The Third
Soil Moisture Active Passive Experiment
WORKPLAN

Alessandra Monerris, Jeffrey Walker, Rocco Panciera, Thomas Jackson,
Mihai Tanase, Douglas Gray, and Dongryeol Ryu

August 2011

CONTENT

1. OVERVIEW AND OBJECTIVES

The Soil Moisture Active Passive Experiment (SMAPEx) comprises three campaigns across an approximately one year timeframe. The first campaign (SMAPEx-1) was conducted in the austral winter from 5-10 July, 2010. Weather conditions allowed observations of moderately wet winter conditions in the range 0.15-0.25m^3/m^3 soil moisture, with an approximate dynamic range of 0.05-0.10 m^3/m^3 during the field experiment. Vegetation contributions were minimal since the experiment was shortly after planting, and with only emergent crops and short grass present in the fields. The crop and grass biomass was within the range 0-1kg/m^2. The second campaign (SMAPEx-2) was conducted in the austral summer from 4-8 December, 2010. Intense rainfall was experienced in the study area in the lead up to the experiment, meaning that wet soil moisture conditions were experienced (0.25-0.33m^3/m^3) with extensive surface water in some locations. Due to warm moist conditions and delayed harvests, vegetation biomass was high, with crops at near-peak biomass (up to 4kg/m^2) and overgrown native pastures (up to 1.6kg/m^2). This third campaign (SMAPEx-3) will take place in the austral spring from 3-23 September, 2011. Being in spring, it is expected that the campaign will commence with moist soils and low vegetation biomass, leading to dry soils and high vegetation biomass towards the end of the 3 week long experiment. A particular objective of the third experiment is to acquire long-term series of data throughout the active part of the growing season, with the purpose of testing time-series retrieval algorithms.

The overall SMAPEx project goal is to develop algorithms and techniques to estimate near-surface soil moisture from the future Soil Moisture Active Passive (SMAP) mission from the National Aeronautics and Space Administration (NASA). This will involve collecting airborne prototype SMAP data together with ground observations of soil moisture and ancillary data for a diverse range of conditions.

Although NASA has its own plans for SMAP-dedicated airborne campaigns, the SMAPEx campaigns are strategically important in addressing scientific requirements of the SMAP mission. Therefore SMAPEx represents a significant contribution to the limited heritage of airborne experiments utilising both active and passive observations, including the passive/active L-band/S-band sensor (PALS) flights undertaken as part of the Southern Great Plains experiment in 1999 (SGP99), the Soil Moisture Experiment in 2002 (SMEX02), the Cloud and Land Surface Interaction Campaign (CLASIC) conducted in Oklahoma in 2007 (see further information in http://hydrolab.arsusda.gov), and the Canadian Experiment for Soil Moisture 2010 (CanEx-SM10; http://pages.usherbrooke.ca/canexsm10/).

The SMAPEx campaigns have been made possible through infrastructure (LE0453434, LE0882509) and research (DP0984586) funding from the Australian Research Council. Initial campaigns, setup, and maintenance of the study catchment were funded by research grants (DP0343778 and DP0557543) from the Australian Research Council, and the CRC for Catchment Hydrology. SMAPEx also relies upon the collaboration of a large number of scientists from throughout Australia and around the world, and in particular key personnel from the SMAP team, which have also provided significant contributions to the campaign design.

1.1. OVERVIEW

Accurate knowledge of spatial and temporal variation in soil moisture at high resolution is critical for achieving sustainable land and water management, and for improved climate change prediction and flood forecasting. Such data are essential for efficient irrigation scheduling and cropping practices, accurate initialization of climate prediction models, and setting the correct antecedent moisture conditions in flood forecasting models. The fundamental limitation is that spatial and temporal variation in soil moisture is not well known or easy to measure, particularly at high resolution over large areas. Remote sensing provides an ideal tool to map soil moisture globally and with high temporal frequency. Over the past two decades there have been numerous ground, air- and space-borne near-surface soil moisture (top 5cm) remote sensing studies, using thermal infrared (surface temperature) and microwave (passive and active) electromagnetic radiation. Of these, microwave is the most promising approach, due to its all-weather capability and direct relationship with soil moisture through the soil dielectric constant. Whilst active (radar) microwave sensing at L-band (~1.4GHz) has shown some positive results, passive (radiometer) microwave measurements at L-band are least affected by land surface roughness and vegetation cover. Consequently, ESA launched the Soil Moisture and Ocean Salinity (SMOS) satellite in November 2009, being the first-ever dedicated soil moisture mission that is based on L-band radiometry. However, space-borne passive microwave data at L-band suffers from being a low resolution measurement, on the order of 40km. 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 smaller scale.

To address the requirement for higher resolution soil moisture data, NASA has proposed the Soil Moisture Active Passive (SMAP) mission. SMAP will carry an innovative active and passive microwave sensing system, including an L-band radar and L-band radiometer. The basis for SMAP is that the high resolution (3km) but noisy soil moisture data from the radar, and the more accurate but low resolution (40km) soil moisture data from the radiometer will be used synergistically to produce a high accuracy and improved spatial resolution (10km) soil moisture product with high temporal frequency. The SMAP sensing configuration will overcome coarse spatial resolution limitations currently affecting pure passive microwave platforms such as the Soil Moisture and Ocean Salinity (SMOS) and the Advanced Microwave Scanning Radiometer (AMSR-E), as well as the limitations due to low signal-to-noise ratio of active microwave systems such as the Advanced Synthetic Aperture Radar (ASAR) and the Phased Array type L-band Synthetic Aperture Radar (PALSAR).

In preparation for SMAP launch (currently planned for Nov 2014), suitable algorithms and techniques need to be developed and validated to ensure that an accurate high resolution soil moisture product, from combined SMAP radar and radiometer data, can be produced. To this end, it is essential that field campaigns with coordinated satellite, airborne and ground-based data collection are undertaken, giving careful consideration to the diverse data requirements for the range of scientific questions to be addressed. The SMAPEx campaigns described in this document have been specifically designed to address these scientific requirements. SMAPEx stems from the availability of a new airborne remote sensing capability, which allows us to have the only sensor combination world-wide able to undertake from a single aircraft, high resolution active and passive microwave remote sensing at L-band with resolution ratios, incidence angles and polarisations that replicate those expected from SMAP. The facility includes the Polarimetric L-band Multibeam Radiometer (PLMR) and the Polarimetric L-band Imaging Synthetic aperture radar (PLIS) which, when used together on the same aircraft, allow simulation of the SMAP data with passive microwave footprints at 1km and active microwave footprints at 10m resolution when flown at a flying height of 3000m. All other existing combined active-passive capabilities currently provide only active-passive data for the same footprint resolution.

1.2. OBJECTIVES

The main objective of SMAPEx-3 is to collect airborne active and passive microwave data which are scaled replicate of the data which will be collected by SMAP, supported by ground observations of soil moisture and ancillary data needed for development and validation of algorithms to estimate soil moisture from future SMAP data. Algorithms for soil moisture retrieval from passive microwave observations (radiometer brightness temperatures) are fairly mature for bare and vegetated surfaces. However, some open questions still remain, particularly on suitable methods to estimate the contribution of Vegetation Water Content (VWC) and surface roughness to the microwave signal. Moreover, ways of mitigating the impact of land surface heterogeneity within the SMAP radiometer pixel (40km) on the soil moisture retrieval accuracy from passive microwave data need to be developed. Conversely, soil moisture retrievals from active microwave observations (radar backscatter coefficients), which are influenced to a greater extent by vegetation and surface scattering, have so far been limited to predominantly bare soil conditions or vegetation cover with VWC less than about 0.5–1kg/m^2. Several theoretical models have been proposed to model the vegetation effects for more severe vegetation conditions. However, such formulations are still to be properly incorporated in soil moisture retrieval algorithms, and require extensive testing with field data. Importantly, techniques to efficiently merge active and passive microwave observations to obtain accurate soil moisture information at 10km resolution need to be developed and tested.

The SMAPEx-3 data set will aim at providing long-term data series with which to:

- Test existing soil moisture retrieval algorithms for bare and vegetated surfaces from radar backscatter coefficients, including time-series retrieval approaches.
- Develop and test techniques to improve the soil moisture retrieval from radiometer brightness temperatures using information on the surface conditions (vegetation water content, and surface roughness) extracted from the radar backscatter coefficients.
- Develop and test techniques to downscale the coarse-resolution soil moisture retrieval from the radiometer brightness temperatures using the fine-resolution radar backscatter coefficients.

- Develop an Australian cal/val site for post-launch verification of SMAP products over Australia.

1.3. GENERAL APPROACH

SMAPEx will comprise three airborne campaigns in the Yanco study area within the Murrumbidgee catchment (see Figure 1-1), in south-eastern Australia. The first campaign (SMAPEx-1) was conducted in the austral winter from 5-10 July, 2010. The second campaign (SMAPEx-2) was conducted in the austral summer from 4-8 December, 2010. The third campaign, described in this document, will take place in the austral spring from 3-23 September, 2011. The three campaigns are planned to span across an approximately one year timeframe to encompass seasonal variation in soil moisture and vegetation. Moreover, the time window was selected to widen the range of soil wetness conditions encountered through capturing wetting and/or drying cycles associated with rainfall events.

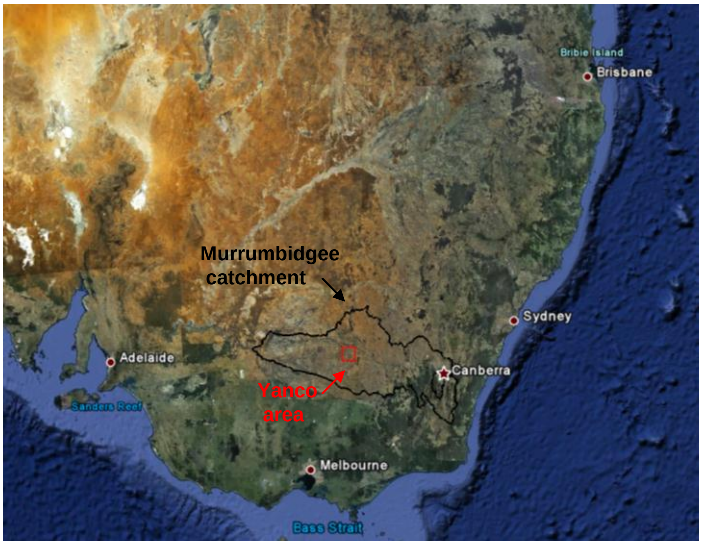


Figure 1-1. Location of the SMAPEx study area within the Murrumbidgee catchment.

The primary aircraft instruments will be the Polarimetric L-band Multibeam Radiometer (PLMR), used in across-track (pushbroom) configuration to map the surface with three viewing angles (±7°, ±21.5° and ±38.5°) to each side of the flight direction, achieving a swath width of about 6km, and the Polarimetric L-band Imaging Synthetic aperture radar (PLIS), with two antennas used to measure the surface backscatter to each side of the flight direction between 15° and 45° angle. The flight lines have been designed so that full PLMR and PLIS coverage of the study area is guaranteed. All flights will be operated out of the Narrandera airport, with the ground undertaking daily activities at the ground sampling areas shown in Figure 1-2. The operations base is the Yanco Agricultural Institute, providing both lodging and laboratory support.

Data collected during SMAPEx-3 will mainly consist of:

- airborne L-band active and passive microwave observations, together with ancillary visible, near-infrared, shortwave infrared, and thermal infrared;
- continuous near-surface (top 5cm) soil moisture and soil temperature monitoring at 29 permanent stations across the study area. Of these stations, 5 will also provide profile (0-90cm) soil moisture and soil temperature data;

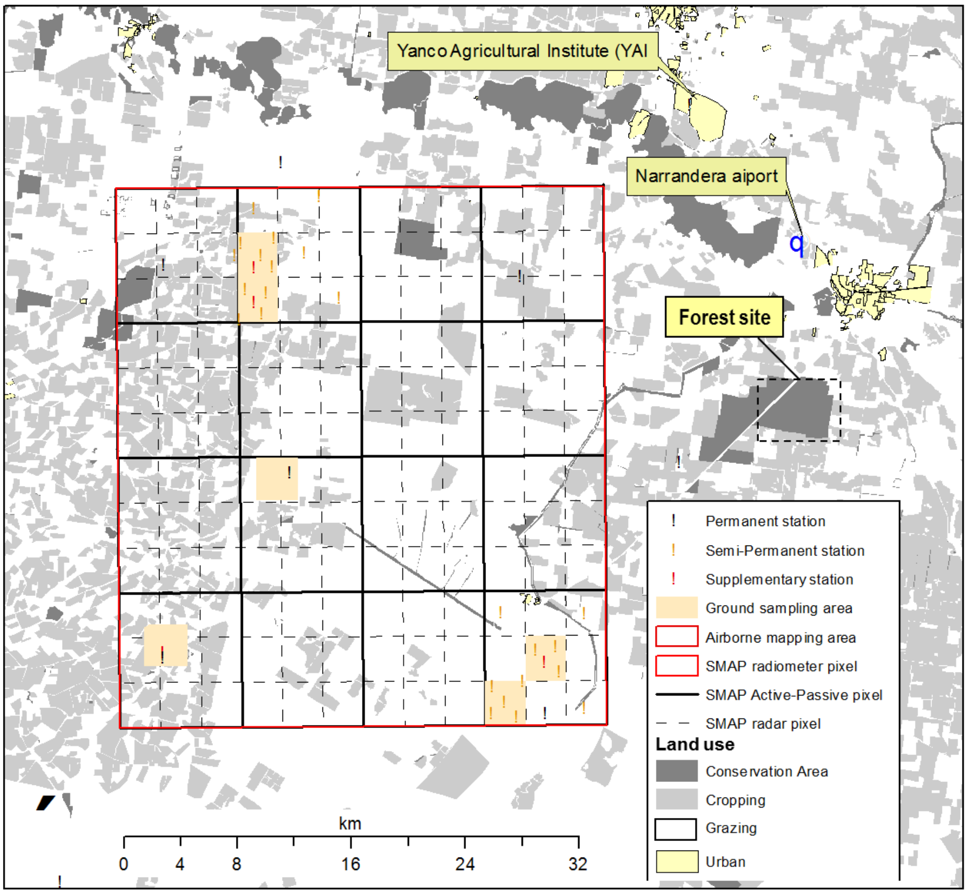


Figure 1-2. Overview of the SMAPEx-3 experiment. The map shows the area covered by airborne mapping (red rectangle), the ground soil moisture networks (coloured dots), ground sampling focus areas and prescribed SMAP grids for radiometer, radar, and active-passive products.

- additional intensive measurements of near-surface (top 5cm) soil moisture spatial distribution, vegetation biomass, water content, reflectance, and surface roughness across six approximately 3km × 3km focus areas.

Taking advantage of the SMAPEx-3 experiment set-up, a set of add-on measurements will also be acquired:

- airbone LIDAR, InSAR, and hyperspectral observations;
- intensive characterisation of four groups of crop plants and 50 forest sites within a 7km × 8km forest area; and
- spatial maps of ground and airborne observations of cosmic-ray fast neutrons above the ground surface.

The main airborne and ground monitoring strategy will follow a “nested grid” approach based on the future SMAP grids (see Figure 1-2). Airborne data will be collected over an area equivalent to a single SMAP radiometer pixel (SMAP L1C_TB product, 40km × 40km nominal resolution) for a total of 9 dates over a 3-week period. Continuous ground permanent monitoring sites will cover the entire SMAP radiometer pixel, but with a denser network in two sub-areas representing pixels of the SMAP downscaled soil moisture product (SMAP L3_SM_A/P product, 9km × 9km). Intensive spatial monitoring will concentrate on six focus areas equivalent to a SMAP radar pixels (L1C_HiRes product, 3km × 3km). This design will allow simulating SMAP prototype data over the Yanco study area by aggregation of the airborne observations to SMAP radiometer and radar resolutions, as well as detailed validation against ground data of the airborne data at all the resolutions of the SMAP products.

This approach was based on the predicted Earth Fixed grid where all SMAP products will be projected. The Earth Fixed grid is an Equal-Area Scalable Earth (EASE) grid has several advantages (easy implementation, suitability for mosaicking) over alternative grids, which come at the cost of a certain level of distortion depending on latitude. Consequently, the actual pixel size of all SMAP products varies with latitude, corresponding to the nominal resolutions only at latitudes +/- 30°. Hence, at the Yanco study area latitude a SMAP radiometer pixel corresponds to a rectangle of 34km × 38km rather than the nominal 40km × 40km resolution. The other SMAP product grids present similar distortion, with a radar pixel corresponding to a 2.8km × 3.1km rectangle and the merged active and passive soil moisture product pixel to an 8.5km × 9.4km rectangle. The airborne monitoring during SMAPEx is designed to match the effective resolutions of the SMAP products, rather than the nominal ones, this way guaranteeing consistency of the data collected with that of SMAP data anticipated for the area. Moreover, the area covered by airborne monitoring was shifted southward with respect to the predicted SMAP grid in order to cover the region south-west of Yanco where the pre-existing monitoring network is denser. The southward shift was equivalent to one full SMAP merged active and passive soil moisture product pixel (9.4km), so as to keep a high level of consistency between the SMAP grids simulated with SMAPEx data and that anticipated from SMAP.

2. RELEVANT SATELLITE OBSERVING SYSTEMS

Satellite observing systems of relevance for soil moisture and vegetation biomass remote sensing are listed below. While passive and active microwave sensors are able to provide direct estimates of near-surface soil moisture, optical data can be used in synergy for direct soil moisture retrieval and/or downscaling.

2.1. MICROWAVE SENSORS

SOIL MOISTURE ACTIVE PASSIVE (SMAP)

SMAP is one of four Tier 1 missions recommended by the National Research Council's Committee on Earth Science and Applications from Space (http://smap.jpl.nasa.gov). The science goal is to combine the attributes of the radar (high spatial resolution) and radiometer (high soil moisture accuracy) observations to provide estimates of soil moisture in the top 5 cm of soil with an accuracy of 0.04 v/v at 10 km resolution, and freeze-thaw state at a spatial resolution of 1-3 km. The payload consists of an L-band radar (1.26 GHz; HH, VV, HV) and an L-band radiometer (1.41 GHz; H, V, U) sharing a single feed horn and parabolic mesh reflector. The reflector is offset from nadir, and rotates about the nadir axis at 14.6rpm, providing a conically-scanning antenna beam with a constant surface incidence angle of approximately 40°. SMAP is scheduled to launch in Nov 2014 into a 680 km near-polar, sun-synchronous orbit with an 8-day exact repeat cycle and 6am/6pm Equator crossing time. The scan configuration yields a 1000 km swath, with a 40 km radiometer resolution and 1-3 km synthetic aperture radar resolution (over the outer 70% of the swath) that provides global coverage within 3 days at the Equator and 2 days at boreal latitudes. The SMAPEx airborne facility will closely simulate the SMAP viewing configuration using the Polarimetric L-band Multibeam Radiometer (PLMR) and the Polarimetric L-band Imaging Synthetic aperture radar (PLIS) (see Section 3).

AQUARIUS

Aquarius (http://aquarius.gsfc.nasa.gov) is also an L-band microwave satellite, but it is designed specifically for measuring the global sea surface salinity. However, it can also be used for soil moisture retrieval, but with a much lower spatial resolution (150km) than SMOS, and with a longer repeat time (8 days). The science instruments will include a set of three L-band radiometers (1.413GHz; 29°, 38°, 45° incidence angles) and an L-band scatterometer (1.26GHz) to correct for the ocean's surface roughness, meaning that it can also be used to explore active-passive retrieval of soil moisture. This mission was launched on June 10, 2011, into a sun-syncronous orbit, with an estimated 3-years lifetime. It is possible that science data from Aquarius will begin to flow at around the time of the SMAPEx-3 campaign, but exact overpass information is not yet available. Consequently there has been no effort to try and coincide flights with Aquarius overpass dates.

SOIL MOISTURE AND OCEAN SALINITY (SMOS)

The SMOS (http://www.esa.int/esaLP/LPsmos.html) satellite was launched on 2 November 2009, making it the first satellite to provide continuous multi angular L-band (1.4GHz) radiometric measurements over the globe. Over continental surfaces, SMOS provides near-surface soil moisture data at ~50km resolution with a repeat cycle of 2-3 days. The payload is a 2D interferometer yielding a range of incidence angles from 0° to 55° at both V and H polarisations, and a 1,000km swath width. Its multi-incidence angle capability is expected to assist in determining ancillary data requirements such as vegetation attenuation. This satellite has a 6am/6pm equator overpass time (6:00am local solar time at ascending node). Due to the synthetic aperture approach of this satellite, brightness temperature observations will be processed onto a fixed hexagonal grid with an approximately 12km node separation. While the actual footprint size will vary according to position in the swath, incidence angle, etc., it will be of approximately 42km diameter on average. Campaigns for validation of SMOS retrieval algorithms were the focus of a separate project, the Australian Airborne Cal/val Experiments for SMOS (AACES). SMOS data for the SMAPEx campaigns will be available through a CAT-1 ESA proposal.

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, http://www.nasda.go.jp/projects/sat/alos/index_e.html) that recently stopped functioning. Consequently there will be no PALSAR acquisitions during SMAPEx-3, but some historic data is available, including for SMAPEx-1. The sensor operated at L-band with HH and VV polarisation (HV and VH polarisations are optional) with beam steering in elevation. The ScanSAR mode allowed 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 was 46 days and the local time at descending node was about 10:30am.

ADVANCED MICROWAVE SCANNING RADIOMETERS (AMSR-E & AMSR-2)

The AMSR-E (http://www.ghcc.msfc.nasa.gov/AMSR/) sensor is a passive microwave radiometer operating at 6 frequencies ranging from 6.925 to 89.0GHz. Both 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 6.925GHz channel (C-band). The AMSR-E is one of six sensors on-board Aqua, which was launched in 2002. It has a 1:30am/pm equator crossing orbit with 1-2 day repeat coverage. Several surface soil moisture products are available globally. AMSR-E brightness temperature data can be downloaded free of charge from the NSIDC web site (http://nsidc.org/data/amsre/order.html) or the Distributed Active Archive Center (DAAC). While the current AMSR sensor continues to outlive its expected lifetime, a follow-on mission is planned by JAXA for the near future, the AMSR-2 sensor on-board the Global Change Observation Mission –

Water (GCOM-W, http://www.jaxa.jp/projects/sat/gcom_w/index_e.html), scheduled for launch in early 2012.

ADVANCED SYNTHETIC APERTURE RADAR (ASAR)

The ASAR (http://envisat.esa.int/instruments/asar/) instrument is operating at C-band and 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 swath coverage more than 400km 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 on-board 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 data for the SMAPEx campaigns will be available through a CAT-1 ESA proposal.

ADVANCED SCATTEROMETER (ASCAT)

The ASCAT (http://www.esa.int/esaME/ascat.html), operating at C-band, provides continuity to the ERS-1 and ERS-2 scatterometers. The ASCAT is on-board the Metop satellite, which was launched into a sun synchronous orbit in October 2006 and has been operational since May 2007. ASCAT operates at a frequency of 5.255GHz in vertical polarisation. Its use of six antennas allows the simultaneous coverage of two swaths on either side of the satellite ground track, allowing for much greater coverage than its predecessors. It takes about 2 days to map the entire globe. A 50km resolution soil wetness product is now operational from ASCAT, available from EUMETSAT (http://www.eumetsat.int/).

WINDSAT

WindSat (http://www.nrl.navy.mil/WindSat/) is a multi-frequency polarimetric microwave radiometer with similar frequencies to the AMSR-E sensor, with the addition of full polarisation for 10.7, 18.7 and 37.0GHz channels, but lacks the 89.0GHz channel. Also, it has a 6:00am/pm local overpass time, which is different to that of AMSR-E. Developed by the Naval Research Laboratory, it is one of two primary instruments on the Coriolis satellite launched in January 2003. WindSat is continuing to outlive its three year design life, with data free to scientists from http://www.cpi.com/twiki/bin/view/ WindSat/WebHome.

CONSTELLATION OF SMALL SATELLITES FOR THE MEDITERRANEAN BASIN OBSERVATION (COSMO-SKYMED)

COSMO-SkyMed (http://www.cosmo-skymed.it/en/index.htm) is a constellation composed of four satellites equipped with X-band Synthetic Aperture Radar operating operated by the Italian Space Agency (Agenzia Spaziale Italiana). The first satellite of COSMO-SkyMed constellation was launched in June 2007. The constellation will consist of 4 medium-size satellites, each equipped with a microwave high-resolution synthetic aperture radar (SAR) operating in X-band, having ~600km single side access ground swath, orbiting in a sun-synchronous orbit at ~620km height over the Earth surface, with the capability to change attitude in order to acquire images for either right or left sides of the satellite ground track (nominal acquisition is right looking mode). The spatial resolution ranges from 1m for the spotlight images to 100m in ScanSAR mode. COSMO-SkyMEd data for the SMAPEx-3 campaign will be provided by the “Consiglio Nazionale della Ricerca” (National Research Council, CNR), Italy.

TERRASAR-X ADD-ON FOR DIGITAL ELEVATION MEASUREMENT (TANDEM-X)

TanDEM-X adds a second (TDX), almost identical spacecraft to TerraSAR-X (TSX) and flies the two satellites in a closely controlled formation to obtain a single-pass SAR-interferometer with adjustable baselines in across-and in along-track directions (http://www.dlr.de/hr/en/desktopdefault.aspx/tabid-2317/3669_read-5488/). TDX has SAR system parameters which are fully compatible with TSX, allowing not only independent operation from TSX in a mono-static mode, but also synchronized operation (e.g. in a bi-static mode). The main objective of the mission is to obtain a global DEM with a spatial resolution of 12m and relative vertical accuracy of 2m using across-track baselines of 200-600m. Local DEMs of even higher accuracy level (spatial resolution of 6m and relative vertical accuracy of 0.8m) will be also generated. Besides the primary goal of the mission, several secondary mission objectives based on new and innovative SAR techniques as for example along-track interferometry (ATI), polarimetric SAR interferometry (PolInSAR), digital beamforming, and bistatic radar represent an important asset of the mission. The SMAPEx-3 experiment will take advantage of the single-pass interferometric capabilities of Tandem-X mission. High resolution radar interferometry will allow the assessment of three dimensional canopy architectural descriptors.

2.2. OPTICAL SENSORS

ADVANCED ALONG TRACK SCANNING RADIOMETER (AATSR)

AATSR (http://envisat.esa.int/instruments/aatsr/) is the most recent in a series of instruments designed primarily to measure Sea Surface Temperature (SST), following on from ATSR-1 and ATSR-2 on-board ERS-1 and ERS-2. AATSR data have a resolution of 1 km at nadir, and are derived from measurements of reflected and emitted radiation taken at wavelengths 0.55µm, 0.66µm, 0.87µm, 1.6µm, 3.7µm, 11µm and 12µm. These can also be used to obtain land surface temperature at a spatial resolution of 1km × 1km over a swath of 500km. AATSR data for the SMAPEx campaigns will be available through a CAT-1 ESA proposal.

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 on-board Terra and has a swath width of about 60km. ASTER is being used to obtain detailed maps of land surface temperature, reflectance and elevation.

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 on-board ALOS. AVNIR-2 is a successor to AVNIR that was on-board the ADvanced Earth Observing Satellite (ADEOS), 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 for the SMAPEx campaigns will be provided by the "Consiglio Nazionale della Ricerca" (National Research Council, CNR), Italy.

COMPACT HIGH RESOLUTION IMAGING SPECTROMETER (CHRIS)

CHRIS (www.chris-proba.org.uk) provides remotely-sensed multi-angle data at high spatial resolution and at superspectral/hyperspectral wavelengths. The instrument has a spectral range of 415-1050nm, and provides observations at 19 spectral bands simultaneously. It has a spatial resolution of 20m at nadir and a swath width of 14km. 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.

LANDSAT

Landsat (http://landsat.usgs.gov/) 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 local Equator crossing time. This data is particularly valuable in land cover and vegetation parameter mapping. Due to an instrument malfunction on-board 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. Consequently, Landsat 5 Thematic Mapper, which is still in operation, it is being increasingly relied upon. The approximate scene size is 170km × 183km. A December 2012 launch date was recently confirmed for the Landsat Data Continuity Mission (LDCM), but it is not likely to have a thermal band.

MEDIUM RESOLUTION IMAGING SPECTROMETER (MERIS)

MERIS is one of the sensors onboard the Environmental Satellite (ENVISAT) of the European Space Agency (http://envisat.esa.int/instruments/meris/MERIS), launched in March 2002 into a sun-synchronous polar orbit at a height of 790 km. MERIS was designed to acquire data over the Earth in the solar reflective spectral range (390 to 1040 nm), using 15 bands selectable across the range. The instrument's 68.5° field of view around nadir covers a swath width of 1150km at a resolution of 260m × 300m. MERIS data for the SMAPEx campaigns will be provided by the "Consiglio Nazionale della Ricerca" (National Research Council, CNR), Italy.

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 0.4µm to 14.4µm. Two bands are imaged at a nominal resolution of 250m at nadir, five bands at 500m, and the remaining 29 bands at 1km. MODIS is operating onboard Terra and Aqua. Terra was launched in December 1999 and Aqua in May 2002. A ±55° scanning pattern at 705km altitude achieves a 2,330km swath that provides global coverage every one to two days. Aqua has a 1:30am/pm local 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.

In general, the range of surface temperature values from MODIS is dependent on the time of acquisition, and is greater for 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 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.

MTSAT-1R

The Multi-functional Transport Satellite (MTSAT) series fulfils a meteorological function for the Japan Meteorological Agency and an aviation control function for the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport. The MTSAT series (http://www.jma.go.jp/jma/jma-eng/satellite/index.html) succeeds the Geostationary Meteorological Satellite (GMS) series as the next generation of satellites covering East Asia and the Western Pacific. This series provides imagery for the Southern Hemisphere every 30min at 4km resolution in contrast to the previous hourly data, enabling the Japan Meteorological Agency to more closely monitor typhoon and cloud movement. The MTSAT series carries a new imager with a new infrared channel (IR4) in addition to the four channels (VIS, IR1, IR2 and IR3) of the GMS-5.

3. AIRBORNE AND GROUND-BASED OBSERVING SYSTEMS

During SMAPEx-3, airborne measurements will be made using two small single engine aircraft, the ESV and the EOS. The ESV aircraft will include, in the nominal configuration, the PLMR radiometer, the PLIS radar, and thermal infrared and multi-spectral sensing instruments. This infrastructure will allow surface backscatters (~10-30m), passive microwave (~1km), land surface skin temperature (~1km) and vegetation index (~1km) observations to be made across large areas. Once during SMAPEx-3, the ESV aircraft will fly the PLIS radar in Interferometric SAR (InSAR) mode (~10-30m) and the COSMOS rover sensor. The EOS aircraft will instead carry a LIDAR with VNIR multispectral scanners and the Hawk SWIR (~1m).

ESV AIRCRAFT

The ESV aircraft (see Figure 3-1, Figure 3-2) can carry a typical science payload of up to 250kg (120kg for maximum range) with cruising speed of 150-270km/h and range of 9hrs with reserve (5hrs for maximum payload). The aircraft ceiling is 3000m or up to 6000m with breathing oxygen equipment, under day/night VFR or IFR conditions. The aircraft can easily accommodate two crew; pilot/scientist plus scientist.

ESV instruments are typically installed in an underbelly pod or in the wingtips of this aircraft. Aircraft navigation for science is undertaken using a GPS driven 3-axis autopilot together with a cockpit computer display that shows aircraft position relative to planned flight lines using the OziExplorer software. The aircraft also has an OXTS (Oxford Technical Solutions) Inertial plus GPS system (two along-track antennae on the fuselage) for position (georeferencing) and attitude (pitch, roll and heading) interpretation of the data. When combined with measurements from a base station, the RT3003 can give a positional accuracy of 2cm, roll and pitch accuracy of 0.03° and heading accuracy of 0.1°. Without a base station the positional accuracy is degraded to about 1.5m (www.oxts.com). No base station is used in the SMAPEx campaigns.

EOS AIRCRAFT

Airborne lidar and hyperspectral measurements will be made for a limited number of dates using a second aircraft during SMAPEx-3. The EOS aircraft is operated by Airborne Research Australia (see Figure 3-3). The aircraft can carry a typical science payload of up to 120kg with cruising speed of 90-200km/h and endurance of 4-8hrs. The aircraft ceiling is 3km or up to 7km with breathing oxygen, under day or night VFR conditions only. While the aircraft can take up to 2 crew (pilot/scientist + scientist), for maximum endurance and/or payload it is only possible to operate with 1 crew. Aircraft instruments are typically installed in one of the certified underwing pods. Aircraft navigation for science is undertaken using a cockpit computer display only that shows aircraft position relative to planned flight lines using the OziExplorer software. The aircraft uses the same OXTS navigation system as the other aircraft (http://ara.es.flinders.edu.au/aircraft.htm).

Figure 3-1. Experimental ESV aircraft showing a wingtip installation in the left inset, and the cockpit with cockpit computer display in the right inset.

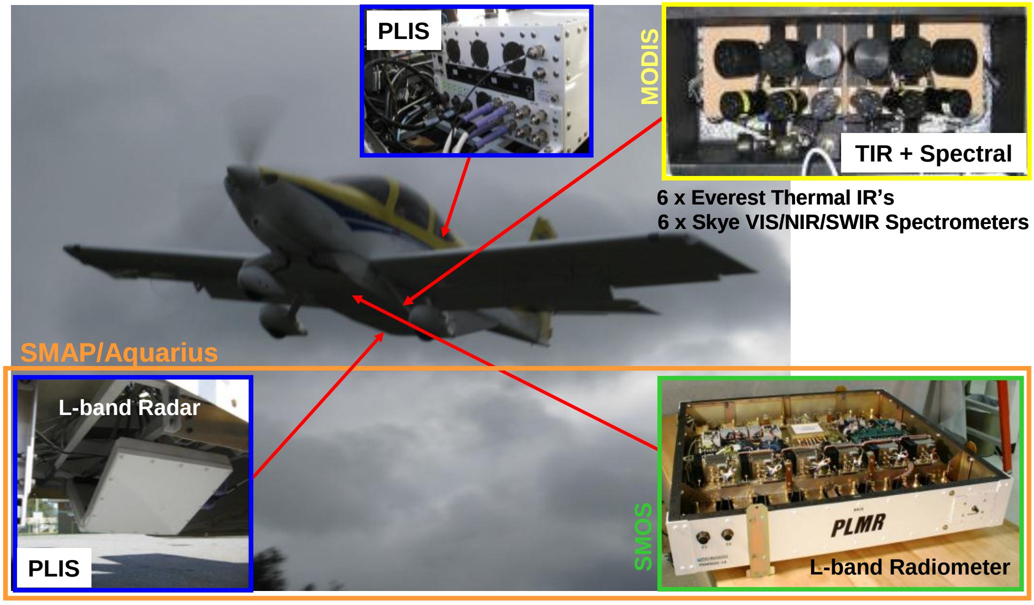


Figure 3-2. View of PLIS antennas, PLIS RF unit, PLMR and the multispectral unit.

Figure 3-3. Experimental EOS aircraft showing the cockpit and the underwing pod.

Figure 3-4. View of PLMR with the cover off.

3.1. L-BAND MICROWAVE SENSORS

PASSIVE: POLARIMETRIC L-BAND MULTIBEAM RADIOMETER (PLMR)

The PLMR (see Figure 3-4) 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 (push broom) or

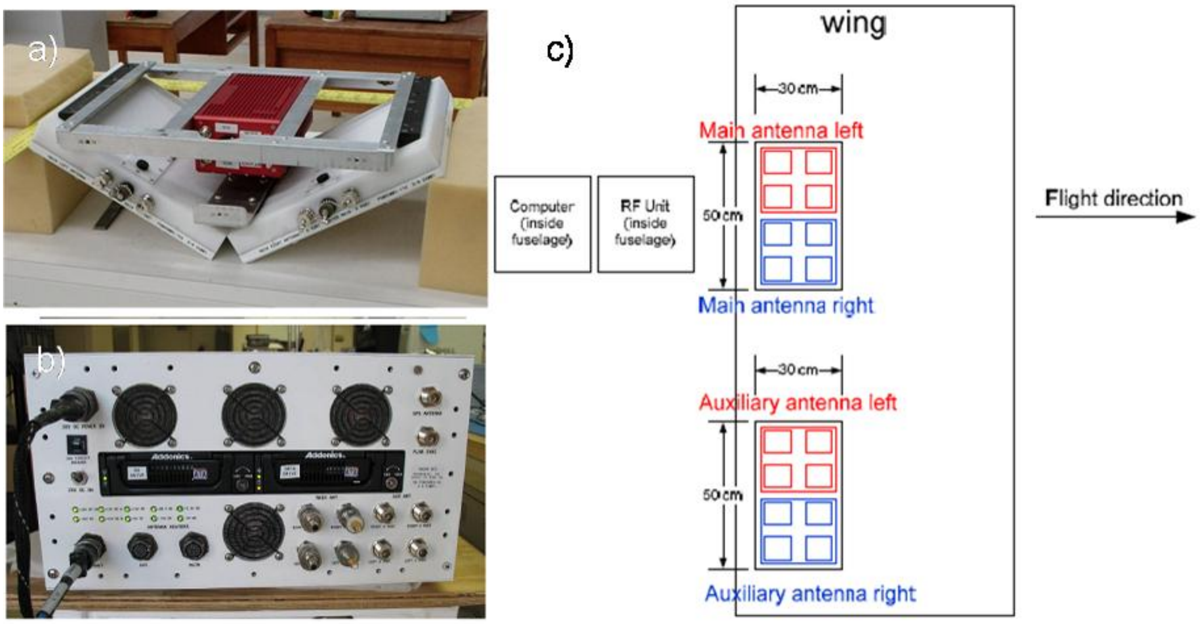


Figure 3-5. View of PLIS antennas (a), RF unit (b) and aircraft configuration (c).

along track configurations. In the normal push broom configuration the 3dB beam width is 17° along track and 14° across track resulting in an overall 90° across track 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. Hot and cold calibrations are performed before, during and after each flight. The before and after flight calibrations are achieved by removing PLMR from the ESV aircraft and making brightness temperature measurements of a calibration target and the sky. The in-flight calibration is accomplished by measuring the brightness temperature of a water body (Lake Wyangan).

ACTIVE: POLARIMETRIC L-BAND IMAGING SCATTEROMETER (PLIS)

PLIS is an L-band radar which can measure the surface backscatters at HH, HV, VH, and VV polarisations (see Figure 3-5). The PLIS is composed of two main 2x2 patch array antennas inclined at an angle of 30° from the horizontal to either side of the aircraft to obtain push broom imagery over a cross track swath of +/-45°. Both antennas are able to transmit and receive at V and H polarisations. Additional secondary antennas can be deployed for interferometry (there will be only one small flight in this configuration during SMAPEx-3). The antenna's two way 6-dB beam width is of 51°, and the antenna gain is 9dBi ± 2dB. In the cross-track direction, the antenna gain is within 2.5dB of the maximum gain between 15° and 45°. PLIS has an output frequency of 1.245-1.275GHz with a peak transmit power of 20W. The instrument can radiate with a pulse repetition frequency of up to 20kHz and pulse width of 100ns to 10µs. The minimum detectable Normalized Radar Cross Section is -45dB for the main antenna. Each antenna has a size of 28.7cm × 28.7cm × 4.4cm and weighs 3.5kg.

Figure 3-7. Multi-spectral sensors; downward looking sensors (left and midddle) and upward looking sensor with cosine diffuser fitted (right).

3.2. MULTI-SPECTRAL SENSORS

THERMAL INFRARED

During ESV flights there will be six thermal infrared radiometers (see Figure 3-6). The thermal infrared radiometers are the 8.0 to 14.0m Everest Interscience 3800ZL (see www.everestinterscience.com) with 15° FOV and 0-5V output (-40°C to 100°C). The six radiometers are installed at the same incidence angles as PLMR so as to give coincident footprints with the PLMR observations. The nominal relationship between voltage (V) and temperature (T) given by the manufacturer is V = 1.42857 + (0.03571428*T).

SHORT-WAVE INFRARED TO VISIBLE

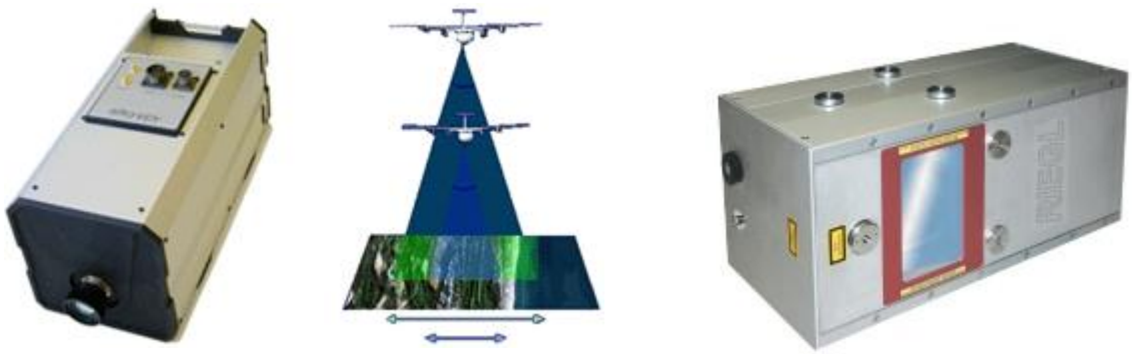
Multispectral measurements are made using arrays of 15° FOV Skye 4-channel sensors (Figure 3-7), each with 0-5V signal output (http://www.skyeinstruments.com). When installed, these sensors are configured in a similar way to the Everest thermal infrared radiometers (see Figure 3-7), such that the six downward looking sensors have the same incidence angle and footprints as the six PLMR beams. However, to correct for incident radiation an upward looking sensor with cosine diffuser is also installed. Each sensor weighs approximately 400g and has a size of 8.2cm × 4.4cm without the cosine diffuser or field of view collar attached. Two arrays of 4 channel sensors are installed, with the following (matched) spectral bands:

Sensor VIS/NIR (SKR 1850A)

Channel 1	MODIS Band 1	620 – 670nm
Channel 2	MODIS Band 2	841 – 876nm
Channel 3	MODIS Band 3	459 – 479nm
Channel 4	MODIS Band 4	545 – 565nm

Sensor SWIR (SKR 1870A)

Channel 1	MODIS Band 6	1628 – 1652nm
Channel 2		2026 – 2036nm



(a) (b)

Figure 3-8. (a) AisaHAWK hyperspectral sensor; (b) RIEGL 2D laser scanner

Channel 3	MODIS Band 7	2105 – 2155nm
Channel 4		2206 – 2216nm

HYPERSPECTRAL

AisaHAWK is a small and low maintenance SWIR (970-2500nm) hyperspectral sensor that provides high speed data acquisition at high sensitivity (see Figure 3-8(a)). The sensor employs Mercury Cadmium Telluride (MCT) SWIR detector technology which provides the highest sensitivity and signal-to-noise ratio over the full SWIR range of 970 to 2500nm. The spectral resolution is 12nm (6.3nm spectral sampling) and the sensor is provided with a wavelength specific radiometric calibration. The field of view (FOV) depends on the mounted fore optics. For SMAPEx-3 flights a 36° FOV will be used. The ground resolution depends on the flight altitude, which in the case of SMAPEx-3 will be 400m ASL (0.8m ground resolution).

