The Fourth
Soil Moisture Active Passive Experiment
WORKPLAN

Nan Ye, Jeffrey Walker, Christoph Rüdiger, Thomas Jackson, Xiaoling Wu, Richard de Jeu, Dara Entekhabi, Olivier Merlin, Edward Kim, and Luigi Renzullo

April 2015

CONTENT

1. OVERVIEW AND OBJECTIVES

The Soil Moisture Active Passive Experiment (SMAPEx) comprises five campaigns across an approximately six year timeframe. The overall objective of SMAPEx project is to develop algorithms and techniques to estimate near-surface soil moisture from the Soil Moisture Active Passive (SMAP) mission developed by the National Aeronautics and Space Administration (NASA), and validate SMAP brightness temperature observations and downscaled soil moisture products after its launch. This will involve collecting airborne SMAP-type data together with ground observations of soil moisture and ancillary data for a diverse range of conditions. The first three were for SMAP pre-launch soil moisture retrieval and downscaling algorithm development, while the last two are for post-launch verification.

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). The third campaign (SMAPEx-3) was conducted in the austral spring from 5-23 September, 2011. Moderate rainfall (35mm) was experienced in the study area the week before the experiment started, while some showers (up to 4mm) were registered during the first week. This led to soil moisture values varying from 0.02-0.32m^3/m^3 in grazing areas and from 0.03-0.46m^3/m^3 in crops across the three weeks of experiment.

The fourth campaign (SMAPEx-4) will take place at the beginning of SMAP operational phase. SMAPEx-4 will take place in the austral autumn from 30 April - 23 May, 2015. Based on historical data records, it is expected to experience an increasing of soil moisture and vegetation biomass during the three week long experiment. A particular objective of the fourth experiment is to acquire airborne microwave observations and ground sampling data concurrent with the overflight of the Soil Moisture Active Passive (SMAP) satellite for the purpose of calibration and validation of the SMAP products.

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, the SMAP Validation Experiment 2008 & 2012 (SMAPVEX08, SMAPVEX12), the San Joaquin Valley 2010 Field Campaign (SJV10), and the Canadian Experiment for Soil Moisture 2010 (CanEx-SM10).

The SMAPEx campaigns have been made possible through infrastructure (LE0453434, LE0882509) and research (DP0984586, DP140100572) 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, as well as improved climate change predictions 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 (1~2 GHz) 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 developed 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 observations from the radar, and the more accurate but low resolution (40km) observation from the radiometer will be used synergistically to produce a high accuracy and improved spatial resolution (10km) soil moisture product with a 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-2), 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, suitable algorithms and techniques have been developed from pre-launch airborne field campaigns such as SMAPEx-1 to 3. To ensure an accurate, high resolution soil moisture product, from combined SMAP radar and radiometer data, it is essential that field campaigns with coordinated satellite, airborne and ground-based data collections are undertaken, giving careful consideration to the diverse data requirements for the range of scientific questions to be addressed. The SMAPEx-4 and -5 are designed to address these scientific requirements. After completion of the SMAP commissioning phase (first three months after launch), SMAP will start providing soil moisture products at 3km, 9km, and 36km resolutions. Consequently, airborne field campaigns are designed to closely follow the completion of the commissioning phase.

The SMAPEx campaigns stem from the availability of a new airborne remote sensing capability, which allows us to have a sensor combination on a single aircraft, providing high resolution active and passive microwave remote sensing capabilities at L-band with characteristics that replicate SMAP. The facility includes the Polarimetric L-band Multi-beam Radiometer (PLMR) and the Polarimetric L-band Imaging Synthetic aperture radar (PLIS).

1.2 Objectives

The main objective of SMAPEx-4 is to collect airborne active and passive microwave data, ground observations of soil moisture, and ancillary data needed for soil moisture retrievals in coincidence with SMAP coverage, providing microwave observation and soil moisture references for SMAP in-orbit validation.

The SMAPEx-4 data sets will provide multi-temporal data to:

- Evaluate SMAP active-passive downscaled 9km brightness temperatures using PLMR brightness temperature observations.
- Compare PLMR brightness temperature and PLIS backscatter observations with SMAP radiometer and radar observations respectively.
- Inter-compare between PLMR, SMAP, Aquarius, and SMOS brightness temperature observations.
- Validate SMAP radiometer (SM_P), radar (SM_A), and radar/radiometer (SM_AP) soil moisture retrieval algorithms using:
    - Coarse and dense monitoring network (OzNet & SMAPEx sites);
    - Airborne soil moisture retrieval results (SMAPEx campaigns).
- Develop radar only soil moisture retrieval algorithm.

1.3 General approach

SMAPEx comprises a total of five airborne campaigns in the Yanco study area within the Murrumbidgee catchment (see Figure 1-1), in south-eastern Australia. The five campaigns are planned to span across an approximately six year timeframe to encompass seasonal variation in soil moisture and vegetation. The first three campaigns (SMAPEx-1 to -3) have been conducted in the austral winter, 2010, summer 2010, and spring 2011. The fourth and fifth campaigns will take place in the austral autumn and spring in April/May and September/October 2015, respectively. Moreover,

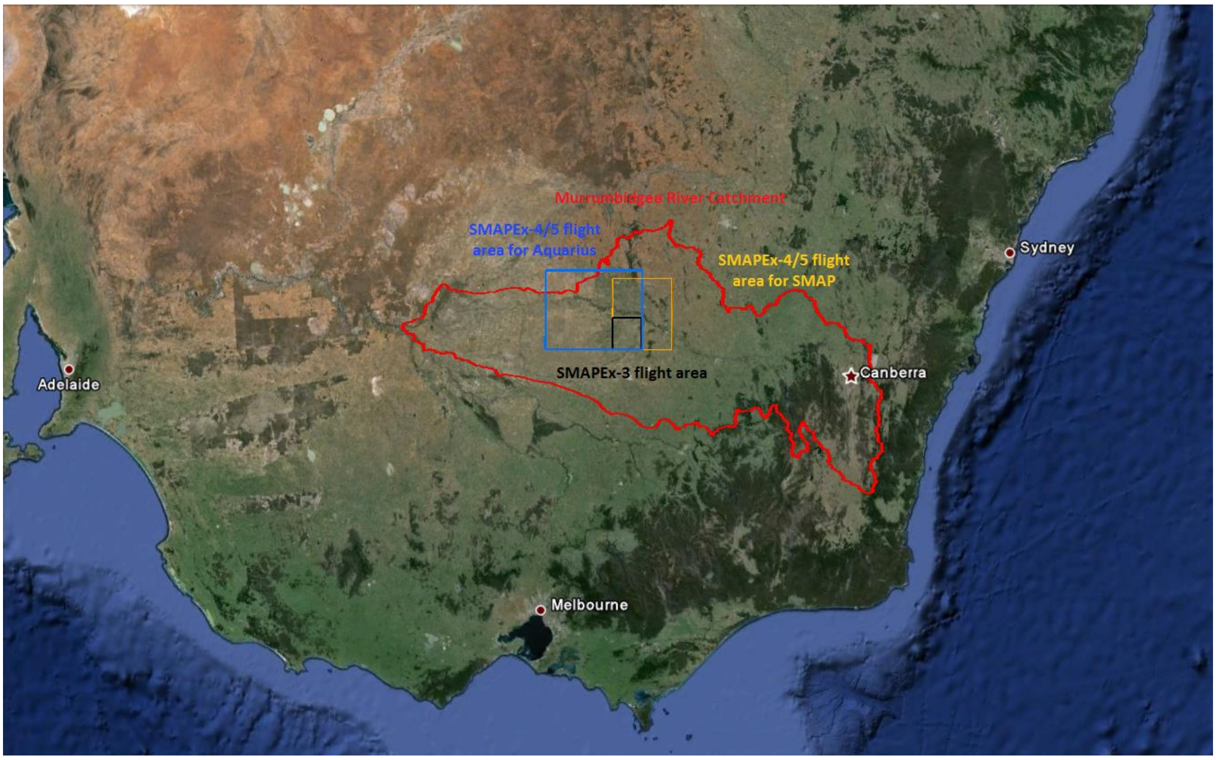

Figure 1-1. Location of the SMAPEx study area within the Murrumbidgee catchment.

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. Specifically, the fourth and fifth campaigns focus on post-launch calibration and validation of the SMAP.

The primary aircraft instruments are 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°. The flight lines have been designed to have full PLMR coverage over at least one entire SMAP 3-dB footprint from each of three different obits/imaging geometries, and have more than 50% PLMR coverage over an Aquarius 3-dB footprint. All flights will be operated out of Narrandera Airport, with the ground team undertaking daily activities at the ground sampling areas shown in Figure 1-2 and Figure 1-3. The operations base is the Yanco Agricultural Institute, providing both lodging and laboratory support.

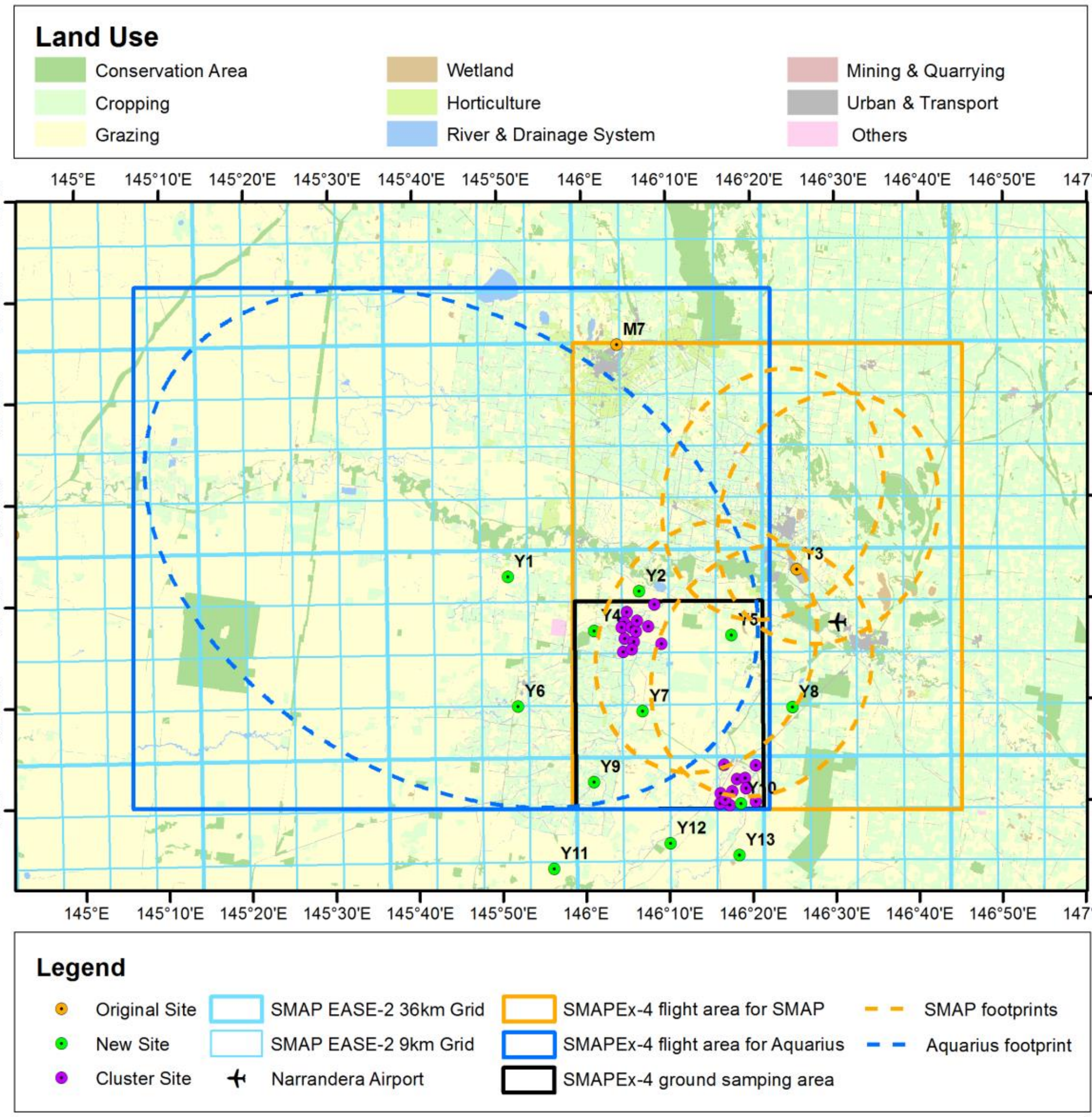

Figure 1-2. Overview of the SMAPEx-4 experiment. The map shows the area covered by airborne mapping (orange rectangle for SMAP 3dB footprints and blue rectangle for Aquarius 3dB footprint), the ground soil moisture networks (coloured dots), and SMAP grids for radiometer (36km) and active-passive (9km) products (light blue grids).

Data collected during SMAPEx-4 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 35 permanent stations across the study area. Of these stations, 11 will also provide profile (0-90cm) soil moisture and soil temperature data;
- 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.

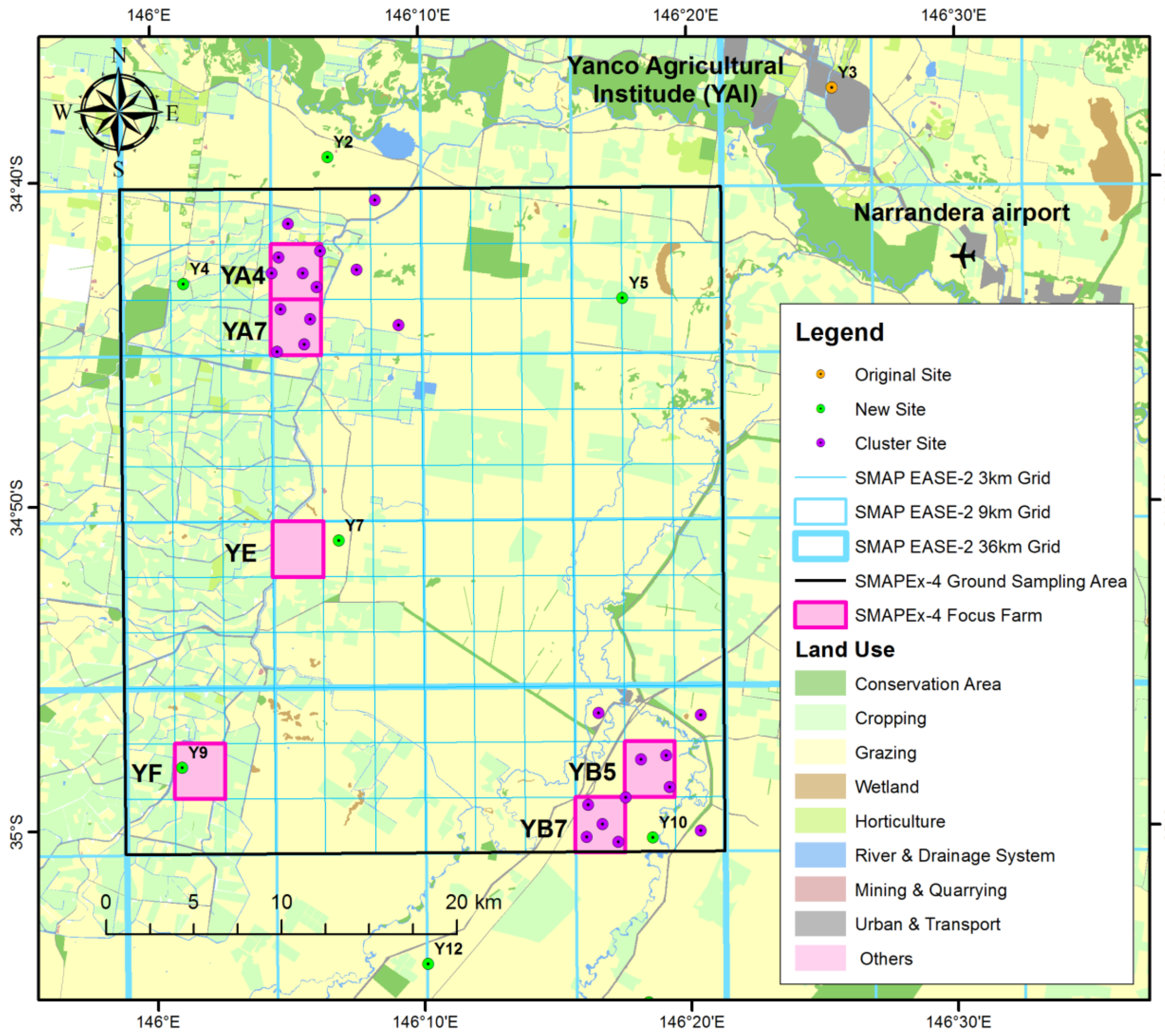

Figure 1-3. Overview of the SMAPEx-4 ground sampling areas. The map shows ground sampling focus areas (pink rectangle) and SMAP grids for radiometer (36km), radar (3km), and active-passive (9km) products (light blue grids).

Taking advantage of the SMAPEx-4 experiment set-up, a set of add-on measurements will also be acquired:

- intensive sampling for radar algorithm development;
- regional soil moisture across the ground sampling area; and
- high resolution soil moisture maps over a 3km × 3km focus area, using vehicle-based sensors including GNSS-R sensor, L-band radiometer, multispectral sensors, thermal infrared sensor, ElectroMagnetic Induction (EMI) sensor and ElectroMagnetic (EM38) soil mapping.

The airborne and ground monitoring strategy will follow a “nested grid” approach based on the SMAP grids (see Figure 1-2 and Figure 1-3). Airborne data will be collected over an area conservatively covering a complete SMAP radiometer 3dB footprint (SMAP L1B_TB product, 39 km by 47km) for a total of 9 dates over a 3-week period. The flight area will completely contain four SMAP radiometer pixels (SMAP L1C_TB product, 40 km by 40 km nominal resolution). Continuous ground permanent monitoring sites will cover an entire SMAP radiometer pixel at the southwest corner, but with a denser network in two sub-areas representing pixels of the SMAP downscaled soil moisture product (SMAP L3_SM_A/P product, 9 km by 9 km). Intensive spatial monitoring will concentrate on six focus areas equivalent to a SMAP radar pixels (L1C_HiRes product, 3km × 3km). This design will allow comparing SMAP products over the Yanco study area to airborne observations aggregated 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 the second version of Equal-Area Scalable Earth (EASE-2) 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 36 km × 36 km 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 SMAPEx-4 ground sampling area was designed based on the SMAP EASE-1 grid which results in a 9 km gap in north-south direction to the closest 36 km × 36 km SMAP EASE-2 pixel. Nevertheless, SMAP will produce data on a range of 36 km grid with 3 km step which keeps a high level of consistency between the SMAP data and SMAPEx observations.

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 m^3/m^3 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 has been launched on 31st January 2015 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. One of totally nine flights is designed over an extended flight area covering the main part of an Aquarius radiometer footprint (Figure 1-2). This flight is planned to be undertaken on the day when the coverage of Aquarius, SMAP, and SMOS will be available, in order to validate Aquarius radiometer observations and inter-compare radiometer observations between three missions. Each of flights for SMAP validation is planned in coincidence with the coverage of both SMAP radiometer and radar so that SMAP active-passive products will be available to compare with SMAPEx observations.

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/SMAP, and with a longer repeat time (7 days). The science instruments 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 10th June 2011, into a sun-syncronous orbit, with an estimated 3-years lifetime. The flight for Aquarius validation is planned on 12th May 2015 to be undertaken with the coverage of Aquarius and SMAP, in order to validate Aquarius radiometer observations and compare radiometer observations with SMAP.

Soil Moisture and Ocean Salinity (SMOS)

The SMOS (http://www.esa.int/esaLP/LPsmos.html) satellite was launched on 2nd 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 used 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 are projected onto a fixed hexagonal grid with an approximately 12km node separation. While the actual footprint size varies 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), and in this project SMOS data over the SMAPEx-4 flight areas will be used to inter-compare with SMAP, Aquarius, and airborne brightness temperature observations and soil moisture retrievals.

Phased Array type L-band Synthetic Aperture Radar 2 (PALSAR-2)

The PALSAR-2 (http://www.eorc.jaxa.jp/ALOS/en/) is an active microwave sensor aboard the Advance Land Observing Satellite-2 (ALOS-2, http://global.jaxa.jp/projects/sat/alos2). 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 on 24th May 2014 into a sun-synchronous orbit at the altitude of 628km, providing a spatial resolution of 10m for the fine resolution mode (swath width of 70km) and 100m for the ScanSAR mode (swath width of 350km). The repeat cycle is 14 days and the local time at descending node was about 12:00pm. PALSAR-2 data for the SMAPEx campaigns will be requested by collaborators in Tokyo University, Japan.

Advanced Microwave Scanning Radiometers 2 (AMSR-2)

The AMSR-2 (http://suzaku.eorc.jaxa.jp/GCOM_W/w_amsr2/whats_amsr2.html) sensor is a passive microwave radiometer operating at 7 channels ranging from 6.925 to 89.0GHz, with an additional channel at 7.3GHz for RFI mitigation compared with its predecessor AMSR-E. Both horizontally and vertically polarized radiation are measured at each frequency with a nominal incidence angle of 55°. The ground spatial resolution at nadir is 62km × 35km for the 6.925GHz and 7.3GHz channels (C-band). The AMSR-2 is on board GCOM-W1 satellite, which was launched on 18th May 2012. It has a 1:30am/pm equator crossing orbit with 1-2 day repeat coverage. Several surface soil moisture products are available globally. AMSR-2 high frequency data with a resolution as high as 3km x 5km will be tested to downscale space-borne L-band brightness temperature observations and soil moisture products. AMSR-2 brightness temperature data can be downloaded free of charge.

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. The possibility of downscale space-borne L-band brightness temperature observations and soil moisture products using WindSat data will be tested.

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-A 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 25km resolution soil wetness product is now operational from ASCAT, available from EUMETSAT (http://www.eumetsat.int/).

Sentinel

Sentinel (https://sentinel.esa.int/web/sentinel) is a series of seven missions developed in the framework of ESA's Copernicus Earth observation programme. Copernicus is the Global Monitoring for Environment and Security (GMES) programme, providing accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security. Each Sentinel mission is based on a constellation of two satellites to fulfil revisit and coverage requirements, monitoring different aspects of land, ocean and atmosphere by applying a range of technologies, such as radar and multi-spectral imaging instruments. To date the first satellite of Sentinel 1 mission has been launched on 3rd April 2014, which provides radar observations in Interferometric Wide swath mode (250 km swath and 5 x 20 m resolution), Wave mode (20 x 20 km data at two different incidence angles every 100 km), and potentially Stripmap (80 km swath and 5 x 5 m resolution) and Extra Wide Swath (20 x 40 m resolution) modes.

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.

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 120 m) regions of the electromagnetic spectrum. These data have an approximately 16 day repeat cycle with a 10:00am local Equator crossing time. These data are 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 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), which are still in operation, they are being increasingly relied upon. The approximate scene size is 170 km by 183 km.

