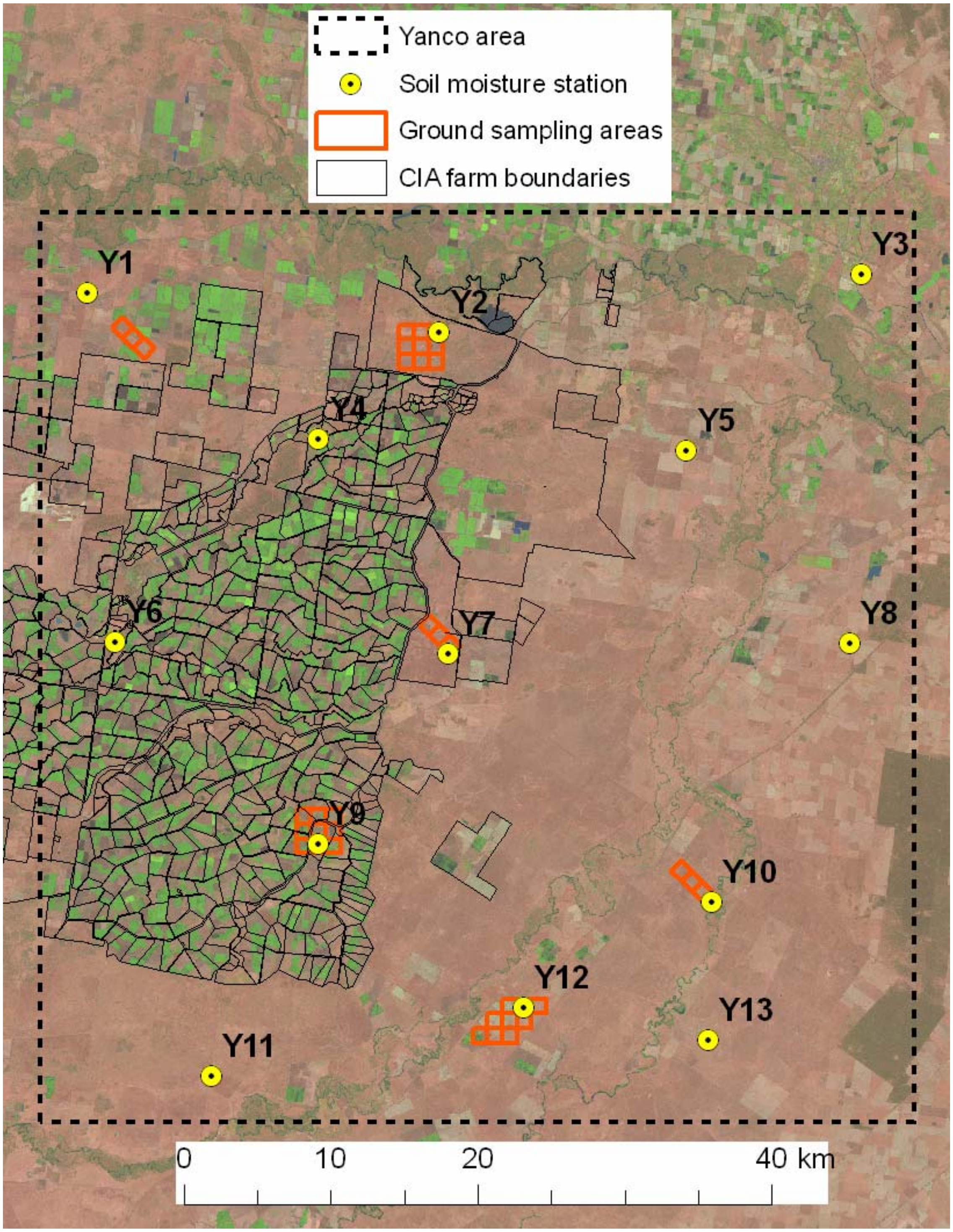


Fig. 4.6. The Yanco site is a 60km box with approximately one third of irrigated area (Coleambally Irrigation Area). The six ground sampling areas of NAFE'06 are indicated.

To estimate the amount of rice cropping at the time of NAFE'06, a spatial analysis was conducted with the Landsat ETM imagery used in Van Niel et al. (2003, 2005). Water was classified at 25-m resolution with the five images available in October-November 2000 (21 Oct, 30 Oct, 6 Nov, 22 Nov) and the five images available in October-November 2001 (8 Oct, 17 Oct, 2 Nov, 9 Nov, 25 Nov).

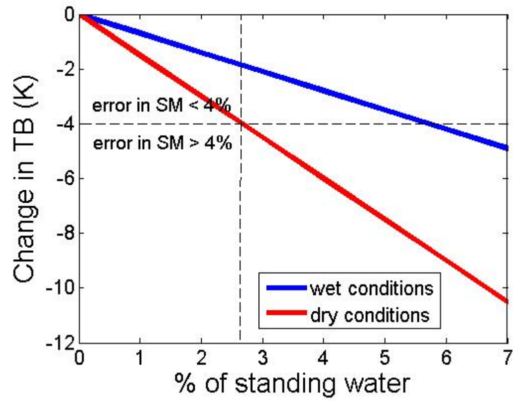


Fig. 4.7. Effect of standing water on PLMR data estimated with a brightness temperature (TB) of water of 110K and a TB of emerged land of 180K (wet conditions) or 260K (dry conditions).

A 25-m resolution ETM pixel was assumed to be standing water if the reflectance of band 5 was below 0.150. The presence of standing water within a 1 km pixel was then estimated by aggregating the flooded/not-flooded ETM pixels from 25 m to 1 km. To account for uncertainty in the actual resolution of airborne data (due to changes in aircraft attitude) and side lobe affects, ETM pixels were also aggregated to 2 km.

The analysis was conducted over two focus areas Zone A and Zone B within the Yanco area. Fig. 4.8 illustrates the spatial extent of both areas: Zone A covers a part of the CIA and the dry lands in the north east of the Yanco area whereas Zone B is chosen to be a smaller area inside the CIA. They allow for comparing the impact of irrigation occurring inside and outside the CIA.

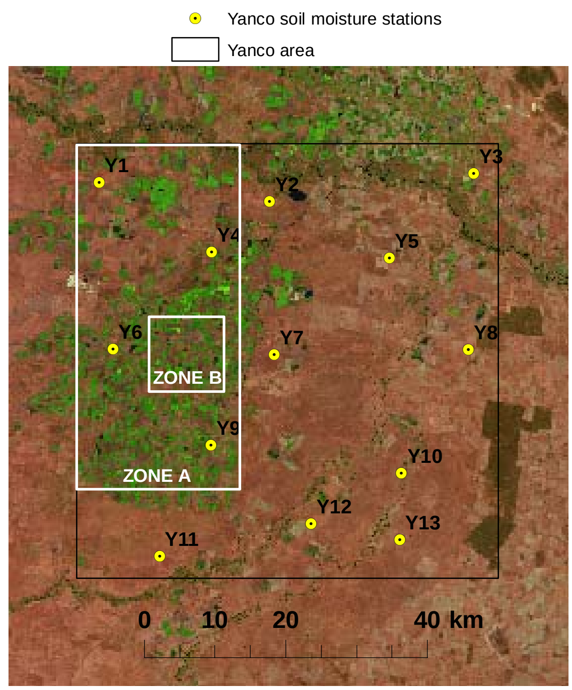


Fig. 4.8. Overview of the areas used for spatial analysis of standing water in October-November: a 1000 km^2 area (Zone A) covering a part of the CIA and the north west part of the Yanco area, and a 120 km^2 area (Zone B) inside the CIA.

Quantitative results are presented in Fig. 4.9 and 4.10, where the amount of NOT-contaminated 1-km and 2-km pixels in Zone A and Zone B are plotted versus time in October-November of 2000 and 2001. The number of pixels affected by less than 2% of the pixel area and less than 5% of the pixel area are also plotted for comparison. They indicate that the onset of irrigation ranges from mid to end October. The Fig. also shows that the number of contaminated pixels typically achieves its maximum at the beginning of November, and decreases significantly towards the end of November. However, this decrease is thought to be an artefact of the processing resulting from significant crop growth during the month, as rice crops in the CIA are not drained before late February. This assertion is confirmed by Van Niel et al. (2003) who have shown that rice plant growth above the water occurs from mid November, making those crops look like the other green crops even though they are still flooded at that time.

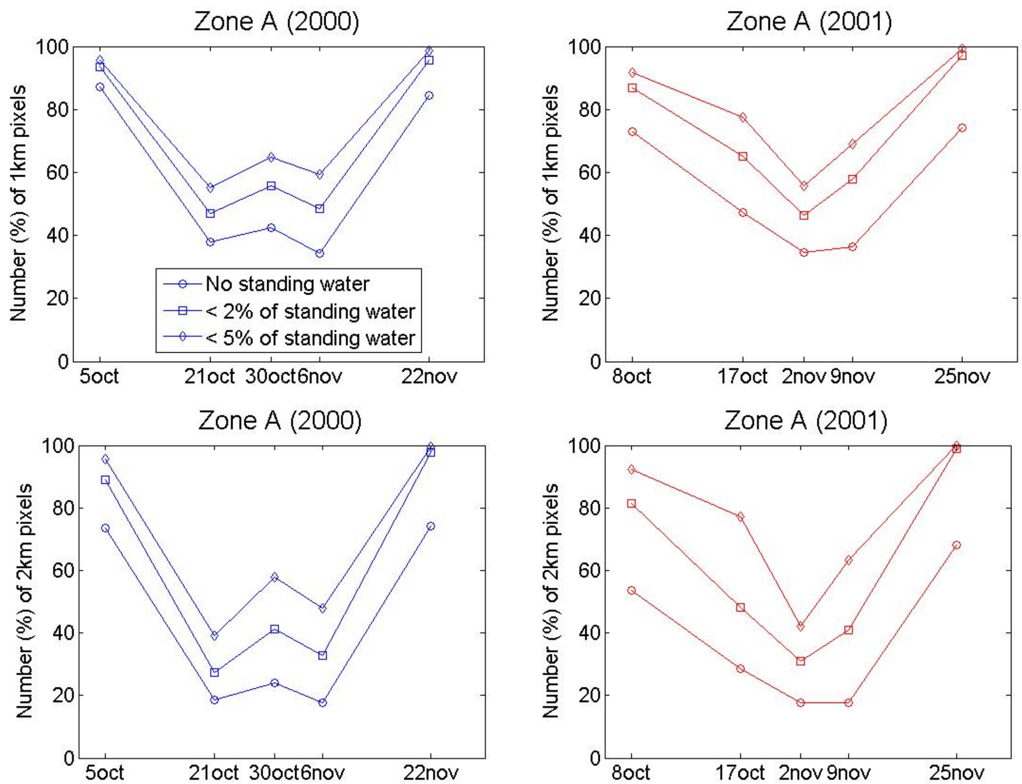


Fig. 4.9. Percentage of the 1-km and the 2-km pixels affected by 0, less than 2% and less than 5% of standing water in Zone A for 2000 and 2001.

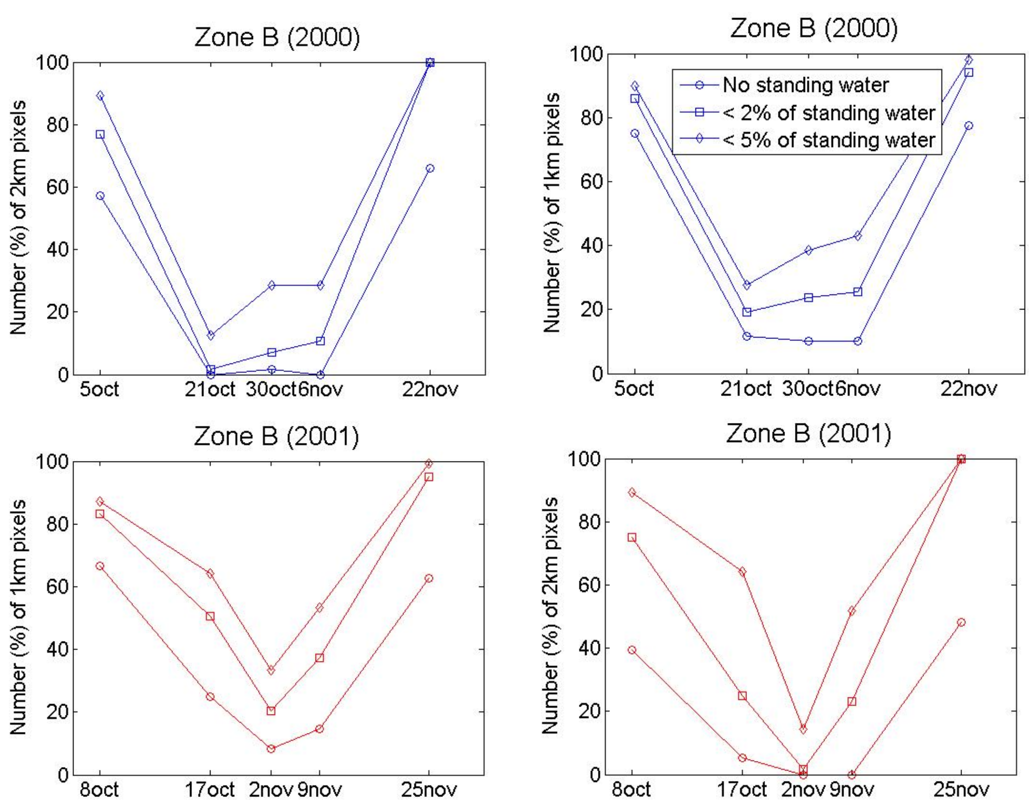


Fig. 4.10. As for Fig. 4.9 but for Zone B.

4.3.2 Yanco soil moisture network

The 13 soil moisture monitoring sites in the Yanco area are located in a grid-based pattern over a 60 km by 60 km area allowing for measurement of the sub-grid variability of remote-sensed observations such as near-surface soil moisture from AMSR and SMOS (see Fig. 4.6).

The sites are evenly divided between the 3 main land uses in the region—irrigated cropping (including the major rice growing region of the Coleambally Irrigation Area, see also Table 4.1), dryland cropping (typically wheat and fallow), and grazing (typically perennial grass type vegetation). The land cover of the area surrounding the soil moisture stations is listed in Table 4.2.

The average daily rainfall collected by the 13 sites in the Yanco area is plotted in Fig. 4.11 for the period October-December of 2004 and 2005. It is clear that major rainfall events have occurred near the beginning of November for each of the past two years. The standard deviation of point measurements is also plotted to illustrate the large spatial variability of local precipitation.

Fig, 4.12 illustrates typical soil moisture data collected at sites Y5, Y9 and Y13 during the period October-December of 2005. Those sites were chosen to be representative of all 13 sites, as they cover the three land use types present in the Yanco area: dry land cropping for Y5, wet land cropping for Y9 and native pasture for Y13. In all cases the 0-30cm soil moisture data indicate some significant dynamics in November. The 30-60 and 60-90cm soil moisture data are correlated in time with the 0-30cm data, with differing dynamics depending on land use. Moreover, periodic irrigation has resulted in the saturated 30-60 and 60-90cm soil moistures for Y9. For dry land cropping and native pasture, the 60-90cm soil moisture increases from October to December due to frequent rainfall events. Note that the results presented are based on a preliminary calibration, which assumes a linear relationship between the CS and TDR sensors. A site specific calibration including correction for temperature effects is underway.

Table 4.2. Land cover at the 13 sites in the Yanco area. The six farms of NAFE'06 are highlighted.

Site Label	Farm name (NAFE'06 only)	Land use
Y1	Uri park	Dry and wet land cropping
Y2	Banandra	Native pasture, grazing
Y3		Yanco Agricultural Institute
Y4		Wet land cropping
Y5		Dry land cropping
Y6		Wet land cropping
Y7	Tubbo	Native pasture, grazing
Y8		Dryland cropping and grazing
Y9	Yammacoona	Dry and wet land cropping
Y10	Cherevelis	Native pasture, grazing
Y11		Native pasture, grazing
Y12	Spring bank	Dry and wet land cropping, grazing
Y13		Native pasture, grazing

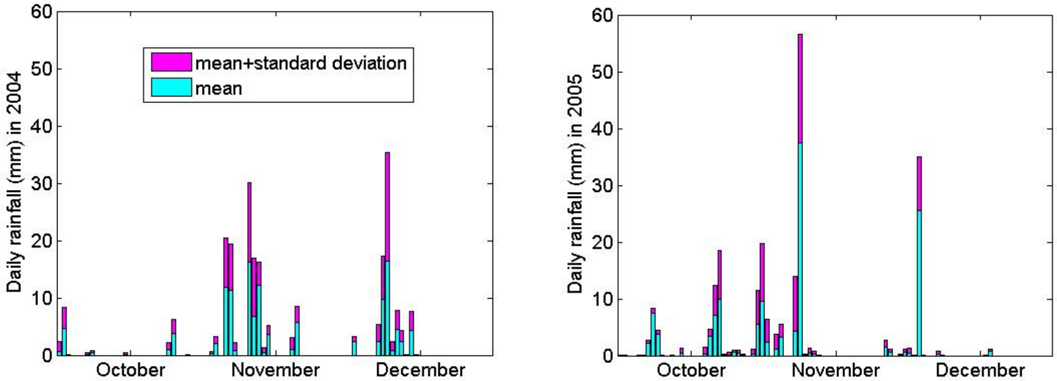


Fig. 4.11. Daily rainfall in the Yanco area in the period October-December of 2004 and 2005. The mean and standard deviation are computed from the 13 data sets collected by the rain gauge network.

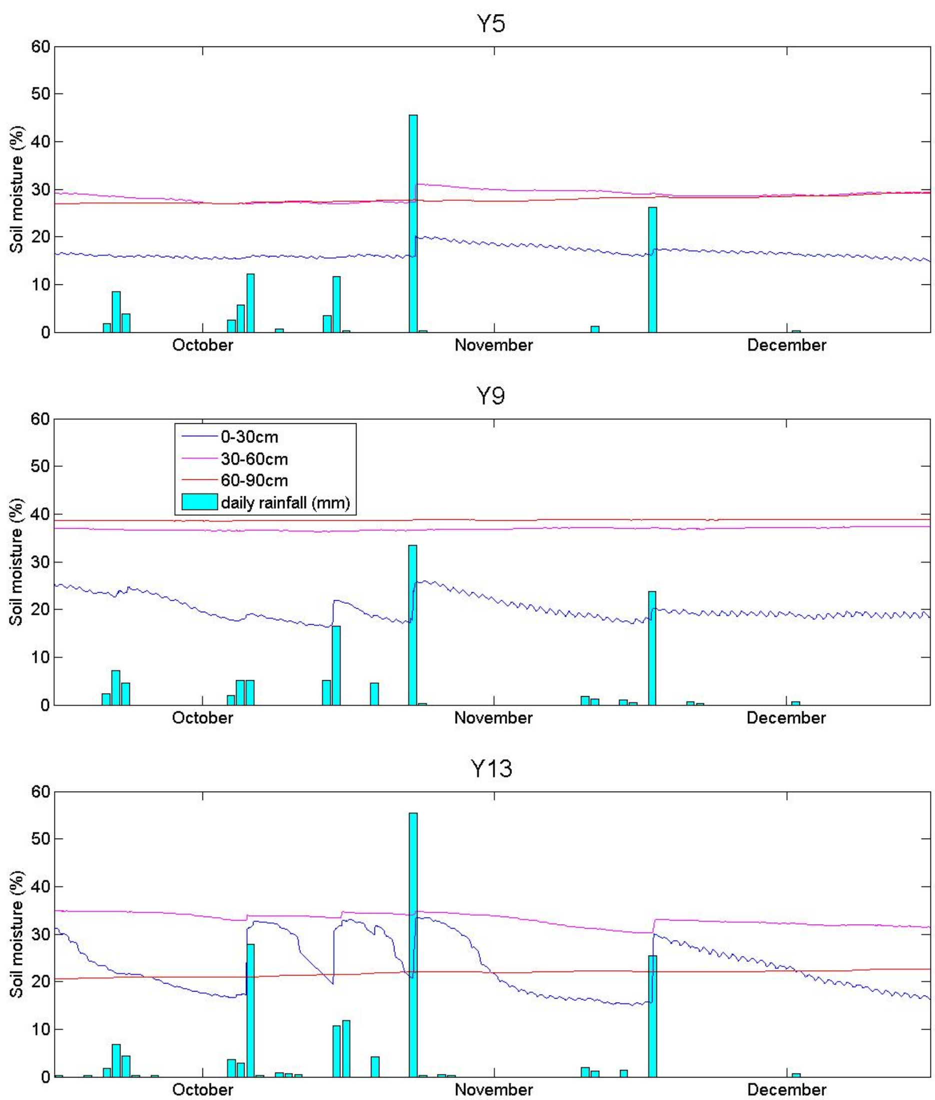


Fig. 4.12. Typical data collected continuously by the network of 13 soil moisture stations in the Yanco area in 2005.

4.4 Kyeamba Catchment

4.4.1 Kyeamba catchment description

Kyeamba Creek is a third-order catchment feeding the Murrumbidgee River. The catchment covers an area of 600 km^2 to the south east of Wagga Wagga in central New South Wales. The major surface drainage features are Kyeamba and Livingstone Creeks. Average annual rainfall is 650 mm, with a gradient decreasing from the highlands in the south to the confluence with the Murrumbidgee in the north. Land use is dominated by cattle grazing, limited sheep grazing, some irrigation of crops and vegetables in the higher country. The geology of the area is characterised by granitoids in the higher regions of the catchment, and deformed metasediments in the lower regions.

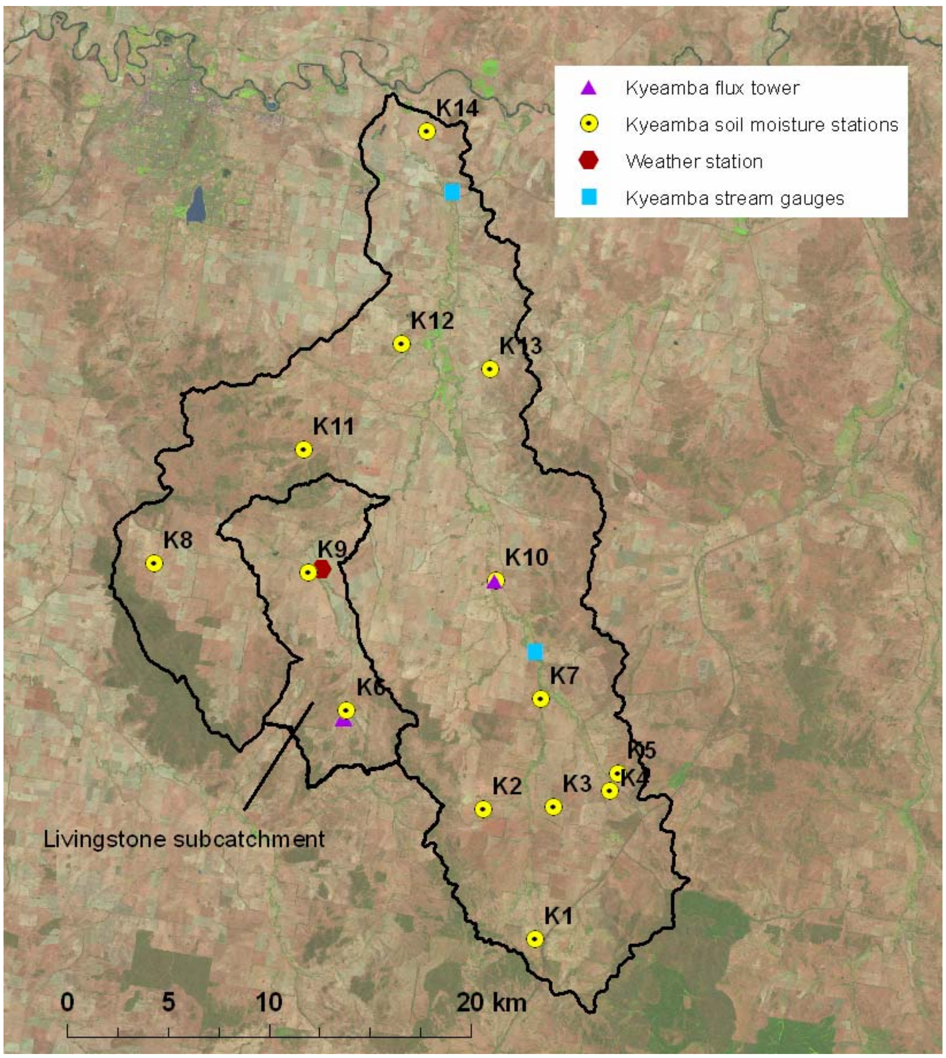


Fig. 4.13. The Kyeamba Creek catchment is currently equipped with 14 soil moisture stations, a 3D Eddy correlation flux tower (K10), and two stream gauges. Ground sampling will take place in the Livingstone Creek subcatchment, which includes a weather station (K9) and a Bowen ratio (K6).

The dominant soil types in the Kyeamba catchment are represented in Fig. 4.14. According to the Digital Atlas of Australian Soils, the three main soil types occurring is this area are described as:

- “Hills and/or undulating ridges often characterized by chips of shaly rock: chief soils are hard neutral red soils.”
- “River flood-plains and terraces, buried soils materials present at shallow depths (2 ft) in some places: chief soils of the gently sloping plains are hard alkaline and neutral yellow mottled soils.”
- “Strongly undulating to hilly country with some steep slopes and rock walls, tors: chief soils are hard neutral red soils with red earths often gritty.”

Note that the soil types occurring in the Livingstone subcatchment are reflective of the main soils in the whole Kyeamba catchment.

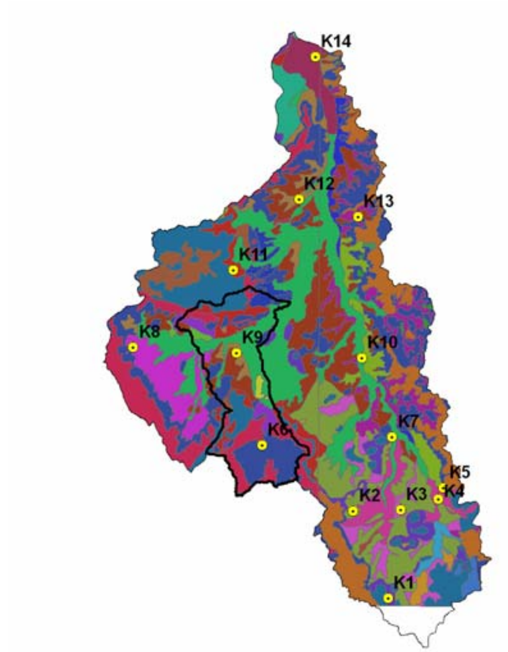


Fig. 4.14. Dominant soil type in the Kyeamba catchment according to Northcote's classification (Bureau of Rural Sciences, 1992).

The topography of the Kyeamba Creek catchment is illustrated in Fig. 4.15. Elevation ranges from 180m in the north near the confluence with the Murrumbidgee River to 620m in the south. More than 90% of the catchment has an elevation ranging from 200m to 400m. The Livingstone subcatchment reproduces the same elevation pattern but at a smaller spatial scale with elevation ranging from 200m in the north to 500m in the south.

There are two aquifers operating within Kyeamba Creek (Cresswell et al., 2001). The upper system is a surface alluvial aquifer that carries most of the main watercourses. The variability of the aquifer thickness creates local flow cells only a few kilometres long. These have local discharge areas that become saline due to evaporative concentration of near-surface water. The other aquifer is a deeper and more extensive intermediate scale fractured rock aquifer that underlies much of the area. Groundwater flow is generally northward, complementary with the direction of surface flow in the larger creeks, and the water levels in this aquifer are near the surface over the lower reaches of Kyeamba Creek near its confluence with the Murrumbidgee River.

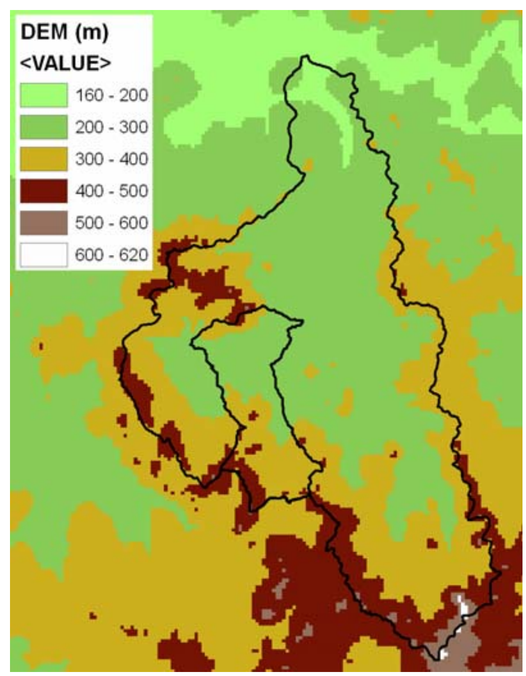


Fig. 4.15. Mean elevation in the Kyeamba catchment.

4.4.2 Kyeamba stations

Relatively long-term data exist for the Kyeamba Creek. The catchment is gauged at two locations as illustrated in Fig. 4.13, hence providing the opportunity for nested catchment studies. Various University of Melbourne research projects have additionally installed a 3D Eddy correlation flux tower and 14 sites monitoring soil moisture profile, rainfall and soil temperature using the same instrumentation as for the Yanco area. Fig. 4.13 also shows the spatial distribution of the 14 sites operating in the Kyeamba catchment. The land cover at the 14 soil moisture stations is reported in Table 4.3.

The average daily rainfall collected by the Kyeamba soil moisture monitoring network is plotted in Fig. 4.16 for the period October-December of 2004 and 2005. The amount of rainfall is significantly larger in the Kyeamba catchment than in the Yanco area. When looking at the standard deviation of point measurements, it is indicated that rainfall fields are relatively more homogeneous compared with those monitored in the Yanco area. Fig. 4.17 illustrates typical soil moisture data collected in the upper (K7), middle (K10) and lower (K14) catchment during the period October-December of 2004.