LIDAR

The RIEGL LMS-Q560 (see Figure 3-8(b)) is a 2D laser scanner which gives access to detailed target parameters by analysis of the full waveform (www.riegl.co.at/airborne_scannerss/lms_q560/). The method is especially valuable when dealing with difficult tasks, such as canopy height investigation or target classification. Fast opto-mechanical beam scanning provides linear, unidirectional and parallel scan lines. The instrument needs a GPS timing signals to provide online monitoring data while logging the precisely time-stamped and digitized echo signal data to the accompanying digital data recorder. During SMAPEx-3 the instrument will be flown at approximately 400m. The field of view is approximately 40°, which results in a swath of almost 300m on the ground. The repetition pulse frequency ensures a point density of about 10 points per square meter. The acquisition plan allows for a 50% overlap between adjacent flight lines. Over the forest two passes from perpendicular direction will be used for a better characterization of forest trees structure.

VISIBLE

A high resolution digital SLR camera, a digital video camera, and a Pika-II hyperspectral camera are available to the campaign (Figure 3-9). However, only the digital camera will be used.

Figure 3-9. Canon EOS-1DS Mark 3 (left), video camera (centre) and Pika II (right).

The digital camera is a Canon EOS-1Ds Mark III that provides 21MegaPixel full frame images. It has a 24mm (23°) to 105mm (84°) variable zoom lens. The digital video camera is a JVC GZ-HD5 with 1920 × 1080 (2.1 MegaPixel) resolution and 10× optical zoom. Also available is a HD-6600PRO58 wide angle conversion lens to provide full swath coverage of PLMR.

The Pika-II is a compact low-cost hyperspectral imaging spectrometer manufactured by Resonon, Inc (see http://www.resonon.com). It acquires data between 400 nm and 900nm at a spectral resolution of 2.1nm. Across track field of view is ~53° using the current Schneider Cinegon 1.8/4.8mm compact lens, with 640 cross-track pixels. It weighs approximately 1kg and has a size of 10cm × 16.5cm × 7cm.

3.3. COSMOS ROVER

Figure 3-10. The COSMOS rover during a transect in Tucson, Arizona, USA.

Cosmic-ray fast neutrons above the ground surface are sensitive to water content changes, and their intensity is inversely correlated with hydrogen content of the soil. The COsmic-ray Soil Moisture Observing System (COSMOS), from the University of Arizona, is a stationary probe that gives time series of soil moisture averaged over the footprint. A mobile probe, the COSMOS rover (see Figure 3-10), yields soil moisture averaged over a footprint whose size depends on the speed of the vehicle and the desired precision of the measurement. Preliminary surveys with this sensor have successfully been carried out in Big Island of Hawaii and Tucson (USA). The COSMOS rover will be installed in a 4WD car during SMAPEx-3, and different transects will be measured once per week. A flight with the COSMOS rover on-board the ESV aircraft is also planned once during the campaign. See Chapter 5 and Chapter 6 for further information.

4. STUDY AREA

SMAPEx will be undertaken in the Yanco intensive study area located in the Murrumbidgee Catchment (see Figure 1-1 and Figure 4-1), New South Wales. The Yanco study area is a semi-arid agricultural and grazing area which has been monitored for remote sensing purposes since 2001 (http://www.oznet.org.au), as well as being the focus of three other campaigns dedicated to algorithm development studies for the SMOS mission: the National Airborne Field Experiment 2006 (NAFE'06, http://www.nafe.unimelb.edu.au) and the Australian Airborne cal/val Experiments for SMOS 1 and 2 (AACES, http://www.moisturemap.monash.edu.au/aaces). It therefore constitutes a very suitable study site in terms of background knowledge and data sets, scientific requirements, and logistics.

4.1. MURRUMBIDGEE CATCHMENT

The Murrumbidgee is a 100,000km^2 catchment located in southeast of Australia with latitude ranging from 33S to 37S and longitude from 143E to 150E. There is significant spatial variability in climate (alpine to semi-arid), soils, vegetation, and land use (see Figure 4-2). The catchment topography varies from 50m in the west of the catchment to in excess of 2000m in the east, with climate variations that 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) is about the same as precipitation in the west but represents only half of the precipitation in the east.

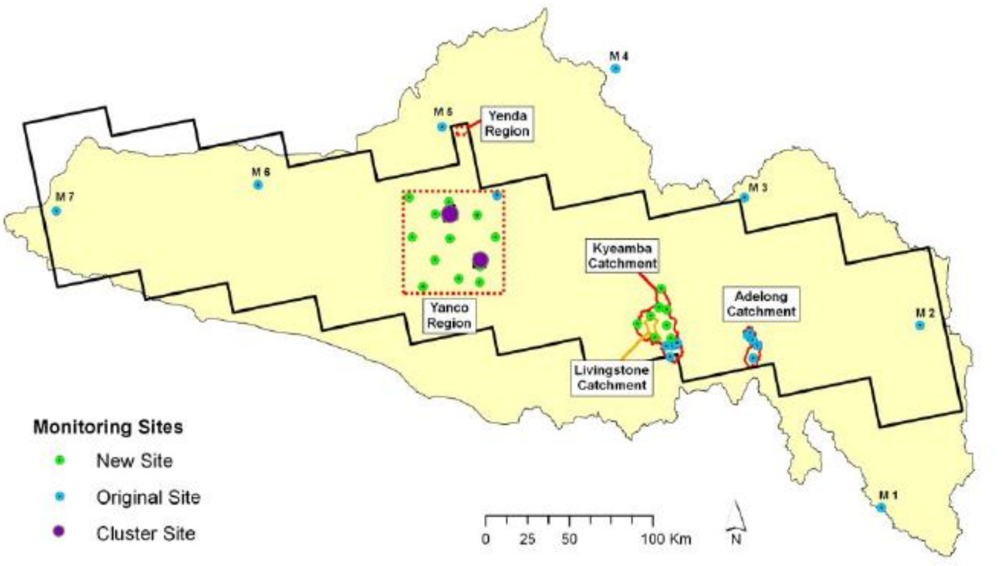


Figure 4-1. Overview of the Murrumbidgee River catchment, soil moisture monitoring sites and the Yanco study area focus of SMAPEx. Also shown in black are the flight boxes monitored by the AACES campaigns

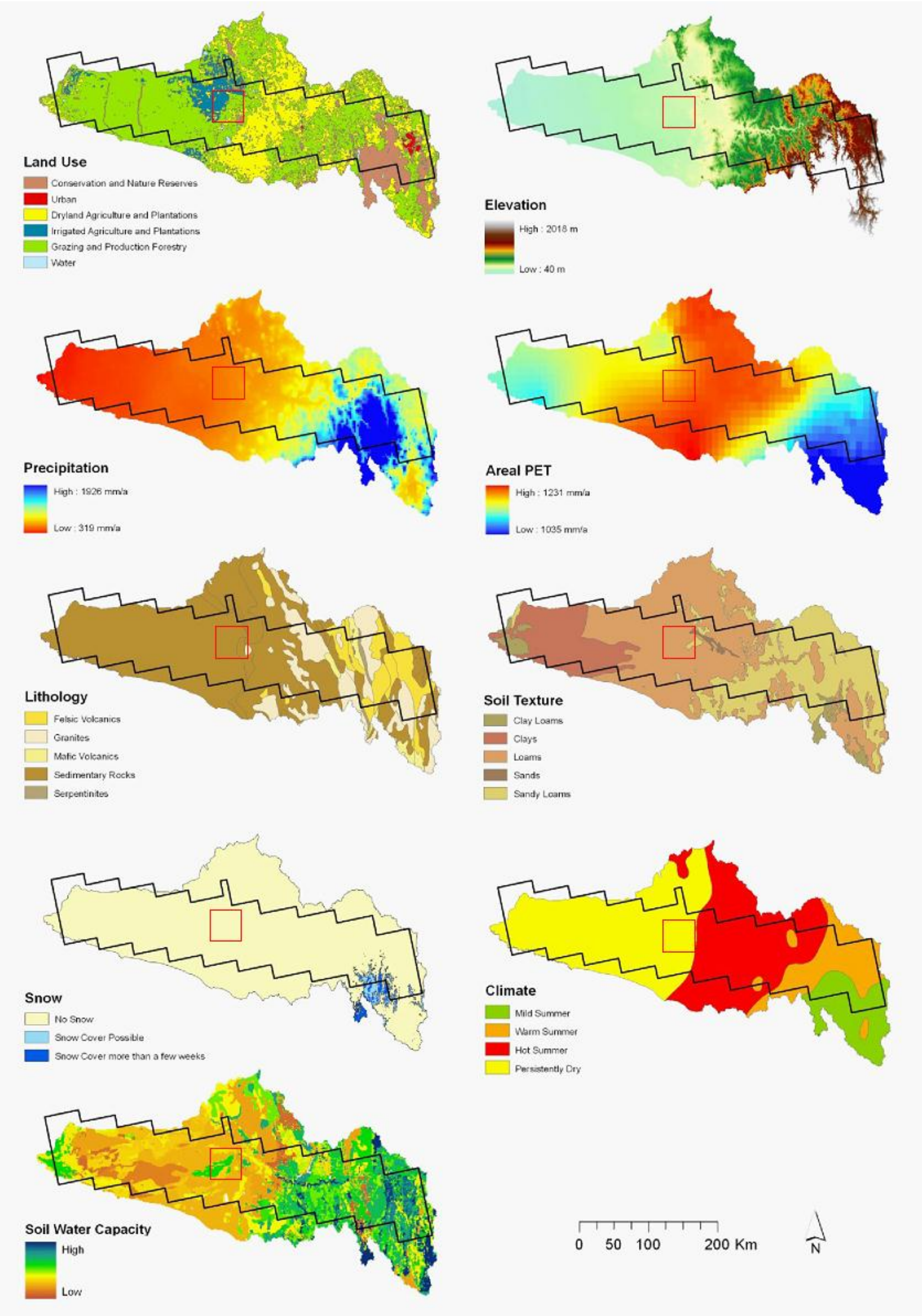


Figure 4-2. Climatic, soil and land use diversity across the Murrumbidgee catchment. Overlain is the outline of the SMAPEx-3 Yanco study area (red). Also shown in black are the flight boxes monitored by the AACES campaigns (data sources: Australian Bureau of Meteorology, Australian Bureau of Rural Science, and Geoscience Australia).

Figure 4-3. The Yanco site is a 60km box with approximately one third of irrigated area (Coleambally Irrigation Area). The six ground sampling areas of SMAPEx and the soil moisture monitoring networks are indicated.

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. Land use 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 land use 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 Murrumbidgee catchment is equipped with a wide-ranging soil moisture monitoring network (OzNet) which was established in 2001 and upgraded with 20 additional sites in 2003 and an additional 24 surface soil moisture only probes in 2009 in the Yanco region (see Figure 4-3). At present, the network consists in total of 38 continuously operating soil moisture profile stations (excluding the additional surface soil moisture stations recently installed) distributed across the whole catchment (see Figure 4-1), with three focus areas (Yanco, Kyeamba and Adelong) comprising about two-third of the existing monitoring sites.

4.2. YANCO REGION DESCRIPTION

The Yanco area is a 60km × 60km area located in the western flat plains of the Murrumbidgee catchment where the topography is flat with very few geological outcroppings. Soil types are

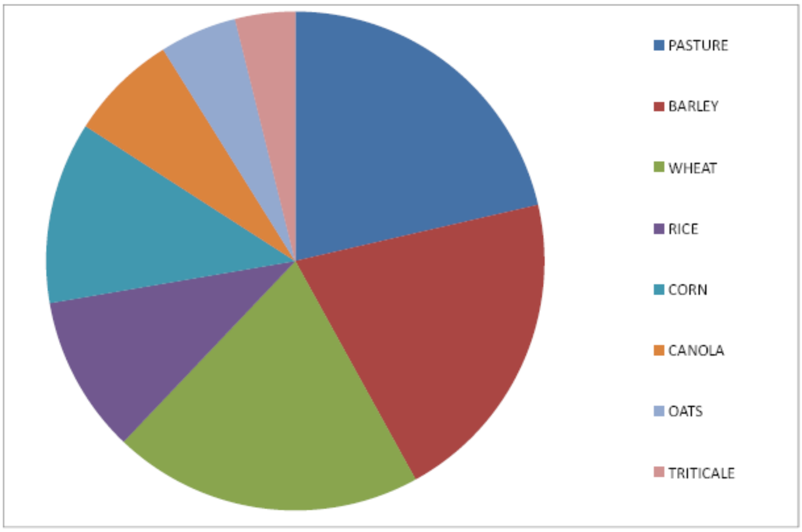


Figure 4-4. Proportions of total irrigated area sown to various crops within the CIA (source: Coleambally Irrigation Annual Compliance Report, 2009).

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".

The area covered by SMAPEx airborne mapping will be a 34km × 38km rectangle within the Yanco area (145°50'E to 146°21'E in longitude and 34° 40'S to 35° 0'S in latitude, see Figure 4-2) Approximately one third of the SMAPEx study 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. Figure 4-2 also illustrates the extension of the CIA within the SMAPEx study area, and the farm boundaries. The principal summer crops grown in the CIA are rice, corn, and soybeans, while winter crops include wheat, barley, oats, and canola. Rice crops are usually flooded in November by about 30cm of irrigation water. However, due to the ongoing drought, summer cropping has tipically been limited with very few rice crops planted for the past few years (source: Coleambally Irrigation Annual Compliance Report, 2009). The average CIA cropping areas for 2009 are listed in Figure 4-4.

4.3. SOIL MOISTURE NETWORK DESCRIPTION

OZNET PERMANENT NETWORK

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). Detailed information about the instruments installed and the data archive can be found at http://www.oznet.org.au.

Reflectometers consist 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).

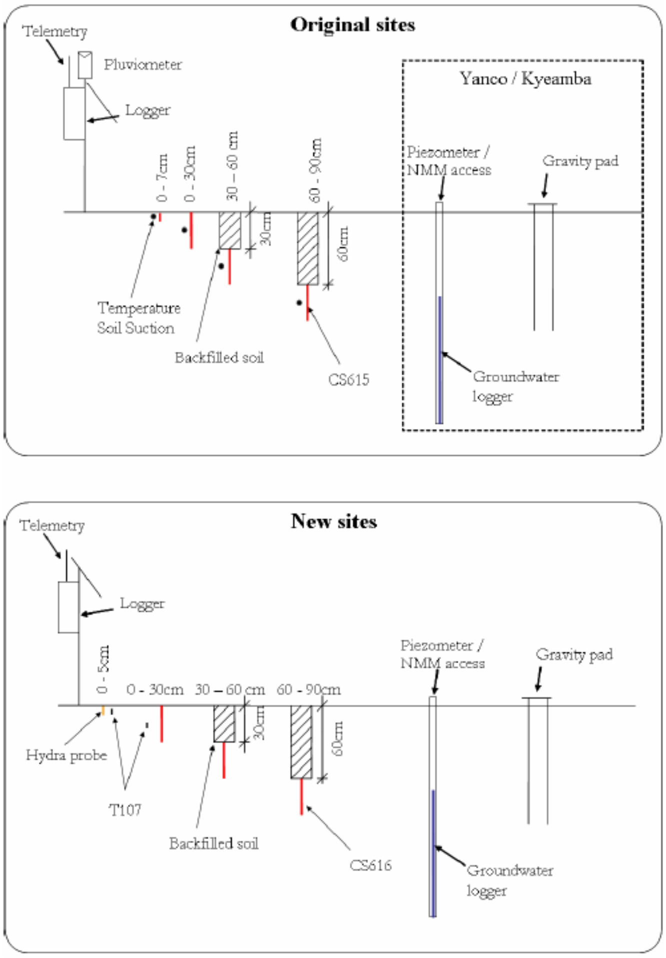


Figure 4-5. Typical equipment at the original (2001) and new (2004) soil moisture sites in the Murrumbidgee catchment. Each site provides continuous data of rainfall, soil moisture at 0- 5cm (or 0-7cm), 0-30cm, 30-60cm and 60-90cm and soil temperature and accommodates periodic measurements of gravity, groundwater and TDR soil moisture measurements.

Soil moisture sites also continuously monitor precipitation (using the tipping bucket rain gauge TB4-L) and soil temperature. Moreover, Time Domain Reflectometry (TDR) sensors are installed and have been used to provide additional calibration information and ongoing checks on the reflectometers. All the stations, except for one in Yanco and five stations in Kyeamba were installed throughout late 2003 and early 2004 (new sites); the eighteen other stations have operated since late 2001 (original sites).

Figure 4-5 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.

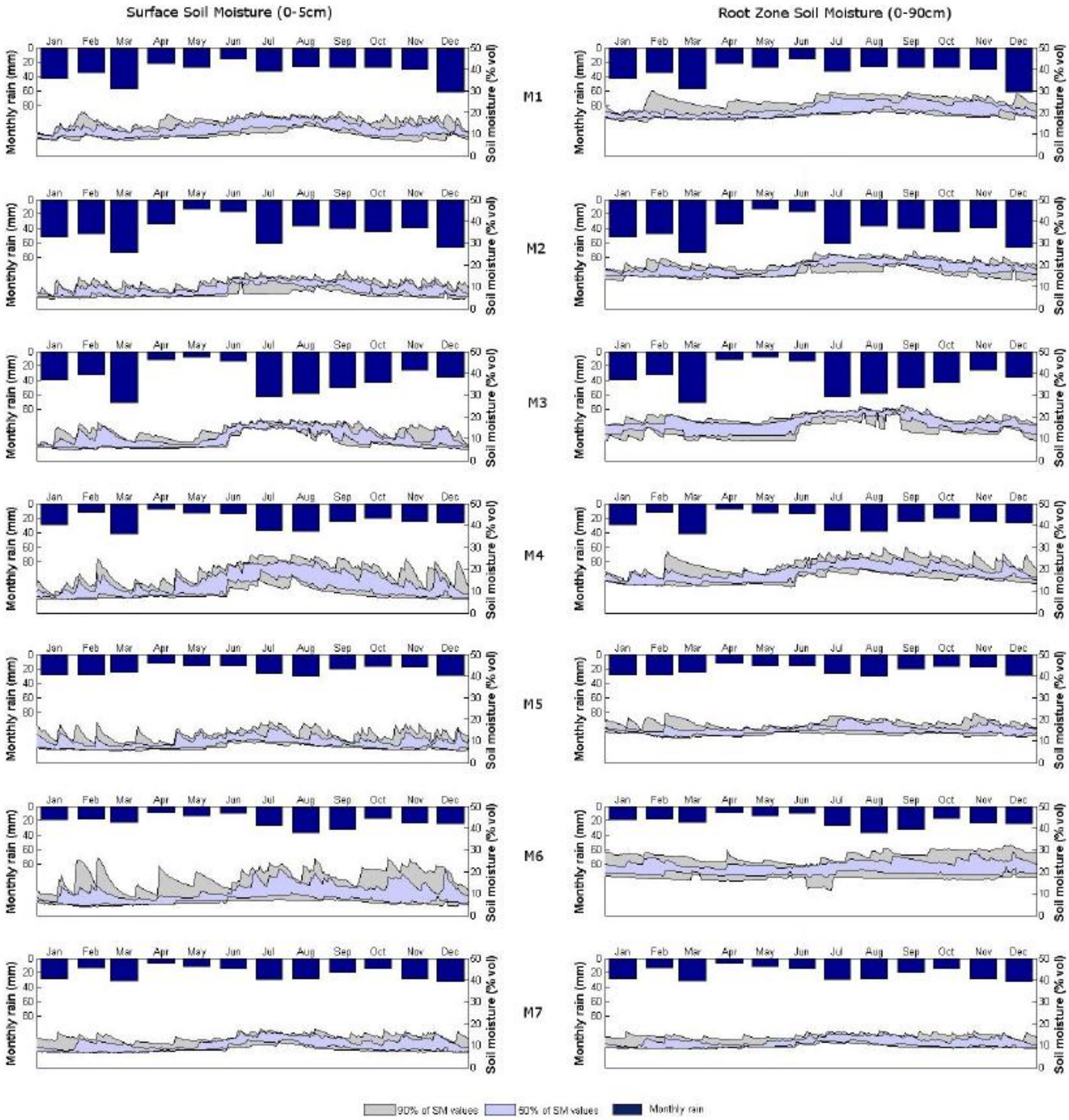


Figure 4-6. Monthly average precipitation and soil moisture variability (left: surface soil moisture 0-5cm; right: root zone soil moisture 0-90cm) across the Murrumbidgee catchment based on data derived from the Murrumbidgee monitoring network stations.

Sensor response to soil moisture varies with salinity, density, soil type and temperature, so a site-specific sensor calibration has been undertaken using both laboratory and field measurements. The on-site calibration consisted 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.

Figure 4-6 shows the seasonal variability of rainfall and soil moisture conditions across the entire catchment captured by seven of the monitoring sites. The surface soil moisture within the top 5cm

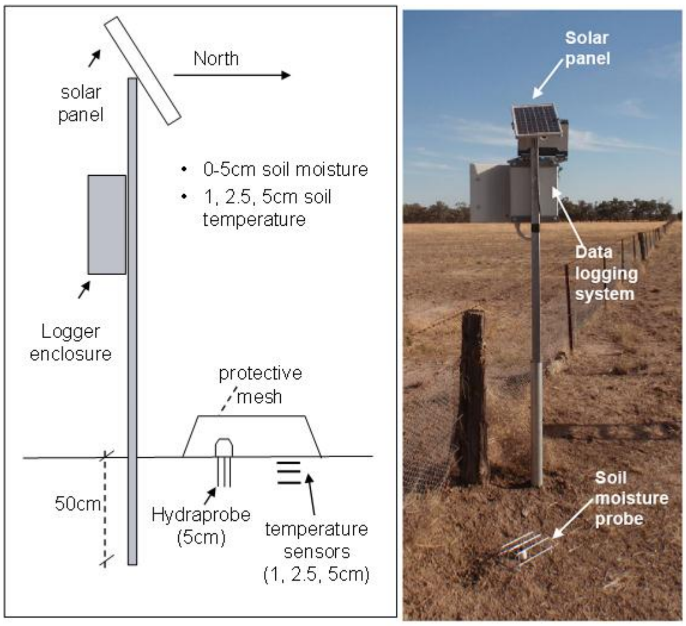


Figure 4-7. Schematic layout of the additional SMAPEx monitoring site and photo of site YA5.

Table 4-1. Characteristics of the OzNet soil moisture stations in the SMAPEx study area.

ID	Latitude	Longitude	Elevation (m)	Land use
Y4	34° 43.17'S	146° 1.2'E	130	Wet land cropping
Y5	34° 43.7'S	146° 17.59'E	136	Dry land cropping
Y7	34° 51.11'S	146° 6.92'E	128	Native pasture, grazing
Y9	34° 58.07'S	146° 0.98'E	122	Dry and wet land cropping
Y10	35° 0.32'S	146° 18.59'E	119	Native pasture, grazing

varies significantly between the different sites resulting in a range of about 0.05-0.25m^3/m^3 (using the upper and lower limit defined by 50% and 90% respectively based on all observations collected within the past eight years). Note that moisture conditions are typically slightly wetter during winter (July-August), which dries over the subsequent months leading to the driest conditions typically in Autumn (April-June). Comparable seasonal variations are recorded for the root zone soil moisture. The site closest to the SMAPEx study area is M5 (see Figure 4-1). These historic data show that there is a good chance of dynamic soil moisture conditions in the SMAPEx study area during September.

The 13 OzNet soil moisture monitoring sites in the Yanco area are all new sites installed throughout late 2003 and early 2004, located in a grid-based pattern within the 60 km × 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. Five of these sites fall within the area covered by the SMAPEx airborne coverage. The five sites are evenly divided between the 3 main land uses in the region—

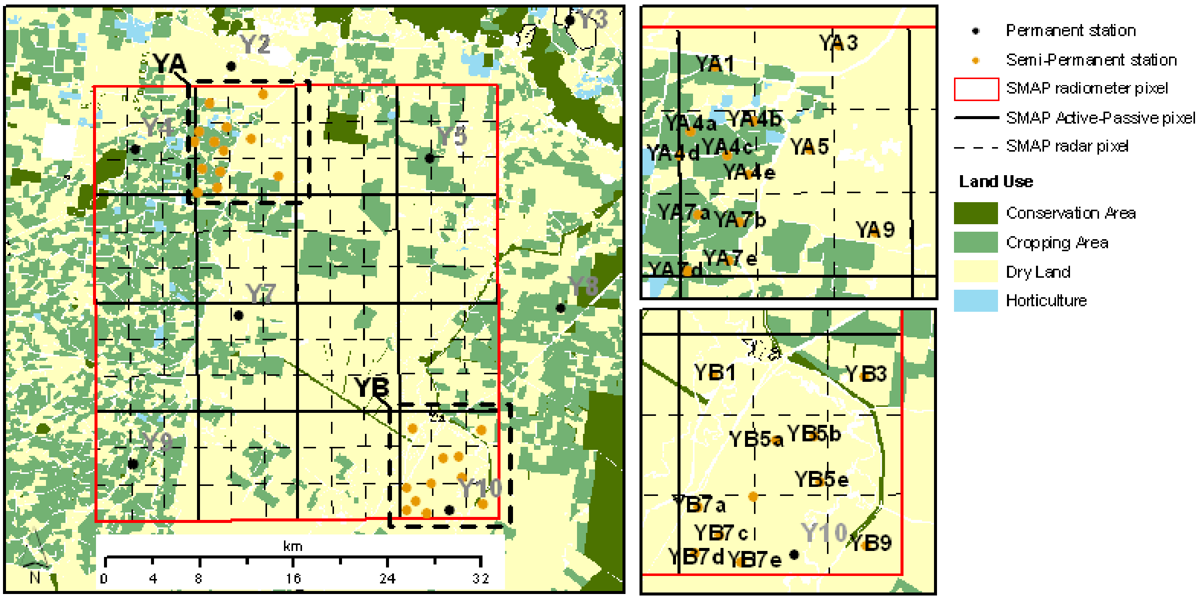


Figure 4-8. Layout of the SMAPEx semi-permanent soil moisture network in the study area.

irrigated cropping (including the major rice growing region of the Coleambally Irrigation Area), dryland cropping (typically wheat and fallow), and grazing (typically perennial grass type vegetation). The characteristics of the OzNet soil moisture stations in the SMAPEx study area are listed in Table 4-1.

SMAPEX SEMI-PERMANENT NETWORK

The 24 additional soil moisture sites were installed in late 2009 to support the SMAPEx project. These will continuously monitoring soil moisture at 0-5cm with a Hydraprobe and soil temperature at 1, 2.5 and 5cm depths (Unidata® 6507A/10 Sensors). The 24 sites are concentrated on two 9km × 9km focus areas within the radiometer pixel (areas YA and YB), corresponding to two pixels of the SMAP grid at which the active and passive soil moisture product (SMAP L3_SM_A/P product) will be produced. Finally, 10 of the sites within areas YA and YB are concentrated on two “sub-areas” of 2.8km × 3.1km (at least 4 stations in each sub-area), corresponding to two SMAP radar pixels. Figure 4-7 shows a schematic of the installation, while Figure 4-8 shows the locations of the SMAPEx semi-permanent sites within the study area.

The sites were installed so as to monitor a variety of land cover conditions in the area as inclusive of the study area conditions as possible. Table 4-2 lists the main characteristics of the SMAPEx semi-permanent sites. The network is equally distributed between irrigated cropping land (occupying approximately 1/3 of the SMAPEx study area) and grazing dry land.

The SMAPEx semi-permanent network will operate throughout the SMAPEx project (2010-2012). Further operation beyond 2012 is subjected to additional funding.

Table 4-2. Characteristics of the SMAPEx semi-permanent monitoring sites. NOTE: the crop types listed are those observed during SMAPEx-2, in December 2010. The list will be updated with the actual ground conditions in an addendum to this document produced after the campaign.

Area ID	Longitude	Latitude	Landuse	Vegetation Type	Irrigated
YA1	146.0897	-34.68425	Fallow	Stubble	No
YA3	146.1397	-34.677153	Grazing	Perennial grass	No
YA4a	146.07937	-34.706005	Cropping	Barley	Yes
YA4b	146.10529	-34.703062	Cropping	Cotton	Yes
YA4c	146.09425	-34.714213	Cropping	Wheat	Yes
YA4d	146.07506	-34.714202	Cropping	Maize	Yes
YA4e	146.10297	-34.721393	Grazing	Perennial grass	No
YA5	146.12771	-34.712858	Grazing	Perennial grass	No
YA7a	146.08197	-34.735208	Cropping	Rice	Yes
YA7b	146.09867	-34.737835	Cropping	Wheat	Yes
YA7d	146.07777	-34.7544	Fallow	Stubble	No
YA7e	146.09493	-34.750728	Fallow	Grass	No
YA9	146.15364	-34.741377	Grazing	Perennial grass	No
YB1	146.27654	-34.941243	Grazing	Perennial grass	No
YB3	146.34015	-34.942698	Cropping	Wheat	No
YB5a	146.30262	-34.965268	Grazing	Perennial grass	No
YB5b	146.31843	-34.963373	Grazing	Perennial grass	No
YB7b/YB5d	146.29299	-34.984833	Grazing	Perennial grass	No
YB5e	146.32052	-34.979712	Grazing	Perennial grass	No
YB7a	146.26941	-34.988457	Grazing	Perennial grass	No
YB7c	146.27852	-34.998378	Grazing	Perennial grass	No
YB7d	146.26853	-35.00497	Grazing	Perennial grass	No
YB7e	146.28805	-35.007732	Grazing	Perennial grass	No
YB9	146.33978	-35.002167	Grazing	Perennial grass	No

5. AIR MONITORING

The PLMR, PLIS and supporting instruments (thermal and multispectral radiometers) will be flown on-board the high performance single engine ESV aircraft (see Section 3.1) to collect airborne data across the SMAPEx-3 study area three times per week, making a total of 9 flights over the experiment period. All flights will be preceded and followed by specific low altitude passes of Lake Wyangan for in-flight calibration of the PLMR (see Section 5.6). In-flight calibration of the PLIS will also be performed (see Section 5.7). For detailed flight line coordinates see Appendix C. Additionally, the LIDAR and VNIR hyperspectral scanners will be flown on-board the EOS aircraft to collect airborne data over crops and grassland twice, and over forests once during the experiment. The COSMOS rover will be flown on-board the ESV aircraft over a selected area within the SMAP pixel once during the campaign. The main type of flights conducted during SMAPEx-3 to serve the main scientific objectives of the project is **Regional** flights (see Section 5.2). These flights will provide prototype SMAP radar and radiometer data over an area equivalent to a SMAP pixel, for development of active and passive microwave retrieval algorithms and techniques to downscaling the passive microwave information using the high-resolution active microwave data. Four types of additional flights will also be performed with specific objectives during the experiment:

- **Target SAR** flights (see Section 0) will collect PLIS data over forest;
- **Target InSAR** flights (see Section 5.4), will collect PLIS observations in InSAR configuration over forests;
- **Target LIDAR** flights (see Section 5.5), will provide LIDAR and VNIR data over crops, grassland, forest and bare soil; and
- **COSMOS rover transect**, will collect COSMOS rover data along a transect overpassing selected stations. The final route for this flight will be given in an addendum to this document.

All flights will be operated out of the Narrandera airport. The ferry flights to and from the airport with the PLMR were designed such that the aircraft will pass over at least one permanent monitoring station before and after covering the monitored area. This will allow identifying any changes in microwave emission between the start and the end of each flight associated to diurnal soil temperature variation rather than soil moisture changes. The criteria used in designing the flight lines are explained in the following section, after which each flight type is described in detail.

5.1. FLIGHT LINE RATIONALE

Regional flights will be conducted along parallel flight lines, with flight line distance designed to allow full coverage of PLMR, PLIS and supporting instruments. Regional flights will be flown along north-south oriented flight lines, which extended 4km outside the monitored area at both ends to ensure

Table 5-1. Summary of SMAPEx-3 flight types

Flight Type	Objectives	Coverage	Ground Resolution	Altitude (ASL)
Regional	- Active/Passive soil moisture retrieval - Downscaling soil moisture	34km × 38km	1km PLMR 10m-30m PLIS+	10,400ft
Target SAR	- Soil moisture retrieval - Forest biomass estimation	8km × 5km	10-30m	10,400ft
Target InSAR	- Interferometric mode test - Forest height retrieval	4km × 4km	10-30m	1,440ft
Target LIDAR/VNIR	- Crops and forest height/biomass retrieval - Surface roughness - Trees profiles	4km × 4km (forest), 3km × 9km & 3km × 3km (crop)	1m	1,700ft

+ *PLIS resolution varies between 10m (45°) and 30m (15°)*

the aircraft has a stable attitude over the monitored area. The median surface elevation under the flight routes was used to determine the optimum flying altitude across the monitored area to maintain the target spatial resolution of airborne data. The flight pattern was largely determined by the viewing configuration of the PLMR and the PLIS as installed on the ESV aircraft. This is illustrated in Figure 5-1.

The PLIS will be installed under the ESV fuselage, behind the PLMR. Since PLIS antennas radiate mainly between 15°-45° from nadir, at 10,000ft flying height this configuration will provide PLIS data over a swath of 2.2km on each side of the aircraft. The central portion of the PLIS swath between +15° and -15° about nadir (approximately 1.6km from 10,000ft flying height) will not provide useful data due to the elevated ground return. The PLMR six across-track beams (±7°, ±21.5° and ±38.5° with 14° across-track beamwidth) provide a swath of 6km from 10,000ft flying height, equivalent to the total PLIS swath, with pixels of approximately 1km size. The viewing configuration for the reflectance and thermal radiometer sensors are the same as that of the PLMR.

The flight patterns were planned according to the following general criteria:

- Ensure full coverage of PLIS and PLMR data for the entire the study area;
- Flight line separation was set so as to guarantee either (i) coverage of the central portion of the swath where PLIS data are affected by the ground return, or (ii) overlap of the PLMR outer beams, whichever is smaller;

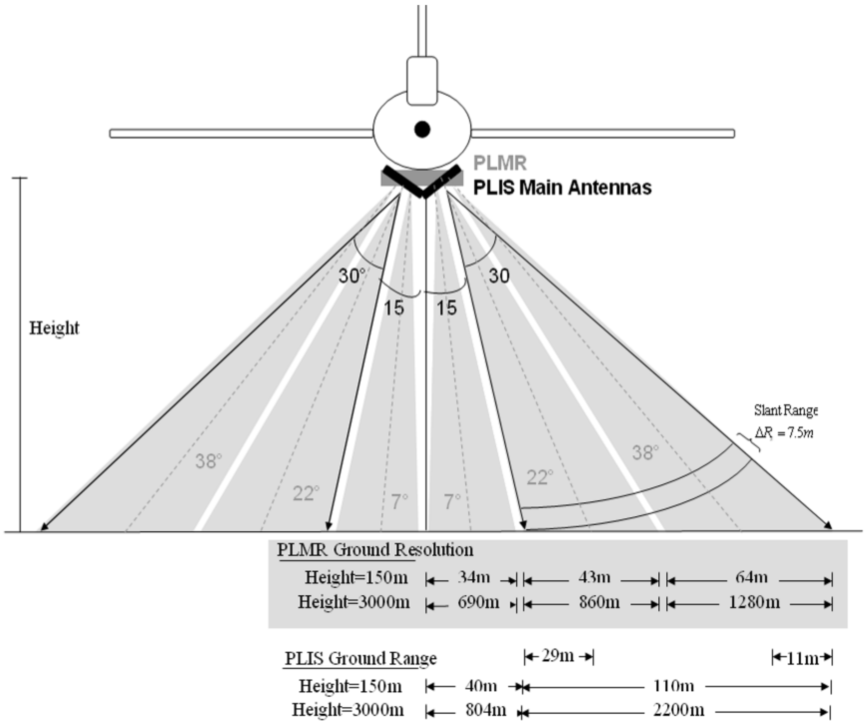


Figure 5-1. PLMR and PLIS viewing configuration on the RV-10 aircraft.

- Allow either (i) full auto-pilot control during the flight, in which case the 180° turns between adjacent flight lines must be wider than 2km or (ii) full manual control, in which case no restriction applies to the width of the 180° turns.

These criteria resulted in variable flight lines separation and routes for each flight type, which are detailed in the following sections.

5.2. REGIONAL FLIGHTS

Regional flights will be the core component of the SMAPEx experiments. These will map a 34km × 38km area, corresponding to a SMAP radiometer pixel. The flying altitude will be 10,000ft AGL, yielding active microwave observations at approximately 10-30m spatial resolution (depending on the position within the PLIS swath) and passive microwave, supporting thermal infrared and spectral observations at 1km resolution. This altitude was chosen to allow coverage of the entire study area in a timely fashion without compromising the functionality of the airborne instruments, which are not designed for altitudes higher than 10,000ft AGL (see Figure 5-2). Aggregation of the active and passive microwave data collected during Regional flights to the resolution of the EASE SMAP grids will provide prototype SMAP data for development and testing of (i) techniques for joint active and passive soil moisture retrieval development and (ii) techniques to downscale the coarse-resolution soil moisture retrieval from SMAP passive microwave observations using the fine-resolution active

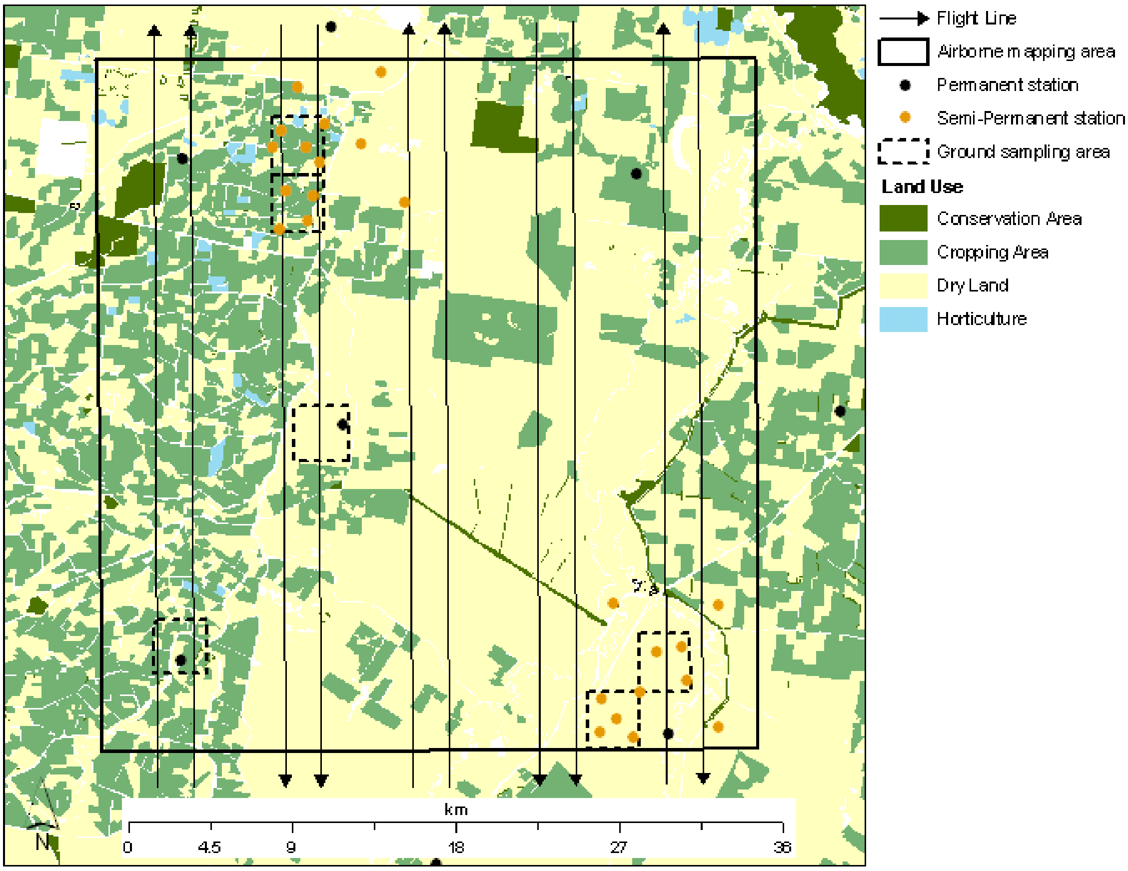


Figure 5-2. Overview of SMAPEx-3 Regional flights over the SMAPEx area. Also indicated are the ground monitoring network and sampling areas.

data. Regional monitoring will be repeated 9 times during SMAPEx-3 (three times per week), closely replicating the SMAP revisit time (~3 days globally). It is expected that this approach will provide prototype SMAP data covering a range of moisture conditions for the study area associated to rainfall events, together with a range of vegetation conditions due to rapid crop growth expected during the campaign period, thus expanding the conditions observed across other seasons.

The flying altitude above sea level will be of 10,400ft, which results from flying above the median elevation of the terrain in the Yanco study area (128m). Given the small relief in the area (33m) the variation in ground spatial resolution for PLMR and supporting instruments due to variation in terrain elevation will not be significant. Regional flights will be conducted over an approximately 5hr time window, with departure from the airport timed so that data acquisition will start within 1hr after sunrise (i.e., 7:45am AET). This time was selected to ensure reliability of the vegetation reflectance data from the Skye sensors and to minimize the effects on the L-band signal due to differences between air, vegetation and soil temperature (being almost in equilibrium around sunrise), which affect the soil moisture retrieval from passive microwave data. Detailed flight line coordinates are given in Appendix C. The flight line pattern for regional flights consists of 10 flight lines of 42km length, with flight line separation of alternatively 2km and 5km, resulting in a swath overlap of 67% and 18% for both PLMR and PLIS respectively.

5.3. TARGET SAR FLIGHTS

The Target SAR flights will be conducted over a forest area together with the Regional flights, which means a total of 9 flights during the experiment. The flying altitude above sea level will be of 10,400ft. The flight line pattern will be of 2 parallel flight lines, each 8km in length and, separated by 2km. An overview of the flight lines is provided in Figure 5-3. Detailed flight line coordinates are given in Appendix C.

5.4. TARGET INSAR FLIGHTS

A specific flight will be conducted once during the experiment to collect high resolution data over forests (10m) with the PLIS flown in Interferometric SAR (InSAR) mode using the auxiliary antenna. The purpose of this is to test the possibility to retrieve vegetation biomass information from InSAR data. The flying altitude above sea level will be of 1,440ft, and the flight will be conducted during a 1.5hr time window. The flight line pattern will be of 13 flight lines of 12km length, with flight line separation of alternatively 200m and 500m, resulting in continuous PLIS data across a 4km swath. An overview of the flight lines is provided in Figure 5-3. Detailed flight line coordinates are given in Appendix C.

5.5. TARGET LIDAR/VNIR FLIGHTS

Target LIDAR/VNIR flights will be conducted during a 4.5hr time window on Sept. 5 and Sept. 23, and during a 1.5hr interval on Sept. 6, 2011. The flying altitude above sea level will be of 1,770ft. Flights on Sept. 5 and Sept. 23 will be conducted over crops (YA in Figure 5-3) and grassland (YB7 in Figure 5-3) with the objective of estimating the plant growth during the 3-weeks interval. Additionally, the flight path will cover a line of about 5 trees that were mapped with LIDAR in the NAFE06 campaign, for comparison. There will also be some low altitude flights over a bare soil field for surface roughness measurement. The target flight on Sept. 6 will be conducted over forest, with flights in a crisscross pattern. The flight line pattern for the forest flights will be of 20 flight lines of 4km length, with flight line separation of 145m, resulting in a LIDAR swath overlap of 50%. An overview of the flight lines is provided in Figure 5-3. Detailed flight line coordinates are given in Appendix C.