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

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.

Himawari-8

Himawari-8 (http://www.data.jma.go.jp/mscweb/en/himawari89/index.html) is a next-generation geostationary meteorological satellite developed by the Japan Meteorological Agency (JMA). It has been launched on 7 October 2014 and scheduled to start operate in 2015 as a replacement for MTSAT-2 (also called Himawari-7). The following Himawari-9 will be launched in 2016 as a backup and successor satellite. Both satellites will be located at around 140 degrees east, and will provide multispectral observations in the East Asia and Western Pacific regions for a period of 15 years. The only payload Advanced Himawari Imager (AHI) has visible (3 bands with 0.5 km – 1 km resolution), near infrared (1 band with 1km resolution), short wavelength infrared (2 bands with 2 km resolution), mid wavelength infrared (4 bands with 2 km resolution), and thermal infrared (6 bands with 2 km resolution) bands, with a temporal resolution of better than ten minutes.

3. AIRBORNE AND GROUND-BASED OBSERVING SYSTEMS

During SMAPEx-4, airborne measurements will be made using a small single engine aircraft. The 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 multispectral (~1km) observations to be made across large areas.

3.1 Aircraft

The aircraft (see Figure 3-1 and Figure 3-2) can carry a typical science payload of up to 250kg (120kg for maximum range) with cruising speed of 150-270 km/h and range of 9 hrs 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.

Aircraft 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

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

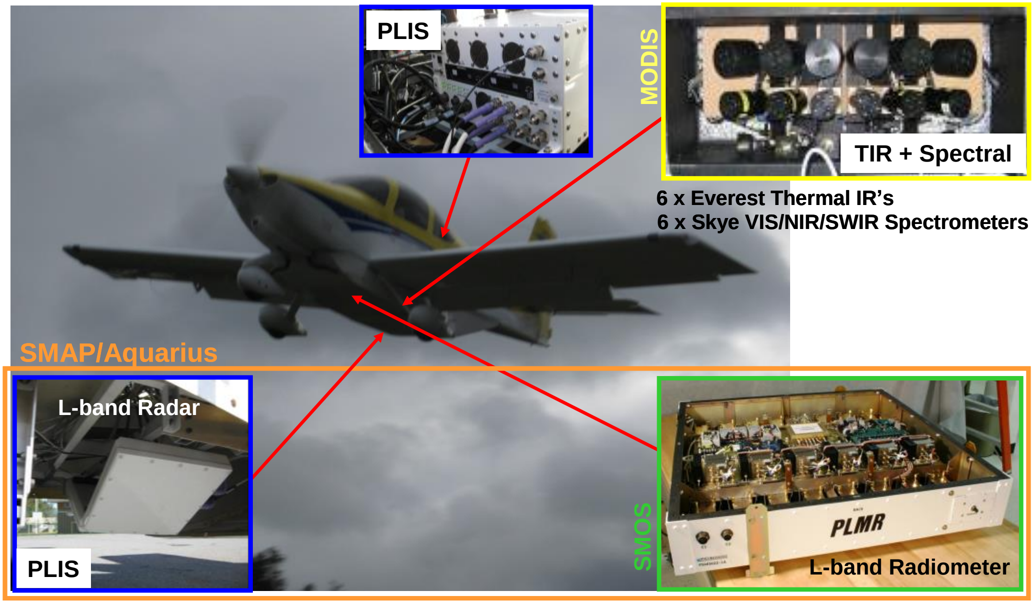

Figure 3-2. View of PLIS antennas, PLIS RF unit, PLMR and the multispectral unit.

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.

3.2 L-band microwave sensors

Passive: Polarimetric L-Band Multibeam Radiometer (PLMR)

The PLMR (see Figure 3-3) measures both V and H polarisations using a single receiver with polarisation switch at incidence angles ±7°, ±21.5° and ±38.5° in either across track (push broom) or 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 centre frequency of 1.413GHz and bandwidth of 24MHz, with specified NEDT and accuracy better

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

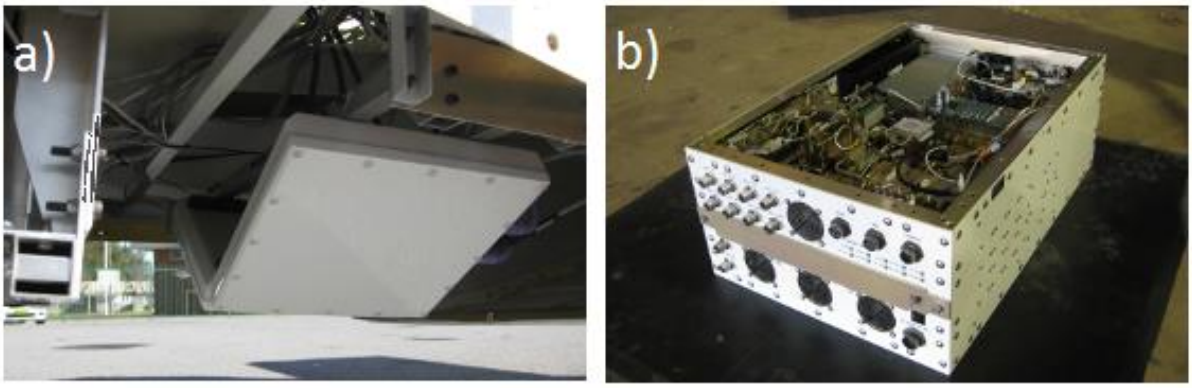

Figure 3-4. View of PLIS antennas (a) and RF unit (b)

than 1K for an integration time of 0.5s, and 1K repeatability over 4 hours. It weighs 46kg and has a size of 91.5 cm by 91.5 cm by 17.25 cm. The calibrations are performed before, during and after each flight. The before and after flight calibrations are achieved by removing PLMR from the aircraft and making brightness temperature measurements of a calibration target and the sky. The in-flight calibration is accomplished by measuring the brightness temperature of a water body (Lake Wyangan).

Active: Polarimetric L-band Imaging Synthetic aperture radar (PLIS)

PLIS is an L-band radar which can measure the surface backscatters at HH, HV, VH, and VV polarisations (see Figure 3-4). 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 (No interferometry flight was planned for SMAPEx-4). The antenna's two-way 6-dB beam width is of 51°, and the antenna gain is 9 dBi ± 2 dB. In the cross-track direction, the antenna gain is within 2.5 dB of the maximum gain between 15° and 45°. PLIS has an output frequency of 1.245-1.275 GHz with a peak transmit power of 20 W. The instrument can radiate with a pulse repetition frequency of up to 20 kHz and pulse width of 100 ns to 10 µs. The minimum detectable Normalized Radar Cross Section is -45 dB for the main antenna. Each antenna has a size of 28.7 cm by 28.7 cm by 4.4 cm and weighs 3.5 kg. At the start and end of SMAPEx-4, PLIS will be calibrated using six Polarimetric Active Radar Calibrators (PARCs) located close to the airport. During each flight, PLIS will be also calibrated using six Passive Radar Calibrators (PRCs) and forest as absorber within the study area. During the SMAPEx-1 to 3, the accuracy of PLIS was ~0.9 dB after calibration using Passive Radar Calibrators.

3.3 Multi-spectral sensors

Thermal infrared radiometer

During airborne flights there will be six thermal infrared radiometers (see Figure 3-5). The thermal infrared radiometers are the 8.0 to 14.0nm 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

Figure 3-5. Optical sensor box with 12 multi-spectral radiometers (two upper rows indicated by blue box) and 6 thermal infrared radiometers (bottom row indicated by red box)

observations. The nominal relationship between voltage (V) and temperature (T) given by the manufacturer is V = 1.42857 + (0.03571428*T).

Visible/near infrared and short-wave infrared radiometers

Multispectral measurements are made using arrays of 15° FOV Skye 4-channel sensors (Figure 3-5), 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, 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
Channel 3	MODIS Band 7	2105 – 2155nm
Channel 4		2206 – 2216nm

Visible cameras

A high resolution digital SLR camera and a digital video camera are available to the campaign (Figure 3-6). However, only the digital camera will be used.

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

Figure 3-6. Canon EOS-1DS Mark 3 (left), video camera (centre), and FLIR A65 thermal infrared camera (right).

× 1080 (2.1 MegaPixel) resolution and 10× optical zoom. The optical photos will be collected only over ground sampling area (Figure 1-3). Also available is a HD-6600PRO58 wide angle conversion lens to provide full swath coverage of PLMR.

The FLIR A65 is a compact thermal infrared (7.5 – 13 μm) camera measuring temperatures between –40°C and +550°C. It has 45° x 37° Field-Of-View and provides 640 x 512 pixels resolution temperature observations with an accuracy of ±5°C. The FLIR A65 will be installed on the aircraft and used to map soil temperature during each flight.

4. STUDY AREA

SMAPEx-4 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 campaigns dedicated to the SMAP pre-launch campaigns: the SMAP Experiment 1 to 3 (SMAPEx-1 to 3, http://smapex.monash.edu) and 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 (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.

Due to its distinctive topography, the Murrumbidgee catchment exhibits a significant spatial variability in climate, topography, soil, vegetation and land cover. Due to the diversity within this confined area, the large amount of complementary data from long-term monitoring sites, and the past airborne field experiment, this region is an ideal test bed for the comprehensive validation of SMAP described here, and is highly complementary to the current study sites in other countries.

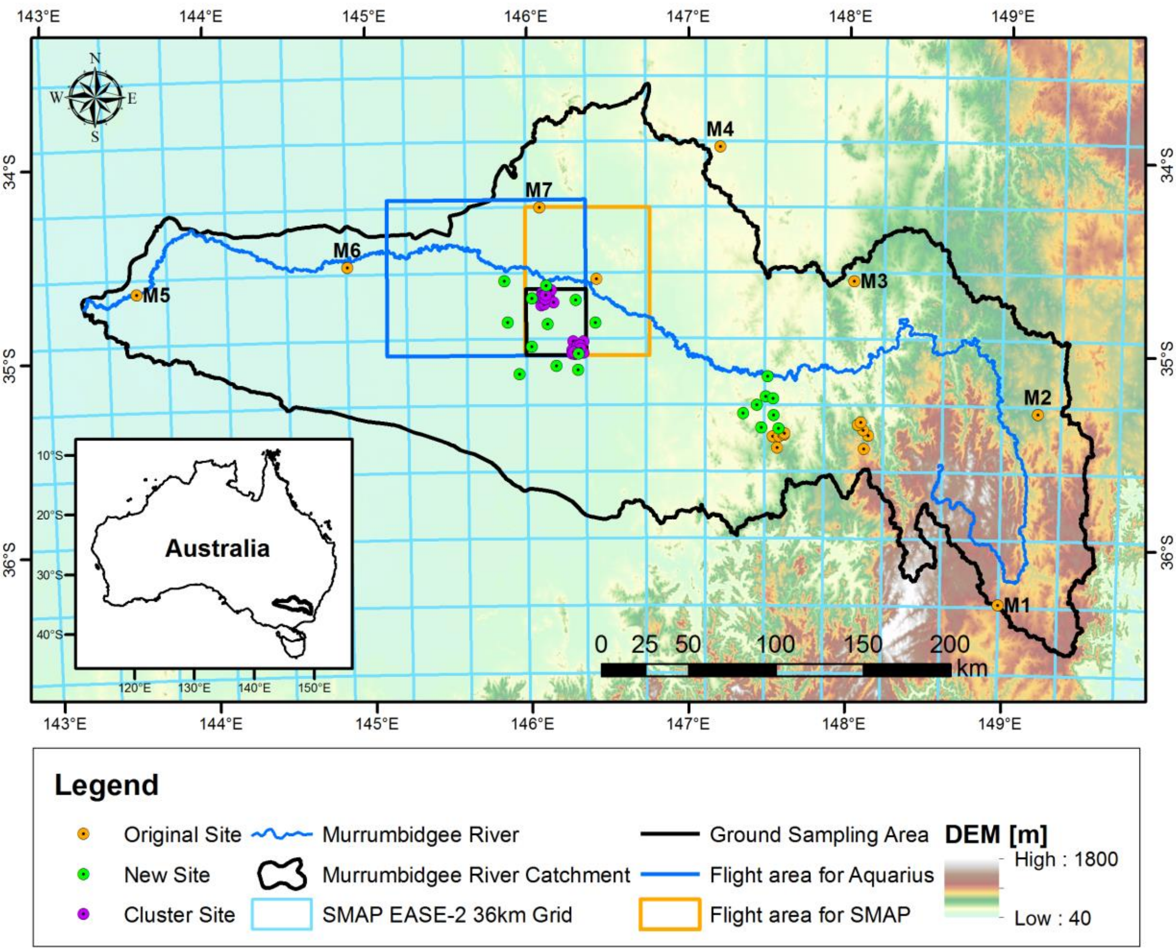

Figure 4-1. Overview of the Murrumbidgee River catchment, soil moisture monitoring sites and the Yanco study area of SMAPEx.

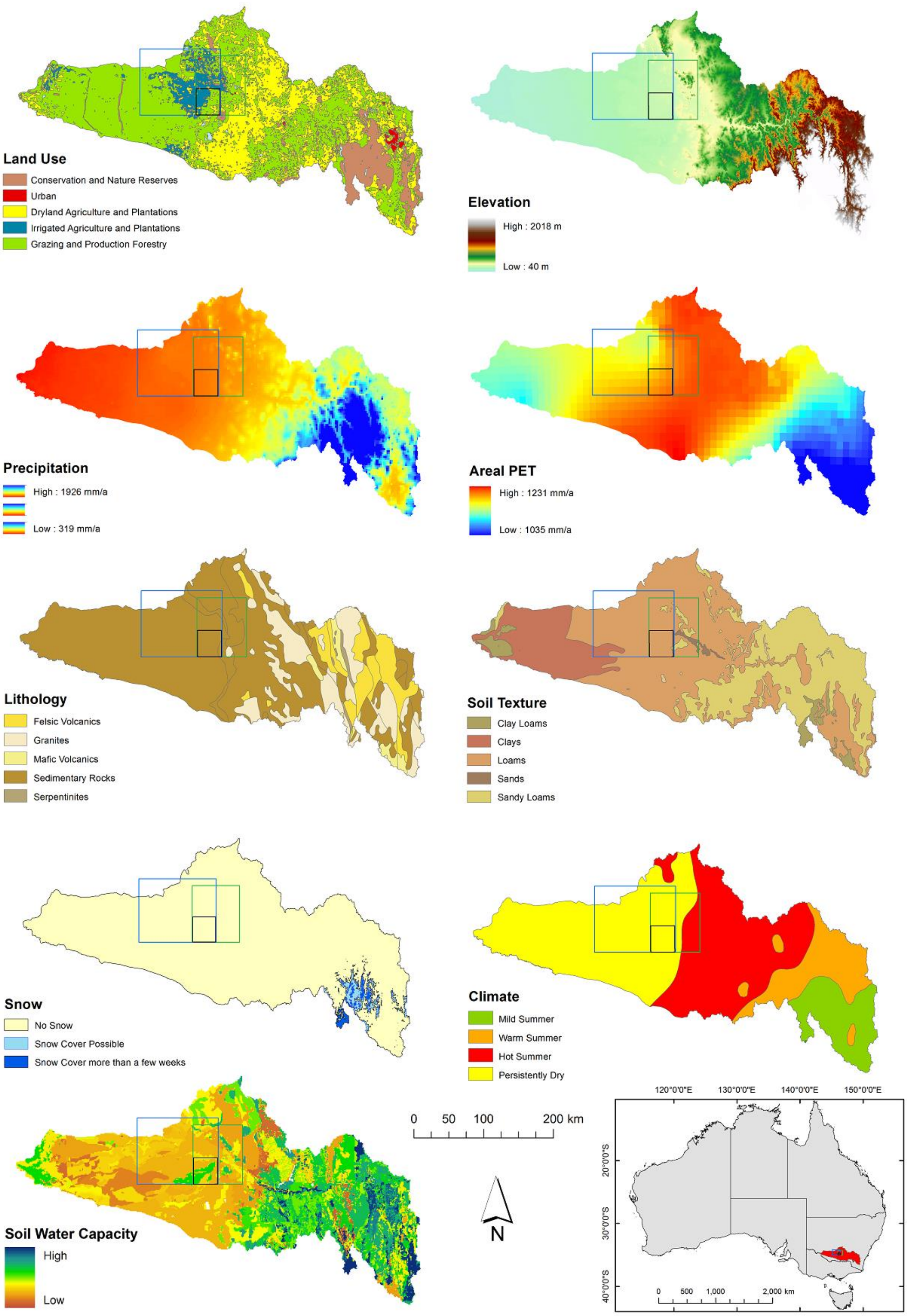

Figure 4-2. Climatic, soil and land use diversity across the Murrumbidgee catchment. Overlain is the outline of the SMAPEx-4 ground sampling area (black), flight area for SMAP (green) and flight area for Aquarius (blue). Data sources: Australian Bureau of Meteorology, Australian Bureau of Rural Science, and Geoscience Australia.

Moreover, considering the size of the satellite footprint, there are still regions that are relatively homogenous (especially in SMAPEx-4 ground sampling area) in regards to climate, soil type and vegetation when compared to other study sites in Europe and the United States. The following sections give a general introduction of the Murrumbidgee Catchment and the operational soil moisture network. Further details on the Yanco and Kyeamba areas can be found in Walker et al. (2006).

4.1 Murrumbidgee catchment

The Murrumbidgee River catchment covers 80,000 km^2 and is located in southeast 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.

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)

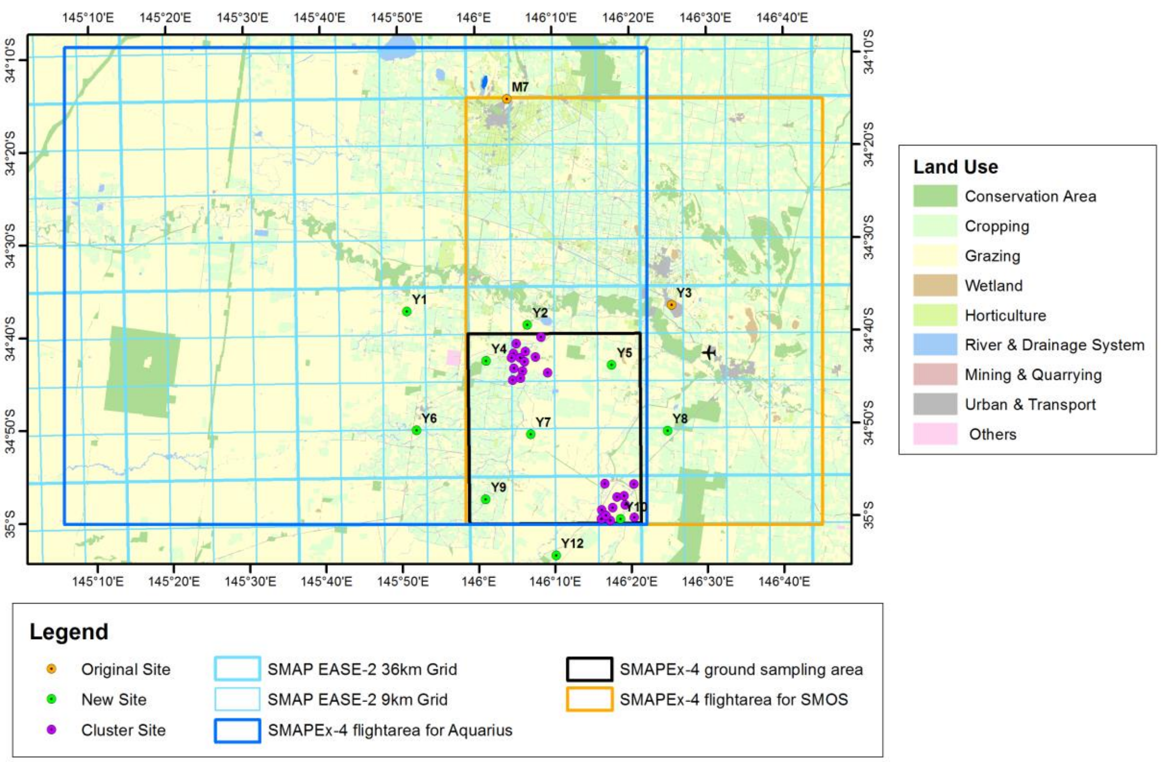

Figure 4-3. The locations of SMAPEx-4 ground sampling area, and flight areas for SMAP and Aquarius.

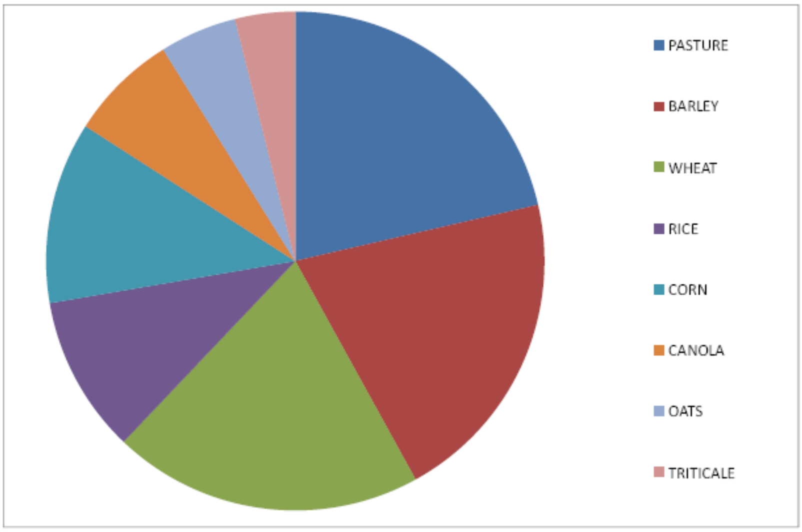

Figure 4-4. Proportions of total irrigated area sown to various crops within the CIA (source: Coleambally Irrigation Annual Compliance Report, 2009).

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)

4.2 Yanco region description

The Yanco area is a 60km × 60km area located in the western flat plains of the Murrumbidgee River catchment where the topography is flat with very few geological outcroppings. Soil types are predominantly clays, red brown earths, transitional red brown earth, sands over clay, and deep sands.

According to the Digital Atlas of Australian Soils, dominant soil is characterised by “plains with domes, lunettes, and swampy depressions, and divided by continuous or discontinuous low river ridges associated with prior stream systems--the whole traversed by present stream valleys; layered soil or sedimentary materials common at fairly shallow depths: chief soils are hard alkaline red soils, grey and brown cracking clays”.

The area covered by SMAPEx airborne mapping will be a 71km × 85km 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 4-1. 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 extended drought, summer cropping has typically been limited with very few rice crops planted for recent years (source: Coleambally Irrigation Annual Compliance Report, 2009). The average CIA cropping areas for 2009 are listed in Figure 4-4.

4.3 Kyeamba region description

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

The dominant soil types in the Kyeamba catchment are represented in Figure 4-7. According to the Digital Atlas of Australian Soils, the three main soil types occurring is this area are described as:

• "Hills and/or undulating ridges often characterized by chips of shaly rock: chief soils are hard neutral red soils."