Table 4.3. Land cover at the 13 sites in the Kyeamba catchment. The farms in the Livingstone catchment are highlighted.

Site Label	Land cover
K1	Grazing/cropping
K2	Grazing/cropping
K3	Grazing/cropping
K4	Grazing/cropping
K5	Grazing/cropping
K6	Grazing
K7	Grazing/cropping
K8	Grazing, perennial grass
K9	Grazing/cropping
K10	Grazing/cropping
K11	Grazing/cropping
K12	Cropping/grazing
K13	Grazing
K14	Native grass/bush and grazing; some irrigation

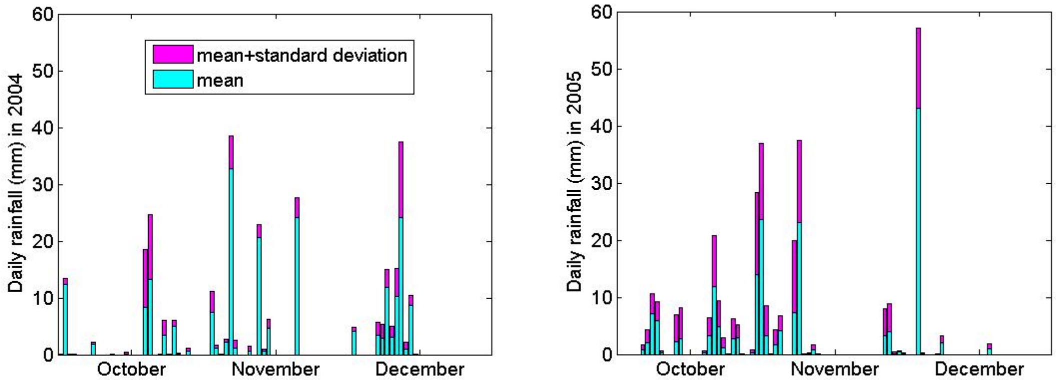


Fig. 4.16. Daily rainfall in the Kyeamba catchment in the period October-December of 2004 and 2005. The mean and standard deviation are computed from the 14 data sets collected by the rain gauge network.

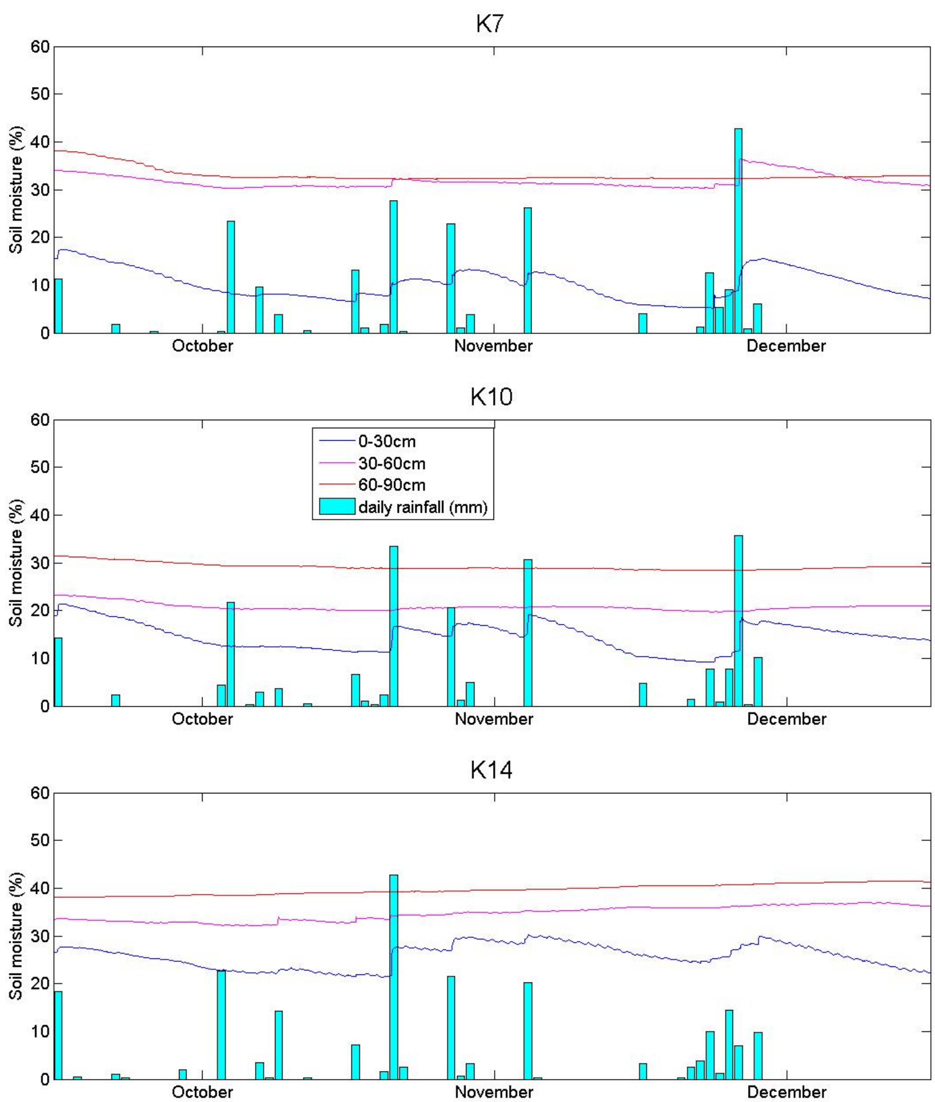


Fig. 4.17. Typical data collected continuously by the network of 14 soil moisture stations in the Kyeamba catchment in 2005.

4.4.3 Livingstone stations

A map of the 47 km^2 Livingstone subcatchment is provided in Fig. 4.18. The Livingstone Creek monitoring network is composed of the two soil moisture stations K6 and K9, eight additional soil moisture profile sites located 1km north of K9, 5 stream gauges on the O'Briens Creek and 2 on the Livingstone Creek, a weather station and a Bowen ratio.

Topography, soil and vegetation in the Livingstone Creek are reflective of the whole Kyeamba Creek catchment and will provide a good basis for extrapolating results from the detailed studies undertaken in this subcatchment.

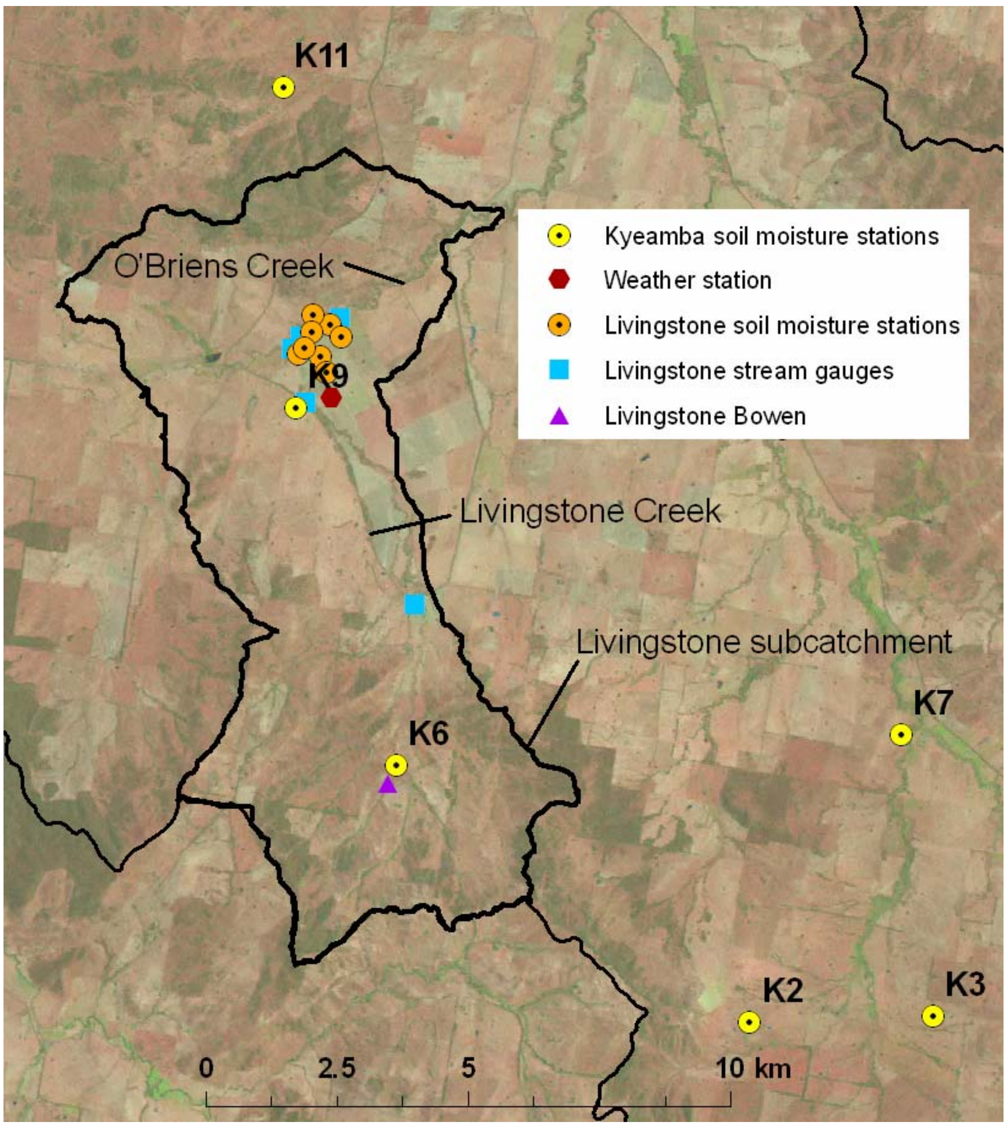


Fig. 4.18. The Livingstone Creek is a subcatchment of Kyeamba. In addition to the 2 soil moisture stations of the Kyeamba network, Livingstone is equipped with 8 supplementary soil moisture stations, 7 stream gauges and 1 Bowen ratio.

The supplementary soil moisture stations were installed at eight strategic locations to represent the main landform elements within the field site (see Fig 4.19). Sites 5 and 8 were in the alluvial landform as a replicated pair. Sites 1 and 4 were located in the alluvial landform at locations above the buried paleo-channels. Sites 3 and 6 were a replicated pair within the meta-sediments landform. Site 2 was located in a surface expressed paleo-channel and site 7 was located in an area where groundwater constrictions occur due to barriers formed by the half buried hard rock hill. Watermark sensors and Theta probes were installed at depths of 0.6m (within the root zone), 1.6m (below the root zone), 3m (above ground water) and 4m (near saturation) at each site (except site 2 which were only 0.6m and 1.6m due to depth of the soil profile). At 0.6m and 1.6m depth, two Watermark sensors were installed to provide a site/depth replication and one at 3m and 4m depths. One Watermark and one Theta probe were installed at 3m and 4m depths.

In July 2006, the eight Livingstone Creek soil moisture sites were upgraded with new Theta probes (0-6cm depth) and temperature sensors (5cm).

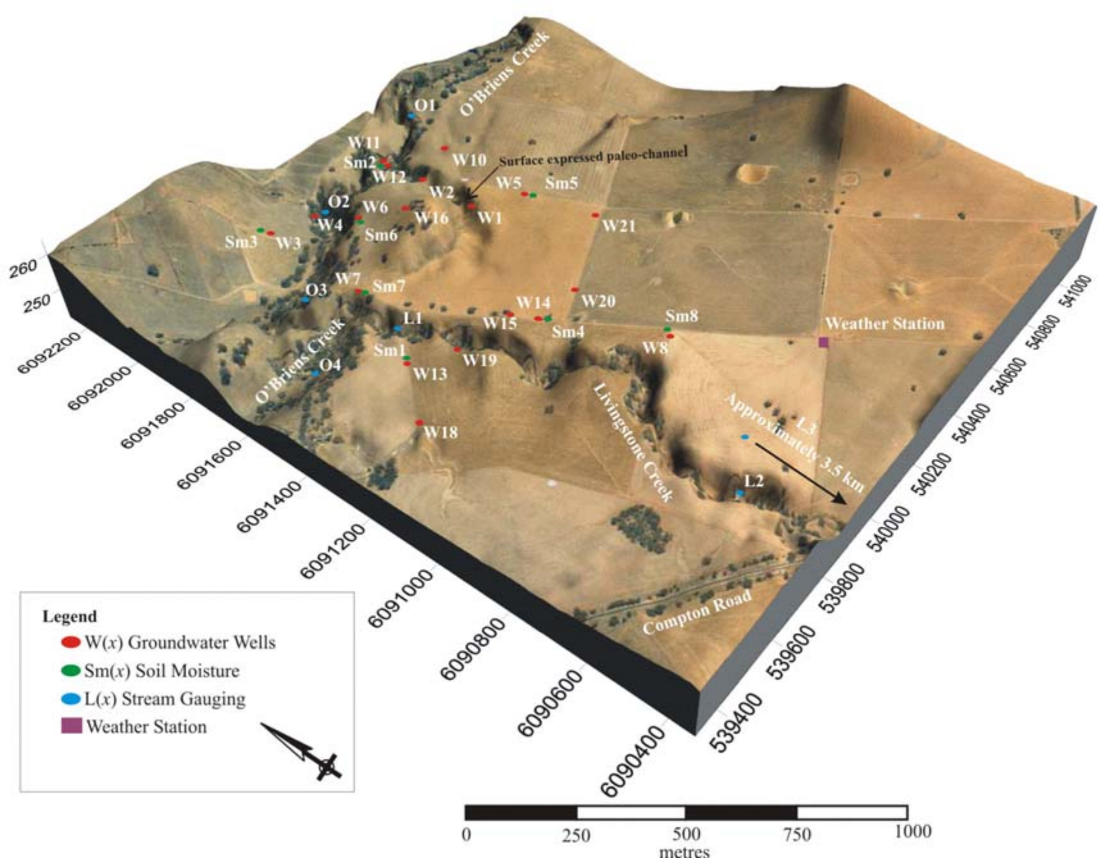


Fig. 4.19. Distribution of the supplementary monitoring stations in the Livingstone Creek subcatchment.

4.5 Yenda site

The Yenda site is an experimental farm of the CSIRO, Griffith. It is located 9km east of Griffith, which is 40km north of the Yanco area. The Yenda site is composed of two adjacent vineyard blocks of 14 and 12 ha. The bigger block is flood irrigated while the other is drip irrigated. Both vineyards have separate irrigation supply, surface drainage and subsurface drainage. Soil types, vine and floor management practices are similar for both blocks and typical of vineyards in the area. These blocks are being used to undertake detailed measurements of water balance and water flux components at detailed spatial and temporal resolution.

The following instrumentation (see Fig. 4.20 and 4.21) will be concurrently operating during the NAFE'06:

- Bowen Ratio Flux Systems: temperature (wet and dry) 2.8m and 3.8m above ground, net radiation, soil heat flux, wind velocity and direction

- Sap Flow Transpiration Stations measuring vine transpiration – 3 vines measured per station

- Sentek enviroscan continuously monitored (30 min intervals) soil capacitance probe sensors at 0.1, 0.2, 0.4, 0.7 and 1m depths measuring soil moisture

- GBug watermark soil tension blocks continuously monitored (30 min intervals) at 0.1, 0.25, 0.45, 0.8 and 1.5m depths measuring soil tension

Fig. 4.20. Soil moisture sensors in the upper left, sap flow sensors in the lower left and the 3 Bowen ratios on the right.

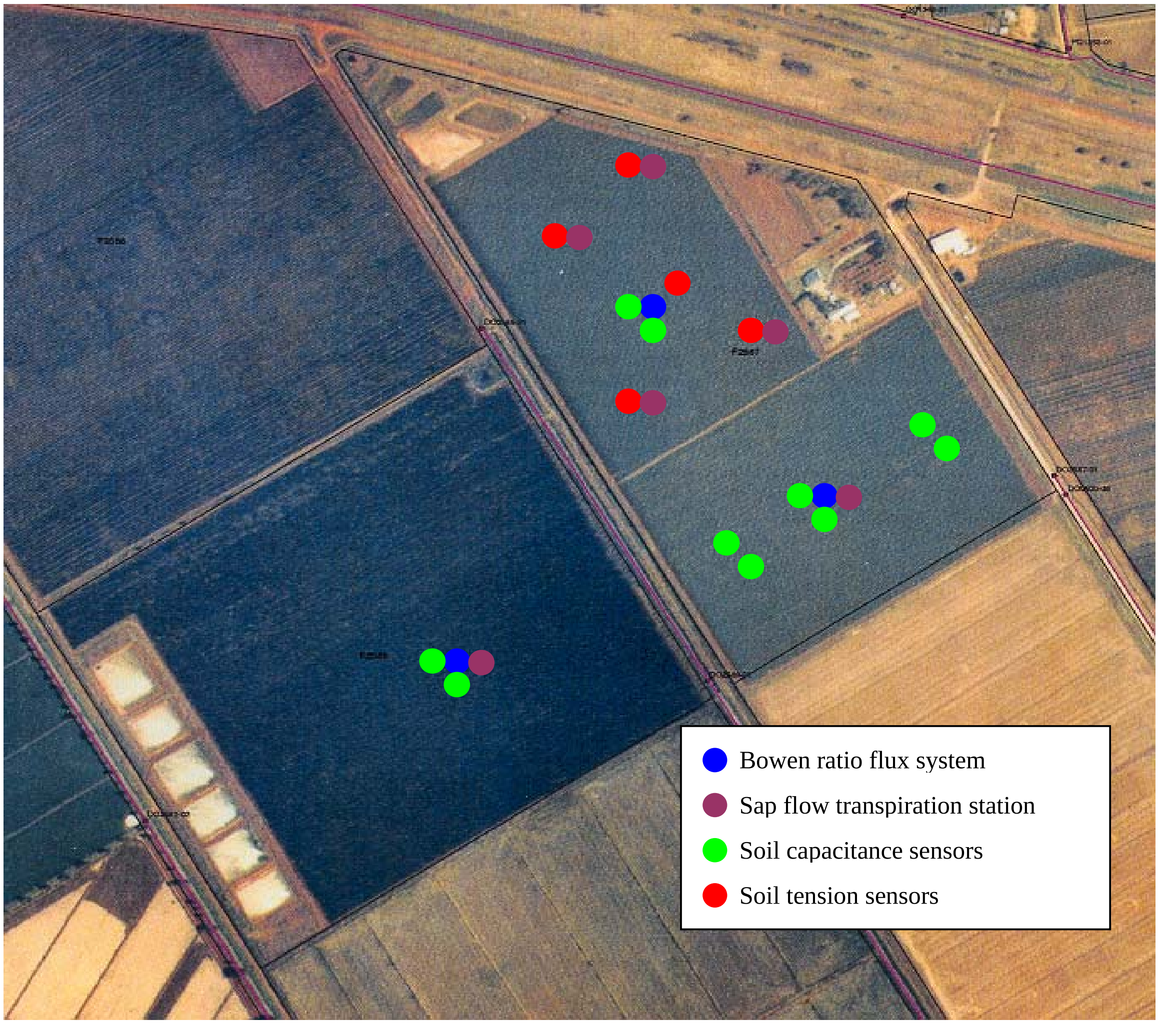


Fig. 4.21. Location of the Bowen ratio flux systems, sap flow stations, and soil capacitance/tension sensors in the two vineyard blocks.

5 Ground Monitoring

An overview of the ground component of NAFE'06 is presented in this section. This includes the list of ground measurements and a description of the strategy used to collect data.

5.1 Ground Monitoring in Yanco

In Yanco, the ground component of the NAFE'06 field campaign consists of four aspects:

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

5.1.1 Focus farms

Ground measurements in the Yanco area will be focused in the six farms that include soil moisture sites Y1 (Uri Park), Y2 (Banandra), Y7 (Tubbo), Y9 (Yammacoona), Y10 (Cherevelis) and Y12 (Spring Bank).

These six farms were chosen because:

- They are well distributed within the 60 by 60km box of the Yanco area (see Fig. 5.1). The spatial distribution of those farms within the study area is expected to provide interesting soil moisture patterns due to spatial variations in rainfall.

- The land cover of the six farms is representative of the whole study area. Farms Y2, Y7 and Y10 are representative of the grazing lands while farms Y1, Y9, Y12 are representative of the wet/dry land cropping (see Table 5.1).

Table 5.1. List of the vegetation types in the farms of NAFE'06.

Farms	Vegetation types in the soil moisture sampling area
Y1	Wheat (dry and irrigated crops), irrigated pasture, other irrigated cropping
Y2	Dry land pasture
Y7	Dry land pasture
Y9	Irrigated wheat, other irrigated cropping, fallow
Y10	Dry land pasture
Y12	Dry wheat, fallow, irrigated pasture

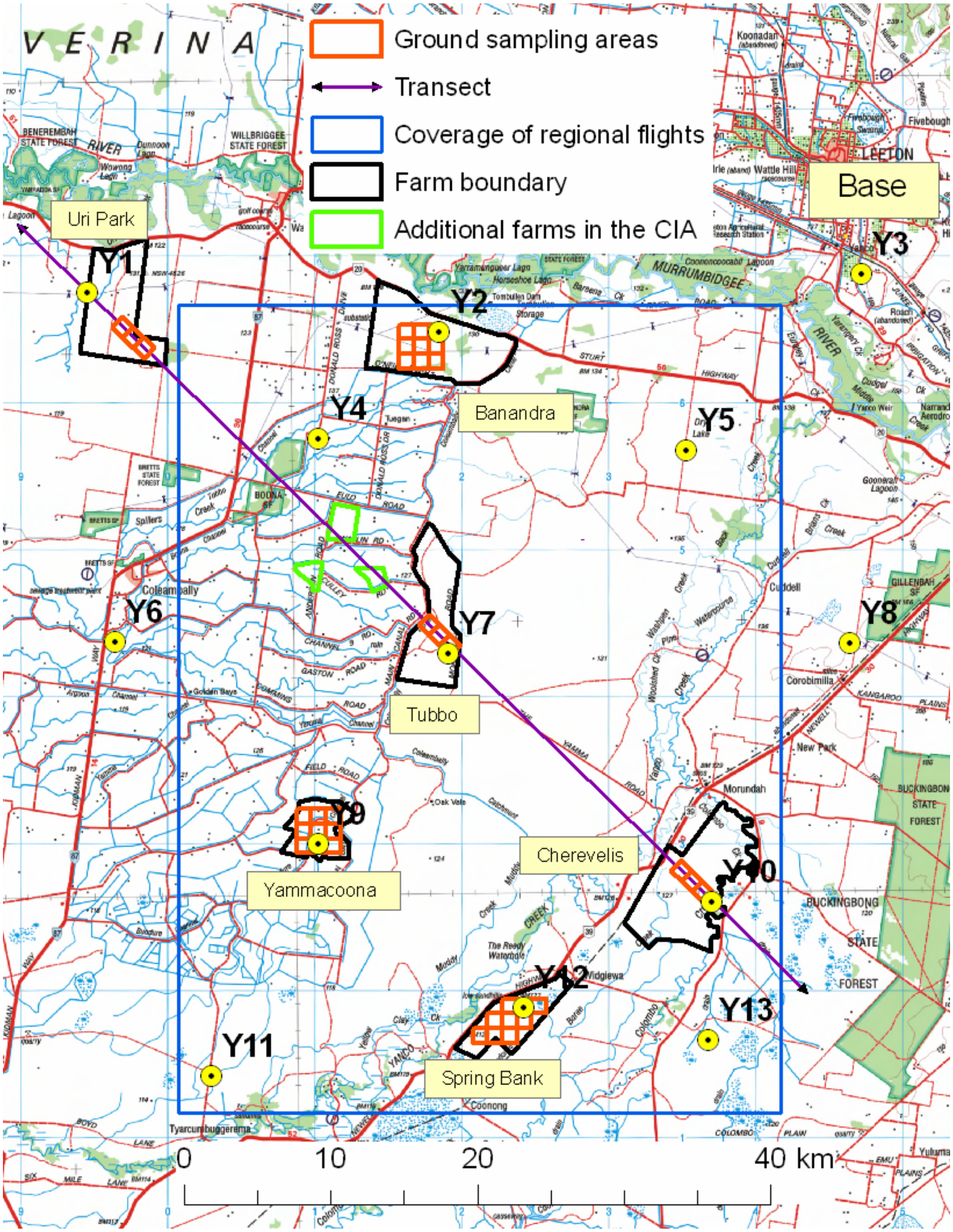


Fig. 5.1. Farms involved in the ground sampling during NAFE'06. There are 3 groups of farms: three farms in the regional area (Y2, Y7 and Y12), three farms along the transect line (Y1, Y7 and Y10), and three additional farms in the CIA.

5.1.2 Supplementary monitoring stations

Additional sensors will be installed for the duration of the campaign in 7 farms of the Yanco area. The primary objectives are to:

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

To capture the relevant information, there will be nominally:

- Six stations that have thermal infrared radiometers (Two Ahlborn Thermalert TX®, two Everest Interscience Inc.® Infrared Temp Transducers, Model 4000, two Apogee Precision Infrared Radiometers, Campbell Scientific, Inc.®), duplicate soil temperature sensors at 1cm, 2.5cm and 4cm (Unidata® 6507A/10 sensors), and leaf wetness sensors (Measurement Engineering Australia 2040®). Fig. 5.2 is a schematic diagram of the supplementary monitoring. The 6 TIR stations will be installed so as to capture the major land covers: dry land pasture (at Y7 and Y10), irrigated cropping (in the sampling area of Y12), irrigated pasture (Y9), dry land cropping (Y1) and bare soil (Y9).

- One weather station. Given that a weather station currently operates at Yanco (northeast of the study area), a second station will be installed in the southwestern part of the Yanco area (Y11).

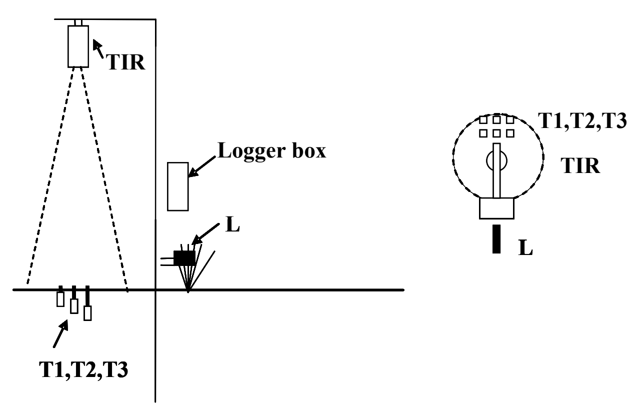


Fig. 5.2. Typical set up of the supplementary monitoring site (side view and top view); showing 1 cm (T1), 2.5 cm (T2) and 4cm (T3) soil temperatures; Thermal infrared (TIR) and leaf wetness (L) sensors.

5.1.3 Spatial soil moisture mapping

The main objectives of the ground surface soil moisture measurements are to:

- Validate PLMR data at a range of spatial resolution (from 50m to 1km) in both mapping and multi-incidence modes;
- Characterize the spatial variability of surface soil moisture within 1km resolution PLMR pixels

The near-surface soil moisture measurements will be made using the Hydraprobe Data Acquisition System (HDAS; Hydraprobes® connected to a pocket PC (iPAQs®) running ArcPAD® and bluetooth connection to GPS for real-time position and data logging). These roving measurements will be made on each of the six farms in order to collect data across a range of soil, vegetation and terrain conditions. Note that a separate HDAS manual will be provided.

Soil moisture measurements will be made on regular grids whose extent and spatial resolution will vary with PLMR flights. Soil moisture measurements will be made in a 3 by 3km area at 250m resolution during the regional flights in Yanco (on regional days), and in a 3 by 1km area at 50m/250m resolution during multi-incidence flights (on transect days). The three farms Y2, Y9 and Y12 will be sampled during regional days and the three other farms Y1, Y7 and Y10 during transect days. The rationale of the soil moisture sampling is shown in Fig. 5.3 and the actual sampling grids in the six farms are illustrated in Fig. 5.3 to 5.9.

To calibrate Hydra probe measurements, HDAS data will be compared to volumetric measurements undertaken at each farm. A total of 5 soil samples will be taken for each soil moisture sampling grid on each day of sampling.

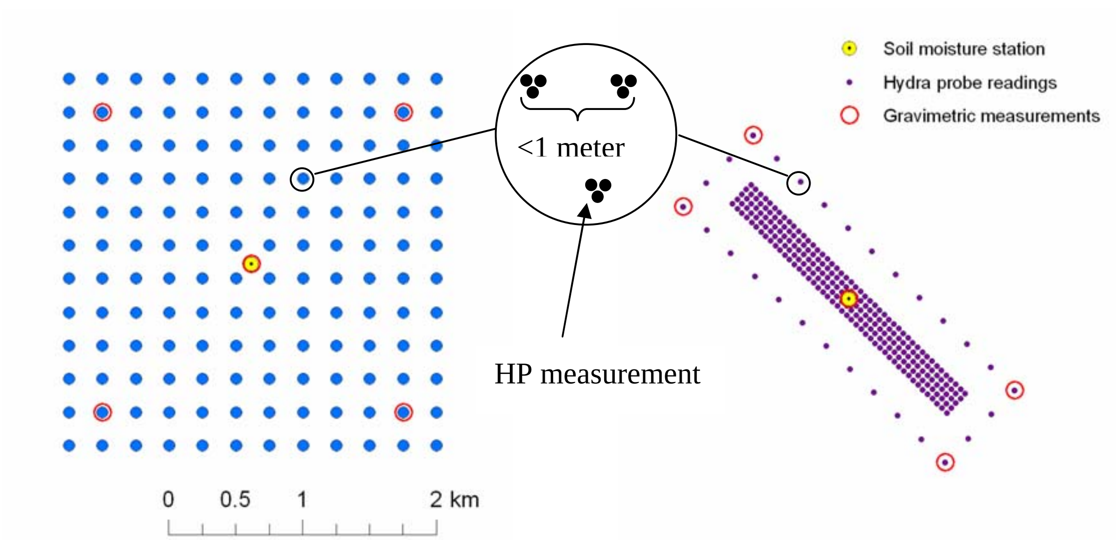


Fig. 5.3. Rationale of the soil moisture sampling during regional (left) and transect (right) days. Three HP measurements are to be made at each sampling point of the 50m and 250m grids.