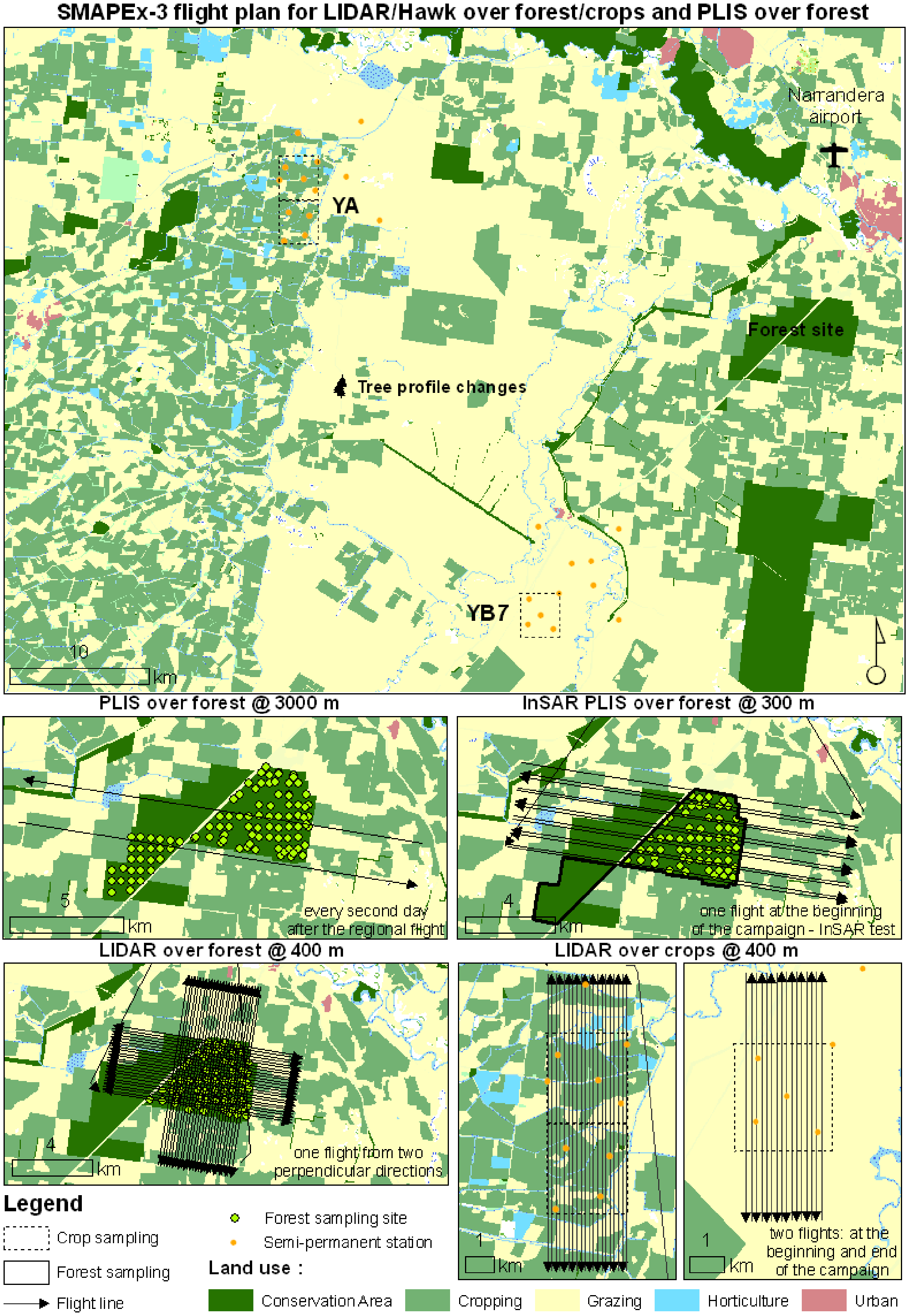


Figure 5-3. Overview of the SMAPEx-3 target SAR, InSAR, and LIDAR flights.

5.6. PLMR CALIBRATION

The normal operating procedure for PLMR is to perform a "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 blackbody calibration target at ambient temperature and the sky (see Figure 5-5). The in-flight calibration is accomplished by flying over a water body and ground stations. Lake Wyangan will be used as the cold target for in-flight calibration of PLMR.

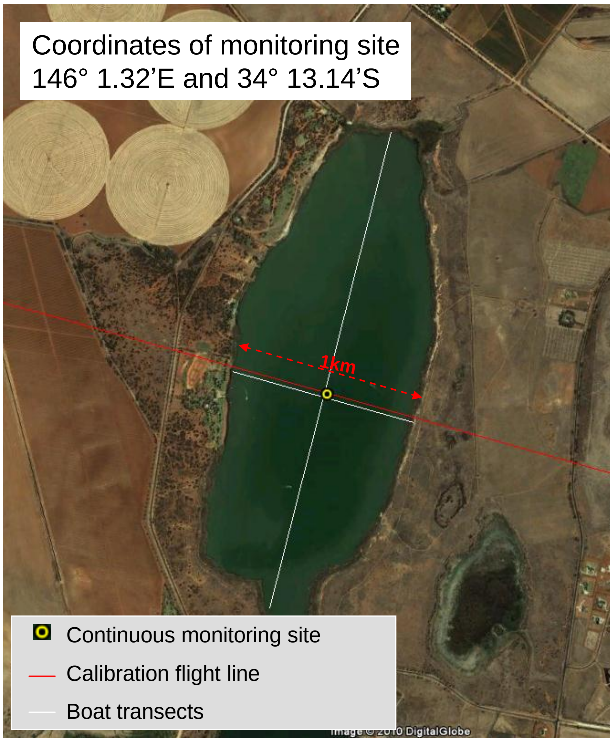


Figure 5-4. Calibration flight (red line) and boat transects (white lines) over Lake Wyangan

Given the relatively small size of the water storage, PLMR will be flown at the lowest permissible altitude (500ft) so as the swath of the instrument (300m at 500ft) and respective footprints (50m resolution) will be entirely included within the lake boundary along a distance of around 1km. Calibration flights are illustrated in Figure 5-4.

Ground requirements for over-water flights include 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 146° 1.32'E and 34° 13.14'S at Lake Wyangan. Furthermore, transects of water temperature and salinity in the top 1cm layer will be undertaken with a handheld temperature and salinity meter (Hydralab Quanta®) once per week coincident with regional flights (see Figure 5-5). This will involve making north-south and east-west transects at 100m spacing centred on the monitoring station. The purpose of these measurements is to check for spatial variability. Frank Winston will be the responsible person for these measurements.

5.7. PLIS CALIBRATION

Calibration of PLIS will be performed using six triangular trihedral Passive Radar Calibrators (PRCs) and three Polarimetric Active Radar Calibrators (PARCs).

POLARIMETRIC ACTIVE RADAR CALIBRATORS (PARCS)

The PARCs are high radar-cross-section transponder with a known scattering matrix (see Figure 5-6). PARCs detect the incident microwave energy radiated by the PLIS and then transmit back to the

Figure 5-5. Upper left: undertaking a sky cold point calibration with PLMR; upper right: undertaking a warm point calibration with the calibration box shown in the inset; lower left: the buoy used to monitor water temperature and salinity; lower right: undertaking a boat transect of water salinity and temperature.

radar an amplified signal at a known level and equivalent radar cross-section. These can be used to calibrate the PLIS radar by employing a set of three PARCs, with one aligned to receive vertical polarization and re-transmit horizontal polarization (PARC #1), a second aligned to receive horizontal polarization and re-transmit vertical polarization (PARC #2), and a third aligned to receive 45° linear polarization and re-transmit -45° linear polarization (PARC #3).

During SMAPEx-3, the PARCs will be located in within the Narrandera airport grounds (see Figure 5-7). Calibration of PLIS will be performed along a "calibration circuit" consisting of 3 overpasses of the PARCs (runs 1, 2 and 3). In order to be clearly distinguishable in the radar images the three PARCs will be aligned at 45° with respect to the calibration flight lines, in the #1, #3 and #2 going outward in the PLIS swath. All PARCs will be oriented at 30° incidence angle, corresponding to the PLIS incidence angle at the center of the swath. Each overpass will be offset with respect to the PARCs so that these fall towards the outer edge (45° incidence angle), in the center (30°) or towards the inner edge (15°) of the PLIS swath in respectively run 1, run 2 and run 3, in order to verify the radar performance across the entire swath and at both polarizations. Flight line coordinates are given in Appendix C. Each flight line will be repeated in both directions to calibrate both left and right antenna of the PLIS. Calibration will be performed at 10,400ft altitude (ASL). Depending on flight conditions, the calibration circuit might be undertaken only at the end of the airborne monitoring, or both at the beginning and at the end of the airborne monitoring to check for calibration drift during flight. The final calibration strategy will be indicated in an addendum to this document.

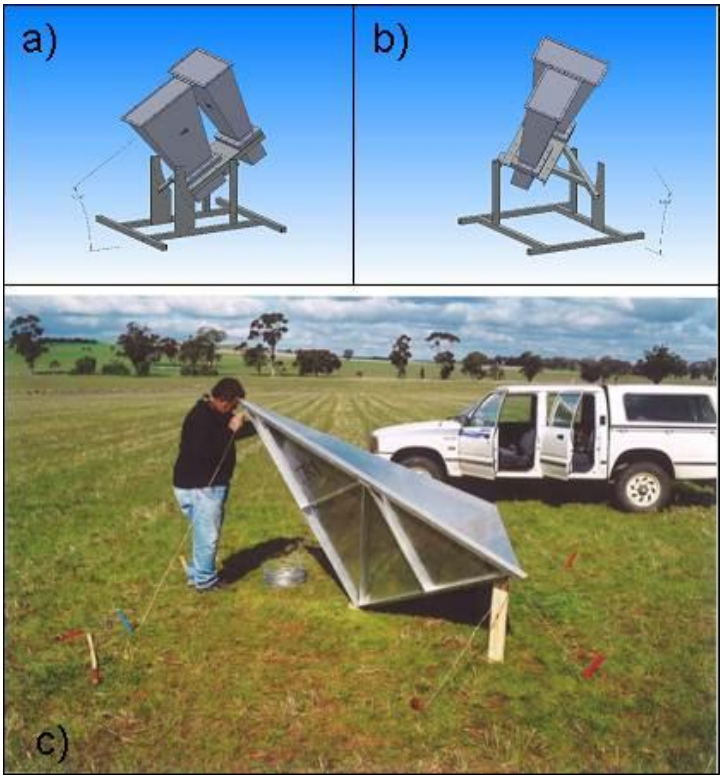


Figure 5-6. Polarimetric Active Radar Calibrators #1 and #2 (a), #3 (b) and Passive Radar Calibrator (c).

Table 5-2. Location of the PARC during SMAPEx-3.

Calibration Type	PARC#1	PARC#2	PARC#3
Regional	146° 30.863' E, 34° 41.861' S	146° 30.821' E, 34° 41.859' S	146° 30.842' E, 34° 41.86' S

Figure 5-7. Location of PARCs and PRCs (yellow rectangle) during SMAPEx-3.

PASSIVE RADAR CALIBRATORS (PRCS)

The PRCs are metallic corner reflectors (see Figure 5-6) capable of reflecting the incident microwave energy radiated by the PLIS back to the radar. Due to the limited scattering of the incident radiation, the PRCs can be used as a point of spatial reference in the radar image. The triangular trihedral configuration ensures a good reflection over a range of angles about bore sight (the angle of view at which they appear symmetrical, 66° from nadir).

The six PRCs will be deployed at a single calibration site located in a flat, uniform grazing area in the YB site. The PRCs will be uniformly distributed across the PLIS swath, with locations and tilt combined so to align the PRCS boresight (36° from nadir plus tilt angle to the PLIS incidence angle at that location, therefore maximizing the reflection of the PLIS incidence microwave radiation back to the radar. This means the PRCs will have an approximate offset with respect to the flight lines between 1400m and 3600m. The PRCs will be approximately aligned at 45° with respect to the flight lines, so that not two PRCs will be aligned in the PLIS azimuthal or range direction. The actual locations of the PRCs will be decided depending on the ground conditions at the time of the campaign and might be subjected to logistic constraints. The proposed locations for the PRCs are shown in Figure 5-7. The actual locations will be communicated in an addendum to this document.

5.8. FLIGHT TIME CALCULATIONS

In order to provide an estimate of the total flight time, climb/turn and cruise speeds of the aircraft were assumed to be 110kts and 140Kts, respectively for ESV. The climb rate was assumed to be 500ft/min and the time to descend from maximum altitude to ground level was set to a minimum of 10min. To account for turns, the flight lines were extended 4km beyond the measurement area to ensure aircraft attitude stability over the data acquisition area. Turning times was set to 1min, 2min and 3min for flight separation of respectively 2km, 5km and 7km (Regional flights). A 10min buffer was also added to the flight time to account for arrival and departure manoeuvres (circuit, etc.). The estimated times for each flight type are given in Table 5-3.

Table 5-3. SMAPEx-3 flight schedule and flight sequence for each flight (M= Mapping, PC=PLMR calibration, LC=PLIS calibration)

Date/Time (UTC)	Date/Time (AEST)	Flight Type	Duration (hrs)	Flight sequence
3/09/2011 21:45	4/09/2011 7:45	Target InSAR	1.5	LC – M - LC
4/09/2011 21:45	5/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
5/09/2011 0:00	5/09/2011 10:00	Target LIDAR/VNIR (crops & trees & bare)	4.5	M
5/09/2011 0:00	6/09/2011 10:00	Target LIDAR/VNIR (forest)	4.5	M
7/09/2011 21:45	8/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC – PC
TBA	TBA	Rover	1	M
10/09/2011 21:45	11/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
12/09/2011 21:45	13/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
15/09/2011 21:45	16/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
17/09/2011 21:45	18/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
18/09/2011 21:45	19/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
20/09/2011 21:45	21/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
22/09/2011 21:45	23/09/2011 7:45	Regional + Target SAR	5	PC – LC – M – LC - PC
23/09/2011 0:00	23/09/2011 10:00	Target LIDAR/VNIR (crops & trees & bare)	4.5	M
Total campaign			**61**	

Table 5-4. Summary of SMOS overpass over the SMAPEx-3 study area during the experiment. Time in UTC. P is for 0 to 12 UTC and A is for 12 to 24 UTC. The symbology ● indicates fully coverage while ○ indicates partly coverage.

5/09		6/09		7/09		8/09		9/09		10/09		11/09	
P	A	P	A	P	A	P	A	P	A	P	A	P	A
	● 20:25	● 7:35			● 20:47	● 7:57					● 20:30	● 7:40	
12/09		**13/09**		**14/09**		**15/09**		**16/09**		**17/09**		**18/09**	
P	A	P	A	P	A	P	A	P	A	P	A	P	A
	● 20:52	● 8:02	○ 20:15				● 20:35	● 7:45			● 20:58	● 8:08	● 20:19
19/09		**20/09**		**21/09**		**22/09**		**23/09**					
P	A	P	A	P	A	P	A	P	A				
● 7:30			● 20:41	● 7:51					● 20:24				

5.9. FLIGHT SCHEDULE

SMAPEx flights will be undertaken during 12 days according to the schedule in Table 5-4. Regional flights will be conducted three times per week for a total of 9 Regional monitoring, to provide prototype SMAP data over an area the size of a SMAP radiometer footprint, with near-daily repeat time, for development and testing of joint active and passive microwave soil moisture retrieval and downscaling techniques. During some of the days not covered by Regional flights, different Target flights will be conducted to provide high-resolution radar, LIDAR, and multispectral data over focus areas.

Low-altitude PLMR calibration flights over Lake Wyangan will be performed right after take-off and prior to landing on Regional monitoring day. The PLIS calibration circuit will also be performed prior to landing at the end of the daily monitoring. Since a secondary objective of SMAPEx includes the evaluation of other satellite soil moisture products and use of other satellite data for ancillary input, Regional flights have been schedule in the same days when SMOS data over the site will be available. A summary of SMOS overpasses during the SMAPEx-3 campaign is given in Table 5-4.

6. GROUND MONITORING

This chapter should be read in conjunction with Chapter 7 where ground sampling protocols are presented, and Chapter 8 where logistics are discussed. Ground monitoring for the SMAPEx-3 campaign is designed with the following objectives:

- Calibrating the aircraft radiometer and radar observation;
- Providing supporting ground data for the prototype SMAP observations that will be created through aggregation of aircraft data at the spatial resolutions of the future SMAP products (36km × 38km for the radiometer-only retrieval, 8.5km × 9.4km for the merged active and passive retrieval and 2.8km × 3.1km for the radar-only retrieval); and
- Providing detailed plant structural parameters for selected vegetation types (agricultural and grazing) to perform discrete forward modelling of L-band radar backscatter.

In addition to the network of continuous soil moisture monitoring stations (permanent and semi-permanent) described in Section 4.3, the ground monitoring component of the SMAPEx-3 campaign will focus on six 3km × 3km areas equivalent to six SMAP radar pixels. Additionally, there will be monitoring of a single forest pixel. Within each area, ground monitoring will include:

- Supplementary monitoring stations (soil moisture, soil temperature and leaf wetness);
- Intensive spatial sampling of the top 5cm soil moisture;
- Intensive spatial vegetation sampling (destructive VWC, spectral and LAI); and
- Intensive spatial monitoring of supporting data (land cover type, soil surface roughness, and soil gravimetric samples).

Apart from this, intensive monitoring of plant density and height, leaves and stalks water content, orientation, and length, etc. in selected crop and forest areas will be done twice per week (see Section 7.4).

6.1. SUPPLEMENTARY MONITORING STATIONS

Permanent monitoring stations are supplemented by four identical temporary monitoring stations, one at each of four out of the six focus areas. These short-term monitoring stations are instrumented with a rain gauge, thermal infrared sensor (Apogee sensors), leaf wetness sensor (MEA LWS v1.1), two soil moisture sensors (Hydraprobes; 0-6cm and 23-29cm) and four soil temperature sensors (MEA6507A; 2.5cm, 5cm, 15cm and 40cm depth) in order to provide time series data during the sampling period (Figure 6-1).

Such measurements will be used for identifying the presence or absence of dew, and verifying the assumptions that (i) effective temperature has not changed significantly throughout the course of

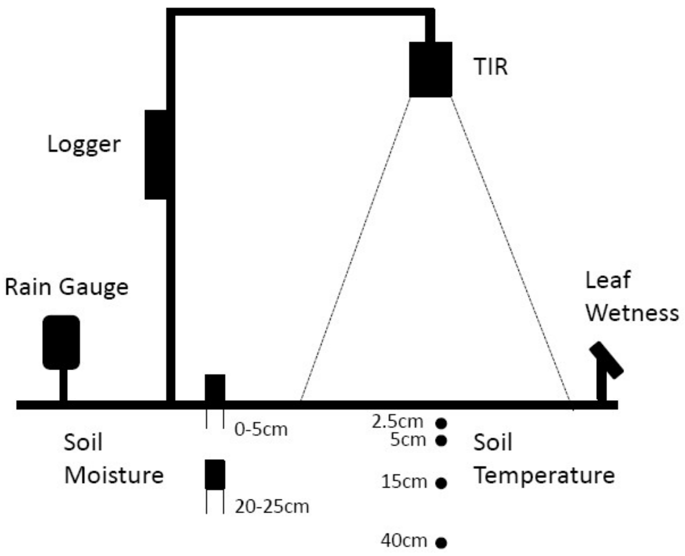


Figure 6-1. Schematic of the temporary monitoring station.

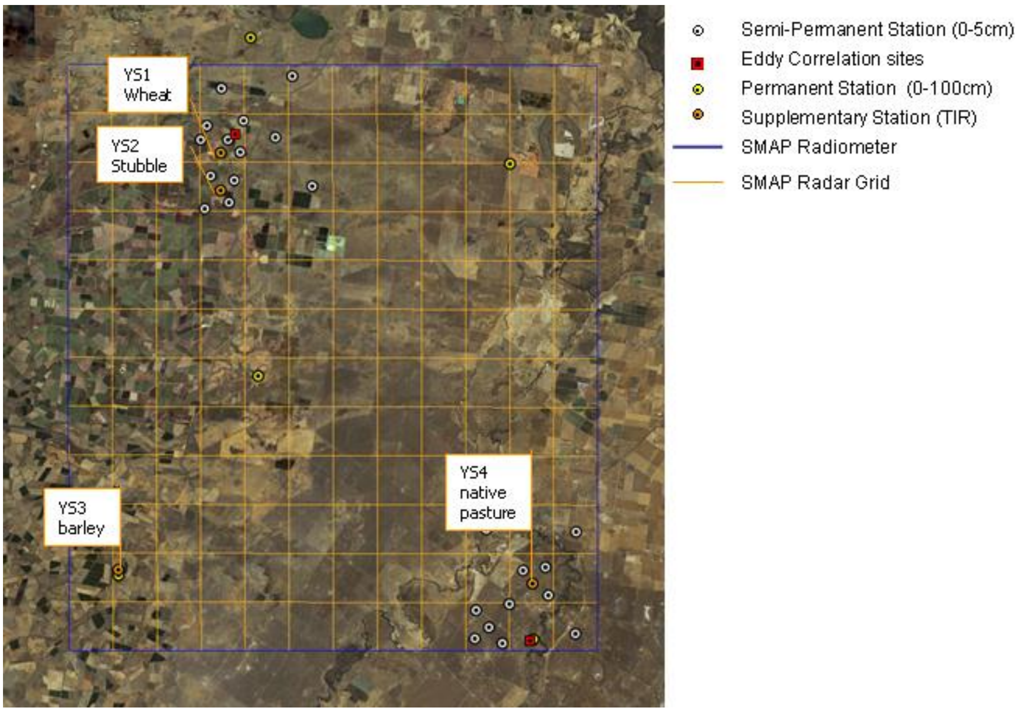


Figure 6-2. Proposed locations of the SMAPEx-3 supplementary monitoring stations.

the aircraft measurements; (ii) vegetation and soil temperature are in near-equilibrium condition; and (iii) soil moisture has not changed significantly during ground sampling. The supplementary stations are distributed across the study area to monitor vegetation and soil temperature in representative areas on the basis of dominant vegetation type. This means that their location depends on the cropping conditions at the time of the campaign, in addition to logistical constraints. The proposed locations of supplementary monitoring stations and the vegetation type covered are indicated in Figure 6-2. The actual locations will be communicated in an addendum to this document. Supplementary monitoring station data will be recorded in UTC time reference.

Table 6-1. Characteristics of the ground sampling areas. Soil texture data are derived from *soil particle analysis of 0-30cm gravimetric samples or **CSIRO, Digital Atlas of Australian Soils (1991)

Area Code	Land Use	Vegetation Type (s)	Mean Elevation	Soil texture (%C/%Si/%S)
YA4	Irrigated cropping (90%); Grazing (10%)	wheat, barley, naturalised pasture	131m	Clay loam (31/48/20)*
YA7	Irrigated cropping (90%); Grazing (10%)	Wheat and barley stubble; Naturalised pasture	130m	Clay loam (31/48/20)*
YC	Grazing (100%)	Native or naturalised pasture	127m	Silty clay loam (39/43/17)*
YD	Irrigated cropping (85%); Grazing (15%)	Barley, rice, oats, native or naturalised pasture	132m	Loam (23/47/29)*
YB5	Grazing (100%)	Native or naturalised pasture	122m	Loam (N/A)**
YB7	Grazing (100%)	Native or naturalised pasture	123m	Loams (N/A)**

6.2. SPATIAL SOIL MOISTURE SAMPLING

Intensive spatial ground soil moisture sampling will focus on six, 2.8km × 3.1km focus areas (hereby referred to as “focus areas”) distributed across the simulated SMAP radiometer pixel. These areas correspond to six radar pixels from the SMAP grid and were selected to cover the representative land cover conditions within the study area. Figure 6-3 gives an overview of the locations of the focus areas in relation to the different SMAP grids. The characteristics of the focus areas are listed in Table 6-1. While most focus areas exactly match the SMAP radar grid, in some cases (YC and YD, see Figure 6-3) the focus areas are slightly shifted with respect to the grid due to property access issues.

Soil moisture will be monitored concurrently with PLMR and PLIS overpasses, three times per week, at the focus areas using the Hydraprobe Data Acquisition System (HDAS). Table 6-2 indicates the ground sampling schedule concurrent with PLMR/PLIS flights with ESV. Spatial soil moisture data will be recorded in UTC time reference to be easily referenced to satellite and aircraft data (also in UTC).

During each of the three regional flight days, two of the six focus areas will be sampled in rotation, one of which will be characterised by cropping land use and the other by grazing. Each 2.8km × 3.1km focus area will be monitored using a north-south oriented regular grid of sampling locations at 250m spacing. This will provide detailed spatial soil moisture information for 2 prototype SMAP radar pixels on each day. The choice of pairing one cropping and one grazing area on each regional day aims at ensuring that a wide range of soil moisture conditions are encountered for both land cover

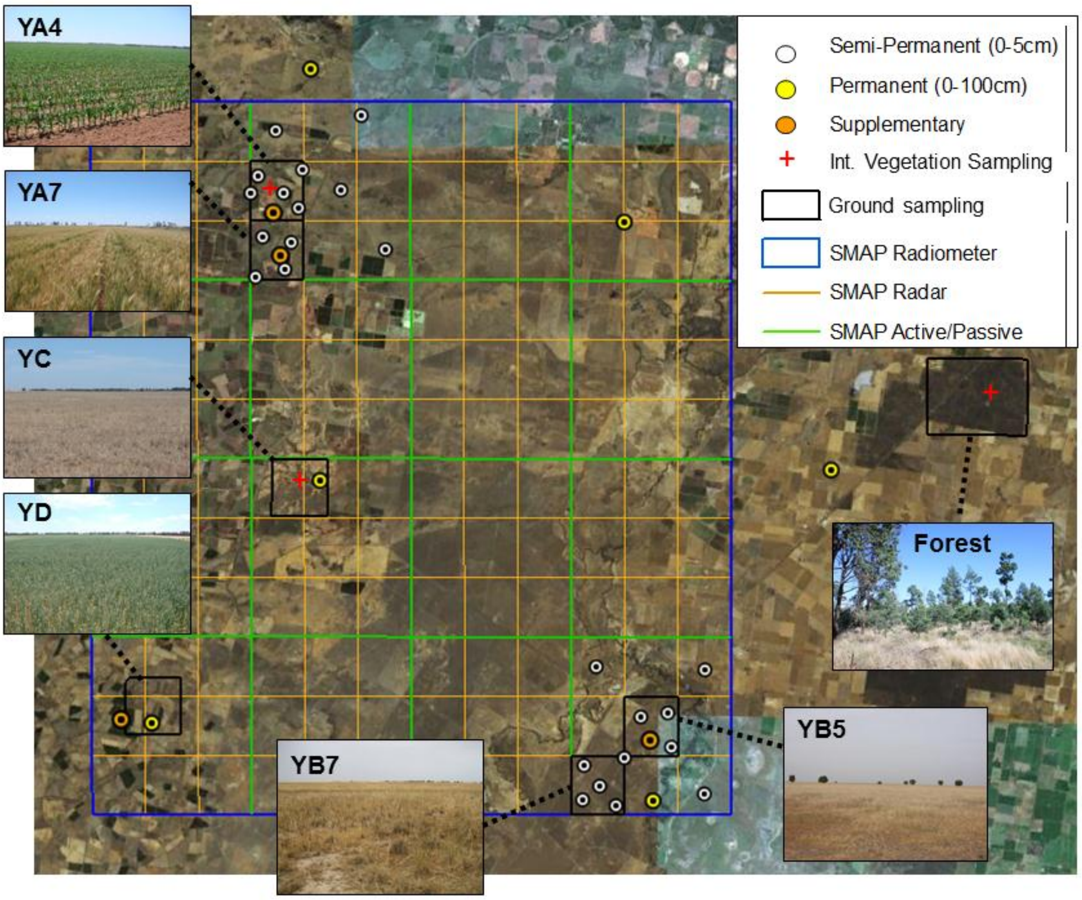


Figure 6-3. Overview of ground sampling areas with photographs. The 6 focus areas of SMAPEx-3 are indicated with black polygons. Focus areas for additional intensive vegetation monitoring are also shown.

types. Local scale (1m) soil moisture variation will be accounted for by taking three surface soil moisture measurements within a radius of 1m at each sampling location; more specific details follow. This will allow the effect of random errors in local scale soil moisture measurements to be minimised.

Figure 6-4, Figure 6-5 and Figure 6-6 show the soil moisture sampling locations during regional monitoring days at all six focus areas, grouped by sampling day (see Table 6-2). The coordinates of the focus area boundaries are shown in Appendix H.

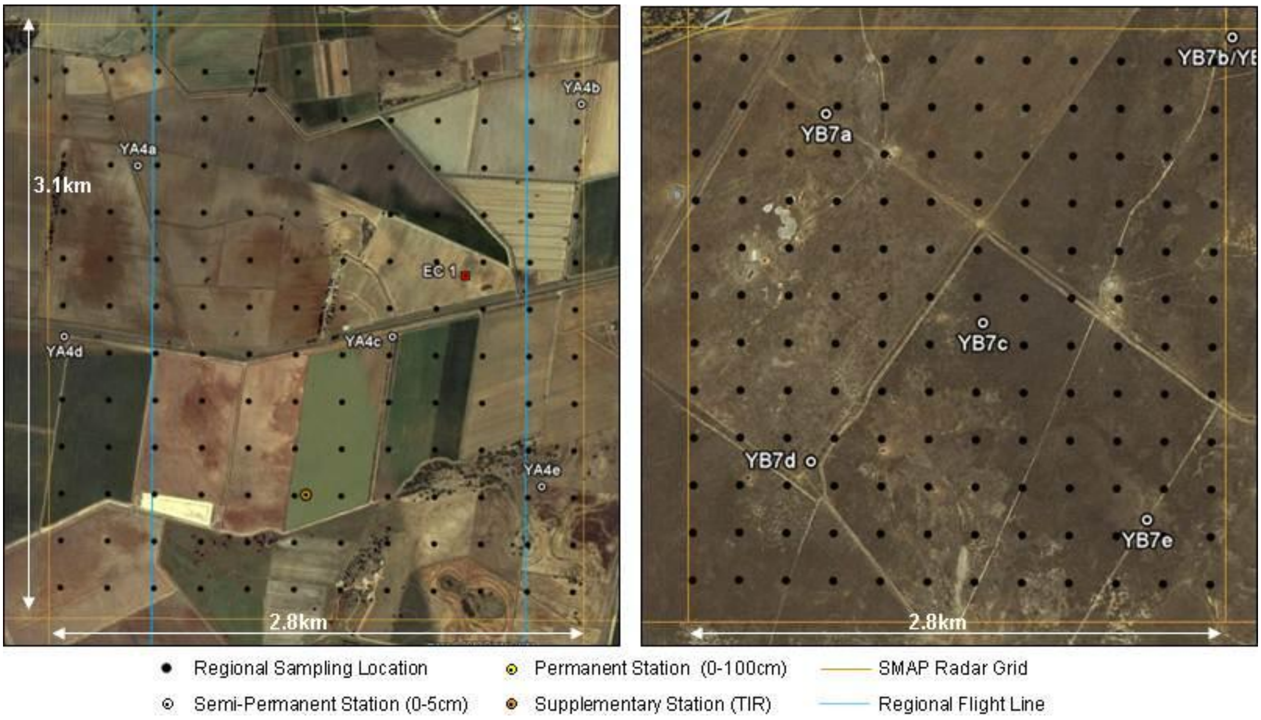


Figure 6-4. Locations of the spatial soil moisture sampling sites during regional days at focus areas YA4 (mostly cropped, left panel) and YB7 (at grazing, right panel).

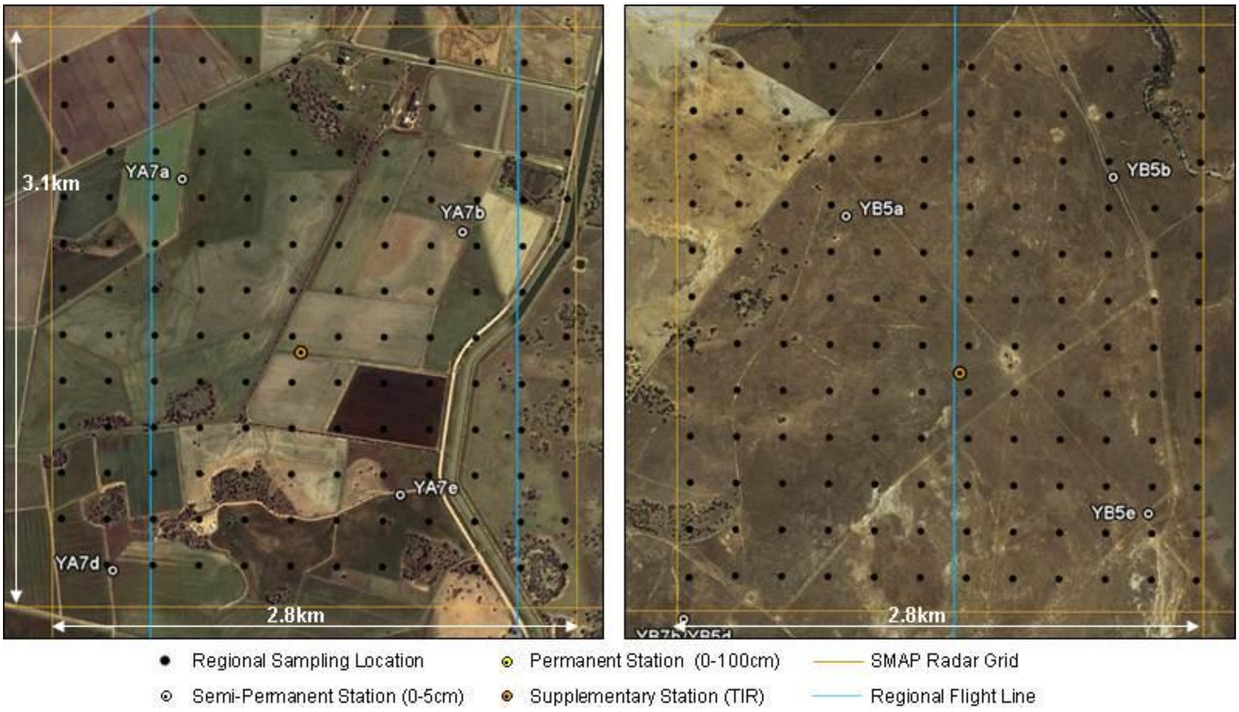


Figure 6-5. Locations of the spatial soil moisture sampling sites during regional days at focus areas YA7 (mostly cropped, left panel) and YB5 (grazing, right panel).

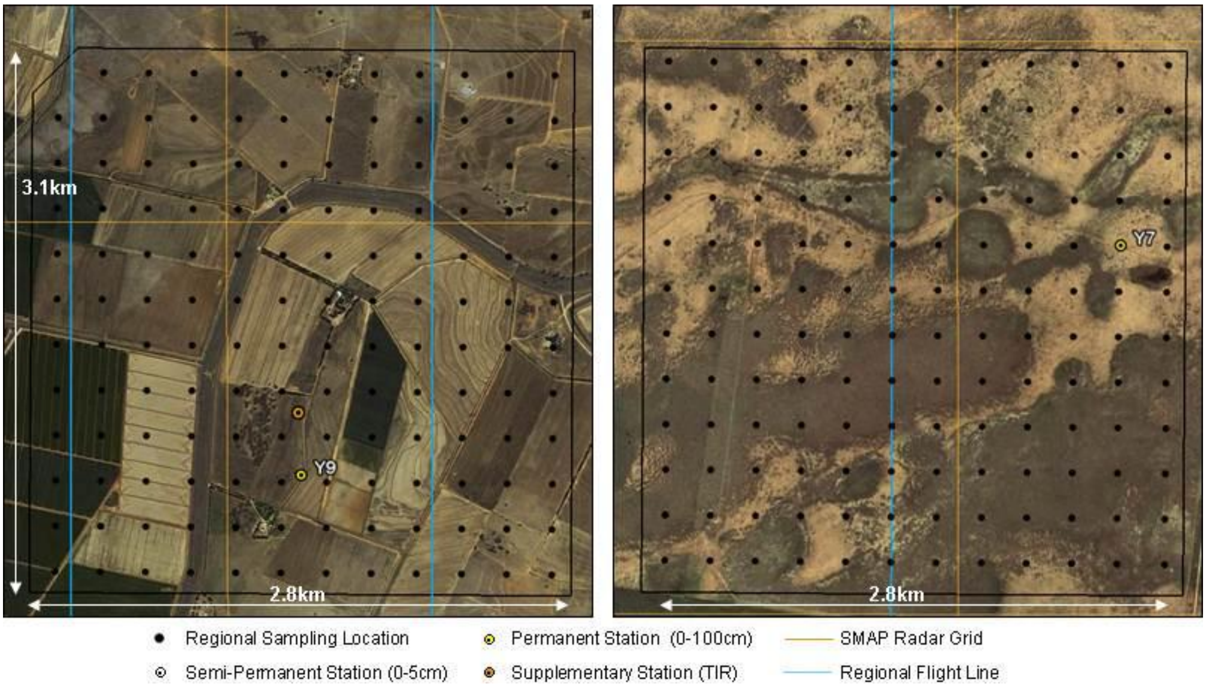


Figure 6-6. Locations of the spatial soil moisture sampling sites during regional days at focus areas YD (mostly cropped, left panel) and YC (grazing, right panel).

Table 6-2. Ground sampling schedule (subject to weather) for SMAPEx-3 concurrent with ESV flights (sampling areas are shown in Figure 6-3). Prefix [c] indicates mostly cropping area while [g] stands for mostly grazing area. No-sampling days are highlighted in black.

	Soil moisture sampling (Team A and B)	Intensive veg sampling (Team A)	Intensive veg sampling (Team B)	Vegetation sampling (Team C)	Roughness sampling (Team E)
Mon 5 Sept	YA4[c], YC[g]	–	–	Start YA4[c]	–
Tue 6 Sept	–	Wheat & corn (YA4[c])	Forest	Finish YA4[c] & YC[g]	TBC
Wed 7 Sept	–	Canola (YA4[c]) & Pasture (YC[g])	Forest	Start YD[g]	TBC
Thu 8 Sept	YD[c], YB7[g]	–	–	Finish YD[g] & YA7[c]	–
Fri 9 Sept	Day-off				
Sat 10 Sept	Day-off				
Sun 11 Sept	YA7[c], YB5[g]	–	–	YB7[g] & YB5[g] & Forest	–
Mon 12 Sept	–	Wheat & corn (YA4[c])	Forest	Start YA4[c]	TBC

Tue 13 Sept	YA4^{c}, YC^{g}	–	–	Finish YA4^{c} & YC^{g}	–
Wed 14 Sept	–	Canola (YA4^{c}) & Pasture (YC^{g})	Forest	Start YD^{g}	TBC
Thu 15 Sept	Day-off				
Fri 16 Sept	YD^{c}, YB7^{g}	–	–	Finish YD^{g} & YA7^{c}	–
Sat 17 Sept	Day-off				
Sun 18 Sept	YA7^{c}, YB5^{g}	–	–	YB7^{g} & YB5^{g} & Forest	–
Mon 19 Sept	YA4^{c}, YC^{g}	–	–	Start YA4^{c}	–
Tue 20 Sept	–	Wheat & corn (YA4^{c})	Forest	Finish YA4^{c} & YC^{g}	TBC
Wed 21 Sept	YD^{c}, YB7^{g}	–	–	Start YD^{g}	–
Thu 22 Sept	–	Canola (YA4^{c}) & Pasture (YC^{g})	Forest	Finish YD^{g} & YA7^{c}	TBC
Fri 23 Sept	YA7^{c}, YB5^{g}	–	–	YB7^{g} & YB5^{g} & Forest	–

6.3. SPATIAL VEGETATION SAMPLING

The objective of the vegetation monitoring is to characterise the individual 2.8km × 3.1km focus areas so as to describe all dominant vegetation types at various stages of maturity and vegetation water content. 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. Full details on sampling procedures at each sampling location are given in section 7.3.

- The vegetation sampling strategy will be based on the assumption that the changes in vegetation (biomass, VWC and plant structure) are negligible within a week, and therefore the same paddock will be sampled with one week revisit time.
- Vegetation samples for biomass, vegetation water content, soil surface reflectance and LAI measurements will be collected daily at the 2.8km × 3.1km focus areas.
- Vegetation sampling will largely follow the sampling schedule of the soil moisture monitoring (see Table 6-2). However, since cropping areas (YA4, YA7 and YD) are expected to present a large variety of vegetation types and growth stages to be sampled, as opposed to the more uniform dry land areas (YB5, YB7 and YC), the former will be strictly sampled when coincident aircraft spectral observation of the area are scheduled.
- Vegetation sampling will cover all the paddocks where intensive vegetation monitoring is planned. Team A and Team B leaders for intensive vegetation sampling will advise Team C leader about their preferred locations.

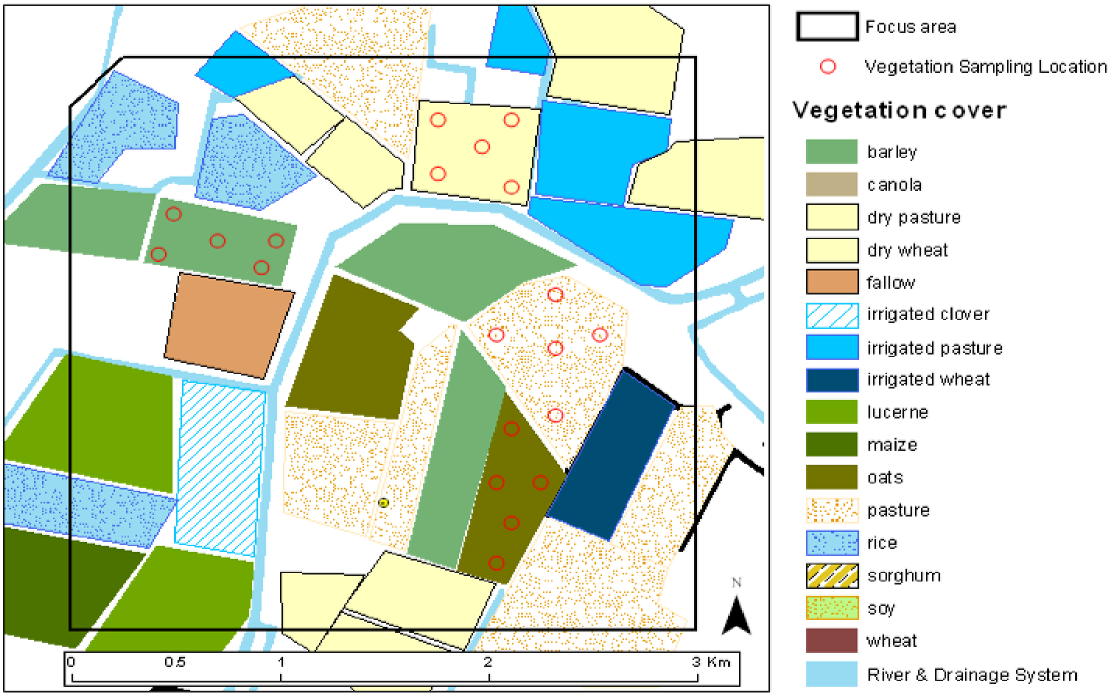


Figure 6-7. Schematic of vegetation sampling strategy for one example focus area (vegetation cover data from November 2006).

- Vegetation sampling will be repeated at the SAME locations as the week before, to accurately track temporal changes in vegetation biomass.
- Within each focus area, ALL major vegetation types will be monitored. In the eventuality that different growth stages of the same vegetation type exist within the sampling area, they will be independently sampled.
- Each major vegetation type (or growth stage of the same vegetation type) will be characterised by making measurements at a minimum of 5 sampling locations distributed within "homogeneous" crops/paddocks. Figure 6-7 illustrates the rationale of the vegetation sampling locations for an example 2.8km × 3.1km sampling area.
- Additional vegetation sampling should be performed outside the focus areas when a major vegetation type observed within the SMAPEx-3 study area is not represented in these.
- All vegetation measurements should be prioritised between approximately 10am and 2pm eastern standard time to optimise the ground spectral observations.
- To assist with interpolation of vegetation water content information and derivation of a land cover map of the region, the vegetation type and vegetation canopy height will be recorded for each vegetation type sampled. In the case of crops, additional information on row spacing, plant spacing and row direction (azimuth angle) will be recorded.