• "River flood-plains and terraces, buried soils materials present at shallow depths (2 ft) in some places: chief soils of the gently sloping plains are hard alkaline and neutral yellow mottled soils."

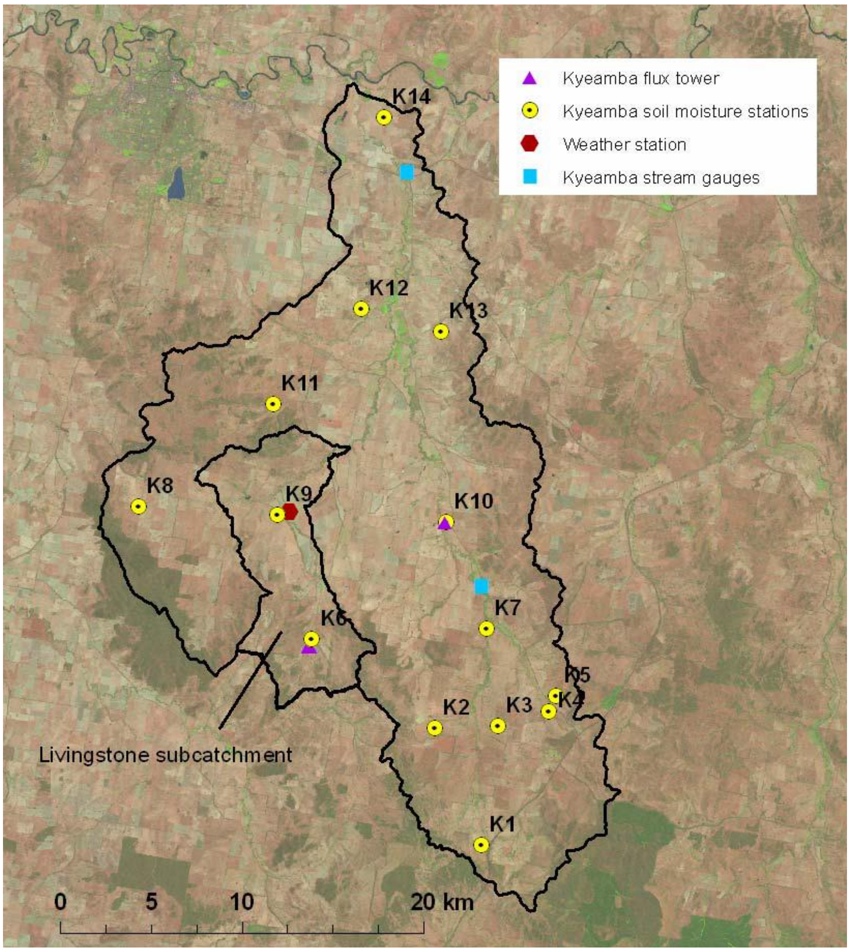

Figure 4-5. The Kyeamba Creek catchment is currently equipped with 14 soil moisture stations.

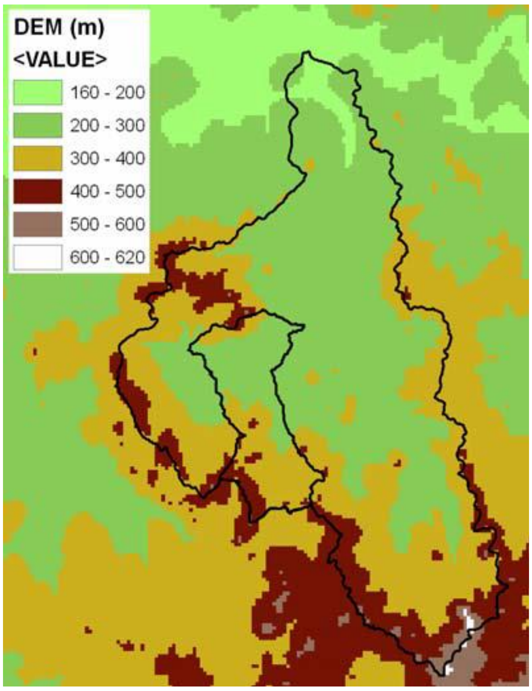

Figure 4-6. Dominant soil type in the Kyeamba catchment according to Northcote's classification (Bureau of Rural Sciences, 1992).

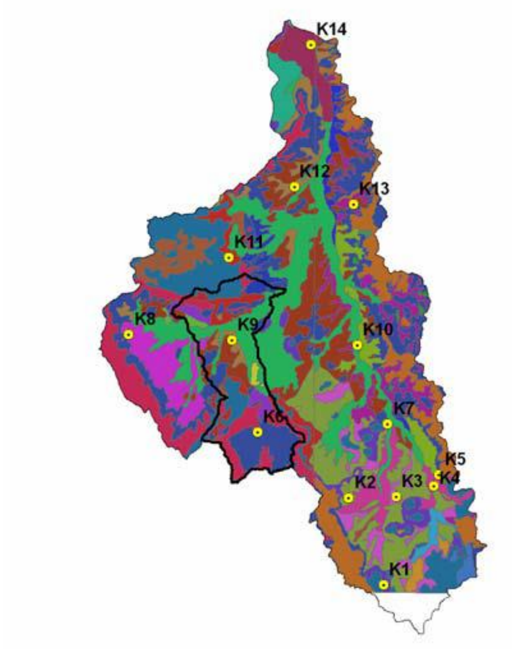

Figure 4-7. Dominant soil type in the Kyeamba catchment according to Northcote's classification (Bureau of Rural Sciences, 1992).

• "Strongly undulating to hilly country with some steep slopes and rock walls, tors: chief soils are hard neutral red soils with red earths often gritty."

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

The topography of the Kyeamba Creek catchment is illustrated in Figure 4-6. Elevation ranges from 180m in the north near the confluence with the Murrumbidgee River to 620m in the south. More than 90% of the catchment has an elevation ranging from 200m to 400m. The Livingstone sub-catchment reproduces the same elevation pattern but at a smaller spatial scale with elevation ranging from 200m in the north to 500m in the south.

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

4.4 Soil moisture network description

OzNet network

Each soil moisture site of the Murrumbidgee monitoring network (Smith et al., 2012) 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).

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 been operated since late 2001 (original sites).

Figure 4-8 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.

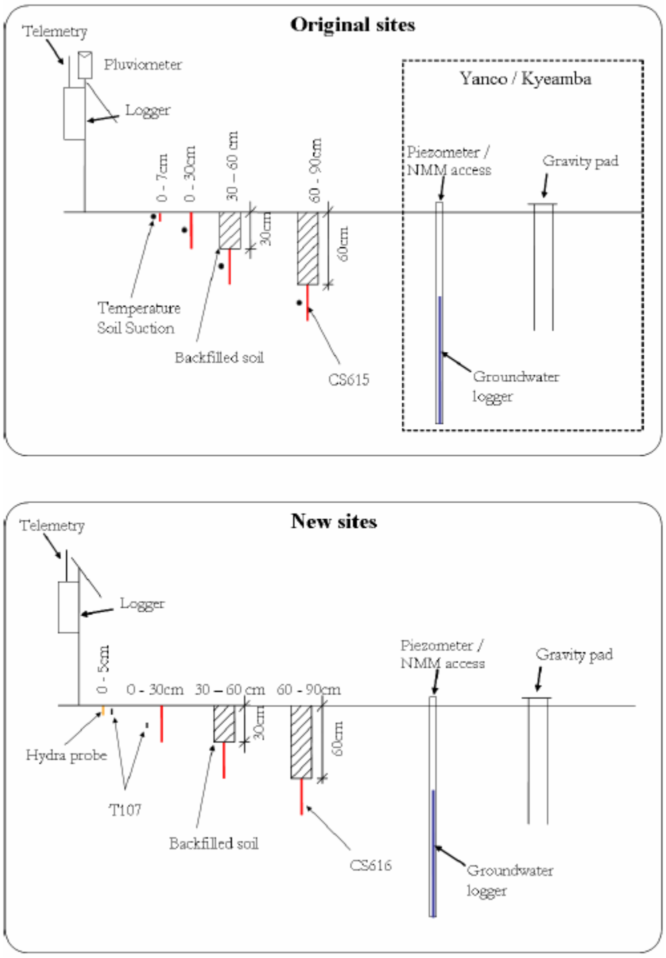

Figure 4-8. Typical equipment at the original (2001) and new (2004) soil moisture sites in the Murrumbidgee catchment. Each site provides continuous data of rainfall, soil moisture at 0- 5cm (or 0-7cm), 0-30cm, 30-60cm and 60-90cm and soil temperature and accommodates periodic measurements of gravity, groundwater and TDR soil moisture measurements.

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 (Rüdiger et al., 2010) 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.

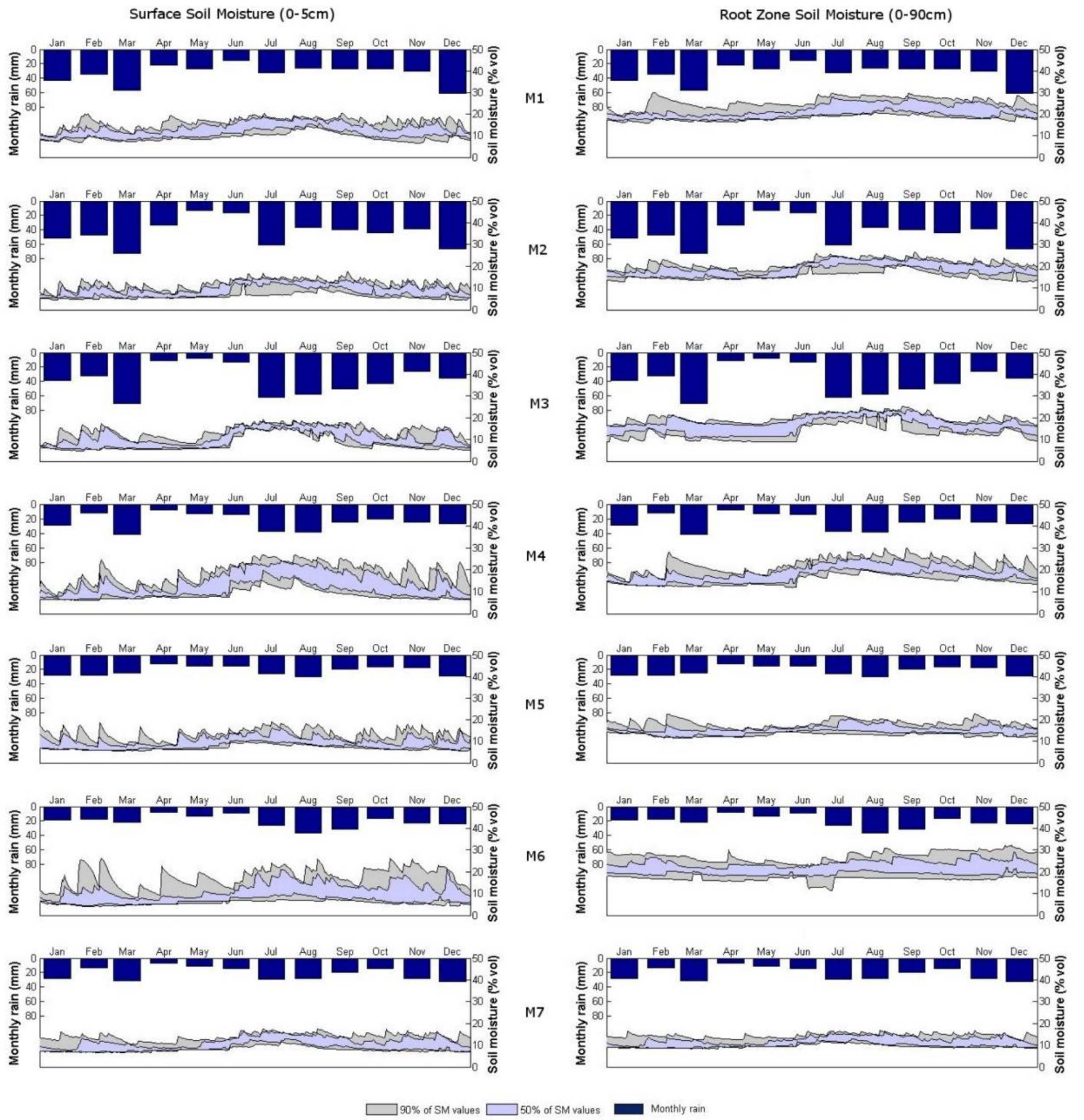

Figure 4-9. Monthly average precipitation and soil moisture variability (left: surface soil moisture 0-5cm; right: root zone soil moisture 0-90cm) across the Murrumbidgee catchment based on data derived from the Murrumbidgee monitoring network stations.

Figure 4-9 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 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 eight years period). 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 M7 (see Figure 4-1). These historic data show that there is a good chance of dynamic soil moisture conditions in the SMAPEx-4 study area during May.

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

ID	Latitude	Longitude	Elevation (m)	Land use
M7	-34.2490	146.0700	137	Grassland
Y1	-34.6288	145.8490	120	Dryland crop/grazing
Y2	-34.6547	146.1103	130	Grazing
Y3	-34.6208	146.4239	144	Grazing
Y4	-34.7194	146.0200	130	Irrigated crop/grazing
Y5	-34.7284	146.2932	136	Dryland cropping
Y6	-34.8426	145.8669	121	Irrigated crop
Y7	-34.8518	146.1153	128	Grazing
Y8	-34.8470	146.4140	149	Grazing
Y9	-34.9678	146.0163	122	Irrigated crop
Y10	-35.0054	146.3099	119	Grazing

The 12 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-2, SMOS, and SMAP. All of these sites fall within the area covered by the SMAPEx airborne coverage. These sites are divided between the 3 main land uses in the region—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 network

The 24 additional soil moisture sites were installed in late 2009 to support the SMAPEx project. These continuously monitor 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 across two 9km × 9km

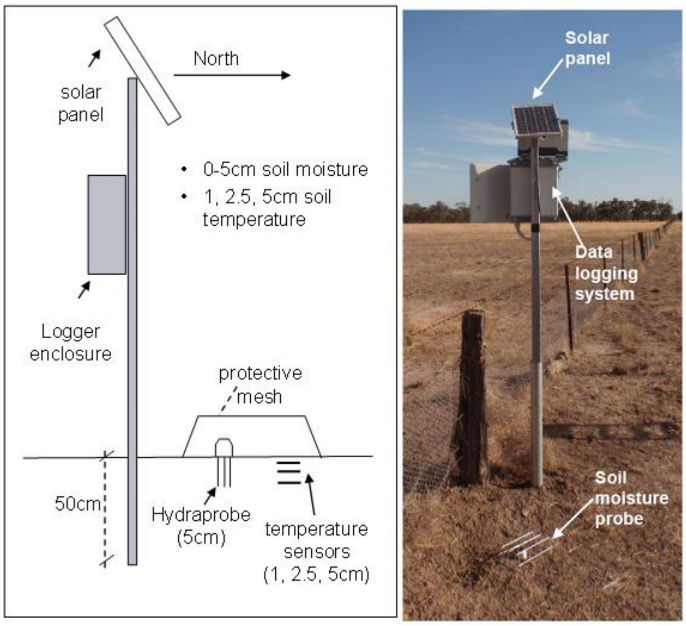

Figure 4-10. Schematic layout of the SMAPEx monitoring site and photo of site YA5.

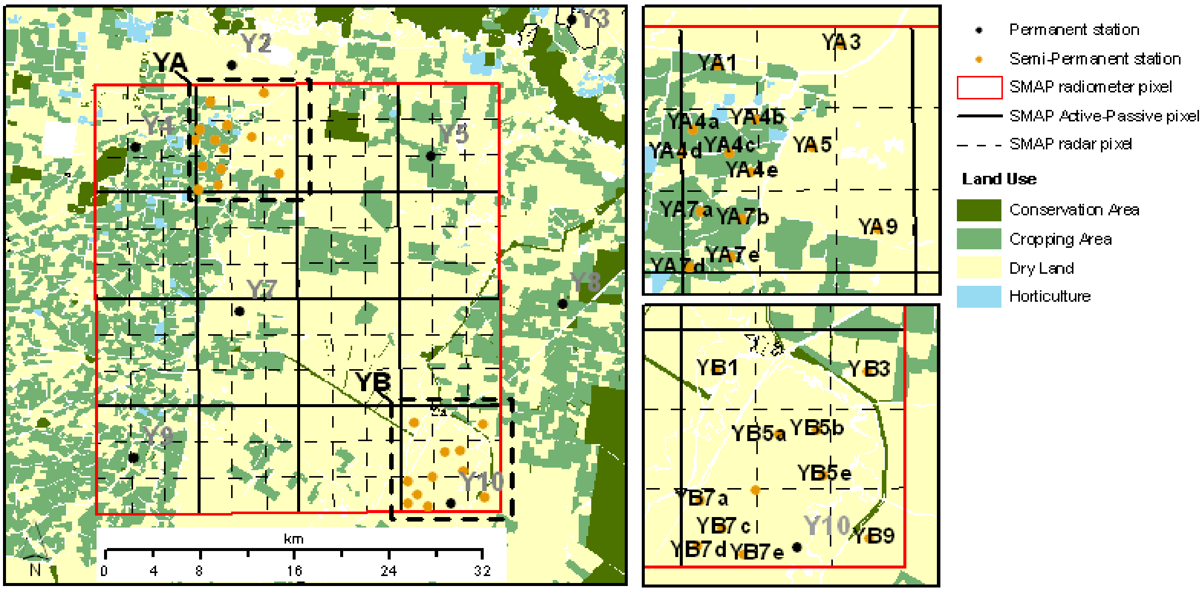

Figure 4-11. Layout of the SMAPEx semi-permanent soil moisture network in the study area.

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 4-10 shows a schematic of the installation, while Figure 4-11 shows the locations of the SMAPEx sites within the study area.

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

Table 4-2. Characteristics of the SMAPEx semi-permanent monitoring sites. NOTE: the crop types listed are those observed during SMAPEx-2 and 3. 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

Kyeamba sites

As a part of OzNet network, 14 sites were installed in the Kyeamba catchment at two locations as illustrated in Figure 4-5, hence providing the opportunity for nested catchment studies. The land cover at the 14 soil moisture stations is summarized in Table 4-3. Due to its topographic feature, the Kyeamba catchment has been considered as a validation site for SMAP soil moisture products. To ensure the continuity and quality of soil moisture data from Kyeamba sites which have been operating for over ten years, the most representative sites were selected and upgraded with new sensors and logger systems. A stability analysis was conducted to determine the most representative sites by assuming the simply average soil moisture from all Kyeamba sites as the spatial average of the entire catchment. The bias and standard deviation of time series of soil moisture were then calculated for each site, as shown in Figure 4-12 and Figure 4-13. Due to their lowest bias and standard deviation, Sites K5 and K11 are identified as the most representative sites, and upgraded to provide reliable soil moisture data for the duration of SMAP.

.

Table 4-3. Land cover at the 14 sites in the Kyeamba catchment.

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

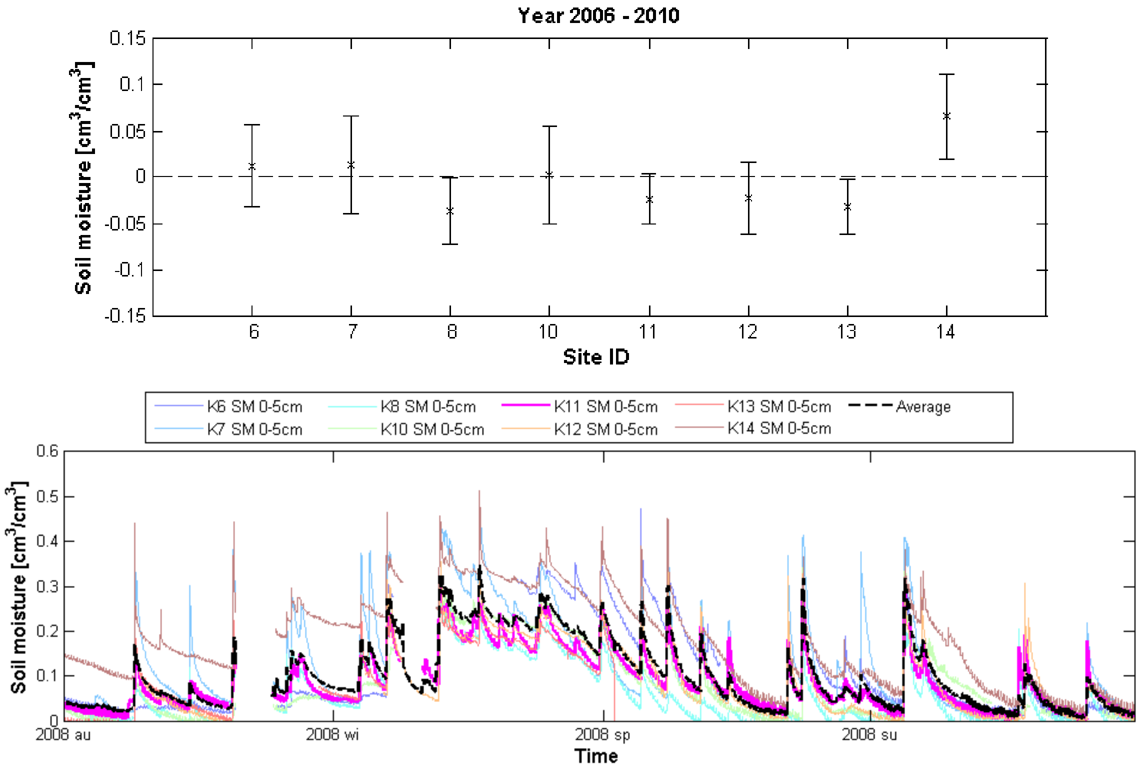

Figure 4-12. The bias (cross mark) and standard deviation (whisker) of top 5cm soil moisture measurements in the period of 2006 to 2010 (top), and the time series of top 5cm soil moisture measurements and the simple average for the year 2008 as an example (bottom).