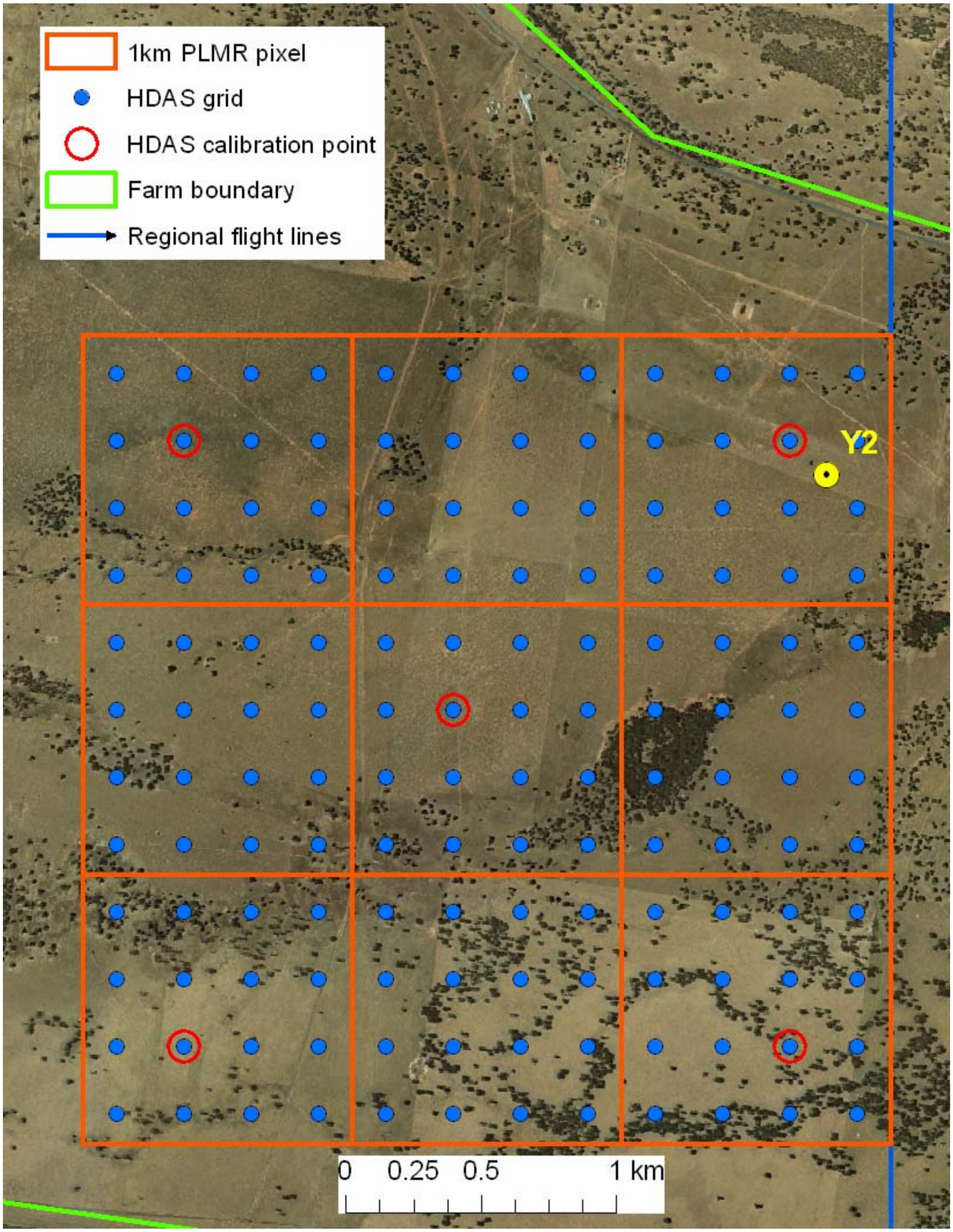


Fig. 5.4. Map of the soil moisture sampling grid in Banandra.

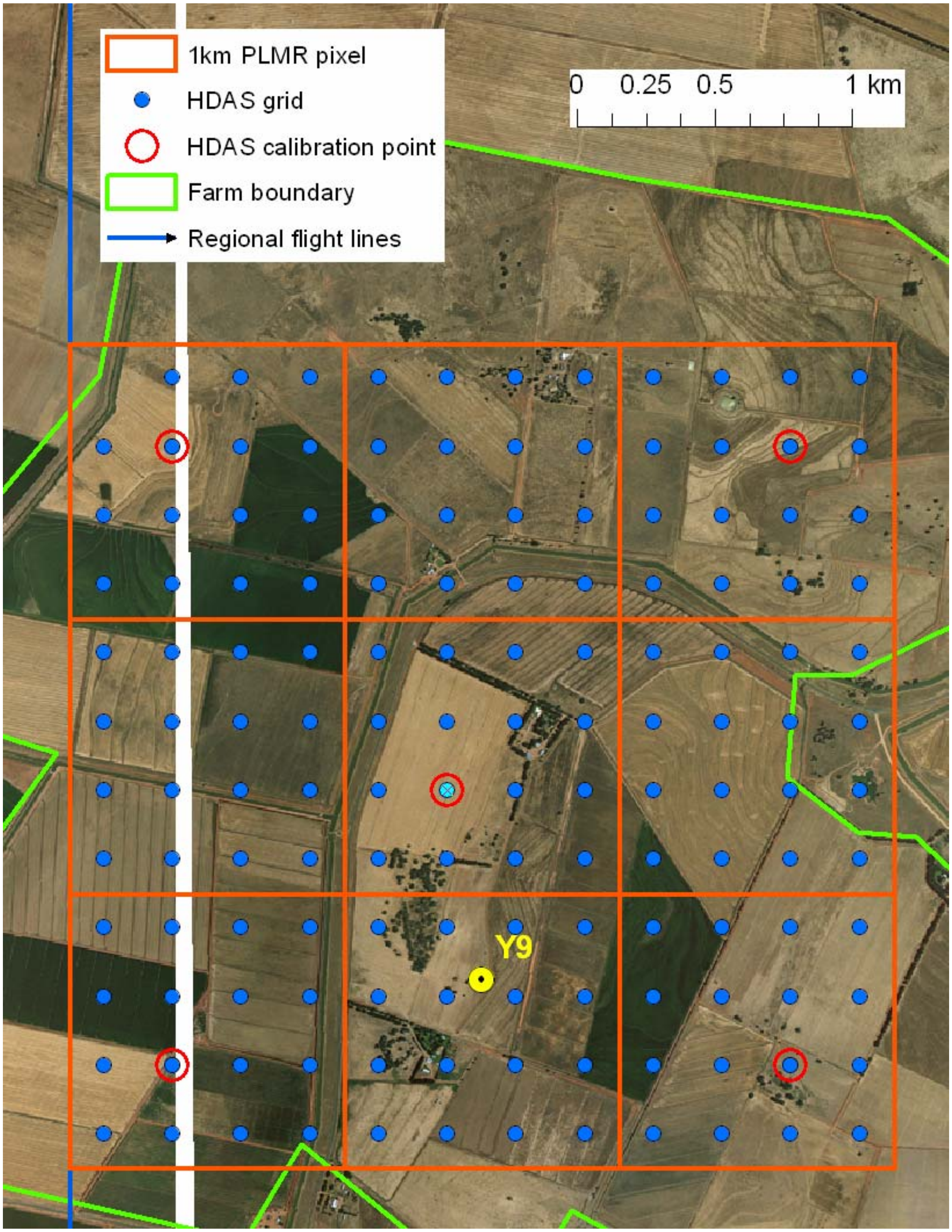


Fig. 5.5. Map of the soil moisture sampling grid in Yammacoona.

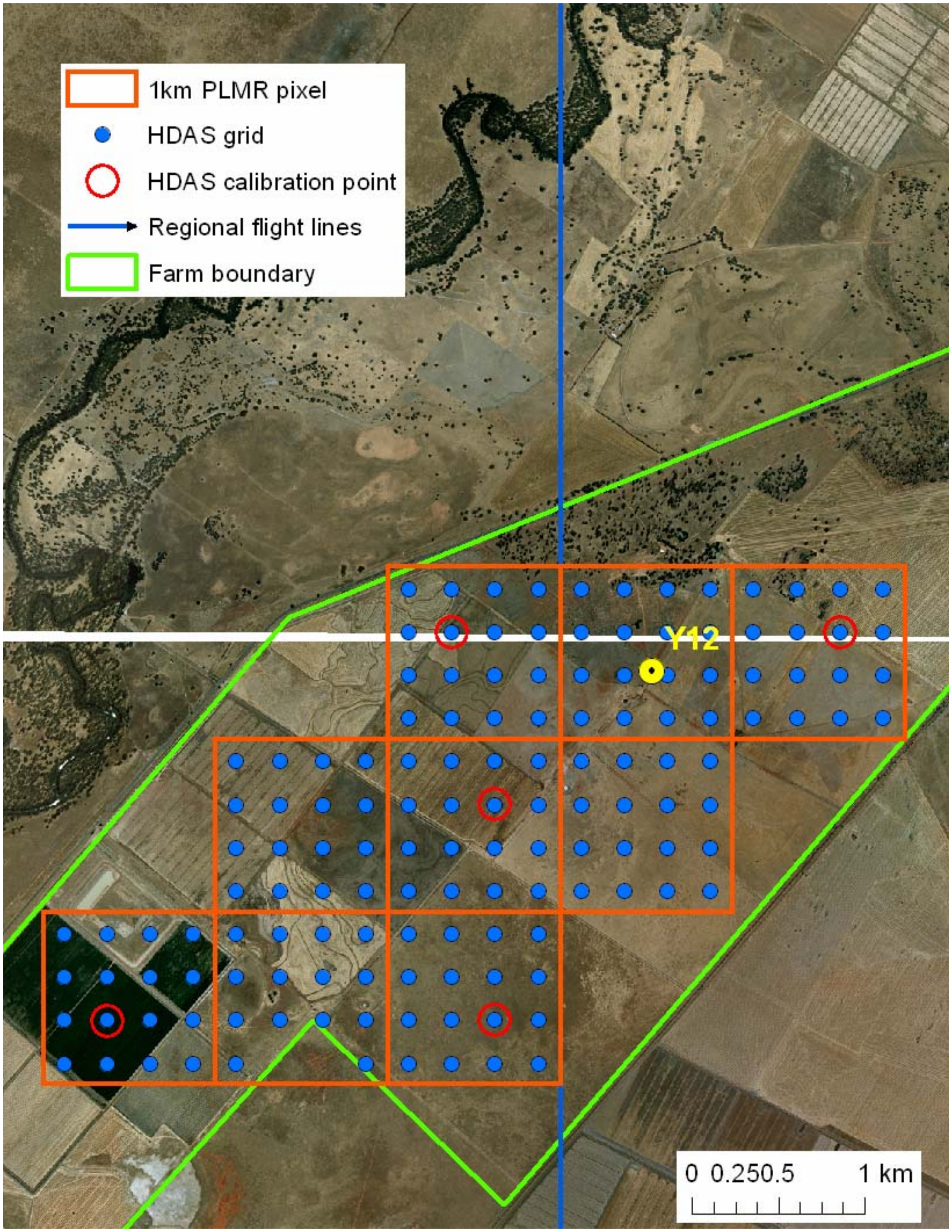


Fig. 5.6. Map the soil moisture sampling grid in Spring Bank.

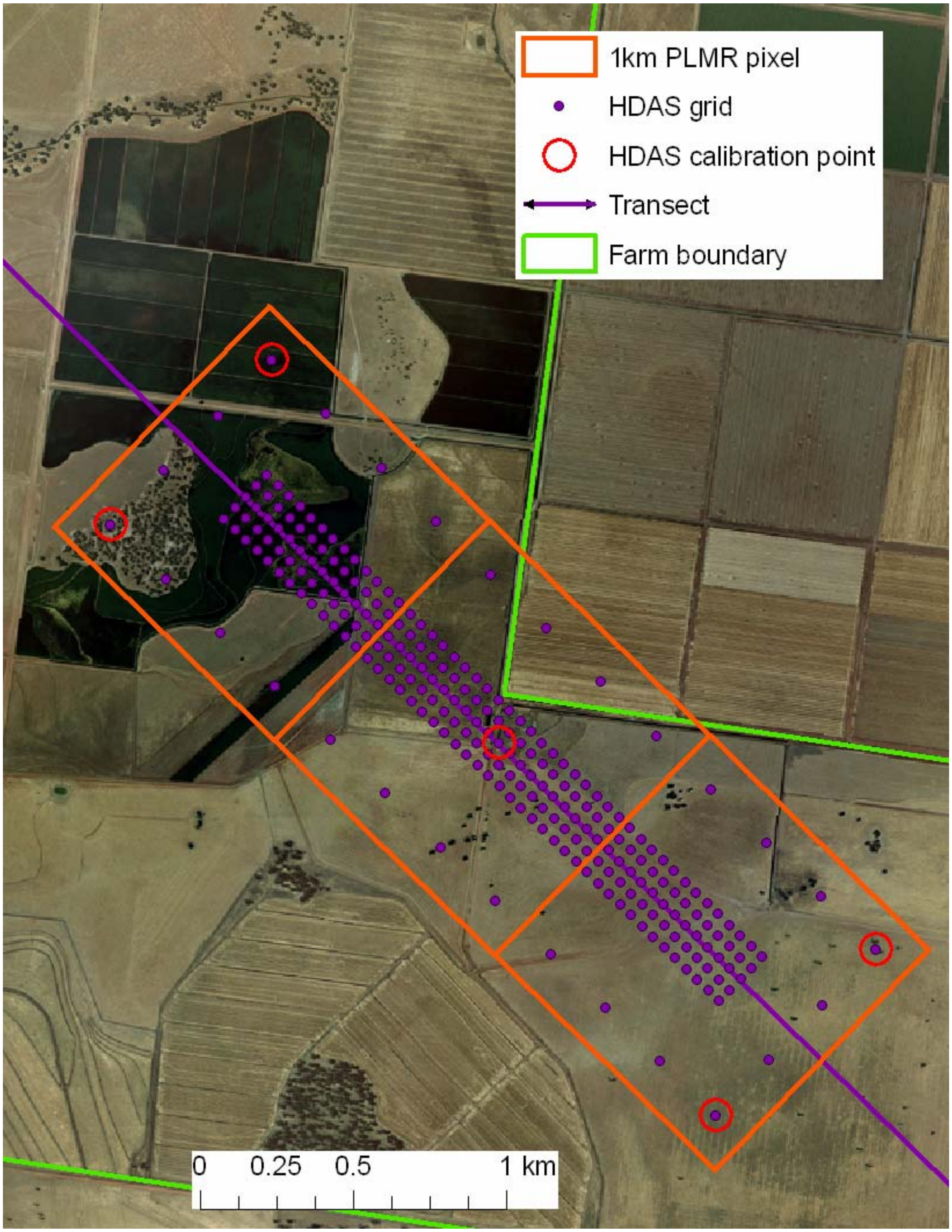


Fig. 5.7. Map of the soil moisture sampling grid in Uri Park (Y1). Note that the monitoring station is off to the top left.

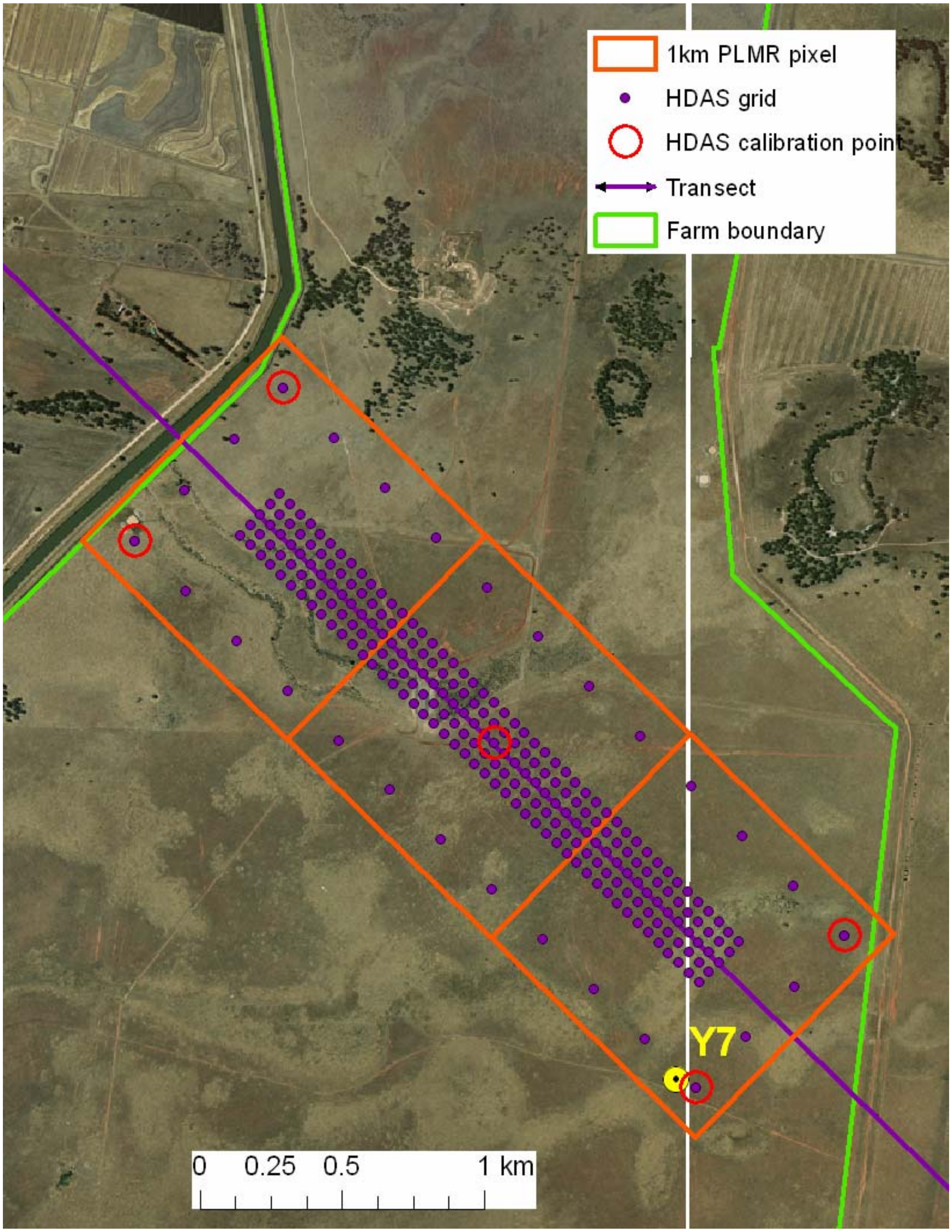


Fig. 5.8. Map of the soil moisture sampling grid in Tubbo.

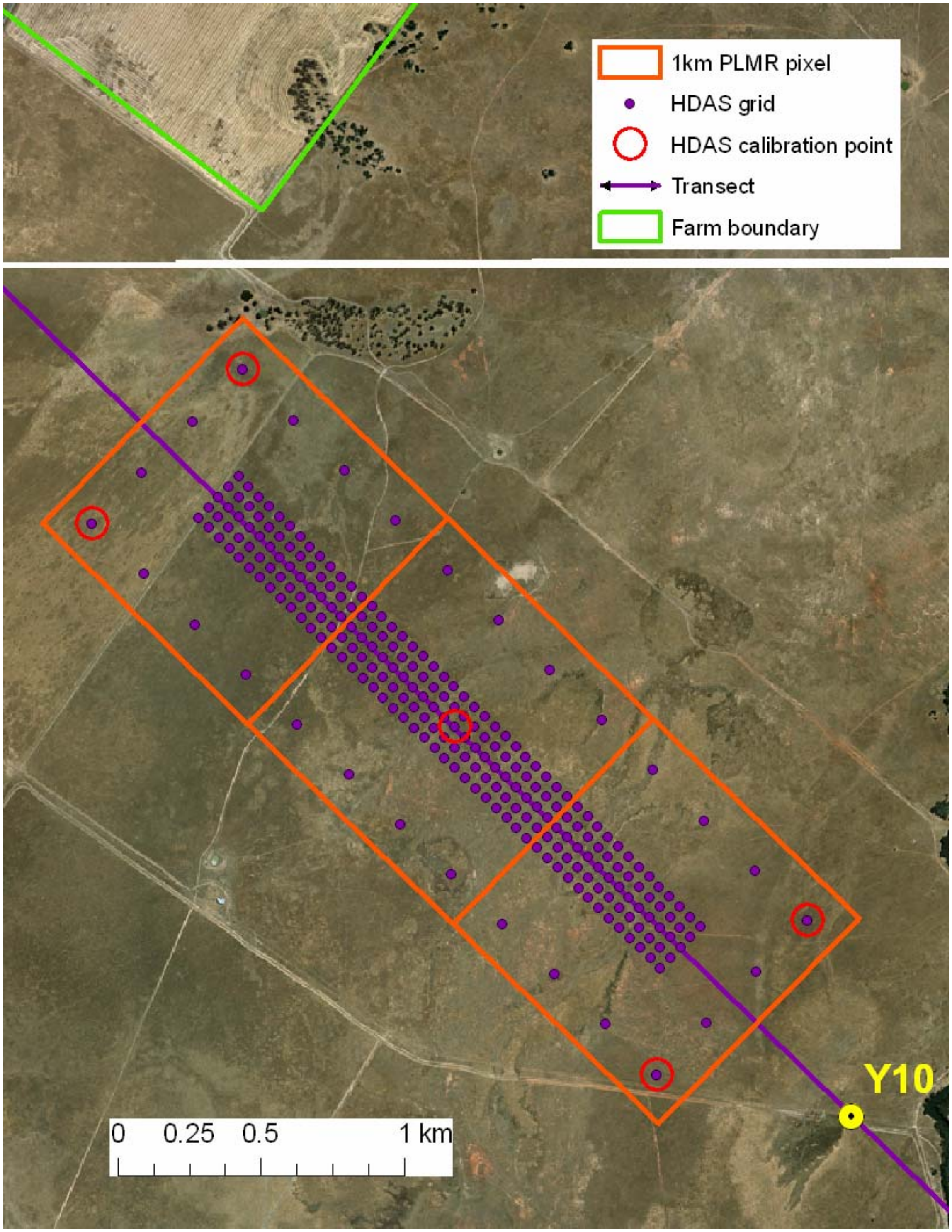


Fig. 5.9. Map of the soil moisture sampling grid in Cherevelis.

5.1.3.1 Regional monitoring

Soil moisture measurements will be made at 250m resolution on regional days. Measurement points are arranged on a regular grid extending 3km in the north-south direction and 3km in the east-west direction. The 3 by 3km box is placed within the farm boundary so as (i) the area surrounding the soil moisture station is covered and (ii) the number of measurement points on both sides of regional flight lines is a multiple of 4. The second requirement will be used when averaging the 250m resolution ground data to the actual spatial resolution of PLMR data (1km).

Three distinct HP measurements (less that 1 meter apart) will be undertaken at each measurement point of the soil sampling grid (see Fig. 5.3). This will allow reducing the effect of random errors in local scale soil moisture measurements. The total number of HP readings per farm will be 144 × 3 = 432.

5.1.3.2 Transect monitoring

Soil moisture measurements will be made at 50m and 250m resolution on transect days. The measurement points are placed on a regular grid along the transect line. The 50m resolution grid is 2250m long, 250m wide and ideally centred on the soil moisture station. To fill the gap in the 1km pixels along the multi-incidence transect line, additional points at 250m resolution are added around the high-resolution soil moisture grid.

Three distinct HP measurements (less that 1 meter apart) will be undertaken at each measurement point of the soil sampling grid. This will allow reducing the effect of random errors in local scale soil moisture measurements. The total number of HP readings per farm will be (225+28) × 3 = 759.

5.1.3.3 HDAS calibration

The HPs require a calibration equation to convert the measured dielectric constant into a soil moisture value. This equation will be derived from the comparison of HP readings and gravimetric measurements.

Volumetric soil samples will be collected every day in the six farms Y1, Y2, Y7, Y9, Y10 and Y12. The gravimetric water content will be computed from the weight of soil samples before and after oven drying. A site specific calibration of all the HP sensors will be developed based on this data set.

For every sampling day, 5 soil samples will be collected per soil moisture grid, resulting in a total of 45 gravimetric measurements for regional farms (3 sampling days/week) and 30 for transect farms (2 sampling days/week). The predefined location of the soil samples is illustrated in Fig. 5.3 to 5.9.

Preferably HP readings are made in the sample being taken. If this proves not to be possible due to moist soil sticking to the probe, a minimum of 3 HP readings should be made at not more that 10cm from the soil sample (see Fig 5.10).

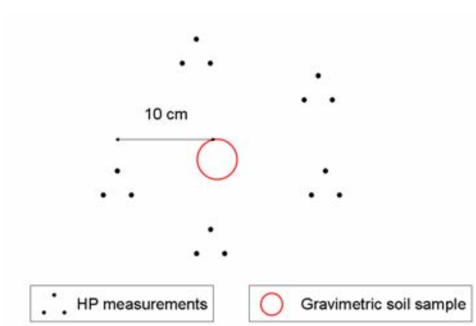


Fig. 5.10. A minimum of 3 HP measurements should be made in a radius of 10 cm around the soil sample.

5.1.4 Vegetation sampling

The objective of the vegetation sampling is to provide observations of vegetation water content in PLMR pixels and establish relationships between ground measurements and optical satellite/airborne data. For these purposes, surface reflectance and LAI measurements will be collected together with vegetation samples for each of the major vegetation types occurring in the region.

5.1.4.1 Vegetation characterisation

Biomass/vegetation water content (g of water/g of biomass) is an important parameter for modelling land surface emission at L-band. Vegetation water content will be derived from vegetation samples taken at the vegetation sampling locations.

Surface reflectance data is valuable in developing methods to estimate the vegetation water content and other canopy variables. Observations made concurrent with biomass sampling provide the essential information needed for larger scale mapping with satellite observations. In addition, reflectance measurements made concurrent with MODIS overpasses allow the validation of reflectance estimates based upon correction algorithms. During NAFE'06, the MultiSpectral Radiometer (MSR) developed by CROPSCAN (http://www.cropscan.com) will be used. Note that MSR bands will coincide with the Landsat Thematic Mapper and MODIS instruments. Leaf area will be measured with a LAI-2000.

5.1.4.2 Vegetation sampling strategy

The objective of the vegetation sampling is to characterise individual 1-km PLMR pixels at focus farms so as to describe all dominant vegetation types at various stages of maturity and vegetation water content throughout the 3-week campaign. The best way to achieve this will be left to the vegetation team. However, following are some recommendations of the general approach to be followed.

Vegetation samples for biomass and vegetation water content and surface reflectance/LAI measurements will be collected in 1km boxes, which are meant to represent 1km resolution PLMR pixels. Within each 1km box, the major vegetation types will be characterised by making measurements at a minimum of 5 sampling locations distributed within homogeneous crops/paddocks. Fig. 5.11 illustrates the rationale of the vegetation sampling locations according to the type of flight undertaken during the day (regional or transect flights), the 1km box classification and the major vegetation types.

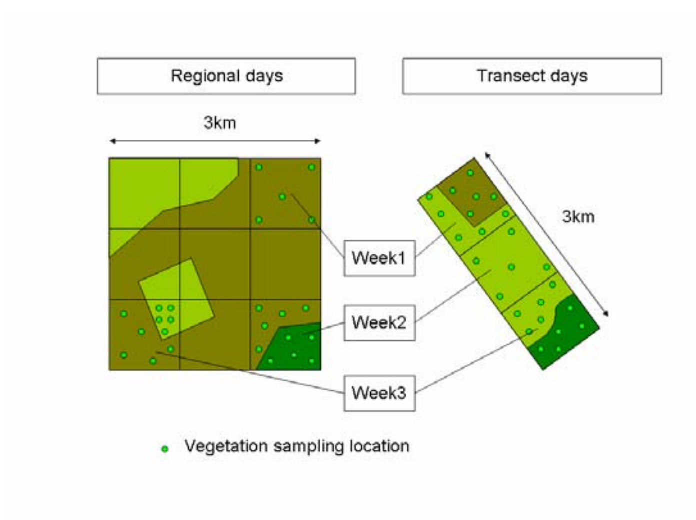


Fig. 5.11. Rationale of the vegetation sampling during regional and transect days.

The main vegetation types occurring in the Yanco area by order of surface area are: dry land pasture, irrigated (flooded) rice, irrigated wheat, irrigated pasture, dry land wheat and fallow. Secondary vegetation types are: barley, maize, canola, soybeans and lucerne.

The main vegetation types that will be sampled are:

- dry land pasture
- irrigated wheat
- irrigated pasture
- dry land wheat
- fallow

Rice is not included in the list of sampled vegetation types for two reasons:

1. rice crops will be either bare soil or standing water at the beginning of the experiment and
2. when rice will stand above water level (likely in early to mid November), there will be access issues to undertake measurements in the field.

However, if access is feasible and the rice growing allows for taking vegetation samples and reflectance/LAI measurements, several vegetation sampling locations could be arranged during the field experiment. This may prove to be important for understanding and removing the rice contamination from 1km PLMR data.

The additional farms in the CIA drawn on the map of Fig 5.12 may be used to sample secondary cropping types and the main cropping types not represented in the primary farms.