Table 6-3. Crop parameters to be monitored during the intensive sampling

Field parameters	Leaf parameters	Stalk parameters
• Plant density • Row orientation (crops) • Row spacing (crops) • Soil moisture • Surface roughness	• Leaves water content • Leaves width • Leaves length • Leaves thickness • Leaves angle (bottom, mid, top) • Nr of leaves per plant	• Stalk VWC • Stalk length • Stalk diameter (bottom, mid, top) • Stalk angle (bottom) • Plant height

6.4. INTENSIVE VEGETATION SAMPLING

Team A (crops) and Team B (forest) will be responsible twice per week. Rocco Panciera will be the Team A leader for intensive crops sampling, while Mihai Tanase will be the Team B leader for intensive forest sampling.

The objective of the crop intensive vegetation sampling during the SMAPEx-3 campaign will be to collect detailed plant structural parameters for selected vegetation types (agricultural and grazing) and to track the evolution of such parameters across the SMAPEx-3 campaign period, for the purpose of radar algorithm development. The data collected are expected to be comprehensive enough to perform forward modelling of L-band radar backscatter using a discrete scatterer approach (in conjunction with surface parameters such as surface roughness and soil moisture). The list of crop parameters that will be monitored during the intensive sampling is shown in Table 6-3. Intensive monitoring of the crop areas will be performed by Team A twice per week.

The forest sampling consists of around 50 focus sites within a 7km × 8km area (see Figure 6-8). The main forest type in the Yanco area consists of Murray Pine (Calitris Glucophylla) and mixed Murray Pine and Eucalyptus species. Calitris species occupy around 2% of the Australian forests (~2 .5 million hectares) most of which (~ 60%) are located in New South Wales. According to Australia's native forests classification two thirds of the Calitris forests are classified as open forests (51-80% crown cover) while the remaining areas fell into woodlands class (20-50% crown cover).

The objective of the intensive forest sampling is to characterise the forest properties such as specie composition, tree height, stem biomass, stem density, basal area and the radial increment (optional). In addition, measurements of surface roughness (2 directions), soil moisture and leaf water content will be taken at each site. These measurements are needed for the development of algorithms for high resolution mapping of forest characteristics and soil moisture under forest canopy. Intensive monitoring of the forest areas will be performed by Team B twice per week.

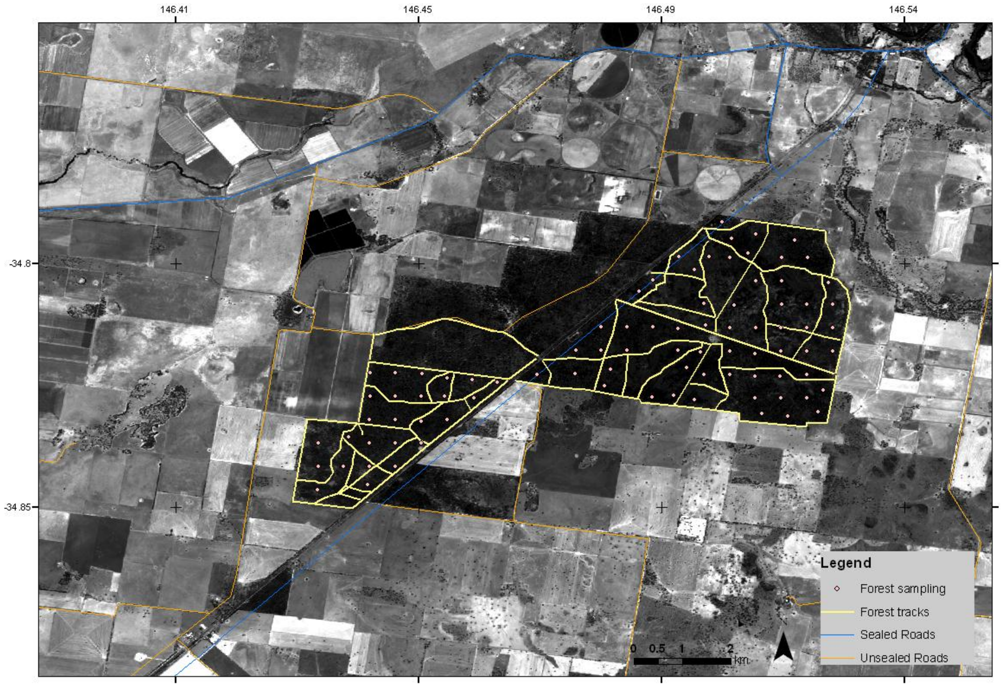


Figure 6-8. Possible site location for forest ground sampling (only 50 sites will be sampled)

Liquid water strongly affects radar backscatter. The equivalent water thickness (EWT) provides an estimate of liquid water per leaf area or canopy when related to leaf are index (LAI). Consequently, leaf samples will be collected from representative trees at selected sites twice per week for computing the EWT. Soil moisture measurements will be taken concurrently with leaf samples at the same sites. Trunk water content will be determined once per week by oven drying core samples extracted from representative trees. Forest vegetation and surface roughness are not expected to change substantially during the field campaign and thus these measurements will be taken once. Supplementary soil moisture and rainfall stations will be installed in the forest area for the duration of the field campaign to provide continuous data. For intensive vegetation sampling protocols refer to Section 7.4.

6.5. ROUGHNESS SAMPLING

Soil surface roughness affects both the radiometric and radar observations. Radar observations can, in certain conditions, be more sensitive to surface roughness than soil moisture itself, due to increased scattering of the incoming radiation. Moreover, surface roughness affects the radiometric observations by effectively increasing the surface area of electromagnetic wave emission. Its effect on observations at L-band frequency is difficult to quantify, and is therefore a critical parameter to be spatially characterised across the different land cover types. During SMAPEx-3 surface roughness will be characterized at 3 locations within each major land cover type in the six focus radar pixel areas and at the 50 sites in the forest sampling area. At each of the locations two, 3m-long surface profiles will be recorded, one oriented parallel to the look direction of the PLIS radar (East-West) and one perpendicular (North-South). Team E will be in charge of the surface roughness measurements. Further details on procedure for roughness measurements with the pin profiler are included in Section 7.6 where measurement protocols are presented.

Note that roughness measurements do not need to be made coincident with PLMR and PLIS overpass dates, since the roughness is expected to be fairly constant in time. Consequently they may be made on the preceding/following day.

6.6. SUPPORTING DATA

In addition to spatial soil moisture and vegetation measurements, the ground teams will be in charge of collecting a range of supporting data, which are needed as input to soil moisture retrieval algorithm. Such data include:

- Land cover type;
- Vegetation canopy height;
- Visual observation of dew presence and characteristics;
- Gravimetric soil moisture samples, and
- Soil texture samples.

Land cover type, vegetation canopy height and visual observations of dew presence will be electronically recorded in the HDAS systems at each location where soil moisture measurements are taken. Soil gravimetric and textural samples will be instead sampled only at certain selected locations. Further details on this supporting data are included below and in Chapter 7 where measurement protocols are presented.

LAND COVER CLASSIFICATION

Land cover information can be used to support the interpretation of remotely sensed data in various ways. In particular, it has been used to interpolate vegetation water content information. It is therefore important to characterise the main land cover types in the study area at the time of the campaign, to help in deriving a land cover map from satellites like LandSat through supervised classification. Land cover will be characterised by visual observation and electronically recorded in the HDAS systems, assigning every sample location to one of the predefined subclasses. Photographs of the typical vegetation types found in the catchment are included in Figure 6-7 which may be a useful reference for identifying the vegetation types encountered in the focus areas.

CANOPY HEIGHT

Information on canopy height can also be used to interpolate vegetation water content information. In particular, it gives an estimate of vegetation biomass and/or crop maturity. Consequently, canopy height will be estimated to the nearest decimetre and electronically recorded in the HDAS systems. To this end, height reference marks with 10cm precision will be provided on the HDAS vertical pole.

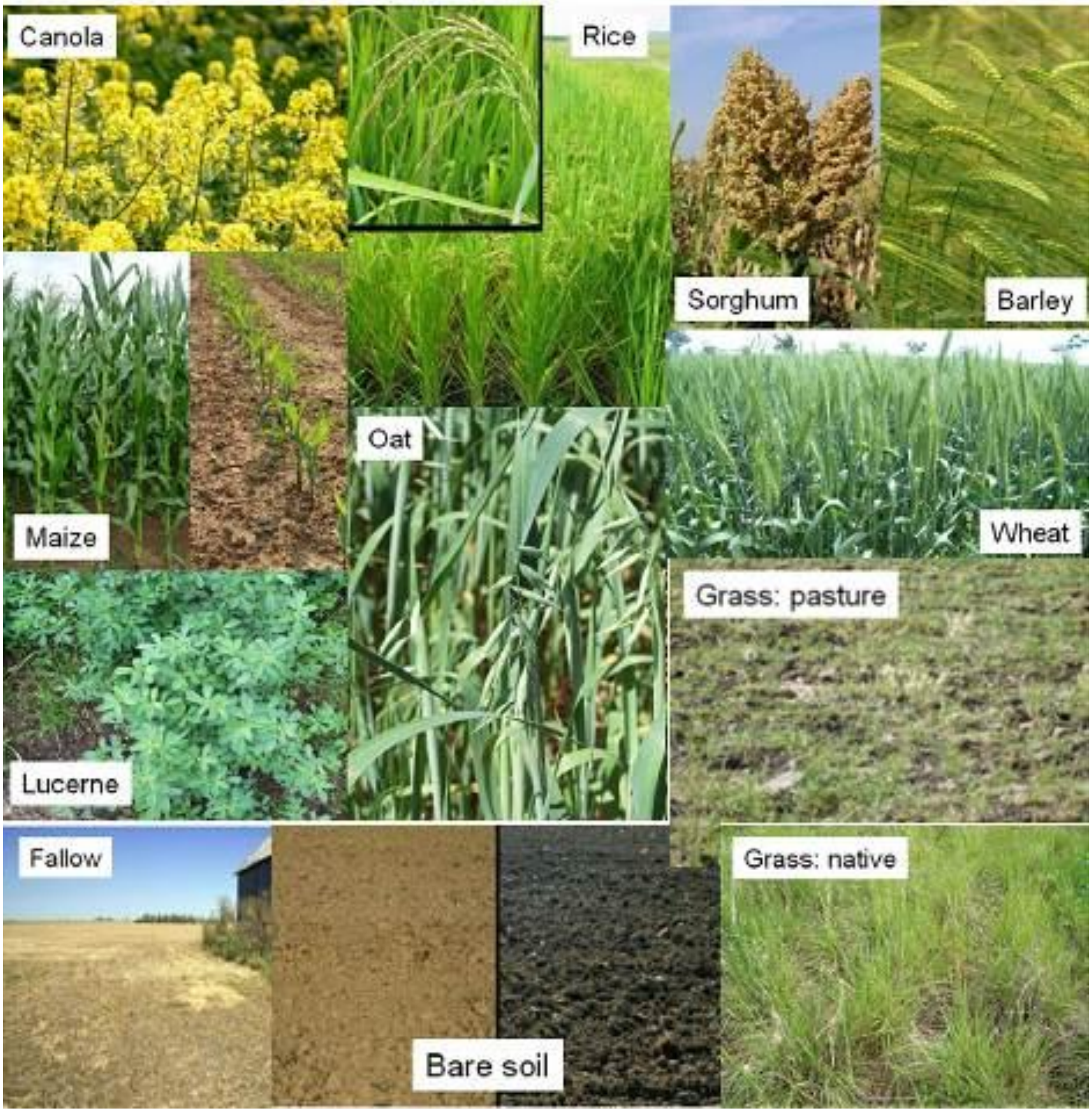


Figure 6-9. Photos of expected vegetation types within the focus farms highlighting features that will be useful for identification.

DEW

The presence of dew on vegetation is likely to affect the passive microwave observation made in the early hours of the morning and hence the subsequent retrieval of soil moisture. In order to support the leaf wetness measurements made by the supplementary monitoring stations, the soil moisture sampling team will make a visual estimate of the leaf wetness conditions during the early hours of the day and record it in the HDAS systems. These measurements only need be recorded until the dew has dried off.

GRAVIMETRIC SOIL SAMPLES

While a generic calibration equation has been derived for the conversion of Hydraprobe voltage readings into a soil moisture value bases on data collected at this site over the past 4 years, the calibration will be confirmed by comparison of Hydraprobe readings with gravimetric measurements.

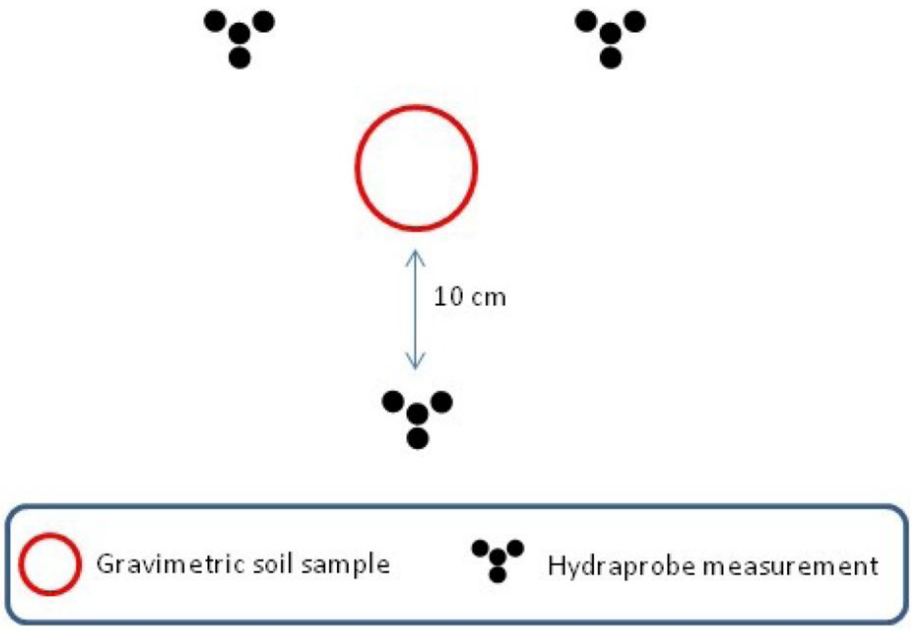


Figure 6-10. A minimum of three Hydraprobe measurements should be made in a radius of 10cm around the gravimetric soil sample.

Volumetric soil samples will be collected for each focus area with the water content computed from the weight of a known soil sample volume before and after oven drying. The team leader of each ground sampling team will be in charge of collecting the gravimetric samples. Preferably, the Hydraprobe readings are made in the sample taken. If this proves not to be possible due to moist soil sticking to the probe, a minimum of 3 Hydraprobe readings should be made at not more that 10cm from the soil sample (see Figure 6-9). The objective of the sampling will be to represent the range of soil types and soil moisture conditions encountered in each focus area. The best way to achieve this will be left to the ground sampling teams. However, following are some recommendations of the general approach to be followed. Full details on sampling procedures at each sampling location are given in Chapter 7.

- At least one gravimetric sample will be collected for each soil type at each of three wetness levels encountered in the focus area. These wetness level are wet (HDAS reading above $0.35m^3/m^3$), intermediate (HDAS reading between $0.15-0.35m^3/m^3$) and dry (Hydraprobe reading below $0.15m^3/m^3$).
- For every focus area a minimum of 3 soil samples will be collected.

SOIL TEXTURAL PROPERTIES

Information on soil textural properties is very important for modeling soil microwave emission, as it strongly affects the dielectric behavior of the soil. Moreover, the information from available soil texture maps is typically poor. Consequently, soil gravimetric samples will be archived for later laboratory soil textural analysis determination of fraction of sand, clay and silt if required.

7. GROUND SAMPLING PROTOCOLS

Field work during SMAPEx-3 will consist of collecting data in the Yanco Region and archiving the information collected during the sampling days. Most of the data collected on the ground will be assisted by the Hydraprobe Data Acquisition System (HDAS). The HDAS system will be used both to store the observations and to visualize the real-time position via a GPS receiver and GIS software.

The ground crew will be comprised of four teams (A, B, C, and E). Team A and B will be responsible for soil moisture sampling using the HDAS system, for the intensive vegetation sampling, and to collect soil gravimetric samples. Team C will mainly take care of the vegetation sampling of the six focus areas, and Team E will be responsible for the soil surface roughness sampling. A list of team participants is included in Chapter 8 together with a daily work schedule. It is important to **note that all sampling devices and field notes should be referenced in Coordinated Universal Time (UTC); local time in the Yanco area is UTC+10 during SMAPEx-3**.

The campaign is comprised of 15 sampling days. Team A and B will work independently on their assigned areas, according to the sampling schedule shown in Table F-1 of Appendix F. A measurement grid will be uploaded on the HDAS screen to improve the accuracy and efficiency of the ground sampling; see also guidelines on farm mobility in Chapter 8. The soil moisture measurements will take place along 250m spaced regular grids. Soil moisture sampling will involve navigating from one predefined location to the next and taking a series of 3 measurements at each predefined sampling locations. Sampling will be assisted by use of a GPS receiver (in-built in the HDAS), which displays the real-time position on the HDAS screen together with the predefined locations. Once the sampling site has been located, the ground measurements of soil moisture and related data (presence of dew, vegetation height and type) are automatically stored into a GIS file on the HDAS storage card. Detailed training on how to use the HDAS system will be given during the training session scheduled on Sept 3, 2011 (for training times and locations see Section 8.6). See also Appendix B for more details on how to use the HDAS. Gravimetric samples will be collected at selected locations along the same grids and transects, with position and other pertinent information stored in the HDAS system while vegetation and surface roughness sampling locations will be established by Team C and Team E leaders, respectively, depending on the actual conditions.

Coincident with soil moisture sampling activities, the vegetation Team C will sample vegetation independently from the other teams and according to the schedule in Table F-2. Between 10am and 2pm (AEST) is the optimal time for spectral measurements, so this time will be prioritised to vegetation destruction sampling and coincident spectral sampling.

At the end of each day, all teams will independently return to the Yanco Agricultural Institute for soil and vegetation sample weighing in the laboratory, data downloading, and archiving. The GIS files stored in the HDAS systems will be downloaded on a laptop computer, the soil gravimetric and vegetation samples will be weighed for wet weight and put in the ovens to dry overnight, and the samples from the day before re-weighed for dry weight. Moreover, the completed vegetation, soil gravimetric and surface roughness forms will be entered into a pre-populated excel spreadsheet proforma. **Team leaders will be responsible to coordinate these operations for each respective team and to ensure that all data are properly downloaded and archived. Please see Appendix F for detailed tasks of each team.**

This Chapter describes the protocols that will be used for the soil moisture and vegetation sampling in order to assure consistency in collecting, processing and archiving the data. Measurement record forms are provided in Appendix G for logging data other than the HDAS measurements.

7.1. GENERAL GUIDANCE

Sampling activities are scheduled, but may be postponed by the ground crew coordinator if it is raining or very likely to rain, there are severe weather warnings, or some other logistic issue arises. In this case the remaining campaign schedule may be revised, and changes will be reported in an addendum to this document.

Each team will make use of a campaign vehicle to access the farms. Members of Team A and Team B will walk along pre-established grids in the focus area, in order to take HDAS readings on the soil moisture sampling grid. They will be dropped off at a location in the focus areas strategically selected and agreed by all team members and will return to the designated location for pick up at the end of the sampling. Team C and Team E will drive independently across the focus areas to undertake their sampling activities, walking to sampling points where driving is not feasible or practical; only qualified personnel are permitted to drive the 4WDs across the farms and 4WDs are not to be driven across crops or boggy ground.

Some general guidance is as follows:

- Leave all gates as you found them; i.e., open if you found it open, closed if you found it closed.
- When sampling on cropped areas, always move through a field along the row direction to minimise impact on the canopy.
- Do not drive on farm tracks if the soil is too wet, because this will mess up the track.
- Do not drive through crops.
- When sampling on regular grids try to first cover all the points falling within the paddock (area enclosed by a fence) where you currently are. When you have covered ALL points, move to the next paddock.
- PROTECT YOURSELF FROM THE SUN AND DEHYDRATION. It is recommended that you bring with you at least 2L of water, since you'll be sampling for the entire day, possibly under the sun. Each team will be assigned a water jerry can of 25L. You should remember to also wear a hat, sturdy shoes (preferably above ankle), and long, thick pants to avoid snake bites.
- All farmers in the area are aware of our presence on their property during the campaign. However, if anyone questions your presence, politely answer identifying yourself as a

"**scientist working on a Monash University soil moisture study with satellites**". If you encounter any difficulties just leave and report the problem to the ground crew leader. A copy of the campaign flyer distributed to farmers is included in Appendix H to assist you should this situation arise.

- Count your paces and note your direction using a distant object. This helps greatly in locating sample points and gives you something to do while walking.
- Although gravimetric and vegetation sampling are destructive, try to minimize your impact by filling holes and minimizing disturbance to surrounding vegetation. Please leave nothing behind you.
- 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.
- Watch your driving speed, especially when entering towns (town speed limits are typically 50km/h and highway speeds 100km/h). Be courteous on dirt and gravel roads, lower speed means less dust and stone.
- Drive carefully and maintain a low speed (~5 km/h) when going through tall grass fields. Hidden boulders, trunks or holes are always a danger. Also check for vegetation accumulation on the radiator.
- When parking in tall grass for prolonged periods of time, turn off the engine. Only diesel vehicles should be used in paddocks as catalytic converters can be a fire hazard.
- Some of the sampling sites may have livestock. Please be considerate towards the cattle and do not try to scare them away. They may be curious but typically harmless.
- For your own security, carry a mobile phone or a UHF radio. Check the mobile phone coverage over your sampling area and be aware of the local UHF security frequencies (if relevant) as well as the team frequency (typically channel 38).
- In case of breakdown of any part of the sampling equipment, report as soon as practical to the Team leader; not later than the end of the day.

7.2. SOIL MOISTURE SAMPLING

Team A and Team B are in charge of collecting (see also Table F-1 for detailed team tasks sheet):

- 0-5cm soil moisture data using the HDAS instrument at each sampling location (minimum of 3 independent measurements per site); if readings vary widely take more) with coordinates automatically given by the HDAS system;
- Information about land use, vegetation type, canopy height and presence of dew at each sampling location (only required once per site);
- GPS location at each sampling location;

- Additionally Team leaders are in charge of collecting soil gravimetric samples.

The HDAS measurements will be made on regular grids of 250m × 250m. The planned sampling locations for each focus area will be loaded onto the HDAS, and visible on your screen via the ArcPad GIS software. Sampling involves navigating along the sampling transect through the use of the GPS in-built in the GETAC that forms part of the HDAS system, which displays the real-time position on the same ArcPad screen as the sampling locations. Once the GPS cursor is located at the predefined sampling point, HDAS measurements can be made and stored in the GETAC.

The information about vegetation type, canopy height and presence of dew will be stored in the HDAS by prompting the values into forms, following the hydraprobe readings. For further details on the HDAS operation see Appendix B. For the sake of quality of the data collected please pay attention to the following:

1. Complete the forms for each of the 3 measurements (i.e., do not leave "vegetation type" blank at one point assuming that we will work out the vegetation type from the nearby point).
2. Check your Hydraprobe at each sample site to ensure it is clean. In wet soils, this is particularly important as a lot of soil will stick!
3. Note in the comment box any anomalous issue you might find at the sampling site (ie. Near a tree or a clay pan, one out of the three soil moisture samples per location differs from the other two but has been checked and the reading is correct because of a difference in vegetation cover).
4. Check the soil moisture readings obtained before saving the points and make a reasonable judgment as to whether the value indicated by the probe is consistent with the conditions you can observe visually (i.e., if the soil looks very wet and the reading is 0.1m3/m3, cancel the point and try again by moving the probe a few cm and checking there is nothing between the tines).
5. The predefined sampling locations are laid down automatically using a GIS software, therefore some of them might fall on unusual ground (paved road, house, canal). In this case, feel free to move the sampling to a nearby location (~10-20m) which is REPRESENTATIVE OF THE DOMINANT CONDITIONS IN THE SURROUNDING 250m.
6. In all cases keep in mind that (i) the predefined sampling location can be shifted within 10-20m to fall on more representative ground and (ii) the selected location must be representative of an area of ~250m radio surrounding it.
7. The shape files visible on the HDAS screen (irrigation channels, roads, farm boundaries etc.) can be wrongly located of up to 50m from their real location. Therefore use them more as a guideline and always check your surrounding visually.

8. If a predefined sampling point seems to fall just outside the sampling area assigned to you (e.g., 10m on the other side of the fence) take a reading anyway. This will avoid points being missed by two Team members.

9. In case of doubts on the vegetation type or mistakes, make a note of the point ID and communicate to the Team leader. Once back at the operations base you will be able to modify the data manually.

FIELD EQUIPMENT

Each soil moisture team will be equipped with the items listed below:

- 4WD vehicle
- 1x hardcopy of the workplan
- 1x 25L water Jerry can
- 1x first aid kit
- 1x first aid book
- 1x sunscreen bottle
- 1x gravimetric sampling kit
- 1x spare HDAS system

The gravimetric sample kit will be assigned to the team leader, who is responsible for collecting the soil gravimetric samples. Each individual in the team will be equipped with the items listed below:

- 1x HDAS system
- 1x hardcopy map of each focus area with the sampling grids and useful topographic information
- 1x UHF radio
- 1x field book and pen. The field book is to be used for comments and must be returned at the end of the campaign to the ground crew coordinator.

Each person will be individually responsible for the use and care of their assigned equipment throughout the campaign, and must report any damaged or lost item to the team leader immediately so that actions can be taken to find, repair or substitute as appropriate. Each person is also responsible for putting their own GETAC unit to recharge each day and downloading/uploading their own GETAC data (see also Table F-1**Error! Reference source not found.** for detailed team tasks sheet). **Each team member will be assigned his/her own HDAS system and for the duration of the campaign. Please do not interchange equipment of your own accord.**

HYDRA PROBE DATA ACQUISITION SYSTEM (HDAS)

Step-by-step information on the operation of the HDAS system, including files upload and download, sampling commands and troubleshooting is included in Appendix B.

Each HDAS system is composed of:

- 1x GETAC unit (with ID marked)
- 1x HDAS battery
- 1x GETAC pencil
- 1x GETAC power cable
- 1x GETAC USB download cable
- 1x HDAS pole (with ID marked)
- 1x Hydraprobe

The GETAC unit has been programmed to automatically read the Hydraprobe at the desired sampling location when a specific command is sent from the GETAC screen, and store the probe readings in a file together with the GPS coordinates provided by the in-built GPS in the GETAC unit. This is achieved with the "ArcPad" software, a geographic information system for handheld devices. The ArcPad program stores the readings of the probe with the coordinates given by the GPS. 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 a series of visible layers in addition to the GPS position indicator:

- Boundaries of the daily sampling area;
- Main roads (paved and unpaved);
- Properties and lot boundaries;
- Property main entrance;
- Locations of known gates and canal bridges;
- Irrigation canals;
- Grid of planned sampling locations;
- Grid of actual sampling locations: this is the file that will be edited every time a soil moisture reading is taken;
- Background GoogleEarth image.

It is important to check daily, BEFORE sampling starts, that the GETAC time is set to the correct UTC time as the time information will be used to interpret the data. Additionally, it is essential to recharge each GETAC after each sampling day, in order to avoid any malfunctions and sampling delay.

At each sampling location the following information will be selected from pre-defined drop down lists, in addition to a free-form comment if desired. The vegetation canopy height is selected from a list with 10cm increments up to a maximum height of 1.5m, while vegetation type and dew amount selected from the lists below:

Vegetation Type (dryland, irrigated:drip, irrigated:spray, irrigated:flood):

- bare soil
- fallow
- grass: native
- grass: pasture
- crop: barley
- crop: canola
- crop: lucerne
- crop: maize
- crop: oats
- crop: rice
- crop: sorghum
- crop: soybean
- crop: wheat
- crop: other
- orchard
- vineyard
- woodland: open
- woodland: closed
- water body
- building
- other

Dew Amount

- none
- small droplets
- medium droplets
- large droplets
- film

7.3. VEGETATION SAMPLING

The vegetation sampling team (Team C) is in charge of collecting (see also Table F-2 for detailed team tasks sheet):

- Vegetation and litter destructive samples;
- Vegetation canopy reflectance measurements;
- Vegetation canopy LAI measurements;
- Information about vegetation type, canopy height, crop row spacing and direction, and
- GPS location of the actual vegetation sampling site.

The vegetation team will be equipped with a GETAC unit in order to navigate through the focus areas using GPS positioning like for the sampling teams. The GETAC will contain information on main roads, properties and lot boundaries and irrigation canal to aid the navigation and selection of the sampling locations.

FIELD EQUIPMENT

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

- 4WD vehicle;

Table 7-1. CROPSCAN vs. MODIS and Skye sensors bands

MODIS		SKYE	CROPSCAN
Band	**Bandwidth (nm)**	**Bandwidth (nm)**	**Bandwidth (nm)**
1	620 - 670	620 - 670	630 - 670
2	841 - 876	841 - 876	830 - 870
3	459 - 479	459 - 479	465 - 475
4	545 - 565	545 - 565	530 - 570
5	1230 - 1250	-	1234 - 1246
6	1628 - 1652	1628 - 1652	1632 - 1648
7	2105 - 2155	2105 - 2155	
		2026 - 2036	704 - 716
		2026 - 2216	965 - 975

- 1x hardcopy of the workplan
- 1x hardcopy map of each focus area with the sampling grids and useful topographic information
- 1x GETAC
- 1x CROPSCAN device
- 1x LAI-2000 device
- 1x vegetation destructive sampling kit
- 5x field books
- Pens, permanent markers
- 1x 25L water Jerry can
- 1x first aid kit
- 1x first aid book
- 1x sunscreen bottle
- 5x pairs of gloves

SURFACE REFLECTANCE OBSERVATIONS

The CROPSCAN is an instrument that has up-and-down-looking detectors and the ability to measure reflected sunlight at different wavelengths. The basic instrument is shown in Figure 7-1. The CROPSCAN multispectral radiometer systems consist of a radiometer, data logger controller (DLC) or

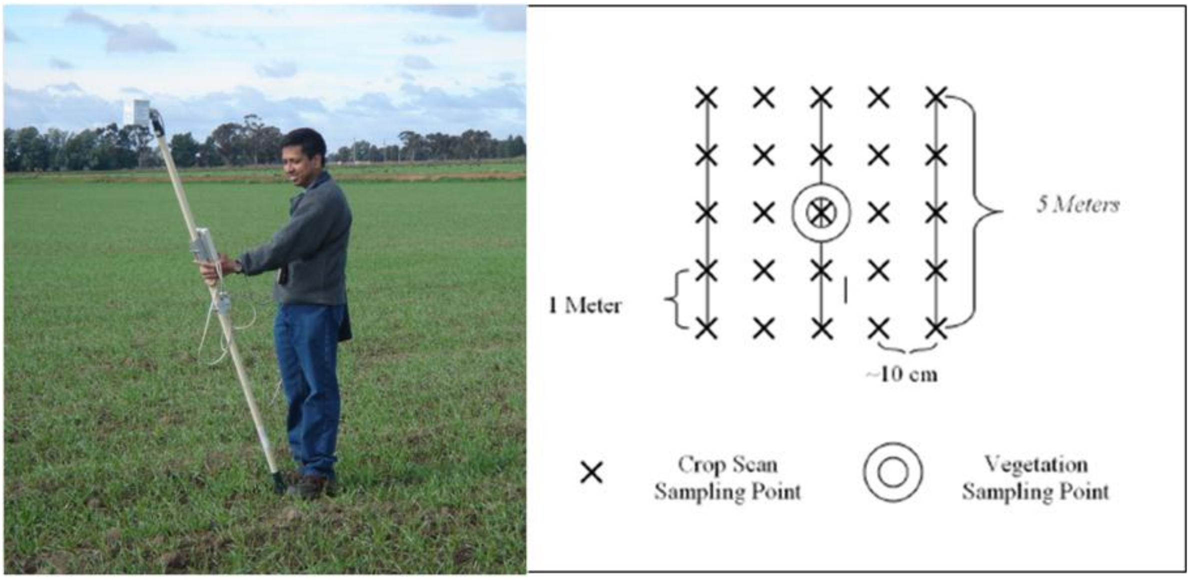


Figure 7-1. (Left) CROPSCAN Multispectral Radiometer (MSR). Size is 8cm × 8cm × 10 cm. (Right) Illustration of the surface reflectance protocol.

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 1720nm are available. For SMAPEx-3 a MSR16R unit will be used with the set of bands indicated in Table 7-1. These bands approximate channels of the MODIS instruments. Channels were chosen to provide NDVI as well as a variety of vegetation water content indices under consideration.

Reflectance data will be collected at each vegetation sampling location (see Figure 7-1) just prior to vegetation removal using the following sampling scheme. Making sure that the radiometer is well above the canopy, take a reading every meter for 5m. Repeat, for a total of 5 replications located 1m or 1 row apart. See Appendix D for detailed instructions on how to operate the CROPSCAN.

LEAF AREA INDEX OBSERVATIONS

The LAI-2000 (see Figure 7-2) will be set to average 4 points into a single value with one observation 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 in the case of row crops. These should be made just before taking the biomass sample. For short vegetation, LAI will be derived from the destruction samples as described below.

If the sun is shining, the observer needs to stand with their back to the sun so that they are shading the instrument. Moreover, they must put a black lens cap that blocks ¼ of the sensor view in place, and be positioned so that 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, irrespective of whether the sky is overcast or if it is partly cloudy but with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked “cloudy”, if shadows could be seen during the measurement then it is marked “sunny”. Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements for a sample location. Also, it is important to check the LAI-2000 internal clock each day to verify they are recording in GMT. See Appendix E for detailed instructions on how to operate the LAI-2000.

Additionally, the vegetation samples taken within the 50cm × 50cm quadrant will be passed through a leaf area scanner, to determine the full leaf area for the sample. These data can then be used to compare the observed and measured leaf area indices.

Figure 7-2. The LAI-2000 instrument.

VEGETATION DESTRUCTIVE SAMPLES

At least five vegetation samples concurrently with reflectance/leaf area index observations will be taken for each major vegetation type across the focus area under consideration for the day, making sure that all significant vegetation types and growth stages encountered across the farm are included. These vegetation samples will be weighed at sample check-in on return to the operations base, and then left in the oven over several days for drying at 45°C.

Note: Vegetation samples should only be taken AFTER the spectral and LAI measurements have been made.

Vegetation destructive sampling kit

- 1x GETAC unit or equivalent
- 1x 0.5m × 0.5m quadrant to obtain vegetation samples
- 1x vegetation clipper
- 1x scissors
- 5x pairs of gloves
- plastic bags
- rubber bands
- permanent markers
- vegetation sampling recording form

Vegetation destruction sampling protocol

The procedure for vegetation biomass sampling is as follows:

1. Note on the vegetation sampling form the type of vegetation sampled (e.g. crop, native grass, improved pasture) using the predefined list in the HDAS, its height and row spacing and direction if relevant.
2. Randomly place the 0.5m × 0.5m quadrant on the ground within the area to be sampled.

3. Label the bag provided using a permanent marker with the following information: Area_ID / DD-MM-YY / Sample_ID. Take a photo of area to be sampled prior to removal of vegetation.
4. Record sample location with GPS and sample location reference number in GETAC.
5. Remove all aboveground biomass within the 0.5m × 0.5m quadrant using vegetation clippers and scissors provided.
6. Place vegetation sample into labelled bag provided.
7. Close bag with sample using rubber bands provided and place this bag into a second bag to ensure that no moisture will be lost.
8. Take a photo of sample plot following removal of aboveground biomass.
9. Fill up the vegetation sampling form with all the required information (a copy of the vegetation sampling form is given in Appendix G).

It is the responsibility of Team C to deliver the vegetation samples to the operations base at the end of the day for determination of wet and dry weight (see protocol below).

LABORATORY PROTOCOL FOR BIOMASS AND VEGETATION WATER CONTENT DETERMINATION

All vegetation samples are processed to obtain a wet and dry weight. Vegetation samples will be processed at the YAI. The YAI facilities that will be used for the processing of vegetation samples are electronic balances and large dehydrators (max 70°C) with 120 trays available.

Wet Weight Procedure

1. Turn on electronic balance.
2. Tare.
3. Remove paper bags with vegetation for a given field from the plastic trash bag. Note any excessive condensation on the inside of the plastic trash bag and record this on the vegetation drying form.
4. Record wet weight (sample + bag) of each paper bag with veg on the vegetation drying form. Record wet weight (sample + bag) in the computer excel vegetation drying form.
5. Put the sample + bag in the oven for drying. Try to keep all bags for a given field on the same shelf in the oven. Note the time that the bags were placed in the oven on the drying form (see procedure below).

Drying Procedure

1. Place the samples in the dehydrator to dry at 65°Cand leave it to dry until a constant weight is reached (typically 2-3 days depending on how wet the vegetation is to start with – very dense wet vegetation could take longer to dry). Record the location of the sample in the

dehydrator (dehydrator ID and shelf ID) together with date and time on the vegetation drying form when you start and end the drying.

2. Dry samples in oven at 65° C until constant weight is reached (typically 2-3 days).
3. Turn on balance.
4. Tare.
5. Remove samples from dehydrator one at the time, close the dehydrator and put samples immediately on the electronic scale.
6. Record dry weight (sample + bag) on the vegetation drying form

NOTE: once out of the dehydrator, the vegetation sample will absorb moisture from the air surprisingly quickly. It is recommended that the dry weight is recorded within not longer than 10 seconds from removing the sample from the oven.

Taring of paper bags

At some point during the field experiment (preferably at the beginning), weigh a reasonable number (20-30) of dry new paper bags under normal room conditions, place in the ovens at the vegetation drying temperature (usually 65° C), and weigh again (taking them out of the oven one at a time) after 2-3 days of drying. The difference between the average before-drying weight of a bag and the after-drying weight of a bag is the amount of weight lost by the bags themselves during the oven drying process. This value needs to be considered in converting the wet & dry weights of the vegetation into an estimate of vegetation water content (VWC).

7.4. INTENSIVE VEGETATION SAMPLING

CROPS INTENSIVE MONITORING

Intensive crop sampling will be performed by Team A, which will be split into two sub-teams working in parallel at the same paddock, twice per week. Due to the time limitation, extensive coverage of the various vegetation types across the 40km × 40km SMAPEx study area will be unfeasible. The intensive sampling will therefore be focused on four vegetation "groups" according to their dominant scattering mechanism (see Table 7-2). For each vegetation group, one plant type will be selected as representative of that group, and intensive measurements of vegetation parameters will be performed on one focus paddock of that plant type. Consequently, a total of 4 paddocks are sampled repeatedly during the campaign. Each paddock will be revisited on a weekly basis to monitor the changes of the vegetation parameters in time. On each day, 2 focus paddocks will be. This timeline will allow a weekly revisit of each of the 4 focus paddocks.

On each focus paddock, 10 evenly distributed locations across the paddock will be selected for intensive vegetation monitoring (see Figure 7-3). At each location a 1m × 1m area will be flagged and 1 full set of measurements will be acquired. One set of plant measurements will be recorded at each location, with 1 plant randomly selected within each 1m × 1m area: on this plant measurements for 1

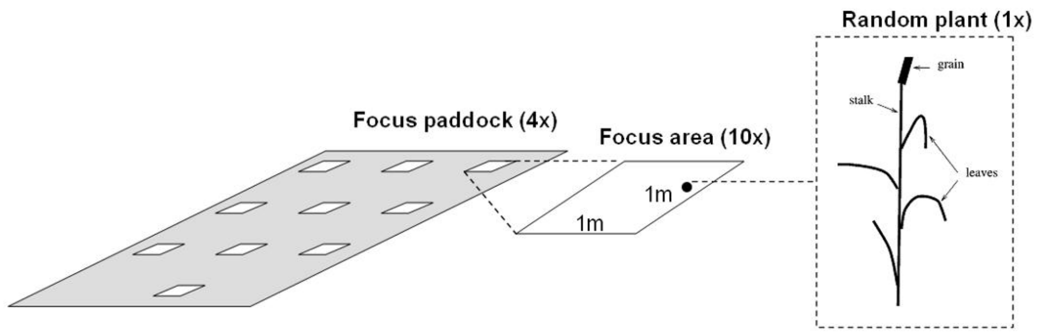


Figure 7-3. Diagram of intensive vegetation sampling strategy

set of stalk parameters and 3 sets of leaf parameters (on 3 randomly selected leaves) will be performed. The 3 leaves/plant × 10 plants/paddock = 30 leaf measurement sets are expected to provide statistically significant data to define the PDF for each leaf parameters. The sampling strategy and is shown schematically in Figure 7-3 with the parameters to be measured listed in Table 6-3. This sampling strategy will allow definition of average leaf and stalk parameters specific to each scattering group, which will be considered applicable to all the areas classified under each group for forward modelling purposes.

Table 7-2. Classification of agricultural crops in the SMAPEx study area by scattering mechanism. In bold the crop tentative selected as representative of each group

Scattering type	Crops
Group 1: Vertically oriented thin scatterers - high density	**Wheat**
	Barley
	Oats
	Cereal Grains
Group 2: Vertically oriented thick scatterers - significant stem return	**Corn**
Group 3: Horizontally oriented scatterers	**Canola**
	Lucerne
	Cotton
Group 4: Variable scatterers orientation- low density	**Pasture**
	Fallow

It is expected that the 4 focus paddocks will be selected prior to the campaign based on the surface conditions at the time of the campaign start. A dedicated roughness team (Team E) will characterise the surface roughness across each of the 4 focus paddocks.

FIELD SAMPLING PROTOCOL

The location of the 10 focus sites on the paddock could be preloaded on a handheld PC or flagged in the field.

1. Record in the form the date, paddock ID, and person recording;
2. Navigate to first location and record in the form the area ID (date/paddock ID/Area1,…,10);

3. If not already flagged, physically flag a 1m × 1m area using four poles
4. Identify the dominant species (e.g. grass or corn) and record on the form the species ID, description and percentage of cover within the 1m × 1m
5. For each dominant species:
6. Select one random plant from the 1m × 1m area (one that can be reached without steeping in the 1m × 1m area).
7. Take a photo of the plant standing and one of the overall site conditions and record the photo ID's on the form.
8. Without removing or disturbing the plant, take measurements of plant height, stalk length (between upper and lower node), stalk diameter (bottom, mid and top most node), stalk angle (at the base) and leaves angle (3 randomly leaves, each measured at the bole, the leaf midpoint, and the leaf tip). Record in the form (NOTE: for stalk-less plants like perennial grass, only record the angles of 3 filaments at base/middle/end).
9. Remove the plant, remove all leaves from the stalk and set 3 random leaves aside.
10. Measure length, width and thickness of each leaf and record.
11. Put leaves into a paper bag. Label a small paper bag as date/paddock ID/species ID/leaves. NOTE: All the leaves from a particular species on a paddock can go in the same paper bag.
12. Store the stalk in a separate big paper bag and label it date/paddock ID/species ID/stalk. All the stalks from a particular species on a paddock can go in the same paper bag.
13. Seal both paper bags inside plastic bags and seal with a rubber band.
14. Record row orientation, row spacing, and number of plants per meter length on one row (for row crops) using the 50cm × 50cm quadrangle and record in the form. NOTE: if measuring plants/m is difficult due the high density, or if no row structure exists (e.g. pasture), only record plant density using the quadrangle.
15. Take 3 HDAS soil moisture reading within the 1m × 1m area and note the site ID in the comment box (date/paddock ID/area1,…,10).
16. Move to next sampling location in the same paddock.