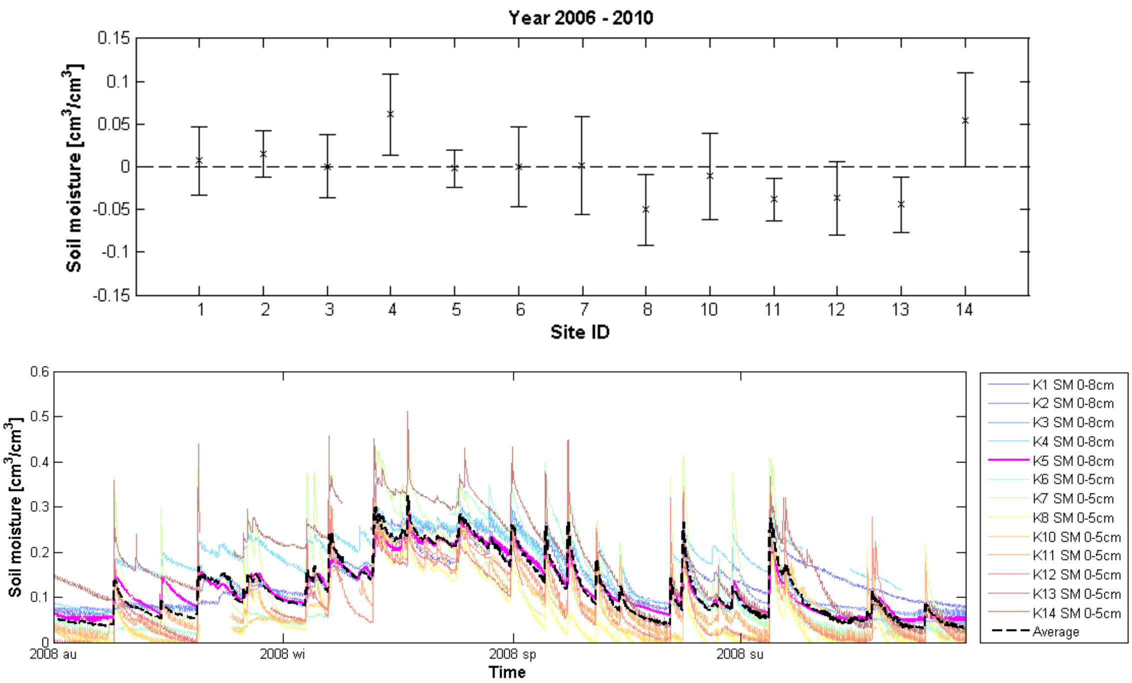

Figure 4-13. The bias (cross mark) and standard deviation (whisker) of top 5 - 8cm soil moisture measurements in the period of 2006 to 2010 (top), and the time series of top 5 - 8cm soil moisture measurements and the simple average for the year 2008 (bottom).

5. AIRBORNE MONITORING

The PLMR, PLIS and supporting instruments (thermal and multispectral radiometers) will be flown on-board a high performance single engine aircraft (see Section 3.1) to collect airborne data across the SMAPEx-4 study area approximately three times per week, making a total of 9 flights over the 3 weeks 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 5.4). In-flight calibration of the PLIS will also be performed (see Section 5.5). For detailed flight line coordinates see Appendix C. The main type of flights conducted during SMAPEx-4 serve the main scientific objectives, the SMAP footprint coverage flights (see Section 5.2). These flights will provide coincident SMAP radar and radiometer data over an area covering at least a complete SMAP radiometer 3dB footprint for each of three SMAP overpasses every 8 days, to calibrate and validate of SMAP observations and soil moisture retrievals. One type of additional flights will also be performed with specific objectives during the experiment:

- Aquarius footprint coverage flight (see Section 0), which will collect coincident PLMR and PLIS data over about half of Aquarius 3dB footprint, on the day when both Aquarius and SMAP will overpass the study area;

All flights will be operated out of 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

SMAP and Aquarius footprint coverage flights will be conducted along parallel flight lines, with flight line distances designed to only allow full coverage of PLMR. All flights will be flown along north-south oriented flight lines, which extend 2km outside the target area at both ends, to ensure the aircraft has a stable attitude over the target area. The median surface elevation under the flight routes was used to determine the optimum flying altitude across the target area to maintain the desired spatial resolution of airborne data. The flight pattern was largely determined by the viewing configuration of PLMR and PLIS as installed on the aircraft. This is illustrated in Figure 5-2.

PLIS will be installed under the fuselage, behind PLMR. Since the 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 six PLMR across-track beams (±7°, ±21.5° and ±38.5° with 14° across-track beamwidth) provide a swath of 6km at 10,000ft flying altitude, equivalent to the total PLIS swath width, with pixels of approximately 1km size. The viewing configuration for the reflectance and thermal radiometer sensors are the same as that of the PLMR.

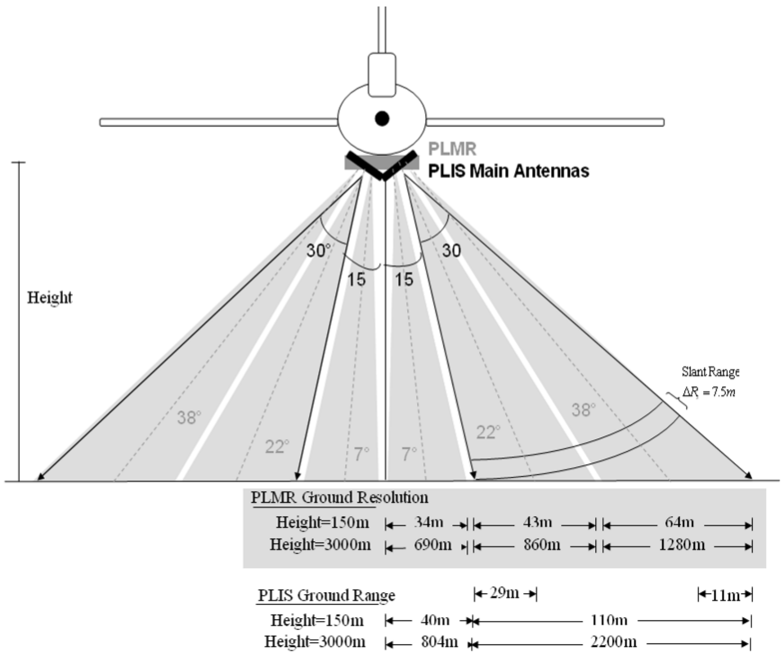

Figure 5-1. PLMR and PLIS viewing configuration on the aircraft.

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

- Ensure full coverage of PLMR data for the flight area of SMAP and minimum 50% coverage for the flight area for Aquarius;
- Ensure full coverage of PLIS data for all six focus farms; and
- Flight line separation was set so as to guarantee the overlap of the PLMR outer beams;

These criteria resulted in consistent 5km flight lines separation (Figure 5-2), in which way a 2km PLIS coverage gap in the middle of PLMR 6km swath.

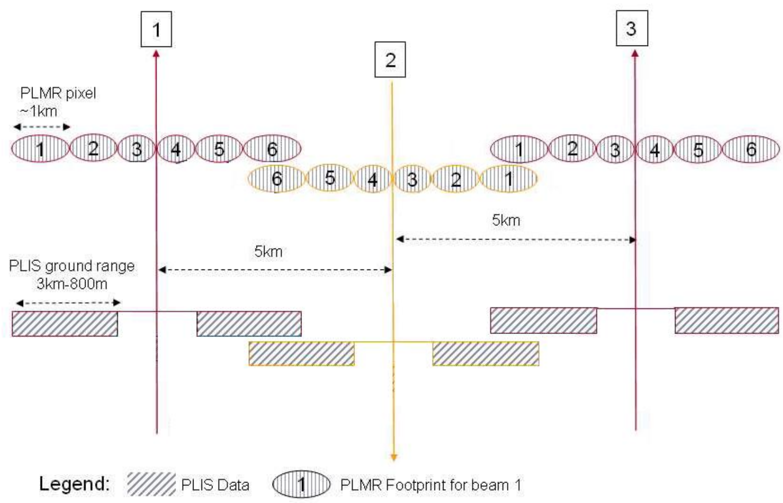

Figure 5-2. PLMR and PLIS viewing configuration on the aircraft.

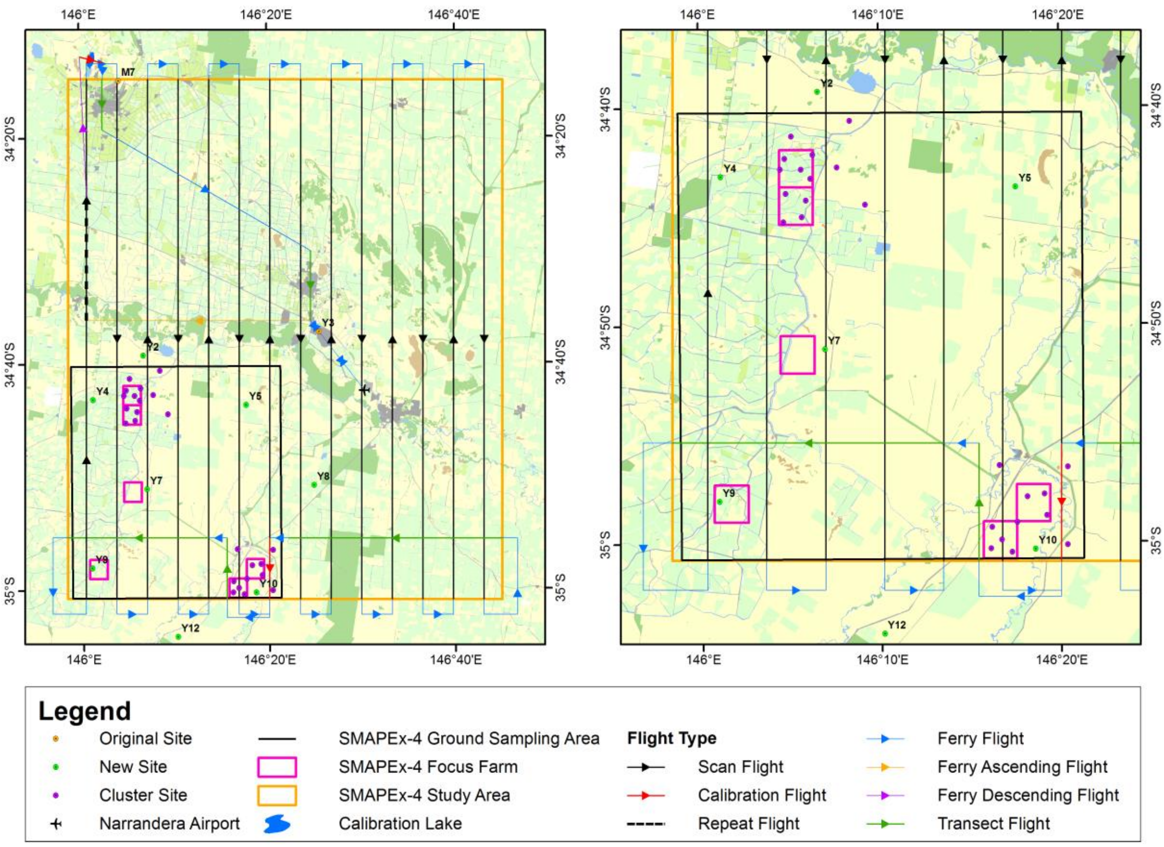

Figure 5-3. Overview of SMAP footprint coverage flights of SMAPEx-4 showing land cover (left) and topography (right). Also indicated are the ground monitoring network and sampling areas.

5.2 SMAP footprint coverage flights

SMAP footprint coverage flights will be the core component of the SMAPEx experiments. These will map a 71km × 85km area, fully covering a complete SMAP radiometer 3-dB footprint. 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 5-3). According to Figure 5-4, all six 3km × 3km focus areas and a 9km × 9km pixel will be fully covered by PLIS. Aggregation of the active and passive microwave data collected during SMAP footprint coverage flights to the resolution of the EASE SMAP grids will provide coincident SMAP data for i) validation of SMAP radiometer and radar observations; ii) evaluation of SMAP active-passive downscaled 9km brightness temperature product; iii) inter-comparison between PLMR, SMAP, and SMOS brightness temperature observations; vi) validation of SMAP radiometer, radar, radar-radiometer soil moisture retrieval algorithms; and v) developments of radar only soil moisture retrieval algorithm. SMAP footprint coverage flights will be repeated 8 times during each of SMAPEx-4 coincident with SMAP descending overpasses. It is expected that this approach will cover a range of moisture conditions for the study area associated to rainfall events, together with a range of vegetation conditions due to crop harvest expected during the campaign period, thus expanding the conditions observed across other seasons.

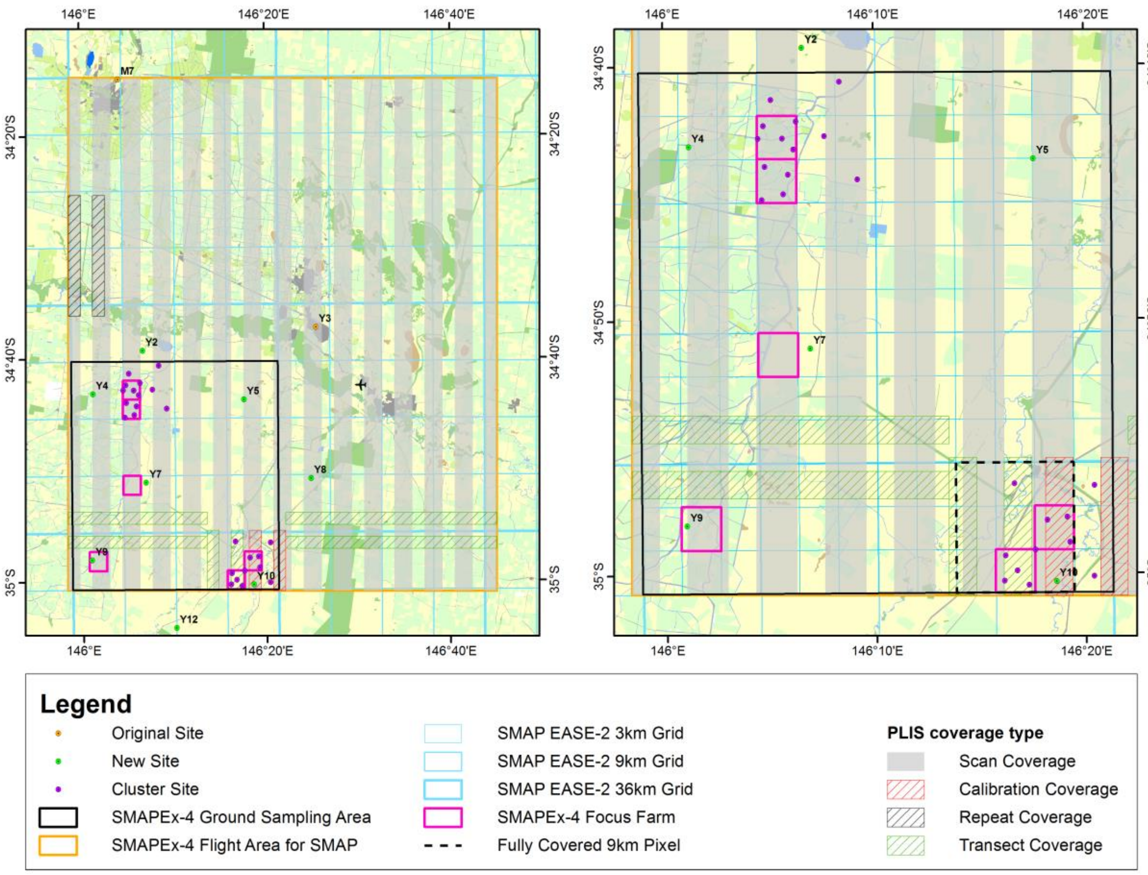

Figure 5-4. PLIS coverage of SMAPEx-4 flight area for SMAP (left) and ground sampling area (right).

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. SMAP footprint coverage flights will be conducted over an approximately 7hr time window, centred on the 6am local overpass time of SMAP so that data acquisition will be between 2:30am and 9:30am. Detailed flight line coordinates are given in Appendix C. The flight line pattern for SMAP footprint coverage flights consists of 14 flight lines of 85km length, with flight line separation of 5km, resulting in a 100% and 60% coverage of PLMR and PLIS, respectively.

5.3 Aquarius footprint coverage flight

A specific flight will be conducted once during the experiment to collect PLMR brightness temperature and PLIS backscatter observations over the closest Aquarius 3dB footprint to Yanco area. As shown in Figure 5-5, the Aquarius footprint is in the size of 84km × 120km with an incidence angle of 37.8°. Given flight time limitation, Aquarius footprint coverage flight is designed to covering about 70% footprint with PLMR and 45% footprint with PLIS flying at an altitude of 10,000ft AGL,. Previous studies using the AACES data set show that airborne brightness temperature observations over approximately half of space borne radiometer footprint are sufficient represent the entire footprint with less than 4K error (Rüdiger et al., 2011). The Aquarius footprint coverage flight will be conducted when Aquarius, SMAP, and/or SMOS coverage are coincident. Therefore, the Aquarius footprint coverage flight will provide coincident data for inter-comparison between PLMR, Aquarius,

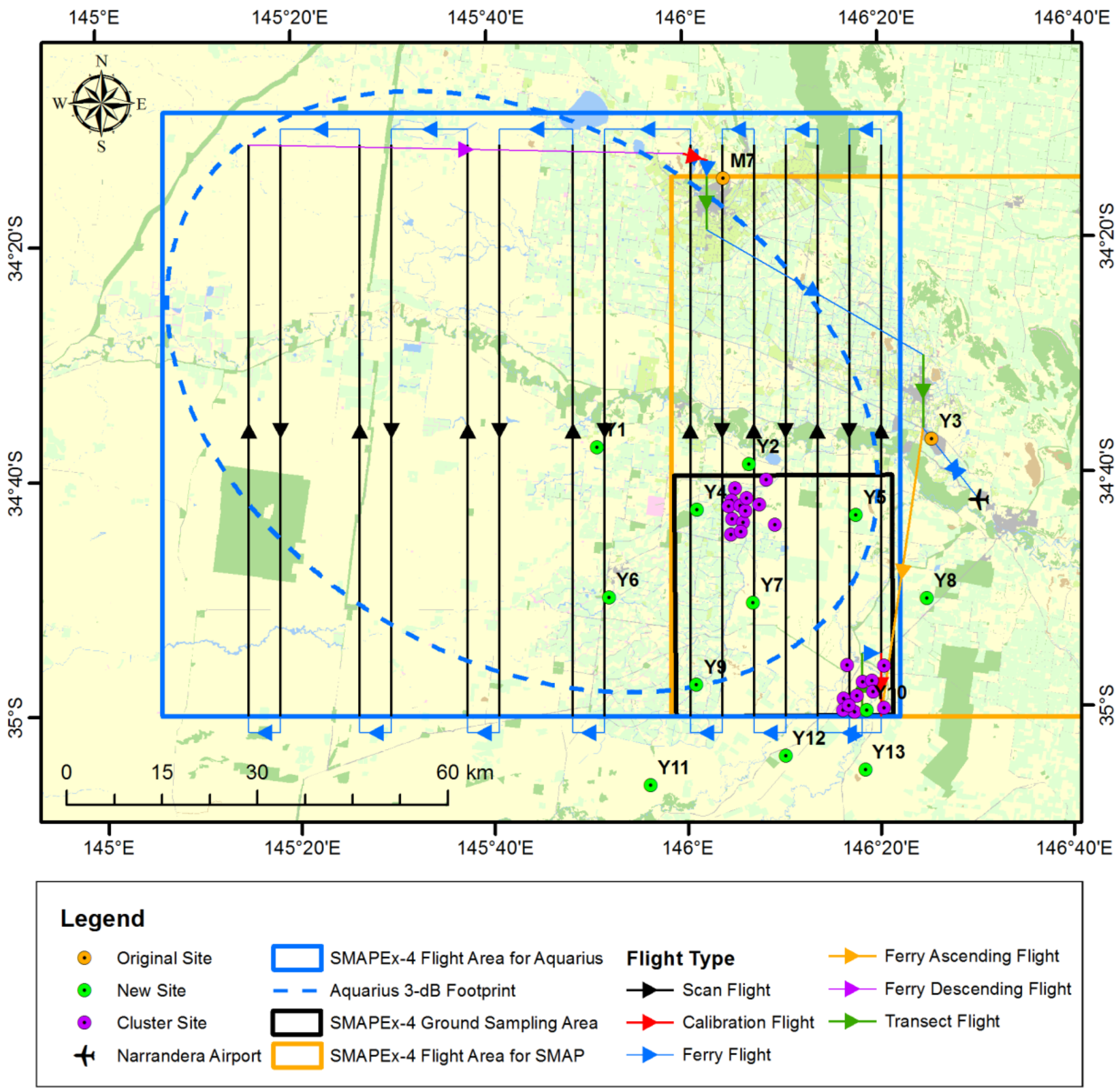

Figure 5-5. Overview of Aquarius foot coverage flights of SMAPEx-4. Also indicated are the ground monitoring network and sampling areas.

and SMAP brightness temperature observations. An overview of the flight lines is provided in Figure 5-5. Detailed flight line coordinates are given in Appendix C.

5.4 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 5-6). 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.

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 5-7.

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®) at the start and end of SMAPEx-4 (see Figure 5-7). 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

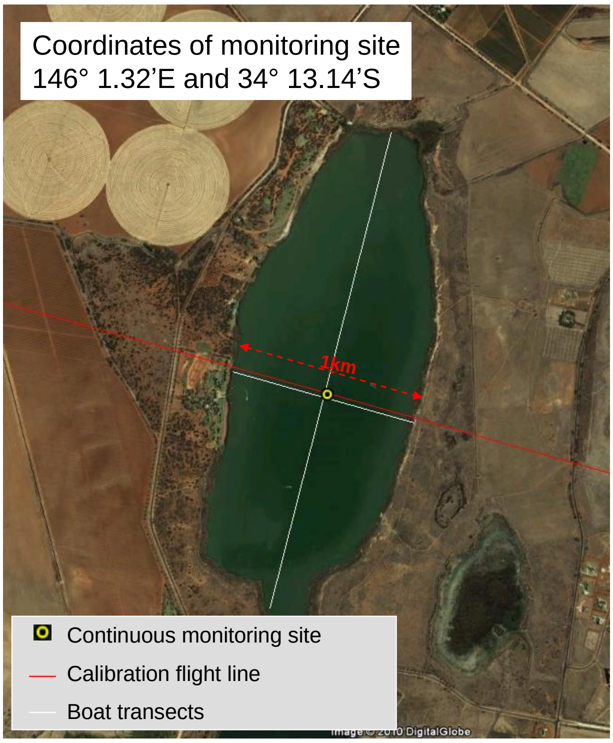

Figure 5-6. Calibration flight (red line) and boat transects (white lines) over Lake Wyangan

Figure 5-7. 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.

Table 5-1. Location of the PARC during SMAPEx-4.

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

variability. Frank Winston will be the responsible person for these measurements.