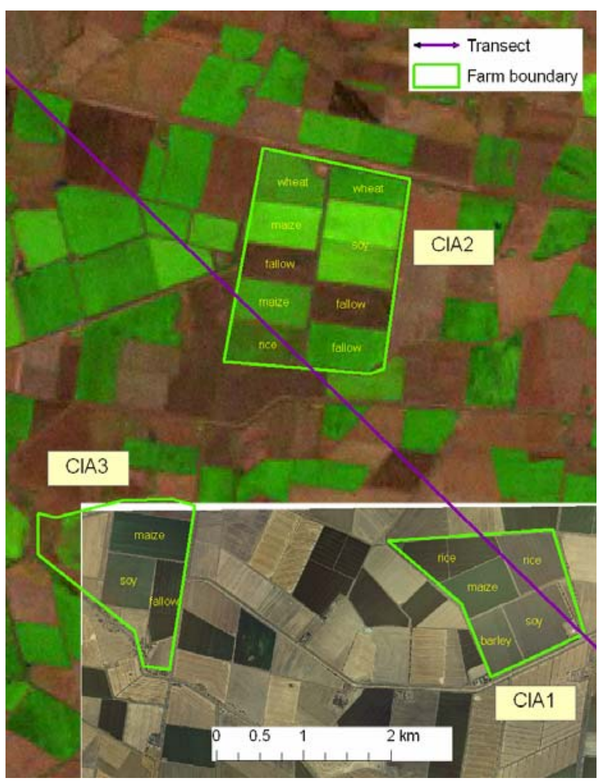


Fig. 5.12. Additional farms in the CIA for the vegetation sampling. See also Fig. 5.1.

5.1.5 Other data

5.1.5.1 Soil 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 only once during the campaign at a minimum of 5 locations on each farm (same locations as gravimetric measurements) to capture the different roughness characteristics according to land cover type.

The equipment will circulate between soil moisture teams so each team has 1 week only to undertake these measurements (2 farms per team).

5.1.5.2 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 collected for hydraprobe calibration.

5.1.5.3 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. The percentage of surface rock cover will be estimated visually at all sampled sites (at least once during the field campaign) and prompted in the individual iPAQs.

5.1.5.4 Leaf wetness

The presence of dew on vegetation at the time of SMOS overpass (6am) 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. 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. These values will be prompted in the individual iPAQs.

5.1.5.5 Land use/cover classification

Land use is useful information that supports the interpretation of remotely sensed data of various natures. It is therefore important to characterise 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 at the sampling location and assigning one of the following subclasses. This will be done once during the field campaign.

The predefined list of land use and cover type is as follows:

1. Dry land pasture
2. Irrigated pasture
3. Cropping: bare soil (rice crops not flooded yet)
4. Cropping: flooded rice
5. Cropping: Irrigated wheat
6. Cropping: Dry land wheat
7. Cropping: Fallow
8. Cropping: Barley
9. Cropping: Soybean
10. Cropping: Maize
11. Cropping: Oats
12. Cropping: Canola
13. Cropping: Lucerne
14. Cropping: Other
15. Open wood land
16. Water body (other than rice)
17. Building

5.1.6 Ground sampling schedule

Ground measurements in Yanco will be made everyday of the 5-day week starting on Tuesday. The four teams will drive from the base in the Yanco Research Institute to the farms located at about 40 to 100 km away and will walk/drive across the farms to collect data.

There will be three dedicated soil moisture (SM) teams and one team focused on the vegetation (VEG) sampling.

SM teams A, B and C will make soil moisture measurements in the 3 regional farms Y2, Y9 and Y12 during regional flights and in the 3 transect farms Y1, Y7 and Y10 during multi-incidence flights respectively. Table 6.2 summarises the ground sampling schedule for the three soil moisture teams. Each team will operate independently and will sample one farm per day.

The schedule for the VEG team will be left flexible, but based upon the following general guidelines:

1. the transect farms (Y1, Y7 and Y10) and the additional farms in the CIA should be sampled on transect days (either on Wednesday or Friday).
2. sample a minimum of one 1km box of each regional farm (Y2, Y9 and Y12) per week.

An example of the ground sampling schedule is provided in Table 6.3.

Table 6.2. Ground sampling schedule for the soil moisture teams A, B and C.

Week	Tue			Wed			Thu			Fri			Sat		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12
2	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12
3	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12	Y1	Y7	Y10	Y2	Y9	Y12

Regional days
Transect days

Table 6.3. Ground sampling schedule for the vegetation team.

Week	Tue	Wed	Thu	Fri	Sat
	VEG	VEG	VEG	VEG	VEG
1	Y9	Y7,Y10	Y12	Y1,CIA	Y2
2	Y9	Y7,Y10	Y12	Y1,CIA	Y2
3	Y9	Y7,Y10	Y12	Y1,CIA	Y2

5.2 Ground Monitoring in Livingstone

In the Livingstone Creek catchment, the ground component of the NAFE'06 field campaign consists of two aspects:

1. Network of ground stations (refer to section 4);
2. Spatial soil moisture mapping;

The objective of the ground measurements in the Livingstone Creek is to collect surface soil moisture data in areas where soil is representative of the major soil types occurring in the subcatchment. Ground measurements will be undertaken on Mondays concurrently with the medium resolution flights in Kyeamba by a team of 2 people from the Department of Natural Resources of Wagga Wagga.

Soil moisture sampling points have been determined based on a soil classification, which was derived from a combination of soil texture mapping and the Fuzzy Landscape Analysis GIS (FLAG) landform modelling of Summerell et al. (2005). Landform information is used to differentiate the soil types as function of the soil catena sequence (ridge tops, upper slopes, lower slopes, and flats). The major soil texture types and landforms, and the location of the 27 soil moisture sampling points within the Livingstone Creek are illustrated in Fig. 5.13.

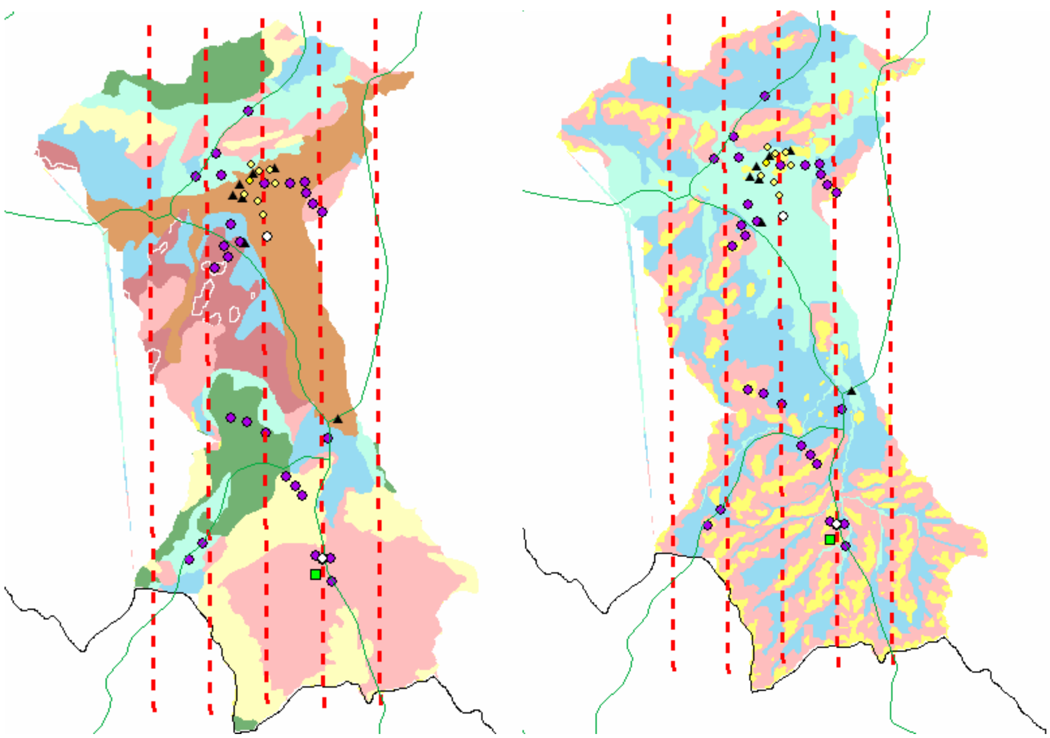


Fig. 5.13. Major soil texture types (left) and landforms (right) of the Livingstone Creek catchment. Yellow dots are existing soil moisture monitoring. Black triangles are stream gauging stations. White dots are weather stations. Green square is a Bowen Ratio. Purple dots are the proposed manual soil moisture field data collection sites. The medium-resolution flight lines are also shown.

These representative sampling will then be extrapolated back through the Livingstone catchment based on the soil landscape combined with FLAG landforms categories. If relationships can be developed between airborne soil moisture data and the combined soil landscape-FLAG landform spatial data then extrapolation to the whole of the Kyeamba catchment should be possible, hence helping to close a water balance at the end of the Kyeamba system. Fig. 5.14 shows the major landforms in the Kyeamba catchment.

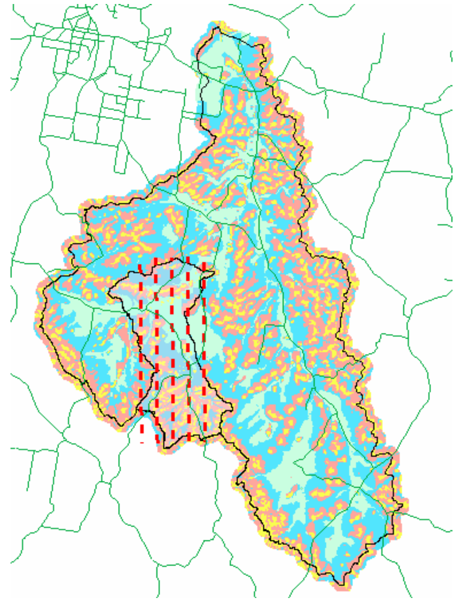


Fig. 5.14. FLAG landform modelling of the Kyeamba Creek catchment.

5.3 Ground Monitoring in Yenda

The ground monitoring in Yenda will be composed of:

1. Network of soil moisture profile stations operating continuously in the Yenda site (refer to section 4);
2. Three Bowen ratios operating continuously in the Yenda site (refer to section 4);
3. Spatial soil moisture mapping;
4. NDVI measurements;
5. Soil/vegetation skin temperature measurements;
6. Canopy cover characterization.

The sampling area will be composed of the two vine paddocks of the Yenda site and several crops along the aircraft path between the Narrandera airport and the Yenda site. While the measurements at Yenda will be undertaken concurrently with aircraft flights, the measurements along the aircraft path to Yenda will take place on the day before the flights. The focus crops on the way to Yenda have been chosen to so as to (i) cover a range of vegetation types occurring between Narrandera and Yenda and (ii) make use of existing additional soil moisture probes. The location and extent of the additional farms in the Yenda area are illustrated in Fig. 5.15.

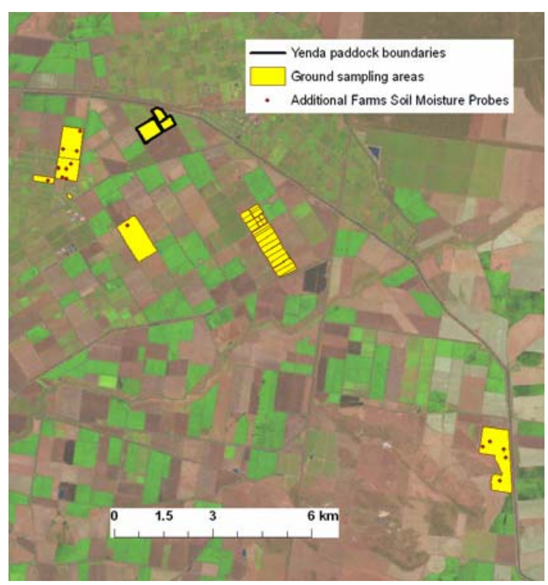


Fig. 5.15 Additional farms in the Yenda area.

A team composed of two people from CSIRO Griffith will be in charge of the sampling operations related to the aircraft flights over Yenda. Ground measurements include:

- Near-surface soil moisture mapping:

The 0-5cm soil moisture will be measured with gravimetric samples taken on a 50m resolution grid, which is the spatial resolution of the high-resolution PLMR data. Three soil samples will be taken at each point of the sampling grid. For row crops (e.g. the vineyards of the Yenda site), 3 soil samples will be taken at the plant foot and 3 in between the rows.

- Ground-based NDVI and skin soil/vegetation temperature:

During the aerial survey time periods, on ground measurements of NDVI and canopy and surface soil temperature will be measured using a portable Greenseeker NDVI sensor and infra red temperature sensors mounted to a quad bike. Instrumentation is described in Hornbuckle et al. (2006) and shown in the photographs of Fig. 5.16.

- Canopy cover assessment:

Canopy cover assessment and light interception measures will be undertaken using a delta T ceptometer and digital photography at multiple areas throughout the vineyards and in the focus crops along the aircraft path to the Yenda site.

Fig. 5.16 The NDVI and TIR sensors are mounted on a quad bike. On the right, using a ceptometer.

6 Air Monitoring

The Polarimetric L-Band Multibeam Radiometer (PLMR) and supporting instruments (thermal imager, NDVI scanner, Lidar, digital camera) will be flown aboard the Small Environmental Research Aircraft (SERA) to collect multi-spectral airborne data over the Yanco area, the Kyeamba catchment and the Yenda site. Technical details about the platform and scientific payload are presented in this section.

Two identical SERAs will be based at Narrandera airport (see Fig. 6.1) and available to operate daily from there. PLMR and the thermal imager will be mounted on one aircraft while the other three instruments will be mounted on the second SERA. A total of 100 mission flight hours will be allocated for the PLMR/thermal imager flights and 20 mission flight hours for the NDVI/Lidar/Aerial photography flights. The different flights are listed in Table 6.1 and illustrated in Fig. 6.1.

The PLMR/thermal imager flights will be undertaken at high, medium and low altitude to provide PLMR data at low (1km), medium (250m) and high (50m) spatial resolution. The flights at high altitude represent the core of NAFE'06. They will provide L-band data 5 days per week in various parts of Yanco and one day per week in Kyeamba. The PLMR instrument will be used in the mapping mode to collect mono-angular data over regional areas and in the multi-incidence mode to collect multi-angle data along a transect line on alternate days in Yanco. Additionally, the PLMR/thermal imager will be flown at medium and low altitude to provide PLMR data at higher spatial resolutions over strategic areas. The medium-resolution flights will be undertaken in a portion of the CIA in Yanco and over the Livingstone catchment in Kyeamba. The high-resolution flights will be undertaken along the multi-incidence transect line over Yanco. Two flights at high-resolution have also been planned over the Yenda site.

The NDVI/Lidar/Aerial photo flights will be undertaken along the multi-incidence transect line in Yanco, over the medium resolution area of the PLMR flights in Yanco and Kyeamba, and for the Yenda site. These flights will only be undertaken twice; once during the first week of the campaign and once during the final week (or early the subsequent week) of the campaign.

Each flight type is presented separately and the flight schedule of NAFE'06 is described in detail at the end of this section.

Table 6.1. List of the different flights that will be undertaken during NAFE'06. PLMR is in "mapping mode" when the six beams are arrayed left-right and in "multi-incidence mode" when beams are arrayed fore-aft. For PLMR flights, the distance between adjacent flight lines is in general equal to 5 PLMR pixels so as the outer PLMR beams overlap the outer beams of adjacent flight lines.

Flight type	**Altitude AGL**	**Altitude ASL**	**PLMR Mode**	**Coverage**	**Number of flight lines**	**Distance between adjacent flight lines**	**Nominal spatial resolution**				**Label**
							PLMR	**TIR**	**NDVI**	**Lidar**	
Regional Yanco	10 000ft (3048m)	10 410ft (3173m)	Mapping	40 by 55km	8	5000m	1000m	20m	N/A	N/A	A
Regional Kyeamba	10 000ft (3048m)	10 997ft (3352m)	Mapping	40 by 50km	8	5000m	1000m	20m	N/A	N/A	B
Multi-incidence Yanco	5 000ft (1524m)	5 410ft (1649m)	Multi-incidence	75 by 1km	3	0	500m	10m	N/A	N/A	C
Medium-resolution CIA	2 500ft (762m)	2 910ft (887m)	Mapping	5 by 32km	4	1250m	250m	5m	N/A	N/A	D
Medium-resolution Livingstone	2 500ft (762m)	4 249ft (1295m)	Mapping	7 by 15km	6	1250m	250m	5m	N/A	N/A	E
High-resolution Yanco	500ft (152m)	925ft (282m)	Mapping	75 by 1km	4	250m	50m	1m	N/A	N/A	F
High-resolution Yenda	500ft (152m)	951ft (290m)	Mapping	3 by 0.8km	5	200m	50m	1m	N/A	N/A	G
NDVI/Lidar/ aerial photos Transect	1 640ft (500m)	2 028ft (618m)	N/A	75 by 1km	3	350m	N/A	N/A	<1m	<1m	H
NDVI/Lidar/ aerial photos CIA	1 640ft (500m)	2 005ft (611m)	N/A	5 by 32km	15	350m	N/A	N/A	<1m	<1m	I
NDVI/Lidar/ aerial photos Livingstone	2 133ft (650m)	3 881ft (1183m)	N/A	7 by 15km	19	500m	N/A	N/A	<1m	<1m	J
NDVI/Lidar/ aerial photos Yenda	1 640ft (500m)	2 093ft (638m)	N/A	3 by 0.8km	3	350m	N/A	N/A	<1m	<1m	K

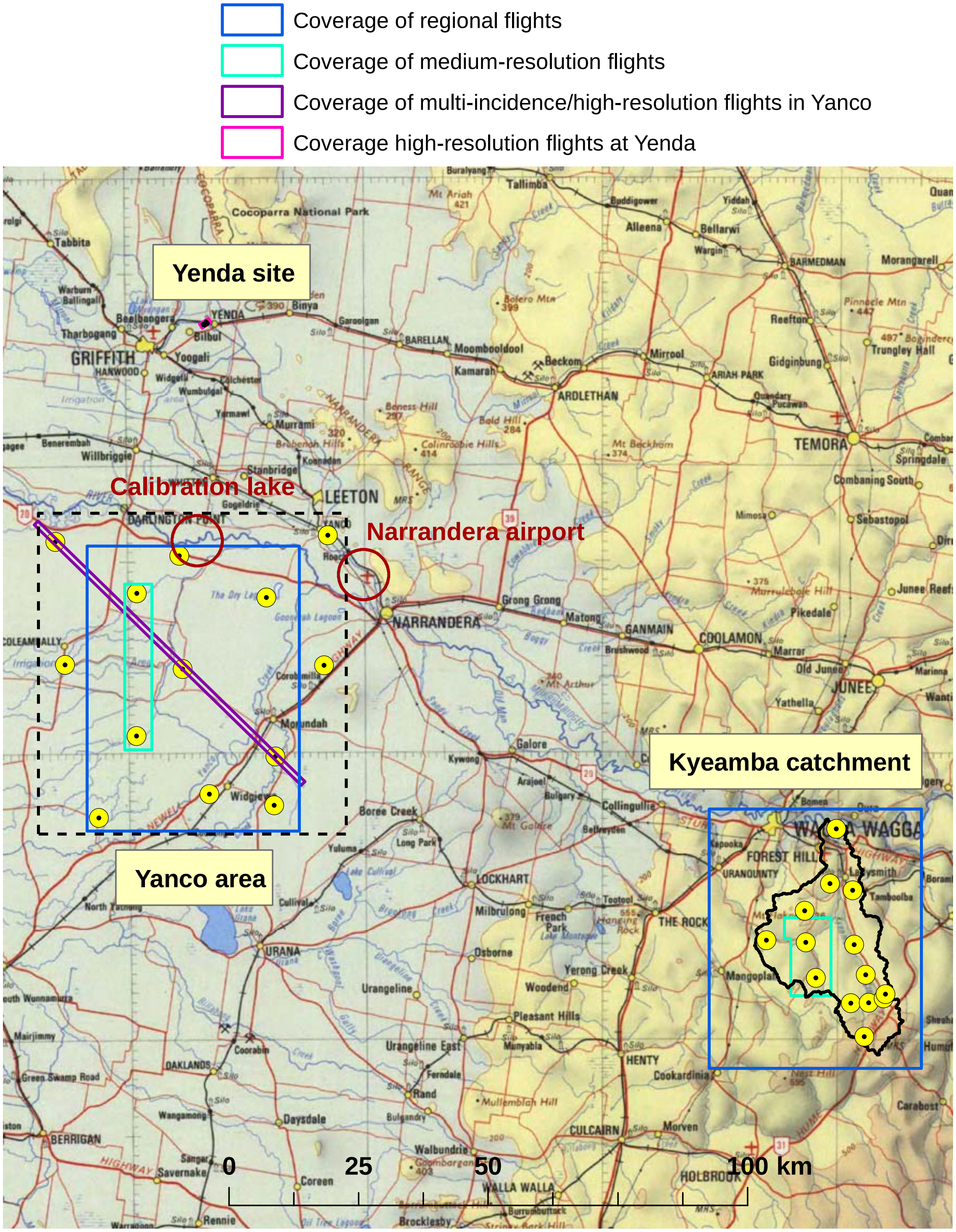


Fig. 6.1. Illustration of the coverage of PLMR/thermal imager flights over the three study sites.

6.1 Regional Flights

Regional flights represent the core activity of NAFE’06. They will provide L-band data at 1km resolution over two areas of approximately 40 by 50km. The 1km PLMR data will be used to mimic a SMOS pixel at two locations 100km apart, one in Yanco and one in Kyeamba. During the campaign, there will be nine regional flights in Yanco with a frequency of 1 flight every 2-3 days and 4 regional flights in Kyeamba with a frequency of 1 flight per week.

The coverage of regional flights in Yanco is a 40 by 55km area centred in the 60km box of the Yanco area. All soil moisture sites are included except Y1, Y3, Y6 and Y8. This area has been determined to maximise the number of ground stations while accounting for the flight times allowed for NAFE’06. A portion of the CIA is included to assess irrigation impacts on PLMR data.

The regional area of Kyeamba is a 40km by 50km area that includes the whole catchment and Wagga Wagga. The city of Wagga Wagga is included in the Kyeamba regional area to assess the impact of urban interferences on L-band airborne data.

Regional mapping will be undertaken at a nominal altitude of 10000ft above ground level (AGL). Actual altitude above sea level (ASL) will be 3173m for the flat Yanco area. For the Kyeamba catchment, actual altitude ASL will be of 3352m, which will result in a pixel resolution varying from approximately 900m to 1030m (due to variable terrain elevation) with a mean resolution of 1000m.

The flight lines over Yanco and Kyeamba are represented on the maps of Fig. 6.2. The aircraft will fly in the direction north-south to minimise the number of turns between flight lines. Note that this also approximates the direction that SMOS will overpass (SMOS inclination is 98.4 degrees). This flight direction will also minimise the sun glint effects on thermal data. In the east-west direction, flight lines have been located so as permanent monitoring stations are as much as possible located near the centre of PLMR swath.

Regional flights will be undertaken between 8am an 12am (not as early as 6am) to minimize possible effects of dew and collect thermal data of relevance for ET estimation.

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, Tables A1 and A2.

6.2 Multi-incidence flights

During multi-incidence 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 (up to six) different incident angles. Given that every observation at a particular angle is bi-polarised, this will provide a set of six or more (up to twelve) independent brightness temperature observations.

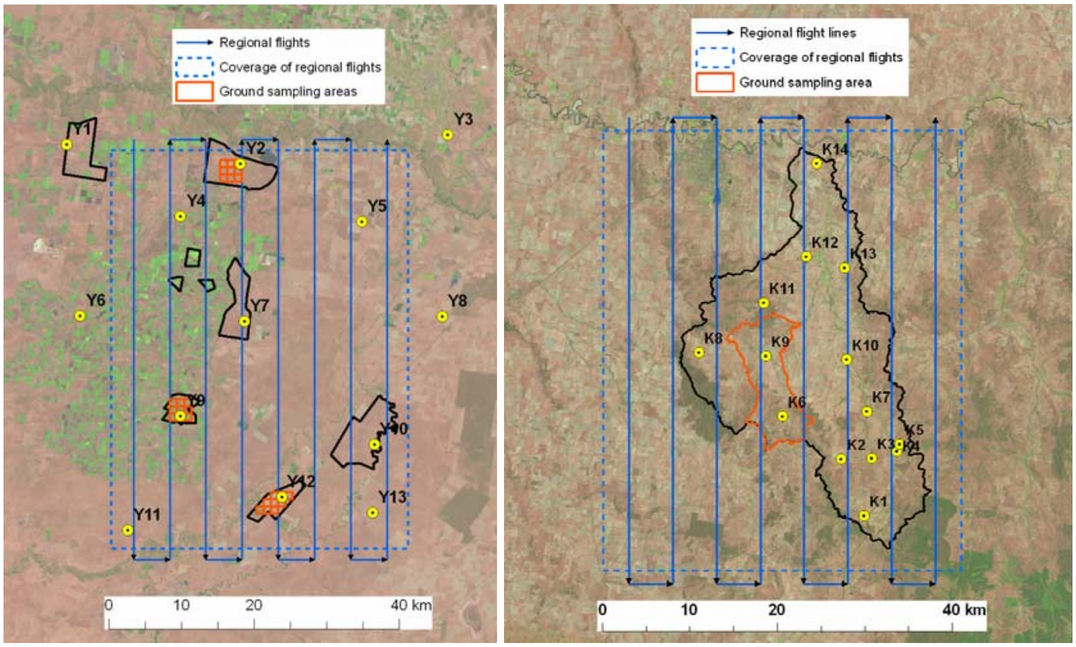


Fig. 6.2. Illustration of the regional flights in Yanco and Kyeamba.

Multi-incidence observations will be undertaken along a transect line crossing the whole Yanco area. The line going through Y1, Y7 and Y10 was chosen because these three stations are practically aligned, and it gives the best possible range of rainfall variations and vegetation types. The 75km-long transect line is illustrated in Fig. 6.3. The start and end point coordinates and coverage are given in Table A3, Appendix A.

The transect line will be flown three times successively to avoid missing some angular data due to variations in the aircraft attitude.

The multi-incidence flights will be flown at the altitude of 5000ft AGL to provide 500m resolution PLMR data along the transect line. In fact, due to slight changes in the aircraft attitude, multi-angle 500m data are expected to fall in the 1km width area shown in Fig. 6.3.

The multi-incidence flights will be flown alternatively as close as practically possible to 6am and 6pm to test the usefulness of the SMOS data collected in the morning and the evening.

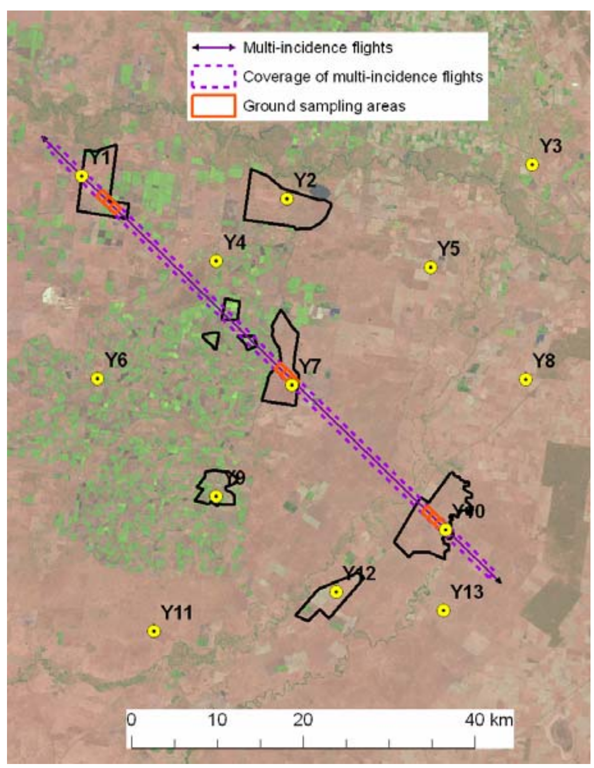


Fig. 6.3. Illustration of the multi-incidence transect line in Yanco.

6.3 Medium-resolution Flights

The medium-resolution flights will be undertaken on the same days as regional flights. The objective of those flights is to provide PLMR data at 250m resolution to investigate the scaling behaviour of 1km L-band brightness temperature and 1km soil moisture over two focus areas. Moreover in the Yanco area, medium-resolution flights will cover a portion of the CIA to assess the impact of irrigation (rice cropping) on the 1km data. In the Kyeamba catchment, medium-resolution flights will cover the Livingstone subcatchment to provide PLMR data at a spatial resolution consistent with the spacing between the soil moisture sites operating on the O'Briens farm (located near K9).

Mapping at medium resolution will be undertaken at a nominal altitude of 2,500ft AGL resulting in a ground resolution of approximately 250m. The actual flight altitude for these flights will be 887m ASL for the CIA and 1081m ASL for the Livingstone subcatchment

The medium-resolution flight lines are illustrated in Fig. 6.4. Flight lines have been arranged so as four 250m resolution pixels fall nominally into the 1km PLMR pixels of the regional flights. Regional and medium-resolution flight lines are therefore parallel and the distance between them is a multiple of 250m.

The coverage of the medium-resolution flights in Yanco is a 5 by 32km area in the CIA. This area has been chosen in such a way that sites Y9 and Y4 as well as the farms involved in the ground sampling around Y9 are included.

The medium-resolution flights in Kyeamba cover a 7 by 15km area that includes K6 and K9 and the Livingstone soil moisture monitoring network at K9.

Coordinates for starting and ending points and coverage of medium-resolution flight lines are described in Tables A4 and A5 in Appendix A.