EQUIPMENT

The following list of tools will be supplied per intensive sampling team for use in the field. In the laboratory a digital scale will be needed (with sufficient accuracy to measure leaves weights).

- 1x Vegetation clipper
- 1x Scissors
- 2x Pairs of gloves

- 50x Paper bags for temporary storage (pre-drying) – small
- 50x Paper bags for temporary storage (pre-drying) – large
- 20x Plastic bags for long term storage (post-drying)
- Rubber bands
- 1x Meter stick
- 1x Measuring tape
- 4x Flagged sticks (to delimitate 1m × 1m area)
- 1x Compass
- 1x Protractor + level
- 1x Micrometer (for stalk diameter, 1mm accuracy, 0-50mm range)
- 1x Digital calliper (for leaves thickness, 0.1mm accuracy, 0-10mm range)
- 1x Digital camera
- 1x Precision Ruler (for leaves width, length)
- 1x Quadrangle 50cm × 50cm
- 1x HDAS system
- 1x Dielectric probe

FOREST INTENSIVE MONITORING

At each of the 50 sites, the vegetation will be assessed at five plots (of ~500m^2 area; see Figure 7-4). This sampling design allows for characterisation of relatively large areas (1ha) with minimal sampling effort. In addition, the high resolution of PLIS, LIDAR and optical sensors allows independent analysis of the sub-plots, if necessary, thus increasing the number of available samples. Inside each plot all trees will be measured for diameter and height. Optionally (depending on manpower and research interests) the radial growth will be measured for a set of representative trees for each species. For representative trees photos will be used to determine the branch insertion angle, and the proportion of primary, secondary and tertiary branches. The total biomass of the understory layer will be computed using the fraction cover of the understory layer (estimated visually at each plot) and an average biomass per square meter value estimated at representative sites using destructive sampling methods.

FOREST MEASUREMENT PROTOCOL

The site locations (centre) will be loaded in the GETAC unit for easy identification. Moreover, the centre point of each site will be marked before the start of the campaign (using 50cm poles with pink flagging tape) to allow faster recognition by the monitoring team during sampling. Forest inventory will be conducted once at each focus site during SMAPEx-3. It is estimated that 4 or 5 forest sites will be measured each sampling day. For each subplot the tree closest to the centre will be marked and the distance and orientation to the centre noted.

Tree inventory sampling

Forest inventory will be conducted once only at each selected site during the campaign. All trees will be measured for diameter at breast height and height. For trees smaller than 2m the diameter will be taken at half of their height.

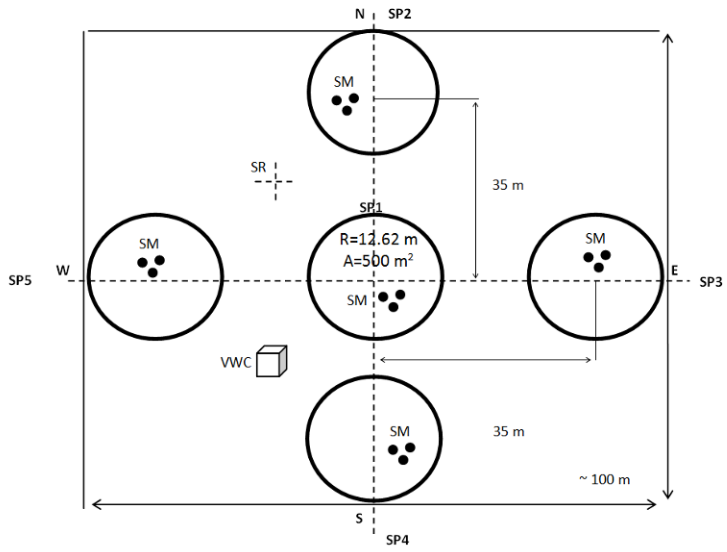
The following list of tools will be provided to the intensive sampling team for field sampling:

- 1x girth tape (diameter at breast height),
- 1x vertex hypsometer (tree and crown height),
- 1x tape or chalk for trees marking,
- 50x recording form,
- 1x HDAS system,
- 2x increment borers,
- 1x fish-eye camera, and
- 1x tripod

The procedure for forest inventory is as follows:

1. Navigate and identify the site centre. The plot ID is formed from the site ID (number) and the letter of the corresponding plot ("C" for centre, "N" for north, "E" for east, "S" for south, and "W" for west).
2. Measure trees characteristics according to the provided field form (take care with border trees). If the centre of a tree (measured at the base of the tree) is outside the 12.62m radius the tree will not be sampled. Measure all trees with heights > 2m. Tree circumference will be measured at 1.3m (breast height) using the girth tape provided.
3. Height will be measured from two positions (preferably from opposite sides) for trees with height > 5m.
4. Once measured mark the tree (tape, chalk, etc.) to avoid confusions.
5. Take photos on the main directions (N,S,E,W) and close ups of ground vegetation.
6. Take photos with the fish-eye camera for LAI estimation (plot level) at the centre of each plot. GPS coordinates of the plot centre must be noted on the field from. The tripod must be levelled before taking each photo using a bubble level.
7. Navigate to subplot N by measuring 35m to north direction (use measuring wheel or Vertex).
8. Mark the centre and record the coordinates.
9. Repeat measurement as for the first subplot.
10. Go back to the site centre and navigate to subplot #3 (east direction).
11. Repeat measurements, navigate to the remaining subplots and repeat measurements

Figure 7-4. Site design for forest sampling (SR-surface roughness, SM-surface moisture, VWC-vegetation water content).



12. Select a representative tree for each species (average diameter and height) and extract two core samples (only for selected sites). Place the core samples in a paper bag to preserve the moisture and write the site ID and specie on the bag.
13. Take fish-eye camera photos on two diagonal transects every 25ms (4x photos in each transect) for characterization of LAI at site level.
14. Move to the next site.

Forest destructive sampling – canopy water content

Destructive sampling for characterization of crown water content will be conducted at selected sites twice per week during SMAPEx-3. The samples will be taken from the buffer area between the site centre (SP#1) and the north plot (SP#2). One sample is required for each tree species present in the forest over-story. Each sample is formed by leaves collected from trees with different heights as described below.

The following list of tools needed by one intensive sampling team for field sampling:

- 1x clipper /scissors,
- 1x pair of gloves,
- 150x paper bags for temporary storage (pre-drying) – large,
- 75x plastic bags for temporary storage (post–drying),
- 150x rubber bands,
- 1x recording form,
- 1x cardboard/paper (with a 5cm × 5cm square for scaling) and,
- 1 field scale to measure leaf weight.

The procedure for forest destructive sampling (a variation of the one used for crops) is as follows:

1. Weigh the paper sampling bags before going to field and calculate the average. Store the paper sampling bags in a plastic bag to avoid picking up moisture. During sampling do not place the paper bags on the soil or other wet surfaces.
2. Note on the vegetation sampling form the species to be sampled (e.g. Calitris, Eucalyptus) and the tree height. Fill up the vegetation sampling form with all the required information. A copy of the vegetation sampling form is given in Appendix xxx)
3. Record sample location with GPS. Use as ID the reference number (ID) of the site in the GETAC. Take the photo of the tree to be sampled prior to removal of vegetation;
4. Collect samples (leaves) from 2 different heights (~2m, ~5m) using the clipper, scissors, knife, etc. provided – use whatever tool works best on the vegetation in that particular site. There should be no condensed water on the surface of the vegetation before it is cut and removed – if there is water from dew or intercepted rainfall, either wait until the vegetation is dry to take the sample or blot the vegetation dry.
5. Place collected leafs in separate pre-drying bags, one for each height. Label paper bags provided using a permanent marker with the following information: Site_ID/DDMonthYYYY /HH:MM/ Sample_height
6. Fold over the top of paper bags multiple times to seal, and then place the bags immediately into a plastic trash bag to ensure that no moisture is lost; loosely knot the plastic bag before moving on to next sampling location;
7. Move to next sampling location.

Leaf samples drying

1. Record wet weight (sample + bag) of each paper bag with veg on the vegetation drying form. Record wet weight (sample + bag) in the computer excel vegetation drying form (Appendix G).
2. Put the sample + bag in the oven for drying. Try to keep all bags for a given field on the same shelf in the oven. Note the time that the bags were placed in the oven on the drying form (see procedure below).
3. Place leafs over the gridded cardboard/paper in such way that leafs do not overlap and you cover the gridded area. The area not covered by leafs has to be minimum. Take a vertical photo of the sample and note the photo ID on the form. If the leafs do not fit all on the cardboard repeat the procedure.
4. Calculate the leaf area for the samples (or each sub-sample) using the provided software
5. Calculate VWC/m^2 for each sample.

Forest destructive sampling – understory content

Destructive sampling for characterization of understory water content will be carried out for the main understory types. Understory types are defined according to vegetation characteristics: short grass (<50cm), tall grass (>50cm), short shrubs (<1m) and tall shrubs (1-2m). Three destructive samples from each vegetation type will be taken once per week from selected forest sites. The sites will be established at the beginning of the campaign. Understory destructive sampling will follow the same protocol as for crops. The total shrub biomass will be obtained by multiplying the biomass obtained from destructive sampling with the percentage cover of each understory vegetation type recorded at each subplot by the inventory team.

Soil moisture sampling

Soil moisture will be measured at selected sites once per week (simultaneously with canopy water content measurements) using HDAS system and protocols. At each site all plots will be sampled.

7.5. SOIL GRAVIMETRIC MEASUREMENTS

At least 3 soil gravimetric samples should be collected per day in each focus area. It will be the responsibility of the team leader to collect these samples, making sure that sure that all soil types and the complete range of soil moisture encountered on the focus area are included. These gravimetric soil samples will be weighed at sample check-in on return to the operations base.

GRAVIMETRIC SOIL MOISTURE SAMPLING KIT

- 1x sampling ring (approximately 7.5cm diameter and 5cm depth)
- 1x hammer and metal block
- 1x garden trowel
- 1x blade
- 1x spatula
- gloves
- plastic bags
- rubber bands
- carton tags
- permanent markers
- 1x soil sample recording form

GRAVIMETRIC SOIL MOISTURE SAMPLING PROTOCOL

1. Take a minimum of 3 soil moisture readings with the Hydraprobe immediately adjacent to the soil to be sampled, plus 1 reading in the soil sample if conditions permit**. Indicate the gravimetric sample ID in page 3 “Other” of the HDAS screen. The ID will be the same for the 3 measurements taken adjacent to the soil sample and will correspond to the ID indicated on the sample bag. Also indicate if the measurement is taken in the sample.**
2. Remove vegetation and litter.
3. Place the ring on the ground.

4. Put the metal 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 but without compacting the ground.
5. Use the garden trowel to dig away the soil at the side of the ring. The hole should reach the bottom of the ring (5cm) and should be sufficiently large to accommodate the spatula for ring removal.
6. Use the spatula to cut the 0-5cm soil sample at the bottom of the ring.
7. Place the 0-5cm soil sample in the plastic bag ensuring that no soil is lost.
8. Write Area_ID / TEAM ID/ DD-MM-YY / Sample_ID on the carton tag provided and place it in the bag.
9. Seal the bag with the rubber band provided then place this bag into a second bag and seal the second bag.

GRAVIMETRIC SOIL MOISTURE DETERMINATION

All gravimetric samples are processed to obtain a wet and dry weight. Gravimetric samples will be processed at the YAI, where an electronic balance and an oven will be available. It is the responsibility of each team leader to deliver the gravimetric samples to the operations base at the end of the day, wet weight, oven-dry and dry weight the samples. All the information will have to be recorded in the Gravimetric_Drying.xls (one form per day, see templates in Appendix G).

Wet Weight determination

1. Turn on balance.
2. Tare.
3. Record wet weight (sample + bags + rubber bands) into the gravimetric drying form
4. Record bags and rubber bands weight into the gravimetric drying form
5. Record aluminum tray weight on the gravimetric drying form.
6. label the aluminum tray uniquely based on the sample ID using a permanent marker
7. Place the used bags in order. The labeled bags will be used for permanently storing the samples after the drying procedure is finished.

Dry Weight determination

1. Place the samples in the oven to dry at 105°C for 24 hours. Record the date and time (local) on the gravimetric drying form when you start and end the drying.
2. Turn on balance.
3. Tare.

4. Remove samples from oven one at the time, close the oven and put samples immediately on the electronic scale. These samples will be hot! Use the gloves provided.
5. Record dry weight (sample + tray) on the gravimetric drying form
6. Return soil into the original plastic bag, close bag with a rubber band and store samples

The dry/wet weight data of soil samples and their associated sample ID will be stored in an excel file "Desktop/SMAPEx-3\Ground_Data\DD-MM-YY\Area_ID\Gravimetric\TEAM_$\Gravimetric.xls" where DD is day, MM is month, YY is the year (**Please note: date/time must be AET**), $ is the team identification letter (A or B) and Area_ID is the focus area identification code (see Table 6-1).

7.6. SURFACE ROUGHNESS MEASUREMENTS

Team E will be responsible for the surface roughness measurements during SMAPEx-3. Three surface roughness profiles will be acquired within each major land cover type present in each focus area. Each measurement will consist of two, 3m-long profiles, one oriented parallel to the look direction of the PLIS radar (east-west)and one perpendicular to it (north-south). The exact location of the 3 profilers is left to Team E. The 3 measurements should cover the variability of surface conditions observed within the land cover patch of interest.

Surface roughness will be measured at selected forest sites once during the campaign. Two perpendicular measurements per site will be taken. The location is to be selected by Team E leader and could be inside of one of the subplots or in the buffer areas, but must be located under the forest canopy following the established protocols. For sites with sparse forest cover the roughness will be taken for the most representative vegetation type (e.g. grass, shrubs, etc.). For each roughness profile photos of the surrounding vegetation will be taken and their ID noted in the field form.

SURFACE ROUGHNESS SAMPLING KIT

- 1x GETAC unit
- 1x pin profiler
- 1x level
- 1x field book
- 1x pencil
- 1x roughness sampling recording form
- 1x digital camera
- 1x compass
- 4x wooden blocks
- 1x marker

SURFACE ROUGHNESS SAMPLING PROTOCOL

Figure 7-5. Pin profiler for surface roughness measurements.

Soil roughness measurements will be made using a 1m long drop pin profiler with a pin separation of 5mm (see Figure 7-5). Photos of the pin profile will be taken at each sampling location and the images post-processed to extract the roughness profiles and thus roughness statistics. At each soil roughness sampling location, 3 lots of consecutive readings (to simulate a 3m long profile) will be performed in North-South and East-West orientations, respectively. A 3m profile has been shown to provide stable correlation lengths in previous campaigns.

The procedure for one roughness measurement is as follows:

1. Note in the roughness sampling form date, the sample ID, the UTC time, the focus area ID, the coordinates (from GPS), the land cover type (from the classification provided in Section 7.2), the vegetation type, the row direction (if crops) the orientation (N-S or E-W determined using the compass) of the roughness measurements as well as the name of the person sampling.
2. Select an area for a 3m roughness transect (N-S or E-W). Assure that the sun will be at your back when taking roughness photos. Position the profiler behind and parallel to the transect.
3. Place the roughness profiler vertically above the first 1m of the desired transect (the right one, defined from perspective of photograph), avoiding stepping over the area chosen for the remaining 2m profile
4. Use the compass to align the profiler exactly N-S or E-W, depending on the transect Clear vegetation if necessary from the proposed transect.
5. Release the profiler legs using the controls at the back of the profiler. Level the profiler horizontally.
6. When the profiler is horizontal, extend the lateral legs to sustain the profiler.

7. Mark the position of the profiler left foot on the side of the pin profiler adjacent to the next meter of the desired transect, using a stick or mark position BEHIND the profiler (left and right defined from perspective of photograph).
8. Release the pins. Make sure that all the profiler pins touch the soil surface. The pins MUST NOT be inserted into the ground or be resting on top of vegetation.
9. Extend the camera bar and position the camera, making sure the lens plane is parallel to the profiler board.
10. Take a photograph (# 1) of the profiler clearly showing the level of all pins. Pay particular attention that ALL the pins are included in the photograph. Note the photo identification number in the roughness sampling form.
11. After retracting the camera bar and the lateral legs, lift the profiler and move it to behind and parallel to the transects.
12. Lean the profiler on its back, retract the pins and block them using the bottom enclosure
13. Shift the profiler over 1m so that its right foot is now in front of the marker which was used to flag the profiler left foot (left and right defined from perspective of photograph).
14. Repeat procedure in Step #3-12 above to take photograph #2.
15. Repeat steps #13-14 for photograph #3 of the transect. Note that the 3 photographs for the 3-m transect are always taken left to right (as you face the profiler with the camera).
16. Repeat steps #1-15 for the 3,1-m long profiles in the perpendicular direction.

This protocol should produce 2 continuous 3m-long profiles (without gaps between photographs #1 and #2, and between photographs #2 and #3) in each direction.

NOTE: In case of intense rain during the campaign, scheduled soil roughness sampling at YC and YA7 could be replaced by sampling at a control paddock in YA4. This will provide an idea of the temporal change soil roughness on crops.

7.7. DATA ARCHIVING PROCEDURES

All the data collected during the daily sampling will be saved onto two field laptops which will be available at the operation base. The exact location of the laptops will be communicated during the training session. Team A and Team B will each use one of these laptops for data downloading and archiving for the campaign duration. Team C and Team E will archive data independently. The data archived will be backed up daily on an external hard drive and CD/DVD. The general data structures for the SMAPEx-3 ground as well as airborne data are shown in Figure 7-6. It is the responsibility of each team member to download and properly archive the data collected with their HDAS system following the procedures outlined below. Data must be downloaded and archived immediately at the end of the sampling, upon returning to the Yanco Agricultural Institute. It is the responsibility of each team leader to make sure that every team member has downloaded their data onto the field laptop. It is the responsibility of the ground crew leader to back up daily on external hard drive and CD/DVD.

DOWNLOADING AND ARCHIVING HDAS DATA

This section explains how to save the data collected in the field to the data archive in the field laptop (if the operating system on the laptop is Windows XP, Microsoft ActiveSync will have to be installed to follow the steps)

1. Connect the GETAC unit to the field laptop using the GETAC USB cable.
2. The GETAC unit will be added as a new drive in the "My Computer" (same as for a normal USB pen).
3. Click on the drive icon in the Windows Explorer.
4. Navigate in the GETAC file system to the folder named "SD Card" in the root directory.
5. Copy and paste all the files with root name "hydra" or "hydraGRID" (extensions .dbf, .shb, .shx, .prj and .apl). Put the files into the field laptop folder named "Desktop\SMAPEx-3\Ground_Data\DD-MM-YY\Area_ID\HDAS\TEAM_$\UserName_PoleID" where DD is day, MM is month, YY is the year (Please note: date/time must be AET), Area_ID is the focus area identification code (see Table 6 1), $ is the team identification letter (A or B), UserName is the Family name of the team member whose HDAS is being downloaded and PoleID is the ID of the HDAS system being downloaded.
6. **Make a backup of the HDAS data as follows:** Once the files have been properly saved on the laptop, go to folder "SD Card" on the GETAC unit, make a copy of the folder "SD Card" and rename the copied folder as "DD-MM-YY _UserName_PoleID
7. Finally, empty the content of the folder "SD Card" by deleting all the files with prefix "hydra" or "hydraGRID".

Step-by-step information on the operation of the HDAS system, including file upload and download, sampling commands and troubleshooting is included in Appendix B.

ARCHIVING SOIL ROUGHNESS DATA

Soil roughness data will be archived both in hardcopy and electronically by Team E:

- The data from the roughness sampling form will be entered at the end of the day in the pre-populated file Roughness.xls, and stored on the data laptop folder "Desktop\SMAPEx-3\Ground_Data\DD-MM-YY\ Area_ID\Roughness\" where DD is day, MM is month, YY is the year (**Please note: date/time must be AET**) and Area_ID is the focus area identification code (see Table 6-1). These data must be typed up at the end of the sampling day or at latest the subsequent day. The photos must also be stored in the same directory as the xls file, renamed as

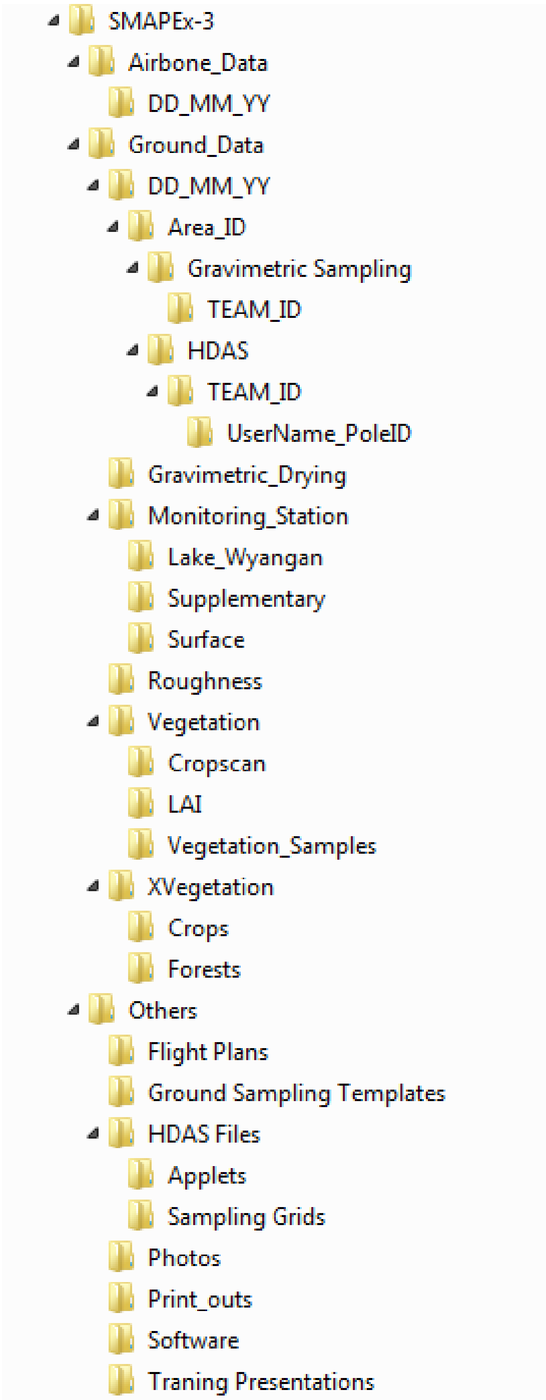


Figure 7-6. Tree diagram of the general SMAPEx-3 file structure

Roughness_DD-MM-YY_#.jpg where # is the photo identification number provided by the camera and crossed-referenced in the hardcopy form.

- The roughness sampling form will be submitted to the ground crew leader Alessandra Monerris at the end of the sampling day after completing the step above.

8. LOGISTICS

SMAPEx-3 activities will be supported by a ground crew, aircraft crew and support crew, overseen by Jeff Walker. The aircraft activities will be conducted from the Narrandera Airport, while the ground and support crew will be based in the Yanco Agricultural Institute (YAI), which will provide lab space and equipment for pre-sampling and post-sampling operations. Frank Winston will be responsible for instrument repair and general technical support. Breakdowns and instrument faults must be reported to him (as well as your team leader) at the end of each day. Your HDAS data and ground samples MUST be archived according to the instruction in this work plan promptly at the end of each sampling day, either directly or via your team leader, so he/she can further process the data/samples, thus ensuring the early identification of sampling issues and availability of quality data at the end of the campaign.

8.1. TEAMS

Ground sampling operations will be undertaken by 4 teams acting independently, and will be coordinated by Alessandra Monerris with the assistance of Rocco Panciera and Mihai Tanase. Teams A and B will be responsible for soil moisture monitoring three times per week. Each of the two ground soil moisture teams have been assigned three of the six focus areas across the SMAPEx-3 study area. Twice per week, Team A will also be responsible for the intensive crop sampling, while Team B will also be responsible for the intensive forest sampling. Regular vegetation sampling will be performed by Team C. Team E will be responsible of surface roughness measurements twice per week. The aircraft crew (Team D) will operate from the Narrandera airport and be coordinated by Jeff Walker.

The composition of the teams and the focus areas of each of them are listed in Table 8-1. Contact details for all participants are given in Chapter 9.

8.2. OPERATION BASE

The Yanco Agricultural Institute (YAI, http://www.agric.nsw.gov.au/reader/yanco) is an 825ha campus located at Yanco, in the Murrumbidgee Irrigation Area. The centre is just 10 min drive from Leeton, and 20 min drive from Narrandera, junction of the Sturt and Newell Highways (see location in Figure 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). A map of the YAI and the facilities available to SMAPEx-3 participants is provided in Figure 8-2.

Table 8-1. Composition of the teams, vehicles, and focus areas for SMAPEx-3. [FA] indicates first-aid person. XVeg indicates intensive vegetation monitoring areas.

Team	Team Leader	Vehicle	Focus Areas	Team Members	Tasks
A	Rocco Panciera [FA]	4WD Hilux (UoM)	Soil moisture sampling : YA4,YA7,YD XVeg crops	Rocco Panciera [FA]	Moisture (M,W,F), XVeg crop (T,T)
				Seungbum Kim / Mariko Bürgin	
				Xiaoling Wu [FA] / Du Jinyang	
				Ian Davenport	
				Sayeh Hassan	
B	Alessandra Monerris [FA]	4WD Hilux (Monash 4WD#1)	Soil moisture sampling : YB5,YB7,YC XVeg forests	Alessandra Monerris [FA]	Moisture XVeg forest
				Christoph Rüdiger [FA] / Giuseppe Satalino	
				Mihai Tanase	
				Jeff Ouellette / Andreas Colliander	
				Cristina Vittucci	
C	Peggy O'Neill	4WD (GSFC)	YA4,YA7,YD, YB5,YB7,YC	Lynn McKee	Vegetation
				Alicia Joseph	
				Peggy O'Neill	
				Karolina Fiebel	
D	Jeff Walker [FA]	Economy car (Monash)	YA4,YA7,YD, YB5,YB7,YC, XVeg crops, XVeg forests	Jeff Walker [FA]	Aircraft
				Heath Yardley	
				Jon Johanson	
				Ying Gao [FA] (M,W,F)	
E	Frank Winston [FA]	4WD Hilux (Monash 4WD#2)	YA4,YA7,YD, YB5,YB7,YC, XVeg crops, XVeg forests	Frank Winston [FA]	Lake transects + Equipment maintenance + ROVER Roughness
				Ying Gao [FA] (T,T)	

Facilities available during the campaign include: lab space, storage shed, two types of accommodation and a conference room. Air crew will also be based in YAI and operate out of the Narrandera Airport.

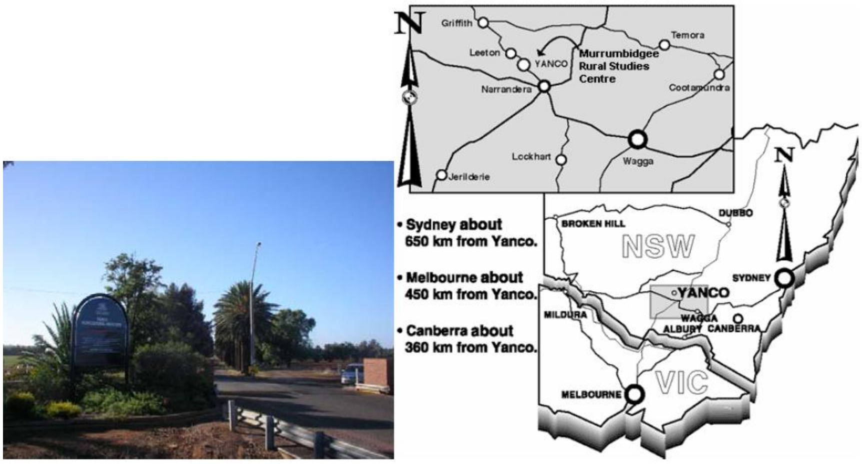


Figure 8-1. Location of the YAI at Yanco.

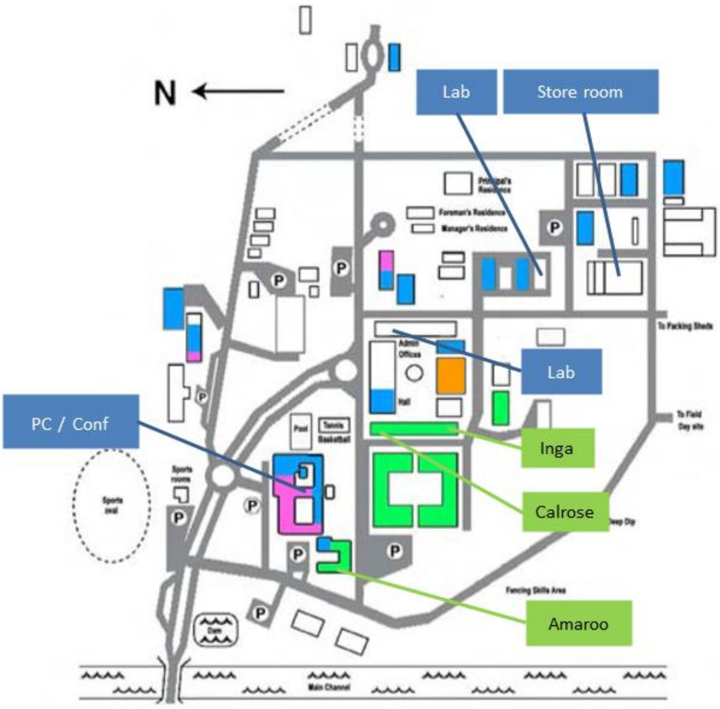


Figure 8-2. Map of the Yanco Agricultural Institute

8.3. ACCOMMODATION

Accommodation costs will be covered by individual's institutions or according to other agreed arrangements. Participants who have accommodation and meals expenses paid by the SMAPEx project will be staying at Inga. Two types of accommodation are available for the other SMAPEx-3 participants: motel-style at Amaroo and the Calrose bunk house at MRSC. Alternatively, there are a range of motels in Leeton where participants can make their own arrangements.

Table 8-2. Accomodation logistics for SMAPEx-3 participants

Person	Funding Organization	Location	Check-in	Check-out
Xiaoling Wu	Monash	Inga	2/09/2011	24/09/2011
Ying Gao	Monash	Inga	2/09/2011	24/09/2011
Alessandra Monerris	Monash	Inga	26/08/2011	30/09/2011
Frank Winston	Monash	Inga	26/08/2011	30/09/2011
Chris Rüdiger	Monash	Inga	2/09/2011	21/09/2011
Jon Johanson	Monash	Inga	2/09/2011	24/09/2011
Jeff Walker	Monash	Inga	2/09/2011	24/09/2011
Heath Yardley	Monash (UoA)	Inga	2/09/2011	7/09/2011
Jeff Ouellette	Monash (Ohio State)	Inga	29/08/2011	14/09/2011
Mariko Bürgin	Monash (UMich)	Inga	13/09/2011	24/09/2011
Rocco Panciera	UoM	Calrose	26/08/2011	25/09/2011
Sayeh Hasan	Jülich	Calrose	2/09/2011	24/09/2011
Cristina Vittucci	Tor Vergata	Calrose	2/09/2011	24/09/2011
Karolina Fieber	Uni Reading	Calrose	2/09/2011	24/09/2011
Ian Davenport	Uni Reading	Calrose	2/09/2011	24/09/2011
Giuseppe Satalino	CNR	Calrose	14/09/2011	24/09/2011
Du Jinyang	IRSA	Calrose	16/09/2011	24/09/2011
Mihai Tanase	UoM	Calrose	26/08/2011	25/09/2011
Andrew McGrath	UoM (Flinders Uni)	Calrose	4/09/2011 22/09/2011	7/09/2011 24/09/2011
Wolfgang Lieff	UoM (Flinders Uni)	Calrose	4/09/2011 22/09/2011	7/09/2011 24/08/2011
Lynn McKee	NASA (USDA)	Heritage Motor Inn	1/09/2011	27/09/2011
Peggy O'Neill	NASA (GSFC)	Heritage Motor Inn	1/09/2011	27/09/2011
Alicia Joseph	NASA (GSFC)	Heritage Motor Inn	1/09/2011	27/09/2011
Seungbum Kim	NASA (JPL)	Amaroo	3/09/2011	14/09/2011
Andreas Colliander	NASA (JPL)	Amaroo	13/09/2011	24/09/2011

'Amaroo' motel-style accommodation

Amaroo, meaning 'a quiet place', features 15 bed and breakfast (continental) motel-style rooms (see location in Figure 8-2). Each room has a queen bed and a single bed, ensuite, TV, toaster, tea and coffee making facilities, bar fridge, and heating and cooling and wi-fi internet access, and are fully serviced except on weekends. The motel rooms are organised around a central courtyard connected to the conference facility. Price is $82.50/night/person for single room and $105/night/room for double room (incl. breakfast).

'Inga' and 'Calrose' bunk house accommodation

Inga has 13 double rooms and one single room while Calrose has 13 double rooms and three single rooms (see location in Figure 8-2). Rooms have a double bunk, wardrobe and desk. Linen and towels are provided. 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 (+$5.50 for breakfast if requested; see note below regarding breakfast). Accommodation arrangements for all participants are listed in Table 8-2.

8.4. MEALS

Meal costs will be covered by the individual's institutions or according to other agreed arrangements (ie. participants staying at Inga will be fully funded by the SMAPEx project up to a reasonable limit. Note that purchase of alcohol attracts FBT and consequently will be supplied only at the individuals own expense). Detailed meal arrangements are as per below.

<u>Breakfast:</u> A variety of breakfast choices (cereals, milk, toasts, jams) will be made available in the Inga kitchen for SMAPEx funded participants (please advise Alessandra Monerris or Frank Winston of any particular dietary requirements upon arrival). While breakfast can be included as part of the accommodation expense for guests staying at Calrose, it is recommended that you pre-purchase your breakfast supplies at the Leeton supermarket. A fridge and range of kitchen supplies are available in the Calrose kitchen for this purpose.

<u>Lunch:</u> No facilities will be open in time on sampling days for buying lunch prior to departure for the field. Moreover, there are typically no facilities near to the sampling areas themselves for buying lunches, nor are you likely to pass any shops on the way to your sampling site. Therefore lunches should be pre-packed for carrying with you into the field; remember to also pack a water bottle. Similarly to breakfast arrangements described above, guests staying at Inga will be provided with a selection of fillings for making sandwiches in the Inga kitchen (please advise Alessandra Monerris or Frank Winston of any particular dietary requirements upon arrival). Guests staying at Calrose and Amaroo should pre-purchase lunch supplies; opportunities to visit the supermarket will be provided at least twice per week. As the kitchens are rather small, participants should consider making his/her own lunch the night before (especially if you are not a morning person) or getting up sufficiently early so that there is no undue kitchen congestion leading to delayed departures for the field.

<u>Dinner:</u> Apart from the supermarket (if you wish to cook your own meal in the Inga or Calrose kitchen; there is no kitchen in the Amaroo rooms), you will be able to purchase a meal from a nearby restaurant or hotel. When at YIA the only options for dinner are to drive into Yanco (2km), Leeton

(5km) or Narrandera (20km). Typically meals are purchased from the Leeton Soldiers Club or Leeton Hotel; other venues do not allow split bills.

8.5. INTERNET

Internet access will be available to SMAPEx-3 participants when at MRSC at a dedicated computer room (see Figure 8-2). A password for login on these computers is provided in the room. An office with internet access will be available with key access for SMAPEx-3 participants with significant archiving and/or processing responsibilities.

8.6. DAILY ACTIVITIES

Field work during SMAPEx-3 will consist of collecting data in the Yanco Region and archiving the information collected during the sampling days. Table 8-3 lists the campaign schedule. Team leaders will in turn report to Frank Winston for technical/equipment repairs, and to Alessandra Monerris for general updates, etc. Team leaders will also be responsible for confirming ALL data is appropriately recorded/archived at the end of EACH sampling day.

The daily schedule during sampling days is shown in Table 8-4. At the end of the day, each team member will need to coordinate with their team leader (as relevant) to:

ON SOIL MOISTURE SAMPLING DAYS

- Download their HDAS data and have it checked for completeness;
- Review the schedule for the following day;
- Check-in their gravimetric samples and any associated information (see section 0); samples must be weighed, details entered on the hardcopy pro-forma (see Appendix G) provided (any additional information should be written down and attached to the check-in sheet and not simply passed word-of-mouth) AND entered in the excel pro-forma provided;
- Check-in the instruments used, ensuring ALL electronic devices are recharged overnight and any repairs needed reported to BOTH your team leader and Frank Winston (please, do not wait until the next sampling day!!); and
- Ensure all electronic devices are put to recharge (GETAC, HDAS batteries, UHF radios).

ON INTENSIVE VEGETATION MONITORING DAYS

- Record data from field forms to electronic format.
- Re-charge batteries for electronic equipment used in the field.
- Save photos to a backup media (different folders for LAI photos and plot photos).
- Download/rewrite the backup shape file with the position of forest plot coordinates.

- Oven dry leaf samples, measure dry weight, calculate the moisture content, record data in electronic form, store dry samples.

VEGETATION TEAM C ONLY

- Check-in all vegetation samples and spectral etc. information; samples must be weighed and details entered on the hard copy pro-forma provided (see Appendix G) as well as entered in the excel pro-forma provided.

ROUGHNESS TEAM E ONLY

- Check-in their roughness data; must be typed in the excel pro-forma provided (hard copy pro-forma is also to be submitted).

Table 8-3. SMAPEx-3 schedule

Date	Time	Location	Activity	Coordinator
Fri 2 Sept	9:30~16:00	-	Travel Melbourne-Yanco	C. Rudiger
	16:00-16:30	YAI	Check in at YAI	A. Monerris
Sa 3 Sept	9:00-17:30	YAI, Computer Room	Training session 1	J. Walker, A. Monerris, R. Panciera, M. Tanase
Sun 4 Sept	8:30-17:00	Focus areas	Survey of sampling areas Practice using equipment	A. Monerris, R.Panciera, M. Tanase
Mon 5 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Tue 6 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Wed 7 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Thu 8 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Fri 9 Sept	Day-off			
Sat 10 Sept	Day-off			
Sun 11 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Mon 12 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Tue 13 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Wed 14 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Thu 15 Sept	Day-off			
Fri 16 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Sat 17 Sept	Day-off			
Sun 18 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Mon 19 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Tue 20 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Wed 21 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation)			
Thu 22 Sept	All day sampling (Team A: intensive crops; Team B: intensive forest; Team C: vegetation; Team E: surface roughness)			
Fri 23 Sept	All day sampling (Team A and B: soil moisture; Team C: vegetation) Clean and pack equipment			
Sat 24 Sept	8:30~14:30	-	Travel Yanco-Melbourne	X. Wu, Y. Gao

Table 8-4. SMAPEx-3 sampling day schedule.

Time	Activity
7:00~7:30	Gathering of the teams at the laboratory Review of the activity of the day Preparation of the instruments for the sampling
7:30	Teams departure for the sampling location
7:30-8:30 (approx.)	Travel to the focus areas
8:30-16:30	Sampling operations
16:30-17:30	Travel to the YAI
17:30-18:30	Teams return to the lab Report to the project leaders Data downloading on the computers Soil and vegetation samples check in Recharge of electronic devices
18:30-onward	Dinner Refuel vehicles Visit supermarket

8.7. TRAINING SESSIONS

A 2-day training session has been scheduled to ensure all SMAPEx-3 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 3-4 September 2011. The training session will be held in the Computer Room of the YAI on 3 Sept (see Figure 8-2) with all the participants. Team A and Team B will have a training session dedicated to the intensive vegetation monitoring on 3 Sept afternoon in rooms TBD. Teams will visit their respective sampling areas on 4 Sept, with the schedule and activities indicated in Table 8-5.

Training sessions will cover:

- Overview of the campaign logistics, ground sampling and flight schedule;
- End-of-day data download and housekeeping procedures;
- Overview of the “code of conduct” on farms, first aid, driving on unsealed farm tracks;

Table 8-5. SMAPEx training schedule and activities.

Date	Time	Location	Activity	Coordinator
Sat 3 Sept	9:00-9:30	YAI, Computer Room	Presentation: SMAPEx-3 Introduction	J. Walker
	9:30-10:00	YAI, Computer Room	Presentation: SMAPEx-3 logistics and safety	A. Monerris
	10:00-11:00	YAI, Computer Room	Presentation: SMAPEx-3 sampling strategy	A. Monerris
	11:00-11:15	Break		
	11:15-11:45	YAI, Computer Room	Presentation: HDAS Overview	R. Panciera
	11:45-12:45	YAI	Training: HDAS practice (all)	R. Panciera
	12:45-14:30	Lunch		
	14:30-15:30	YAI, Computer Room	Presentation: Post-work day check-in & downloads	A. Monerris
	15:30-17:30	TBC	Presentation: Intensive vegetation monitoring. Note: Team A and Team B members will attend parallel sessions	R. Panciera (Team A session) M. Tanase (Team B session)
Sun 4 Sept	8:30-17:00	Focus Areas	Training: Survey of focus areas	R.Panciera (Team A) A. Monerris / M. Tanase (Team B)

- Use of the Hydraprobe Data Aquistion System (HDAS);
- Vegetation height estimation;
- Vegetation type recognition;
- Dew amount recognition; and
- Intensive vegetation sampling procedures.

As regular vegetation sampling activities will be undertaken by well-trained NASA personnel, and gravimetric samples by the team leaders, no dedicated training sessions are scheduled for the regular vegetation and gravimetric sampling that will be undertaken.

8.8. FARM ACCESS AND MOBILITY

Farms will be accessed regularly for the ground sampling operations. Transport from the ground operations base 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 therefore requires extreme attention and care and should only be undertaken after appropriate training. **Driving through cultivated areas should be avoided at all times, due to the serious damage the transit could cause to crops**. As there will be poor or no mobile phone coverage at many farms, each team member will be issued with a small UHF radio for team communication, as an additional security measure. These have a range of 3-4km and a channel for communication will be announced at the training session (Please take care not to lose it!).

The sampling locations have been organised so that only reasonably accessible areas will be the object of the sampling.

During regional sampling days, a 2.8km × 3.1km area will be sampled over a regular grid of sampling locations, spaced at 250m. It is left to the team leader to agree a sampling strategy with the team members. However, it is recommended to follow these guidelines:

- Sampling will be undertaken in pairs, for safety reasons.
- Before starting the sampling, the team should agree and identify clearly on the map a meeting point and a meeting time where to gather at the end of the sampling. **NOTE: the UHF radio provided and mobile phones might not always be effective due to various factors, so it is important that each team member is able to locate the meeting point on the map and return to it.**
- At the beginning of the sampling, team leaders will define a sampling approach with the team members. Each pair of team members will be assigned a number of sections of the 2.8km × 3.1km area, and will be solely responsible for sampling the entire section. Each section will be identified on the hardcopy maps provided using clearly visible features, such as irrigation canals, paddock fences and roads. The sections should be defined and agreed to avoid having two groups accidentally sampling the same location at different times during the day.
- Each group should then identify an access point to their section from the main roads. The team leader will drive the team members to their access location, and leave the car at the agreed meeting point before starting his/her own sampling.
- It is highly recommended that each group of 2 people sample their own section by “area” rather than by “line”, i.e., once you enter an area delimited by a fence, canal or road, sample all the locations falling within the delimited area along transects, keeping your group mate always in sight. Only move to the adjacent area after fully completing the first area.
- When sampling on cropped areas, always move through a field along the row direction to avoid impact on the canopy.