5.5 PLIS calibration

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

Polarimetric Active Radar Calibrators (PARCs)

The PARCs are high radar-cross-section transponder with a known scattering matrix (see Figure 5-8). PARCs detect the incident microwave energy radiated by the PLIS and then transmit back to the 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-4, the PARCs will be located within the Narrandera airport grounds (see Figure 5-9). 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

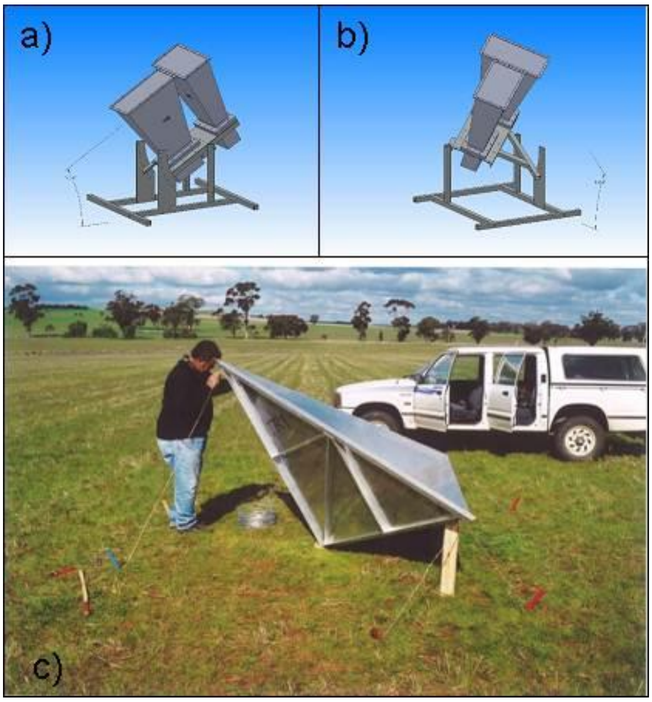

Figure 5-8. Polarimetric Active Radar Calibrators #1 and #2 (a), #3 (b) and Passive Radar Calibrator (c)

Table 5-2. Location of the PRC during SMAPEx-4.

	Latitude	Longitude	Incidence angle [°]	Tilt angle [°]
PRC #1	34°59.834’S	146°20.553’E	15	39.736
PRC #2	35°00.023’S	146°20.780’E	21	33.736
PRC #3	35°00.228’S	146°21.026’E	27	27.736
PRC #4	35°00.457’S	146°21.300’E	33	21.736
PRC #5	34°59.839’S	146°21.622’E	39	15.736
PRC #6	35°00.150’S	146°21.994’E	45	9.736

the PLIS swath. All PARCs will be oriented at 30° incidence angle, corresponding to the PLIS incidence angle at the center of the swath. The 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. The 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). The calibration circuit will be undertaken only at the start and end of each airborne campaign to check for calibration drift.

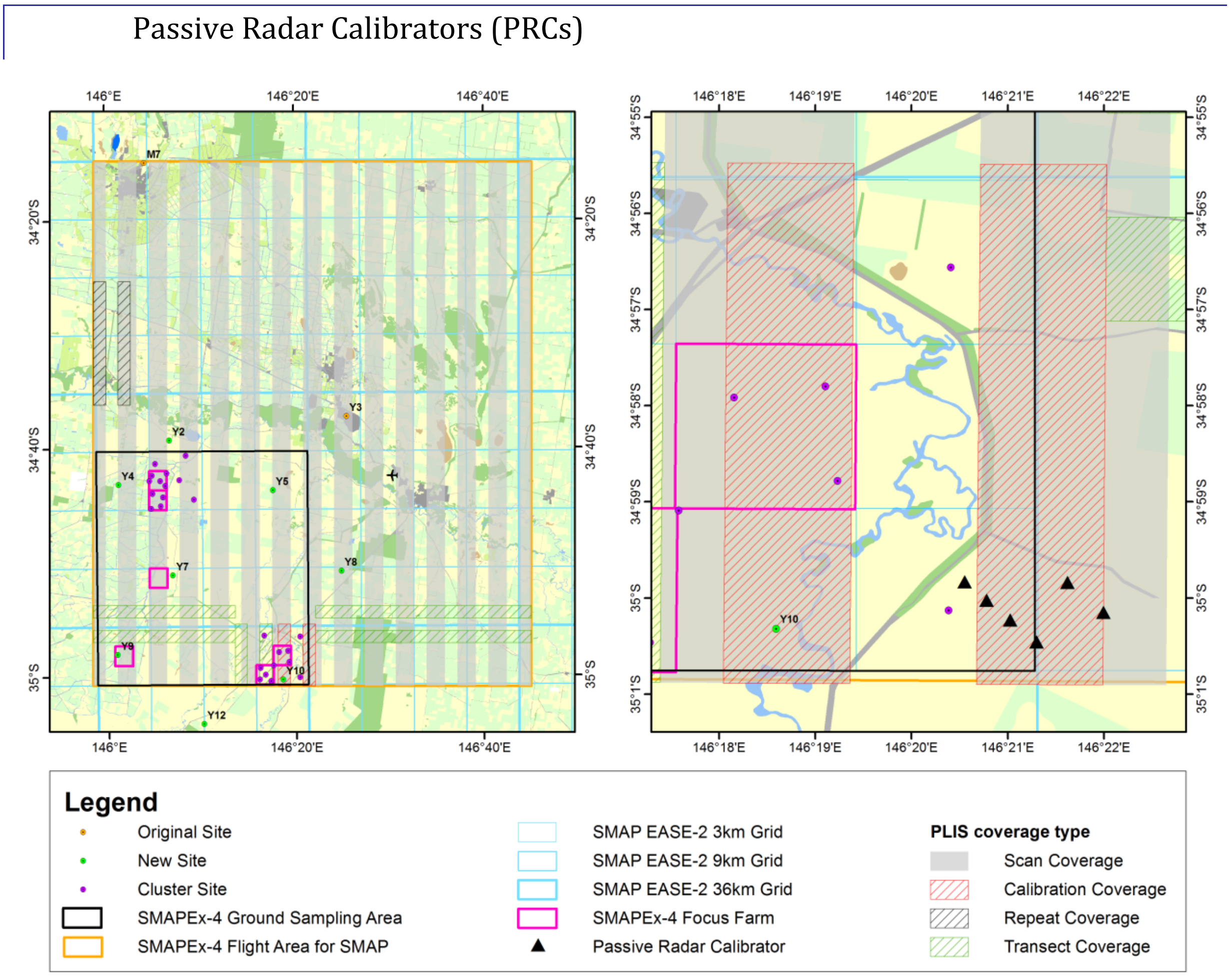

Figure 5-9. Location of PRCs during SMAPEx-4.

The PRCs are metallic corner reflectors (see Figure 5-8) 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 around the YB area. 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 no two PRCs will be aligned in the PLIS azimuthal or range direction. The locations for the PRCs are shown in Figure 5-9.

5.6 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 150km/h and 255km/h, respectively. The climb rate was 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 2km beyond the measurement area to ensure aircraft attitude stability over the data acquisition area. Turning times was set to 2.25min for flight separation of 5km. A 10min buffer was also added to the flight time to account for arrival and departure manoeuvres (circuit, etc.). The estimated times for SMAP and Aquarius footprint flight types are 6.8h and 7.6h.

5.7 Flight schedule

SMAPEx-4 flights will be undertaken during 24 days according to the schedule in Table 5-3. SMAP footprint coverage flights will be conducted approximately three times per week for a total of 8 flights according to the coverage over the flight area for SMAP, to provide coincident SMAP brightness temperature and backscatter observations. Consequently, only 3 of 4 SMAP overpasses every 8 days having both SMAP radar and radiometer coverages over the flight area are considered. SMAP has 2-4 days repeat time, for validation SMAP brightness temperature and soil moisture products. Aquarius footprint coverage flight will be conducted on 12th May, 2015 to collect PLMR brightness temperature observation coincident with Aquarius, SMAP and/or SMOS overpass. Low-altitude PLMR calibration flights over Lake Wyangan will be performed prior to landing of each flight. The PLIS calibration circuit will also be performed at the start and end of the each campaign over PARCs, while PRCs will be covered during each flight.

Table 5-3. Summary of SMAP, SMOS, and Aquarius overpass over the SMAPEx-4 study area during the experiment. Orange shade, and blue shade indicate SMAP footprint coverage flights, and Aquarius footprint coverage flight respectively.

May	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SMOS			○	●		●			●		●			●		●	○		●		●	●		●			●		●		
Aquarius					●							●							●							●					
SMAP			○	●		●			X		○	●		●			X		○	●		●			X		○	●		●	

Note:

Orange shaded: Airborne sampling over flight area for SMAP

Blue shaded: Airborne sampling over flight area for Aquarius

Solid black dot: full coverage (radar and radiometer for SMAP)

Hollow black dot: partly coverage (radar and radiometer for SMAP)

X: full coverage of SMAP radiometer only

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-4 campaign is designed with the following objectives:

- Calibrating the aircraft radiometer and radar observation;
- Providing supporting ground data for validation of PLMR soil moisture retrievals; 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 described in Section 4.4, the ground monitoring component of the SMAPEx-4 campaign will focus on six 3km × 3km areas equivalent to six SMAP radar pixels. 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 and spectral); 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 6.5).

6.1 Supplementary monitoring stations

Permanent monitoring stations are supplemented by six 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; 0-5cm and 20-25cm) 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 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

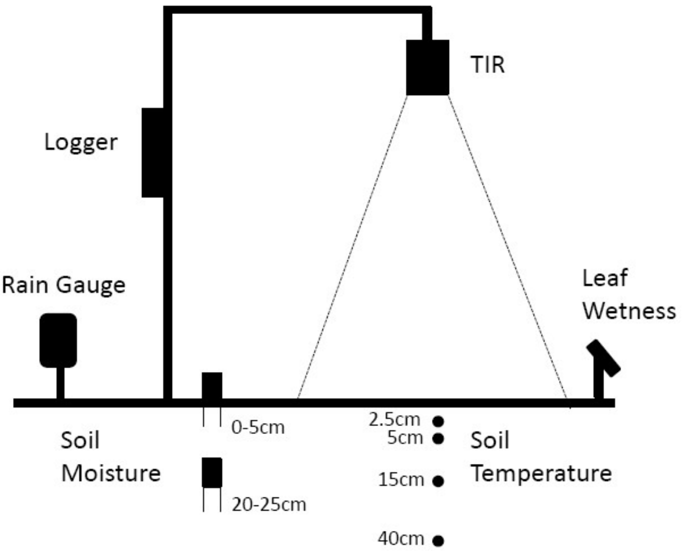

Figure 6-1. Schematic of the temporary monitoring station.

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.

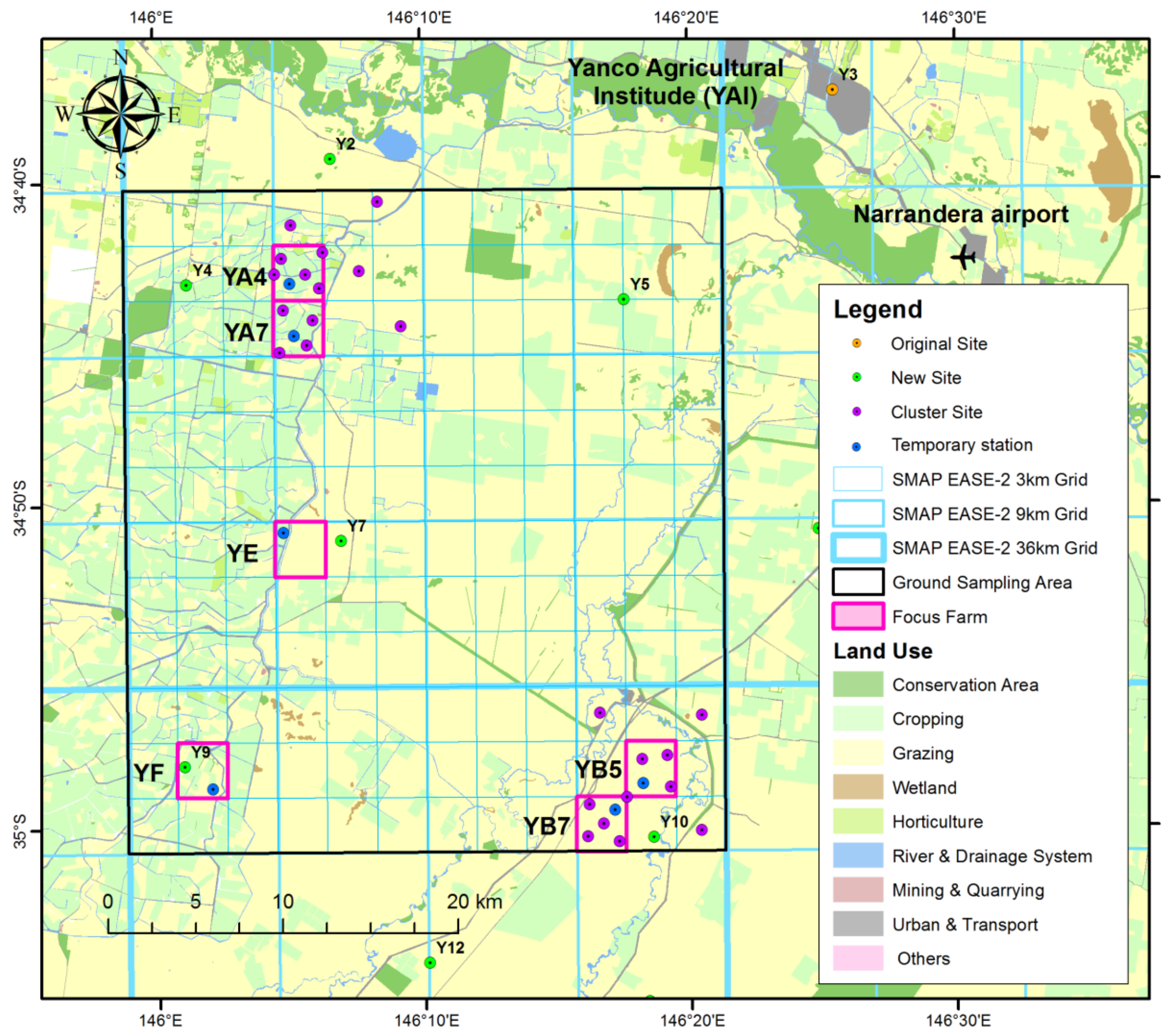

Figure 6-2. Proposed locations of the SMAPEx-4 temporary monitoring stations (blue).

Table 6-1. Characteristics of the intensive 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)*
YE	Grazing (100%)	Native or naturalised pasture	127m	Silty clay loam (39/43/17)*
YF	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)**

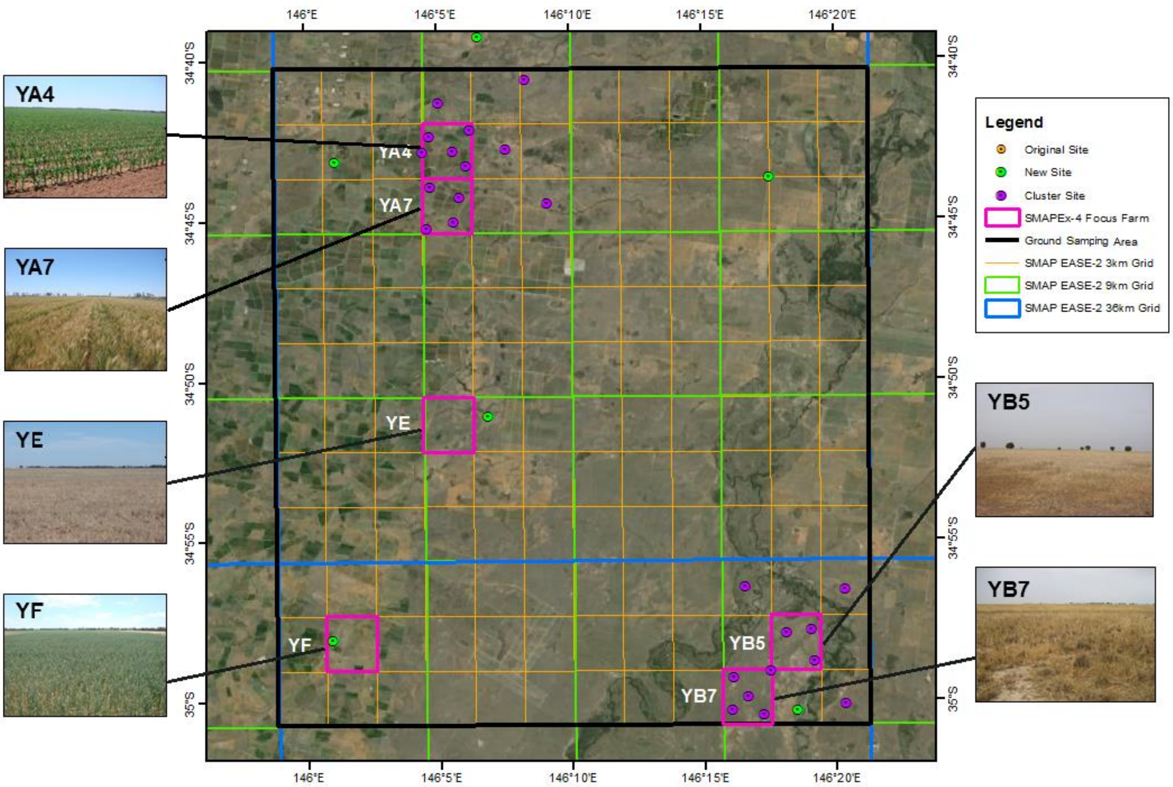

Figure 6-3. Overview of ground sampling areas with photographs. The 6 focus areas of SMAPEx-4 are indicated with black polygons. Focus areas for additional intensive vegetation monitoring are also shown.

6.2 Intensive soil moisture sampling

Intensive spatial ground soil moisture sampling will focus on six, 2.8km × 3.1km focus farms 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. All focus areas exactly match the SMAP radar grid.

Table 6-2. Ground sampling schedule (subject to weather) for SMAPEx-4 concurrent with flights (sampling areas are shown in Figure 6-3). Prefix c indicates mostly cropping area while g stands for mostly grazing area.

Local Date	Local Day	Flight	Soil moisture Team A	Soil moisture Team B	Soil moisture Team C	Vegetation Team D	Buggy Team E	Roughness Team F
4/30/2015	Thurs				Travel to YAI			
5/1/2015	Fri				Training			
5/2/2015	Sat				Training			
5/3/2015	Sun	Flight 1	YA4	YB5	YF	Focus farm sampling	YB5	-
5/4/2015	Mon	Flight 2	YA7	YB7	YE	Focus farm sampling	YB7	-
5/5/2015	Tues		Intensive vegetation sampling (YA4)	Intensive vegetation sampling (YA7)	Regional sampling	Focus farm sampling	Processing	YA4
5/6/2015	Wed	Flight 3	YA4	YB5	YF	Focus farm sampling	YB5	-
5/7/2015	Thurs		Intensive vegetation sampling (YA4)	Intensive vegetation sampling (YA7)	Regional sampling	Focus farm sampling	Processing	YA7
5/8/2015	Fri		Intensive vegetation sampling (YE/YF)	Intensive vegetation sampling (YB)	Regional sampling	Focus farm sampling	Processing	YB/YE/YF
5/9/2015	Sat	Backup option			Day-off			
5/10/2015	Sun				Day-off			
5/11/2015	Mon	Flight 4	YA7	YB7	YE	Focus farm sampling	YB7	-
5/12/2015	Tues	Flight 5 (Aquarius)	YA4	YB5	YF	Focus farm sampling	YB5	-
5/13/2015	Wed		Intensive vegetation sampling (YA4)	Intensive vegetation sampling (YA7)	Regional sampling	Focus farm sampling	Processing	YA4
5/14/2015	Thurs	Flight 6	YA7	YB7	YE	Focus farm sampling	YB7	-
5/15/2015	Fri		Intensive vegetation sampling (YA4)	Intensive vegetation sampling (YA7)	Regional sampling	Focus farm sampling	Processing	YA7
5/16/2015	Sat		Intensive vegetation sampling (YE/YF)	Intensive vegetation sampling (YB)	Regional sampling	Focus farm sampling	Processing	YB/YE/YF
5/17/2015	Sun	Backup option			Day-off			
5/18/2015	Mon				Day-off			
5/19/2015	Tues	Flight 7	YA4	YB5	YF	Focus farm sampling	YB5	-
5/20/2015	Wed	Flight 8	YA7	YB7	YE	Focus farm sampling	YB7	-
5/21/2015	Thurs		Intensive vegetation sampling (YA4)	Intensive vegetation sampling (YA7)	Regional sampling	Focus farm sampling	Processing	YA
5/22/2015	Fri	Flight 9	YA4	YB5	YF	Focus farm sampling	YB5	-
5/23/2015	Sat				Packing and travel back to Melbourne			

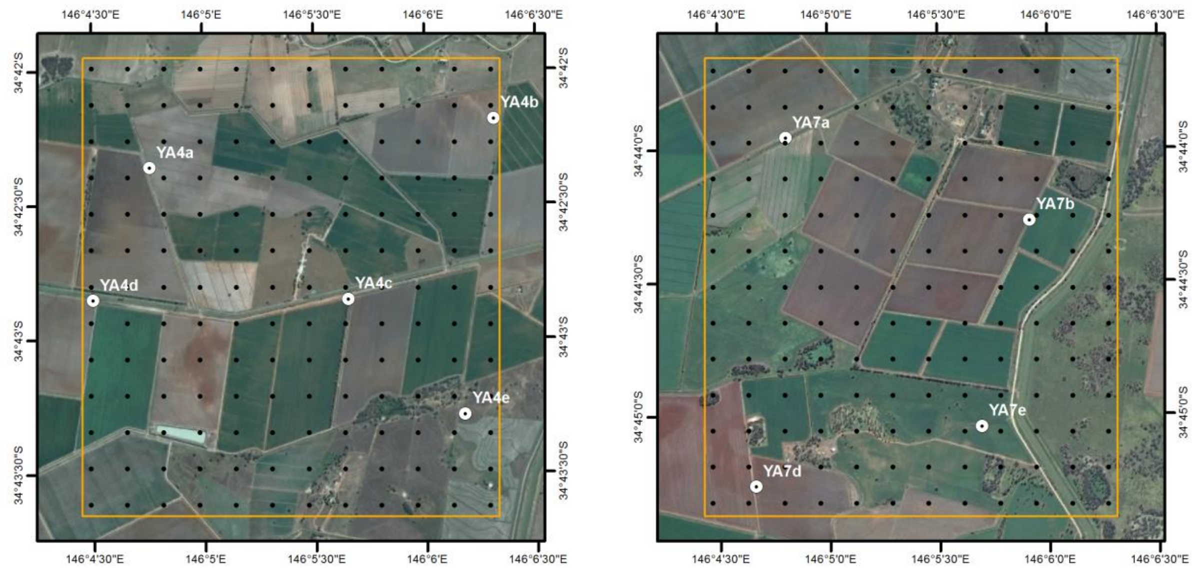

Figure 6-4. Locations of the spatial soil moisture sampling sites at focus areas YA4 and YA7 (mostly cropped).

Soil moisture will be monitored concurrently with PLMR and PLIS overpasses, approximately 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. 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 two flight days, three of the six focus areas will be sampled in rotation. 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 3 SMAP radar pixels on each day. Team A and B will be responsible for YA (YA4 and YA7) dominated by cropping area and YB (YB5 and YB7) dominated by grazing area, respectively, which ensures that a wide range of soil moisture conditions are encountered for both land cover types. Team C will be responsible for YE and YF area which are cropping and grazing scenarios. 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.

