The First Active Passive P- and L-band Experiment (APPLEx-1)

WORKPLAN

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1. CONTENT

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1.   OVERVIEW AND OBJECTIVES

The Active Passive P- and L-band Experiments (APPLEx) comprise a series of airborne campaigns in New South Wales, commencing from 2022. The overall objective of APPLEx is to develop algorithms and techniques to demonstrate that the top ~30cm layer of soil moisture can be remotely sensed at 1km resolution using a combination of P-band radiometer data at 36km resolution, L-band radiometer data at 18km resolution, and P-/L-band radar data at 1km resolution using a range of alternative combinations. Timely soil moisture information on this near-surface layer is critical to a range of applications including improvement of water management for food production in the face of extreme climate variability. Current satellite technologies are limited to the top ~5cm layer of soil using an L-band radiometer or L-band radiometer/C-band radar combination.

The APPLEx airborne campaigns involve collecting airborne P-band data together with L-band data, with concurrent ground observations of soil moisture and ancillary data for a diverse range of conditions. The campaigns will be conducted in the Yanco area, with the aims to

i)   develop candidate soil moisture retrieval strategies that combine the active/passive L-/P-band data, including passive-passive, active-active, and active-passive methodologies and their combinations; and

ii)   select and test the optimal active/passive L-/P-band soil moisture retrieval strategie(s) in an airborne satellite simulation study over various land cover types.

The first campaign (APPLEx-1) is scheduled to take place during the austral summer in February 2022, while the second campaign (APPLEx-2) is scheduled to take place in the austral spring during October/November 2022. Based on historical data records, it is expected that these are the best options to experience a range of soil moisture and vegetation biomass conditions during four-week long experiments.

The APPLEx campaigns have been made possible through infrastructure (LE0453434, LE0882509, LE150100047, LE190100045) and research (DP170102373 and DP210100430) funding from the Australian Research Council. Initial setup and maintenance of the study catchment were funded by research grants from the Australian Research Council (DP0343778, DP0557543, DP0879212, DP140100572 and DP170102373), and the CRC for Catchment Hydrology. APPLEx also relies upon the collaboration of interested scientists from throughout Australia and around the world.

1.1   Overview

Economic, social and environmental planning for a water-limited future requires a capacity to provide information on soil moisture content in a way that is useful for such applications. Of particular importance is meeting the world's growing demand for food production, which is limited primarily by the soil moisture available for germination and growth of crops and pasture. Timely soil moisture status and forecasts are therefore critical for (i) grain growers to make informed decisions on what and when to plant based on likely germination rates and crop yield, (ii) graziers to be proactive in their management of stocking rates based on likely pasture growth, and (iii) dairy and other high water use agriculture to undertake more efficient irrigation scheduling practices. With

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agriculture being by far the largest water user in Australia, even a moderate water saving of 10% in that sector would lead to a water saving equivalent to one-third of the total consumptive use by Australian capital cities. Moreover, soil moisture information is essential to providing information on drought severity and extent to support relief claims for drought exceptional circumstances, and to predict likely flow-on effects in food availability. Soil moisture is also an important boundary condition in weather and climate prediction, providing important information on both short and long-term rainfall and heat-waves. Furthermore, monitoring of soil moisture data will afford a greater understanding of the water resource impacts from global climate change and variability.

Over the past three decades there have been numerous ground-, air- and space-based near-surface soil moisture remote sensing studies using visible, thermal-infrared (surface temperature) and microwave (passive and active) electromagnetic radiation. Of these, L-band microwave has proven to be the most promising approach due to its all-weather capability and direct relationship with soil moisture through the soil dielectric constant, and due to it being in a protected Earth observation band. However, it suffers from being a low-resolution measurement, which has led to research on enhancement of spatial resolution by downscaling the passive microwave measurements at L-band. Moreover, another current fundamental limitation is that L-band remote sensing technology can only provide moisture information on the top approximately 5 cm layer of soil at most, being one-tenth to one-quarter of the wavelength (21 cm at L-band; 1.4 GHz) using the current soil moisture dedicated missions of NASA and ESA. Consequently, this project will demonstrate a new state-of-the-art satellite concept that will provide soil moisture data for the top 30cm layer (rather than 5cm) of soil at high spatial resolution, by combining P-band (40 cm; 750 MHz) and L-band (21cm; 1.24 GHz) radiometer observations. Moreover, it will demonstrate the potential for downscaling the radiometer measurements using L-band (1.24 GHz) and/or P-band (440MHz / 860 MHz) radar observations.

It is postulated that P-band radiometer observations will not only provide soil moisture information on a soil layer thickness that more closely relates to that affecting crop and pasture growth, but that it will produce greater spatial coverage with improved accuracy to that from L-band. This is because P-band should be less affected by surface roughness conditions and have a reduced attenuation by the overlaying vegetation. The APPLEx project will demonstrate the expected improvements by contrasting results from the use of L- and P-band soil moisture retrieval, as well as evaluate downscaling algorithms from the combination of active and passive sensors. Therefore, this project seeks to undertake a complete end-to-end evaluation of P-/L-band radar/radiometer soil moisture remote sensing readiness for the next-generation of soil moisture satellite missions. It also represents Australia's commitment to Earth observation and a realisation that we cannot rely on others to determine the future of such an important observing capability for us.

The APPLEx field campaigns stem from the availability of a dedicated airborne remote sensing capability, which allows us to have a sensor combination on a single aircraft, that provides high resolution multi-frequency passive and active microwave remote sensing capabilities at P- and L-band. The facility includes the Polarimetric P-band Multi-beam Radiometer (PPMR), Polarimetric L-band Multi-beam Radiometer (PLMR), the Polarimetric L-band Imaging SAR (PLIS), and Polarimetric P-band Imaging SAR (PPIS).

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1.2   Objectives

The overall objective of this project is to establish and evaluate a new national capability for microwave remote sensing in environmental research that will provide unprecedented information on soil moisture and allow for demonstrating a new satellite concept. Specifically, by combining different sensors, data can be collected at P- and L- band with approximately half the spatial resolution at P-band as for L-band at the same flying height. Apart from the airborne observations, simultaneous ground observations of soil moisture and ancillary data will be conducted for soil moisture retrieval.

The APPLEx data sets will provide multi-temporal data to:

- Evaluate soil moisture retrieval at 1km resolution using PPMR brightness temperature observations.

- Evaluate soil moisture retrieval at 1km resolution using combined PPMR/PLMR brightness temperature observations.

- Evaluate soil moisture retrieval at 100m resolution using PLIS or PPIS backscatter observations.

- Evaluate downscaling algorithms by integrating radar and radiometer observations at P- and/or L-band.

1.3   General approach

The APPLEx-1 campaign will take place in the Yanco study area within the Murrumbidgee catchment (see Figure 1-1) in south-eastern Australia in austral summer February 2022. This time was selected based on historical surface conditions, with the expectation to maximise the chance of capturing drying down periods of soil moisture together with a range of vegetation biomass through the main summer growing season.

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. The operations base is the Yanco Agricultural Institute, providing both lodging and laboratory support.

Data collected during APPLEx will mainly consist of:

- airborne P- and L-band active and passive microwave observations, together with ancillary optical cameras;

- continuous near-surface (top 5 cm) soil moisture and soil temperature monitoring at 28 permanent stations within the flight area, with sensors at 5 cm depth increments to a depth of 25 cm and also at 40 cm. An additional 6 stations within the broader Yanco Study Area include profile (0-90 cm) soil moisture and soil temperature data;

- additional intensive measurements of near-surface (top 5 cm) and deeper (to 20 cm) soil moisture spatial variation, vegetation biomass, water content and reflectance, and surface

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roughness across four approximately 3 km × 3 km focus area and a 1 km × 1 km focus paddock to add an additional vegetation type.
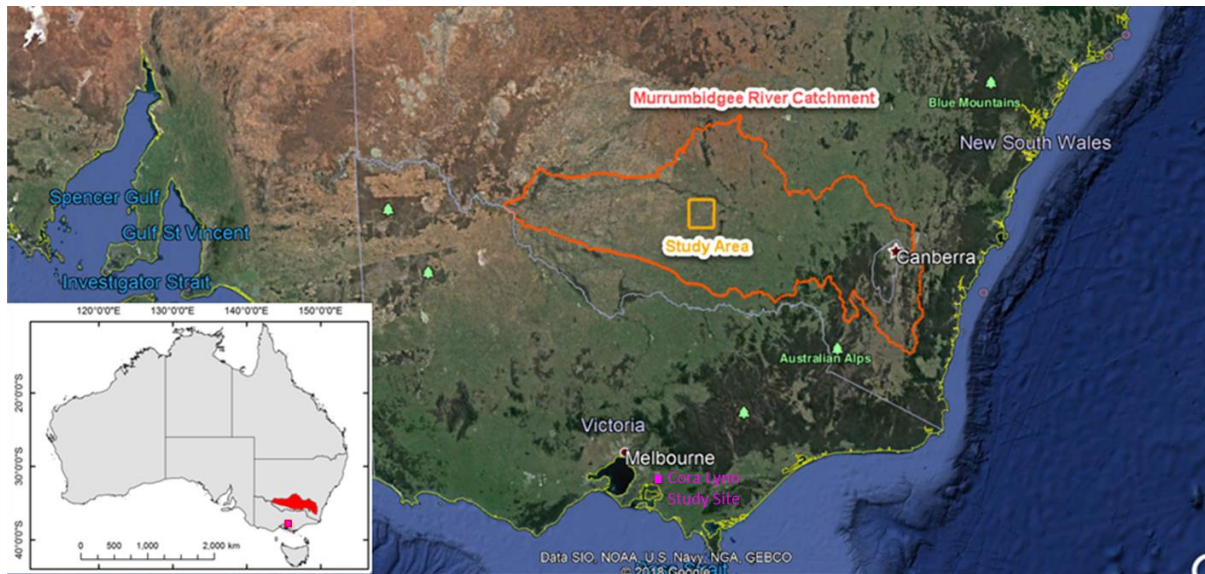
Figure 1-1. Location of the APPLEx study area within the Murrumbidgee catchment NSW.
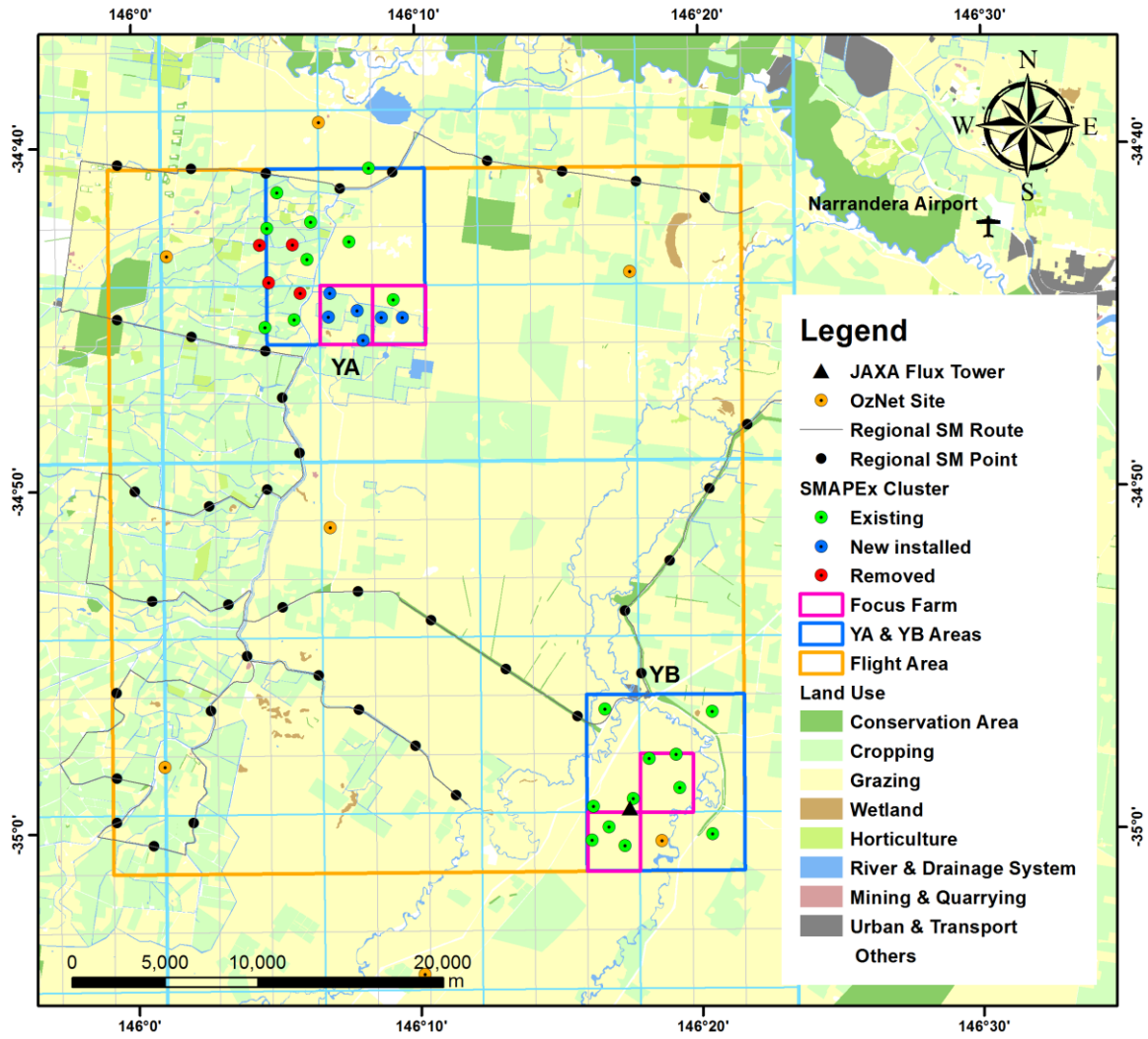
Figure 1-2. Overview of the APPLEx ground sampling areas. The map shows the YA and YB study area, land use and soil moisture monitoring sites across the study area.

2.   AIRBORNE AND GROUND-BASED OBSERVING SYSTEMS

During APPLEx-1, airborne measurements will be made using a small single engine aircraft. The aircraft (Figure 2-1) will include, in the nominal configuration, the PPMR, or PLMR, or PLIS and PPIS (860 MHz and 440 MHz). Additionally, thermal infrared and multi-spectral sensing cameras will be carried in a wing pod (see Figure 2-2). This infrastructure will allow three different flight types including: i) PPMR; ii) PLMR, PLIS and PPIS 860 MHz, and iii) PLIS and PPIS 860 MHz and 440 MHz.