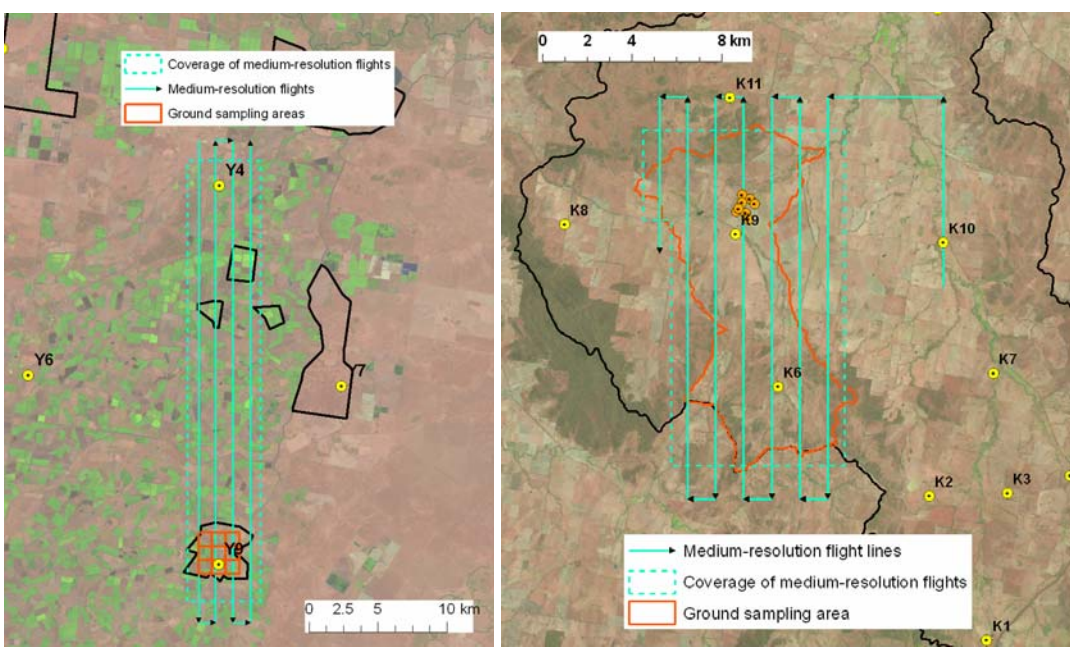


Fig. 6.4. Illustration of the medium-resolution flights in the CIA in Yanco and over the Livingstone subcatchment in Kyeamba.

6.4 High-resolution Flights

6.4.1 Yanco high-resolution flights

The high-resolution flights in Yanco will be undertaken on the same days as multi-incidence flights. The objective of those flights is to provide 50m resolution PLMR data for verification of 500m multi-incidence PLMR data. High-resolution data will be directly comparable to ground measurements, and will thus provide the linkage between ground sampling and airborne data.

The transect line used for multi-incidence flights will be flown at 500ft AGL to provide 50m resolution data along this transect. Four flight lines at 125m and 375m on each side of the multi-incidence flight line are required to cover the width of multi-incidence PLMR data (the multi-incidence data at 500m resolution are expected to fall in a width of 1km along the transect line).

Yanco high-resolution flight lines and coverage are illustrated in Fig. 6.5 and described in Table A.6 in Appendix A.

6.4.2 Yenda high-resolution flights

The high-resolution flights in Yenda will provide 50m surface soil moisture and 1m resolution TIR data. Given the relatively small size of the site, SERA will fly at the lowest altitude allowed (500ft) to achieve the highest spatial resolution. Actual flight altitude will be 290m ASL (Yenda altitude: 138m).

Airborne TIR data will be used to monitor crop water stress within the three adjacent paddocks. To make sure that no TIR data will be missed at the edges, the distance between

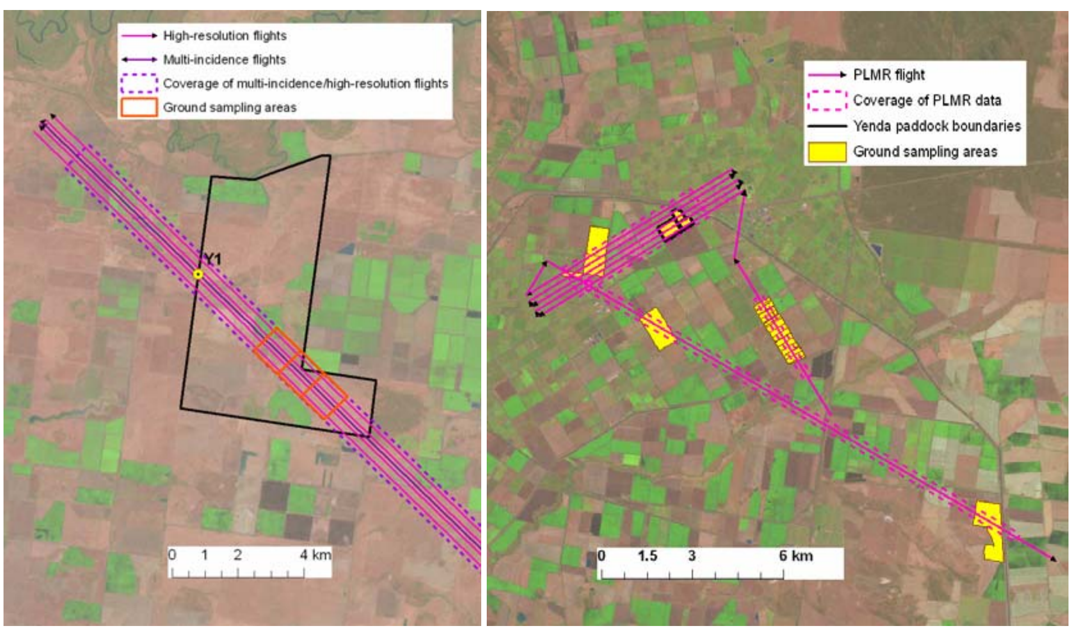


Fig. 6.5. Illustration of the high-resolution flights along the multi-incidence transect line in Yanco (left) and over the Yenda area (right).

adjacent flight lines has been shortened by 20% compared to the other PLMR flights (see Table 6.1). The flights over Yenda site and coverages are illustrated in Fig. 6.5 and described in Table A.7 in Appendix A.

6.5 PLMR 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 (see Fig 6.6). 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 to be used is Tombullen water storage located in the north of the Yanco area near Y2 (Fig. 6.6). Note that dead trees stand over the water level over half of the area of the lake, mostly in the eastern part.

As Tombullen storage is on the way from the Narrandera airport to the first flight line of all flights in Yanco, the calibration flight will occur during the airport-study site ferry. Given the relatively small size of the water storage, PLMR will be flown at the lowest altitude allowed (500ft) so as the 300m swath of the instrument will be totally included within the lake boundary along a distance of at least 1km Calibration flights are illustrated in Fig 6.7.

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 34.649S and 146.152E. Furthermore, transects of water temperature and salinity in the top 1cm layer will be undertaken with a handheld temperature and salinity meter (Hydralab

Fig. 6.6. Upper left: undertaking a sky cold point calibration with PLMR; upper right: the calibration box used for warm point calibration; downer left: the buoy used to monitor water temperature and salinity on the lake Tombullen; downer right: view of the Tombullen water storage from the bank.

Quanta®) on four occasions. This will involve making transects at 100m spacing once per week (on Mondays) through on the monitoring station. The purpose of these measurements is to check for spatial variability. Rodger Young will be responsible for these measurements.

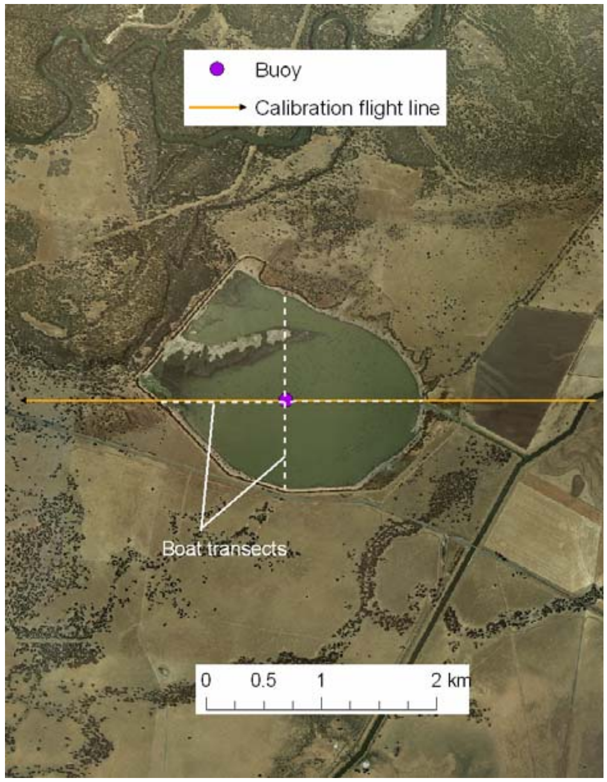


Fig. 6.7. Calibration flight over the Tombullen water storage.

6.6 NDVI, Lidar and aerial photography

The NDVI scanner, laser scanner and digital camera will be carried onboard the second SERA to obtain high-resolution NDVI mapping, terrain (and possibly vegetation height) and aerial photography over four focus areas: the transect line in Yanco, the medium-resolution area in the CIA, the medium-resolution area in Kyeamba (Livingstone) and the Yenda site. Given that NDVI and vegetation height are not expected to vary significantly over a 3-week time period, those flights will take place around noon, only twice but on clear sky day, in weeks 1 and 3 (or early week 4).

Given the maximum measurement range of the laser scanner (650 m for vegetation), the NDVI/Lidar/aerial photography flights will be undertaken at 500m AGL for Yanco and Yenda flights, resulting in a ground resolution of 25cm for NDVI (0.80m in the along track direction at 50Hz) and laser data. The flight lines will be planned to have a nominal 1/6th of a swath width overlap based on the NDVI and laser scanners so that the distance between adjacent flight lines will be 350m. The flights in Livingstone will be at 650m above the highest point in the subcatchment (533m). The spacing between flight lines will be 500m to get a nominal 1/6th of a swath width overlap. Note that given the relatively high flight altitude over the Livingstone, Lidar data will not provide information on canopy height (only terrain). For all flights, the timing between photos will be 10s (to have a nominal 1/6th overlap, the needed timing between photos at 140km/h is 15s).

The NDVI/Lidar/aerial photography flight lines and coverages are described in Tables A.8-11 in Appendix A.

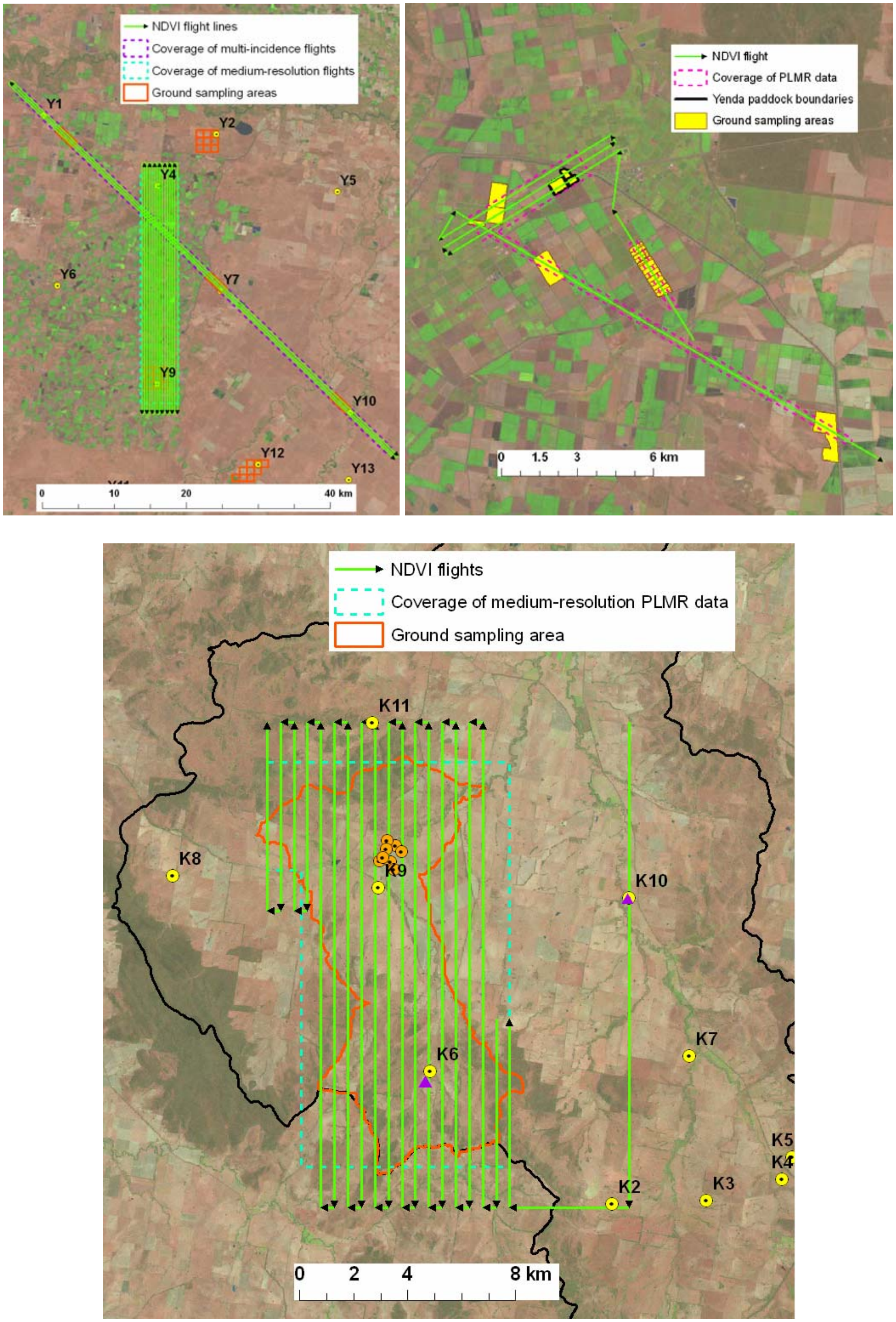


Fig. 6.8. Illustration of the NDVI/Lidar/aerial photos flights in Yanco, Yenda and Kyeamba.

6.7 Flight over the Tumbarumba Flux Station

The Tumbarumba flux station (see Fig. 6.9) is located in the Bago State forest in south eastern New South Wales: 35° 39' 20.6" S, 148° 09' 07.5" E. The forest is classified as wet sclerophyll, the dominant species is Eucalyptus delegatensis, and average tree height is 40 m. Elevation of the site is 1200 m and mean annual precipitation is 1000 mm. The instrument mast is 70 m tall. Fluxes of heat, water vapour and carbon dioxide are measured using the open-path eddy flux technique. Supplementary measurements above the canopy include temperature, humidity, windspeed, wind direction, rainfall, incoming and reflected shortwave radiation and net radiation. Profiles of temperature, humidity and CO2 are measured at seven levels within the canopy. Soil moisture content is measured using Time Domain Reflectometry, while soil heat fluxes and temperature are also measured. Hyperspectral radiometric measurements are being used to determine canopy leaf-level properties. More information about the Tumbarumba site can be found at http://www.dar.csiro.au/lai/ozflux/monitoringsites/tumbarumba/.

CSIRO Canberra will undertake an intensive campaign at the Tumbarumba station from 6 to 19 November. The experiment has 3 themes. One is to use 12C and 13C isotopes in CO_2 to partition respiration and photosynthesis. The second is to use the different fractionations of H_2O and HDO to partition evaporation from transpiration. The third is to study volatile organic emissions from the canopy. Normal flux and meteorological measurements will continue to be made during the campaign.

As part of this field campaign, the SERA used during NAFE'06 will fly over the Tumbarumba flux station on 12 November. The aircraft will carry the Lidar, thermal imager, NDVI scanner, digital camera, and some flux instruments to provide extra remote sensing data. Note that the flight date may change depending on weather.

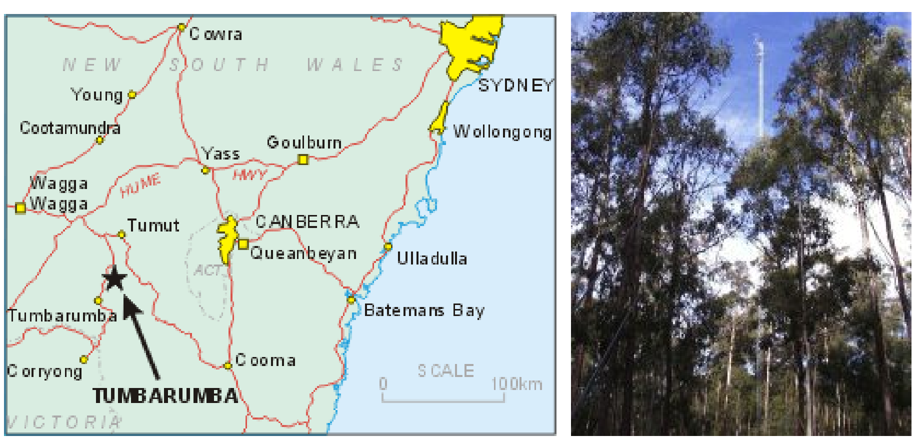


Fig. 6.9. Location and photo of the Tumbarumba 70m instrument mast.

6.8 Flight Schedule

One primary objective of NAFE'06 is to provide 1km soil moisture data for verification of downscaling techniques based on MODIS type data. Regional flights will therefore be undertaken so as to maximise Aqua/Terra overpasses.

Table 3.3 indicates that Aqua overpasses the study sites with a spacecraft elevation greater than 60° on Thursday and Saturday. Given the temporal frequency of the regional flights in Yanco (one every 2-3 days as SMOS), airborne L-band data should be mapped on Tuesday, Thursday and Saturday.

A summary of the flight schedule is provided in Table 6.2. The regional flights over Yanco will be undertaken on the same days as MODIS/Aqua overpasses on Thursday and Saturday and on the same days as MODIS/Terra overpasses on Tuesday and Thursday. The regional flights over Kyeamba will be undertaken on Monday concurrently with the MODIS/Aqua overpass on 6, 13 and 20 November.

Tables 3.6 and 3.7 report the collection time predicted for ASTER and Landsat. Given the flight schedule of Table 6.2, Landsat will collect data over Yanco during the regional flights on Tuesday 31 October and Thursday 16 November and during the transect flights on Wednesday 8 November. ASTER will collect data over Yanco concurrently with the regional/medium-resolution flights on the three Tuesdays of the experiment.

The multi-incidence flights will be undertaken in early morning on Wednesday (6am flights) and in late afternoon on Friday (6pm flights). The high-resolution flights in Yanco will be done on the same days as the multi-angular flights. The two high-resolution flights at Yenda will take place in week 1 and 3. The NDVI/Lidar/aerial photo flights will be undertaken twice, the first flight towards the start of the experiment (week 1) and the second towards the end (week 3 or early week 4). The flight days will be determined based on cloud free conditions.

Table 6.2. Flight schedule for the PLMR/thermal imager.

Week	Mon		Tue		Wed		Thu		Fri		Sat	
1	K	K	Y	Y	6am		Y			6pm	Y	
2	K	K	Y	Y	6am		Y			6pm	Y	
3	K	K	Y	Y	6am		Y			6pm	Y	
4	K	K										

Y/K	Regional flights in Yanco/Kyeamba
Y/K	Medium-resolution flights in Yanco/Kyeamba
	Multi-incidence flights in Yanco
	High-resolution flights in Yanco
	Time available for the flights over Yenda
	Note: only 1 Yenda flight in each of weeks 1 and 3 based on cloud free conditions

6.9 Flight time

The flight time is a strong constraint of the flight plans for NAFE'06. During the airborne experiment, the maximum number of flight hours is 4-5 h for a single flight. To allow time for pre/post flight activities, the flight hours should not exceed 6-7 h for an entire flight day. In addition, legislation regulations limit the total number of flight hours for a given aircraft to 110 h before the next scheduled maintenance. The flight schedule has been optimised so as to respect those limitations and to maximise the coverage of airborne data.

The expected duration of each flight is listed in Table 6.3. Flight hours are computed from an estimation of the flight distance, the aircraft speed and the time required for aligning the aircraft on a given flight line. The flight speed is estimated as 100km/h (54 knots) when the SERA climbs onto its nominal flight altitude, 180km/h (97 knots) during ferry and 144km/h (78 knots) when airborne instruments are collecting data. Based on similar flights undertaken during NAFE'05, the time between adjacent flight lines is estimated to be about 3 minutes.

The predicted daily flight time is about 6h on Monday, Tuesday, Wednesday and Friday. On

Table 6.3. Duration of each flight.

Flight type	Number of flight lines	Flight line length	Aircraft speed (km/h)	Time between lines (h)	Flight time (h)
Ferry Adelaide<->Narrendera	N/A	N/A	N/A	N/A	8.0
Ferry airport->site	1	50	100	N/A	0.5
Ferry site->airport	1	50	180	N/A	0.3
Ferry Narrendera<->Kyeamba	1	200	180	N/A	1.0
Regional Yanco	8	58	144	0.05	3.6
Total/flight including ferry					4.4
Regional Kyeamba	8	53	144	0.05	3.3
Total/flight including ferry					4.3
Multi-incidence Yanco	3	75	144	0.05	1.7
Total/flight including ferry					2.5
High-resolution Yanco	4	75	144	0.05	2.2
Total/flight including ferry					3.0
High-resolution Yenda	5	8	144	0.05	0.5
Total/flight including ferry					1.3
Medium-resolution Yanco	4	35	144	0.05	1.1
Total/flight including ferry					1.9
Medium-resolution Kyeamba	7	18	144	0.05	1.2
Total/flight including ferry					2.0
NDVI/Lidar/Aerial photo Transect	3	75	144	0.05	1.7
Total/flight including ferry					2.5
NDVI/Lidar/Aerial photo CIA	15	35	144	0.05	4.3
Total/flight including ferry					5.1
NDVI/Lidar/Aerial photo Livingstone	19	18	144	0.05	3.3
Total/flight including ferry					4.1
NDVI/Lidar/Aerial photo Yenda	3	8	144	0.05	0.3
					1.1

Thursday and Saturday, a gap of 1 to 3 hours will be available for the high-resolution flights at Yenda.

The total number of flight hours computed for PLMR/thermal imager flights and NDVI/Lidar/aerial photos flights are reported in Table 6.4 (note that the ferry Adelaide-Narrandera-Adelaide of about 16h has to added).

Table 6.4. Total mission flight time for the PLMR/thermal imager and the NDVI/Lidar/Aerial photos.

Flight type	Flight time (h)	Number of flights/week	Number of flights/campaign	Total time (h)
Regional Yanco (+ferry)	4.4	3	9	39.4
Regional Kyeamba (+ferry)	4.3	1	4	17.2
Multi-incidence Yanco (+ferry)	2.5	2	6	14.8
High-resolution Yanco	3.0	2	6	18.2
High-resolution Yenda	1.3	1	2	2.6
Medium-resolution Yanco	1.9	1	3	5.8
Medium-resolution Kyeamba	2.0	1	4	7.9
Total mission flight hours (PLMR)				105.7
NDVI/Lidar/Aerial photo Transect	2.5	1	2	4.9
NDVI/Lidar/Aerial photo CIA	5.1	1	2	10.3
NDVI/Lidar/Aerial photo Livingstone	4.1	1	2	8.2
NDVI/Lidar/Aerial photo Yenda	1.1	1	2	2.2
Total mission flight hours (NDVI)				25.5

7 Field Work in Yanco

Field work in Yanco will consist of collecting data in the 9 farms involved in the experiment and archiving the information collected during the day. Most of the information collected on the ground will be assisted by an iPAQ Pocket PC. The iPAQ system will be used both to store the observations and to visualise the real-time position via a GPS receiver.

The ground crew will be composed of 4 teams: 3 teams (A B and C) dedicated to soil moisture sampling and 1 team (VEG) dedicated to vegetation sampling. Teams A, B and C will share out 6 focus farms as follows:

- Team A with farms Y7 and Y9
- Team B with farms Y10 and Y12
- Team C with farms Y1 and Y2

The VEG team will operate across all six of these farms plus 3 additional farms in the CIA. The ground crew will be based in the Yanco Agricultural Institute (YAI) and will drive from there to the farms involved in the field experiment.

Measurement points will be downloaded and visible on the iPAQ screen. Sampling will involve navigating to the predefined sampling points through the use of a GPS receiver, which displays the real-time position on the same screen. Once the GPS receiver is positioned on a given sampling point, the ground measurements can be stored in the iPAQ's storage card.

This section describes the protocols that will be used by the soil moisture and vegetation teams for collecting, processing and archiving ground data.

7.1 General Guidance

Sampling is conducted every day. It may be canceled by the group leader if it is raining, there are severe weather warnings, or a logistic issue arises. Each team will make use of a 4-wheel drive vehicle to access the farms. The soil moisture teams will walk across the farm to take HP readings on the soil moisture sampling grid. The vegetation team will drive across the farms and walk to the measurement points where driving is not feasible.

Some general guidance is as follows:

- **Close any gate** you open as soon as you pass.
- Do not mess up farm tracks.
- Do not drive through cropped areas.
- All farmers in the area are aware of our presence on their property during the 3 week 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 and minimizing disturbance to surrounding vegetation. 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.
- Beware of the possible presence of stock in the sampling areas.
- Watch your **driving speed**, especially when entering towns. Be courteous on dirt and gravel roads, lower speed=less dust and stones.
- 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. Only diesel vehicles should be used in paddocks as catalytic converters can be a **fire hazard**.
- **For your own security, carry a cell phone or UHF transmitter. Check the mobile phone coverage over your sampling area** and be aware of the local UHF security frequencies. Leave your mobile turned off when aircraft is ahead.
- In case of breakdown of any part of the sampling equipment, **report immediately** to the group leader.

7.2 Soil Moisture Team Measurements

The soil moisture (SM) teams will be in charge of collecting:
- 0-5cm soil moisture data using the Stevens water Hydra Probe® instrument at each sampling location;
- 0-5cm soil samples (5 samples per team per day);
- Information about land use, vegetation type, canopy height, presence of dew at each sampling location;
- Soil roughness measurements
- GPS location at each sampling location.

The HP measurements will be made on grids of 50 to 250m spacing that will vary between regional and transect days and between farms. The planned sampling locations for each farm will be loaded onto the iPAQ, and visible with the GIS software ArcPad. Sampling involves navigating to the sampling location through the use of the GPS receiver, which displays the real-time position on the same ArcPAd screen. Once the GPS is located at the predefined sampling point, HP measurements can be made and stored in the iPAQ.

The information about vegetation type, canopy height and the presence of dew will be stored in the iPAQ by prompting the values into forms, following the HP readings. For details, see section 5.1.

The 0-5cm soil samples will be taken at 5 predefined locations per farm per day. One person in each SM team will be responsible for this additional task throughout the entire campaign (team leaders). **This task may not be delegated to another team member**.

7.2.1 Field equipment

Each SM team will be equipped with the items listed below:
- 4-wheel drive vehicle
- 1 soil sampling kit

- 1 hardcopy of the farm sampling plan

Each person of the three SM teams will be equipped with a Hydraprobe Data Acquisition System (HDAS) that consists of the items listed below:

- 1 iPAQ pocket PC
- 1 wireless GPS receiver
- 1 Probe Stevens water Hydraprobe®
- 1 Bumpack
- 1 Gel cell battery
- 1 Gel cell battery connector
- 1 Spare gel cell battery.

Additionally, each person will be assigned a field book and pens. The field book is to be used for comments and must be returned at the end of the campaign.

Each 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. The person will also be responsible for charging batteries each day and downloading/uploading data. **Please do not interchange equipment of your own accord.**

7.2.2 Hydra probe Data Acquisition System (HDAS)

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. The ArcPad program stores the readings of the probe with the coordinates given by the GPS device. 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 5 visible layers:

- Main roads of the Yanco area
- Tracks of the sampling farms
- 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

Note that a manual of the HDAS will be provided separately.

Downloading iPAQ data

Make a backup of iPAQ files before the downloading. Each person will make a copy of the “hydra.*” files on the SD card of the iPAQ. The backup folder will be named “My device/SD Card/Backup/DDMMFL” (where DD is day, MM is month, FL is first and last initials of user).

Download the Arcpad files named “hydra.*” into the required folder on the PC. The downloading will be done with the software Microsoft ActiveSync:

1. Connect the iPAQ to the computer through the iPAQ USB cable

2. Start Microsoft ActiveSync

3. Establish a “Guest” partnership between the iPAQ and the computer: Navigate to the /SD card/Yanco folder on the iPAQ

4. Copy the *FIVE FILES* named “hydra.*” and paste it into the appropriate folder on the computer.

7.2.3 Gravimetric soil samples

Each team leader of the three SM teams will take 5 soil samples per day at the predefined locations (see section 5.1). These 5 gravimetric soil samples will be processed by each team at the YAI at the end of each sampling day.

Soil sampling kit

- sampling ring (approximately 7.5cm diameter and 5cm depth)
- hammer and block
- garden trowel
- blade
- gloves
- plastic bags
- rubber bands
- permanent markers

Soil sampling protocol

1. Remove vegetation and litter.
2. Lay the ring on the ground
3. 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 level with the ground surface.
4. Use the garden trowel to dig away the side of the ring. The hole should reach the bottom of the ring (5cm) and sufficiently large to fit the spatula
5. Use the spatula to cut the 0-5cm soil sample at the bottom of the ring
6. Place the 0-5cm soil sample in the plastic bag ensuring that no soil is lost and seal with the rubber band provided
7. Label the external plastic bag as **farm/team/date(dd-mm-yy)/time(hh:mm)/Sample ID**

Lab facilities

Soil samples will be processed at the Yanco Agricultural Institute (YAI). The YAI facilities that will be used for the processing of soil moisture samples are the following:

- Electronic balances
- Clayson oven (max 105 degrees) and Hereus Instruments oven (max 250 degrees).