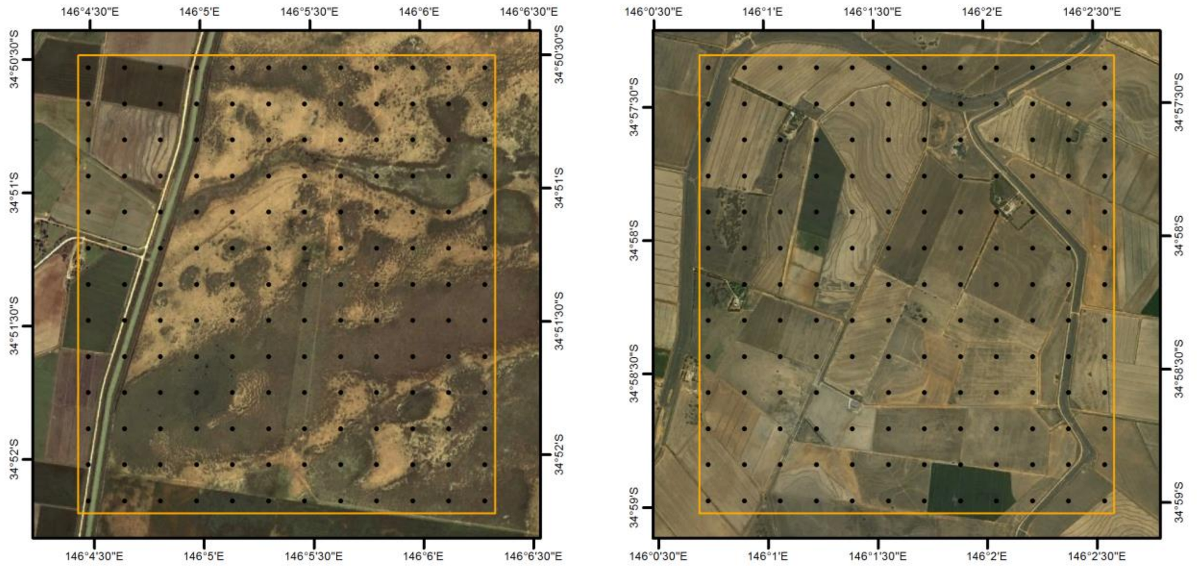

Figure 6-5. Locations of the spatial soil moisture sampling sites at focus areas YE (mostly grazing mixed partly cropped, left panel) and YF (mostly cropped, right panel).

6.3 Regional soil moisture sampling

In addition to intensive ground soil sampling in the six focus farms, regional ground soil moisture sampling is also planned across the entire ground sampling area. The objective of regional sampling is to better understand the spatial variability of soil moisture within the ground sampling area (the SMAP 36 km × 36 km pixel) during the SMAPEx-4. Team C will be responsible to regional sampling on non-flight days. Figure 6-7 shows the suggested regional soil moisture sampling locations, together with road map over the SMAPEx-4 ground sampling area. Ideally, regional soil moisture can cover the whole range of soil moisture within the ground sampling area, and also capture its temporal variation. Totally 40 locations along a ~220 km long route throughout the SMAPEx-4 ground

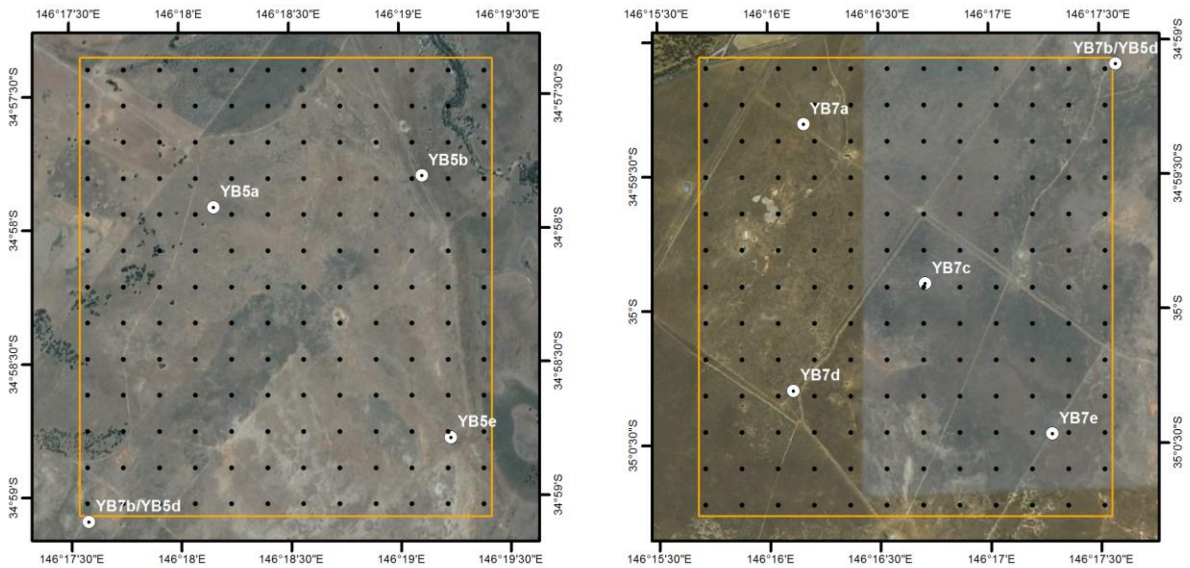

Figure 6-6. Locations of the spatial soil moisture sampling sites at focus areas YB5 (mostly grazing, left panel) and YB7 (mostly grazing, right panel).

sampling area have been suggested to be sampled within ~6.5hr. The actual sampling locations will be selected during the first regional sampling day based on roads, land surface classification, soil texture distribution, and soil moisture retrieval results from the SMAPEx-3. Then all selected locations will be re-sampled in each of following regional sampling days.

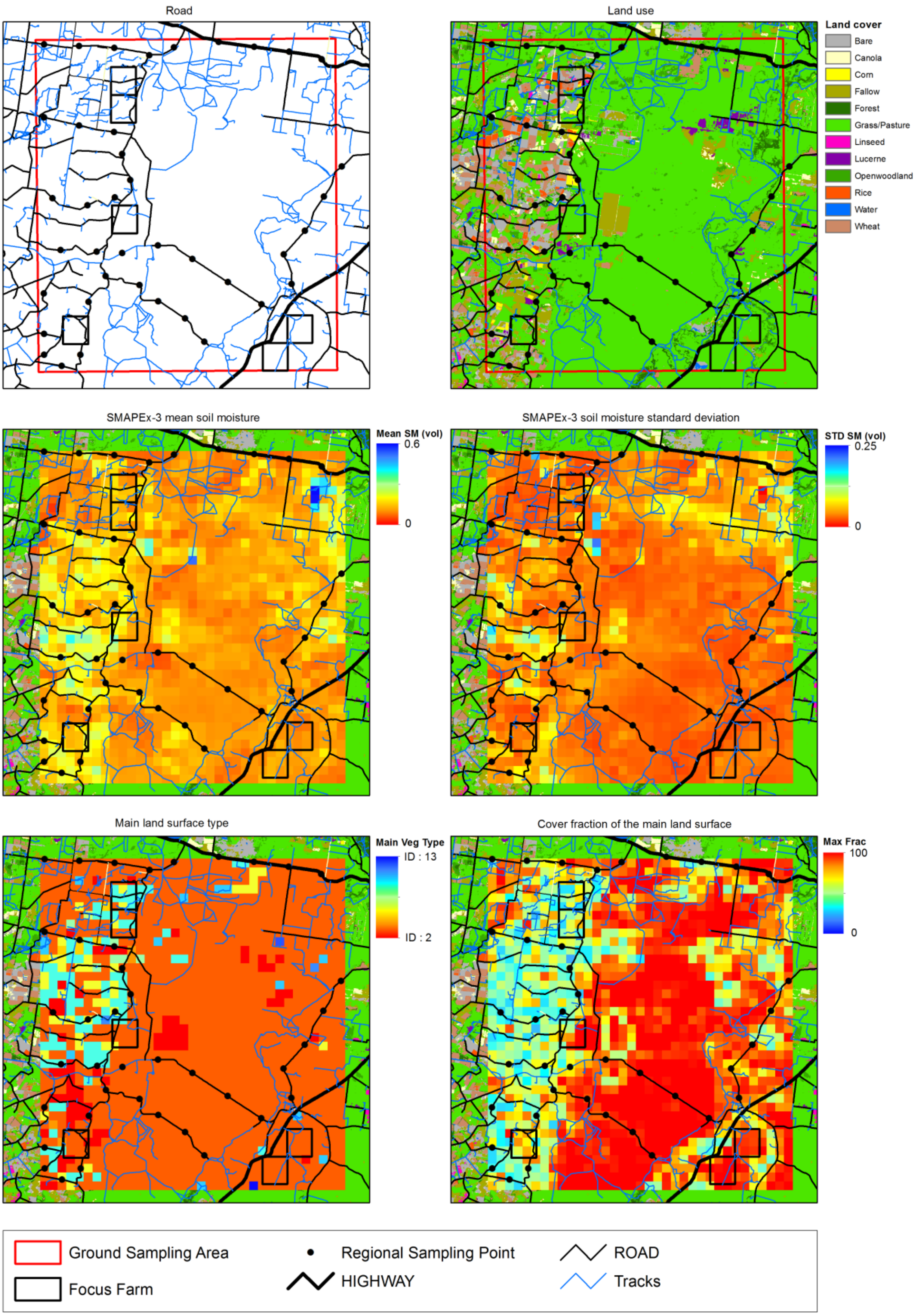

Figure 6-7.Suggested regional soil moisture sampling locations with road map (top left), land use map (top right), mean soil moisture during SMAPEx-3 (middle left), standard deviation of soil moisture during SMAPEx-3 (middle right), dominate land surface at 1-km (bottom left), and cover fraction of dominate land surface (bottom right).

6.4 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, below 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 YF) 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 YE), 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 D leader about their preferred locations.

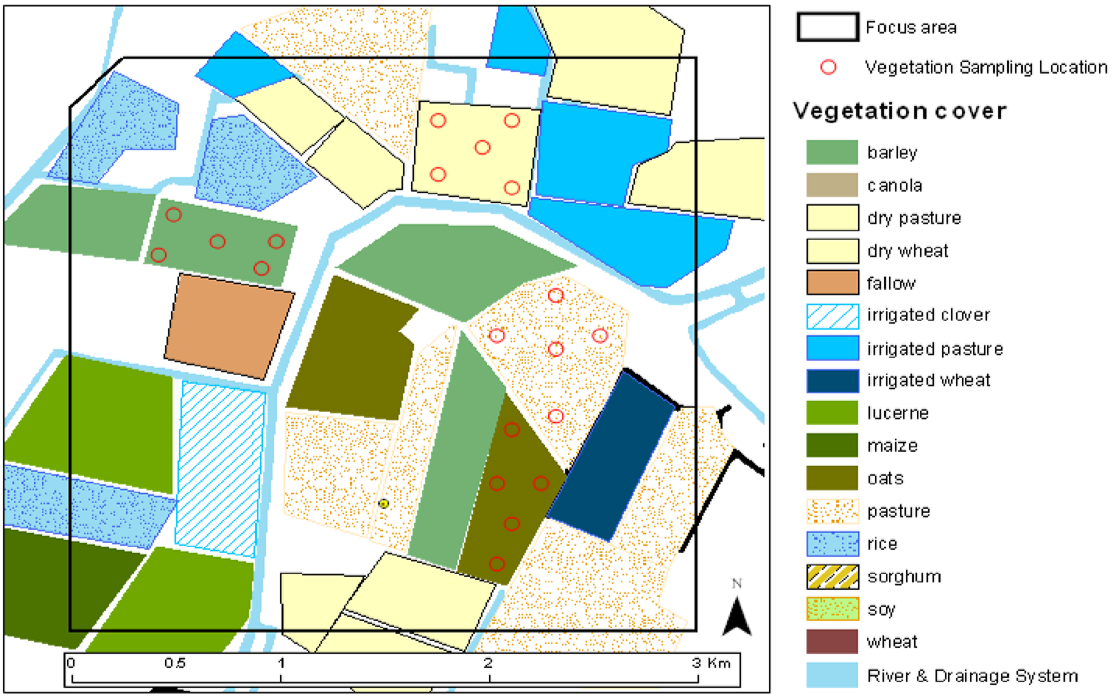

Figure 6-8. Schematic of vegetation sampling strategy for one example focus area (vegetation cover data from November 2006).

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

• 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 6-8 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 study area is not represented in these.

• All vegetation measurements should be prioritised between approximately 10am and 2pm Australian 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.

6.5 Intensive vegetation sampling

Team A (YA4) and Team B (YA7) will be responsible twice per week. Nan Ye and Luigi Renzullo will be the Team A and B leaders respectively for intensive vegetation sampling.

The objective of the intensive vegetation sampling during the SMAPEx-4 campaign is to collect detailed plant structural parameters for selected vegetation types (agricultural and grazing) and to track the evolution of such parameters across the SMAPEx-4 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 two to three times per week.

6.6 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-4 surface roughness will be characterized at 3 locations within each major land cover type in the six focus radar pixel areas. 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). Over furrowed area, additional sampling along and cross row direction will be taken. Team F 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.

6.7 Ancillary sampling activities

A buggy-based remote sensing platform will also be used in SMAPEx-4 (see Figure 6-9), consisting of an L-band radiometer (ELBARA III), multi-spectral sensors (VNIR, SWIR, and TIR), GNSS-R sensor (LARGO), and EM38. These sensors each have a resolution of 1 to 2 m. In addition, EMI will be carried by a 4WD car measuring the soil moisture profile over the same areas covered by the buggy. The 'buggy' team will be responsible for the field testing, operation, and data archiving of these instruments. During each flight day, the buggy team will work on the same focus area (YB5/YB7) as Team B. The buggy will be driven along the intensive soil moisture sampling lines in a north-south direction. The 4WD will follow the buggy, and the different soil moisture retrieval techniques subsequently validated using the point-based soil moisture measurements.

6.8 Supporting data

In addition to spatial soil moisture 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 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 6-10 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. Buggy platform, consisting of ELBARA III, multi-spectral sensors (VNIR, SWIR, and TIR), GNSS-R sensor (LARGO), and EM38.

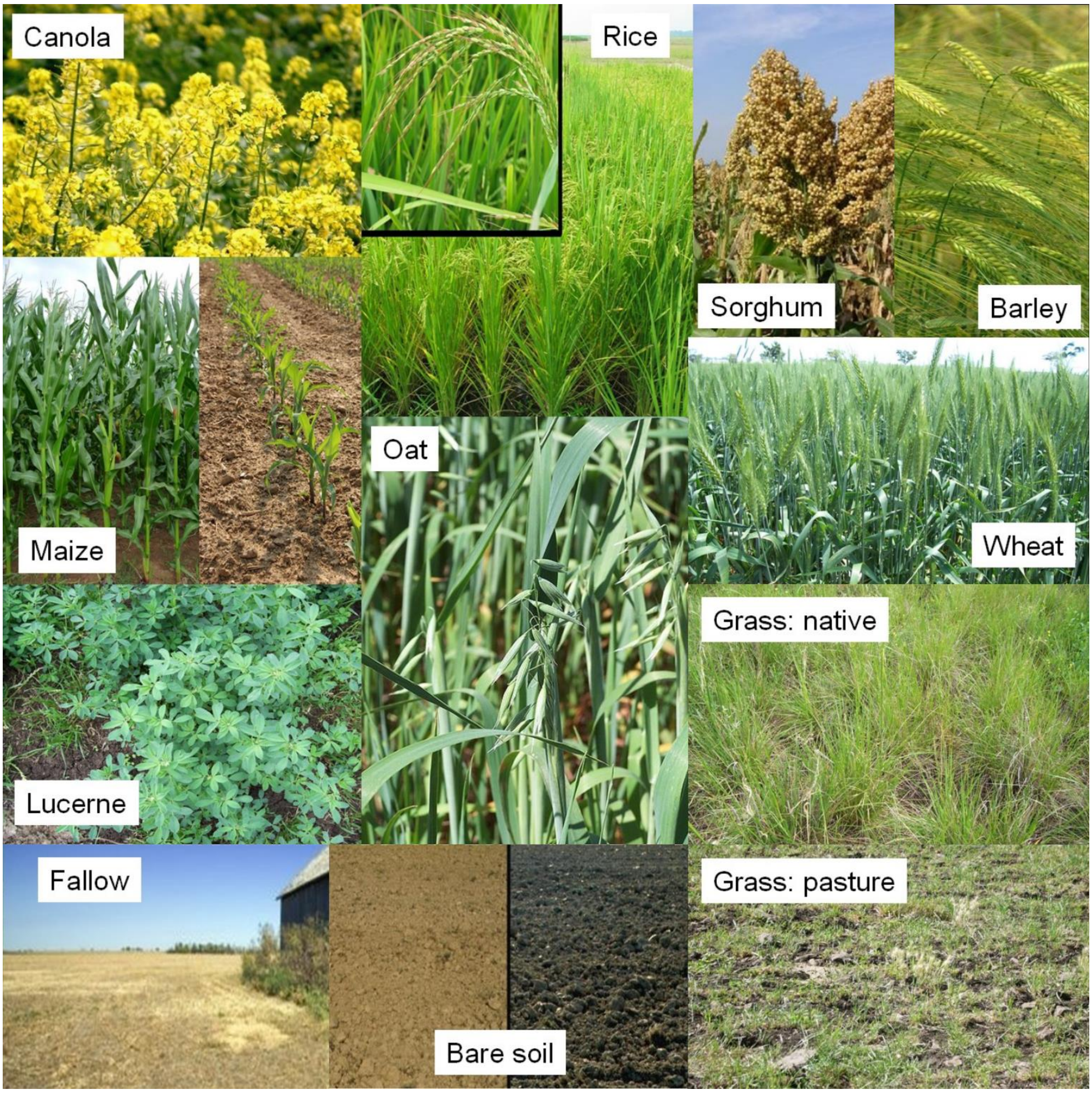

Figure 6-10. Photos of expected vegetation types within the focus farms highlighting features that will be useful for identification.

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 and record it in the HDAS systems.

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.

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 than 10cm from the soil sample (see Figure 6-11). 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 ideally collected for each soil type at each of three wetness levels encountered in the focus area on the sampling day. These wetness level are wet (HDAS reading above $0.35m^3/m^3$), intermediate (HDAS reading between $0.15\text{-}0.35m^3/m^3$) and dry (Hydraprobe reading below $0.15m^3/m^3$).
- For every focus area a minimum of 3 soil samples will be collected per day.

Soil textural properties

Information on soil textural properties is very important for modelling soil microwave emission, as it

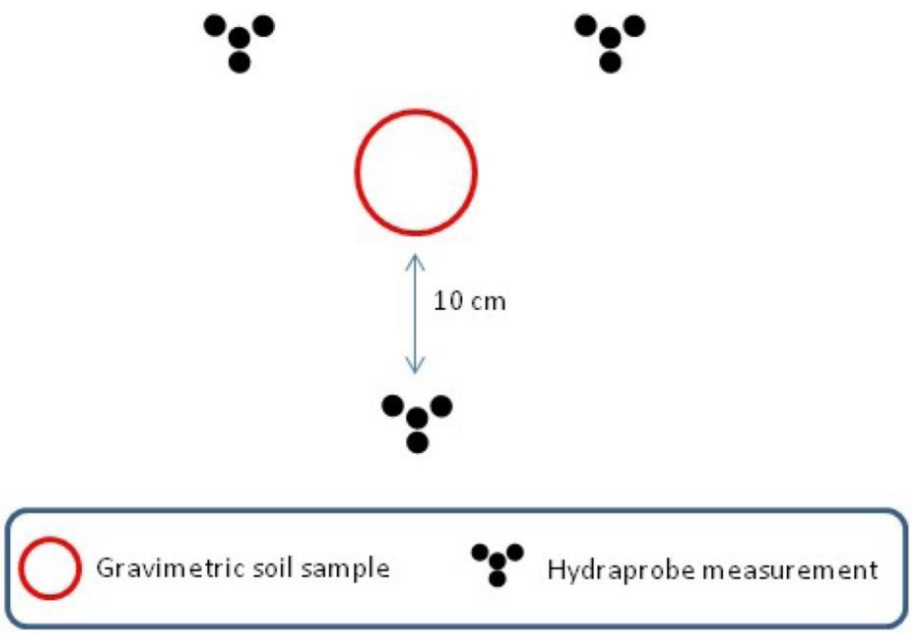

Figure 6-11. A minimum of three Hydraprobe measurements should be made in a radius of 10cm around the gravimetric soil sample.

strongly affects the dielectric behaviour 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. CORE GROUND SAMPLING PROTOCOLS

Field work during SMAPEx-4 will consist of collecting data in the Yanco Region and archiving the information collected during the sampling days. Most of the ground data collection will be applied using 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 six teams (A, B, C, D, E and F). In the flight sampling day, all ground teams will work in focus areas that Team A, B and C will be responsible for soil moisture sampling using the HDAS system and to collect soil gravimetric samples, while Team D and E will conduct vegetation sampling and vehicle-based sampling respectively. In non-flight sampling days, Teams A and B will be responsible for the intensive vegetation sampling in two of the six focus areas, while Team C will mainly take care of regional soil moisture sampling across the SMAPEx-4 ground sampling area. Team F will take soil surface roughness samples. 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-4**.

The campaign is comprised of approximately 16 sampling days. Team A, B and C will work independently on their assigned areas, according to the sampling schedule shown in 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 point to the next and taking a series of three measurements at each predefined sampling location. 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 observations of 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 scheduled training session (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 D and Team F leaders, respectively, depending on the actual conditions.

Coincident with soil moisture sampling activities, the vegetation Team D will sample vegetation independently from the other teams and according to the schedule in Appendix F. 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, all equipment are cleaned and checked back on. Any damages to the equipment should be handed to Frank Winston for fixing. 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, 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, B, and C 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 D 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. Team E will work together with Team B on flight days for buggy-based sampling, and with Team F on non-flight days for soil surface roughness sampling.

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, and locked in the same way you found it.
- 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 that includes food scraps (rubbish bags will be provided in the cars).
- 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 (if necessary, clean the car upon return).
- 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 are typically harmless.
- For your own security, carry a mobile phone or a UHF radio (provided to each team member). 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

Teams A, B, and C 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 three independent measurements per location if readings vary widely take more) with coordinates automatically given by the HDAS system;
- Information about land use and vegetation type at each sampling location (only required once per site);

- Information about canopy height and presence of dew at each sampling location;
- GPS location at each sampling location;
- Additionally, team leaders are in charge of collecting soil gravimetric samples.

The HDAS measurements will be made across 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 three 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 and straight. 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 0.1m^3/m^3, 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 radius 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 surroundings 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 20L 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 Appendix F 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.**

Hydraprobe 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.

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 at the end of each sampling day, in order to avoid any malfunctions and sampling delays during the subsequent sampling days.