- The team leader is to do an in-field inspection of sample locations on the GETAC prior to returning to YIA to ensure that no points have been missed.

8.9. 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. Moreover, each team member will have a hand-held UHF radio on a pre-agreed channel; normally channel 38. Additionally, working together as a team, or at least in pairs, will ensure that contact within the individual team members is maintained. Ensure that each team member can be accounted for each half an hour. If a team member cannot be accounted for, search initiation should be immediate. On most farms the mobile phone coverage is extensive, while on some it is poor, and thus use of UHF radio, visual contact, and other means of communication will be more important. Contact information of the SMAPEx-3 participants is listed in Section 9.3.

8.10. SAFETY

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

- Always work in teams of two.
- Carry a phone and/or UHF radio.
- Please keep unnecessary UHF communication (jokes, chit-chat, etc.) to a minimum. Your Team mate might be trying to communicate if he/she is in trouble.
- Know where you are. Keep track of your position on the provided farm map.
- Do not approach, touch or eat any unidentified objects in the field.
- Dress correctly; long pants, long sleeves, hiking boots, hat, etc.
- Use sunscreen.
- Carry plenty of water with you in a backpack for hydration.
- Notify your Team mate and Team leader of any pre-existing conditions or allergies before going into the field.
- Beware of harvesting machinery. When sampling on crop, always make sure your presence is noted and watch out for moving harvesting machines.
- Beware of snakes. Always wear sturdy hiking boots and long work pants to avoid penetrating bites. Refer to http://www.australianfauna.com/australiansnakes.php for detailed info about the most common Australian snake species. Treat all Australian snakes as potentially deadly. In 99.9% of all encounters, the snake will try to avoid any human contact. For detailed

information on how to avoid a snake bite and how to treat a person who has been bitten, see **Error! Reference source not found.**.

- Do not run through high grass or uneven ground to avoid injuries.
- The temperature used for the soil drying ovens is 105°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.

8.11. TRAVEL LOGISTICS

GETTING THERE

In terms of booking flights etc., international participants should fly into Melbourne (or Sydney). To travel to Yanco there are three options below:

- get a lift to Yanco on the "Melbourne shuttle" (see below; please contact Alessandra Monerris if you want to join the shuttle to or from Yanco),
- 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 ~20min drive away (please give your arrival details to Alessandra Monerris if that is the case) or
- if you are planning to have a rental car for your own purposes, arrange to pick it up in Sydney/ Melbourne/elsewhere 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: All ground crew are expected to attend the training sessions on Saturday 3 and Sunday 4 September. Those arriving mid-experiment are expected to get a detailed briefing from their campaign "buddy" who they are switching with, and to have studied this plan extensively; a short quiz will be provided to ensure competency.

The travel itinerary and detailed driving instructions from Melbourne, Sydney, Canberra and Wagga Wagga to Yanco can be found on Googlemaps.

MELBOURNE SHUTTLE

A "Melbourne shuttle" will be organized to transport all participants of Team A and Team B from Melbourne to Yanco on Friday 2 September (Meeting point: Monash Clayton Campus Bus Loop at 9:30am) and return to Melbourne on Saturday 24 September (arrival sometime in the afternoon/evening). The "Melbourne shuttle" will consist of 2 vehicles (Monash economy car and Monash 4WD#1, see Table 8-6). Details on seat allocations are TBD and will be announced prior to

Table 8-6. Pick-up and drop-off dates and responsible person for rented vehicles during SMAPEx-3

Name	Dates	Rental company	Responsible person
Monash 4WD#1	Pick-up 1/09/2011	Off Road Rentals	Chris Rüdiger
	Drop-off 24/09/2011	Off Road Rentals	Xiaoling Wu
Monash 4WD#2	Pick-up 26/08/2011	Off Road Rentals	Frank Winston
	Drop-off 30/09/2011	Off Road Rentals	Frank Winston
Monash Economy Car	Pick-up 2/08/2011	Avis	Chris Rüdiger / Xiaoling Wu
	Drop-off 24/09/2011	Avis	Xiaoling Wu
UoM 4WD	Pick-up 26/08/2011	Off Road Rentals	Rocco Panciera
	Drop-off 25/09/2011	Off Road Rentals	Rocco Panciera

Friday 2 September. Chris Rüdiger will coordinate the shuttle from Melbourne to Yanco, while Xiaoling Wu will coordinate the shuttle from Yanco to Melbourne.

GETTING TO THE FARMS

Each ground sampling team will each use their vehicle (see Table 8-1) to drive to the focus areas in the morning and return to the YAI at the end of the sampling. The team leaders will have knowledge of the routes to/from the focus areas to the YAI. However, driving directions from the YAI to the focus areas are provided in Appendix H.

VEHICLES

Table 8-6 provides useful information on pick-up and drop-off dates, and responsible person for Team A, Team B, Team D, and Team E vehicles during SMAPEx-3. Team C will do its own arrangements for renting their vehicle.

9. CONTACTS

9.1. PRIMARY CONTACTS FOR SMAPEX-3

The primary contacts for the SMAPEx-3 experiment are:

Professor Jeffrey Walker
Phone: 03 990 59681
Mobile: 0413 023 915
Email: jeff.walker@monash.edu

Department of Civil Engineering,
Monash University
Clayton, Victoria 3800, Australia

Alessandra Monerris
Phone: 03 990 54976
Mobile: 0402 641 029
Email: sandra.monerris-belda@monash.edu

Department of Civil Engineering,
Monash University
Clayton, Victoria 3800, Australia

The satellite phone numbers are 0011 872 761 151 283 and 0011 872 762 482 911. Those are only used for emergencies. For any other call, please contact the participants via the hotel in the evening.

9.2. KEY PERSONNEL DURING FIELD WORK

A list of contacts for key personnel during the campaign is provided below:

Person	Organization	Function	Phone Number
Walker, Jeff	Monash University	Campaigns coordinator, Team D coordinator	0413 023 915
Monerris, Alessandra	Monash University	Ground crew coordinator, Team B coordinator	0402 641 029
Winston, Frank	Monash University	Technical support, Team E coordinator	0421 255 392
Panciera, Rocco	Univ. of Melbourne	Team A coordinator	0431 688 696
O'Neill, Peggy	NASA	Team C coordinator	0424 125 035

9.3. PARTICIPANTS DETAILS

Contact details for all SMAPEx-3 participants are listed below:

Person	Organization	Phone number	E-mail
Bürgin, Mariko	University of Michigan		mburgin@umich.edu
Colliander, Andreas	NASA/JPL		andreas.colliander@jpl.nasa.gov
Davenport, Ian	University of Reading		i.j.davenport@reading.ac.uk
Fieber, Karolina	University of Reading		k.fieber@pgr.reading.ac.uk
Gao, Ying	Monash University	0433 329 610	ying.gao@monash.edu
Hassan, Sayeh	IBG Jülich		s.hasan@fz-juelich.de
Jinyang, Du	Inst Remote Sens Appl		djy@irsa.ac.cn
Joseph, Alicia	NASA/GSFC		alicia.t.joseph@nasa.gov
Kim, Seungbum	NASA/JPL		seungbum.kim@jpl.nasa.gov
McKee, Lynn	USDA		lynn.mckee@ars.usda.gov
Monerris, Alessandra	Monash University	0402 641 029	sandra.monerris-belda@monash.edu
O'Neill, Peggy	NASA/GSFC	0424 125 035	peggy.e.oneill@nasa.gov
Ouellette, Jeff	Ohio State University		jeffoue@gmail.com
Panciera, Rocco	University of Melbourne	0431 688 696	panr@unimelb.edu.au
Rüdiger, Chris	Monash University	0410 131 407	chris.rudiger@monash.edu
Satalino, Giuseppe	CNR/ISSIA		satalino@ba.issia.cnr.it
Tanase, Mihai	University of Melbourne	0466 969 936	mtanase@unimelb.edu.au
Vittucci, Cristina	Tor Vergata		cristina.vittucci@libero.it
Walker, Jeff	Monash University	0413 023 915	jeff.walker@monash.edu
Winston, Frank	Monash University	0421 255 392	frank.winston@monash.edu
Wu, Xiaoling	Monash University	0425 118 055	xiaoling.wu@monash.edu
Yardley, Heath	University of Adelaide		hyardley@eleceng.adelaide.edu.au

9.4. EMERGENCY

Emergency number in Australia 000 or 112 on a mobile phone

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: Cnr Douglas and Adams Streets

Narrandera, NSW 2700

Phone: (02) 6959 1166

9.5. FARMERS

Focus Area	Farmer Name (Farm Nr.)	Home Phone	Mobile Phone
YA4	John Wallace (4)	02 6954 1220	0428 696 330
	Greg Kelly (6,7,13,14)	02 6954 1212	0427 541 217
	Keith Burge (3)	02 6954 1204	0428 541 104
	Ian Scifleet (5)	02 6954 1504	N/A
YA7	Adrian Hay (15,16,25)	N/A	0427 541 256
	Lance Harland (17)	02 6954 1261	N/A
YB5	Wayne Durnan	02 6959 7466	0407 275 534
YB7	Wayne Durnan	02 6959 7466	0407 275 534
YC	Adrian Hay	N/A	0427 541 256
YD	Franck McKersie (606)	02 6954 8566	N/A
	Danny Graham (551)	02 6954 8551	0427 548 545
	Lawrence Graham (552)	02 6964 6403	0448 368 527

	Rodney Foster (554)	02 6954 8322	0428 948 322
	Ross McIntyre (607)	02 6954 8514	0428 548 500
	Craig Perkins (615)	02 6954 8520	0407 274 110

9.6. ACCOMODATION AND LOGISTICS

Yanco Agricultural Institute (YAI)

Mail: Narrandera Road, PBM, Yanco NSW 2703 Australia

Contact person: George Stevens

Phone: (02) 6951 2652

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

Phone: (02) 6951 2725

Fax: (02) 6955 7580

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

Australian Defence

Contact person: Sgt Shaun Chessher

Phone: (02) 4424 2109

Email: Shaun.Chessher@defence.gov.au

Off Road Rentals

Contact person: Greg Lack

Address: 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

AVIS Rentals

Address: AVIS Clayton, 2215C Princes Highway, Clayton VIC 3168

Phone: (03) 9562 3300

Web: http://www.avis.com.au

Working hours: Sun 8:30 AM - 11:00 AM, Mon - Fri 8:30 AM - 6:00 PM, Sat 8:30 AM - 12:30 PM

APPENDIX A. EQUIPMENT LIST

Item	#
Yanco base	
Gel cell battery charger	2
Power board	5
HDAS battery charger	5
Star pickets with flag for PARCs locations	6
Big water-proof tarps to cover PARCs	3
RS232 download cable	1
Laptop	4
Hard drive for ground data	2
Backup DVDs	50
Colour printer	1
Scales	2
Weight recording forms	1
Laptop projector	1
White board	1
Ovens	1
Aluminium trays	2
Extension leads	150
White board markers	
Vegetation + grave samples storage boxes	

Soil moisture sampling teams (2x)		
	per team	**total**
Pairs of gloves	1	2
Two-way UHF Radio	1	2
Walkie-talkie	5	10
Gravimetric sampling kit	1	2
HDAS	5	10
25 litres water Jerry can	1	2
Sunscreen Bottle	1	2
First aid kit	1	2
First aid book	1	2
Field book	5	10
SMAPEx workplan	1	2
Pens		

Vegetation sampling teams (2x)	
Vegetation sampling kit	2
Gloves pair	2
25 litres water Jerry can	2
Sunscreen Bottle	2
First aid kit	1
First aid book	1
Pens	5
Field book	5
SMAPEx workplan	1
Hardcopy whole area map	1

HDAS (12x)	
GETAC	12
Poles	12
Batteries	12
GETAC power cable	12
GETAC download cable	12

Gravimetric sampling kits (2x)		
	per kit	total
Soil sample ring (5cm)	5	10
Garden trowel	1	2
Blade	1	2
Spatula	1	2
Hammer	1	2
Metal base for hammering rings	1	2
Plastic bags (SMALL)	80	160
Rubber bands	80	160
Paper tags (to label samples inside bags)	40	80
Print out of soil recording form	5	
Pens		
Markers		

Vegetation sampling kits (2x)	
GETAC unit	2
Large vegetation clipper	2
Small vegetation clipper	2
Scissors	2
Quadrant	2
Serrated Knife	2
Box of Large Trash Bags	240
Compass	2

1x metered sticks	2
Back Pack (to carry equipment)	1
CROPSCAN + pole	2
LAI2000	2
Print-out of Vegetation recording form	5
Paper bags with flat bottoms	30
Package of pencils	
Permanent markers	

Surface Roughness Sampling (1 x)	
iPAQ unit	1
Pin profiler	1
Level	2
Field book	1
Roughness sampling recording form	80
Digital camera	1
Compass	1
Wooden blocks	4
Markers	

Intensive vegetation sampling kits	
Compass	2
Fish-eye camera	1
Digital photo camera	2
Digital calliper	4
Digital level	2
Inclinometers	2
Precision ruler	2
1m metered sticks	2
2m sticks	8
Tripod	1
Vegetation clippers	4
Paper bags (large/small)	250/150
Plastic bags (large/small)	30/50
Vertex III + transponder	1
Measuring wheel	1
Cocky clippers + pole	1
Diameter tape	1
Protractor with level	2
Digital micrometer	2
Plastic poles	50
Others	
PRC	6
PARC	2
Lake station	1

APPENDIX B. OPERATING THE HDAS

HDAS Quick Instruction!

1. HDAS set up

- Connect the GETAC unit to the field laptop using the GETAC USB cable (if the operating system on the laptop is Windows XP, Microsoft ActiveSync will have to be installed to follow these steps)
- The GETAC unit will be added as a new drive in the "My Computer" (same as for a normal USB pen)
- Click on the drive icon in the windows explorer
- Copy and paste all the files provided in the HDAS software package ("Applets folder") to the GETAC subdirectory "My Mobile Device\Program Files\ArcPad\Applets". These files are required to display the HDAS custom toolbar and perform the hydraprobe reading commands.
- Create a folder named "SD Card" in the device root folder "\". This is the folder where the files with the point recorded ("hydra" and hydraGRID") will be saved by the software.
- Copy and paste the Arcpad layers (or map files) you want to have as a background on the ArcPad screen into a folder of your choice
- If it is the first time the unit is being used goto "Start" (see Figure 1) → "Settings" → "System" → "GPS" → set GPS program port to COM8

2. Hydra Probe

- Make sure that the power cable (black socket) is connected to the battery
- Make sure that the connection cable (gray socket) is connected and screwed to the bottom port of the GETAC
- Check Hydra Probe sensors prongs regularly to see if they are straight and not broken! Clean the sensor prongs after each measurement!

3. ArcPad

- Tap on start icon to see the menu. Tap on ArcPad 7.1.1 icon to open the program (see figure 1).
- If there is no ArcPad 7.1.1 icon in the menu, go to Programs and load the software from there.
- Press the "add layers" icon to load the Arcpad layers (or map files) you want to have as a background on the ArcPad screen

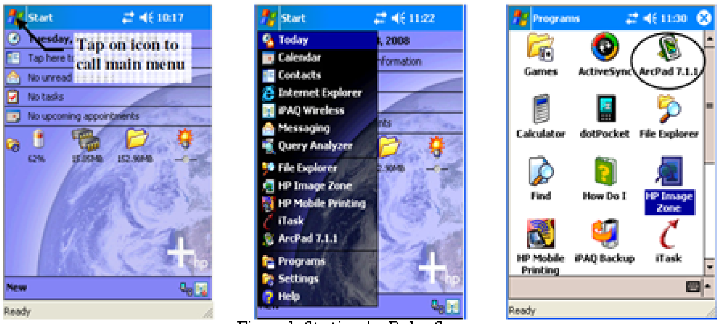


Figure 1. Starting ArcPad software

- Tap the icon in the second toolbar to activate the HDAS file system

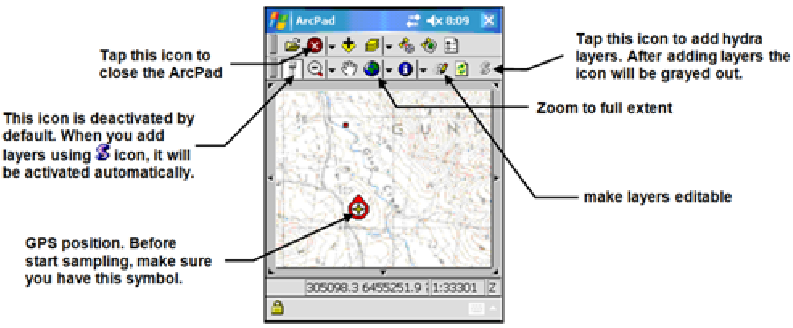


Figure 3. Customised toolbars for HDAS in ArcPad

- Wait for the "Hydra Files loaded successfully" message window and hit the OK button.
- The first icon in the second (HDAS) toolbar should now be active. This means HDAS is ready to take a reading.
- The general commands of ArcPad are illustrated below in Figure 3

- The Symbol indicates your GPS position is lost or is not accurate. **You need to wait until you have a fixed position (symbol) before sampling.**
- If you don't have a fixed position symbol, check that the GPS is activated by pressing the GPS icon . If the GPS icon is active but you still have the symbol , you will have to wait until the GPS established a fixed position .
- Before taking a reading tap on the hydraprobe icon to prepare the HydraProbe for reading (unless the hydraprobe icon is already active).
- Put the Hydra Probe into the ground at the sampling point, tap wherever within the map area of the screen (**don't tap on the toolbars**) and wait for a few seconds (**NOTE: the exact point on the map area where you tap does not matter, since the coordinates will be taken from the GPS**).
- Tapping on touch screen will start a few seconds event procedure that will communicate with the Hydra Probe and GPS to gather both position and soil moisture related data.
- After a few seconds, a form with collected data will appear in the screen.
- Fill out each of the pages in the form as described in figure 4.

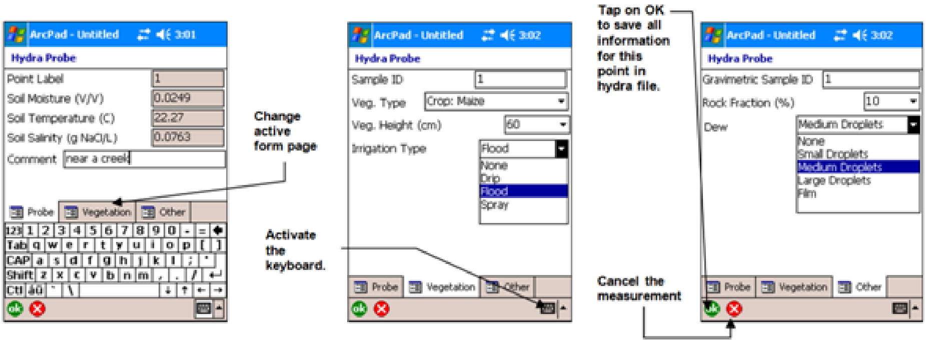


Figure 4. HDAS data entry pages with instructions

- press the ok icon to save the point or press the red cross icon to delete the point
- to check the data you have saved at a particular point, activate the information icon and tap on the desired point

4. Troubleshooting

- "Error 55: Your connection to GPS has not been established". This means that the wrong communication port is set for the GPS. To correct problem, from the desktop "Start" (see Figure 1) → "Settings" → "System" → "GPS" → set GPS program port to COM8. Then go back to ArcPad.
- "Hydra Probe Reading Error: Check connection cable between GETAC and Hydra Probe.". Make sure that the connection cable (gray socket) is connected and screwed to the bottom port of the GETAC
- In case the GETAC freezes for a long time, reboot the GETAC by pressing and holding the power button (bottom right button in the GETAC keypad).

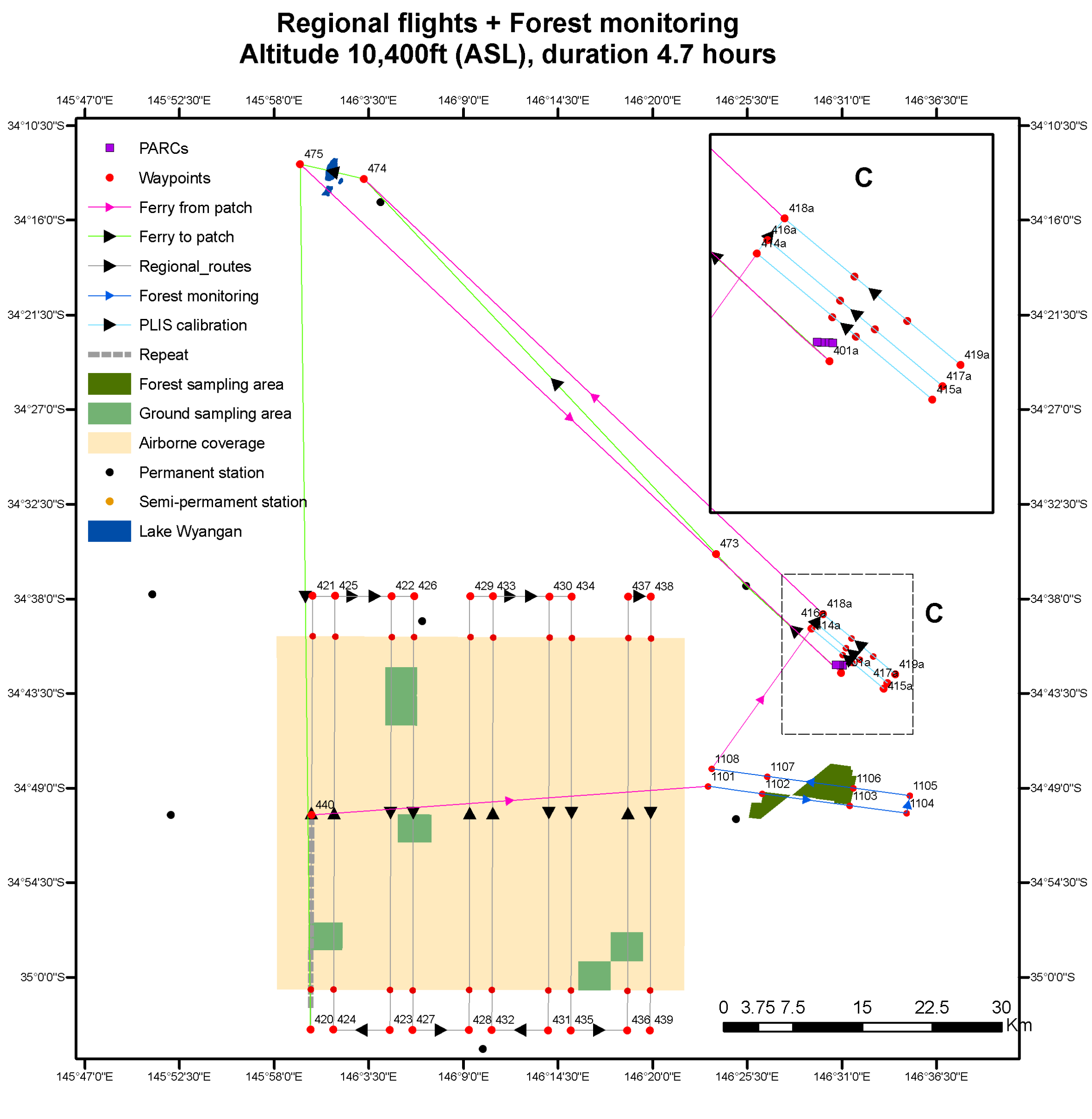
5. Data downlading

This section explaines how to save the data collected in the field to the data archive in the field laptop (if the operating system on the laptop is Windows XP, Microsoft ActiveSync will have to be installed to follow these steps)
- Connect the GETAC unit to the field laptop using the GETAC USB cable
- The GETAC unit will be added as a new drive in the "My Computer" (same as for a normal USB pen)
- Click on the drive icon in the windows explorer
- Navigate in the GETAC file system to the folder names "SD Card" in the root directory
- Copy and paste all the files with root name "hydra" or "hydraGRID" (extensions .dbf, .shb, .shx, .prj and .apl)
- Past the files into the desired folder on the field laptop
- empty the folder of the "SD Card" folder by deleting all "hydra" and hydraGRID" shapefiles.

6. Checking out

- Disconnect the GETAC from the laptop
- Put the GETAC to recharge overnight using the GETAC power cable
- Turn off the GETAC by pressing and holding the power button (bottom right button in the GETAC keypad).
- Return all GETAC components (GETA unit, power cable, USB cable, pencil) to the boxes with the same label.

APPENDIX C. FLIGHT LINES COORDINATES

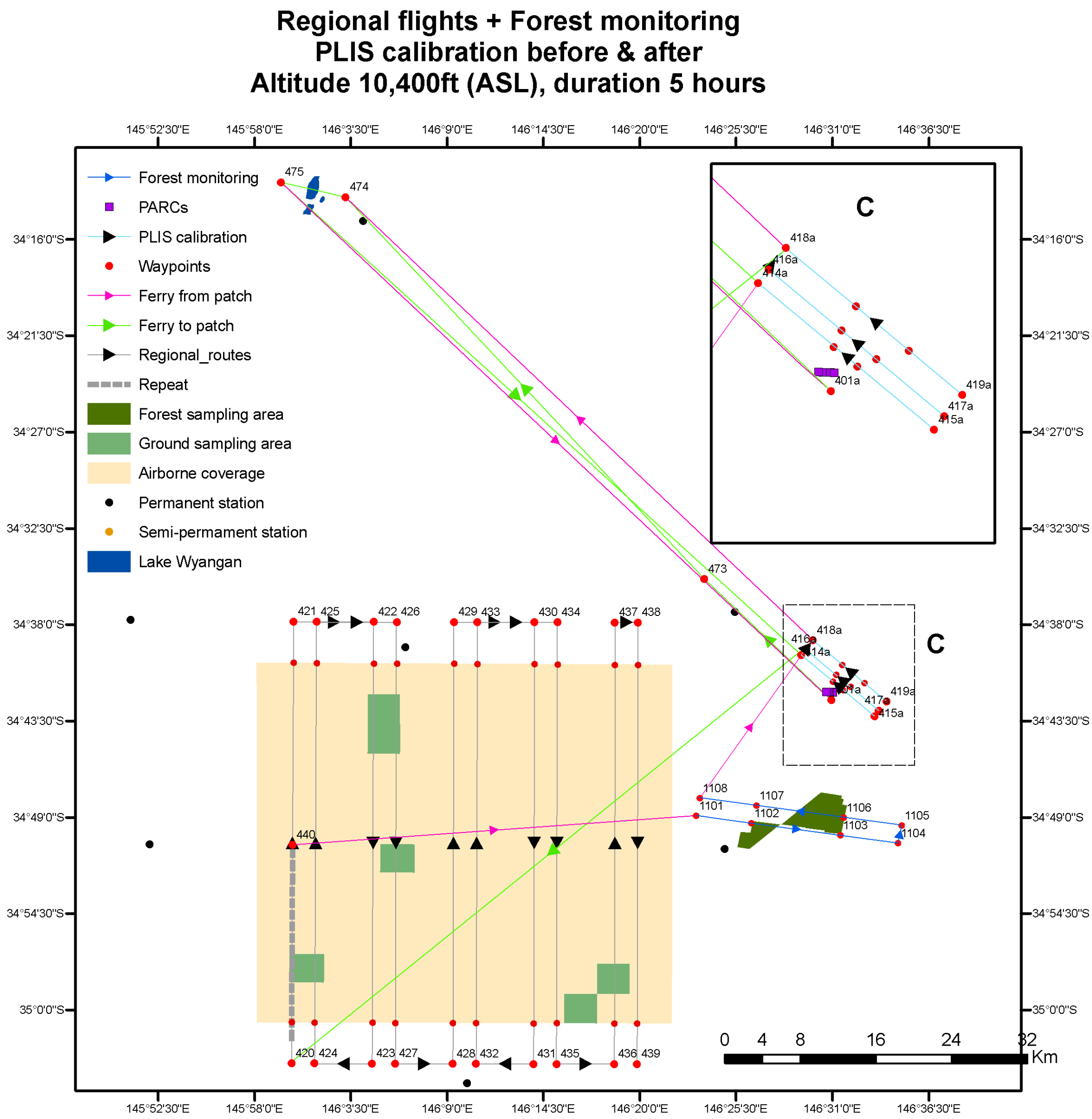


Regional Flights + Forest monitoring

Altitude 10,400ft (ASL) and duration 4.7 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
401a	146° 30.953' E	34° 42.3' S	433	146° 10.72' E	34° 37.857' S
474	146° 3.205' E	34° 13.577' S	434	146° 15.304' E	34° 37.866' S
475	145° 59.512' E	34° 12.728' S	435	146° 15.243' E	35° 3.092' S
414a	146° 29.221' E	34° 39.729' S	436	146° 18.532' E	35° 3.098' S
415a	146° 33.407' E	34° 43.221' S	437	146° 18.577' E	34° 37.871' S
416a	146° 29.468' E	34° 39.407' S	438	146° 19.887' E	34° 37.873' S
417a	146° 33.646' E	34° 42.904' S	439	146° 19.847' E	35° 3.099' S
420	146° 0.116' E	35° 3.049' S	440	146° 0.18' E	34° 50.574' S
421	146° 0.245' E	34° 37.824' S	473	146° 23.676' E	34° 35.392' S
422	146° 4.828' E	34° 37.84' S	474	146° 3.205' E	34° 13.577' S
423	146° 4.72' E	35° 3.065' S	475	145° 59.512' E	34° 12.728' S
424	146° 1.431' E	35° 3.054' S	1101	146° 23.203' E	34° 48.895' S
425	146° 1.555' E	34° 37.829' S	1102	146° 26.355' E	34° 49.326' S
426	146° 6.137' E	34° 37.844' S	1103	146° 31.431' E	34° 50.017' S
427	146° 6.035' E	35° 3.07' S	1104	146° 34.73' E	34° 50.464' S
428	146° 9.324' E	35° 3.079' S	1105	146° 34.932' E	34° 49.449' S
429	146° 9.411' E	34° 37.853' S	1106	146° 31.636' E	34° 49.003' S
430	146° 13.994' E	34° 37.864' S	1107	146° 26.649' E	34° 48.325' S
431	146° 13.928' E	35° 3.09' S	1108	146° 23.407' E	34° 47.881' S
432	146° 10.639' E	35° 3.082' S			

Route:401a, 473, 474**, (500ft→)**,475 **(500ft↑10,400ft)**, 420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,420,440,1101, 1102,1103,1104,1105,1106,1107,1108,414a, 415a, 414a,416a, 417a, 416a, 418a, 419a,418a**(10,400ft↓500ft)**,474**(500ft→)**,475,473,401a


Regional flights + Forest monitoring
PLIS calibration before & after
Altitude 10,400ft (ASL), duration 5 hours
Forest monitoring
PARCs
PLIS calibration
Waypoints
Ferry from patch
Ferry to patch
Regional_routes
Repeat
Forest sampling area
Ground sampling area
Airborne coverage
Permanent station
Semi-permanent station
Lake Wyangan
C
C
0 4 8 16 24 32
Km

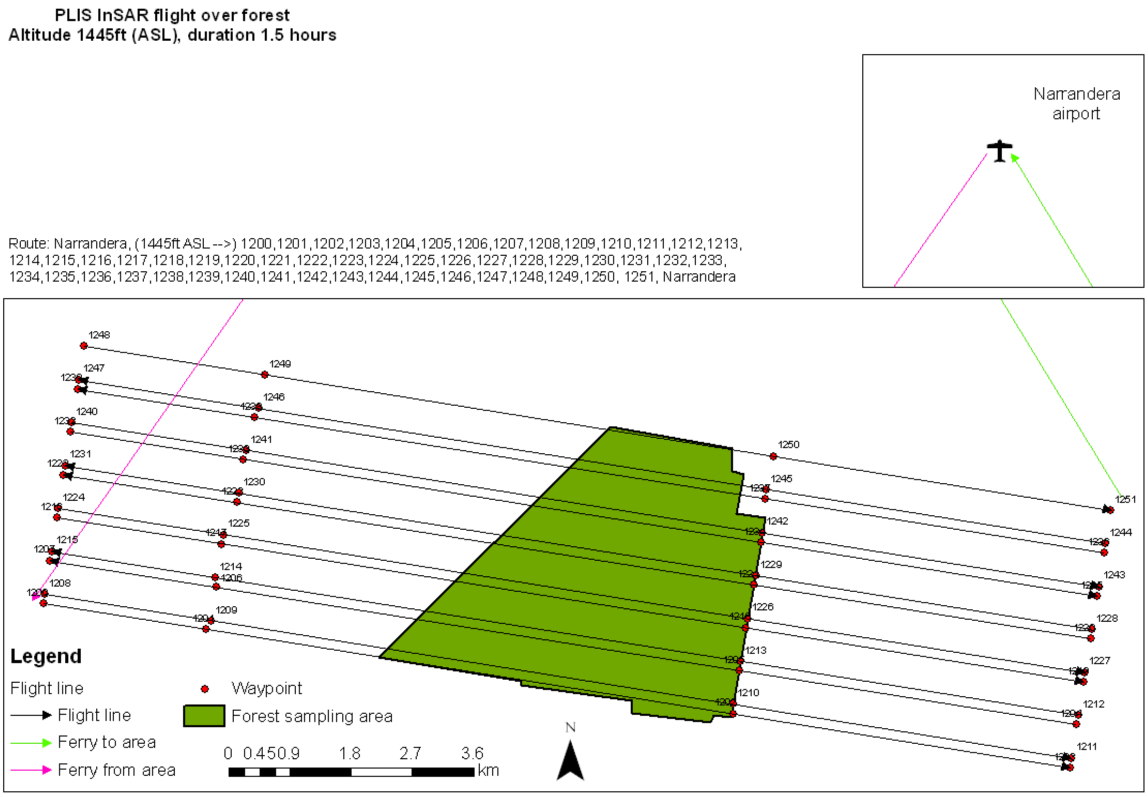
Regional Flights + Forest monitoring

PLIS calibration before & after

Altitude 10,400ft (ASL) and duration 5.0 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
401a	146° 30.953' E	34° 42.3' S	433	146° 10.72' E	34° 37.857' S
474	146° 3.205' E	34° 13.577' S	434	146° 15.304' E	34° 37.866' S
475	145° 59.512' E	34° 12.728' S	435	146° 15.243' E	35° 3.092' S
414a	146° 29.221' E	34° 39.729' S	436	146° 18.532' E	35° 3.098' S
415a	146° 33.407' E	34° 43.221' S	437	146° 18.577' E	34° 37.871' S
416a	146° 29.468' E	34° 39.407' S	438	146° 19.887' E	34° 37.873' S
417a	146° 33.646' E	34° 42.904' S	439	146° 19.847' E	35° 3.099' S
420	146° 0.116' E	35° 3.049' S	440	146° 0.18' E	34° 50.574' S
421	146° 0.245' E	34° 37.824' S	473	146° 23.676' E	34° 35.392' S
422	146° 4.828' E	34° 37.84' S	474	146° 3.205' E	34° 13.577' S
423	146° 4.72' E	35° 3.065' S	475	145° 59.512' E	34° 12.728' S
424	146° 1.431' E	35° 3.054' S	1101	146° 23.203' E	34° 48.895' S
425	146° 1.555' E	34° 37.829' S	1102	146° 26.355' E	34° 49.326' S
426	146° 6.137' E	34° 37.844' S	1103	146° 31.431' E	34° 50.017' S
427	146° 6.035' E	35° 3.07' S	1104	146° 34.73' E	34° 50.464' S
428	146° 9.324' E	35° 3.079' S	1105	146° 34.932' E	34° 49.449' S
429	146° 9.411' E	34° 37.853' S	1106	146° 31.636' E	34° 49.003' S
430	146° 13.994' E	34° 37.864' S	1107	146° 26.649' E	34° 48.325' S
431	146° 13.928' E	35° 3.09' S	1108	146° 23.407' E	34° 47.881' S
432	146° 10.639' E	35° 3.082' S			

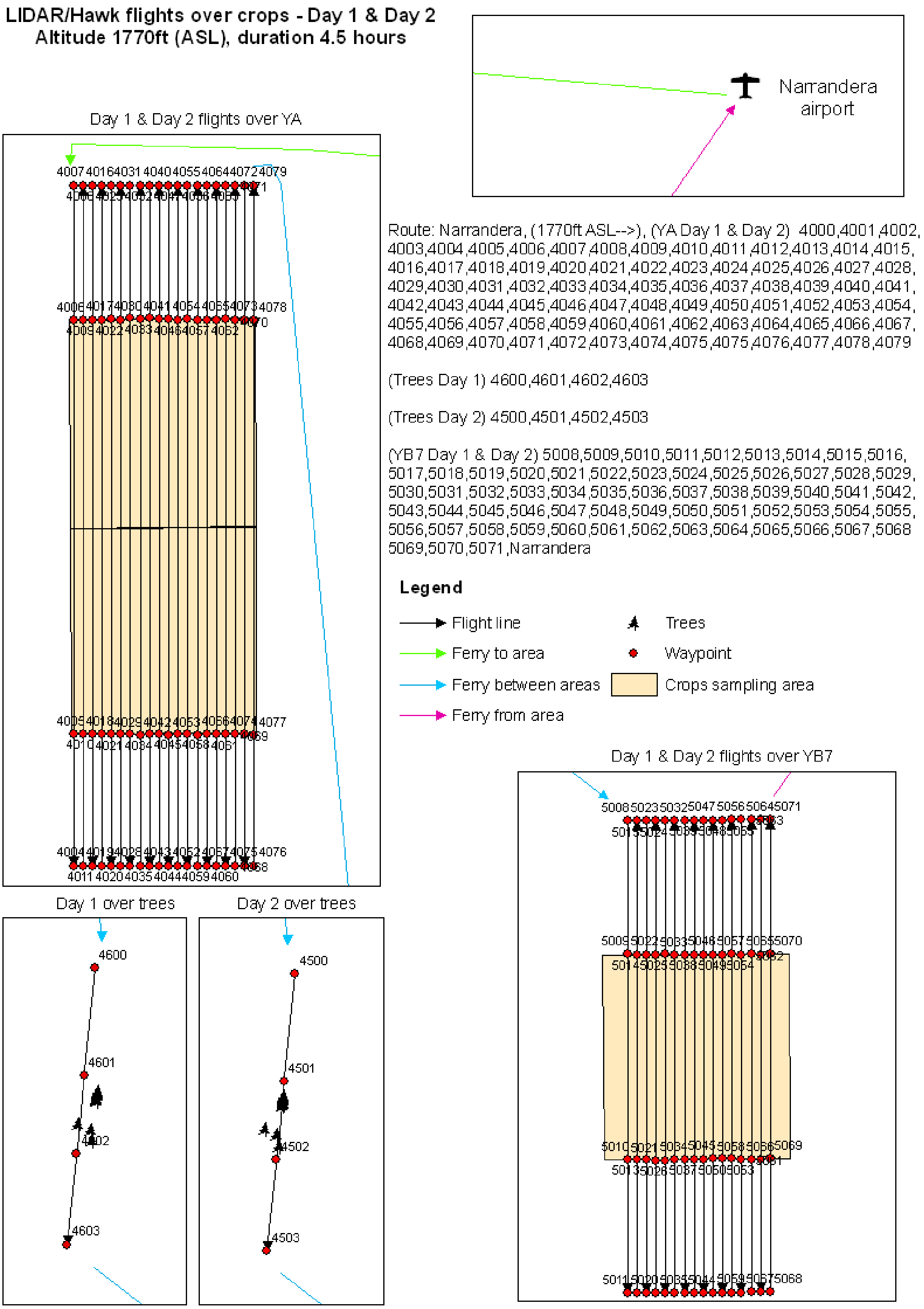
Route:401a, 473, 474, **(500ft→)**,475 **(500ft↑10,400ft)**, 414a**(10,400ft→)**, 415a, 414a, 416a, 417a,416a,418a,419a,418a,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437, 438,439,420,440, 1101, 1102,1103,1104,1105,1106,1107,1108, 414a, 415a, 414a,416a, 417a, 416a, 418a, 419a,418a**(10,400ft↓500ft)**,474**(500ft→)**,475,473,401a


PLIS InSAR flight over forest
Altitude 1445ft (ASL), duration 1.5 hours
Route: Narrandera, (1445ft ASL -->) 1200,1201,1202,1203,1204,1205,1206,1207,1208,1209,1210,1211,1212,1213, 1214,1215,1216,1217,1218,1219,1220,1221,1222,1223,1224,1225,1226,1227,1228,1229,1230,1231,1232,1233, 1234,1235,1236,1237,1238,1239,1240,1241,1242,1243,1244,1245,1246,1247,1248,1249,1250, 1251, Narrandera
Narrandera airport
Legend
Flight line
Flight line
Ferry to area
Ferry from area
Waypoint
Forest sampling area
0 0.45 0.9 1.8 2.7 3.6 km
N

PLIS InSAR flight over forest – 4/09/2011
Altitude 1445 ft (ASL), duration 1.5 hours, ESV

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
1200	146° 24.844′ E	34° 48.96′ S	1226	146° 31.654′ E	34° 49.109′ S
1201	146° 26.42′ E	34° 49.176′ S	1227	146° 34.913′ E	34° 49.55′ S
1202	146° 31.508′ E	34° 49.867′ S	1228	146° 34.981′ E	34° 49.208′ S
1203	146° 34.762′ E	34° 50.308′ S	1229	146° 31.735′ E	34° 48.769′ S
1204	146° 34.83′ E	34° 49.967′ S	1230	146° 26.747′ E	34° 48.09′ S
1205	146° 31.569′ E	34° 49.525′ S	1231	146° 25.065′ E	34° 47.861′ S
1206	146° 26.523′ E	34° 48.838′ S	1232	146° 25.119′ E	34° 47.594′ S
1207	146° 24.913′ E	34° 48.619′ S	1233	146° 26.787′ E	34° 47.821′ S
1208	146° 24.859′ E	34° 48.886′ S	1234	146° 31.791′ E	34° 48.502′ S
1209	146° 26.464′ E	34° 49.105′ S	1235	146° 35.034′ E	34° 48.942′ S
1210	146° 31.507′ E	34° 49.791′ S	1236	146° 35.102′ E	34° 48.6′ S
1211	146° 34.777′ E	34° 50.233′ S	1237	146° 31.827′ E	34° 48.156′ S
1212	146° 34.845′ E	34° 49.892′ S	1238	146° 26.901′ E	34° 47.486′ S
1213	146° 31.585′ E	34° 49.45′ S	1239	146° 25.188′ E	34° 47.252′ S
1214	146° 26.51′ E	34° 48.76′ S	1240	146° 25.134′ E	34° 47.519′ S
1215	146° 24.928′ E	34° 48.544′ S	1241	146° 26.812′ E	34° 47.748′ S
1216	146° 24.982′ E	34° 48.277′ S	1242	146° 31.796′ E	34° 48.426′ S
1217	146° 26.574′ E	34° 48.495′ S	1243	146° 35.049′ E	34° 48.867′ S
1218	146° 31.634′ E	34° 49.183′ S	1244	146° 35.117′ E	34° 48.525′ S
1219	146° 34.898′ E	34° 49.625′ S	1245	146° 31.841′ E	34° 48.082′ S
1220	146° 34.966′ E	34° 49.283′ S	1246	146° 26.937′ E	34° 47.415′ S
1221	146° 31.717′ E	34° 48.843′ S	1247	146° 25.203′ E	34° 47.177′ S
1222	146° 26.727′ E	34° 48.165′ S	1248	146° 25.256′ E	34° 46.91′ S
1223	146° 25.05′ E	34° 47.935′ S	1249	146° 26.997′ E	34° 47.148′ S
1224	146° 24.997′ E	34° 48.202′ S	1250	146° 31.908′ E	34° 47.817′ S
1225	146° 26.591′ E	34° 48.42′ S	1251	146° 35.17′ E	34° 48.258′ S
9999	146° 30.739' E	34° 42.053' S			

Route: 9999, (**↑1445ft ASL→**) 1200,1201,1202,1203,1204,1205,1206,1207,1208 ,1209,1210,1211, 1212, 1213,1214,1215,1216,1217,1218,1219,1220,1221,1222,1223,1224,1225,1226,1227,1228,1229, 1230,1231,1232,1233,1234,1235,1236,1237,1238,1239,1240,1241,1242,1243,1244,1245,1246,1247, 1248,1249,1250, 1251, (↓) 9999.