2.1   Aircraft

The aircraft can carry a typical science payload of up to 250 kg (120 kg for maximum range) with cruising speed of 150-270 km/h and range of 9 hrs with reserve (5 hrs for maximum payload). The aircraft ceiling is 3000 m or up to 6000 m 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 station, the RT3003 can give a positional accuracy of 2 cm, roll and pitch accuracy of 0.03° and

Figure 2-1. Experimental aircraft showing a wingtip installation in the left inset, and the cockpit with cockpit computer display in the right inset.
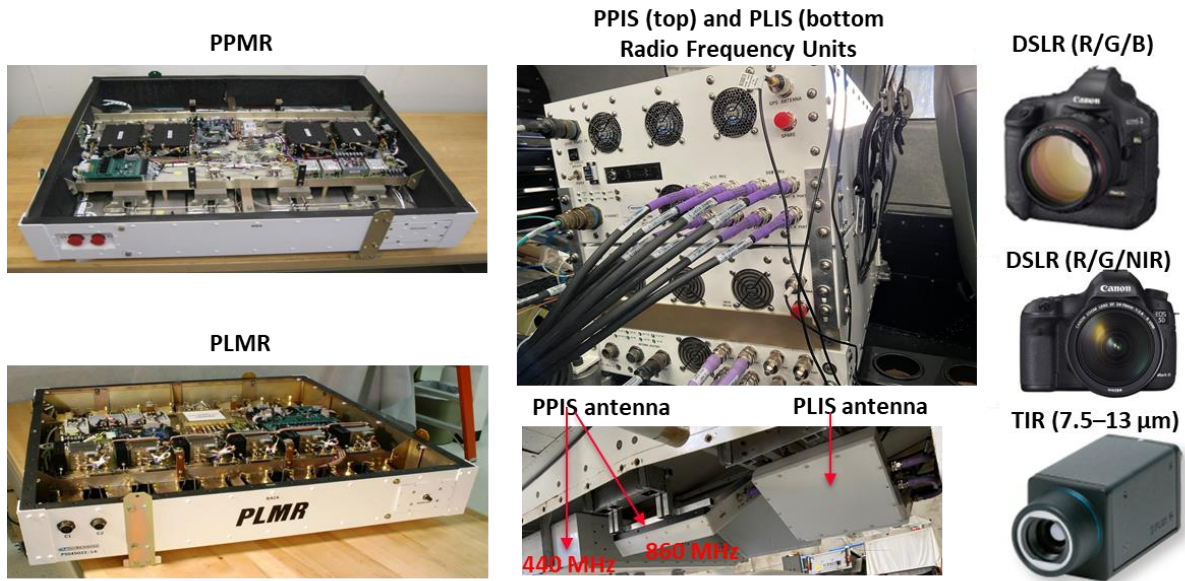
Figure 2-2. View of PPMR, PLMR, PLIS and PPIS, and visible cameras including Canon EOS-1DS Mark 3, video camera and FLIR A65 thermal infrared camera.

heading accuracy of 0.1°.

2.2 Active and passive microwave sensors

Polarimetric L-Band Multibeam Radiometer (PLMR)

The PLMR (see Figure 2-3) measures both V and H polarisations using a single receiver with polarisation switch at incidence angles ±7°, ±21.5° and ±38.5° in either across track (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 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 × 91.5 cm × 17.25 cm. Calibrations will be performed before and after each flight, and also be performed during the flight (once every ~3 flights). The before and after flight calibrations

Figure 2-3. View of PLMR with the cover off.

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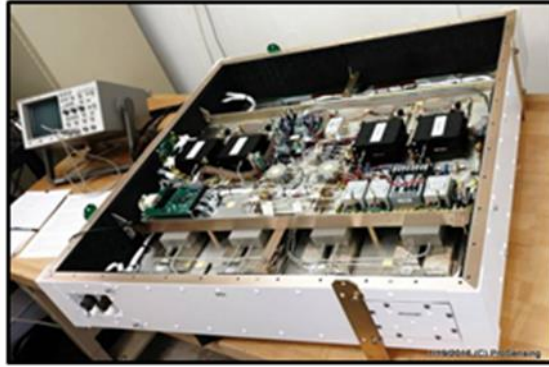
Figure 2-4. View of PPMR with cover off.

are achieved by removing PLMR from the aircraft and making brightness temperature measurements of a calibration target and the sky for each flight. The in-flight calibration is accomplished about every three flights by measuring the brightness temperature of a water body (Lake Wyangan).

Polarimetric P-band Mulitbeam Radiometer (PPMR)

PPMR measures brightness temperature at H and V polarisations (see Figure 2-4). It has a frequency band of 742-752MHz and is composed of a 4x4 array of dual polarized microstrip patches, with incidence angles of ±15˚ and ±45˚. The nominal beam width is 30˚. As for PLMR, calibrations will be performed before, during and after flights. The before and after flight calibration is achieved by removing PPMR from the aircraft and making brightness temperature measurements of a calibration target and the sky for each flight. The in-flight calibration is accomplished about every three flights by measuring the brightness temperature of a water body (Lake Wyangan).

Polarimetric L-band Imaging SAR (PLIS)

PLIS can measure the surface backscatter at HH, HV, VH, and VV polarisations (see Figure 2-5). It 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. The antenna's two-way 6-dB beam width is 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. PLIS will be calibrated using three Polarimetric Active Radar Calibrators (PARCs) located close to the airport, this calibration will be performed once per week. During each flight, PLIS will be also calibrated using five Passive Radar Calibrators (PRCs) and a forest site within the study area.

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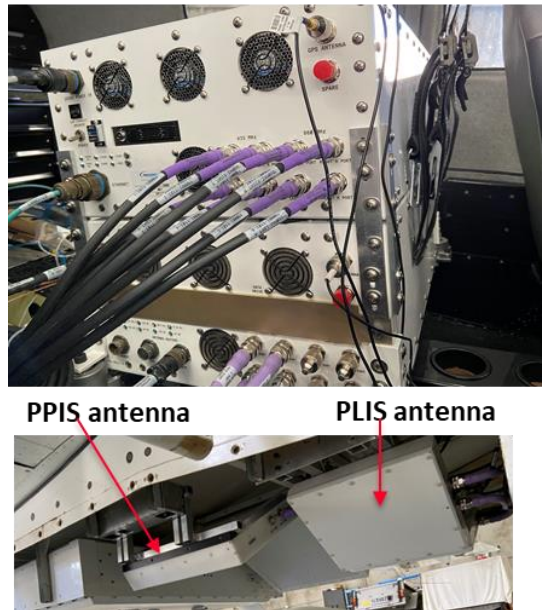
Figure 2-5. Radio Frequency unit and antenna of PPIS and PLIS.

Polarimetric P-band Imaging SAR (PPIS)

PPIS can also measure the surface backscatter at HH, HV, VH, and VV polarisations (see Figure 2-5). The system can be configured to operate independently at 440 MHz (430 to 450 MHz) or 860 MHz (850 MHz to 870 MHz), or can be operated in interleaved mode with simultaneous measurements at both frequencies. The PPIS is composed of two 2x2 patch array antennas operating at 860 MHz, inclined at an angle of 30° from the horizontal to either side of the aircraft, and a single electronically beam steered 4x4 patch array antenna operating at 440 MHz. These antennas obtain push broom imagery over a cross track swath of +/-45°. Both antennas are able to transmit and receive at V and H polarisations. The antenna gain is 9 dBi for 440 MHz and 10dBi for 860 MHz. In the cross-track direction, the antenna gain is within 2.5 dB of the maximum gain between 15° and 45°. The peak transmit power at the output of the RF unit is 20 W for 440 MHz and 14 W for 860 MHz. PPIS will be calibrated once per week using three Polarimetric Active Radar Calibrators (PARCs) located close to the airport. During each flight, PPIS will be also calibrated using five Passive Radar Calibrators (PRCs) and forest within the study area.

Figure 2-6. Canon EOS-1DS Mark 3 (left), NDVI camera (centre), and FLIR A65 thermal infrared camera (right).

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2.3 Optical sensors

Optical camera

A high resolution digital SLR camera and an NDVI camera as well as a FLIR camera are available to the campaign (Figure 2-6).

The digital camera is a Canon EOS-1Ds Mark III that provides 21 MegaPixel full frame images. It has a 24 mm (23°) to 105 mm (84°) variable zoom lens that has been set to 84°. The NDVI camera is a Canon EOS 90D DSLR with 32.5 MegaPixel resolution and has 18-55mm lens. The optical photos will be collected over the entire sampling area at least once.

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 centre swath skin temperature during each flight.

3.   STUDY AREA

APPLEx will be undertaken in the Yanco intensive study area located in the Murrumbidgee Catchment (see Figure 1-1), 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) and was the core site for P-band radiometry studies in 2019 and 2021 (http://www.prism.monash.edu), as well as the focus of previous SMAP pre- and post-launch campaigns: the SMAP Experiment 1 to 5 (SMAPEx-1 to 5, http://smapex.monash.edu), and algorithm development studies for the SMOS mission: the National Airborne Field Experiment 2006 (NAFE'06, http://www.nafe.monash.edu) 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 landscape, the Murrumbidgee catchment exhibits a significant spatial variability in climate, topography, soil, vegetation and land cover. The diversity within this confined area, the large amount of complementary catchment data from long-term monitoring sites, and the past airborne field experiment makes this region an ideal test bed for the comprehensive validation of the new satellite concept described here, and is highly complementary to the current study sites in other countries.

The following sections give a general introduction of the Murrumbidgee Catchment and the operational soil moisture network. Further details on the Yanco area can be found in Walker et al. (2006).

3.1   Murrumbidgee

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
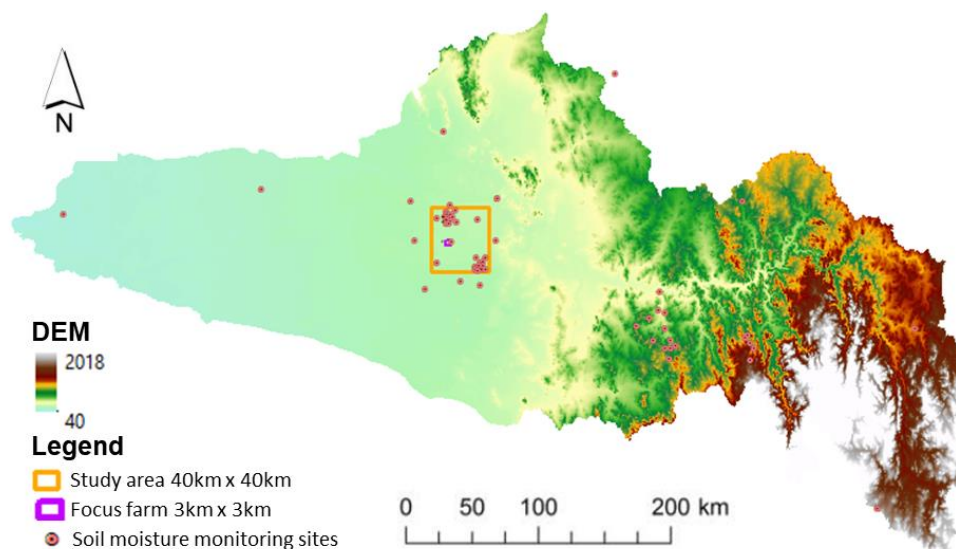
Figure 3-1. Murrumbidgee River catchment and soil moisture monitoring network within the catchment.

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Table 3-1. Top 5 Crop Area's, Intensity, ML Total and % of Total Use 2016/17 within CIA (source: Coleambally Irrigation Annual Compliance Report, 2017).

Crop	Area (Ha)	Intensity (ML/Ha)	Total ML	% Total Use
Rice	11,484	15.14	173,843	53.6%
Pasture	10,679	1.23	13,145	4.1%
Wheat	8,462	1.35	11,450	3.5%
Cotton	6,623	8.77	58,060	17.9%
Corn	5,105	8.55	43,654	13.5%

variability in climate (alpine to semi-arid), soils, vegetation, and land use. 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 the exception of steeper parts of the catchment, which are a mixture of native eucalypt forests and exotic forestry plantations. Agricultural land use varies greatly in intensity and includes pastoral, more intensive grazing, broad-acre cropping, and intensive agriculture in irrigation areas along the mid-lower Murrumbidgee.

The Murrumbidgee catchment is equipped with a wide-ranging soil moisture monitoring network (OzNet) which was established in 2001 (see Figure 3-1). It was upgraded with 20 additional sites in 2003 and an additional 24 surface soil moisture only probes in 2009, with additional sensors in the top 25 cm layer for stations in the Yanco YA region in 2019, and a further upgrade during 2021.

3.2   Yanco region description

The Yanco area is a 60 km × 60 km 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, the 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 included by the APPLEx airborne mapping will be an ~36 km × 36 km area within the Yanco area (145°50'E to 146°21'E in longitude and 34°40'S to 35°0'S in latitude). Approximately one third of the broader APPLEx 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. The principal summer crops grown in the CIA are rice, corn, cotton, and soybeans, while winter crops include wheat, barley, oats, and canola. Rice crops are usually flooded in November by about 30 cm 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, 2017). The average CIA cropping areas for 2017 are listed in Table 3-1.

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There will be intensive ground sampling activities performed concurrently with airborne observations. The ground experiment will be conducted on four focus areas, each of 3 km x 3 km size, being a cropping area YA and a grassland YB as seen in Fig. 1-2. An additional 1 km x 1 km focus paddock will also be included to ensure that all dominant crops are included.

3.3   Soil moisture network description

OzNet network

Each site of the monitoring network (Smith et al., 2012) measures the soil moisture at 0-5 cm, 0-30 cm, 30-60 cm and 60-90 cm 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

Figure 3-3. 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- 5 cm (or 0-7 cm), 0-30 cm, 30-60 cm and 60-90 cm and soil temperature and accommodates periodic measurements of gravity, groundwater and TDR soil moisture measurements.

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).

The 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), though due to resource limitations many of these are now no longer maintained.

Figure 3-3 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 monitored soil temperature and soil suction (in the 60-600kPa range) at the midpoint of the four layers 0-7 cm, 0-30 cm, 30-60 cm and 60-90 cm, whereas the new sites only monitor 15
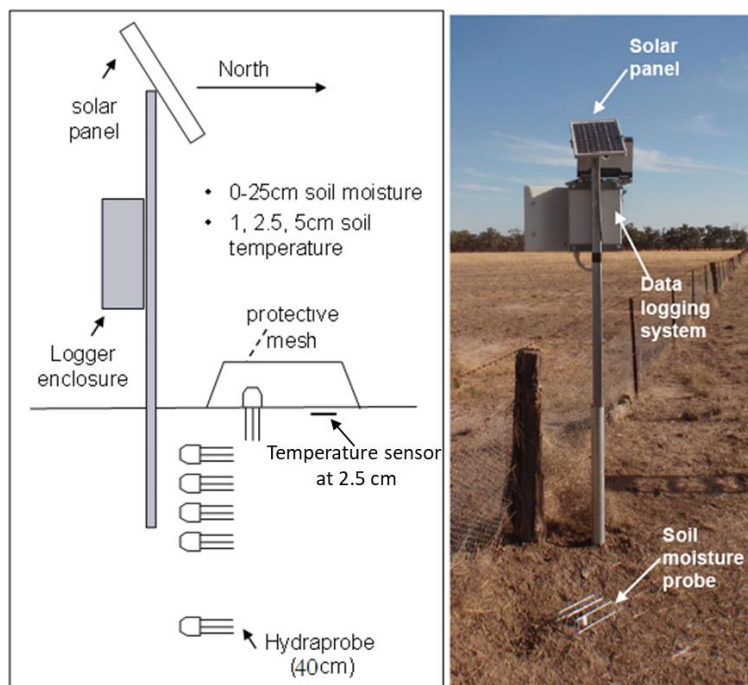
Figure 3-4. Schematic layout of the SMAPEx monitoring site and photo of site YA5.

cm soil temperature from T-107 thermistors (Campbell, http://www.campbellsci.com/107-l). All new sites were upgraded in April 2006 to include a 0-5 cm soil moisture from a Hydraprobe (Stevens Water; http://www.stevenswater.com/catalog/stevensProduct.aspx?SKU='70030'), 2.5 cm soil temperature from thermistors (Campbell Scientific model T-107) and telemetry.