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 D) is in charge of collecting (see also Appendix F 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 or equivalent 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;
- 1x hardcopy of the workplan
- 1x hardcopy map of each focus area with the sampling grids and useful topographic information.
- 1x GETAC unit or equivalent
- 1x CROPSCAN device
- 1x LAI-2000 device
- 1x vegetation destructive sampling kit
- 1x field book
- Pens, permanent markers
- 1x 20L water Jerry can
- 1x first aid kit
- 1x first aid book
- 1x sunscreen bottle
- 1x pair 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 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

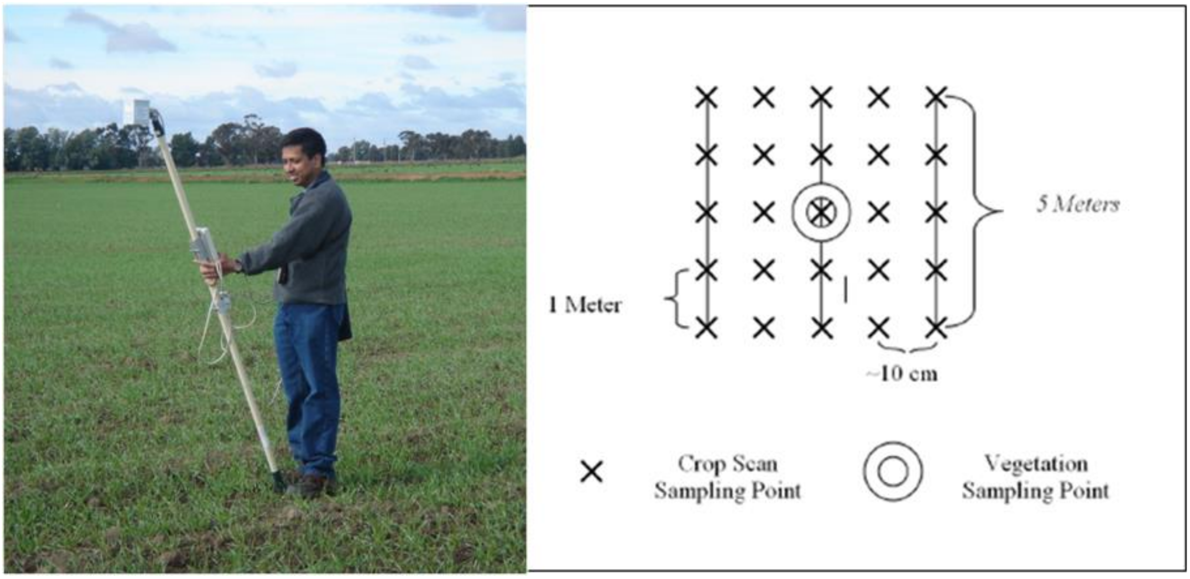

Figure 7-1. (Left) CROPSCAN Multispectral Radiometer (MSR). Size is 8cm × 8cm × 10 cm. (Right) Illustration of the surface reflectance protocol.

available. For SMAPEx-4 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.

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	
		2026 - 2216	
			704 - 716
			965 - 975

Figure 7-2. The LAI-2000 instrument.

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.

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
- 1x pair 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. wheat, corn, native grass, etc) 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 sampled by Cropscan/ASD/LAI-2000.
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 above-ground 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 above-ground 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 D 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).

Wet Weight Procedure

1. Turn on electronic balance.

2. Tare.

3. Remove the plastic bags with vegetation for a given field from the large 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 > 45° 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 plastic bags

At some point during the field experiment (preferably at the beginning), weigh a reasonable number (20-30) of dry new plastic 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).

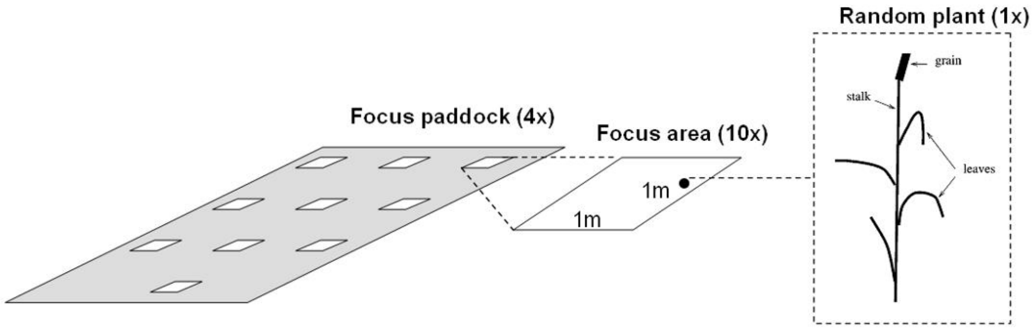

Figure 7-3. Diagram of intensive vegetation sampling strategy.

7.4 Intensive vegetation sampling

Intensive vegetation sampling will be performed by Team A and B, which will sample each of six focus farms 1 to 2 times per week. Due to the time limitation, extensive coverage of the various vegetation types across the entire SMAPEx ground sampling 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 6 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 sampled.

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 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

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

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 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.

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

The location of the 10 focus sites on the paddock will be preloaded on the Getac 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 plastic bag. Label a small plastic bag as date/paddock ID/species ID/leaves. NOTE: All the leaves from a particular species on a paddock can go in the same bag.
12. Store the stalk in a separate big plastic 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 bag.
13. Seal both bags inside another big plastic bag 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
- 1x Pair of gloves
- 100x Plastic bags for storage
- Rubber bands
- 1x Meter stick
- 1x Measuring tape
- 4x Flagged sticks (to delineate 1m × 1m area)
- 1x Digital calliper (for leaves thickness, 0.1mm accuracy, 0-10mm range)
- 1x Build-in camera of Getac
- 1x Precision Ruler (for leaves width, length)
- 1x Quadrangle 50cm × 50cm
- 1x HDAS system

7.5 Soil gravimetric measurements

At least three 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 gravimetric sample 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 aluminium tray weight on the gravimetric drying form.
6. Label the aluminium tray uniquely based on the sample ID using a permanent marker
7. Place the used bags in order. The labelled bags will be used for permanently storing the samples after the drying procedure is finished.

Dry weight 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-4\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, B, or C) and Area_ID is the focus area identification code (see Table 6-1).

7.6 Surface roughness measurements

Jon Johanson and Ying Gao from Team F and Sabah Sabaghy from Team C will be responsible for the surface roughness measurements during SMAPEx-4. 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 F. 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 F 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 Built-in level
- 1x Field book
- 1x Pencil
- 1x Roughness sampling recording form
- 1x Digital camera
- 4x Wooden blocks
- 1x Marker

Surface roughness sampling protocol

Soil roughness measurements will be made using a 1m long drop pin profiler with a pin separation of 5mm (see Figure 7-4). 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. For furrowed crop areas, the pin profiler will be placed along/across rows. 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 (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 and note photo ID #2.

Figure 7-4. Pin profiler for surface roughness measurements.

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 YE 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 Ancillary ground sampling

The buggy-based sampling activities are performed concurrently with regional airborne flights and ground soil moisture sampling activity. The Buggy, with L-band radiometer (ELBARA III), multi-spectral sensors (VNIR, SWIR, and TIR), GNSS-R sensor (LARGO), EM38 and INS mounted, will drive at a speed of 3-5 km/h (as permissible by the terrain) along every second track (due to the time required to cover the sampling area) of soil moisture sampling. A total of 6 out of a possible 12 tracks will be covered in each of the YB5/YB7 areas; each track being approximately 3 km in length. As the 4WD with EMI can drive at faster speed, up to 10-15 km/h, it is anticipated that the EMI data will be acquired for all the tracks as well as in the inter-track area.

The procedure for the Buggy-based platform is as follows:

1. Switch on ELBARA and warm up for at least 20 minutes until stable instrument temperatures are achieved; do sky calibration by pointing the horn to the sky (45˚ upward) for about 5 minutes, make sure to avoid looking into the sun or the moon, cars, buildings, towers and etc.; and then do warm calibration by pointing to a blackbody target (microwave absorbing foam) for about 5 minutes. The temperature of the blackbody is measured before and after taking the ELBARA measurements. Repeat the calibration at the end of day.

2. Switch on EM38 and warm up for at least 15 minutes; do battery test, reading of which will be between -1500 and -720 for a good battery; Perform calibration at least 3 times a day: beginning of the day, in the middle, end of the day. Remember to remove any surrounding metal objects (including the phone, ring, coin etc.) before calibration. Use RS232 cable to transmit the real-time data from EM38 to the field laptop.

3. Switch on LARGO, NVIR, SWIR, and TIR, and check if they are measuring, then leave them running until end of experiment of that day. Switch on INS and initialize it by accelerating the buggy to a speed more than 18km/h. Check the status of initialization and real-time. Use the field laptop to control INS and check real-time speed and heading information for Buggy.

4. Start driving Buggy and follow the tracks provided by OziExplorer. The speed likely cannot exceed 4 km/h due to the rough surface, to limit the shaking of the mounted instruments while moving, and also to make sure the ELBARA measurements fully cover the ground without any gaps.

5. At the end of running, make sure data from ELBARA, EM38, INS are saved to an external device; SD card for LARGO and SF card for Multi-spectral sensors are unmounted for backup in the evening. Check the battery life of EM38 and the fuel of the buggy.

The procedure for EMI is as follows:

1. Electromagnetic induction measurements will be performed using the CMD-MiniExplorer (GF-Instruments) towed by a 4WD at the YB5 and YB7 focus farms. During the flights, geo-referenced parallel EMI tracks will be measured with 125 m distance, i.e. half the track separation of the ground-sampling grid and therefore 23 tracks of EMI measurement for each of the focus areas. The sampling frequency is of 2 Hz and an acquisition speed is 10 – 15 km/h. Based on the data acquired from those 23 tracks, a subarea with high ECa variability will be selected to perform repeated EMI measurements between the flights.

2. Vertical electrical sounding (VES) measurements will be performed at specific locations to calibrate the EMI measurements. These calibration spots will be identified by the first sampling of EMI 23 tracks and subarea measurements such that a large apparent electrical conductivity (ECa) range is covered. Here, collocated EMI and VES measurements will be performed. During the campaign, the same spots will serve for calibration measurements throughout.

3. At the calibration spots, soil samples (at 0-5, 5-10, 10-30, 30-50, 50-70 cm depth) will be taken with a hand auger for volumetric soil moisture determination by oven drying. Four Theta-probe measurements will be taken at each of the surface and in 10 cm depth increments. The soil samples will be sealed off in plastic bags and weighted the same day/evening prior to putting in the oven. If possible, the soil texture will be analysed in the lab.

7.8 Data archiving procedures

All the data collected during the daily sampling will be saved onto three 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-4 ground as well as airborne data are shown in Figure 7-5. 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.

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-4\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, B, or C), 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 F:

- 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-4\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 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 Nan Ye at the end of the sampling day after completing the step above.

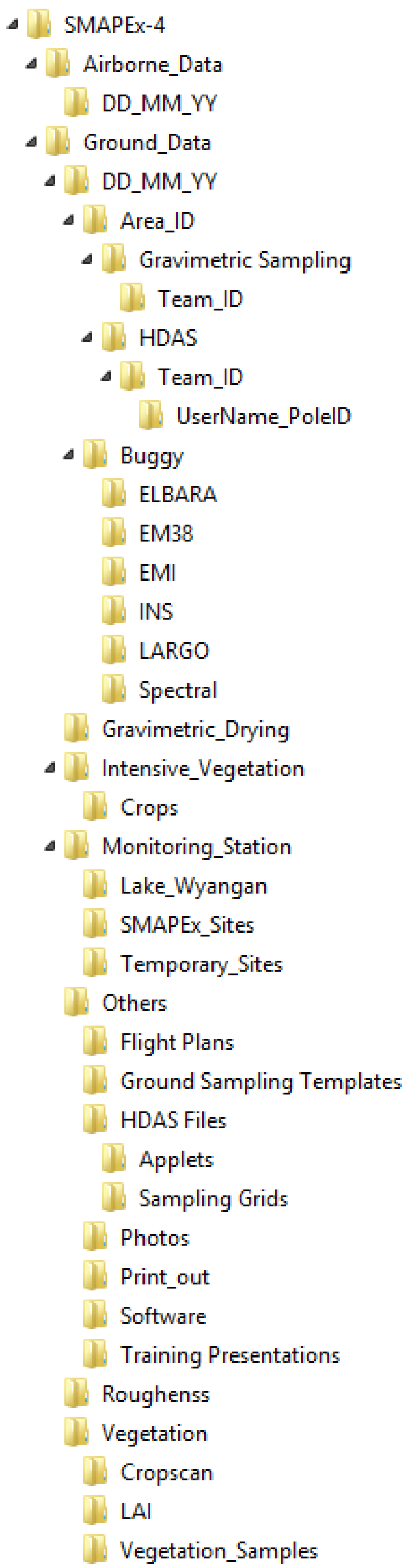

Figure 7-5. Tree diagram of the general SMAPEx-4 file structure.

8. LOGISTICS

SMAPEx-4 activities will be supported by a ground crew, aircraft crew and support crew, overseen by Jeff Walker. The aircraft activities will be conducted from 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 Nan Ye and 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 five teams acting independently, and will be coordinated by Nan Ye with the assistance of Xiaoling Wu. Teams A, B and C will be responsible for soil moisture monitoring three times per week. Each of the three ground soil moisture teams have been assigned two of the six focus areas across the SMAPEx-4 study area. Two to three times per week, Team A and B will also be responsible for the intensive crop sampling, while Team C will be responsible for the regional soil moisture sampling. Regular vegetation sampling will be performed by Team D. Team E will be responsible for buggy-based observation, working in the same focus area as Team B. Team F will be responsible for surface roughness measurements two to three times per week. The aircraft crew (Team F) 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-4 participants is provided in Figure 8-1.

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 Narrandera Airport.

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

Table 8-1. Composition of the teams, vehicles, and focus areas for SMAPEx-4. FA indicates first-aid person.

Team	A	**Team Leader**	Nan Ye	**Vehicle**	Monash rental 4WD #2
Focus Area	Soil moisture sampling: YA4,YA7, intensive vegetation sampling				
Team Members	Yoann Malbéteau, Shuvashis Dey/Siyuan Tian, Robert Parinussa/Wosin Chaivaranont/Chiara Callipari, Grey Nearing/Kiersten Newtoff				
Tasks	Intensive soil moisture sampling, intensive vegetation sampling				

Team	B	**Team Leader**	Luigi Renzullo	**Vehicle**	CSIRO 4WD
Focus Area	Soil moisture sampling: YB5,YB7, intensive vegetation sampling				
Team Members	Anouk Gevaert, Ashley Wright/Yuan Li/Stefania Grimaldi, Vivien Stefan, Ian Marang				
Tasks	Intensive soil moisture sampling, intensive vegetation sampling				

Team	C	**Team Leader**	Alan Marks	**Vehicle**	CSIRO 4WD
Focus Area	Soil moisture sampling: YE,YF Regional soil moisture sampling				
Team Members	Fuqin Li/Erika Podest, Sabah Sabaghy, Seokhyeon Kim, Amy McNally/Alicia Joseph				
Tasks	Intensive soil moisture sampling, regional soil moisture sampling				

Team	D	**Team Leader**	Lynn McKee	**Vehicle**	USDA 4WD
Focus Area	YA4, YA7, YB5, YB7, YE, and YF				
Team Members	Paul Daniel, Alex White/John Prueger				
Tasks	Vegetation sampling				

Team	E	**Team Leader**	Xiaoling Wu	**Vehicle**	Juelich rental 4WD
Focus Area	Buggy sampling: YB5,YB7				
Team Members	Francois Jonard, Philipp Pohlig, Muhsiul Hassan				
Tasks	Buggy sampling				

Team	F	**Team Leader**	Jeff Walker	**Vehicle**	Jeff 4WD
Focus Area	YA4,YA7, YB5,YB7, YE,YF				
Team Members	Jon Johansson, Ying Gao				
Tasks	Airborne sampling, roughness				

Team	G	**Team Leader**	Frank Winston	**Vehicle**	Monash rental 4WD #1
Focus Area	YA4, YA7, YB5, YB7, YE, YF				
Team Members	Nan Ye				
Tasks	Lake transects sampling, equipment maintenance, monitoring station checking and data downloading				

project will be staying at Inga. Two types of accommodation are available for the other SMAPEx-4 participants: motel-style at Amaroo and the Inga bunk house at MRSC. Alternatively, there are a range of motels in Leeton where participants can make their own arrangements.

'Amaroo' motel-style accommodation

Amaroo, meaning 'a quiet place', features 15 bed and breakfast (continental) motel-style rooms (see location in Figure 8-1). 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 with barbecue facilities. Price is $82.50/night/person for single room and $105/night/room for double room (incl. breakfast). There are also a small number of rooms in Amaroo for students that could not be accommodated in Inga with a negotiated cheaper rate of $50/night/room.

'Inga' bunk house accommodation

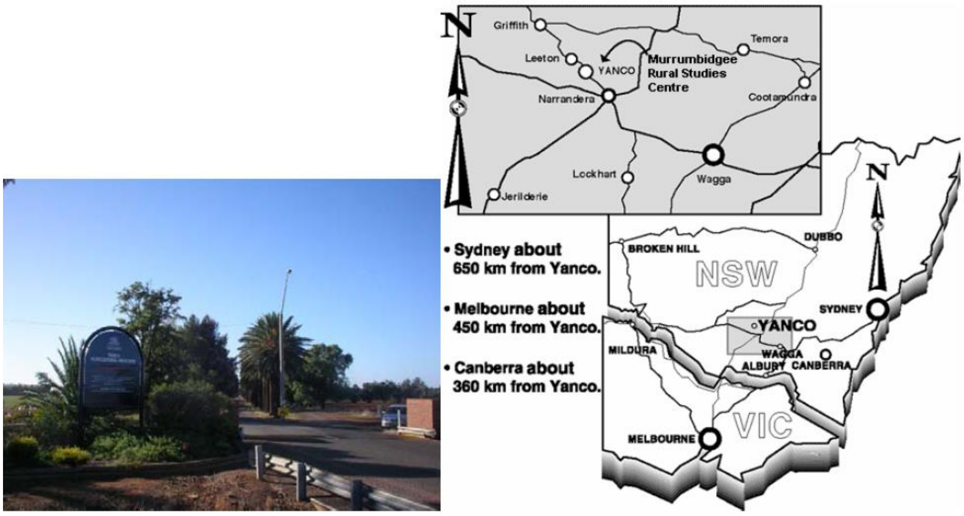

Figure 8-2. Location of the YAI at Yanco.

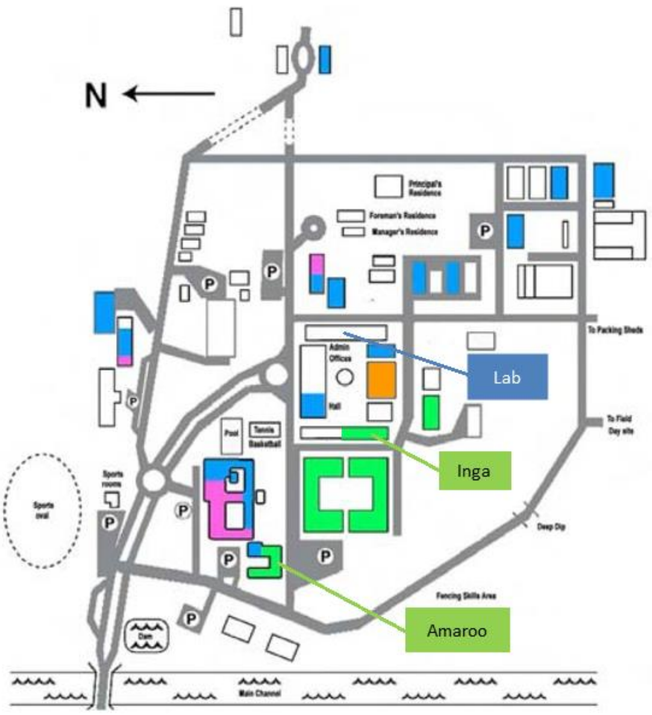

Figure 8-1. Map of the Yanco Agricultural Institute.

Table 8-2. Accommodation logistics for SMAPEx-4 participants.

Name of participant	Accommodation type	Check in	Check out
Alan Marks	Amaroo	30th April	22nd May
Alex White	Offsite	28th April	11th May
Alicia Joseph	Bunkhouse in Amaroo	TBC: 10th May	TBC: 23rd May
Amy McNally	Bunkhouse in Amaroo	30th April	TBC: 11th May
Anouk Gevaert	Bunkhouse in Amaroo	30th April	22nd May
Ashley Wright	Bunkhouse	12th May	17th May
Chiara Callipari	Bunkhouse	12th May	19th May
Chris Rudiger	Amaroo	30th April	2nd May
Erika Podest	Offsite-Leeton Motor Lodge	5th May	23rd May
Francois Jonard	Amaroo	27th April	8th May
Frank Winston	Bunkhouse	17th April	31st May
Fuqin Li	Amaroo	30th April	5th May
Grey Nearing	Bunkhouse in Amaroo	30th April	TBC: 11th May
Ian Marang	Bunkhouse in Amaroo	1st May	23rd May
Jeff Walker	Bunkhouse	30th April	23rd May
John Prueger	Offsite	TBC	TBC
Jon Johanson	Bunkhouse	30th April	23rd May
Kiersten Newtoff	Bunkhouse in Amaroo	10th May	23rd May
Luigi Renzullo	Amaroo	30th April	22nd May
Lynn McKee	Offsite	28th April	22nd May
Muhsiul Hassan	Bunkhouse	30th April	23rd May
Paul Daniel	Amaroo	30th April	TBC: 22 May
Philipp Pohlig	Bunkhouse in Amaroo	27th April	23rd May
Robert Parinussa	Bunkhouse	4th May; 17th May	14th May; 23rd May
Sabah Sabaghy	Bunkhouse	30th April	23rd May
Seokhyeon Kim	Bunkhouse	30th April	23rd May
Shuvashis Dey	Bunkhouse	30th April	9th May
SiyuanTian	Bunkhouse	10th May	23rd May
Stefania Grimaldi	Bunkhouse	30th April	13th May
Tom Jackson	Offsite-Leeton Heritage Motor Inn	29th April	5th May
Vivien Stefan	Bunkhouse	30th April	23rd May
Wasin Chaivaranont	Bunkhouse	30th April	6th May
Xiaoling Wu	Bunkhouse	30th April	23rd May
YeNan	Bunkhouse	17th April	31st May
Ying Gao	Bunkhouse	30th April	23rd May
Yoann Malbéteau	Bunkhouse	29th April	23rd May
Yuan Li	Bunkhouse	18th May	23rd May

Inga has 14 rooms (see location in Figure 8-1). Rooms have a double bunk, wardrobe and desk. Linen and towels are provided. The bunk house has a kitchen with microwave, kettle and fridge. A free laundry, lounge room and separate-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 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.

Breakfast: A variety of breakfast choices (cereals, milk, toasts, jams) will be made available in the Inga kitchen for SMAPEx funded participants (please advise Xiaoling Wu 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 Inga, 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 Inga kitchen for this purpose.