LIDAR/Hawk flights over crops - Day 1 & Day 2
Altitude 1770ft (ASL), duration 4.5 hours
Day 1 & Day 2 flights over YA
Narrandera airport
Route: Narrandera, (1770ft ASL-->), (YA Day 1 & Day 2) 4000,4001,4002,4003,4004,4005,4006,4007,4008,4009,4010,4011,4012,4013,4014,4015,4016,4017,4018,4019,4020,4021,4022,4023,4024,4025,4026,4027,4028,4029,4030,4031,4032,4033,4034,4035,4036,4037,4038,4039,4040,4041,4042,4043,4044,4045,4046,4047,4048,4049,4050,4051,4052,4053,4054,4055,4056,4057,4058,4059,4060,4061,4062,4063,4064,4065,4066,4067,4068,4069,4070,4071,4072,4073,4074,4075,4075,4076,4077,4078,4079
(Trees Day 1) 4600,4601,4602,4603
(Trees Day 2) 4500,4501,4502,4503
(YB7 Day 1 & Day 2) 5008,5009,5010,5011,5012,5013,5014,5015,5016,5017,5018,5019,5020,5021,5022,5023,5024,5025,5026,5027,5028,5029,5030,5031,5032,5033,5034,5035,5036,5037,5038,5039,5040,5041,5042,5043,5044,5045,5046,5047,5048,5049,5050,5051,5052,5053,5054,5055,5056,5057,5058,5059,5060,5061,5062,5063,5064,5065,5066,5067,5068,5069,5070,5071,Narrandera
Legend
Flight line
Ferry to area
Ferry between areas
Ferry from area
Trees
Waypoint
Crops sampling area
Day 1 & Day 2 flights over YB7
Day 1 over trees
4600
4601
4603
Day 2 over trees
4500
4501
4502
4503

LIDAR/Hawk flight over crops– 5/09/2011
Altitude 1770 ft (ASL), duration 4.5 hours, EOS
Day1

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
Focus area YA			4046	146° 5.552' E	34° 41.953' S
4000	146° 4.519' E	34° 40.839' S	4047	146° 5.564' E	34° 40.846' S
4001	146° 4.507' E	34° 41.951' S	4048	146° 5.659' E	34° 40.847' S
4002	146° 4.469' E	34° 45.353' S	4049	146° 5.647' E	34° 41.947' S
4003	146° 4.457' E	34° 46.439' S	4050	146° 5.61' E	34° 45.361' S
4004	146° 4.552' E	34° 46.44' S	4051	146° 5.597' E	34° 46.447' S
4005	146° 4.564' E	34° 45.353' S	4052	146° 5.693' E	34° 46.448' S
4006	146° 4.602' E	34° 41.952' S	4053	146° 5.704' E	34° 45.376' S
4007	146° 4.614' E	34° 40.839' S	4054	146° 5.741' E	34° 41.954' S
4008	146° 4.709' E	34° 40.84' S	4055	146° 5.754' E	34° 40.847' S
4009	146° 4.697' E	34° 41.946' S	4056	146° 5.849' E	34° 40.848' S
4010	146° 4.659' E	34° 45.354' S	4057	146° 5.837' E	34° 41.955' S
4011	146° 4.647' E	34° 46.44' S	4058	146° 5.8' E	34° 45.363' S
4012	146° 4.742' E	34° 46.441' S	4059	146° 5.788' E	34° 46.449' S
4013	146° 4.754' E	34° 45.355' S	4060	146° 5.883' E	34° 46.45' S
4014	146° 4.792' E	34° 41.954' S	4061	146° 5.895' E	34° 45.37' S
4015	146° 4.804' E	34° 40.84' S	4062	146° 5.932' E	34° 41.956' S
4016	146° 4.899' E	34° 40.841' S	4063	146° 5.944' E	34° 40.849' S
4017	146° 4.887' E	34° 41.941' S	4064	146° 6.039' E	34° 40.849' S
4018	146° 4.849' E	34° 45.363' S	4065	146° 6.026' E	34° 41.949' S
4019	146° 4.837' E	34° 46.442' S	4066	146° 5.99' E	34° 45.371' S
4020	146° 4.932' E	34° 46.443' S	4067	146° 5.978' E	34° 46.45' S
4021	146° 4.944' E	34° 45.363' S	4068	146° 6.073' E	34° 46.451' S
4022	146° 4.982' E	34° 41.949' S	4069	146° 6.085' E	34° 45.372' S
4023	146° 4.994' E	34° 40.842' S	4070	146° 6.122' E	34° 41.957' S
4024	146° 5.089' E	34° 40.843' S	4071	146° 6.133' E	34° 40.851' S
4025	146° 5.077' E	34° 41.935' S	4072	146° 6.229' E	34° 40.851' S
4026	146° 5.039' E	34° 45.364' S	4073	146° 6.217' E	34° 41.958' S
4027	146° 5.027' E	34° 46.443' S	4074	146° 6.18' E	34° 45.373' S
4028	146° 5.122' E	34° 46.444' S	4075	146° 6.168' E	34° 46.452' S
4029	146° 5.134' E	34° 45.372' S	4076	146° 6.263' E	34° 46.453' S
4030	146° 5.172' E	34° 41.943' S	4077	146° 6.275' E	34° 45.38' S
4031	146° 5.184' E	34° 40.843' S	4078	146° 6.311' E	34° 41.965' S
4032	146° 5.279' E	34° 40.844' S	4079	146° 6.324' E	34° 40.852' S
4033	146° 5.267' E	34° 41.937' S	Trees		
4034	146° 5.229' E	34° 45.366' S	4600	146° 7.398' E	34° 49.52' S
4035	146° 5.217' E	34° 46.445' S	4601	146° 7.264' E	34° 50.536' S
4036	146° 5.312' E	34° 46.445' S	4602	146° 7.167' E	34° 51.269' S
4037	146° 5.325' E	34° 45.366' S	4603	146° 7.054' E	34° 52.127' S

4038	146° 5.362' E	34° 41.944' S	Focus area YB7		
4039	146° 5.374' E	34° 40.845' S	5008	146° 15.943' E	34° 57.965' S
4040	146° 5.469' E	34° 40.845' S	5009	146° 15.932' E	34° 59.059' S
4041	146° 5.456' E	34° 41.945' S	5010	146° 15.917' E	35° 0.751' S
4042	146° 5.419' E	34° 45.374' S	5011	146° 15.908' E	35° 1.854' S
4043	146° 5.407' E	34° 46.446' S	5012	146° 16.003' E	35° 1.854' S
4044	146° 5.503' E	34° 46.447' S	5013	146° 16.013' E	35° 0.751' S
4045	146° 5.515' E	34° 45.361' S	5014	146° 16.028' E	34° 59.065' S

LIDAR/Hawk flight over crops– 5/09/2011
Altitude 1770 ft (ASL), duration 4.5 hours, EOS
Day1 – continuation

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
5015	146° 16.038' E	34° 57.964' S	5044	146° 16.766' E	35° 1.853' S
5016	146° 16.133' E	34° 57.964' S	5045	146° 16.775' E	35° 0.751' S
5017	146° 16.123' E	34° 59.07' S	5046	146° 16.791' E	34° 59.069' S
5018	146° 16.108' E	35° 0.757' S	5047	146° 16.8' E	34° 57.962' S
5019	146° 16.099' E	35° 1.854' S	5048	146° 16.895' E	34° 57.962' S
5020	146° 16.194' E	35° 1.854' S	5049	146° 16.886' E	34° 59.07' S
5021	146° 16.204' E	35° 0.762' S	5050	146° 16.871' E	35° 0.751' S
5022	146° 16.219' E	34° 59.066' S	5051	146° 16.861' E	35° 1.853' S
5023	146° 16.228' E	34° 57.964' S	5052	146° 16.957' E	35° 1.853' S
5024	146° 16.324' E	34° 57.964' S	5053	146° 16.966' E	35° 0.752' S
5025	146° 16.314' E	34° 59.062' S	5054	146° 16.981' E	34° 59.066' S
5026	146° 16.299' E	35° 0.762' S	5055	146° 16.991' E	34° 57.961' S
5027	146° 16.29' E	35° 1.854' S	5056	146° 17.086' E	34° 57.961' S
5028	146° 16.385' E	35° 1.854' S	5057	146° 17.077' E	34° 59.071' S
5029	146° 16.394' E	35° 0.758' S	5058	146° 17.062' E	35° 0.762' S
5030	146° 16.41' E	34° 59.067' S	5059	146° 17.052' E	35° 1.853' S
5031	146° 16.419' E	34° 57.963' S	5060	146° 17.147' E	35° 1.853' S
5032	146° 16.515' E	34° 57.963' S	5061	146° 17.157' E	35° 0.763' S
5033	146° 16.504' E	34° 59.072' S	5062	146° 17.172' E	34° 59.067' S
5034	146° 16.49' E	35° 0.754' S	5063	146° 17.182' E	34° 57.961' S
5035	146° 16.48' E	35° 1.853' S	5064	146° 17.276' E	34° 57.96' S
5036	146° 16.575' E	35° 1.853' S	5065	146° 17.267' E	34° 59.072' S
5037	146° 16.585' E	35° 0.754' S	5066	146° 17.253' E	35° 0.759' S
5038	146° 16.6' E	34° 59.068' S	5067	146° 17.243' E	35° 1.852' S
5039	146° 16.61' E	34° 57.963' S	5068	146° 17.338' E	35° 1.852' S
5040	146° 16.705' E	34° 57.963' S	5069	146° 17.348' E	35° 0.754' S
5041	146° 16.695' E	34° 59.069' S	5070	146° 17.362' E	34° 59.068' S
5042	146° 16.681' E	35° 0.755' S	5071	146° 17.372' E	34° 57.96' S
5043	146° 16.671' E	35° 1.853' S	9999	146° 30.739' E	34° 42.053' S

Route: 9999, (↑ **1770ft ASL→**) 4000,4001,4002,4003,4004,4005,4006,4007,4008,4009,4010,4011, 4012,4013,4014,4015,4016,4017,4018,4019,4020,4021,4022,4023,4024,4025,4026,4027,4028,4029, 4030,4031,4032,4033,4034,4035,4036,4037,4038,4039,4040,4041,4042,4043,4044,4045,4046,4047, 4048,4049,4050,4051,4052,4053,4054,4055,4056,4057,4058,4059,4060,4061,4062,4063,4064,4065, 4066,4067,4068,4069,4070,4071,4072,4073,4074,4075,4075,4076,4077,4078,4079→

→Trees : (**1770ft ASL→**) **4600,4601,4602,4603** →

→ (**1770ft ASL→**) 5008,5009,5010,5011,5012,5013,5014,5015,5016,5017,5018,5019,5020,5021,5022, 5023,5024,5025,5026,5027,5028,5029,5030,5031,5032,5033,5034,5035,5036,5037,5038,5039,5040, 5041,5042,5043,5044,5045,5046,5047,5048,5049,5050,5051,5052,5053,5054,5055,5056,5057,5058, 5059,5060,5061,5062,5063,5064,5065,5066,5067,5068,5069,5070,5071, (↓) 9999.

LIDAR/Hawk flight over crops– 23/09/2011
Altitude 1770 ft (ASL), duration 4.5 hours, EOS
Day2

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
Focus area YA			4046	146° 5.552' S	34° 41.953' E
4000	146° 4.519' E	34° 40.839' S	4047	146° 5.564' E	34° 40.846' S
4001	146° 4.507' E	34° 41.951' S	4048	146° 5.659' E	34° 40.847' S
4002	146° 4.469' E	34° 45.353' S	4049	146° 5.647' E	34° 41.947' S
4003	146° 4.457' E	34° 46.439' S	4050	146° 5.61' E	34° 45.361' S
4004	146° 4.552' E	34° 46.44' S	4051	146° 5.597' E	34° 46.447' S
4005	146° 4.564' E	34° 45.353' S	4052	146° 5.693' E	34° 46.448' S
4006	146° 4.602' E	34° 41.952' S	4053	146° 5.704' E	34° 45.376' S
4007	146° 4.614' E	34° 40.839' S	4054	146° 5.741' E	34° 41.954' S
4008	146° 4.709' E	34° 40.84' S	4055	146° 5.754' E	34° 40.847' S
4009	146° 4.697' E	34° 41.946' S	4056	146° 5.849' E	34° 40.848' S
4010	146° 4.659' E	34° 45.354' S	4057	146° 5.837' E	34° 41.955' S
4011	146° 4.647' E	34° 46.44' S	4058	146° 5.8' E	34° 45.363' S
4012	146° 4.742' E	34° 46.441' S	4059	146° 5.788' E	34° 46.449' S
4013	146° 4.754' E	34° 45.355' S	4060	146° 5.883' E	34° 46.45' S
4014	146° 4.792' E	34° 41.954' S	4061	146° 5.895' E	34° 45.37' S
4015	146° 4.804' E	34° 40.84' S	4062	146° 5.932' E	34° 41.956' S
4016	146° 4.899' E	34° 40.841' S	4063	146° 5.944' E	34° 40.849' S
4017	146° 4.887' E	34° 41.941' S	4064	146° 6.039' E	34° 40.849' S
4018	146° 4.849' E	34° 45.363' S	4065	146° 6.026' E	34° 41.949' S
4019	146° 4.837' E	34° 46.442' S	4066	146° 5.99' E	34° 45.371' S
4020	146° 4.932' E	34° 46.443' S	4067	146° 5.978' E	34° 46.45' S
4021	146° 4.944' E	34° 45.363' S	4068	146° 6.073' E	34° 46.451' S
4022	146° 4.982' E	34° 41.949' S	4069	146° 6.085' E	34° 45.372' S
4023	146° 4.994' E	34° 40.842' S	4070	146° 6.122' E	34° 41.957' S
4024	146° 5.089' E	34° 40.843' S	4071	146° 6.133' E	34° 40.851' S
4025	146° 5.077' E	34° 41.935' S	4072	146° 6.229' E	34° 40.851' S
4026	146° 5.039' E	34° 45.364' S	4073	146° 6.217' E	34° 41.958' S
4027	146° 5.027' E	34° 46.443' S	4074	146° 6.18' E	34° 45.373' S
4028	146° 5.122' E	34° 46.444' S	4075	146° 6.168' E	34° 46.452' S
4029	146° 5.134' E	34° 45.372' S	4076	146° 6.263' E	34° 46.453' S
4030	146° 5.172' E	34° 41.943' S	4077	146° 6.275' E	34° 45.38' S
4031	146° 5.184' E	34° 40.843' S	4078	146° 6.311' E	34° 41.965' S
4032	146° 5.279' E	34° 40.844' S	4079	146° 6.324' E	34° 40.852' S
4033	146° 5.267' E	34° 41.937' S	Trees		
4034	146° 5.229' E	34° 45.366' S	4500	146° 7.555' E	34° 49.534' S
4035	146° 5.217' E	34° 46.445' S	4501	146° 7.422' E	34° 50.544' S
4036	146° 5.312' E	34° 46.445' S	4502	146° 7.324' E	34° 51.282' S
4037	146° 5.325' E	34° 45.366' S	4503	146° 7.21' E	34° 52.141' S

4038	146° 5.362' E	34° 41.944' S	Focus area YB7		
4039	146° 5.374' E	34° 40.845' S	5008	146° 15.943' E	34° 57.965' S
4040	146° 5.469' E	34° 40.845' S	5009	146° 15.932' E	34° 59.059' S
4041	146° 5.456' E	34° 41.945' S	5010	146° 15.917' E	35° 0.751' S
4042	146° 5.419' E	34° 45.374' S	5011	146° 15.908' E	35° 1.854' S
4043	146° 5.407' E	34° 46.446' S	5012	146° 16.003' E	35° 1.854' S
4044	146° 5.503' E	34° 46.447' S	5013	146° 16.013' E	35° 0.751' S
4045	146° 5.515' E	34° 45.361' S	5014	146° 16.028' E	34° 59.065' S

LIDAR/Hawk flight over crops– 23/09/2011
Altitude 1770 ft (ASL), duration 4.5 hours, EOS
Day2 – continuation

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
5015	146° 16.038' E	34° 57.964' S	5044	146° 16.766' E	35° 1.853' S
5016	146° 16.133' E	34° 57.964' S	5045	146° 16.775' E	35° 0.751' S
5017	146° 16.123' E	34° 59.07' S	5046	146° 16.791' E	34° 59.069' S
5018	146° 16.108' E	35° 0.757' S	5047	146° 16.8' E	34° 57.962' S
5019	146° 16.099' E	35° 1.854' S	5048	146° 16.895' E	34° 57.962' S
5020	146° 16.194' E	35° 1.854' S	5049	146° 16.886' E	34° 59.07' S
5021	146° 16.204' E	35° 0.762' S	5050	146° 16.871' E	35° 0.751' S
5022	146° 16.219' E	34° 59.066' S	5051	146° 16.861' E	35° 1.853' S
5023	146° 16.228' E	34° 57.964' S	5052	146° 16.957' E	35° 1.853' S
5024	146° 16.324' E	34° 57.964' S	5053	146° 16.966' E	35° 0.752' S
5025	146° 16.314' E	34° 59.062' S	5054	146° 16.981' E	34° 59.066' S
5026	146° 16.299' E	35° 0.762' S	5055	146° 16.991' E	34° 57.961' S
5027	146° 16.29' E	35° 1.854' S	5056	146° 17.086' E	34° 57.961' S
5028	146° 16.385' E	35° 1.854' S	5057	146° 17.077' E	34° 59.071' S
5029	146° 16.394' E	35° 0.758' S	5058	146° 17.062' E	35° 0.762' S
5030	146° 16.41' E	34° 59.067' S	5059	146° 17.052' E	35° 1.853' S
5031	146° 16.419' E	34° 57.963' S	5060	146° 17.147' E	35° 1.853' S
5032	146° 16.515' E	34° 57.963' S	5061	146° 17.157' E	35° 0.763' S
5033	146° 16.504' E	34° 59.072' S	5062	146° 17.172' E	34° 59.067' S
5034	146° 16.49' E	35° 0.754' S	5063	146° 17.182' E	34° 57.961' S
5035	146° 16.48' E	35° 1.853' S	5064	146° 17.276' E	34° 57.96' S
5036	146° 16.575' E	35° 1.853' S	5065	146° 17.267' E	34° 59.072' S
5037	146° 16.585' E	35° 0.754' S	5066	146° 17.253' E	35° 0.759' S
5038	146° 16.6' E	34° 59.068' S	5067	146° 17.243' E	35° 1.852' S
5039	146° 16.61' E	34° 57.963' S	5068	146° 17.338' E	35° 1.852' S
5040	146° 16.705' E	34° 57.963' S	5069	146° 17.348' E	35° 0.754' S
5041	146° 16.695' E	34° 59.069' S	5070	146° 17.362' E	34° 59.068' S
5042	146° 16.681' E	35° 0.755' S	5071	146° 17.372' E	34° 57.96' S
5043	146° 16.671' E	35° 1.853' S	9999	146° 30.739' E	34° 42.053' S

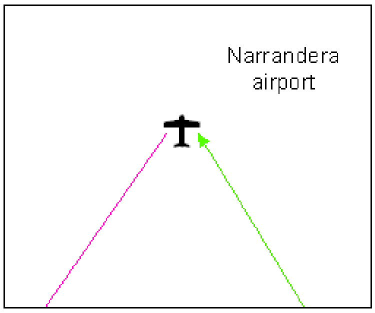
Route: 9999, (**↑1770ft ASL→**) 4000,4001,4002,4003,4004,4005,4006,4007,4008,4009,4010,4011, 4012,4013,4014,4015,4016,4017,4018,4019,4020,4021,4022,4023,4024,4025,4026,4027,4028,4029, 4030,4031,4032,4033,4034,4035,4036,4037,4038,4039,4040,4041,4042,4043,4044,4045,4046,4047, 4048,4049,4050,4051,4052,4053,4054,4055,4056,4057,4058,4059,4060,4061,4062,4063,4064,4065, 4066,4067,4068,4069,4070,4071,4072,4073,4074,4075,4075,4076,4077,4078,4079 →

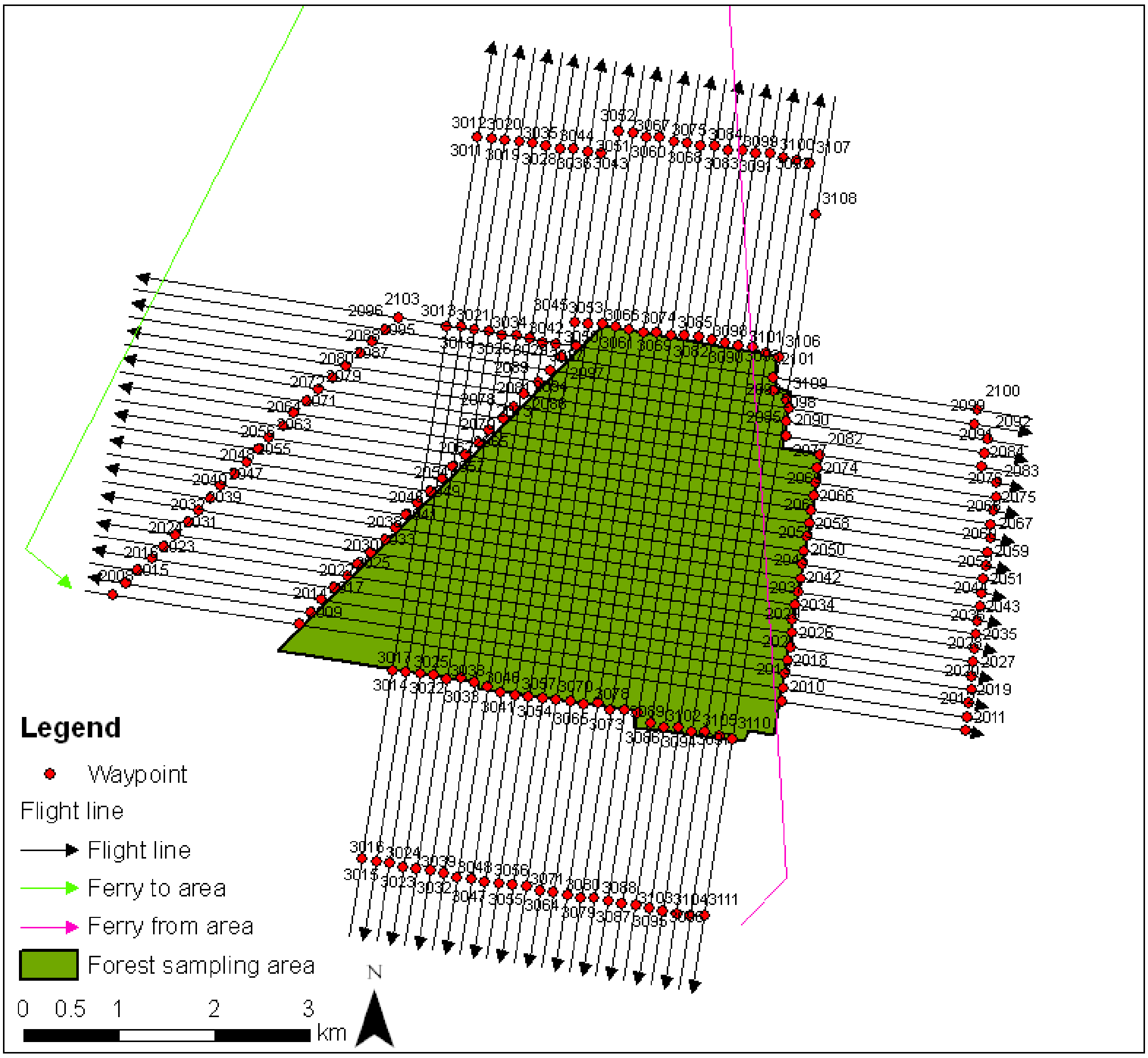
→ Trees: (**1770ft ASL→**) **4500,4501,4502,4503** →

→ (**1770ft ASL→**) 5008,5009,5010,5011,5012,5013,5014,5015,5016,5017,5018,5019,5020,5021, 5022,5023,5024,5025,5026,5027,5028,5029,5030,5031,5032,5033,5034,5035,5036,5037,5038,5039, 5040,5041,5042,5043,5044,5045,5046,5047,5048,5049,5050,5051,5052,5053,5054,5055,5056,5057, 5058,5059,5060,5061,5062,5063,5064,5065,5066,5067,5068,5069,5070,5071,(↓) 9999.

LIDAR/HAWK flight over forest
Altitude 1770ft (ASL), duration 4.6 hours

Route: Narrandera, (1770ft ASL-->), 2008, 2009,2010,2011,2012,2013,2014,2015,2016,2017,2018,2019,2020,2021,2022,2023, 2024,2025,2026,2027,2028,2029,2030,2031,2032,2033,2034,2035,2036,2037,2038,2039,2040,2041,2042,2043,2044,2045, 2046,2047,2048,2049,2050,2051,2052,2053,2054,2055,2056,2057,2058,2059,2060,2061,2062,2063,2064,2065,2066,2067, 2068,2069,2070,2071,2072,2073,2074,2075,2076,2077,2078,2079,2080,2081,2082,2083,2084,2085,2086,2087,2088,2089, 2090,2091,2092,2093,2094,2095,2096,2097,2098,2099,2100,21001,2102,2103 --> cross flight (1770ft ASL-->)
cross flight: 3008,3009,3010,3011,3012,3013,3014,3015,3016,3017,3018,3019,3020,3021,3022,3023,3024,3025,3026,3027, 3028,3029,3030,3031,3032,3033,3034,3035,3036,3037,3038,3039,3040,3041,3042,3043,3044,3045,3046,3047,3048,3049, 3050,3051,3052,3053,3054,3055,3056,3057,3058,3059,3060,3061,3062,3063,3064,3065,3066,3067,3068,3069,3070,3071, 3072,3073,3074,3075,3076,3077,3078,3079,3080,3081,3082,3083,3084,3085,3086, 3087,3088,3089,3090,3091,3092,3093,3094,3095,3096,3097,3098,3099,3100, 3101,3102,3103,3104,3105,3106,3107,3108,3109,3110,3111, Narrandera





LIDAR/Hawk flight over forest – 6/09/2011 ,
Altitude 1770 ft (ASL), duration 4.6 hours, EOS

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
2008	146° 26.959' E	34° 49.09' S	2056	146° 27.961' E	34° 48.272' S
2009	146° 28.235' E	34° 49.264' S	2057	146° 29.222' E	34° 48.444' S
2010	146° 31.543' E	34° 49.713' S	2058	146° 31.721' E	34° 48.784' S
2011	146° 32.809' E	34° 49.885' S	2059	146° 32.95' E	34° 48.95' S
2012	146° 32.818' E	34° 49.807' S	2060	146° 32.967' E	34° 48.872' S
2013	146° 31.56' E	34° 49.636' S	2061	146° 31.745' E	34° 48.707' S
2014	146° 28.314' E	34° 49.195' S	2062	146° 29.298' E	34° 48.374' S
2015	146° 27.052' E	34° 49.023' S	2063	146° 28.036' E	34° 48.203' S
2016	146° 27.133' E	34° 48.955' S	2064	146° 28.131' E	34° 48.136' S
2017	146° 28.387' E	34° 49.125' S	2065	146° 29.388' E	34° 48.307' S
2018	146° 31.564' E	34° 49.557' S	2066	146° 31.754' E	34° 48.629' S
2019	146° 32.827' E	34° 49.729' S	2067	146° 32.979' E	34° 48.795' S
2020	146° 32.844' E	34° 49.651' S	2068	146° 32.986' E	34° 48.717' S
2021	146° 31.591' E	34° 49.482' S	2069	146° 31.774' E	34° 48.552' S
2022	146° 28.485' E	34° 49.059' S	2070	146° 29.476' E	34° 48.24' S
2023	146° 27.228' E	34° 48.888' S	2071	146° 28.21' E	34° 48.067' S
2024	146° 27.311' E	34° 48.82' S	2072	146° 28.301' E	34° 48' S
2025	146° 28.567' E	34° 48.991' S	2073	146° 29.55' E	34° 48.171' S
2026	146° 31.605' E	34° 49.404' S	2074	146° 31.783' E	34° 48.473' S
2027	146° 32.853' E	34° 49.573' S	2075	146° 33.006' E	34° 48.64' S
2028	146° 32.862' E	34° 49.495' S	2076	146° 33.02' E	34° 48.562' S
2029	146° 31.618' E	34° 49.326' S	2077	146° 31.794' E	34° 48.396' S
2030	146° 28.641' E	34° 48.921' S	2078	146° 29.642' E	34° 48.103' S
2031	146° 27.392' E	34° 48.751' S	2079	146° 28.372' E	34° 47.931' S
2032	146° 27.477' E	34° 48.683' S	2080	146° 28.478' E	34° 47.866' S
2033	146° 28.736' E	34° 48.855' S	2081	146° 29.717' E	34° 48.034' S
2034	146° 31.623' E	34° 49.247' S	2082	146° 31.819' E	34° 48.319' S
2035	146° 32.872' E	34° 49.417' S	2083	146° 33.024' E	34° 48.483' S
2036	146° 32.882' E	34° 49.338' S	2084	146° 32.928' E	34° 48.391' S
2037	146° 31.642' E	34° 49.17' S	2085	146° 31.585' E	34° 48.208' S
2038	146° 28.832' E	34° 48.789' S	2086	146° 29.789' E	34° 47.965' S
2039	146° 27.55' E	34° 48.614' S	2087	146° 28.57' E	34° 47.799' S
2040	146° 27.634' E	34° 48.546' S	2088	146° 28.666' E	34° 47.732' S
2041	146° 28.9' E	34° 48.718' S	2089	146° 29.885' E	34° 47.898' S
2042	146° 31.658' E	34° 49.093' S	2090	146° 31.583' E	34° 48.128' S
2043	146° 32.892' E	34° 49.26' S	2091	146° 32.942' E	34° 48.313' S
2044	146° 32.907' E	34° 49.183' S	2092	146° 32.962' E	34° 48.236' S
2045	146° 31.679' E	34° 49.016' S	2093	146° 31.604' E	34° 48.052' S
2046	146° 28.971' E	34° 48.648' S	2094	146° 29.968' E	34° 47.83' S
2047	146° 27.701' E	34° 48.475' S	2095	146° 28.752' E	34° 47.664' S

2048	146° 27.799' E	34° 48.409' S	2096	146° 28.836' E	34° 47.596' S
2049	146° 29.054' E	34° 48.58' S	2097	146° 30.045' E	34° 47.761' S
2050	146° 31.689' E	34° 48.938' S	2098	146° 31.5' E	34° 47.958' S
2051	146° 32.917' E	34° 49.105' S	2099	146° 32.88' E	34° 48.145' S
2052	146° 32.932' E	34° 49.027' S	2100	146° 32.9' E	34° 48.069' S
2053	146° 31.7' E	34° 48.86' S	2101	146° 31.498' E	34° 47.878' S
2054	146° 29.145' E	34° 48.513' S	2102	146° 30.146' E	34° 47.695' S
2055	146° 27.888' E	34° 48.342' S	2103	146° 28.928' E	34° 47.529' S
9999	146° 30.739' E	34° 42.053' S			

LIDAR/Hawk flight over forest – 6/09/2011
Altitude 1770 ft (ASL), duration 4.6 hours, EOS
Continuation – cross flight

Point ID	Longitude (dd)	Latitude(dd)	Point ID	Longitude(dd)	Latitude(dd)
3008	146° 28.661' E	34° 50.592' S	3060	146° 30.728' E	34° 46.518' S
3009	146° 28.874' E	34° 49.527' S	3061	146° 30.513' E	34° 47.602' S
3010	146° 29.263' E	34° 47.581' S	3062	146° 30.093' E	34° 49.705' S
3011	146° 29.478' E	34° 46.508' S	3063	146° 29.878' E	34° 50.774' S
3012	146° 29.572' E	34° 46.519' S	3064	146° 29.973' E	34° 50.786' S
3013	146° 29.359' E	34° 47.586' S	3065	146° 30.185' E	34° 49.723' S
3014	146° 28.97' E	34° 49.533' S	3066	146° 30.605' E	34° 47.618' S
3015	146° 28.755' E	34° 50.605' S	3067	146° 30.821' E	34° 46.538' S
3016	146° 28.848' E	34° 50.62' S	3068	146° 30.915' E	34° 46.552' S
3017	146° 29.064' E	34° 49.543' S	3069	146° 30.701' E	34° 47.619' S
3018	146° 29.453' E	34° 47.598' S	3070	146° 30.282' E	34° 49.719' S
3019	146° 29.666' E	34° 46.531' S	3071	146° 30.066' E	34° 50.801' S
3020	146° 29.762' E	34° 46.533' S	3072	146° 30.159' E	34° 50.817' S
3021	146° 29.546' E	34° 47.611' S	3073	146° 30.371' E	34° 49.758' S
3022	146° 29.159' E	34° 49.551' S	3074	146° 30.795' E	34° 47.634' S
3023	146° 28.94' E	34° 50.643' S	3075	146° 31.008' E	34° 46.568' S
3024	146° 29.035' E	34° 50.653' S	3076	146° 31.104' E	34° 46.568' S
3025	146° 29.25' E	34° 49.576' S	3077	146° 30.89' E	34° 47.641' S
3026	146° 29.639' E	34° 47.63' S	3078	146° 30.467' E	34° 49.759' S
3027	146° 29.857' E	34° 46.542' S	3079	146° 30.255' E	34° 50.823' S
3028	146° 29.95' E	34° 46.56' S	3080	146° 30.347' E	34° 50.84' S
3029	146° 29.735' E	34° 47.634' S	3081	146° 30.56' E	34° 49.777' S
3030	146° 29.347' E	34° 49.574' S	3082	146° 30.985' E	34° 47.647' S
3031	146° 29.13' E	34° 50.658' S	3083	146° 31.196' E	34° 46.588' S
3032	146° 29.223' E	34° 50.679' S	3084	146° 31.291' E	34° 46.596' S
3033	146° 29.438' E	34° 49.599' S	3085	146° 31.079' E	34° 47.66' S
3034	146° 29.828' E	34° 47.649' S	3086	146° 30.645' E	34° 49.834' S
3035	146° 30.041' E	34° 46.581' S	3087	146° 30.442' E	34° 50.851' S
3036	146° 30.138' E	34° 46.58' S	3088	146° 30.536' E	34° 50.86' S
3037	146° 29.919' E	34° 47.676' S	3089	146° 30.737' E	34° 49.857' S
3038	146° 29.53' E	34° 49.622' S	3090	146° 31.171' E	34° 47.681' S
3039	146° 29.315' E	34° 50.699' S	3091	146° 31.386' E	34° 46.606' S
3040	146° 29.41' E	34° 50.707' S	3092	146° 31.481' E	34° 46.612' S
3041	146° 29.62' E	34° 49.654' S	3093	146° 31.264' E	34° 47.702' S
3042	146° 30.013' E	34° 47.687' S	3094	146° 30.832' E	34° 49.861' S
3043	146° 30.231' E	34° 46.597' S	3095	146° 30.63' E	34° 50.876' S
3044	146° 30.326' E	34° 46.601' S	3096	146° 30.722' E	34° 50.898' S
3045	146° 30.136' E	34° 47.557' S	3097	146° 30.925' E	34° 49.879' S

3046	146° 29.714' E	34° 49.668' S	3098	146° 31.358' E	34° 47.709' S
3047	146° 29.502' E	34° 50.727' S	3099	146° 31.572' E	34° 46.637' S
3048	146° 29.597' E	34° 50.735' S	3100	146° 31.665' E	34° 46.655' S
3049	146° 29.809' E	34° 49.677' S	3101	146° 31.448' E	34° 47.743' S
3050	146° 30.23' E	34° 47.568' S	3102	146° 31.021' E	34° 49.884' S
3051	146° 30.447' E	34° 46.483' S	3103	146° 30.815' E	34° 50.911' S
3052	146° 30.542' E	34° 46.487' S	3104	146° 30.91' E	34° 50.92' S
3053	146° 30.326' E	34° 47.569' S	3105	146° 31.111' E	34° 49.912' S
3054	146° 29.903' E	34° 49.687' S	3106	146° 31.54' E	34° 47.765' S
3055	146° 29.691' E	34° 50.746' S	3107	146° 31.758' E	34° 46.671' S
3056	146° 29.787' E	34° 50.75' S	3109	146° 31.588' E	34° 48.008' S
3057	146° 29.997' E	34° 49.698' S	3108	146° 31.798' E	34° 46.955' S
3058	146° 30.42' E	34° 47.584' S	3110	146° 31.206' E	34° 49.925' S
3059	146° 30.633' E	34° 46.513' S	3111	146° 31.006' E	34° 50.925' S
9999	146° 30.739' E	34° 42.053' S			

Route: 9999, (**↑1770ft ASL→**), 2008,2009,2010,2011,2012,2013,2014,2015,2016,2017, 2018, 2019,2020,2021,2022,2023,2024,2025,2026,2027,2028,2029,2030,2031,2032,2033,2034,2035,2036, 2037,2038,2039,2040,2041,2042,2043,2044,2045,2046,2047,2048,2049,2050,2051,2052,2053,2054, 2055,2056,2057,2058,2059,2060,2061,2062,2063,2064,2065,2066,2067,2068,2069,2070,2071,2072, 2073,2074,2075,2076,2077,2078,2079,2080,2081,2082,2083,2084,2085,2086,2087,2088,2089,2090, 2091,2092,2093,2094,2095,2096,2097,2098,2099,2100,21001,2102,2103 → cross flight

→ cross flight(**1770ft ASL→):** 3008,3009,3010,3011,3012,3013,3014,3015,3016,3017,3018, 3019,3020, 3021,3022,3023, 3024,3025,3026,3027,3028,3029,3030,3031,3032,3033,3034,3035,3036,3037,3038, 3039,3040,3041,3042,3043,3044,3045,3046,3047,3048,3049,3050,3051,3052,3053,3054,3055,3056, 3057,3058,3059,3060,3061,3062,3063,3064,3065,3066,3067,3068,3069,3070,3071,3072,3073,3074, 3075,3076,3077,3078,3079,3080,3081,3082,3083,3084,3085,3086,3087,3088,3089,3090,3091,3092, 3093,3094,3095,3096,3097,3098,3099,3100,3101,3102,3103,3104,3105,3106,3107,3108,3109,3110, 3111, (↓) 9999.

APPENDIX D. 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.

Figure D-1. CT100 hand terminal.

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.

Figure D- 2. Data logger controller & cable adapter box

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 -

1. MSR16 (radiometer itself)
2. Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps)
3. CT100 (hand terminal, connected to the DLC with a serial cable)
4. Calibration stand and opal glass plate
5. Memory cards

6. Extension pole (with spirit level adjusted so that the top surface of the radiometer and the spirit level are par level)

SET UP

1. Mount the radiometer pole bracket on the pole and attach the radiometer.
2. Mount the spirit level attachment to the pole at a convenient viewing position.
3. Lean the pole against a support and adjust the radiometer so that the top surface of it is level
4. 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)
5. Attach the 9ft cable MSR87C-9 to the radiometer and to the rear of the MSR Cable Adapter Box (CAB)
6. Connect ribbon cables IOARC-6 and IODRC-6 from the front of the CAB to the front of the Data Logger Controller (DLC)
7. 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)
8. Mount the CT100 on the pole at a convenient position
9. 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

1. Perform once at the beginning of the experiment, or if the system completely loses power
2. Switch the CT100 power to on
3. Press ENTER 3 times to get into main menu
4. At Command * Press 2 then ENTER to get to the ReconFig. MSR menu
5. At Command * Press 1 then ENTER, input the correct date, Press ENTER
6. At Command * Press 2 then ENTER, input the correct time, Press ENTER
7. At Command * Press 3 then ENTER, input the number of sub samples/plot (5), Press ENTER
8. 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
9. At Command * Press 9 then ENTER, input the GMT difference, Press ENTER
10. At Command * Press M then ENTER until you return to the main menu

CALIBRATION

1. We are using the 2-point up/down calibration method
2. Calibrate everyday before you begin to take readings
3. Switch the CT100 power to on
4. Press ENTER 3 times to get into main menu
5. At Command * Press 2 then ENTER to get to the ReconFig. MSR menu
6. At Command * Press 11 then ENTER to get to the Calibration menu
7. At Command * Press 3 then ENTER to get to the Recalibration menu
8. At Command * Press 2 then ENTER for the 2-point up/down calibration
9. 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)
10. Place the separate opal glass plate on top of the upper surface and press SPACE to initiate scan
11. 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
12. CT100 will acknowledge that the recalibration was stored
13. At Command * Press M then ENTER until you return to the main menu
14. Return the radiometer to the pole bracket
15. Store configuration onto the memory card

MEMORY CARD USAGE

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

g. M. Main menu

5. 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.

APPENDIX E. OPERATING THE LAI-2000

Plug the sensor cord into the port labelled “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 144
- 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 × 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 × 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.

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 according to the archiving instructions later in this chapter.
14. Once you are 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 configured 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 your com port is, 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 then proceed with step 3 in the download instructions above. When finished and leaving HyperTerminal you will be prompted to save this connection.

APPENDIX F. TEAM TASKS SHEET

Table F-9-1. Soil moisture sampling task sheet (Team A and Team B)

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
HDAS	2.8km × 3.1km	250m	3 per point	All team members
Land Use	2.8km × 3.1km	250m	3 per point	All team members
Vegetation Type	2.8km × 3.1km	250m	3 per point	All team members
Vegetation Height	2.8km × 3.1km	250m	3 per point	All team members
Presence of Dew	2.8km × 3.1km	250m	3 per point	All team members
Gravimetric Soil Samples	2.8km × 3.1km	variable	Min. 3 per focus area	Team leader

Table F-2. Vegetation sampling task sheet (Team C)

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
Vegetation Destructive Sample	3km × 3km area	variable	5 per vegetation type	All team members
LAI	3km × 3km area	variable	5 per vegetation type	All team members
CROPSCAN	3km × 3km area	variable	5 per vegetation type	All team members
Vegetation Height	3km × 3km area	variable	5 per vegetation type	All team members
Row crop spacing	3km × 3km area	variable	5 per vegetation type	All team members
Row crop direction	3km × 3km area	variable	5 per vegetation type	All team members

Table F-3. Roughness sampling task sheet (Team E)

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
Surface roughness	3km × 3km area	variable	3 per surface type	All team members

Table F-5. Intensive sampling of forests task sheet (Team B)

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
Forest structure (dBH, height, LAI, etc.)	500m^2 area	70m	5	3 team members
Understory destructive sample	1m × 1m area	variable	3 per vegetation type	All team members
Tree destructive leaf samples	1 tree	variable	3 per tree at selected sites	1 team member
Soil moisture	Point measurement	70m	5	1 team member

Table F-6. Intensive sampling of crops task sheet (Team A)

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
Plant height	1m × 1m area	variable	1 per focus area	All team members
Stalk length	1m × 1m area	variable	1 per focus area	All team members
Stalk diameter	1m × 1m area	variable	1 per focus area	All team members
Stalk angle	1m × 1m area	variable	1 per focus area	All team members
Leaves angle (bottom, mid, top)	1m × 1m area	variable	1 per focus area	All team members
Leaves width, length & thickness	1m × 1m area	variable	1 per focus area	All team members
Nr of leaves per plant	1m × 1m area	variable	1 per focus area	All team members
1x stalk & 3x leaves biomass sample	1m × 1m area	variable	1 per focus area	All team members
Row crop spacing	1m × 1m area	variable	1 per focus area	All team members
Row crop direction	1m × 1m area	variable	1 per focus area	All team members
Nr plants per row	1m × 1m area	variable	1 per focus area	All team members
Soil moisture	1m × 1m area	variable	3 per focus area	All team members

APPENDIX G. SAMPLING FORMS

The following tables are the pro-forma sheets to be used for vegetation water content, gravimetric sampling and surface roughness.