Sensor response to soil moisture varies with salinity, density, soil type and temperature, so a site-specific sensor calibration 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 sites and are therefore estimated from detailed soil temperature profile measurements made at the original soil moisture sites.

The 10 OzNet soil moisture monitoring sites in the Yanco area are all 'new' sites installed throughout late 2003 and early 2004, located on 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. A majority of these sites fall within the area covered by the broader APPLEx area. 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).

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Table 3-2. Characteristics of the OzNet soil moisture stations in the APPLEx study area.

ID	Latitude	Longitude	Elevation (m)	Land use
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 characteristics of the OzNet soil moisture stations in the APPLEx study area are listed in Table 3-2.

SMAPEx network

The 24 additional soil moisture sites were installed in late 2009 to support the Soil Moisture Active Passive Experiment (SMAPEx) project. These continuously monitor soil moisture at 0-5 cm with a Hydraprobe and soil temperature at 1, 2.5 and 5 cm depths (Unidata® 6507A/10 Sensors). These sites were further upgraded in 2021 to include a soil moisture measurement at 40 cm depth and a rain gauge. Moreover, some YA sites were removed and others added, and the YB sites upgraded to the same standard as those in YA. Figure 3-4 shows a schematic of the installations, while Figure 3-5
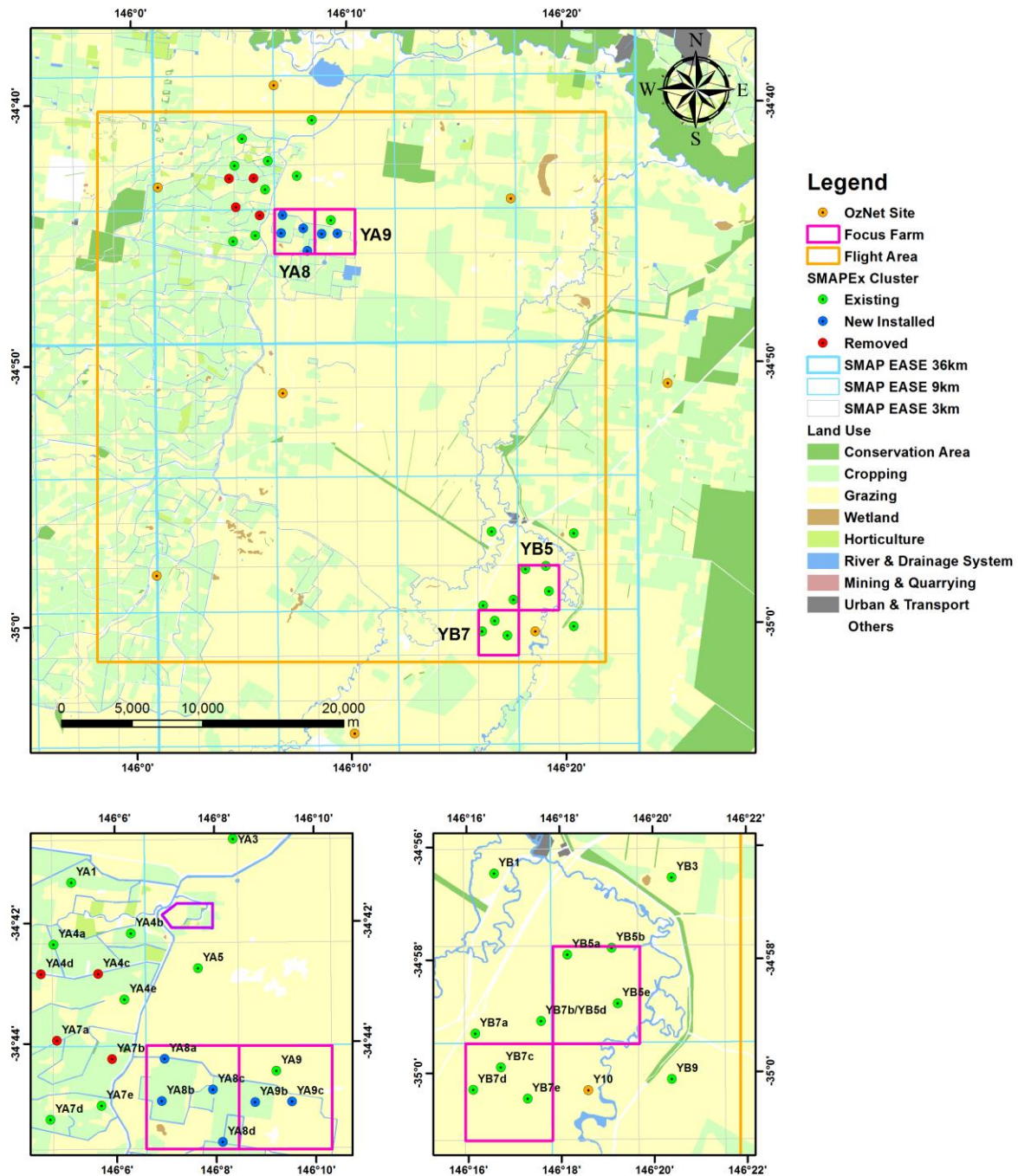
Figure 3-5. Layout of the SMAPEx soil moisture network in the study area.

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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 3-3 lists the main characteristics of the SMAPEx sites. The network is distributed between irrigated cropping land (occupying approximately 1/3 of the APPLEx study area) and grazing dry land.

Table 3-3. Characteristics of the SMAPEx semi-permanent monitoring sites. NOTE: the crop types listed are those observed during PRISM-2021. 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	Cotton	Yes
YA4b	146.10529	-34.703062	Bare	Bare soil	Yes
YA4e	146.10297	-34.721393	Grazing	Perennial grass	No
YA5	146.12771	-34.712858	Grazing	Perennial grass	No
YA7d	146.07777	-34.7544	Bare	Bare soil	No
YA7e	146.09493	-34.750728	Bare	Bare soil	No
YA9	146.15364	-34.741377	Grazing	Perennial grass	No
YB1	146.27654	-34.941243	Grazing	Perennial grass	No
YB3	146.34015	-34.942698	Grazing	Perennial grass	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

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4. AIRBORNE MONITORING

The PPMR, PLMR, PLIS, PPIS and supporting instruments (optical cameras) will be flown on-board a high performance single engine aircraft (see Section 2.1) to collect airborne data across the APPLEx study area approximately every 3 days, making a total of 9 combined active and passive P- and L-band observations (27 flights in total) over the 4 weeks experiment period. Radiometer flights will be followed by specific low altitude passes of Lake Wyangan approximately once each week for in-flight calibration of the P-/L-band radiometers, while all radar flights will have passes of a forest site and the radar calibration targets. For detailed flight line coordinates see Appendix N. These flights will provide brightness temperature and backscatter observations at different frequency bands to develop soil moisture retrieval and downscaling algorithms.

All flights will be operated out of Narrandera Airport. The radiometer ferry flights to and from the airport are 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.

4.1 Flight line rationale

Flight Type 1: PPMR

The PPMR flight is designed for covering an entire hypothetical 36 km satellite footprint at 1 km resolution. All flights use the across-track configuration (see Figure 4-1) and will aim to normalise the data to a common incidence angle of approximately 40°. The flight lines shown in Figure 4-3 will be flown at an altitude of 866 m (AGL) and flying speed of 130 knot (240 km/h). A total of 12 flight lines
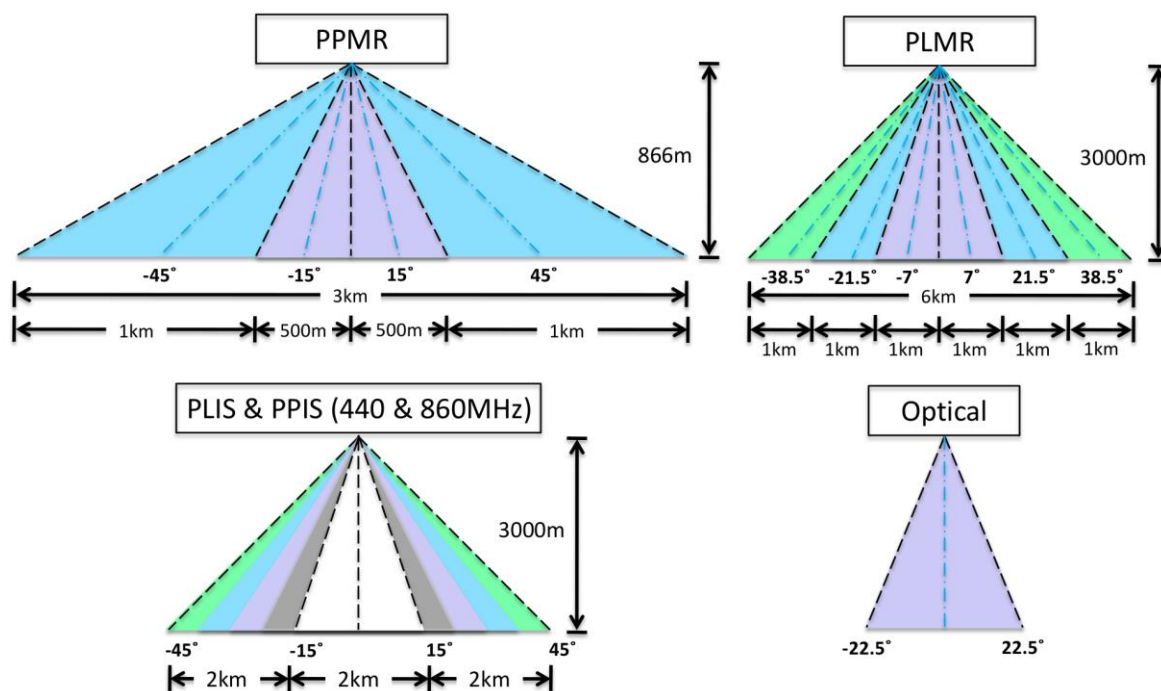
Figure 4-1. Nominal viewing configuration on the aircraft for PLMR, PPMR, PLIS, PPIS, and optical sensors.

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are required to cover the area of 36 km x 36 km, with an estimated total flight time of approximately 3.2 hrs without lake calibration and 3.6 hrs with lake calibration.

Flight Type 2: PLMR (PLMR, PLIS and PPIS 860 MHz)

PLIS and PPIS 860 MHz will be mounted on the aircraft throughout the entire campaign, and operated together with PLMR for several of the flight lines indicated in Figure 4-3 so as to provide radar backscatter observations at two incidence angles when combined with data from Flight Type 3. However, the main purpose of this flight is to collect PLMR data. It is intended that Flight Types 2 and 3 will typically be undertaken on the same day. The PLMR flight is designed to cover an entire hypothetical 36 km satellite footprint at 1 km resolution under as close to the same conditions as for the PPMR flight. All flights use the across-track configuration (see Figure 4-1) and will aim to normalise the data to a common incidence angle of approximately 40°. The PLIS and PPIS 860 MHz observations will be at around 10-15 m resolution but only over the focus areas (Figure 4-2 and
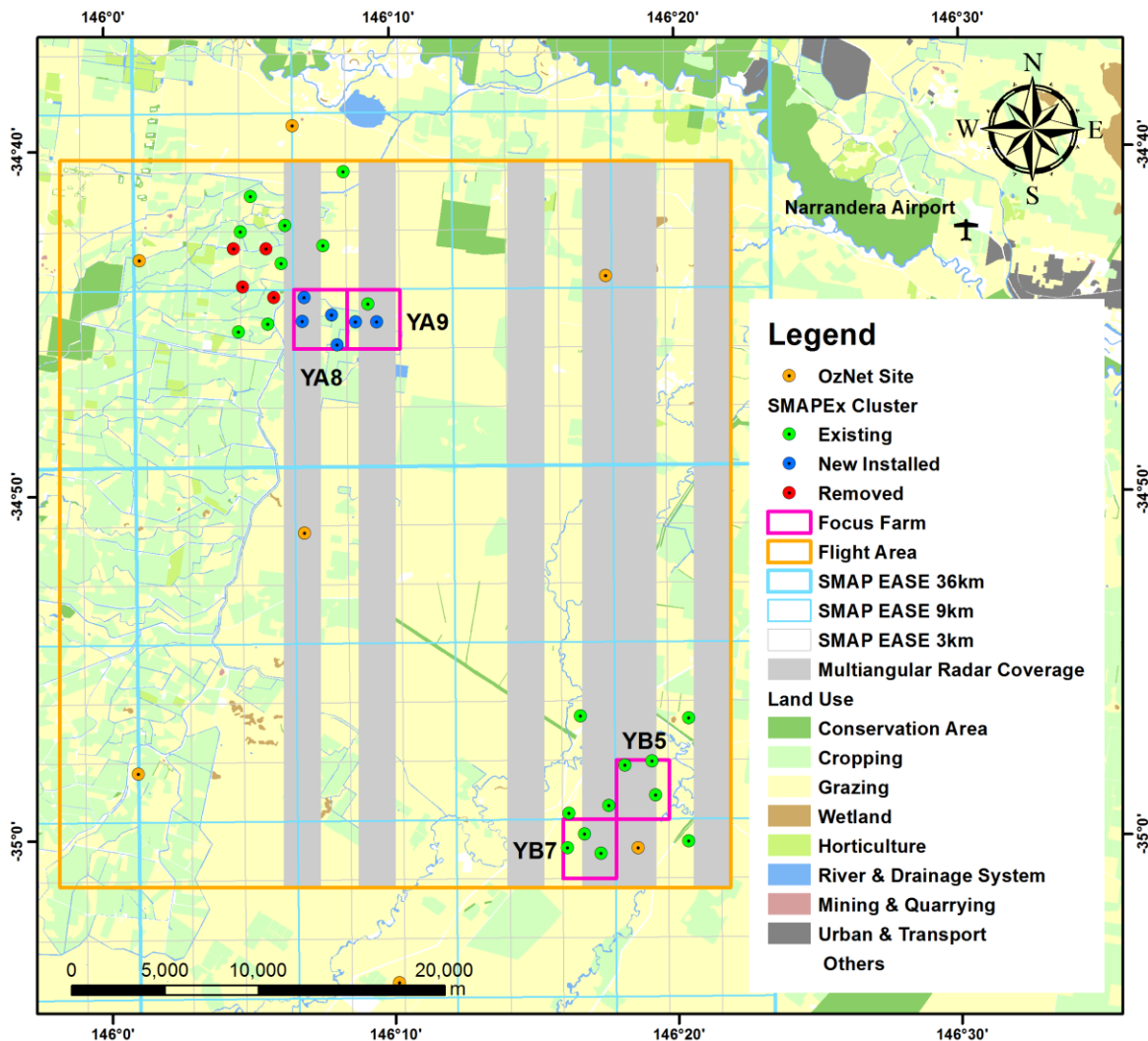
Figure 4-2. Coverage area of multi-angular radar (PLIS and PPIS at 860 MHz) observations.