Lunch: 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 Xiaoling Wu or Frank Winston of any particular dietary requirements upon arrival). Guests staying at Inga 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.

Dinner: 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

Wireless Internet access will be available to SMAPEx-4 participants. Wifi vouchers will be provided to each participant in free of charge. The vouchers have to be activated within two days of printing.

8.6 Daily activities

Field work during SMAPEx-4 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 Nan Ye 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 7); 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

Table 8-3. SMAPEx-4 schedule.

Date	Time	Location	Activity	Coordinator
Thurs, 4/30/2015	9:30~16:00	-	Travel Melbourne-Yanco	X. Wu, Y. Gao
	16:00-16:30	YAI	Check in at YAI	X. Wu, N. Ye
Fri, 5/1/2015	9:00-17:30	YAI, Computer Room	Training session 1	J. Walker, C. Rudiger. N. Ye, X. Wu
Sat, 5/2/2015	8:30-17:00	Focus areas	Survey of sampling areas Practice using equipment	N. Ye, X. Wu
Sun, 5/3/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Mon, 5/4/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Tues, 5/5/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Wed, 5/6/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Thurs, 5/7/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Fri, 5/8/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Sat, 5/9/2015	Day-off			
Sun, 5/10/2015	Day-off			
Mon, 5/11/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Tues, 5/12/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Wed, 5/13/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Thurs, 5/14/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Fri, 5/15/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Sat, 5/16/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Sun, 5/17/2015	Day-off			
Mon, 5/18/2015	Day-off			
Tues, 5/19/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Wed, 5/20/2015	All day sampling (Team A and B: intensive vegetation; Team C: regional soil moisture; Team D: vegetation; Team F: roughness)			
Thurs, 5/21/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Fri, 5/22/2015	All day sampling (Team A, B, and C: soil moisture; Team D: vegetation; Team E: buggy)			
Sat, 5/23/2015	8:30-14:30	-	Travel Yanco - Melbourne	X. Wu, Y. Gao

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

Time	Activity
6:00~6:30	Gathering of the teams at the laboratory Review of the activity of the day Preparation of the instruments for the sampling
6:30	Teams departure for the sampling location
6:30~7:30	Travel to the focus areas
7:30~16:30	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

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

Vegetation Team D 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 F

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

8.7 Training sessions

A 2-day training session has been scheduled to ensure all SMAPEx-4 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 1-2 May 2015. The training session will be held in the Computer Room of the YAI on 1 May (see Figure 8-1) with all the participants. Team A and Team B will have a training session dedicated to the intensive vegetation monitoring on 1 May afternoon in conference room. Teams will visit their respective sampling areas on 2 May, 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;
- 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 USDA, NASA, and CSIRO 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.

Table 8-5. SMAPEx training schedule and activities.

Date	Time	Location	Activity	Coordinator
Fri, 5/1/2015	8:30-9:00	YAI, Computer Room	Presentation: SMAPEx-4 Introduction	J. Walker
	9:00-9:30	YAI, Computer Room	Presentation: Updates on SMAP mission	T. Jackson
	9:30-10:00	YAI, Computer Room	Presentation: SMAPEx-4 logistics and safety	C. Rudiger
	10:00-11:00	YAI, Computer Room	Presentation: SMAPEx-4 sampling strategy	Y. Gao, N. Ye, X, Wu
	11:00-11:15	Break		
	11:15-11:45	YAI, Computer Room	Presentation: HDAS Overview	N. Ye
	11:45-12:45	YAI	Training: HDAS practice (all)	X. Wu
	12:45-14:30	Lunch		
	14:30-15:30	YAI, Computer Room	Presentation: Post-work day check-in & downloads	X. Wu
	15:30-17:30	YAI, Computer Room	Presentation: Intensive vegetation monitoring.	N. Ye
Sat, 5/2/2015	8:30-17:00	Focus Farms	Training: Survey/familiarisation of focus areas	N. Ye, X, Wu

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 SMAP overpass 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:

- 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-4 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.

Table 8-6. Pick-up and drop-off dates and responsible person for rented vehicles and trailer during SMAPEx-4.

Name	Dates	Rental company	Responsible person
Monash Rental 4WD #1	Pick-up	Off Road Rentals	Frank Winston
	Drop-off		Frank Winston
Monash Rental 4WD #2	Pick-up	Off Road Rentals	Xiaoling Wu
	Drop-off		Xiaoling Wu
Juelich Rental 4WD	Pick-up	Off Road Rentals	Philipp Pohlig
	Drop-off		Philipp Pohlig
Monash Rental compact car	Pick-up	AVIS	Chris Rudiger
	Drop-off		Chris Rudiger
Trailer	Pick-up	U-haul	Frank Winston
	Drop-off		Frank Winston

- 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 Appendix K.
- 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 Nan Ye 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 Nan Ye 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 Friday 1 and Saturday 2 May. Those arriving mid-experiment are expected to have a detailed safety and first aid briefing, and to study how to conduct field sampling with their instruments from their campaign "buddy" who they are switching with. 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 from Melbourne to Yanco on Thursday, 30 April (Meeting point: Monash Clayton Campus Bus Loop at 9:30am) and return to

Melbourne on Saturday 23 May (arrival sometime in the afternoon/evening). The "Melbourne shuttle" will consist of 4 vehicles (Monash 4WD #2, Monash compact car, Juelich 4WD and Jeff's 4WD, see Table 8 6). Details on seat allocations are TBD. Xiaoling Wu and Ying Gao will coordinate the shuttle from Melbourne to Yanco, and from Yanco back 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 each 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, E, and G vehicles during SMAPEx-4. Team B, C, D, and F will do its own arrangements for renting their vehicle.

9. CONTACTS

9.1 Primary contacts for SMAPEx-4

The primary contacts for the SMAPEx-4 experiment are:

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

Nan Ye
Phone: 03 990 54950
Mobile: 0410 168 213
Email: nan.ye@monash.edu

Xiaoling Wu
Phone: 03 990 54950
Mobile: 0425 118 055
Email: xiaoling.wu@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 accommodation in the evening.

9.2 Participants

Contact details for all SMAPEx-4 participants are listed below:

Person	Organization	Phone number	E-mail
Alan Marks	CSIRO	0423084737	
Alex White	USDA		Alex.White@ars.usda.gov
Alicia Joseph	NASA GSFC		alicia.t.joseph@nasa.gov
Amy McNally	NASA GSFC		amy.l.mcnally@nasa.gov
Anouk Gevaert	VUA		a.i.gevaert@vu.nl
Ashley Wright	Monash Civil Eng	0421147863	Ashley.Wright@monash.edu
Chiara Callipari	UNSW	0401334304	
Christoph Rudiger	Monash Civil Eng	0410131407	Chris.Rudiger@monash.edu
Erika Podest	NASA	US: +1 626 375 2472	Erika.Podest@jpl.nasa.gov
Francois Jonard	Juelich		f.jonard@fz-juelich.de
Frank Winston	Monash Civil Eng	0421255392	frank.winston@monash.edu
Fuqin Li	Geoscience Australia	0262495867	Fuqin.Li@ga.gov.au
Grey Nearing	NASA GSFC		grey.s.nearing@nasa.gov
Ian Marang	Maquarie University	0466589757	ian.marang@students.mq.edu.au
Jeff Walker	Monash Civil Eng	0413023915	jeff.walker@monash.edu
Jon Johansson	Monash Civil Eng		
John Prueger	USDA		John.Prueger@ars.usda.gov
Kiersten Newtoff	NASA GSFC		kiersten.n.newtoff@nasa.gov
Luigi Renzullo	CSIRO	0459835106	Luigi.Renzullo@csiro.au
Lynn McKee	USDA	0477136234 US:+1 301 648 6644	Lynn.McKee@ars.usda.gov
Muhsiul Hassan	Monash Elec Eng	0432615633	Muhsiul.Hassan@monash.edu
Nan Ye	Monash Civil Eng	0410168213	nan.ye@monash.edu
Paul Daniel	CSIRO	0497365077	
Philipp Pohlig	Juelich		p.pohlig@fz-juelich.de
Robert Parinussa	UNSW	0402931040	r.parinussa@unsw.edu.au
Sabah Sabaghy	Monash Civil Eng	0405153545	sabah.sabaghy@monash.edu

Seokhyeon Kim	UNSW	0435925683	Seokhyeon.kim@student.unsw.edu.au
Shuvashis Dey	Monash Elec Eng		Shuvashis.Dey@monash.edu
Siyuan Tian	ANU		siyuan.tian@anu.edu.au
Stefania Grimaldi	Monash Civil Eng		stefania.grimaldi@monash.edu
Tom Jackson	USDA	US:+1 301 646 3260	Tom.Jackson@ars.usda.gov
Vivien Stefan	CESBIO		stefanv@cesbio.cnes.fr
Wasin Chaivaranont	UNSW	0434216326	
Xiaoling Wu	Monash Civil Eng	0425118055	xiaoling.wu@monash.edu
Ying Gao	Monash Civil Eng	0433329610	ying.gao@monash.edu
Yoann Malbéteau	CESBIO		malbeteauy@cesbio.cnes.fr
Yuan Li	Monash Civil Eng	0425600120	Yuan.Li2@monash.edu

9.3 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

9.4 Farmers

Focus Area	Farmer Name (Farm Nr.)	Home Phone	Mobile Phone
YA4	[illegible]	[illegible]	[illegible]
	[illegible]	N/A	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	N/A
	[illegible]	[illegible]	N/A
	[illegible]	N/A	[illegible]
	[illegible]	N/A	[illegible]
YA7	[illegible]	N/A	[illegible]

	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
YB5	[illegible]	[illegible]	[illegible]
YB7	[illegible]	[illegible]	[illegible]
YE	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
YF	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]

9.5 Accommodation 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

General ground access contact person: Joe Valenzisi

Phone: 0417 274 344

Dehydrator, oven and scales access contact person: Brian Dunn

Phone: 0428 860 204

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: Charmaine Lee

Phone: (02) 6951 2696

Fax: (02) 6951 2620

Email: charmaine.lee@dpi.nsw.gov.au

Leeton heritage motor inn

Contact person: Evelyn Vogt

Address: 439 Yanco Avenue, Leeton, NSW 2705

Phone: (02) 6953 4100

Fax: (02) 6953 3445

Off road rentals

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

Narrandera Airport

Council person in charge: Andrew Pearson

Phone: (02) 6959 5550

Email: Andrew.pearson @narrandera.nsw.gov.au

Airport groundsman: Quinton Young

Phone: 0428 690 518

REFERENCES

Smith, A. B., Walker, J. P., Western, A. W., Young, R. I., Ellett, K. M., Pipunic, R. C., Grayson, R. B., Siriwidena, L., Chiew, F. H. S., and Richter, H., 2012. The Murrumbidgee Soil Moisture Monitoring Network Data Set. Water Resources Research, 48, W07701, 6pp, doi:10.1029/2012WR011976.

Rüdiger, C., Walker, J. P., Kerr, Y. H., Mialon, A., Merlin, O. and Kim, E. J., 2011. Validation of the Level 1c and Level 2 SMOS Products with Airborne and Ground-based Observations. In Chan, F., Marinova, D. and Anderssen, R. S. (eds) MODSIM2011, 19th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 12-16 2011, pp. 2002-2008.

Rüdiger, C., Western, A. W., Walker, J. P., Smith, A. B., Kalma, J. D. and Willgoose, G. R., 2010. Towards a General Equation for Frequency Domain Reflectometers. Journal of Hydrology, 383: 319-329. doi:10.1016/j.jhydrol.2009.12.046

APPENDIX B. OPERATING THE HDAS

SMAP footprint coverage flight

Altitude 10,400ft (ASL) and duration 6.7 hours (departure time 2.30am local time)

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146° 30.293' E	34° 42.454' S	23	146° 33.168' E	35° 0.955' S
2	146° 24.532' E	34° 36.300' S	24	146° 33.414' E	34° 14.965' S
3	146° 0.584' E	34° 36.145' S	25	146° 36.672' E	34° 14.976' S
4	146° 0.835' E	34° 14.775' S	26	146° 36.456' E	35° 0.967' S
5	146° 4.093' E	34° 14.800' S	27	146° 39.744' E	35° 0.977' S
6	146° 3.576' E	35° 0.786' S	28	146° 39.930' E	34° 14.986' S
7	146° 6.864' E	35° 0.811' S	29	146° 43.188' E	34° 14.994' S
8	146° 7.351' E	34° 14.825' S	30	146° 43.033' E	35° 0.985' S
9	146° 10.608' E	34° 14.847' S	31	146° 45.022' E	34° 55.579' S
10	146° 10.152' E	35° 0.834' S	32	146° 22.030' E	34° 55.495' S
11	146° 13.440' E	35° 0.856' S	33	146° 20.059' E	34° 55.485' S
12	146° 13.866' E	34° 14.868' S	34	146° 15.413' E	35° 0.868' S
13	146° 17.124' E	34° 14.888' S	35	146° 15.461' E	34° 55.458' S
14	146° 16.728' E	35° 0.876' S	36	146° 13.491' E	34° 55.446' S
15	146° 20.016' E	35° 0.895' S	37	145° 58.384' E	34° 55.334' S
16	146° 20.382' E	34° 14.906' S	38	146° 0.289' E	35° 0.760' S
17	146° 23.640' E	34° 14.923' S	39	146° 0.712' E	34° 25.325' S
18	146° 23.304' E	35° 0.912' S	40	146° 0.080' E	34° 12.797' S
19	146° 26.592' E	35° 0.928' S	41	146° 2.590' E	34° 13.377' S
20	146° 26.898' E	34° 14.938' S	42	146° 2.464' E	34° 14.788' S
21	146° 30.156' E	34° 14.952' S	43	146° 2.413' E	34° 19.279' S
22	146° 29.880' E	35° 0.942' S	44	146° 24.576' E	34° 30.078' S

Route:1, **(alt↑)**, 2, **(10,400ft)**, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 15, 34, 35, 36, 37, 38, 39 **(10,400ft↓500ft)**,40**(500ft→)**,41, 42, 43, 44, 2, 1

Operational limitation: not more than 175Kts GROUND speed

Aquarius footprint coverage flight

Altitude 10,400ft (ASL) and duration 7.5 hours (departure time 2.15am local time)

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146° 30.293' E	34° 42.454' S	50	146° 10.661' E	34° 9.437' S
2	146° 24.532' E	34° 36.300' S	51	146° 7.407' E	34° 9.414' S
6	146° 3.576' E	35° 0.786' S	52	146° 4.153' E	34° 9.390' S
7	146° 6.864' E	35° 0.811' S	53	146° 0.898' E	34° 9.365' S
10	146° 10.152' E	35° 0.834' S	54	145° 52.113' E	34° 9.289' S
11	146° 13.440' E	35° 0.856' S	55	145° 51.413' E	35° 0.682' S
14	146° 16.728' E	35° 0.876' S	56	145° 48.125' E	35° 0.650' S
15	146° 20.016' E	35° 0.895' S	57	145° 48.859' E	34° 9.258' S
33	146° 20.059' E	34° 55.485' S	58	145° 41.375' E	34° 9.182' S
38	146° 0.289' E	35° 0.760' S	59	145° 40.565' E	35° 0.571' S
40	146° 0.080' E	34° 12.797' S	60	145° 37.277' E	35° 0.535' S
41	146° 2.590' E	34° 13.377' S	61	145° 38.122' E	34° 9.147' S
42	146° 2.464' E	34° 14.788' S	62	145° 30.314' E	34° 9.056' S
43	146° 2.413' E	34° 19.279' S	63	145° 29.389' E	35° 0.441' S
44	146° 24.576' E	34° 30.078' S	64	145° 26.102' E	35° 0.399' S
45	146° 20.424' E	34° 9.495' S	65	145° 27.061' E	34° 9.015' S
46	146° 17.170' E	34° 9.477' S	66	145° 18.928' E	34° 8.908' S
47	146° 18.043' E	35° 0.884' S	67	145° 17.886' E	35° 0.289' S
48	146° 18.089' E	34° 55.474' S	68	145° 14.600' E	35° 0.242' S
49	146° 13.915' E	34° 9.458' S	69	145° 15.675' E	34° 8.863' S

Route:1, **(alt↑)**, 2, **(10,400ft)**, 15, 45, 46, 14, 47, 48, 33, 15, 11, 49, 50, 10, 7, 51, 52, 6, 38, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, **(10,400ft↓500ft)**,40**(500ft→)**,41, 42, 43, 44, 2, 1

Operational limitation: not more than 175Kts GROUND speed

PLIS calibration flight

Altitude 10,400ft (ASL) and duration 0.7 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146° 30.293 E	34° 42.454' S	415A	146° 32.608' E	34° 42.682' S
15	146° 20.016' E	35° 0.895' S	416A	146° 30.627' E	34° 40.286' S
33	146° 20.059' E	34° 55.485' S	417A	146° 32.947' E	34° 42.427' S
70	146° 29.948' E	34° 49.696' S	418A	146° 31.164' E	34° 39.889' S
71	146° 29.960' E	34° 47.692' S	419A	146° 33.480' E	34° 42.026' S
414A	146° 30.286' E	34° 40.538' S			
Route:1, **(alt↑)**, 33, **(10,400ft)**, 15, 33, 70, 71, 414A, 415A, 414A, 416A, 417A, 416A, 418A, 419A, 418A, **(10,400ft↓)**, 1 **Operational limitation: not more than 175Kts GROUND speed**					

PLIS configuration: Range settings

PLIS Settings					**Gamma RS Parameters**	
Height AGL (ft)	**Height AGL (m)**	**Max. Pulse Length (us)**	**Range Samples Used**	**Max. Trigger Delay (ns)**	**Range Extension**	**Image Samples**
1000	304.8	2	192	3700	100	211
1500	457.2	3	256	4700	100	235
10000	3048	10	832	22000	100	531
10400	3169.92	10	832	22800	100	531

PLIS configuration: PRI settings

Max. Speed (m/s): 90 Frequency (GHz): 1.26 Wavelength (m): 0.2381 Max. Doppler Bandwidth (Hz): 756					
Antenna	Mode	Channels	PRF Min. (Hz)	PRI Max. (us)	PRI Used (us)
Main Only	Single Tx Pol – Single Side	1	756	1322.751323	1320
Main Only	Single Tx Pol – Two Side	2	1512	661.3756614	660
Main Only	Dual Tx Pol – Single Side	2	1512	661.3756614	660
Main Only	Dual Tx Pol – Two Side	4	3024	330.6878307	330 (320 for SMAPEx-3)

Main / Aux	Single Tx Pol – Single Side	2	1512	661.3756614	660
Main / Aux	Single Tx Pol – Two Side	4	3024	330.6878307	330
Main / Aux	Dual Tx Pol – Single Side	4	3024	330.6878307	330
Main / Aux	Dual Tx Pol – Two Side	8	6048	165.3439153	160

PLIS configuration: other settings

Decimation	3
Bandwidth (MHz)	30
Attenuator	0
Filter	none
****Operational limitation: not more than 175Kts GROUND speed**	

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)

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”

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.

Table F-4. Intensive sampling of crops task sheet (Team A and B).

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.

Vegetation sampling form

Local Date:				Focus Area:					Team:				
Sample ID	Local Time (HH:MM)	Coordinate		Veg. Type	Canopy Height (cm)	Row Spacing (cm)	Plant Spacing (cm)	Row Direction (°)	Number of Rows	Weight before drying (g)	Weight after drying (g)	Tare (g)	VWC (kg/m^2)
		Lat.	Long.										
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
	:												
Comments: Label bag as Area_ID/DD MM YY/Sample_ID and time													

Surface roughness sampling form

Local Date	Focus Area ID	Name of Person	Team ID
DD/MM/YY			

Sample ID	Local Time	Lat.	Long.	Land Cover	Veg. Type*	Row Direction**	Photo ID N-S-1	Photo ID N-S-2	Photo ID N-S-3	Photo ID E-W-1	Photo ID E-W-2	Photo ID E-W-3
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											
	:											

Comments: * Select from the Getac list
** ** express in degree from North clockwise**

Figure H-2. Road map over the YA4.

Figure H-5. Road map over the YF. Note that access to Farm 59 is via prearranged escort by Neil Callaghan only. Call 0269546763 the day before and meet at house. Only walking access and soil moisture sampling are permitted.

For access to Farm 608, MUST let Shaun Callaghan know on or before the day that we are entering.

Figure H-6. Road map over the YB5.

Figure H-7. Road map over the YB7.

APPENDIX I. SMAPEX FLYER

High-resolution Soil Moisture Measurement from Space

NASA launched a new satellite called SMAP on the 31st January 2015, providing 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 Monash University are planning to undertake two experiments in the Yanco/Coleambally area, and your farm has been selected as a ground validation site 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.

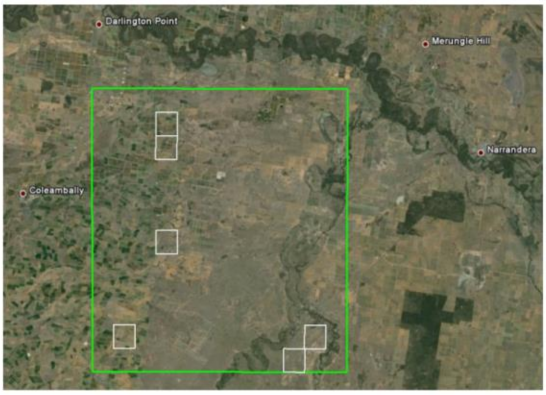

Fig. 1: *Location of the Study Area (green) and ground sampling areas (white) in the Coleambally district.*

In order to make sure that the soil moisture information provided by the NASA satellite is accurate over Australia, researchers at Monash University are planning to make aircraft measurements in the Yanco area of the surface soil moisture with instruments similar to those that are onboard the satellite. This is necessary to validate this new measuring system. 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.

Two aircraft campaigns are envisaged, May and Sep/Oct 2015, covering a range of soil moisture and vegetation conditions during different seasons in the Yanco/Coleambally area. Airborne sampling will be made across a 40km × 40km area including the Coleambally irrigation district and surrounding areas, while the main ground measurements will be conducted within six 3km × 3km sampling 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.

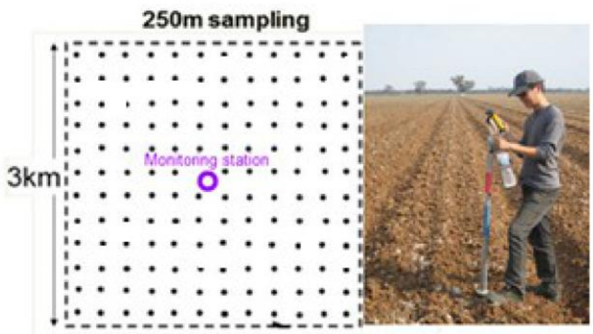

Fig. 2: *Field technician with soil moisture probe and typical soil moisture sampling across a farm.*

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

The ground measurement undertaken on your farm will be conducted by a small team of researchers carrying non-destructive soil