Forest inventory form

Site ID:	Focus area:	Date:	Team:
Latitude/ Longitude:		Photo Ids:	
Understory type 1:	Height (cm)	Cover (%)	
Understory type 1:	Height (cm)	Cover (%)	

Plot #	Latitude	Longitude	
Tree No.	DBH (mm)	Height (m)	Crown height (m)

Plot #	Latitude	Longitude	
Tree No.	DBH (mm)	Height (m)	Crown height (m)

Forest destructive sampling form

Date:		Focus area:		Photo Ids:		Team:			
Sample ID	Local Time (hh:mm)	Latitude	Longitude	Specie	Tree height (m)	Wet weight (g)	Dry weight (g)	Tare (g)	VWC (kg/m^2)

* For drying use the same form as for crops

Vegetation sampling form

Local Date:				Focus Area					Team:				
Sample ID	Local Time (HH:MM)	Coordinate		Vegetation Type	Canopy Height (cm)	Row Spacing	Plant spacing	Row Direction	Number of Rows	Wet Weight before drying(g)	Dry Weight after drying (g)	Tare (g)	VWC (Kg/m^2)
		Lat.	Long.										
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												

Comments: 4. Label paper bag as Area_ID / DD Month YYYY / Sample_ID and time

Vegetation sample drying form

Local Date:												
Person making entry												
Sample ID	Oven ID		Weight before drying (g)				Oven In & Out Date (DD/MM/YY) and Time (HH:MM)				Weight after drying (g)	
	Oven #	Shelf #	Bag + Wet Sample	Bag #	Scale #	Tare (g)	Date in Oven	Starting time	Date out of oven	Ending time	Bag + dry samplem(g)	Tare (g)
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		
							/ /	:	/ /	:		

Comments:

Gravimetric soil moisture sample drying form

Local Date	DD / MM / YY	Focus Area ID:		Team ID.:	

Sample ID	Pre-Weighing (g)		Weight before drying (g)			Drying Date (DD/MM/YY) and Time (HH:MM)					Weight after drying (g)	
	Wet Sample + Bags	Operator Name	Wet Sample + Bags	Bags	Tray	Starting date	Starting time	Operator Name	Ending date	Ending time	Tray + dry sample	Operator Name
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		
						/ /	:		/ /	:		

Comments:

Surface Roughness Sampling Form

Local Date:			Focus Area ID		Name of Person		Team ID					
Sample ID	Local Time:	GPS Latitude	GPS Longitude	Land Cover*	Vegetation Type*	Row Direction**	Photo ID					
							N-S-1	N-S-2	N-S-3	E-W-1	E-W-2	E-W-3

*Select from the GETA list
**express in degrees from North clockwise

APPENDIX H. SAMPLING AREAS MAPS AND DIRECTIONS

Directions to get from the Yanco Agricultural Institute to the six SMAPEx focus areas:

FOCUS AREA YA4 – APPROX. DRIVING TIME (30MIN)

1. From The YAI, turn right on irrigation way and immediately left on Euroley Rd.
2. After approx 8km turn right left into Uroly Rd
3. After approx 5kmturn right into Sturt Hwy (20)
4. Continue on Sturt Hwy for approx. 20km
5. After having crossed the Coleambally Main Canal, turn left into Main Canal Rd
6. After approx 7km turn left into Wallace Rd
7. YA4 is west of Main Canal Rd. Wallace Rd crosses YA4 at middle latitude

FOCUS AREA YA7 – APPROX. DRIVING TIME (30MIN)

1. As per YA4 (point 1-5)
2. YA7 is west of Main Canal Rd., 1.5km south of Wallace Rd until Eulo Rd.

FOCUS AREA YC – APPROX. DRIVING TIME (45MIN)

1. As per YA4 (point 1-5)
2. Continue south on Main Canal Rd past Wallace Rd.
3. Turn left into unpaved Morundah Rd. (or Old Morundah Rd.)
4. YC is west of Morundah Rd., after approx. 8km from Main Canal Rd.

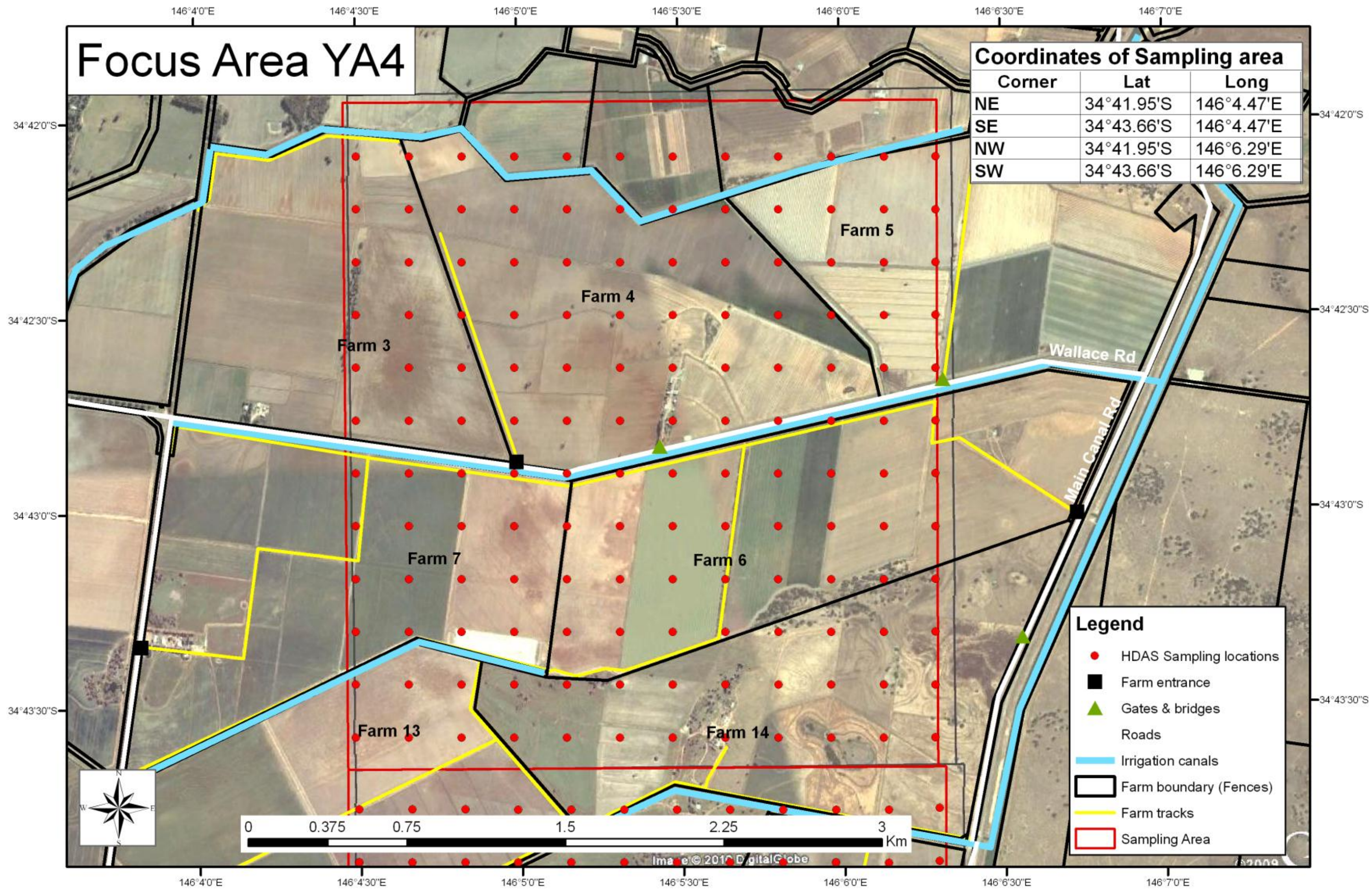
FOCUS AREA YD – APPROX. DRIVING TIME (50MIN)

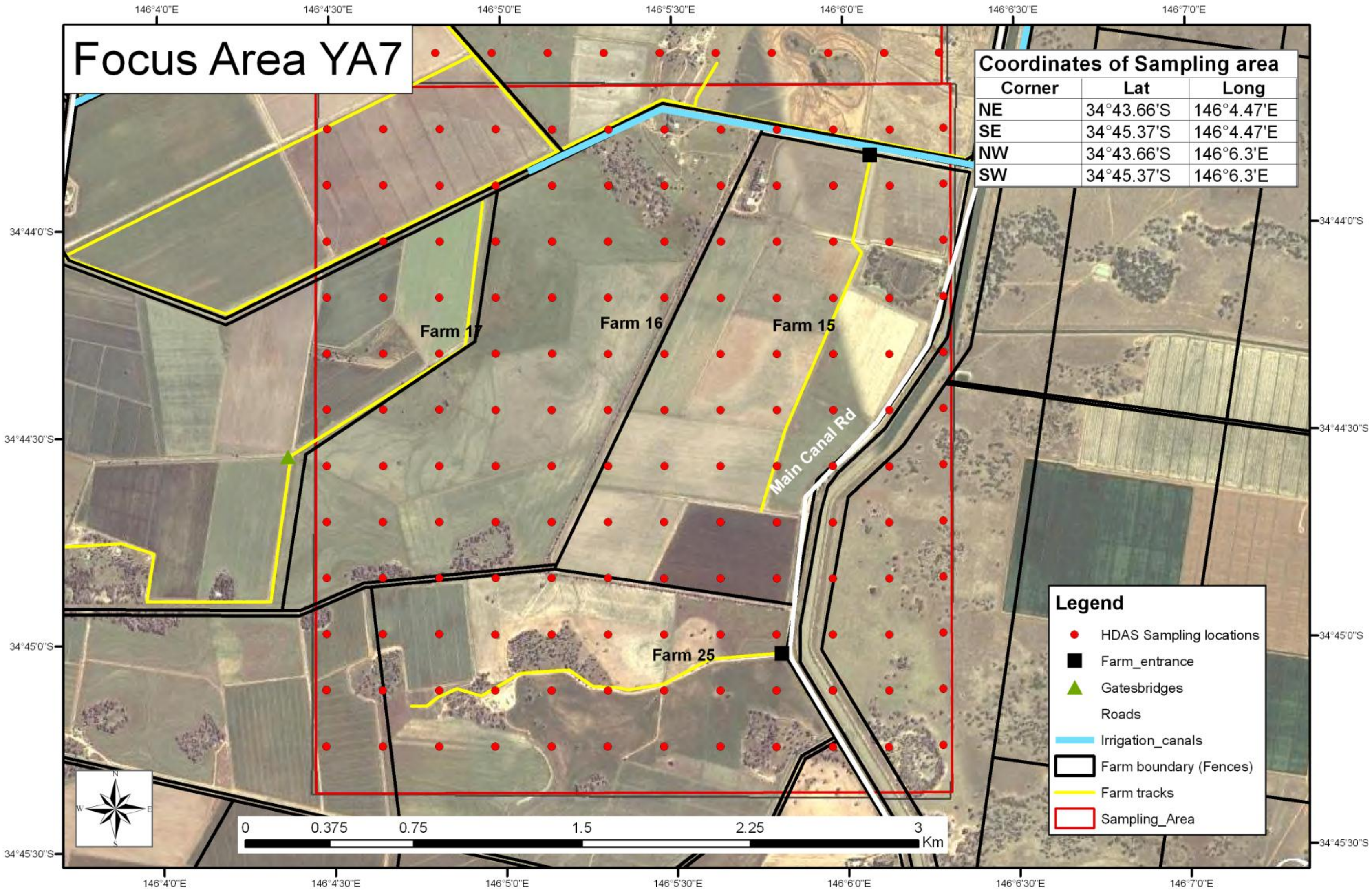
1. As per YA4 (point 1-5)
2. Continue south on Main Canal Rd past Wallace Rd.
3. After approx. 30km, pass Yamma Rd. and continue on Main Canal Rd., which turns into Gilber Rd.
4. After approx 7km, Gilber Rd. veers toward west (leaving Glenn Rd to the left) and enters YD from the east

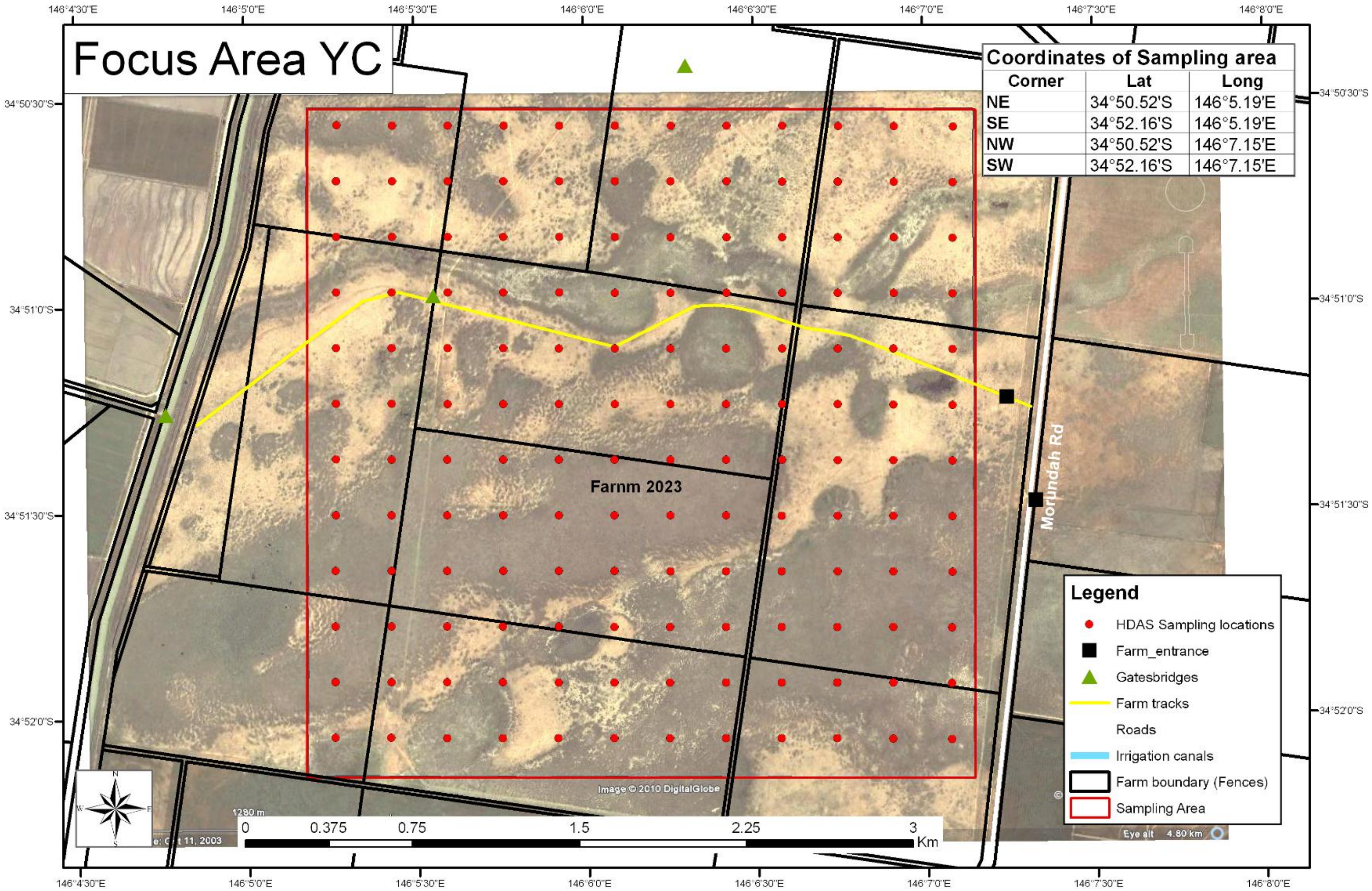
FOCUS AREA YB7 AND YB5 – APPROX. DRIVING TIME (60MIN)

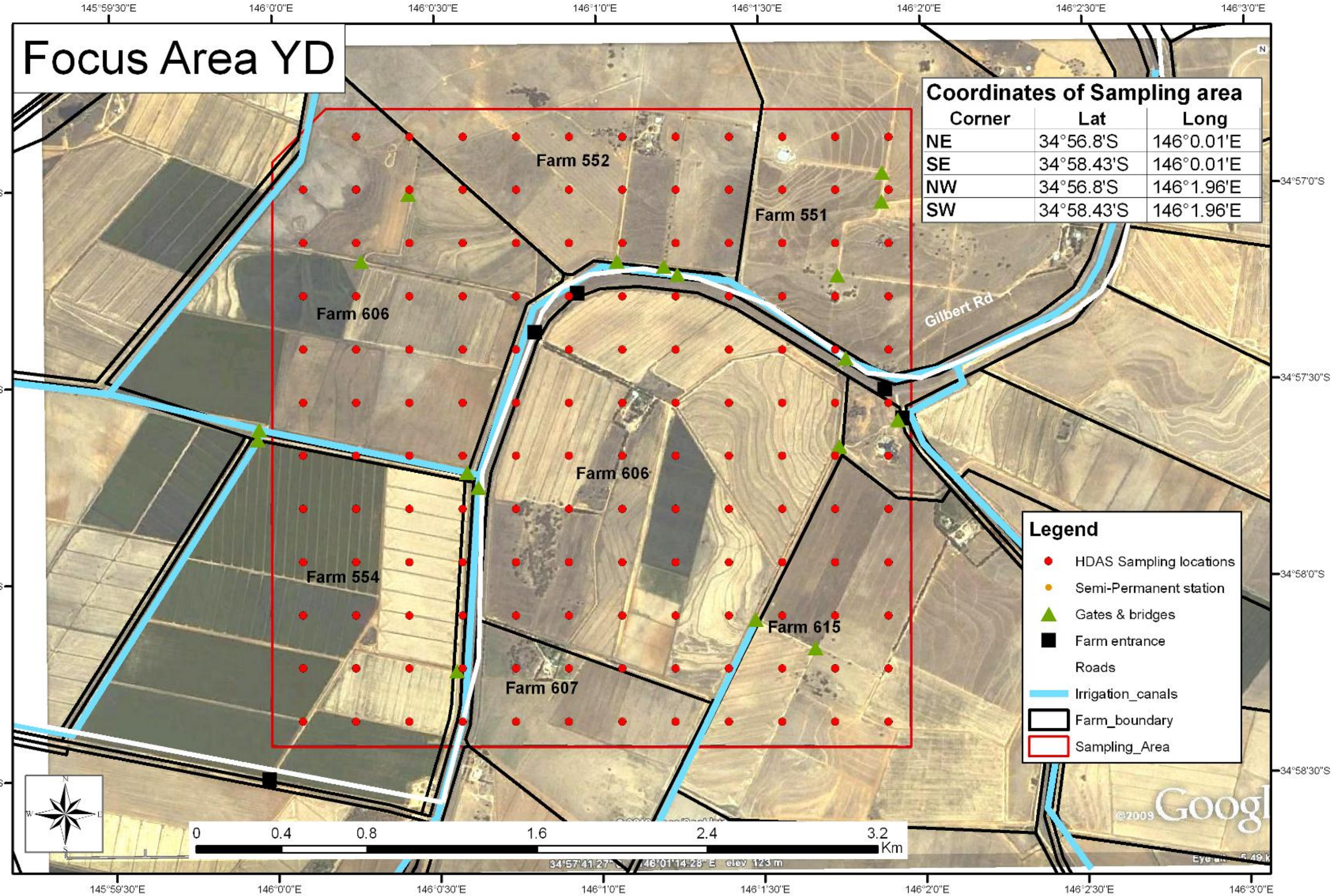
1. From The YAI, turn left on irrigation way towards Narrandera.

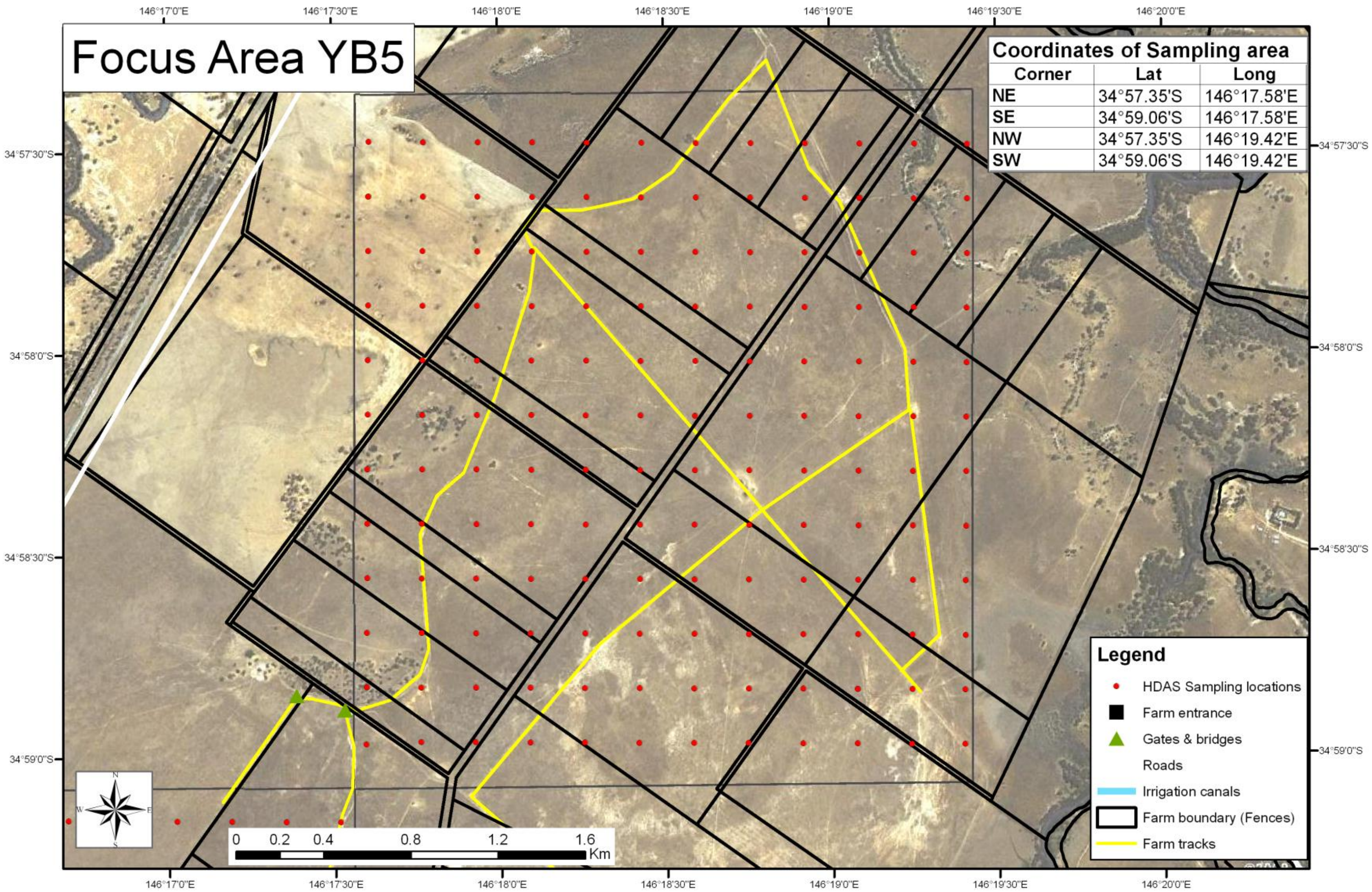
2. Once reached Narrandera (approx. 25km), turn right on Newel Highway
3. Continue on Newell Highway for approx. 35km until reaching the Morundah (notice big silos on the right side of the Rd.)
4. 100m before Morundah, turn left into Urana Morundah Rd.
5. After approx. 15km, look to the right of the road for sign "The Overflow"
6. At the overflow, turn right onto unpaved road with gate
7. Go through gate (please remember to close it behind you!) and follow the unpaved road over bridge
8. Go through Stockyards keeping the river flow on your right side
9. To get to YB7, turn left at the next gate after stockyards and continue westward on track for 2km, entering YB7 from the east. For YB5, go straight until the next gate after stockyard and follow the track along the river, entering YB5 from the south

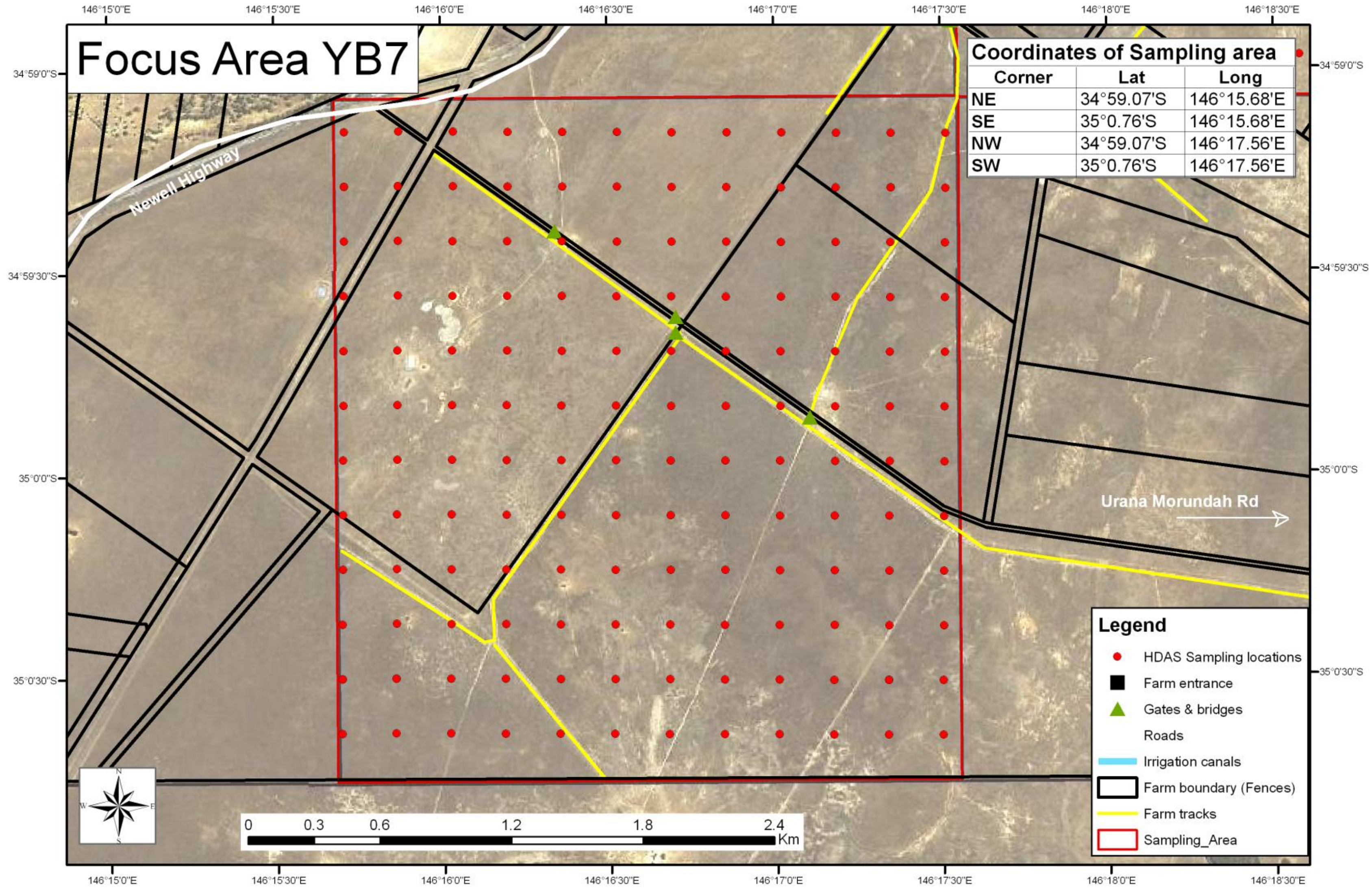

Focus Area YA4
Coordinates of Sampling area
Corner | Lat | Long
NE | 34°41.95'S | 146°4.47'E
SE | 34°43.66'S | 146°4.47'E
NW | 34°41.95'S | 146°6.29'E
SW | 34°43.66'S | 146°6.29'E
Farm 3
Farm 4
Farm 5
Farm 6
Farm 7
Farm 13
Farm 14
Wallace Rd
Main Canal Rd
Legend
HDAS Sampling locations
Farm entrance
Gates & bridges
Roads
Irrigation canals
Farm boundary (Fences)
Farm tracks
Sampling Area
0 0.375 0.75 1.5 2.25 3 Km
146°4'0"E
146°4'30"E
146°5'0"E
146°5'30"E
146°6'0"E
146°6'30"E
146°7'0"E
34°42'0"S
34°42'30"S
34°43'0"S
34°43'30"S


Focus Area YA7
Coordinates of Sampling area
Corner | Lat | Long
NE | 34°43.66'S | 146°4.47'E
SE | 34°45.37'S | 146°4.47'E
NW | 34°43.66'S | 146°6.3'E
SW | 34°45.37'S | 146°6.3'E
Farm 17
Farm 16
Farm 15
Farm 25
Main Canal Rd
Legend
HDAS Sampling locations
Farm_entrance
Gatesbridges
Roads
Irrigation_canals
Farm boundary (Fences)
Farm tracks
Sampling_Area
0 0.375 0.75 1.5 2.25 3 Km
146°4'0"E
146°4'30"E
146°5'0"E
146°5'30"E
146°6'0"E
146°6'30"E
146°7'0"E
34°44'0"S
34°44'30"S
34°45'0"S
34°45'30"S


Focus Area YC
Coordinates of Sampling area
Corner | Lat | Long
NE | 34°50.52'S | 146°5.19'E
SE | 34°52.16'S | 146°5.19'E
NW | 34°50.52'S | 146°7.15'E
SW | 34°52.16'S | 146°7.15'E
Farnm 2023
Morundah Rd
Legend
HDAS Sampling locations
Farm_entrance
Gatesbridges
Farm tracks
Roads
Irrigation canals
Farm boundary (Fences)
Sampling Area
0 0.375 0.75 1.5 2.25 3 Km
Image © 2010 DigitalGlobe
146°4'30"E
146°5'0"E
146°5'30"E
146°6'0"E
146°6'30"E
146°7'0"E
146°7'30"E
146°8'0"E
34°50'30"S
34°51'0"S
34°51'30"S
34°52'0"S


Focus Area YD
Coordinates of Sampling area
Corner | Lat | Long
NE | 34°56.8'S | 146°0.01'E
SE | 34°58.43'S | 146°0.01'E
NW | 34°56.8'S | 146°1.96'E
SW | 34°58.43'S | 146°1.96'E
Farm 552
Farm 551
Farm 606
Gilbert Rd
Farm 606
Farm 554
Farm 615
Farm 607
Legend
HDAS Sampling locations
Semi-Permanent station
Gates & bridges
Farm entrance
Roads
Irrigation_canals
Farm_boundary
Sampling_Area
0 0.4 0.8 1.6 2.4 3.2 Km
145°59'30"E 146°0'0"E 146°0'30"E 146°1'0"E 146°1'30"E 146°2'0"E 146°2'30"E 146°3'0"E
34°57'0"S 34°57'30"S 34°58'0"S 34°58'30"S


Focus Area YB5
Coordinates of Sampling area
Corner | Lat | Long
NE | 34°57.35'S | 146°17.58'E
SE | 34°59.06'S | 146°17.58'E
NW | 34°57.35'S | 146°19.42'E
SW | 34°59.06'S | 146°19.42'E
Legend
HDAS Sampling locations
Farm entrance
Gates & bridges
Roads
Irrigation canals
Farm boundary (Fences)
Farm tracks
0 0.2 0.4 0.8 1.2 1.6 Km
146°17'0"E
146°17'30"E
146°18'0"E
146°18'30"E
146°19'0"E
146°19'30"E
146°20'0"E
34°57'30"S
34°58'0"S
34°58'30"S
34°59'0"S



Coordinates of Sampling area

Corner	Lat	Long
NE	34°59.07'S	146°15.68'E
SE	35°0.76'S	146°15.68'E
NW	34°59.07'S	146°17.56'E
SW	35°0.76'S	146°17.56'E

APPENDIX I. SMAPEX FLYER

THE UNIVERSITY OF MELBOURNE

MONASH University

High-resolution Soil Moisture Measurement from Space

In 2013 NASA will launch a new satellite which will provide soil moisture measurements at unprecedented resolution (approximately 3km) for all Australia. In order to validate the soil moisture information provided by the NASA satellite, researchers at the University of Melbourne are planning to undertake an experiment in the Yanco area, and your farm has been selected as a ground validation sites of interest. The availability of soil moisture information at 3km resolution will have important implications in water resources management. It will allow better knowledge of the soil moisture distribution across farms and improved prediction of water availability and consequently will provide farmers with the ability to make better decisions for managing their water resources.

Fig. 1. Location of the Study Area (blue) and ground sampling areas (white) in the Colleambally district.

In order to make sure that the soil moisture information provided by the NASA satellite is accurate over Australia, researchers at the University of Melbourne are planning to make aircraft measurements of the surface soil moisture with instruments similar to those that will be onboard the satellites in the Yanco area. This is necessary to test this new measuring system in preparation of the future satellite data. Aircraft measurements
will be supported by ground measurement of the surface soil moisture content in carefully selected areas, together with a small number of soil and vegetation samples.

A total of four aircraft campaigns are envisaged over the next two years, covering the complete range of soil moisture and vegetation conditions experienced in the Yanco area. Airborne and ground measurements will be made across a 40km x 40km area including the Colleambally irrigation district and surrounding areas (Fig. 1). In return for granting us the access to your farm, you will have access to all the data collected in the campaigns. More importantly, you will contribute to the development of leading-edge technology needed in Australia to achieve a sustainable and efficient use of our natural resources.

The ground measurements undertaken on your farm will be completed by a small team of researcher in a few days for each campaign. In addition, we would like to install an additional 5 small semi-permanent monitoring stations on your farm to supplement the existing soil moisture stations we have operated since 2004, providing us with spatial information on soil moisture. Further details of the measurements to be made are given below for your information.

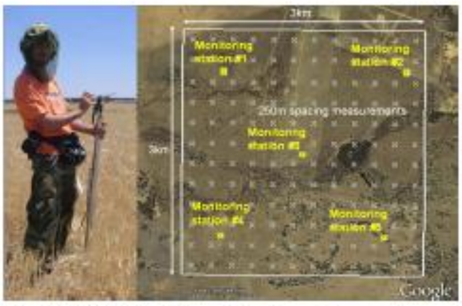


Fig. 2. Field technician with soil moisture probe and typical soil moisture sampling across a farm.

<u>**Ground Measurements of Surface Soil Moisture**</u>

This is the primary measurement we would like to make on your farm. It involves use of a non-destructive soil moisture probe, having four 5cm long tines that are stuck in the ground and measured using some electrical circuitry. No soil will be removed during this measurement. Using an integrated GPS, the field technicians will navigate to predefined sampling points at 250m spacing, covering a squared area of 3km x 3km size (Fig. 2).

Fig. 3. Typical vegetation sampling within a 40cm x40cm area and example of non-destructive spectral measurements

Vegetation Sampling

Vegetation sampling is required to determine the vegetation water content of the plants in order to estimate soil moisture from the aircraft and satellite. Assuming that vegetation conditions are relatively uniform across the sampling area, only five sampling locations will be required for each campaign. Both non destructive spectral measurements and complete removal of vegetation to ground level from within a 40cm x 40cm area (Fig. 3) will be required at each location. This will allow calibration of the spectral data for estimating the vegetation water content at other locations.

Semi-permanent Monitoring Stations

The semi-permanent monitoring stations will include a soil moisture sensor at the soil surface and three small soil temperature sensors at three depths of 1, 2.5 and 5cm (Fig. 4). The five stations will be uniformly distributed across the 3km x 3km sampling area. We hope to have these stations installed by September 2009, and keep them operating until at least after the satellite launch in 2013. Each station will occupy a minimal space, consisting of a small (10cm x 30cm) metallic mesh sitting on the ground to protect the sensors and a 3m high pole where the data logging system and solar panel will be mounted. The pole will be inserted 0.5m into the ground.

General Note on Property Access

Permission to access your property for these campaigns will be treated with the utmost respect, minimising any impact on the soil and vegetation. You will recall that our team undertook a similar ground monitoring campaign in your farm during the National Airborne Field Experiment 2006 (NAFE'06) and we hope to continue our good working relationship into the future. Moreover, all participants are intimately aware of the requirements for a good collaboration with local property owners and will be closely monitored during the planned campaign activities.

Contact Details

If you have further questions, please don't hesitate to contact us:

Professor Jeffrey Walker - Monash University
(Project Leader)
Ph: 03 9905 9681
Email: jeff.walker@eng.monash.edu.au

Dr. Rocco Panciera – The University of Melbourne
(Project Co-ordinator)
Ph: 03 8344 7560
Email: panr@unimelb.edu.au

Fig. 4. Set up of a typical semi-permanent station

APPENDIX J. SAFETY

Field Work Safety Form

Safety Briefing – Surveying Fieldwork

Please ensure all necessary paperwork has been completed prior to commencing the Fieldwork.
- EHS Field Work Form
- Off Campus Medical Questionnaire
- Risk Assessment

FIELDWORK SAFETY BRIEFINGS SHOULD BE CONDUCTED ON-SITE AND HELD DAILY TO ENSURE IMPORTANT INFORMATION CONCERNING EHS IS COMMUNICATED AND UNDERSTOOD BY ALL FIELDWORK PARTICIPANTS.

1. All Fieldwork participants should ensure an 'In case of Emergency' (ICE) number is stored in their mobile phone. (Name: ICE, Number: (Area Code) (Phone Number)
2. All participants should have access to a mobile phone. If a member of the group does not have a mobile phone then a 'buddy system' should be established.
3. Any participant who requires medication as declared on their Off Campus Medical Questionnaire, must ensure that they have sufficient amounts for the duration of the trip.
4. All Fieldwork participants must ensure that they have appropriate Personal Protective Equipment (as identified on the Risk Assessment)
5. All Participants should make themselves aware of the exact location (Street name, nearest cross-road, suburb etc) at which they are working each day. You will need this information if you have the need to contact any of the Emergency Services.
6. A First Aid procedure should be in place. If a First Aid Officer is unavailable to attend the trip then alternative arrangements such as, familiarizing yourself with the local medical facilities, is vital.
7. Continuous communication shall be established at all times of the Fieldwork. This can be verbal/visual – staying within sight and hearing distance of the group or via communication devices – mobile phones, 2-way radios etc. Alternative arrangements can be set up if appropriate.
8. If an incident occurs, all participants must take the following action:
   a. Assess the medical requirements
   b. If serious, call the emergency services (000 or 112 from mobile phones) for assistance
   c. Notify the individual's contact person (their ICE contact)
   d. Complete an S3 Incident report as soon as possible
   e. Notify the Supervisor of the Incident as soon as possible
10. If a dangerous situation (natural disaster, personal threat, animal presence) occurs and you believe you need to evacuate the area, take the following action:
    a. Remove any persons from immediate danger
    b. Notify all members of the group for the need to leave the area
    c. Contain or eliminate the problem, if possible
    d. Evacuate yourself and others if you cannot contain the problem
11. Remember to adopt safe work practices and look out for each other
12. All participants are responsible for their own health and safety and that of others who may be affected by their conduct, including members of the public.
13. If there is something you are not sure of, seek clarification from your Supervisor before commencing the task
14. Do not operate/use equipment that you are not familiar with
15. Ensure appropriate clothing is worn AT ALL TIMES when required, this includes, enclosed footwear, High-visibility vests, sunscreen, hats, long sleeved, long legged clothing etc.
16. Ensure water and snacks are available at all times
17. Conduct regular rest breaks
18. Report any unsafe conditions or hazards to your Fieldwork Supervisor
19. Treat all other members of Fieldwork with respect and courtesy
20. Clean up after yourselves – leave the Fieldwork environment in the same (or better) condition than when you arrived.
21. Notify all members of any planned rest breaks or lunch breaks and where your meeting spot is, i.e. the car, the café etc
22. Work hard and have fun!

APPENDIX K. HOW TO PREVENT SNAKE BITES GUIDELINES

Step 1

Prior to your hike, familiarize yourself with the local species of snakes: knowing their habits and habitats may help you avoid coming into contact with them unexpectedly. Plan your route in advance and let someone know where you will be located in case of an emergency.

Step 2

For your hike, wear heavy, knee-high socks, high-top boots, and long pants tucked into your shoes. Stay on the trail, if one is available and keep out of tall grass unless you wear thick leather boots, chaps or gaiters. Walk around logs or large stones, instead of stepping over them.

Step 3

During your hike, bang a walking stick against the ground. The vibrations will coax the snake out of your path. Take special care not to reach or step into places that you cannot see and be especially careful when climbing rocks, whose crevices may house quiet, venomous tenants.

Step 4

If you come across a snake, stay as far away from it as possible. at least six feet or more than the snake's body length. If you find yourself close to a snake, take at least two giant steps back. Leave the snake alone as they can strike much faster and farther than most people think. Stay away even from dead snakes because their reflexes can still cause a bite for an hour after death.

Step 5

When you make camp, do so on open ground. Check the area for likely hiding places such as rock piles, holes or empty burrows. And don't collect firewood (especially after dark) with your bare hands; instead, break a piece away from the pile with a long stick. Each night, zip your tent firmly closed and ensure that your sleeping bags are snake-free before entering them.

Read more: How to Prevent Snakebites While Hiking | eHow.com

http://www.ehow.com/how_2279574_prevent-snakebites-hiking.html#ixzz0rRUq1Qjk

http://www.ehow.com/how_2282699_prevent-snakebites-camping.html

Snake Bites First Aid Instructions

First in First Aid

St John

SNAKE BITES

MANAGING A SNAKE BITE

1) Check for signs of life:

- if casualty is unconscious, follow DRABCD (Danger, Response, Airway, Breathing, CPR, Defibrillation).

2) Calm casualty.

3) Apply pressure immobilisation bandage:

- apply a firm roller bandage starting just above the fingers or toes and moving up the limb as far as can be reached
- the bandage needs to be very firm.

4) Immobilise casualty:

- apply a splint to immobilise the bitten limb
- check circulation in fingers or toes
- ensure casualty doesn't move.

5) Call 000 for an ambulance.

SIGNS & SYMPTOMS

- puncture marks
- nausea, vomiting, diarrhoea
- headache
- double or blurred vision
- breathing difficulties
- drowsiness, giddiness
- pain or tightness in chest or abdomen
- respiratory weakness or arrest.

WARNING

Do not wash venom off the skin as retained venom will assist identification.

Do not cut bitten area or try to suck venom out of the wound.

Do not use a constrictive bandage (i.e. arterial tourniquet).

Do not try and catch the snake.

*Carry the **Bites and Stings** first aid kit with you when camping or bushwalking. Call St John on 1300 360 455 for further information about the full range of first aid kits.*

For more information on St John first aid training and kits, visit www.stjohn.org.au or call Toll free 1300 360 455.