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Figure 4-3). The flying altitude is 3000 m (AGL) and flying speed is 130 knot (240 km/h). A total of 6 flight lines are required for PLMR to cover an area of 36 km x 36 km; PLIS and PPIS 860 MHz will be operated for 3 of these lines to cover the focus areas. The total flight time is estimated to be approximately 2.1 hrs without lake calibration and 2.5 hrs with lake calibration. Although PLMR and PPMR flight will be operated on different days they will commence at approximately the same starting time to miniminse variations due to temperature.

Flight Type 3: Radars (PLIS, PPIS 860 MHz and PPIS 440 MHz)

Once landed from Flight Type 2, PLMR will be swapped with PPIS 440 MHz, and the three radar bands operated together. If this is not possible due to weather, the radar flight will be conducted the subsequent day. This flight is designed to cover an entire hypothetical 36 km satellite footprint at 100 m resolution under as close to the same conditions as for the PPMR and PLMR flights. The PLIS and PPIS observations will be at around 10 m resolution over the entire 36 km area (Figure 4-2 and Figure 4-3). The flying altitude is 3000 m (AGL) and flying speed is limited to a maximum ground speed of 175 knot (325 km/h). A total of 10 flight lines are required to cover the 36 km x 36 km area. The total flight time is estimated to be 3.6 without calibration and 3.9 hrs with flights over the active and passive calibration targets.

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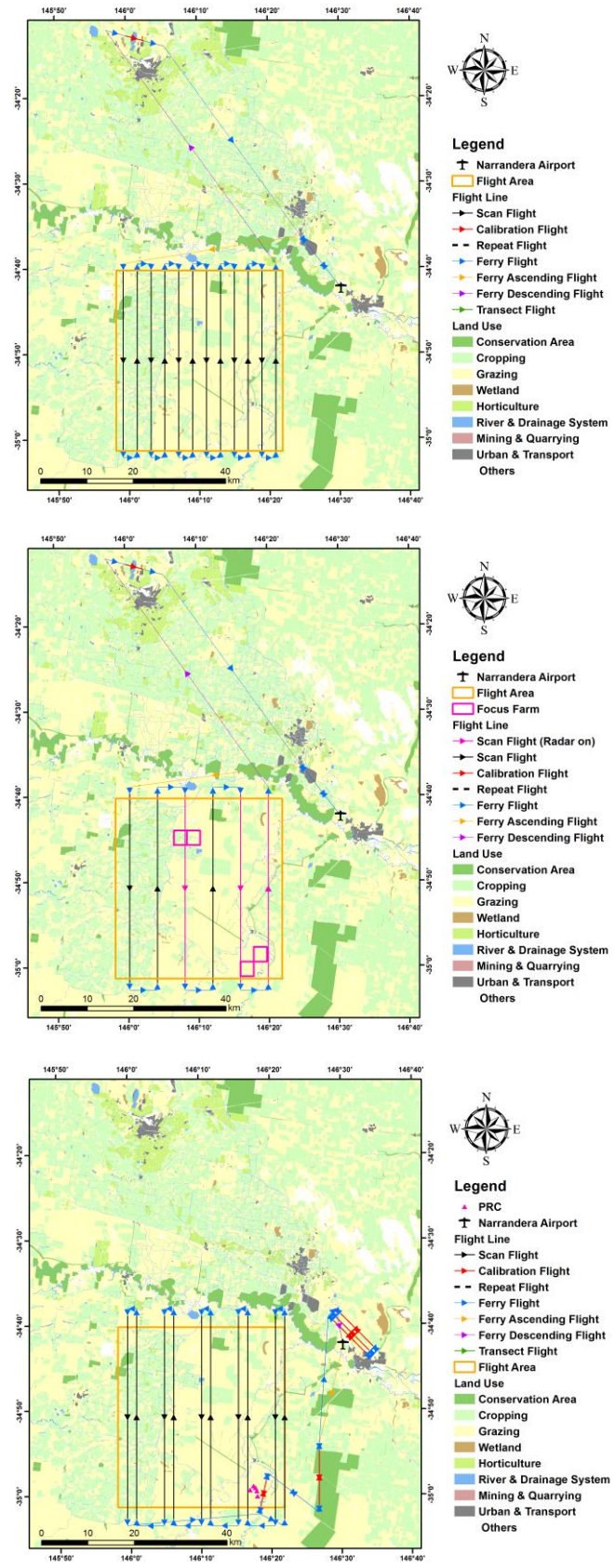
Figure 4-3. Flight design of PPMR (top), PLMR/PLIS/PPIS 860 MHz (middle), and all three radars (bottom)

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4.2   Calibration

Radiometer Calibration

The normal operating procedure for radiometer calibration is to perform a "warm" and "cold" calibration before and after each flight, with an in-flight calibration check. The before and after flight calibrations are achieved by removing the radiometer from the aircraft and making brightness temperature measurements of a blackbody calibration target at ambient temperature, and the sky (see Figure 4-4). The in-flight calibration check is accomplished by flying over a water body and ground stations. Lake Wyangan (Figure 4-5) will be used as the cold in-flight calibration target of P- and L-band radiometers. Given the relatively small size of the water storage, the aircraft will be flown at the lowest permissible altitude (500ft) within the lake boundary and at the slowest possible speed (90 kts) along a distance of around 1 km.

Ground requirements for over-water flights include monitoring of the water temperature and salinity within the top 1 cm 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 1 cm layer will be undertaken with a handheld temperature and salinity meter (Hydralab Quanta®) once per week of the APPLEx campaign (see Figure 4-4). This will involve making north-south and east-west transects at 100 m spacing centred on the monitoring station. The purpose of these measurements is to check for spatial variability.
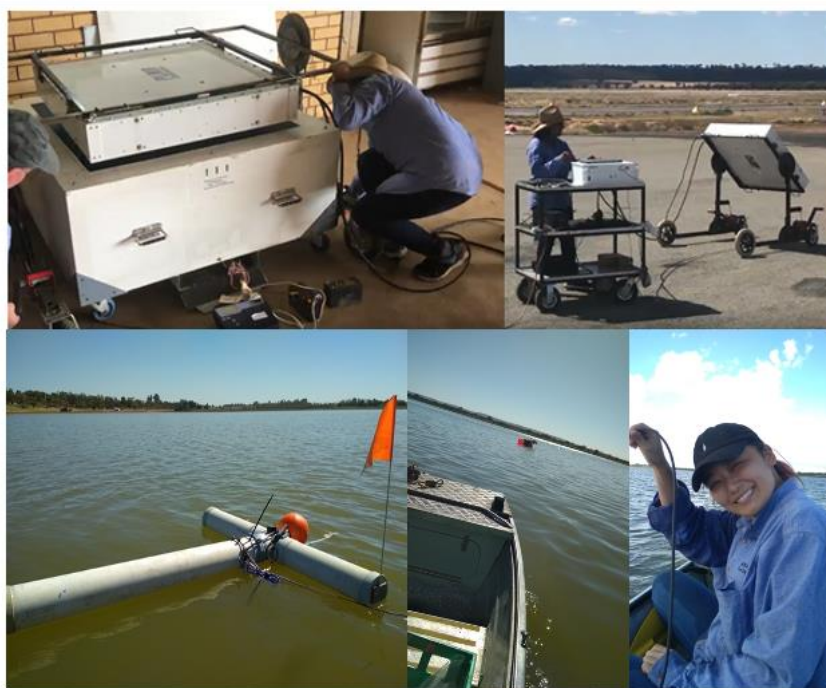
Figure 4-4. Upper right: undertaking a sky cold point calibration; upper left: undertaking a warm point calibration with the calibration box shown in the inset; lower: the buoy used to monitor water temperature and salinity, and undertaking a boat transect of water salinity and temperature.

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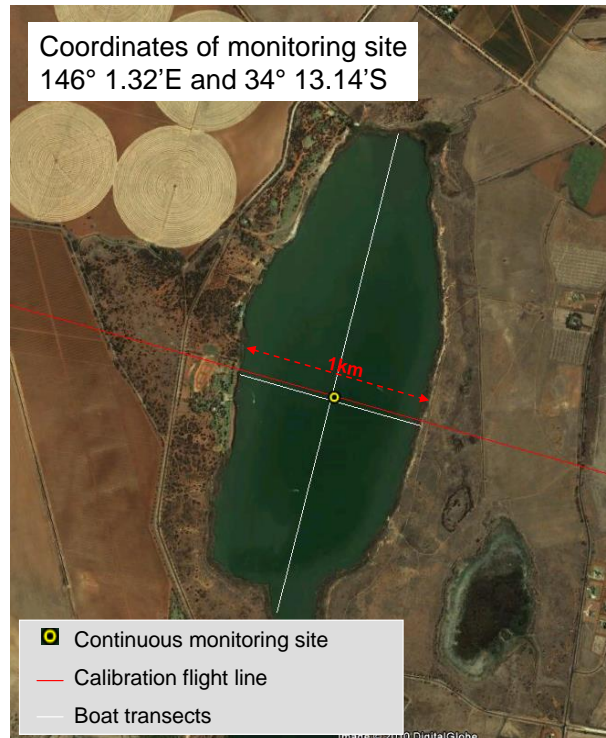
Figure 4-5. Calibration flight (red line) and boat transects (white lines) over Lake Wyangan.

Radar Calibration

Calibration of the radar will be performed using five 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 transponders with a known scattering matrix (see Figure 4-6). PARCs detect the incident microwave energy radiated by the radar and then transmit back to the radar an amplified signal at a known level and equivalent radar cross-section. A set of three PARCs will be used to calibrate the radars 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 APPLEx-1, the PARCs will be located within the Narrandera airport grounds. Calibration of the radars 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 perpendicular with respect to the calibration flight lines. The flight line will be repeated in both directions to calibrate both left and right antenna of the radar. Calibration will be performed at 3000 m altitude (AGL). The PARC calibration circuit will be undertaken weekly during the campaign to check for calibration drift.

Details for PARCs including the locations, azimuth angles and incidence angles for respective runs can be found in Appendix M.

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Figure 4-6. Polarimetric Active Radar Calibrators (top) and Passive Radar Calibrator (bottom).

Passive Radar Calibrators (PRCs)

The PRCs are metallic corner reflectors (see Figure 4-6) capable of reflecting the incident microwave energy radiated by the radar back to the radar. Due to the limited scattering of the incident radiation, the PRCs can also 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 five 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 radar swath, with locations and tilt combined so as to align the PRCs boresight (36° from nadir plus tilt angle to the radar incidence angle at that location), therefore maximizing the reflection of the radar incidence microwave radiation back to the radar. This means the PRCs will have an approximate offset with respect to the flight lines of between 1400 m and 3600 m. The PRCs will be aligned approximately perpendicular with respect to the flight direction, offset in a way that no two PRCs will be aligned in the radar azimuthal or range direction.

The location coordinates azimuth and tilt angles for the PRCs can be found in Appendix N.

4.3   Flight schedule

The APPLEx-1 flights will be undertaken over a 28 day period according to the schedule in Table 4-1. A total of 27 flights over 18 flight days will be conducted across the 4-week time period so as to capture the changes in soil moisture and vegetation.

5. GROUND MONITORING

This chapter should be read in conjunction with Chapter 6 where ground sampling protocols are presented, and Chapter 7 where logistics are discussed. Ground monitoring for the APPLEx-1 campaign is designed for providing supporting ground data for validation of P- and L-band soil moisture retrievals.

In addition to the network of continuous soil moisture monitoring stations described in Section 3.3, the ground monitoring component of the APPLEx-1 campaign will focus on four 3 km × 3 km areas and an additional 1 km × 1 km area to ensure all dominant vegetation types are covered. Ground monitoring will include:

- Supplementary monitoring stations (soil moisture, soil temperature and leaf wetness);

- Intensive spatial sampling of the top 5 cm soil moisture;

Table 4-1. Schedule of flight and ground sampling activities. (*Only half of Team A & B work.)

Week	Day	Flight Team	Instrument	Ground Sampling
0	0	Setup & training	-	-
1	1	PPMR # 1 **cal**	PPMR	**Team A** in YA, **Team B** & **C** in YB
	2	**PLMR & Radars # 1 cal**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	3*	-	-	**Lake transect Team A** deep SM & **C** in YA, **Team B** Regional
	4	PPMR # 2	PPMR	**Team A** & **C** in YA, **Team B** in YB
	5	**PLMR & Radars # 2**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	6*	-	-	**Team A** deep SM in YA, **Team B** Regional
	7	PPMR # 3	PPMR	**Team A** in YA, **Team B** & **C** in YB
2	8	**PLMR & Radars # 3**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	9*	-	-	**Team A** deep SM & **C** in YA, **Team B** Regional
	10	PPMR # 4	PPMR	**Team A** & **C** in YA, **Team B** in YB
	11	**PLMR & Radars # 4**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	12*	-	-	**Lake transect Team A** deep SM in YA, **Team B** Regional
	13	PPMR # 5 **cal**	PPMR	**Team A** in YA, **Team B** & **C** in YB
	14	**PLMR & Radars # 5 cal**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
3	15*	-	-	**Team A** deep SM & **C** in YA, **Team B** Regional
	16	PPMR # 6	PPMR	**Team A** & **C** in YA, **Team B** in YB
	17	**PLMR & Radars # 6**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	18*	-	-	**Team A** deep SM in YA, **Team B** Regional
	19	PPMR # 7	PPMR	**Team A** in YA, **Team B** & **C** in YB
	20	**PLMR & Radars # 7**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	21*	-	-	**Team A** deep SM & **C** in YA, **Team B** Regional
4	22	PPMR # 8	PPMR	**Team A** & **C** in YA, **Team B** in YB
	23	**PLMR & Radars # 8**	**PLMR & PLIS/PPIS**	**Team A** & **C** in YA, **Team B** in YB
	24*	-	-	**Lake transect Team A** deep SM in YA, **Team B** Regional
	25	PPMR # 9 **cal**	PPMR	**Team A** in YA, **Team B** & **C** in YB
	26	**PLMR & Radars # 9 cal**	**PLMR & Radar**	**Team A** in YA, **Team B** in YB, **Team C** finish in lab and pack

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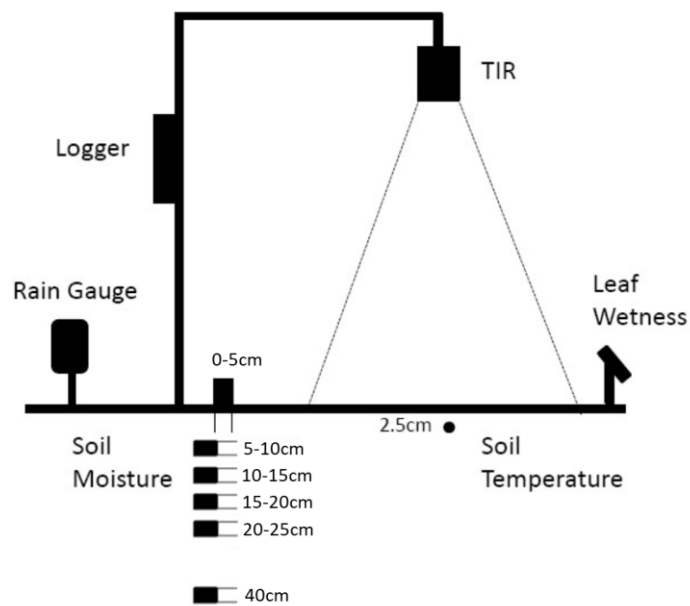
Figure 5-1. Schematic of the temporary monitoring station.