Gravimetric soil moisture sample processing

All gravimetric soil moisture samples are processed to obtain a wet and dry weight. It is the SM 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 lab area. All volumetric soil moisture samples taken on one day will be put in to the ovens to dry 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 by weighing in bag and record on sheet.
4. Subtract weight of a bag and elastic.
5. Process your samples in numeric order, carefully emptying contents in the trays provided.
6. Place the used bags in order. The labelled bags will be used 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. 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 location.
7. Load new samples into oven.

Archiving soil weight data

The dry/wet weight data of soil samples and their associated sample ID will be stored in an excel worksheet /“farm name”/SOIL/“date”/SOILDDMMFL.XLS where DD is day, MM is month and FL is first and last initials of user.

7.2.4 Soil roughness measurements

Each SM team will undertake soil roughness measurements at the 5 gravimetric soil sampling locations predefined for each farm (see section 5.1).

Soil roughness procedure

Soil roughness measurements will be made using a 1 m long drop pin profiler with a pin separation of 25 mm (see Fig. 7.1). The same measurements will be repeated at 5 locations within each of the six primary farms. At each soil roughness sampling location, 2 readings will be performed with respectively North-South and East-West orientation.

The procedure for one measurement is as 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 have to be read from left to right, and indicated on the field book with sequential numbers from 1 to 41.

Archiving soil roughness data

Soil roughness data, sampling GPS location and orientation will be stored in an excel worksheet /"farm name"/ROUGHNESS/"date"/ROUGHDDMMFL.XLS where DD is day, MM is month and FL is first and last initials of user.

Fig. 7.1. Pin profiler for surface roughness measurements

7.3 Vegetation Team Measurements

The vegetation (VEG) team will be in charge of collecting:

- Vegetation samples
- Reflectance measurements
- LAI measurements
- Information about vegetation type and canopy height
- GPS location of the actual sampling points

The coordinates (and shape files) of the farm boundaries together with boundaries of sampling areas will be provided to the VEG team. Sampling will involve navigating within the sampling areas through the use of a GPS receiver. Measurements/samples should be made in the first instance in the sampling area, but definitely within the focus farms, unless other arrangements are made with landholders so as to cover all vegetation types.

7.3.1 Field equipment

The VEG team will be equipped with the items listed below:

- 4-wheel drive vehicle
- 1 vegetation sampling kit
- 1 CROPSCAN Multispectral Radiometer (MSR)
- 1 LAI-2000 device
- 1 fieldbook
- Pens, permanent markers
- 1 hardcopy of the farm sampling plan

7.3.2 Gravimetric vegetation samples

Vegetation sampling kit

- A 0.50m x 0.50m quadrant will be used to obtain vegetation samples.
- vegetation clipper
- scissor
- gloves
- plastic bags
- rubber bands
- permanent markers

Vegetation sampling protocol

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) using the predefined list.
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.

Lab facilities

Vegetation samples will be processed at the YAI. The YAI facilities that will be used for the processing of vegetation samples are the following:

- Electronic balances
- Large dehydrators (max 70 degrees) – 120 trays available.

Biomass/Vegetation water content sample processing

It is the responsibility of the VEG team to deliver the vegetation samples to NAFE headquarters at the end of the day, weigh, dry and store them in the appropriate place. The procedure for vegetation biomass processing will be as follows:

Wet Weight Procedure

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

Dry Weight Procedure

1. Dry samples in oven at 40^{o}C until constant weight is reached (typically 2-3 days).
2. 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 location.
7. Load new samples into oven.

Archiving vegetation weight data

The dry/wet weight data of vegetation samples and their associated sample ID will be stored in an excel worksheet /“farm name”/VEGETATION/“date”/VEGDDMMFL.XLS where DD is day, MM is month and FL is first and last initials of user.

7.3.3 Surface reflectance data

The CROPSCAN is an inexpensive instrument that has up-and-down-looking detectors and the ability to measure reflected sunlight at different wavelengths. The basic instrument is shown in Fig. 7.2. The CROPSCAN multispectral radiometer systems consist of a radiometer, data logger controller (DLC) or A/D converter, terminal, telescoping support pole, connecting cables and operating software. The radiometer uses silicon or germanium photodiodes as light transducers. Matched sets of the transducers with filters to select wavelength bands are oriented in the radiometer housing to measure incident and reflected irradiation. Filters of wavelengths from 450 up to 1720 nm are available. For NAFE'06 a MSR16R unit will be used with the following set of bands:

Satellite	***ID***	***CenterWavelength (Bandwidth)***
Thematic Mapper	MSR16R-485TMU	485 nm up sensor (90 nm BW)
	MSR16R-485TMD	485 nm down sensor (90 nm BW)
	MSR16R-560TMU	560 nm up sensor (80 nm BW)
	MSR16R-560TMD	560 nm down sensor (80 nm BW)
	MSR16R-660TMU	660 nm up sensor (60 nm BW)
	MSR16R-660TMD	660 nm down sensor (60 nm BW)
	MSR16R-830TMU	830 nm up sensor (140nm BW)
	MSR16R-830TMD	830 nm down sensor (140nm BW)
	MSR16R-1650TMU	1650 nm up sensor (200nm BW)
	MSR16R-1650TMD	1650 nm down sensor (200nm BW)
MODIS	MSR16R-650U2	650 nm up sensor (40 nm BW)
	MSR16R-650D2	650 nm down sensor (40 nm BW)
	MSR16R-850U2	850 nm up sensor (60 nm BW)
	MSR16R-850D2	850 nm down sensor (60 nm BW)
	MSR16R-1240U	1240 nm up sensor (12 nm BW)
	MSR16R-1240D	1240 nm down sensor (12 nm BW)
	MSR16R-1640U	1640 nm up sensor (16 nm BW)
	MSR16R-1640D	1640 nm down sensor (16 nm BW)

These bands coincide with channels of the Landsat Thematic Mapper and MODIS instruments. Channels were chosen to provide NDVI as well as a variety of vegetation water content indices under consideration.

Fig. 7.2. CROPSCAN Multispectral Radiometer (MSR). (Size is 8 X 8 X 10 cm).

Reflectance data will be collected for each vegetation sampling location (Fig. 7.3) just prior to vegetation removal using the following sampling scheme. Making sure that the radiometer is well above the plant canopy, take a reading every meter for 5 meters. Repeat, for a total of 5 replications located 1 meter or 1 row apart.

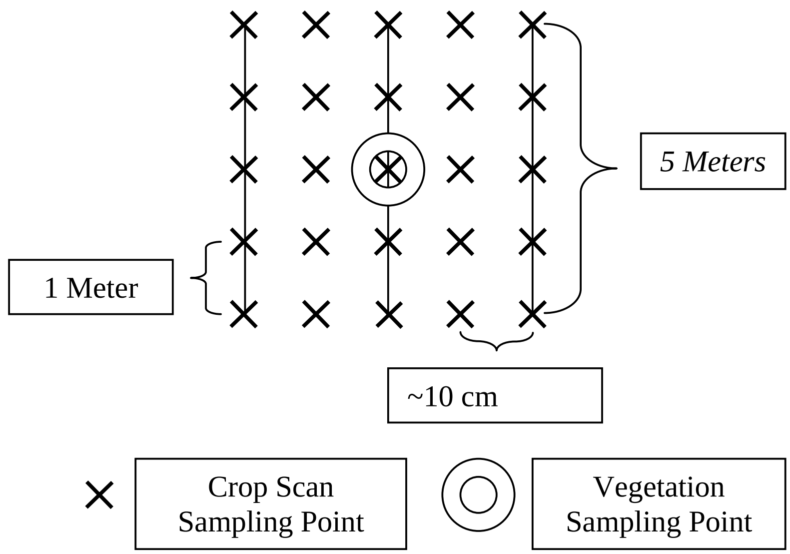


Fig. 7.3. Illustration of the surface reflectance protocol.

Downloading reflectance data

1. Plug the cable RS9M9F-5 into the RS232 connectors on the front DLC and the serial port of your PC

2. Start the Cropscan software on the PC

3. Choose RETRIEVE from the menu and press **ENTER**

4. Select your PC COM port and press **ENTER**

5. Enter your file name (REFLDDMMFL.MV, where DD is day, MM is month, FL is first and last initials of user and MV for raw millivolt data files)

6. After the data is downloaded, press **Y** then **ENTER** to clear the data from the DLC

7.3.4 LAI data

The LAI-2000 (see Fig 7.4) will be set to average 4 points into a single value so one observation is taken above the canopy and 4 beneath the canopy; in the row, ¼ of the way across the row, ½ of the way across the row and ¾ of the way across the row. This gives a good spatial average for row crops of partial cover. For *grasses and weeds and non-row crops*, five sets of measurements (each set consisting of 1 above the canopy and 4 beneath the canopy) will be made. If possible these should be made just before clipping.

If the sun is shining, the observer needs to stand with their back to the sun and put a black lens cap that blocks ¼ of the sensor view in place and positioned so the **sun and the observer are never in the view of the sensor**. The observer should always note if the sun was obscured during the measurement, whether the sky is overcast or partly cloudy with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked “shaded”, if shadows could be seen during the measurement then the measurement is marked “sunny”. Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements. Also, it is important to check the LAI-2000 internal clock each day to verify they are recording in CDT.

For *row crops*, LAI measurements will be made in the inter-row region at least one meter away from where the biomass sample was taken, but still in a region of similar canopy amount.

Fig. 7.4. The LAI-2000 instrument.

Downloading LAI-2000 files to a PC Using HyperTerminal -

Before beginning use functions 21 (memory status) and 27 (view) to determine which files you want to download. Make a note of their numbers.

1. Connect wire from LAI-2000 (25pin) to PC port (9 pin).

2. Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | LAI2000.ht)

3. On the LAI-2000, go to function 31 (config i/o) and conFig. I/O options. Baud=4800, data bits=8, parity=none, xon/xoff=no.

4. On the LAI-2000, go to function 33 (set format) and setup format options. First we use Spdsheet and take the default for FMT.

5. In HyperTerminal go to Transfer | Capture text. Choose a path and filename (LAIMMDDFL.SPR, where MM is month, DD is day, FL is first and last initials of user and SPR for spreadsheet data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.

6. On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.

7. Once you hit enter in function 32, lines of text data will be sent to HyperTerminal. The LAI-2000 readout will say 'Printing file 1, 2, etc'. Check the window in HyperTerminal to ensure the data is flowing to the PC. This may take a few minutes, wait until all the desired files have been sent.

8. In HyperTerminal go to Transfer | Capture text | Stop.

9. On the LAI-2000, go to function 33 (set format) and setup format options. Now set to Standard, Print Obs = yes

10. In HyperTerminal go to Transfer | Capture text Choose a path and filename (LAIDDMMFL.STD, where DD is day, MM is month, FL is first and last initials of user and STD for standard data files) to store the LAI data. Hit Start. HyperTerminal is now waiting to receive data from the LAI-2000.

11. On the LAI-2000, go to function 32 (print) and print the files. 'Print' means send them to the PC. You will be asked which file sequence you want. Eg. Print files from:1 thru:25 will print all files numbered 1-25. Others will not be downloaded.

12. In HyperTerminal go to Transfer | Capture text | Stop.

13. Using a text editor (like notepad) on the PC, open and check that all the LAI data has been stored in the text file specified in step 3. Make a back up of this file. Once you're sure the LAI values look reasonable and are stored in a text file on the PC, use function 22 on the LAI-2000 to delete files on the LAI-2000 and free up its storage space.

Note: The above instructions assume that HyperTerminal has been conFig.d to interface with the LAI-2000, i.e. the file LAI2k.ht exists. If not, follow these instructions to set it up.

1. *Run HyperTerminal on the PC (Start | Programs | Accessories | Communications | HyperTerminal | Hypertrm*

2. Pick a name for the connection and choose the icon you want. Whatever you pick will appear as a choice in the HyperTerminal folder in the start menu later. Hit OK.

3. Connect using com1 or com2. Choose which is your com port, hit OK. Setup Port settings as follows: Bits per second = 4800, Data Bits = 8, Parity = none, Stop bits = 1, Flow control = Hardware. Say OK.

4. *Make sure the wire is connected to the LAI-2000 and the PC and proceed with step 3 in the download instructions above. When finished and leaving HyperTerminal you will be prompted to save this connection.*

7.4 Data Archiving Procedures

All data collected during the day will be downloaded and backed up upon return to the NAFE headquarters on PC computers. There will be a computer 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 Fig. 7.5) and to insert into an excel worksheet all the data collected in the fieldbooks and on lab data sheets. Daily data will be backed up on both DVD's and external hard disk drive. It will be the responsibility of Rocco Panciera to do the back up and assist with archiving of data.

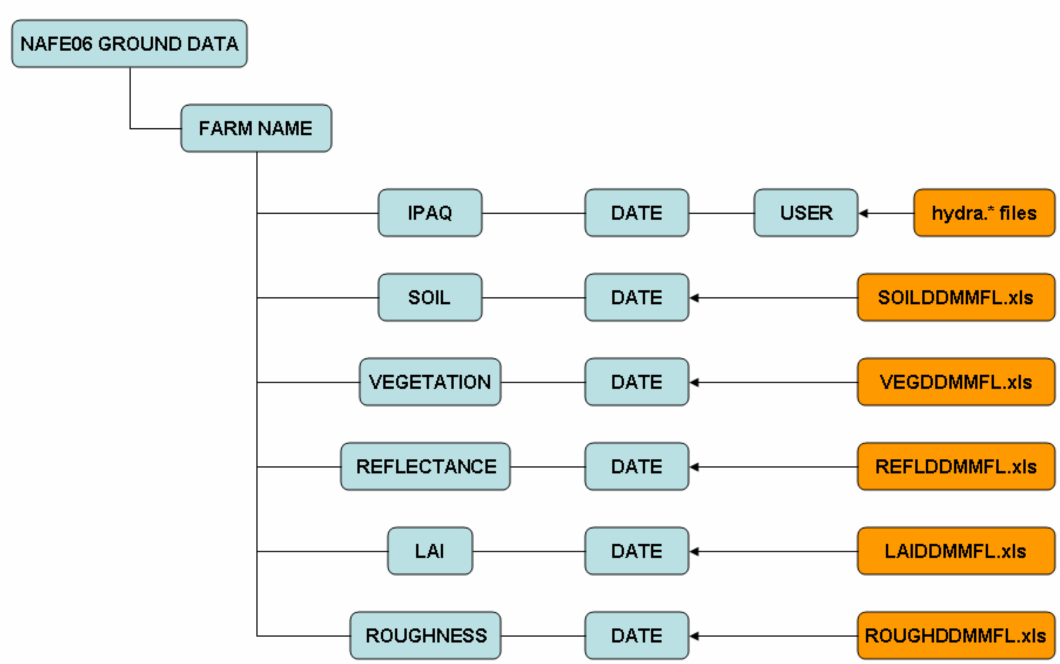


Fig. 7.5. Tree diagram of the NAFE file structure

8 Logistics

NAFE'06 participants will be based in the Yanco Agricultural Institute (YAI), which will provide lab space and equipment for pre-sampling and post-sampling operations. One of the ground crew members, Rodger Young, 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. Another ground crew member, Rocco Panciera, will be dedicated to ground data archive and process support.

8.1 Operation Bases

The Yanco Agricultural Institute (YAI, http://www.agric.nsw.gov.au/reader/yanco) is a 825 hectare campus located at Yanco, in the Murrumbidgee Irrigation Area. The centre is just 10 minutes drive from downtown busy Leeton, and 20 minutes drive from the town of Narrandera, junction of the Sturt and Newell Highways (see location in Fig. 8.1).

YAI shares the site and resources with Murrumbidgee Rural Studies Centre (MRSC, http://www.mrsc.nsw.edu.au), formerly known as Murrumbidgee College of Agriculture. Both MRSC and YAI are run by the NSW Department of Primary Industries (NSW DPI).

During NAFE'06, the YAI will make available a lab space (see Fig. 8.2 and 8.3) with all the equipment needed for pre-sampling and post-sampling operations, including scales for sample weighing, ovens for drying soil and plant samples, storage spaces for processed samples and field equipment. It will be the responsibility of each team to make sure instruments and tools are stored properly overnight.

Facilities available during the NAFE'06 campaign include: lab space, storage shed, two types of accommodation and a conference room.

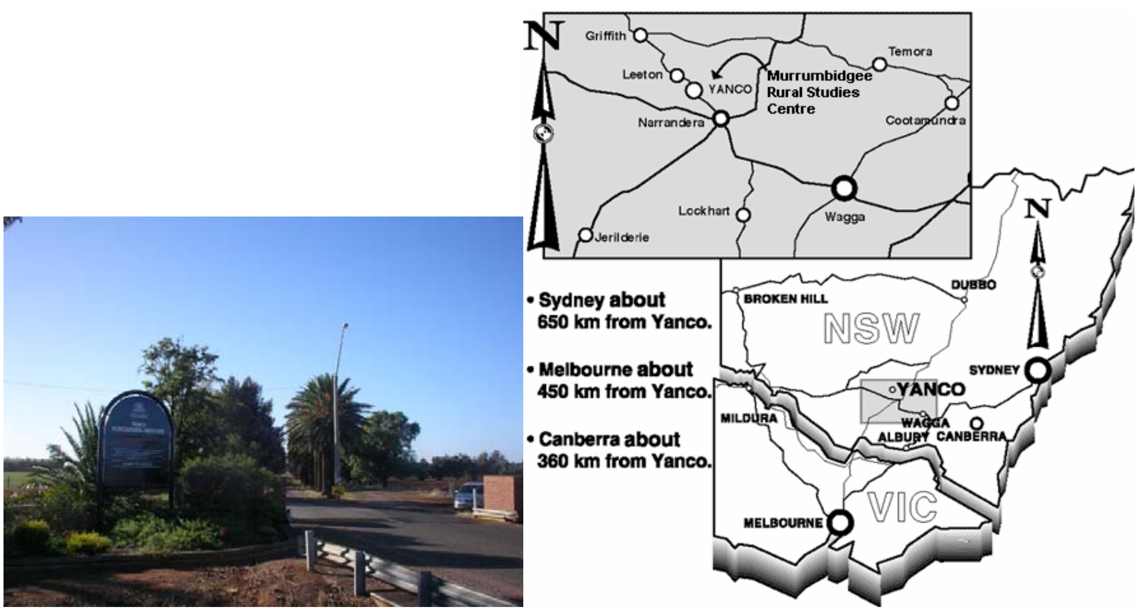
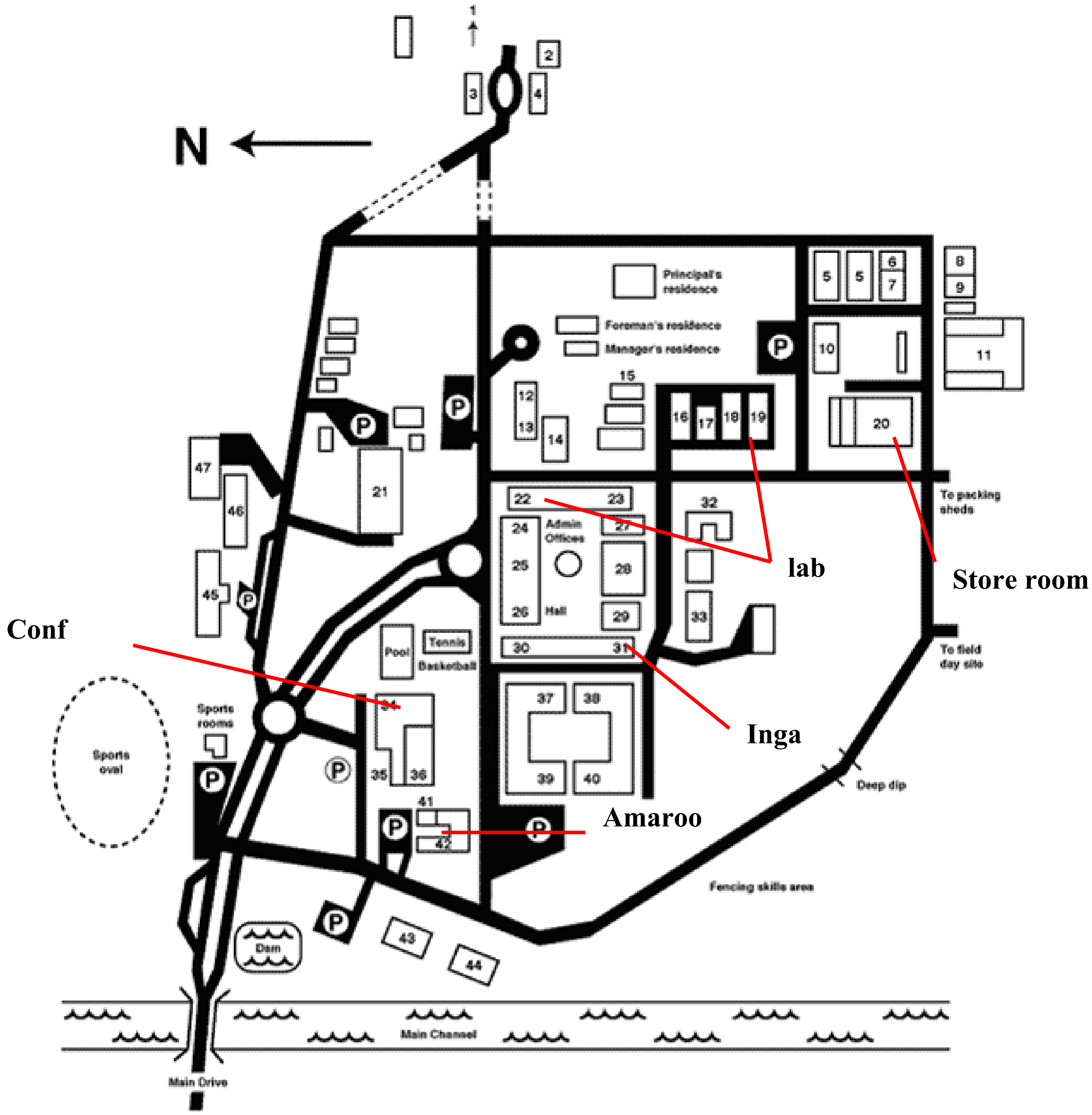


Fig. 8.1 Location of the YAI at Yanco.



1. Beef Section
2. Security Officer's Residence
3. Shearing Shed
4. Animal Demonstration Bldg
5. Maintenance Workshops 1 & 2
6. Teaching Workshop 4
7. Mechanics Workshop
8. Teaching Workshop 5
9. Teaching Workshop 3
10. Teaching Workshop 2
11. Farm Machinery Compound
12. Offices
13. Lecture Rooms 1 & 2
14. Library
15. Glasshouses
16. Lecture Room 4
17. Rice Store
18. Woolclassing Room
19. Agronomy Room
20. Store/Farm Foreman's Office
21. Research Laboratory
22. Research Officers (Pelde)
23. Agronomy Rooms (Kulu)
24. Irrigation Services
25. Administration
26. Recreation Hall
27. Conference Room 2
28. Dining Room
29. Gymnasium
30. Accommodation (Calrose)
31. Accommodation (Inga)
32. Administrative Paying Centre
33. Accommodation (Doongara)
34. Continuing Education/Conf Rm 1
35. Advisory Offices
36. College Teaching Centre
37. Accommodation (Pearson East)
38. Accommodation (Heath East)
39. Accommodation (Pearson West)
40. Accommodation (Heath West)
41. Amaroo Conference Centre
42. Accommodation (Amaroo)
43. Lecture Rm 5/Soils Laboratory
44. Teaching Wshp 1/Hydraulics Lab
45. National Vegetable Industry Centre
46. Food Industry Training Centre
47. Food Industry Training Centre (Factory)

Fig. 8.2. Map of the YAI campus. NAFE'06 participants will be accommodated in the bunk house "Inga" (31) and in the Motel "Amaroo" (42). A lab space (22) will be made available for the duration of the campaign, as well as a storage shed (20) and a conference room (34).

Fig. 8.3. Lab space and storage shed at the YAI.

Air crew will also be based in YAI and operate the SERA aircraft out of the Narrandera Airport (see Fig. 8.4).

Fig. 8.4. Narrandera airport.

8.2 Accommodation

Three types of accommodation are available for NAFE'06 participants: motel-style and bunk house at MRSC, and a more up-market motel in Leeton.

'Amaroo' motel-style accommodation

Amaroo, meaning 'a quiet place', features 15 bed and breakfast (continental) motel-style rooms (see location No.42 on the map and pictures Fig. 8.5). Each room has a queen bed and a single bed, ensuite, TV, toaster, tea and coffee making facilities, bar fridge, and heating and cooling. The motel rooms are organised around a central courtyard connected to the conference facility. Price is $70/night/person for single room and $90/night/room for double room.

'Inga' Bunk house accommodation

Inga bunk house accommodation is self-catered with continental breakfast provided. Rooms have a double bunk, wardrobe and desk (Fig 8.6). Linen and towels are provided. Inga (No.31 on map Fig. 8.2) has 13 double rooms and one single room. The bunk house has a kitchen with microwave, toaster, kettle and fridge. Barbecue facilities are available on site by request. A free laundry, lounge room and shared single-sex bathroom facilities are also featured. Cost is $35/night/person. It may be necessary to share a room, depending on final numbers.

Leeton Heritage Motor Inn
This is premier accommodation in Leeton (http://www.leetontourism.com.au/gallery.htm). Beautifully appointed ground floor, spacious air-conditioned units, ISD phones, in-room internet access, pool and BBQ. Charley's Restaurant, Bar and function room. Close to golf, bowls and licensed clubs. Single room is $90/night (Fig. 8.7).

Fig. 8.5. Bunk house at MRSC.

Fig. 8.6. Motel at MRSC.

Fig. 8.7. Leeton Heritage Motor Inn.

Accommodation details for all participants are listed in the Tables below.

Table 8.1. Accommodation logistics for the NAFE'06 participants at the bunkhouse Inga.

Name	Start date	End date	N. days	Price/night	Total person
Olivier Merlin	23-Oct	22-Nov	31	35	1085
Rocco Panciera	23-Oct	22-Nov	31	35	1085
Mohsin Hafeez	28-Oct	19-Nov	23	35	805
Rodger Young	28-Oct	19-Nov	23	35	805
Vadim Kuzmin	28-Oct	19-Nov	23	35	805
Clara Draper	28-Oct	19-Nov	23	35	805
Gilles Boulet	27-Oct	19-Nov	24	35	840
Philippe Maisongrande	27-Oct	19-Nov	24	35	840
Jessica Toyra (share Dionne)	28-Oct	19-Nov	23	35	805
Dionne Hansen (share Jessika)	28-Oct	19-Nov	23	35	805
Ruud Hurkmans (share Ryan)	28-Oct	19-Nov	23	35	805
Ryan Teuling (share Ruud)	28-Oct	19-Nov	23	35	805
Iliana Mladenova	27-Oct	21-Nov	23	35	805
Mark Thyers delegate (?)	28-Oct	19-Nov	23	35	805
Carmen Navarro Gomez	28-Oct	19-Nov	23	35	805
Yunming Chen	28-Oct	19-Nov	23	35	805

Table 8.2. Accommodation logistics for the NAFE'06 participants at the Amaroo Motel.

Name	Start date	End date	N. days	Price/night	Total person
Jeff Walker	28-Oct	21-Nov	25	70	1750
Ed Kim/Rodger Young	28-Oct	19-Nov	23	70	1610
Jon Johanson	29-Oct	21-Nov	24	70	1680
Jorg Hacker	30-Oct	21-Nov	23	70	1610

Table 8.3. Accommodation logistics for the NAFE'06 participants at the Leeton Heritage Motor Inn.

Name	Start date	End date	N. days	Price/night	Total person
Lynn McKee	26-Oct	22-Nov	28	90	2520
Peggy O'Neill	27-Oct	21-Nov	26	90	2340
Walter Rawls	30-Oct	20-Nov	22	90	1980
Tom Jackson	27-Oct	3-Nov	8	90	720
Venkat Lakshmi	27-Oct	3-Nov	8	90	720

8.3 Meals

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

Breakfast: continental breakfast will be provided at the bunkhouse/motel but you may wish to supplement this depending on your appetite and dietary requirements.

Lunch: there are no facilities in Yanco itself for buying lunches, nor will you pass any shops on the way to your sampling site. You should therefore pre-purchase from the supermarket in Leeton the supplies you will need to make your lunch in the morning prior to leaving for the field.

Dinner: apart from the supermarket (if you wish to cook your own meal), the only options for dinner are to drive into Yanco (2km), Leeton (5km) or Narrandera (20km) (see location of some restaurants in Fig 8.8).