- Additional intensive spatial sampling of top and deep layers soil moisture;

- Regional sampling of the top 5 cm soil moisture;

- Intensive spatial vegetation sampling (destructive VWC, spectral and geometrics); and

- Spatial monitoring of supporting data (land cover type, soil surface roughness, and soil gravimetric samples).

5.1   Supplementary monitoring stations

Permanent monitoring stations will be supplemented by one identical temporary monitoring station at the 1 km focus area, and the addition of thermal infrared and leaf wetness measurements in the 3 km focus areas. Accordingly, these instrumented sites will include a rain gauge, thermal infrared sensor (Apogee), leaf wetness sensor (MEA LWS v1.1), six soil moisture sensors (Hydraprobes; 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm and 40 cm) and one soil temperature sensor (MEA6507A; 2.5 cm) in order to provide time series data during the sampling period (Figure 5-1).

Such measurements will be used for identifying the presence or absence of dew, and verifying the assumptions that (i) effective temperature has not changed substantially throughout the course of the aircraft measurements; (ii) vegetation and soil temperature are in near-equilibrium condition; and (iii) soil moisture has not changed substantially during ground sampling. The supplementary monitoring will be 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 land cover conditions at the time of the campaign. The proposed locations of supplementary monitoring and the vegetation type covered are indicated in **Error! Reference source not found.**. All station data will be recorded in local time reference.

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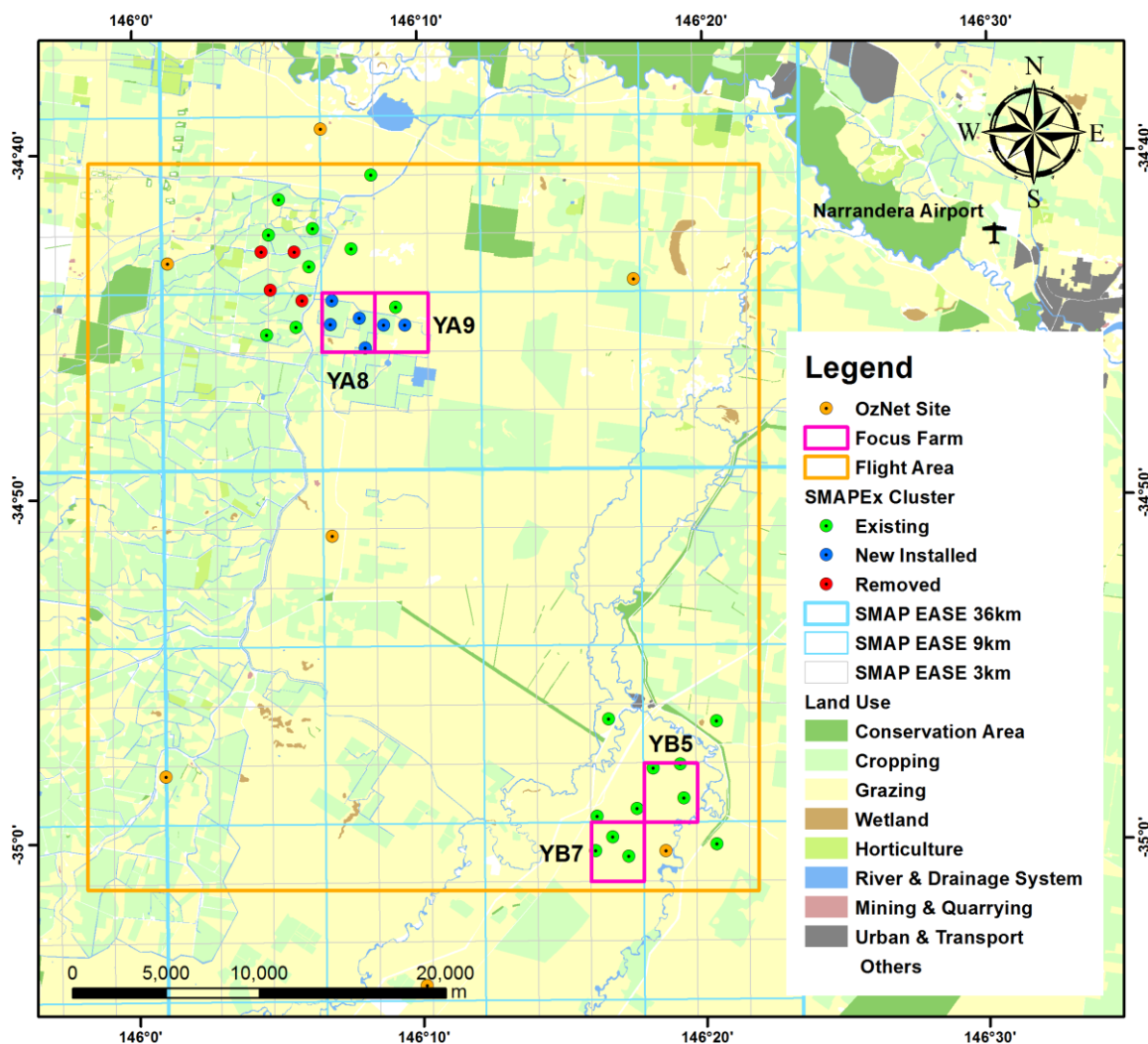
Figure 5-2. Overview of ground sampling areas with photographs. The four focus farms of APPLEx are indicated with purple polygons.

5.2 Spatial soil moisture sampling

Intensive spatial ground soil moisture sampling will focus on four 3 km × 3 km focus areas and a 1 km × 1 km focus paddock to cover the representative land cover conditions within the study area. Figure 5- gives an overview of the locations of the focus areas within the study area. The characteristics of the focus areas are listed in Table 5-1. Soil moisture will be monitored concurrently with each flight using the Hydraprobe Data Acquisition System (HDAS). Spatial soil moisture data will be recorded in local (UTC+10) time reference.

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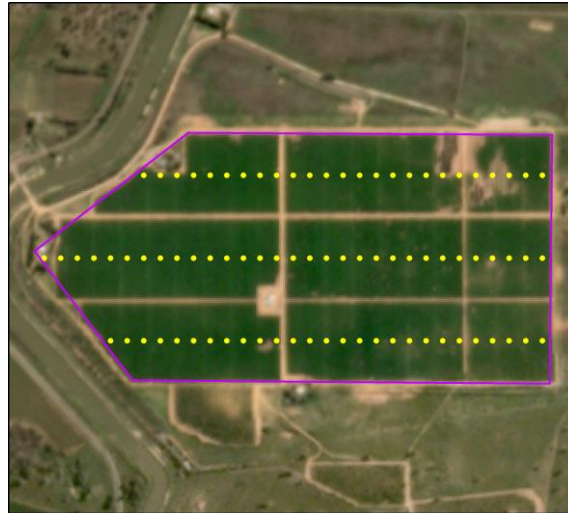
Figure 5-3. Locations of the intensive spatial soil moisture sampling sites at focus paddock.

During each flight day, focus areas will be sampled by two dedicated teams; Team A and Team B. Sampling grids for each focus area can be found in Figure 5-3, Figure 5-4 and Figure 5-5. Due to the limited number of samplers (4-5 for each team), fewer points than indicated may need to be selected across the focus area according to different land cover types. The coordinates of the focus area boundaries are given in Appendix G.

Team A will be responsible for YA (YA8 / YA9 and the 1 km focus paddock) dominated by cropping area while Team B will be responsible for YB (YB5 / YB7) dominated by grazing area, ensuring that a wide range of soil moisture conditions are encountered for both land cover types. Local scale (1m) soil moisture variation will be accounted for by taking a minimum of three surface soil moisture measurements within a radius of 1 m at each sampling location until a consensus measurement is

Table 5-1. Characteristics of the intensive ground sampling areas. Soil texture data are derived from *soil particle analysis of 0-30 cm gravimetric samples

Area Code	Land Use	Vegetation Type (s)	Mean Elevation	Soil texture (%C/%Si/%S)
YA8	Irrigated cropping (90%); Grazing (10%)	wheat, barley, cotton, naturalised pasture	131m	Clay loam (31/48/20)*
YA9	Irrigated cropping (90%); Grazing (10%)	Wheat and barley, cotton; Naturalised pasture	130m	Clay loam (31/48/20)*
YB5	Grazing (100%)	Native or naturalised pasture	127m	Silty clay loam (39/43/17)*
YB7	Grazing (100%)	Native or naturalised pasture	127m	Silty clay loam (39/43/17)*

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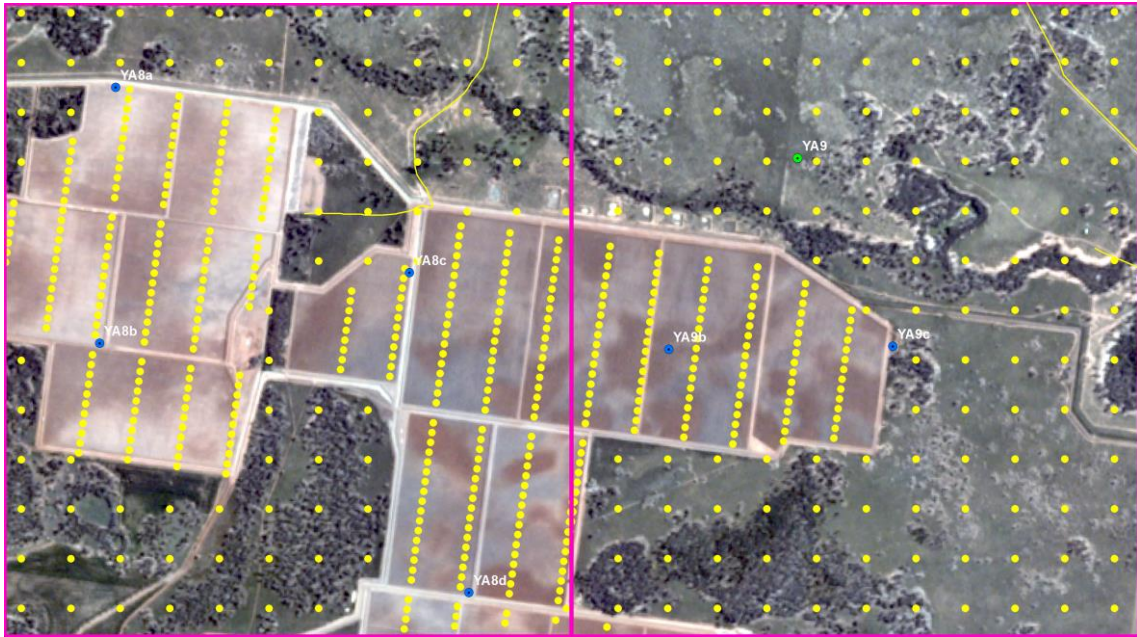
Figure 5-2. Locations of the intensive spatial soil moisture sampling sites at focus areas YA8 (left) or YA9 (right) (mostly cropped).

achieved; more specific details follow. This will allow the effect of random errors in local scale soil moisture measurements to be minimised. In cases where there are rows, measurements should be taken as follows: minimum of three at top of row, three at middle height of row, and three in the furrow.
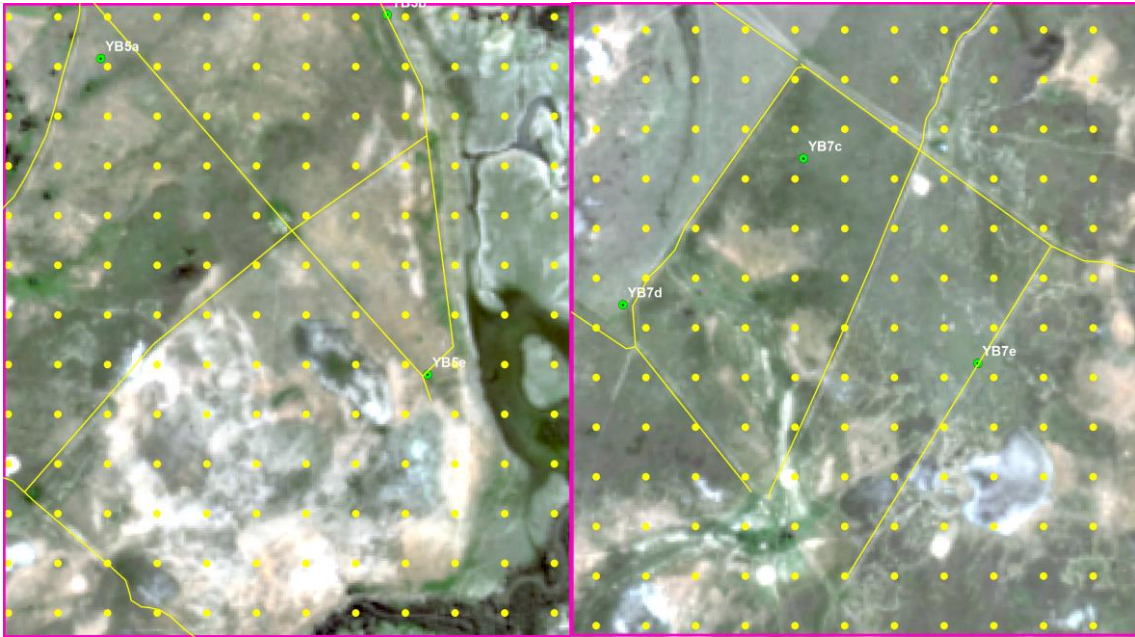
Figure 5-5. Locations of the intensive spatial soil moisture sampling sites at focus area YB5 and YB7 (mostly grazing).

5.3   Supplementary soil moisture sampling using Scout sensor

Supplementary soil moisture sampling will be conducted using a Scout sensor on the non-flight days. This handheld sensor is a FieldScout TDR 100 soil moisture meter allowing the user to easily and rapidly take many measurements to a depth of 20 cm (Figure 5-6). Based on the proven time-domain measurement technology, the portable TDR 100 sensor can be fitted with different sized pins (rods) to measure soil moisture from different depths: 3.8 cm, 7.6 cm, 12 cm and 20 cm.

Soil moisture measurements by the Scout will be compared with HDAS measurements at each point. Locations of sampling points by both sensors are the same as shown in Figure 5-4 and Figure 5-5 but with fewer lines (to be decided upon on-site). Parts of each YA focus area will be monitored using a north-south oriented regular grid of sampling locations at 50 m x 250 m spacing.

Figure 5-6. Scout Sensor and pins (sizes of pins for this study: 3.8cm (1.5in), 7.6cm (3in), 12cm (4.7in) and 20cm (7.9in))

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Team A will be responsible for the Scout sampling on non-flight days at YA dominated by cropping. The Scout sampling will not be conducted at YB dominated by grazing as it is expected that the ground will be too hard to insert the probes. Accordingly, deeper soil moisture measurement at YB will rely upon the network of stations, with the expectation of a relatively smaller spatial variation.

At each sampling point, a team of two people will be in charge of measurements by HDAS and Scouts respectively: at least 3 HDAS measurements and 3 Scouts measurements for each size pins (in total 12 measurements) will be taken within a radius of 1 m until a consensus measurement is achieved. Numbers and soil moisture values of each Scout probe length measurements will be recorded in the HDAS comments field in order to geolocate Scout points during post-processing. The data will also be stored in the Scout for downloading and cross checking.

5.4   Regional soil moisture sampling

In addition to intensive ground soil sampling in the four focus farms, regional ground soil moisture sampling is planned across the entire ground sampling area. The objective of regional sampling is to better understand the spatial variability of soil moisture within the entire 36 km × 36 study area. Team B will be responsible for regional sampling on non-flight days. Figure 5-7 shows the suggested regional soil moisture sampling locations, together with the road map over the APPLEx study area. Ideally, regional measurements will represent the spatial average of the 18 km and 36 km pixels. Totally 40 locations along a ~220 km long route throughout the APPLEx ground sampling area have been suggested with an expected sampling time of ~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 access. Then all selected locations will be re-sampled in each of following regional sampling days.

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5.5 Intensive vegetation sampling

The objectives of the intensive vegetation monitoring are:

i)   to characterise the paddocks monitored for soil moisture in the individual focus areas, so as to describe all dominant vegetation types at various stages of maturity and vegetation water content for the purpose of radiometer modelling; and

ii) to collect detailed plant structural parameters for dominant vegetation types (agricultural and grazing) and to track the evolution of such parameters across the APPLEx campaign periods, for the purpose of radar algorithm development. The data collected are expected to be sufficiently comprehensive to perform forward modelling of L-/P-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 5-2.

Repeated intensive monitoring of the crop areas will be performed by Team C on each flight day and
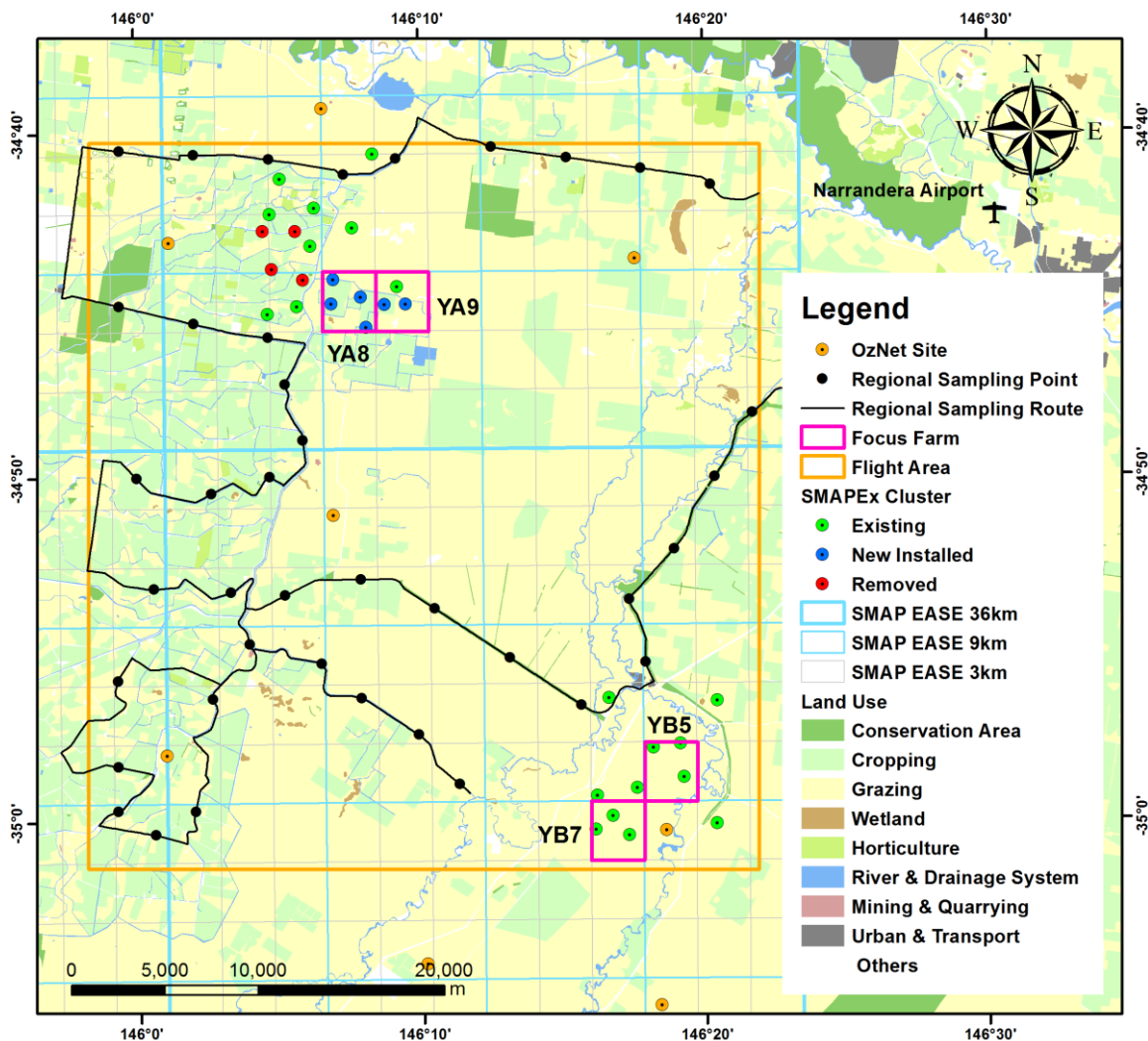
Figure 5-7. Locations of the regional soil moisture sampling across the flight area.

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Table 5-2. **Crop parameters to be monitored during the intensive sampling.**

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

also on one non-flight day each week. Below are some recommendations of the general approach to be followed. Full details on sampling procedures at each sampling location are given in section 6.3.

- The vegetation sampling strategy will be based on the assumption that the changes in vegetation (biomass, VWC and plant structure) are negligible within a few days, and therefore the same paddock will only be sampled every few days.

- Vegetation samples for biomass, vegetation water content, soil surface reflectance, LAI measurements and structural parameters etc will be collected at each location.

- Vegetation sampling will be repeated at approximately the SAME locations as the previous sampling, 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 5-8 illustrates the rationale of the vegetation sampling locations for an example 3km × 3km sampling area.

- All vegetation spectral measurements should be prioritised between approximately 10am and 2pm Australian Eastern Standard Time to optimise the ground spectral observations. Outside of this time the teams should focus on roughness and/or geometric sampling.

- 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.

5.6   Roughness sampling

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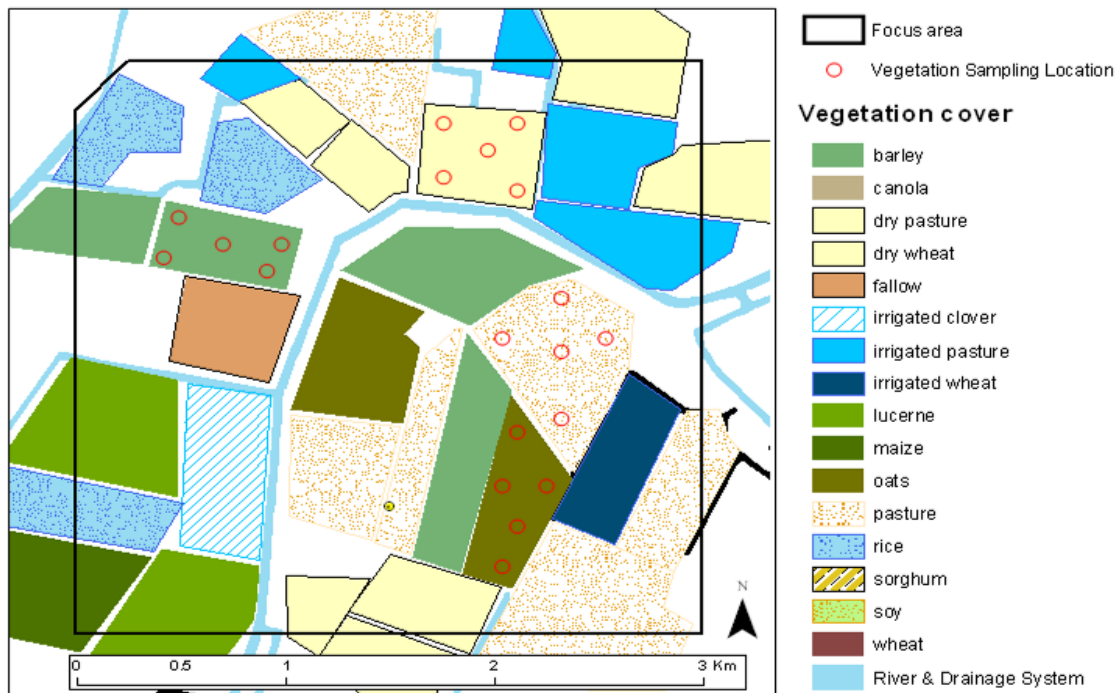
Figure 5-8. Schematic of vegetation sampling strategy for one example focus area.

Soil surface roughness affects the radiometric observations by effectively increasing the surface area of electromagnetic wave emission. Its effect on observations at P- and L-band frequencies is difficult to quantify, and is therefore a critical parameter to be spatially characterised across the different land cover types. During APPLEx, surface roughness will be characterized at three locations within each of the selected paddocks, representing major land cover type and roughness conditions in the focus areas. At each of the locations two 3m-long surface profiles will be recorded. In non-tilled areas, one profile will be oriented parallel to flight line (North-South) and one perpendicular (East-West). Over furrowed areas, sampling along and across the row direction will be undertaken. Team C will be conducting the surface roughness measurements in each focus areas interspersed with vegetation sampling. Further details on the procedure for roughness measurements with the pin profiler are included in Section 6.5 where measurement protocols are presented.

5.7   Supporting data

In addition to spatial soil moisture measurements, Teams A and B 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

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- 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 6 where measurement protocols are presented.

Land cover classification

Land cover information will be used to support the interpretation of remotely sensed data in various ways. In particular, it will be used to interpolate vegetation water content information. It is therefore
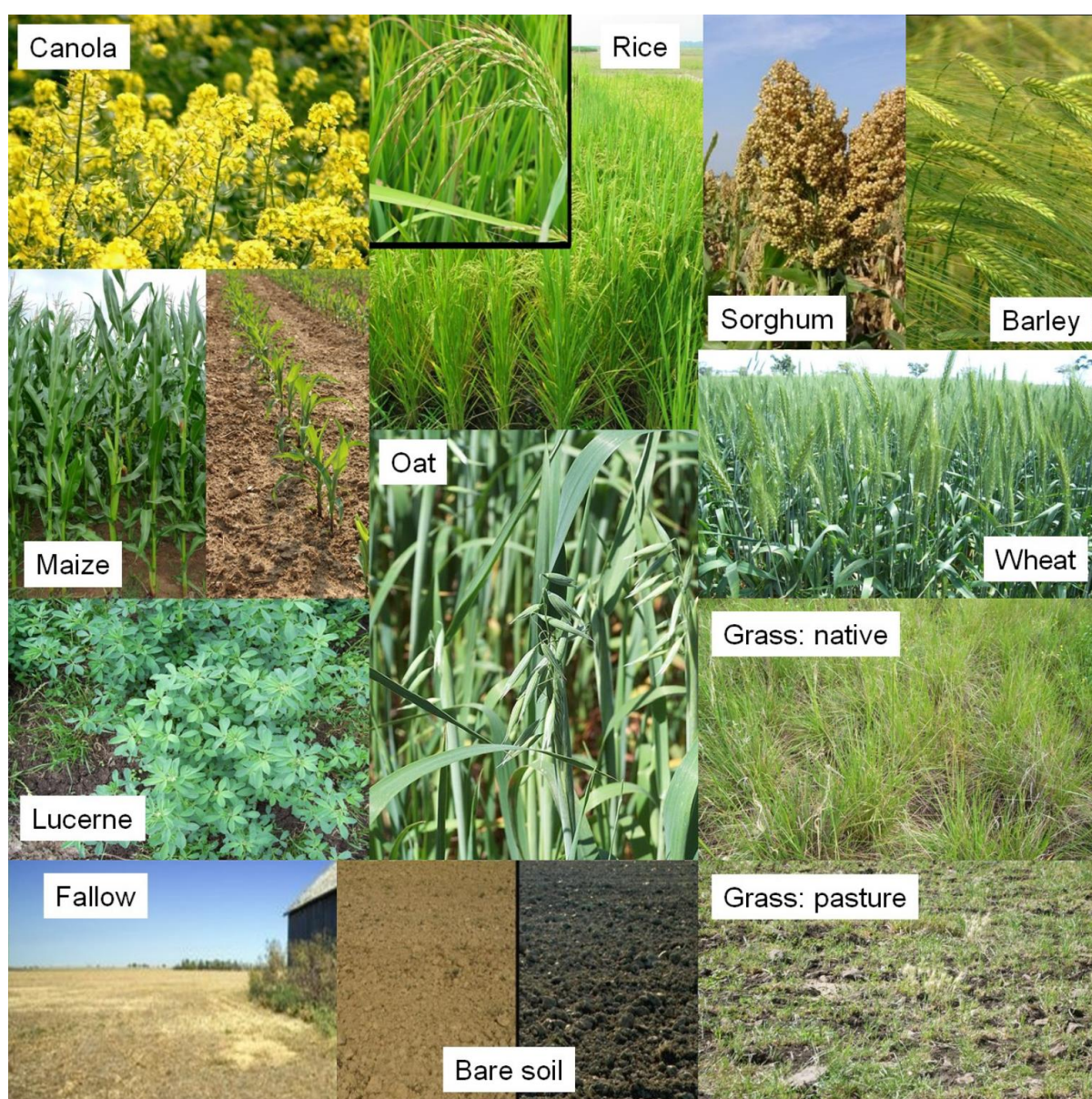
Figure 5-9. Photos of expected possible vegetation types within the focus farms highlighting features that will be useful for identification.