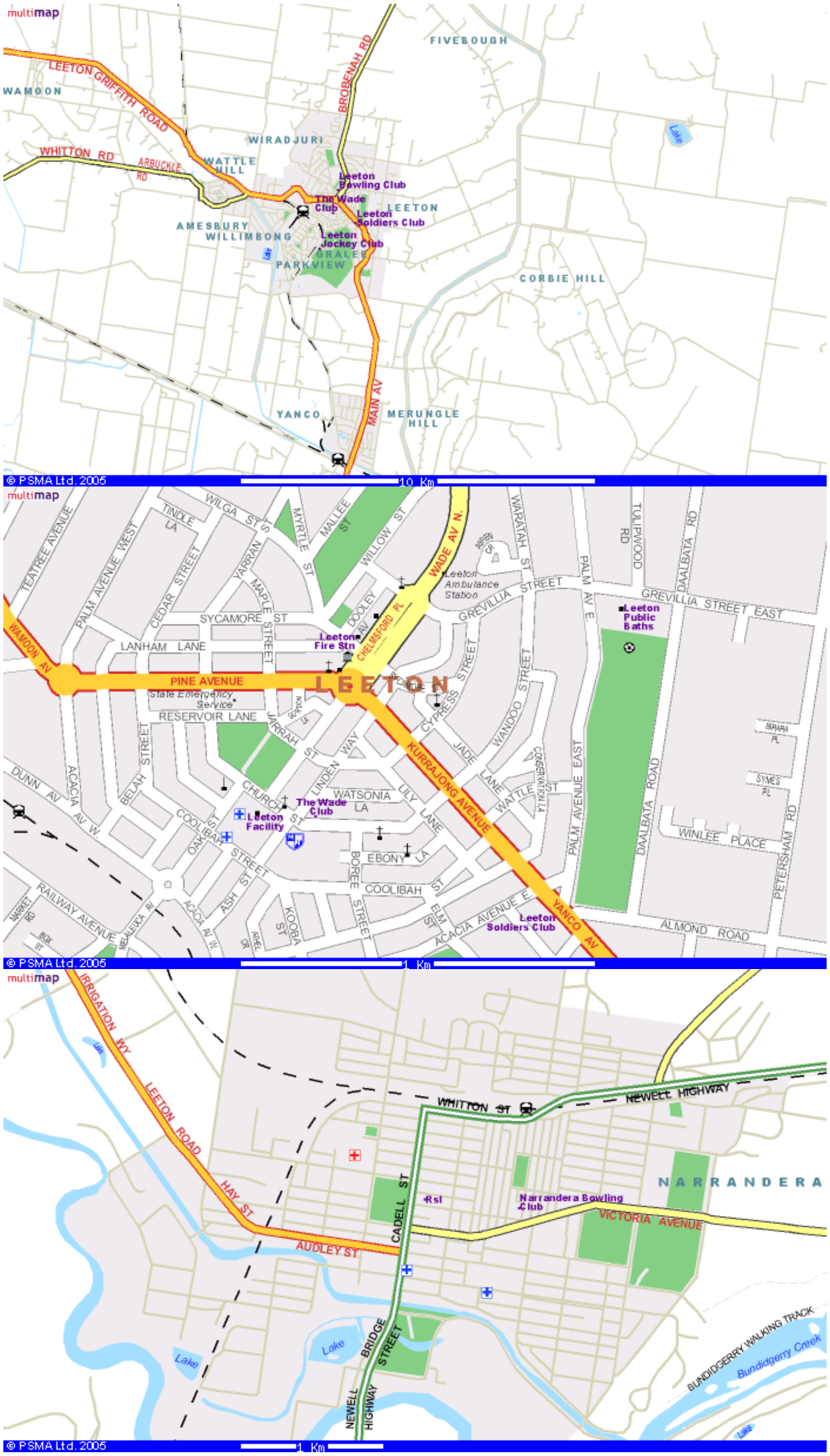


Fig. 8.8. Maps of Leeton and Narrandera.

8.4 Internet

An internet access will be provided to NAFE'06 participants at MRSC (see N36 on map Fig 8.2). The computer room is equipped with 15 computers and will be open every day from 7pm to12pm. A password will be provided for login on these computers.

8.5 Other facilities

The modern Amaroo Conference Centre (No.41 on the map and picture in Fig 8.9) contains a large conference room for meetings, seminars and gatherings, seating up to 60 people, and has its own kitchenette. Conference facilities include access to data projectors, laptops, computers, whiteboards, screens and overhead projectors upon request.

Fig. 8.9. Conference room at MRSC.

With its park-like setting, the campus swimming pool is a delightful place to cool off at the end of the day, and the nearby barbecue and picnic facilities are perfect for outdoor get-togethers. Tennis and basketball courts and a football oval are also part of the extensive outdoor facilities.

8.6 Maps and Directions

8.6.1 Getting there

In terms of booking flights etc, international participants should fly into Melbourne (or Sydney for options below

a) get a lift to Yanco on the "Melbourne shuttle" -- see below,
b) get a connecting flight to Narrandera with Regional Express (REX), where there will be somebody waiting to pick you up and take you to Yanco which is ~10min drive away (please give your arrival details if that is the case) or
c) if you are planning to have a rental car for your own purposes, arrange to pick it up in Sydney or Melbourne and drive direct to Yanco/Leeton (~5-7hrs; some people may want to car pool and do this); see detailed driving directions below. You may also wish to take a connecting flight to Canberra (~4hrs from Yanco) with Qantas, Virginblue or Jetstar, or to Wagga Wagga (~1hr from Yanco) with REX.

Note 1: The "**Melbourne shuttle**" will transport participants between Yanco and Melbourne on Sat 28 October (departure will be in the morning; details TBA) and return on Sun 19 Oct (arrival sometime in the afternoon); so please book your flights/make your Melbourne accommodation arrangements accordingly.

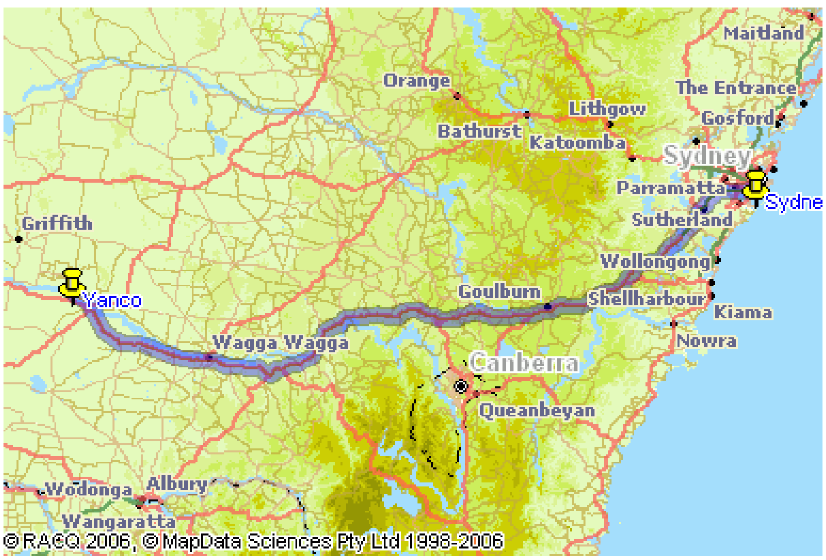
Note 2: All ground crew are expected to attend the **extensive training sessions** on Sunday 29 October and Mon 30 October.

From Melbourne Airport to Yanco

No.	Instruction	Road	Town	For	Time
1	Start on	C743 <> Sunbury Road	Melbourne Airport VIC	1.11 kms	1:09 Minutes
2	Continues as	M2 <> Tullamarine Freeway	Melbourne Airport VIC	4.99 kms	3:40 Minutes
3	Continues as	Western Ring Road exit	Gladstone Park VIC	766 metres	36 Seconds
4	Continues as	M80 <> Western Ring Road	Gladstone Park VIC	6.48 kms	4:51 Minutes
5	Continues as	M80 <> Northern Ring Road	Fawkner VIC	1.29 kms	58 Seconds
6	Continues as	M31 <> Hume Freeway exit	Thomastown VIC	641 metres	28 Seconds
7	Continues as	M31 <> Hume Freeway	Thomastown VIC	87.22 kms	53:54 Minutes
8	Bear left	Goulburn Valley Freeway exit	Seymour VIC	462 metres	27 Seconds
9	Bear left	Goulburn Valley Freeway exit Northbound	Seymour VIC	322 metres	28 Seconds
10	Bear left	A39 <> Goulburn Valley Freeway	Seymour VIC	15.57 kms	10:22 Minutes
11	Bear left	A39 <> Goulburn Valley Highway	Tabilk VIC	110.31 kms	1:25 Hours
12	Turn right	A39 <> Murray Valley Highway	Strathmerton VIC	14.24 kms	11:06 Minutes
13	Turn left	A39 <> Goulburn Valley Highway	Yarroweyah VIC	14.07 kms	10:12 Minutes
14	Bear left	39 <> Newell Highway	Tocumwal NSW	541 metres	43 Seconds

15		Take the 2nd roundabout exit	39 <> Newell Highway	[Tocumwal NSW]()	164.82 kms	2 Hours
16		Turn left	Audley Street	[Narrandera NSW]()	842 metres	1:15 Minutes
17		Continues as	Hay Street	[Narrandera NSW]()	405 metres	36 Seconds
18		Continues as	Leeton Road	[Narrandera NSW]()	327 metres	26 Seconds
19		Continues as	Irrigation Way	[Narrandera NSW]()	21.44 kms	17:30 Minutes
20		Continues as	Main Avenue	[Yanco NSW]()	179 metres	16 Seconds
21		Continues as	Back Yanco Road	[Yanco NSW]()	0 metres	0 Seconds
22		Finish on	Back Yanco Road	[Yanco NSW]()	0 metres	0 Seconds
Totals					**446.09 kms**	**5:25 Hours**

From Sydney Airport to Yanco

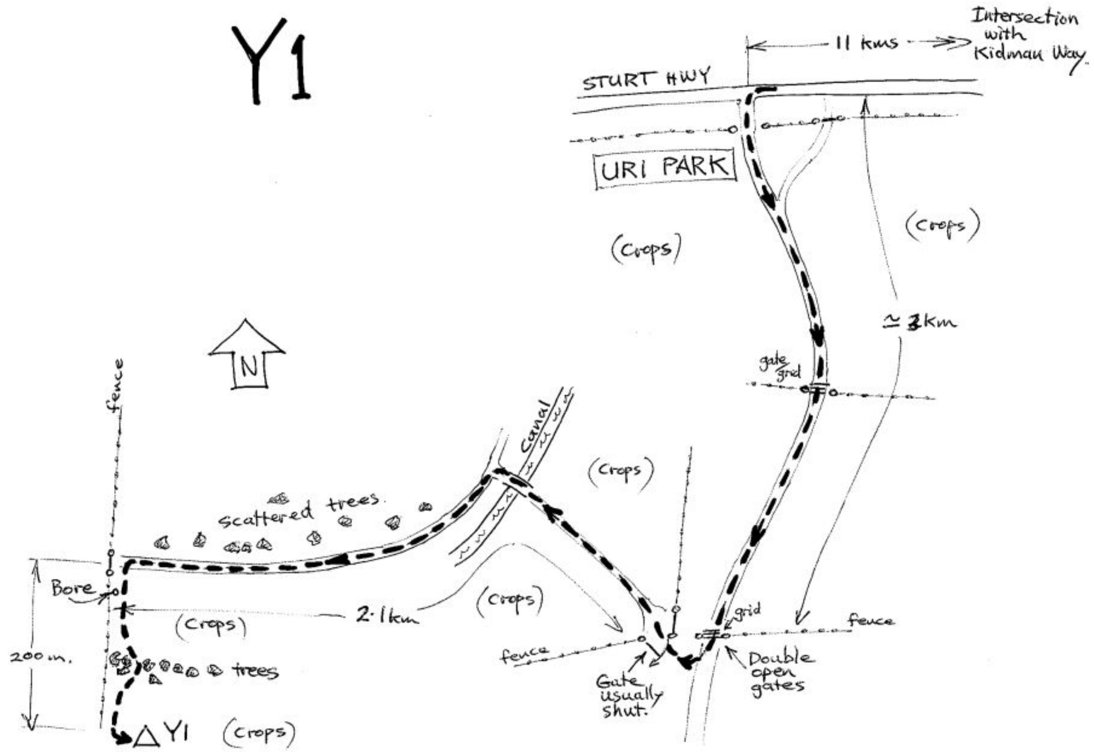


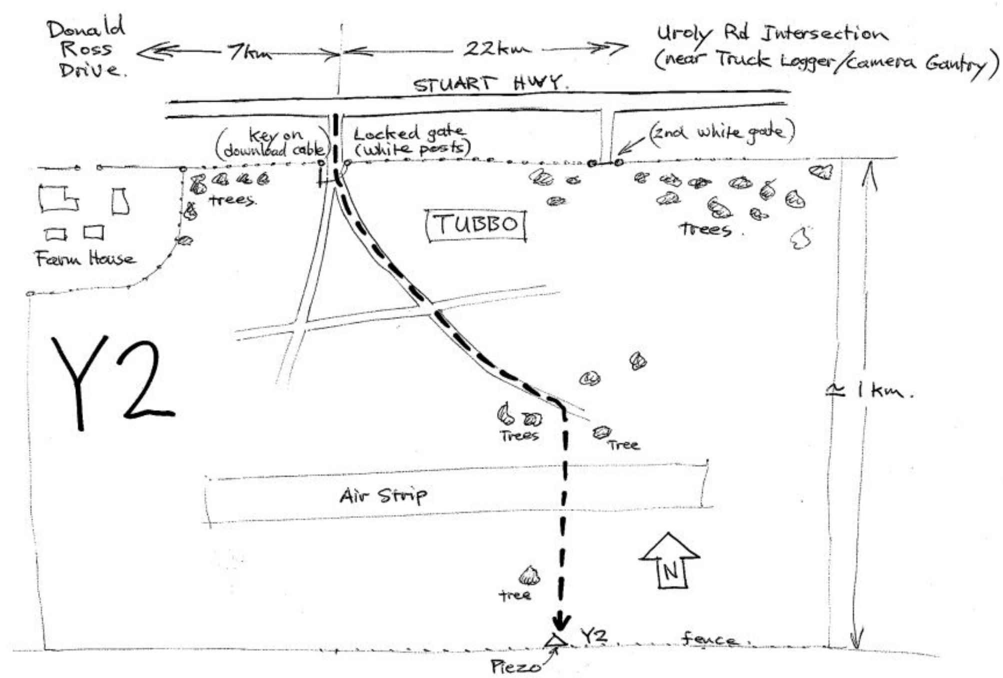
No.		Instruction	Road	Town	For	Time
1		Start on	Airport Drive	[Sydney International Airport NSW]()	218 metres	26 Seconds
2		Continues as	Marsh Street	[Sydney International Airport NSW]()	897 metres	1:47 Minutes
3		Turn right	M5 <> South Western Motorway on ramp	[Arncliffe NSW]()	110 metres	8 Seconds
4		Bear left	5 <> South Western Motorway	[Arncliffe NSW]()	25.11 kms	20:11 Minutes
5		Continues as	5 <> South Western Freeway	[Casula NSW]()	17.24 kms	12:37 Minutes

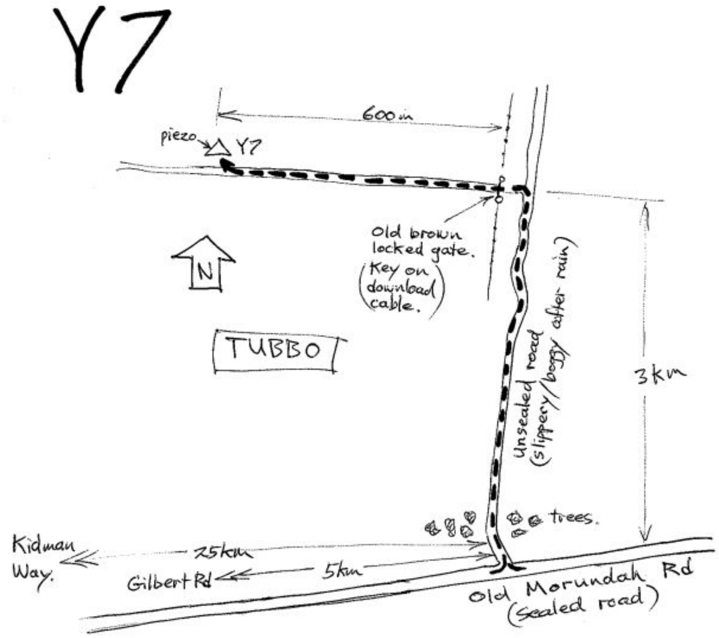
6	Continues as	31 <>	South Western Freeway	Mount Annan NSW	24.48 kms	15 Minutes
7	Bear right	31 <>	Hume Highway	Pheasants Nest NSW	329.61 kms	4:03 Hours
8	Bear left		Sturt Highway exit	Tarcutta NSW	881 metres	35 Seconds
9	Continues as	20 <>	Sturt Highway	Tarcutta NSW	46.17 kms	39:22 Minutes
10	Take the 2nd roundabout exit	20 <>	Sturt Highway	Wagga Wagga NSW	93.20 kms	1:04 Hours
11	Continues as	39 <>	Newell Highway	Gillenbah NSW	1.87 kms	1:54 Minutes
12	Turn left		Audley Street	Narrandera NSW	842 metres	1:15 Minutes
13	Continues as		Hay Street	Narrandera NSW	405 metres	36 Seconds
14	Continues as		Leeton Road	Narrandera NSW	327 metres	26 Seconds
15	Continues as		Irrigation Way	Narrandera NSW	21.44 kms	17:30 Minutes
16	Continues as		Main Avenue	Yanco NSW	179 metres	16 Seconds
17	Continues as		Back Yanco Road	Yanco NSW	0 metres	0 Seconds
18	Finish on		Back Yanco Road	Yanco NSW	0 metres	0 Seconds
Totals					**563.04 kms**	**7 Hours**

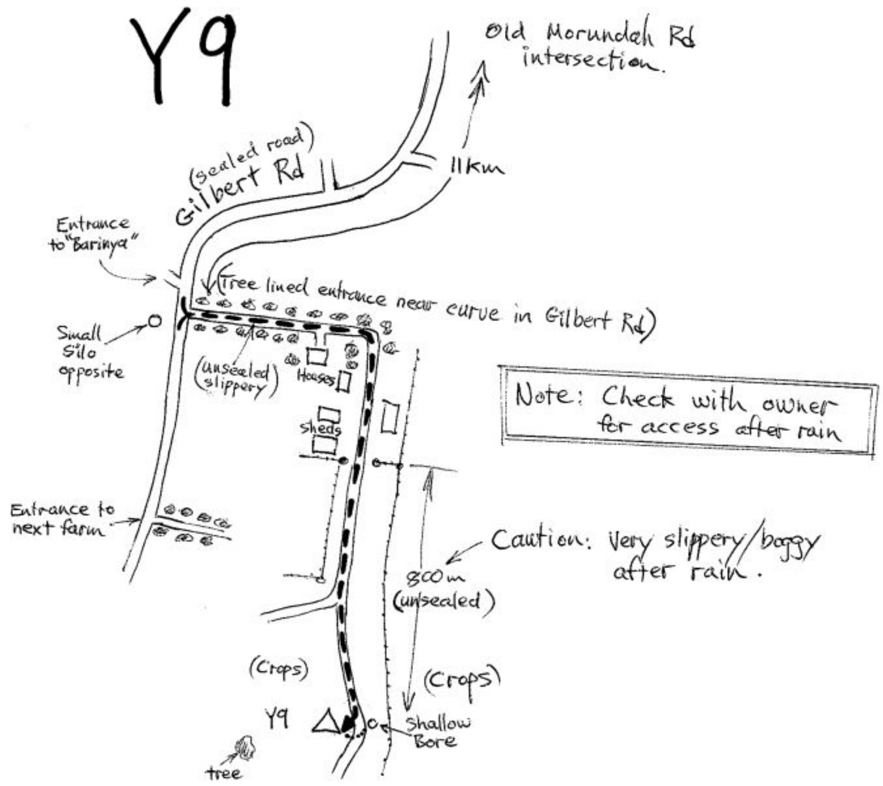
8.6.2 Getting to the farms

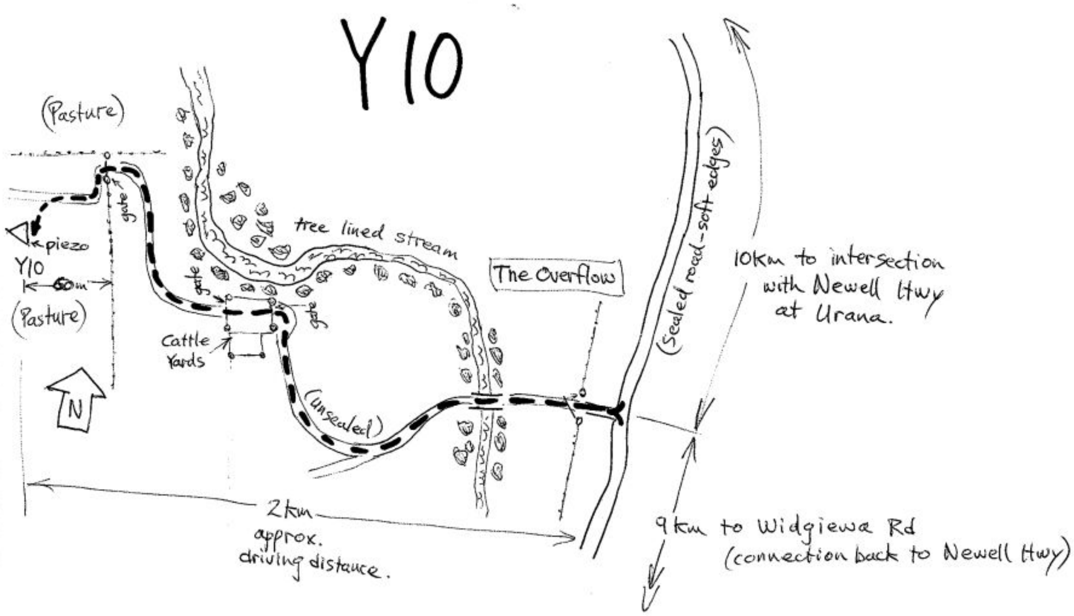
These drawings give directions for how to get from the main road to the permanent monitoring sites located on the 6 focus farms.

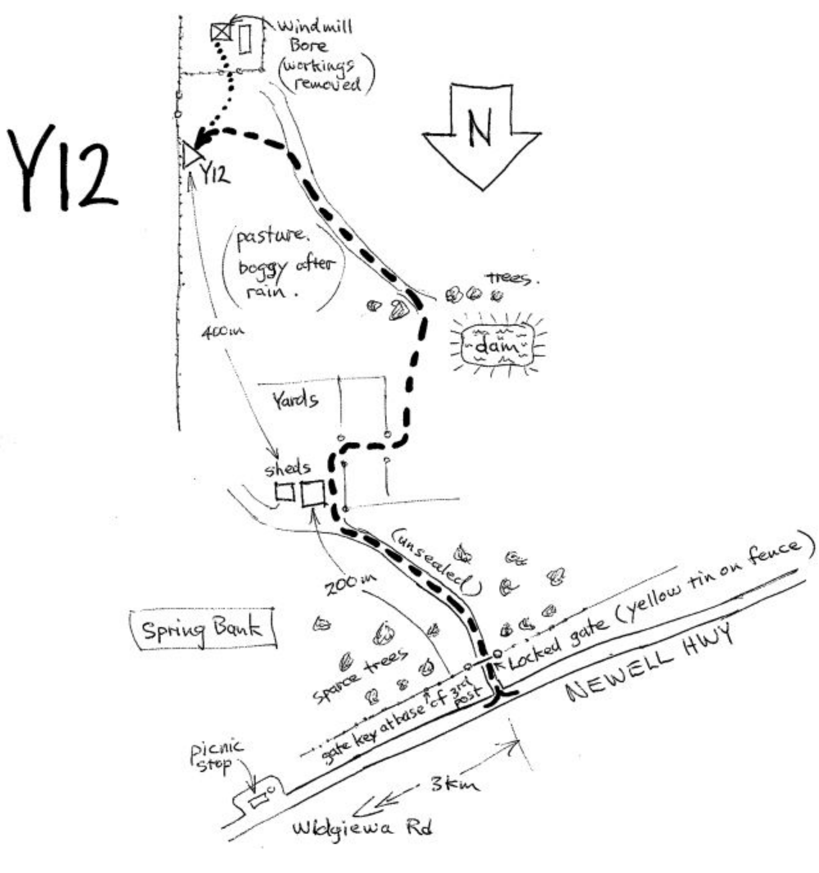





Y7
600 m
piezo
Y7
Old brown locked gate. Key on download cable.
N
TUBBO
Unsealed road (slippery/boggy after rain)
3 km
trees.
Kidman Way.
25 km
Gilbert Rd
5 km
Old Morundah Rd (Sealed road)


Y9
Old Morundah Rd intersection.
11 km
(sealed road) Gilbert Rd
Entrance to "Barinya"
Tree lined entrance near curve in Gilbert Rd
Small Silo opposite
(unsealed slippery)
Houses
Sheds
Note: Check with owner for access after rain
Entrance to next farm
Caution: Very slippery/boggy after rain.
800 m (unsealed)
(Crops)
(Crops)
Y9
Shallow Bore
tree


Y10
(Pasture)
piezo
Y10
60m
(Pasture)
gate
gate
gate
Cattle Yards
N
tree lined stream
The Overflow
(Sealed road-soft edges)
(unsealed)
10km to intersection with Newell Hwy at Urana.
2km approx. driving distance.
9km to Widgiewa Rd (connection back to Newell Hwy)


Y12
Windmill Bore (workings removed)
Y12
N
pasture. boggy after rain.
400m
trees.
dam
Yards
sheds
(unsealed)
200m
Spring Bank
sparce trees
Locked gate (yellow tin on fence)
gate key at base of 3rd post
NEWELL HWY
picnic stop
3km
Widgiewa Rd

8.7 Groups

Ground crew sampling operations will be undertaken by 4 teams acting independently and will be coordinated by Olivier Merlin with the assistance of Jeff Walker and Gilles Boulet. Each of the three soil moisture teams will be assigned two of the six focus farms, one with pasture and one with wet/dry land cropping. The vegetation team will sample farms in rotation with all the farms involved in the experiment. Table 8.5 indicates the composition of each team and the focus farm assigned to each group. The air segment will operate from the Narrandera airport and will be coordinated by Jeff Walker (Table 8.6).

Table 8.5. NAFE'06 ground crew.

Team	Farms	Team members	Transport	Team leader
A	Tubbo (Y7) and Yammacoona (Y9)	Olivier Dionne Ruud Ryan	Uni 4WD STT256	Olivier
B	Cherevelis (Y10) and Spring Bank (Y12)	Moshin Philippe Clara Mark delegate Carmen	CSIRO 4WD	Moshin
C	Uri Park (Y1) and Banandra (Y2)	Gilles Iliana Jessica Vadim Yunming	Rental 4WD (Off road rentals in Melbourne)	Gilles
VEG	6 farms	Lynn Walter Peggy	Own rental 4WD	Lynn

Table 8.6. NAFE'06 aircraft/base crew.

Person	Transport	Dates
Jeff Walker	Rental Ghetz (Melbourne)	28 Oct - 21 Nov
Ed Kim	With Jeff	TBD
Rocco Panciera	With Olivier	23 Oct – 22 Nov
Rodger Young	Uni Truck	28 Oct - 19 Nov
Jon Johanson	With Jeff	29 Oct - 21 Nov
Jorg Hacker	ARA van	29 Oct - 21 Nov

8.8 Daily Activities

The lab (building 22 in Fig. 8.2) will be the meeting point for the morning group assembly and sampling preparation. At the end of the day, each group will download the data collected, put the samples in the oven for drying, check (and repair) the instruments, ensure electronic devices are recharged overnight and report to the team leader. Team leaders should also in turn report to Rodger Young for technical/equipment repairs, to Rocco Panciera for data archiving, and to Olivier/Jeff for general updates etc. Daily operations will proceed as per the following schedule:

- **7.00am:** Gathering of the teams at the NAFE headquarters.
  Morning briefing
  Review of the activity of the day on the notice board
  Preparation of the instruments and tool for the sampling
- **7.15am:** Teams departure for the sampling locations
- Sampling operations
- **5.00pm:** Teams return to the lab
  Report to the project leaders
  Data downloading on the computers
  Soil and vegetation samples in ovens for drying
  Recharge of electronic devices
  Refuel vehicles
- **6.30pm:** Dinner and free time

8.9 Training sessions

A 2-day training session has been scheduled to ensure all NAFE participants are familiar with the project objectives, the sampling strategy and the use of all the instruments involved in the sampling. The training session is scheduled for Sunday 29th October and Monday 30th November. The training session will be held at the YAI on Sunday with all the participants and by teams at the respective farms on Monday, with the schedule and activities indicated in Table 8.7.

Training on instrument use will include:

- iPAQ basics
- Soil moisture sampling with Stevens Hydraprobe®
- Gravimetric soil sampling
- Vegetation height estimation
- Vegetation type estimation
- Surface roughness measurements

Table 8.7. Schedule of training sessions.

Date	Time	Location	Activities	Coordinator
Sunday 29th October	9am-10am	YAI conference room	NAFE'06 Presentation	Jeff
	10.30am-11.30am	YAI conference room	Sampling strategy	Olivier
	11.30am-12.30am	YAI conference room	Instrument use explanation	Rocco
	12.30pm-2pm	YAI	Lunch	
	2pm-6pm	YAI	iPAQ use practice, roughness	Team leaders
Monday 30th November	8am-12pm	2 Farms	Study areas recognition	Team leaders
	12pm-1pm		Lunch	
	1-3pm	YAI	iPAQ use at farms	Team leaders
	3-4pm	YAI	"dry run"	Team leaders
	4-5pm	YAI	Downloading data	Rocco

8.10 Farm Access and Mobility

Farms will be accessed every day for the sampling operations. Transport from YAI to the farm (and in some case across the farm) for sampling will be done using 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. 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 the object of the 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, it is the responsibility of the team leader to ensure that all points have been measured at the end of each day prior to leaving the field. 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 on “transect lines”: walking on a straight line for the soil moisture sampling helps locating the sampling points with the GPS receiver.
- Start from one end of the sampling area. Walk as a team on adjacent lines.
- It is recommended to walk by pair, on two adjacent sampling lines, so as nobody is left alone far from the rest of the team.
- Take the sample exactly at the location indicated on the map: exception to this rule might be the case of a sampling point falling within an undesirable location which might create local soil moisture conditions not representative of the site (e.g. an isolated tree in a vast short grass area, or creek bed). In this case, shift the sampling far enough to capture the average site conditions (up to 30m).
- Always sample in the same locations as the previous days to ensure consistency.

Remember that NAFE’06 activities are allowed by the property owners in the agreement that no damage will be caused to the properties. In particular:

- Use gates when transiting between paddocks. The location of gates (and bridges over irrigation canals) will be loaded on the iPAQs.
- When you open a gate, shut it immediately after you crossed the fence and make sure that the locking system is securely positioned.
- In the case of heavy rain, stop sampling and wait for better weather conditions. If rain appears to “set-in”, return to the operations base.
- 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.