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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 study area are included in Figure 5-9, 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 10 cm precision are provided on the HDAS vertical pole.

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 based on data collected at this site over the past years, the
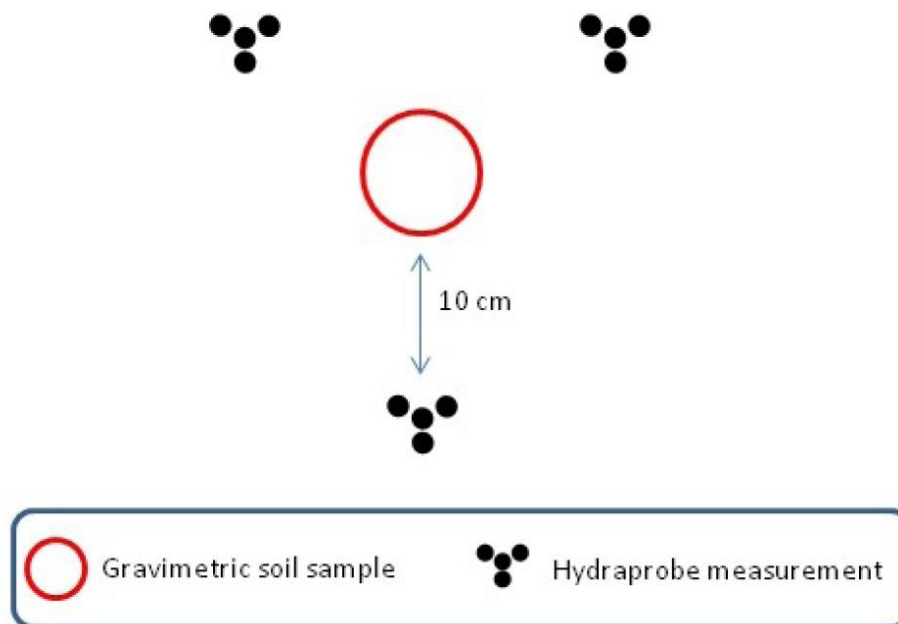
Figure 5-10. A minimum of three Hydraprobe measurements should be made in a radius of 10 cm around the gravimetric soil sample.

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calibration will be further 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 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 10 cm from the soil sample (see Figure 5-10). The objective of the sampling is 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 6.

- 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.

- For every focus area a minimum of 3 soil samples will be collected per day.

- A single probe will be used throughout the experiment, with probes cross-verified in air, water and a homogenous damp soil daily.

Soil textural properties

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

6.   CORE GROUND SAMPLING PROTOCOLS

Field work during APPLEx 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 three teams (A, B and C). On flight days, ground teams A and B will be responsible for soil moisture sampling using the HDAS system to collect soil gravimetric samples at their respective focus farms, while ground Team C will be in charge of surface condition sampling (vegetation and roughness sampling). On non-flight days, half of Team A will be responsible for soil moisture profile sampling using HDAS and Scout probes in YA focus areas, half of Team B will be conducting regional soil moisture sampling, and Team C will continue vegetation and roughness samplings on alternate non-flight days. A list of team participants is included in Chapter 7 together with a daily work schedule. It is important to **note that all sampling devices and field notes should be referenced in local time, and all orientations should be recorded in terms of MAGNETIC north**.

The campaign is comprised of approximately 26 sampling days. Team A and B will work independently on their assigned areas, according to the sampling schedule shown in Tlable 4-1. 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 7. The intensive soil moisture measurements will take place every 50m along grid lines spaced 250 m apart, while the regional soil moisture sampling will take place at ~4km spacing within the 36 km regional. Soil moisture sampling will involve navigating from one point to the next and taking a minimum 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. 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. Detailed training on how to use the HDAS system will be given during the scheduled training session (for training times and locations see Chapter 7). See also Appendix B for more details on how to use the HDAS.

For Team C, 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. Roughness and geometric vegetation sampling will be undertaken outside of this period.

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 and the paper forms archived. **Team leaders will be responsible to coordinate these**

operations for each respective team and to ensure that all data are properly downloaded, archived and checked, and that all equipment are cleaned and checked. Any damaged equipment should be handed to the team leader for fixing overnight. Please see Appendix E 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 ensure consistency in collecting, processing and archiving the data. Measurement record forms are provided in Appendix F for logging data other than the HDAS measurements and these MUST be used.

6.1   General guidance

Sampling activities will run as scheduled, but may be postponed or altered 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, including moving of sampling to "break" days. Any changes are to be recorded and will be reported in an addendum to this document.

Each team will make use of a campaign vehicle to access the farms. Members of Team A and B will walk along pre-established grids in the focus area, in order to take HDAS readings on the soil moisture sampling grid. They will be dropped off at a location in the focus areas strategically selected and agreed by all team members, and will return to the designated location for pick up at the end of the sampling. Remember to walk 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 off the farm tracks or on farm tracks following rain.

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 wet, because this will mess up the track.

- Do not drive through crops or even across grassed paddocks.

- When sampling on 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 at least 2L of water with you, since you'll be sampling for the entire day, possibly under a hot 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 the potential of 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

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"**scientist working on a Monash University soil moisture study with satellites**". **Accordingly, please also wear your Monash branded shirts on each sampling day.** 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.

• Do not enter any paddocks marked "Sprayed".

• 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 at Yanco Agriculture Institute. 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 50 km/h and highway speeds 100 km/h). Be courteous on dirt and gravel roads, lower speed means less dust and stone.

• Do not drive through grass fields as hidden boulders, trunks or holes are always a danger. and vegetation accumulation on the radiator can cause overheating, or grass in contact with the exhaust can start fires. **Importantly, the farmers have requested that we not do this.**

• 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 and/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.

6.2 Soil moisture sampling

Both Team A and Team B are in charge of collecting:

• 0-5 cm 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 location);

• Information about canopy height and presence of dew at each sampling location;

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- GPS location at each sampling location; and

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

The HDAS measurements will be made every 50m along grid lines spaced 250 m apart. 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 etc).

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 $0.1 m^3/m^3$, 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 125 m.

6. In all cases keep in mind that (i) the predefined sampling location can be shifted within 10-20 m to fall on more representative ground and (ii) the selected location must be representative of an area of ~25 m radius surrounding it.

7. The shape files visible on the HDAS screen (irrigation channels, roads, farm boundaries etc.) can be wrongly located by up to 50 m from their real location. Therefore use them more as a guideline and always check your surroundings visually.

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8.   If a predefined sampling point seems to fall just outside the sampling area assigned to you (e.g., 10 m 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 doubt about the vegetation type or a mistake, 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 ground 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 25 L water Jerry can

- 1x first aid kit

- 1x first aid book

- 1x sunscreen bottle

- 1x gravimetric sampling kit

- 1x spare HDAS system

- 3 x Scouts sensor with pins of varying length (Team A only)

- 1x spare GETAC unit or equivalent

- 1x CROPSCAN device (Team C only)

- 2x LAI-2000 device (one as spare; Team C only)

- 1x vegetation destructive and intensive sampling kit (Team C only)

- 1x field book

- 1x pair of gloves

- Pens, permanent markers

- Portable toilet and privacy screen

The gravimetric sample kit will be assigned to the team leader, who is responsible for collecting the soil gravimetric samples.

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

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- 1x HDAS system

- 1x hardcopy map of each focus area with the sampling grids and useful topographic information and vegetation ID chart

- 1x UHF radio

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 E 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 file upload and download procedures, 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 directly displayed 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;

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- 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 local time** as the time information will be used to interpret the data. Additionally, it is essential to recharge each GETAC and HDAS battery 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 10 cm increments up to a maximum height of 1.5 m, 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

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- medium droplets

- large droplets

- film

At the end of each sampling day, the team leader needs to check there is **NO** missing data points <u>before</u> leaving the field. A plot of soil moisture sampling data is to be produced each evening.

Scout Sensor

Step-by-step information on the operation and data download of the Scout Sensor is included in Appendix B.

Each Scout box is composed of:

- 1x Meter

- 4x AAA battery

- 1x box of pins with varying sizes (3.8, 7.6, 12 and 20 cm)

- 1x Software CD for data downloading

- 1x Black software cable (connection to laptop)

The Scout meter does not have in-built GPS. Therefore numbers and values of measurements from the Scout for each location need to be recorded in the HDAS system in the Comment Tab.

It is important to check daily, BEFORE sampling starts, the level of battery and if backup batteries are prepared. Batteries should be recharged DAILY.

6.3 Vegetation sampling

Team C is in charge of collecting the following (see also Appendix F for detailed team tasks sheet):

- Vegetation and litter destructive samples;

- Vegetation canopy reflectance measurements (Cropscan);

- Vegetation canopy LAI measurements;

- Information about vegetation parameters (type, density, canopy height, crop row spacing and direction), leaves parameters (leaves water content, width, length, thickness, angles, number of leaves per plant), and stalk parameters (stalk VWC, length, diameter, and angle) and

- GPS location of the actual vegetation sampling site.

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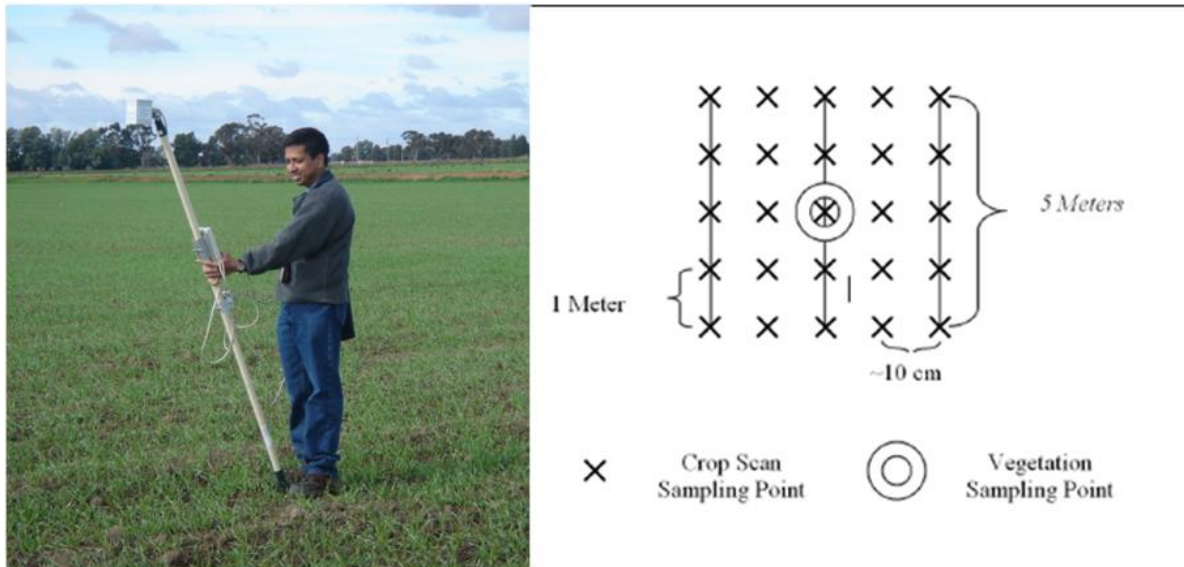
Figure 6-1. (Left) CROPSCAN Multispectral Radiometer (MSR). Size is 8 cm × 8 cm × 10 cm. (Right) Illustration of the surface reflectance protocol.

The teams will be equipped with a GETAC unit or equivalent in order to navigate through the focus areas using GPS positioning like for the soil moisture sampling. The GETAC will contain information on main roads, property boundaries and irrigation canals, to aid the navigation and selection of the sampling locations.

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 6-1. 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 available. For APPLE a MSR16R unit will be used with the set of bands indicated in Table 6-1. 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 6-1) 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 1 m or 1 row apart. See Appendix C for detailed instructions on how to operate the CROPSCAN.

Leaf area index observations

The LAI-2000 (see Figure 6-2) will be set to average 4 points into a single value with one observation taken above the canopy and 4 beneath the canopy; in the row, ¼ of the way across the row, ½ of the way across the row and ¾ of the way across the row in the case of row crops. These should be made just before taking the biomass sample. For short vegetation, LAI will be derived from the destruction samples as described below.

If the sun is shining, the observer needs to stand with their back to the sun so that they are shading the instrument. Moreover, they must put a black lens cap that blocks ¼ of the sensor view in place, and be positioned so that the sun and the observer are never in the view of the sensor. The observer should always note if the sun was obscured during the measurement, irrespective of whether the sky is overcast or if it is partly cloudy but with the sun behind the clouds. If no shadows could be seen during the measurement, then the measurement is marked "cloudy", if shadows could be seen during the measurement then it is marked "sunny". Conditions should not change from cloudy to sunny or sunny to cloudy in the middle of measurements for a sample location. Also, it is important to check the LAI-2000 internal clock each day to verify they are recording in UTC. See Appendix D for detailed instructions on how to operate the LAI-2000.

Table 6-1. CROPSCAN vs. MODIS and Skye (not used) 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

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Figure 6-2. The LAI-2000 instrument.

Vegetation destructive samples

At least five vegetation samples concurrently with reflectance/leaf area index observations will be taken for each major vegetation type represented by the chosen paddocks in the focus areas, making sure that all significant vegetation types and growth stages encountered 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 until no further change in mass is observed.

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 0.5 m × 0.5 m quadrant to obtain vegetation samples

- 1x vegetation clipper

- 1x scissors

- 1x pair of gloves

- plastic bags

- paper bags

- rubber bands

- permanent markers

- vegetation sampling recording form

Vegetation destruction sampling protocol

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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 0.5 m × 0.5 m quadrant on the ground within the area sampled by Cropscan/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 0.5 m × 0.5 m quadrant using vegetation clippers and scissors provided.

6. Place vegetation sample into labelled paper bag provided.

7. Close paper bag with sample using rubber bands provided and place this bag into a second plastic 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 F).

It is the responsibility of each team 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) and placement in the dehydrators.