8.11 Communication

Communication between team members, teams and experiment coordinators is essential both from a logistic and safety point of view. In every team there will be at least one mobile phone with the team leader. Working together will provide contact within the individual teams.

Ensure that each team member can be accounted for each half an hour. On most farms the mobile phone coverage is extensive, while on some it is poor.

8.12 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
- 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 pre-existing conditions or allergies before going into the field.
- 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 and long pants to avoid bites. Refer to http://www.australianfauna.com/australiansnakes.php for detailed info about the most common of Australian snake 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.

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

8.13 Getting Around

The Riverina Tourism website at www.riverinatourism.com.au (from Tourism New South Wales) has a wealth of information on the region, including how to get to the Riverina (with details for travelling by plane, train and coach), events calendar, organised tours, self-drive tours, walking tracks, wineries, towns in the region, art galleries, eating out, and sporting facilities.

9 Contacts

Field work

Name	Function	Phone
Jeffrey Walker	Air crew coordinator	0413 023 915
Olivier Merlin	Team A coordinator	0409 953 736
Moshin Hafeez	Team B coordinator	0411 768 900
Lynn McKee	Team VEG coordinator	0424 125 033
Panciera Rocco	Data archive and process support	0431 688 696
Rodger Young	Technical support	0417 504 593
Geoff Beecher	YAI facilities	(02)69 512 725
Greg Summerell	Livingstone data collection	0427 907 213
John Hornbuckle	Yenda data collection	0429 862 920
Tom Jackson		0424 125 034
Peggy O'Neill		0424 125 035
Vadim Kuzmin	Team C contact	0448 715 856
Ed Kim		0405 719 707

Emergency

Emergency number in Australia	000
NSW Poisons information centre	131 126
Leeton District Hospital	Address: Cnr Wade and Palm Avenue, Leeton, NSW, 2705 Phone: (02) 6953 1111
Narrandera District Hospital	Address: Corner of Adams and Douglas Street, Narrandera, NSW Phone: (02) 6959 1166

Farmers

Farm	Farmer Name	Home Phone	Mobile Phone
Uri Park (Y1)	<u>Murray (or Charly) Shaw</u>	(02) 69 684 109	0428 460 029
	Mat Hewstott		0427 552 682
Banandra (Y2)	Danean Smith	(02) 69 596 227	0429 932 193
Tubbo (Y7)	Danean Smith	(02) 69 596 227	0429 932 193
Yammacoona (Y9)	<u>Franck McKersie</u> (Farms 606, 553)	(02) 69 548 566	NA
	John (or Danny) Graham (551)	(02) 69 548 551	0427 548 545
	Greg Perkins (615)		
	Ross McEntire (607)	(02) 69 548 514	NA
	Rob Foster (554)		
	Adrian Hays (Tubbo manager)	(02) 69 541 256	0427 541 256
	Phil Smith (552)	(02) 69 548 550	0428 113 954
Cherevelis (Y10)	Wayne Durnan	(02) 69 597 466	0407 275 534
Spring bank (Y12)	<u>David Gooden</u>	(02) 69 561 148	0428 561 148
	Don Younger	(02) 69 597 450	NA
3 farms in CIA	Grant Mc Millan*	(02) 69 541 503	0427 541 503

*Grant needs to be noticed one day before any sampling in his property.

Accommodation & logistics

Yanco Agricultural Institute (YAI)
Mail: Narrandera Road
PBM
Yanco NSW 2703 Australia
Contact person: George Stevens
Phone: (02) 69512652
Fax: (02) 6955 7580
Email: georges.stevens@dpi.nsw.gov.au
Web: http://www.dpi.nsw.gov.au

The YAI facilities (lab space and equipment)
Contact person: Geoff Beecher
Research Agronomist
NSW Dept Primary Industries
Yanco Agricultural Institute
YANCO NSW 2703
Ph 0269512725
Fx 0269557580

Murrumbidgee Rural Studies Centre (MRSC)
Mail: Murrumbidgee Rural Studies Centre
PMB
YANCO NSW 2703 Australia
Phone: 1800 628 422 (From overseas: +61 2 6951 2696)
Fax: (02) 6951 2620
Email: mrsc@dpi.nsw.gov.au

Accommodation in the MRSC
Contact person: Kellie Goring
Phone: (02) 69 512 775
Fax: (02) 69 512 620
Email: kellie.goring@dpi.nsw.gov.au

Leeton Heritage Motor Inn
Contact person: Evelyn Vogt
Address: 439 Yanco Avenue, Leeton, NSW 2705
Phone: (02) 6953 4100
Fax: (02) 6953 3445

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

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10 Equipment List

The following tables list all the equipments that will be required for NAFE'06, grouped per person, team and operation base

SOIL MOISTURE TEAM EQUIPMENT		TOTAL (3 TEAMS)
4WD vehicle	1	3
HDAS	4	12
hx2110 iPaq	4	12
ipaq container box	4	12
postpack	4	12
ipaq storage card	4	12
battery connector	4	12
gel cell battery	8	24
ipaq mount	4	12
bumpack	4	12
ipaq split sync cable	4	12
ipaq power cable	4	12
ipaq AC adaptor	4	12
hydra probe	4	12
sampling pole	4	12
foam (for hydra probe)	4	12
Soil sampling kit	1	3
soil sample ring	1	3
garden trowel	1	3
blade	1	3
spatula	1	3
wooden base	1	3
plastic bags	300	1200
rubber bands	300	1200
markers for bags	4	12
hardcopy farm map	4	12
hardcopy whole area map	1	3
copy of workplan	1	3
pencil	6	18
field book	1	3
first aid kit	1	3
water jerry can	1	3
flags/colored stripes	10	30
hat	4	12
sunscreen bottle	1	12
insect repellent	1	12

VEGETATION TEAM EQUIPMENT (3 PEOPLE)	
4WD vehicle	1
Vegetation sampling kit	2
veg clipper	2
pair of scissors	2
vegetation quadrant	2
plastic bags	300
rubber bands	300
LAI device	1
Surface reflectance kit	1
iPAQ-GPS kit	1
hx2110 iPaq	1
ipaq container box	1
postpack	1
ipaq storage card	1
battery connector	1
gel cell battery	2
ipaq mount	1
bumpack	1
ipaq split sync cable	1
ipaq power cable	1
ipaq AC adaptor	1
hardcopy farm map	3
hardcopy whole area map	1
copy of workplan	1
pencil	6
field book	1
first aid kit	1
water jerry can	1
flags/colored stripes	10
hat	3
sunscreen bottle	3
insect repellent	3

GENERAL EQUIPMENT	
Yanco Agricultural Institute	
ovens	2
scales	2
alluminium tray	300
weight recording form	4
samples container boxes	4
desktop computer	1
field laptop	1
backup dvd	50
backup hard drive	1
color printer	1
cd's with data	1
multi plug base	5
gel cell battery charger	4
plug extension	5
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
Instrument	
Pin profiler	1
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	
Narrandera airport	
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

Appendix A: Flight Line Coordinates

Table A1. PLMR flight lines and coverage reference coordinates for regional days in Yanco. 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	10 000	10 410	58	145.9495	-34.6232	145.9428	-35.1462
A2	10 000	10 410	58	145.9977	-35.1466	146.004	-34.6237
A3	10 000	10 410	58	146.0585	-34.6241	146.0526	-35.1471
A4	10 000	10 410	58	146.1074	-35.1475	146.1131	-34.6245
A5	10 000	10 410	58	146.1676	-34.6249	146.1623	-35.1479
A6	10 000	10 410	58	146.2172	-35.1482	146.2222	-34.6253
A7	10 000	10 410	58	146.2767	-34.6256	146.2721	-35.1486
A8	10 000	10 410	58	146.327	-35.1489	146.3312	-34.6259

Corner	Longitude (Deg)	Latitude (Deg)
1	145.9162	-34.6365
2	146.3635	-34.6396
3	146.3597	-35.1356
4	145.9097	-35.1323

Table A2. PLMR flight lines and coverage reference coordinates for regional days in Kyeamba. 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.)
B1	10 000	10 997	53	147.2617	-35.0857	147.2632	-35.5636
B2	10 000	10 997	53	147.3184	-35.5635	147.3165	-35.0856
B3	10 000	10 997	53	147.3714	-35.0854	147.3736	-35.5633
B4	10 000	10 997	53	147.4288	-35.5631	147.4262	-35.0852
B5	10 000	10 997	53	147.4811	-35.085	147.4839	-35.5629
B6	10 000	10 997	53	147.5391	-35.5627	147.5359	-35.0848
B7	10 000	10 997	53	147.5908	-35.0846	147.5943	-35.5624
B8	10 000	10 997	53	147.6494	-35.5621	147.6456	-35.0843

corner	Longitude (Deg)	Latitude (Deg)
1	147.2288	-35.0993
2	147.6787	-35.0976
3	147.6824	-35.5484
4	147.2301	-35.5501

Table A3. PLMR flight lines and coverage reference coordinates for multi-incidence flights. 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.)
C1	5 000	5 410	78	145.7978	-34.5861	146.38	-35.0623
C2	5 000	5 410	78	146.38	-35.0623	145.7978	-34.5861
C3	5 000	5 410	78	145.7978	-34.5861	146.38	-35.0623

corner	Longitude (Deg)	Latitude (Deg)
1	145.8055	-34.5988
2	145.8132	-34.5924
3	146.3721	-35.0496
4	146.3644	-35.056

Table A4. PLMR flight lines and coverage reference coordinates for medium resolution flights in the CIA. 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.)
D1	2 500	2 910	35	146.0032	-34.6898	145.9994	-35.0054
D2	2 500	2 910	35	146.0131	-35.0055	146.0169	-34.69
D3	2 500	2 910	35	146.0305	-34.6901	146.0268	-35.0056
D4	2 500	2 910	35	146.0405	-35.0057	146.0441	-34.6902

corner	Longitude (Deg)	Latitude (Deg)
1	145.9949	-34.7033
2	146.0522	-34.7038
3	146.0489	-34.9923
4	145.9913	-34.9918

Table A5. PLMR flight lines and coverage reference coordinates for medium resolution mapping in the Livingstone. 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.)
E1	2 500	4 249	8.5	147.5369	-35.3508	147.5364	-35.2742
E2	2 500	4 249	5.2	147.5364	-35.2742	147.4795	-35.2744
E3	2 500	4 249	18	147.4795	-35.2744	147.4804	-35.4367
E4	2 500	4 249	18	147.4666	-35.4368	147.4657	-35.2745
E5	2 500	4 249	18	147.452	-35.2745	147.4529	-35.4368
E6	2 500	4 249	18	147.4391	-35.4369	147.4382	-35.2746
E7	2 500	4 249	18	147.4245	-35.2746	147.4253	-35.4369
E8	2 500	4 249	18	147.4116	-35.4370	147.4107	-35.2747
E9	2 500	4 249	7	147.3970	-35.2747	147.3973	-35.3378

corner	Longitude (Deg)	Latitude (Deg)
1	147.3888	-35.2883
2	147.4878	-35.2879
3	147.4886	-35.4231
4	147.4032	-35.4235
5	147.4027	-35.3243
6	147.3890	-35.3243

Table A6. PLMR flight lines and coverage reference coordinates for high-resolution resolution mapping along the transect line in Yanco. 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.)
F1	500	925	75	145.7949	-34.5885	146.3771	-35.0647
F2	500	925	75	146.379	-35.0631	145.7968	-34.5869
F3	500	925	75	145.7987	-34.5853	146.381	-35.0615
F4	500	925	75	146.3829	-35.0599	145.8006	-34.5837

corner	Longitude (Deg)	Latitude (Deg)
1	145.8055	-34.5988
2	145.8132	-34.5924
3	146.3721	-35.0496
4	146.3644	-35.056

Table A7. PLMR flight lines and coverage reference coordinates for high-resolution resolution mapping over Yenda site. 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.)
G1	500	951	8	146.1941	-34.2410	146.1198	-34.2784
G2	500	951	8	146.1187	-34.2768	146.1930	-34.2395
G3	500	951	8	146.1919	-34.2379	146.1175	-34.2753
G4	500	951	8	146.1164	-34.2737	146.1907	-34.2364
G5	500	951	8	146.1897	-34.2349	146.1153	-34.2722

corner	Longitude (Deg)	Latitude (Deg)
1	146.1574	-34.2521
2	146.1758	-34.2426
3	146.1810	-34.2494
4	146.1626	-34.2590

Table A8. PLMR flight line for calibration flights over Tombullen water storage.

Line No.	Altitude AGL (ft)	Altitude ASL (ft)	Length (km)	Start Longitude (Deg)	Start Latitude (Deg.)	Stop Longitude (Deg)	Stop Latitude (Deg.)
X	500	925	5	146.1809	-34.6491	146.1263	-34.6487

Table A8. NDVI flight lines and coverage reference coordinates for mapping along the transect line in Yanco. 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.)
H1	1640	2028	75	145.8004	-34.5838	146.3827	-35.06
H2	1640	2028	75	146.38	-35.0623	145.7978	-34.5861
H3	1640	2028	75	145.7951	-34.5883	146.3773	-35.0645

corner	Longitude (Deg)	Latitude (Deg)
1	145.8055	-34.5988
2	145.8132	-34.5924
3	146.3721	-35.0496
4	146.3644	-35.0560

Table A9. NDVI flight lines and coverage reference coordinates for mapping in the CIA. 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.)
I1	1640	2005	35	145.9969	-34.6898	145.9931	-35.0054
I2	1640	2005	35	145.9969	-35.0054	146.0008	-34.6898
I3	1640	2005	35	146.0046	-34.6899	146.0008	-35.0054
I4	1640	2005	35	146.0046	-35.0055	146.0084	-34.6899
I5	1640	2005	35	146.0122	-34.6899	146.0084	-35.0055
I6	1640	2005	35	146.0123	-35.0055	146.016	-34.6899
I7	1640	2005	35	146.0199	-34.69	146.0161	-35.0056
I8	1640	2005	35	146.0199	-35.0056	146.0237	-34.69
I9	1640	2005	35	146.0275	-34.69	146.0238	-35.0056
I10	1640	2005	35	146.0276	-35.0056	146.0313	-34.6901
I11	1640	2005	35	146.0351	-34.6901	146.0314	-35.0057
I12	1640	2005	35	146.0353	-35.0057	146.039	-34.6901
I13	1640	2005	35	146.0428	-34.6902	146.0391	-35.0057
I14	1640	2005	35	146.043	-35.0058	146.0466	-34.6902
I15	1640	2005	35	146.0504	-34.6902	146.0468	-35.0058

corner	Longitude (Deg)	Latitude (Deg)
1	145.9949	-34.7033
2	146.0522	-34.7038
3	146.0489	-34.9923
4	145.9913	-34.9918

Table A10. NDVI flight lines and coverage reference coordinates for mapping in the Livingstone. 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.)
J1	2133	3 881	7	147.4886	-35.4366	147.4883	35.3735
J2	2133	3 881	7	147.4827	-35.3735	147.4831	35.4366
J3	2133	3 881	18	147.4776	-35.4367	147.4767	35.2744
J4	2133	3 881	18	147.4712	-35.2744	147.4721	35.4367
J5	2133	3 881	18	147.4666	-35.4367	147.4657	35.2744
J6	2133	3 881	18	147.4602	-35.2744	147.4611	35.4367
J7	2133	3 881	18	147.4556	-35.4367	147.4547	35.2744
J8	2133	3 881	18	147.4492	-35.2745	147.4501	35.4368
J9	2133	3 881	18	147.4446	-35.4368	147.4437	35.2745
J10	2133	3 881	18	147.4382	-35.2745	147.4391	35.4368
J11	2133	3 881	18	147.4335	-35.4368	147.4327	35.2745
J12	2133	3 881	18	147.4272	-35.2745	147.428	35.4368
J13	2133	3 881	18	147.4225	-35.4369	147.4217	35.2746
J14	2133	3 881	18	147.4162	-35.2746	147.417	35.4369
J15	2133	3 881	18	147.4115	-35.4369	147.4107	35.2746
J16	2133	3 881	7	147.4052	-35.2746	147.4055	35.3377
J17	2133	3 881	7	147.4	-35.3378	147.3997	35.2746
J18	2133	3 881	7	147.3942	-35.2747	147.3945	35.3378
J19	2133	3 881	7	147.389	-35.3378	147.3887	35.2747

corner	Longitude (Deg)	Latitude (Deg)
1	147.3888	-35.2883
2	147.4878	-35.2879
3	147.4886	-35.4231
4	147.4032	-35.4235
5	147.4027	-35.3243
6	147.3890	-35.3243

Table A11. NDVI flight lines and coverage reference coordinates for mapping of the Yenda site. 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.)
K1	1640	2093	8	146.1936	-34.2403	146.1192	-34.2776
K2	1640	2093	8	146.1172	-34.2749	146.1916	-34.2376
K2	1640	2093	8	146.1896	-34.2349	146.1153	-34.2722

corner	Longitude (Deg)	Latitude (Deg)
1	146.1574	-34.2521
2	146.1758	-34.2426
3	146.1810	-34.2494
4	146.1626	-34.2590

Appendix B: Operating the CROPSCAN MSR16R

In the field the radiometer is held level by the support pole above the crop canopy. The diameter of the field of view is one half of the height of the radiometer above the canopy. It is assumed that the irradiance flux density incident on the top of the radiometer (upward facing side) is identical to the flux density incident on the target surface. The data acquisition program included with the system facilitates digitizing the voltages and recording percent reflectance for each of the selected wavelengths. The program also allows for averaging multiple samples. Ancillary data such as plot number, time, level of incident radiation and temperature within the radiometer may be recorded with each scan.

Each scan, triggered by a manual switch or by pressing the space key on a terminal or PC, takes about 2 to 4 seconds. An audible beep indicates the beginning of a scan, two beeps indicate the end of scan and 3 beeps indicate the data is recorded in RAM. Data recorded in the RAM file are identified by location, experiment number and date.

The design of the radiometer allows for near simultaneous inputs of voltages representing incident as well as reflected irradiation. This feature permits accurate measurement of reflectance from crop canopies when sun angles or light conditions are less than ideal. Useful measurements of percent reflectance may even be obtained during cloudy conditions. This is a very useful feature, especially when traveling to a remote research site only to find the sun obscured by clouds.

Three methods of calibration are supported for the MSR16R systems.

2-point Up/Down - Uses a diffusing opal glass (included), alternately held over the up and down sensors facing the same incident irradiation to calibrate the up and down sensors relative to each other (http://www.cropscan.com/2ptupdn.html).

Advantages:

- Quick and easy.
- Less equipment required.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.
- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Up & Down - Uses a white card with known spectral reflectance to calibrate the up and down sensors relative to each other.

Advantages:

- Provides a more lambertian reflective surface for calibrating the longer wavelength (above about 1200 nm) down sensors than does the opal glass diffuser of the 2-point method.
- Radiometer may then be used in cloudy or less than ideal sunlight conditions.
- Recalibration required only a couple times per season.
- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

White Standard Down Only - Uses a white card with known spectral reflectance with which to compare down sensor readings.

Advantages:

- Only down sensors required, saving cost of purchasing up sensors.
- Best method for radiometer use in greenhouse, under forest canopy or whenever irradiance flux density is different between that striking the top of the radiometer and that striking the target area.

Disadvantages:

- White card must be carried in field and recalibration readings must be taken periodically to compensate for sun angle changes.
- Less convenient and takes time away from field readings.

Readings cannot be made in cloudy or less than ideal sunlight conditions, because of likely irradiance change from time of white card reading to time of sample area reading.

There are six major items you need in the field -

- MSR16 (radiometer itself) (Fig. 7.4)
- Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps) (Fig. 7.5)
- CT100 (hand terminal, connected to the DLC with a serial cable)
- Calibration stand and opal glass plate
- Memory cards
- Extension pole (with spirit level adjusted so that the top surface of the radiometer and the spirit level are par level)

Fig. B1. Data logger controller & cable adapter box.

Fig. B2. CT100 hand terminal.

Set Up **–**

- Mount the radiometer pole bracket on the pole and attach the radiometer.
- Mount the spirit level attachment to the pole at a convenient viewing position.
- Lean the pole against a support and adjust the radiometer so that the top surface of it is level
- Adjust the spirit level to center the bubble (this will insure that the top surface of the radiometer and the spirit level are par level)
- Attach the 9ft cable MSR87C-9 to the radiometer and to the rear of the MSR Cable Adapter Box (CAB)
- Connect ribbon cables IOARC-6 and IODRC-6 from the front of the CAB to the front of the Data Logger Controller (DLC)
- Plug the cable CT9M9M-5 into the RS232 connectors of the CT100 and the DLC (the DLC and CAB may now be placed in the shoulder pack for easy carrying)
- Mount the CT100 on the pole at a convenient position
- Adjust the radiometer to a suitable height over the target (the diameter of the field of view is one half the height of the radiometer over the target)

ConFig. MSR –

- Perform once at the beginning of the experiment, or if the system completely loses power
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the ReconFig. MSR menu
- At Command * Press **1** then **ENTER**, input the correct date, Press **ENTER**
- At Command * Press **2** then **ENTER**, input the correct time, Press **ENTER**
- At Command * Press **3** then **ENTER**, input the number of sub samples/plot (5), Press **ENTER**
- At Command * Press **6** then **ENTER**, input a 2 or 3 character name for your sampling location (ex OS for Oklahoma South), Press **ENTER;** input the latitude for your location, Press **ENTER;** input the longitude for your location, Press **ENTER**
- At Command * Press **9** then **ENTER**, input the GMT difference, Press **ENTER**

- At Command * Press **M** then **ENTER** until you return to the main menu

Calibration –

- ***We are using the 2-point up/down calibration method***
- Calibrate everyday before you begin to take readings
- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the ReconFig. MSR menu
- At Command * Press **11** then **ENTER** to get to the Calibration menu
- At Command * Press **3** then **ENTER** to get to the Recalibration menu
- At Command * Press **2** then **ENTER** for the 2-point up/down calibration
- Remove the radiometer from the pole bracket and place on the black side of the calibration stand, point the top surface about 45° away from the sun, press **SPACE** to initiate the scan (1 beep indicates the start of the scan, 2 beeps indicate the end of the scan, and 3 beeps indicate the data was stored)
- Place the separate opal glass plate on top of the upper surface and press **SPACE** to initiate scan
- Turn the radiometer over and place it back in the calibration stand, cover it with the separate opal glass plate and press **SPACE** to initiate scan
- CT100 will acknowledge that the recalibration was stored
- At Command * Press **M** then **ENTER** until you return to the main menu
- Return the radiometer to the pole bracket
- Store configuration onto the memory card

Memory Card Usage –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **7** then **ENTER** to get to the Memory Card Operations menu
- Memory Card Operations menu is:
    1. Display directory
    2. Store data to memory card (use to save data in the field)
    3. Load data from memory card (use first to download data from memory card)
    4. Save program/configuration to card (use to save after calibrating)
    5. Load program/configuration from card (use when DLC loses power)
    6. Battery check

    M Main menu
- There are 2 memory cards, 64K for storing the program/configuration and 256 for storing data in the field

Taking Readings in the Field –

- Switch the CT100 power to on
- Press **ENTER** 3 times to get into main menu
- At Command * Press **2** then **ENTER** to get to the ReconFig. MSR menu
- At Command * Press **5** then **ENTER,** input your plot ID (numbers 1-999 only), Press **ENTER**
- Press **M** to return to the MSR main menu
- At Command * Press **8** then **ENTER** to get to the MSR program
- Press **ENTER** to continue or **M** to return to the MSR main menu
- Enter beginning plot number, **ENTER**

- Enter the ending plot number**, ENTER**, record plot numbers and field ID in field notebook
- Adjust the radiometer to a suitable height (about 2 meters) over the target, point the radiometer towards the sun, center the bubble in the center of the spirit level and make sure that there are no shadows in the sampling area
- **Do not** take measurements if IRR < 300
- Initiate a scan by pushing **SPACE,** the message ‘scanning’ will appear on the screen and a beep will be heard
- When the scan is complete (about 2 seconds) ‘**’ will be displayed and 2 beeps will be heard
- Now, you can move to the next area
- 3 Beeps will be heard when the data has been stored
- Press **SPACE** to start next scan, **R** to repeat scan, **P** to repeat plot, **S** to suspend/sleep, **M** to return to the MSR main menu, **W** to scan white standard, and **D** to scan Dark reading
- When you are done scanning at that field location, press **M** to return to the MSR main menu, then press **10** to put the DLC to sleep
- Switch the CT100 power off

Appendix C: Operating the LAI-2000

Plug the sensor cord into the port labeled “X” and tighten the two screws.

Place a black view-cap over the lens that blocks 1/4 of the sensor view; that 1/4 that contains the operator. Place a piece of tape on the view cap and body of the sensor so if the cap comes loose it will not be lost.

Turn on the logger with the “**ON**” key (The unit is turned off by pressing “**FCT**”, "**0**" , "**9**".)

Clear the memory of the logger -
Press “**FILE**”
Use “↑” to place “Clear Ram” on the top line of display
Press “**ENTER**”
Press “↑” to change “NO” to “YES”
Press “**ENTER**”

General items –
When changing something on the display, get desired menu item on the top line of display and then it can be edited.
Use the “↑” and “↓” to move items through the menu and the “**ENTER**” key usually causes the item to be entered into the logger.
When entering letters, look for the desired letter on the keys and if they are on the lower part of the key just press the key for the letter; if the desired letter is on the upper part of the key then press the “↑” and then the key to get that letter.
Press “**BREAK**” anytime to return to the monitor display that contains time, file number or sensor readings on one of the five rings that are sensed by the LAI-2000.
Do not take data with the LAI-2000 if the sensor outputs are less than 1.0 for readings above the canopy.

To Begin -
Press “**SETUP**”
Use “↑” to get “XCAL” on the top line of the display and press “**ENTER**”
Following XS/N is the serial number of the sensor unit, enter appropriate number
Check or put appropriate cal numbers from LICOR cal sheet into the 5 entries.
Final press of “**ENTER**” returns you to “XCAL”
Use “↑” to get to “RESOLUTION”
Set it to “HIGH”
Use “↑” to get to “CLOCK”
Update the clock (set to local time using 24 hr format)

Press “**OPER**”
Use “↑” to get “SET OP MODE” on top line of display
Choose “MODE=1 SENSOR X”
Enter “↑”, “↓”, “↓”, “↓”, “↓” in “SEQ”
Enter "1" in “REPS”
Use “↑” to get to “SET PROMPTS”
Put “SITE” in first prompt
Put “LOC” in second prompt

Use “↑” to get to “BAD READING”
Choose "A/B=1"

Press “**BREAK**”
Display will contain the two monitor lines
Use “↑” and “↓” to control what is displayed on the top line in the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If FI is selected, then the file number is displayed)
Use the “→” and “←” to control what is displayed on the bottom line of the monitor mode, time, file number or sensor ring output 1 through 5 for the X sensor. (If X2 is selected, then ring #2 output is displayed)

Press “**LOG**” to begin collecting data
Type in the response to the first prompt (if “**ENTER**” is pressed the same entry is kept in response to the prompt).
Type in the response to the second prompt (if “**ENTER**” is pressed the same entry is kept in response to the prompt).
Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

For grasslands:
1. Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
2. Place the sensor below the plant canopy in one corner of your sampling area level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Repeat for the other 3 corners

Repeat steps 1-3 so that you have a total of 5 sets of measurements.

For Row crops:
1. Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.
2. Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.
3. Place the sensor one-quarter (1/4) of the way across the row and record data again.
4. Place the sensor one-half (1/2) of the way across the row and record data again.
5. Place the sensor three-quarters (3/4) of the way across the row and record data again.

Repeat steps 1-5 so that you have a total of 5 sets of measurements.

The logger will compute LAI and other values automatically. Using the “↑” you can view the value of the LAI.
NOTE: You will record the “SITE” and “LOC” along with the LAI value on a data sheet.
The LAI-2000 is now ready for measuring the LAI at another location. Begin by pressing “**LOG**” twice. The file number will automatically increment. When data collection is complete, turn off the logger by pressing “**FCT**”, "**0**", "**9**". The data will be dumped onto a laptop back at the Field Headquarters.

Appendix D: Team Task Sheets

Table D.1. Task sheet for soil moisture teams (SM A, B and C) during regional days (Tuesday, Thursday and Saturday).

Measurement	Extent	Spacing	Number	Frequency
Hydra probe readings	3 by 3km	250m	144*3 per farm	Everyday
Land use	3 by 3km	250m	144 per farm	Only once
Vegetation type	3 by 3km	250m	144 per farm	Only once
Canopy height	3 by 3km	250m	144 per farm	1 per week
Presence of dew	3 by 3km	250m	144 per farm	Everyday
Gravimetric soil samples*	3 by 3km	1500m	5 per farm	Everyday
Soil roughness	3 by 3km	1km	5*2 per farm	Only once

* Team leader responsibility

Table D.2. Task sheet for soil moisture teams (SM A, B and C) during transect days (Wednesday and Friday).

Measurement	Extent	Spacing	Number	Frequency
Hydra probe readings	3 by 1km	50m/250m	225*3 at 50m + 28*3 at 250m	Everyday
Land use	3 by 1km	50m/250m	253 per farm	Only once
Vegetation type	3 by 1km	50m/250m	253 per farm	Only once
Canopy height	3 by 1km	50m/250m	253 per farm	1 per week
Presence of dew	3 by 1km	50m/250m	253 per farm	Everyday
Gravimetric soil samples*	3 by 1km	500m	5 per farm	Everyday
Soil roughness	3 by 1km	1km	5*2 per farm	Only once

* Team leader responsibility

Table D.3. Task sheet for the vegetation (VEG) team.

Measurement	Extent	Spacing	Number	Frequency
Vegetation samples	1km	Paddock scale	5 per vegetation type	Everyday
Surface reflectance	1km	Paddock scale	Flexible	Everyday
LAI	1km	Paddock scale	Flexible	Everyday
Vegetation type	1km	Paddock scale	number of vegetation samples	Only once
Canopy height	1km	Paddock scale	number of vegetation samples	Every day