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 paper bags with vegetation for a given field from the large plastic 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. 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 and < 65° C until constant weight is reached (typically 2-3 days), and 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)

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. The dry weight should be recorded within <u>not longer than 10 seconds</u> 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 paper bags under normal room conditions, place in the ovens at the vegetation drying temperature (usually 65° C), and weigh again (taking them out of the oven one at a time) after 2-3 days of drying. The difference between the average before-drying weight of a bag and the after-drying weight of a bag is the amount of weight lost by the bags themselves during the oven drying process. This value needs to be considered in converting the wet & dry weights of the vegetation into an estimate of vegetation water content (VWC).

6.4   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 soil moisture sampling team leader** to collect these samples, making sure that all soil types and the complete range of soil moisture encountered in the focus area on that day 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 7.5 cm diameter and 5 cm depth)
>
> - 1x Crate medium size

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- 1x Garden trowel

- 1x Blade

- 1x Spatula

- 1x Hammer

- 1x Metal base for hammering rings

- Plastic bags

- Rubber bands

- Print out of soil recording form

- Pens

- Markers

Gravimetric soil moisture sampling protocol

1. Remove vegetation and litter from the gravimetric sampling location.

2. Take a minimum of three soil moisture readings with the Hydraprobe immediately adjacent to the cleared location, plus one reading in the soil to be sampled 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 three 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.

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 just 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 (5 cm) and should be sufficiently large to accommodate the spatula for ring removal.

6. Use the spatula to cut the 0-5 cm soil sample at the bottom of the ring.

7. Place the 0-5 cm soil sample in the plastic bag ensuring that no soil is lost from either the top or the bottom.

8. Write Area_ID / TEAM_ID / DD-MM-YY / Sample_ID on the carton tag provided and place it in the bag. Note the ring ID used for sampling

9. Seal the bag with the rubber band provided then place this bag into a second bag and seal the second bag.

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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, determine wet weight, oven-dry and determine dry weight of the samples. All the information are to be recorded in the Gravimetric_Drying.xls (one form per day, see templates in Appendix F).

Wet weight determination

1.   Turn on balance.

2.   Tare.

3.   Record wet weight (sample + bags + rubber bands) into the gravimetric drying form.

4.   Record clean bags and rubber bands weight into the gravimetric drying form.

5.   Record new 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.

6.5 Surface roughness measurements

Team C will be responsible for the surface roughness measurements during APPLEx. Three surface roughness profiles will be acquired within each paddock representing a major land use and land cover type in each focus area. Each measurement will consist of two, 3m-long profiles. In non-furrowed fields, one will be oriented parallel to the flight line and one perpendicular to it. In furrowed fields, the measurement will follow along the row and across and row. The three measurements should cover the variability of surface conditions observed within the land cover patch of interest.

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Surface roughness sampling kit

- 1x GETAC unit

- 1x Toughbook

- 1x roughness profiler (pin profiler with camera or pin profiler with scanner or the laser scanning for bare soil)

- 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 one of three techniques, including 1) pin profiler, 2) laser profiler, or 3) laser-pin profiler, which will be introduced as follows. At each soil roughness sampling location, two perpendicular 3 m long profile will be measured. In non-furrowed areas, North-South and East-West orientations measurements will be made. For furrowed crop areas, the pin profiler will be placed along/across rows. A 3 m profile has been shown to provide stable correlation lengths in previous campaigns and so has been chosen for use here.

Pin profiler: The pin profiler consists of 220 metal pins placed at 0.485cm intervals, creating a profile length of approximately 1m (Fig. 6-3). The pins are suspended by a metal plate which can be released gently using a lever mechanism to lower the pins (do not drop them or they will penetrate the soil). Three consecutive 1m meter transects are taken across each of the 3m profile lengths. A mounted Sony RX100 camera is used to photograph the top of the metal pins which have been marked red. These photos are then corrected and analysed using image digitalization techniques to extract the roughness profiles and thus roughness statistics. The main drawback of this pin profiler is that when it is applied to vegetated areas, you need to make sure that all pins touch the soil surface rather than resting on vegetation components, such as leaves, roots, etc. In addition, if the vegetation is high and shades the view of the photo, another operator needs to push down the vegetation to get a full and clear focus on the pins, especially the red top of the pins.

The procedure for one roughness measurement is as follows:

1. Note in the roughness sampling form the date, the sample ID, the UTC time, the focus area ID, the coordinates (from GPS), the profiler type (pin, laser, or laser-pin), the land cover type, 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.

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2.   Select an area for a 3 m roughness transect (N-S or E-W). Assure that the sun will be at your back when taking roughness photos. Position the profiler parallel to the transect.

3.   Place the roughness profiler vertically above the first 1 m of the desired transect (the right one, defined from perspective of photograph), avoiding stepping over the area chosen for the remaining 2 m 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. If rows note the orientation with the compass and whether across or along rows orientation.

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.   Gently 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.   Lift the profiler on to its back without bending any pins, retract the pins and block them using the bottom enclosure.

13.   Shift the profiler over 1 m 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.

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Figure 6-3. Pin profiler for surface roughness measurements.

15.   Repeat steps #13-14 for photograph #3 of the transect. Note that the three 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 three 1-m long profiles in the perpendicular direction.

Laser profiler: The laser profiler produces a total profile length of 1.5m at 0.4cm intervals (Figure 6-4). A Bosch PLR 40C laser scanner is mounted to a motorized convey or belt positioned on the metal beam of the profiler. This allows the laser to measure the elevations of the soil surface, as the LiDAR slowly transitions along the belt. The main drawback of this laser profiler is that it cannot be used over vegetated areas. Please use one of the other two methods (the laser-pin one is preferred) instead. Two successive 1.5m transects are taken along each 3m long profile. Data is recorded using a connected laptop and exported as a csv file.

The procedure for one roughness measurement is as follows:

1.   Note in the roughness sampling form the date, the sample ID, the UTC time, the focus area ID, the coordinates (from GPS), the profiler type (pin, laser, or laser-pin), the land cover type, 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 3 m roughness transect (N-S or E-W). Position the profiler parallel to the transect.

3.   Place the roughness profiler vertically above the first 1.5 m of the desired transect, avoiding stepping on the area being sampled or that chosen for the remaining 1.5 m profile.

4.   Use the compass to align the profiler exactly N-S or E-W, depending on the transect. If rows note the orientation with the compass and whether across or along rows orientation.

5.   Using the controls at the side of the profiler to make sure the level attached to the profiler horizontal.

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Figure 6-4. Laser profiler for surface roughness measurements.

6. Connect the USB at the **back** of the Toughbook to the USB of the profiler using the cable. Turn on the laser and push the "Bluetooth" button. Make sure the battery inside the laser is not draining out, otherwise replace a new set of battery. Open the "soil roughness.exe" program on the Toughbook. If the program raises warnings, please go back to check and redo step 6.

7. Start the scanning using the switch on the profiler. After that, you can see the laser is moving and the real-time soil profile is being plotted on the Toughbook.

8. As soon as the measurement is finished, click "Create csv" on the program, rename the file with No. sampling location, direction, and the number of the two consecutive measurements (1st or 2nd). After you make sure the data is saved, click "clear data" to get ready for the next consecutive measurement.

9. Mark the position of the last point where the laser scanned profiler to be the start point of the next measurement using a stick. Rotate the profiler 180 degrees and shift the profiler over 1.5 m because the laser has moved to the other end of the beam. Using the controls at the side of the profiler to make sure the level attached to the profiler horizontal. Align the laser to the point where you marked as the starting point of the second measurement.

10. Repeat steps 7-8 for the second 1.5m profile measurement.

11. Repeat steps #1-10 for the two 1.5m profiles in the perpendicular direction.

Laser-pin profiler: The laser-pin profiler consists of 100 metal pins at 1 cm intervals, producing a total profile length of 1 m. The pins are suspended by a steel frame which can be slowly lowered to the surface by hand. This mechanism has its advantages over the pin profiler which possibly drops its pins directly into the soil resulting in higher impact and increased chance of insertion into the soil. A Bosch PLR 40C laser scanner is mounted to a motorized convey or belt positioned above the pins. This allows the laser to measure the elevations of the top of the pins directly, as the LiDAR slowly

transitions along the belt. Three successive 1 m transects are taken along each 3 m long profile. Data is recorded using the connected laptop and exported as a csv file.

The procedure for one roughness measurement is as follows:

1. Note in the roughness sampling form the date, the sample ID, the UTC time, the focus area ID, the coordinates (from GPS), the profiler type (pin, laser, or laser-pin), the land cover type, 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 3 m roughness transect (N-S or E-W). Position the profiler parallel to the transect.

3. Place the roughness profiler vertically above the first 1 m of the desired transect, avoiding stepping on the area chosen for the remaining 2 m profile.

4. Use the compass to align the profiler exactly N-S or E-W, depending on the transect. If rows note the orientation with the compass and whether across or along rows orientation.

5. Release the profiler legs using the controls at the side of the profiler. Level the profiler horizontally.

6. When the profiler is horizontal, release the two bolts at the sides at the same time, hold the handle of the slider, and gently release the pins. Make sure that all the pins touch the soil surface. The pins MUST NOT be inserted into the ground or be resting on top of vegetation.

7. Connect the USB at the **back** of the Toughbook to the USB of the profiler using the cable. Turn on the laser and push the "Bluetooth" button. Make sure the battery inside the laser is not draining out, otherwise replace a new set of battery. Open the "soil roughness.exe" program on the Toughbook. If the program raises warnings, please go back to check and redo step 6.

8. Start the scanning using the switch on the profiler. After that, you can see the laser is moving and the real-time soil profile is being plotted on the Toughbook.

9. As soon as the measurement is finished, click "Create csv" on the program, rename the file with No. sampling location, direction, and the number of the two consecutive measurements (1st, 2nd or 3rd). After you make sure the data is saved, click "clear data" to get ready for the next consecutive measurement.

10. Mark the position of the last pin which was scanned to be the start point of the next measurement using a stick. Use the handle of the slider and slide it back to return all pins until the two bolts at the side are locked.

11. Rotate the profiler 180 degrees and shift the profiler over 1 m because the laser has moved to the other end of the beam. Using the controls at the side of the profiler to make sure the level attached to the profiler horizontal. Align the first pin to the point where you marked as the starting point of the next measurement.

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Figure 6-5. Laser-pin profiler for surface roughness measurements.

12. Repeat steps 6-11 for the next two 1m profile measurements.

13. Repeat steps 1-12 for the three 1m profiles in the perpendicular direction.

6.6   Data archiving procedures

All the data collected during the daily sampling will be saved onto a field laptop which will be available at the operation base. The exact location of the laptop will be communicated during the training session. Each ground team will use the laptop for data downloading and archiving for the campaign duration. The aircraft team will archive data independently. The data archived will be backed up daily on an external hard drive. 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

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 drive).

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.

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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\APPLE\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, $ 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

The roughness sampling form will be archived both in hardcopy and electronically by each ground team. It will be entered at the end of the day in the pre-populated file Roughness.xls, and stored on the data laptop folder "Desktop\APPLE\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. These data must be typed up at the end of the sampling day or at latest the subsequent day. The profile data will be archived in the same folder and for three techniques respectively as follows:

1.   Pin Profiler. The photos must be renamed as # *Area_ID Location_ID Direction Sampling_ID*.jpg where # is the photo identification number provided by the cross-referenced in the sampling form. For an example of 15 YA7 3 ACR 2.jpg, 15 denotes the identification number that can be cross-referenced in the sampling form, YA7 is the area ID which you sampled, 3 is the location ID showing which location you did the roughness sampling, ACR (ALO) means the measurement was taken across (along) the row. Over flat areas, *Direction* could be either N-S or E-W. 2 means this is the second 1 m profile taken of the 3 m across profile.

2.   The data archiving for laser and laser-pin profilers are same. The csv files must be renamed as # *Area_ID Location_ID Direction Sampling_ID*.jpg where # is the file identification number provided by the cross-referenced in the sampling form. For an example of 15 YA7 3 ACR 2.csv, 15 denotes the identification number that can be cross-referenced in the sampling form, YA7 is the area ID which you sampled, 3 is the location ID showing which location you did the roughness sampling, ACR (ALO) means the measurement was taken across (along) the row. Over flat areas, *Direction* could be either N-S or E-W. 2 means this is the second 1/1.5m profile taken of the 3/2m across profile.

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7.   LOGISTICS

APPLEx activities will be supported by a ground crew, aircraft crew and support crew, overseen by Prof 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. Dr Xiaoling Wu and Kiri Mason will be responsible for instrument repair and general technical support. Breakdowns and instrument faults must be reported to one of them (as well as your team leader) at the end of each day. Your HDAS data and ground samples MUST be archived according to the instruction in this work plan promptly at the end of each sampling day, either directly or via your team leader, so he/she can further process the data/samples, thus ensuring the early identification of sampling issues and availability of quality data at the end of the campaign.

7.1   Teams

Ground sampling operations will be undertaken by three teams acting independently. Teams A and B will be responsible for soil moisture monitoring, while Team C will be in charge of vegetation and roughness sampling. Each of the two ground soil moisture teams have been assigned two focus areas. The aircraft crew (Team D) will operate from the Narrandera airport and be coordinated by Prof Jeff Walker.

The composition of the teams and the focus areas of each are listed in Table7-1. Contact details for all participants are given in Chapter 8.

7.2   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 7-2). 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 APPLEx participants is provided in Figure 7-2.

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

7.3   Accommodation

Accommodation costs will be covered by Monash University or individual's institutions according to agreed arrangements. Participants who have accommodation and meals expenses paid by the APPLEx project will be staying at Inga.

![Monash University logo]

Table7-1. Composition of the teams, vehicles, and focus areas for APPLEx-1. * indicates first-aid person. Members for each team subject to change.

Team	A	Team Leader	Xiaoling Wu	Vehicle	Monash rental 4WD #1
Focus Area	YA (YA8 or YA9)				
Team Members	Xiaoji*, Ziwei*, Brian/James, Javier/Abby, Rebecca				
Tasks	Intensive soil moisture sampling, Scouts sampling				

Team	B	Team Leader	Foad Brakhasi	Vehicle	Monash rental 4WD #2
Focus Area	YB (YB5 or YB7) and regional area				
Team Members	Siyuan/Foad*, Lixiaozhou*/ANU student, Atharva, Zesheng*, Daniel				
Tasks	Intensive soil moisture sampling, Regional sampling				

Team	C	Team Leader	Luisa	Vehicle	Monash rental 4WD #3
Focus Area	YA and YB and/or almond (1km x 1km focus area)				
Team Members	Luisa*, Louise*, Tatyana*, Anna*, Alexandra				
Tasks	Vegetation and roughness sampling				

Team	D	Team Leader	Jeff Walker	Vehicle	Monash rental compact car
Focus Area	Yanco				
Team Members	Jeff Walker*, Jon Johansson*, Foad*/Zhou*				
Tasks	Airborne sampling and calibrations				

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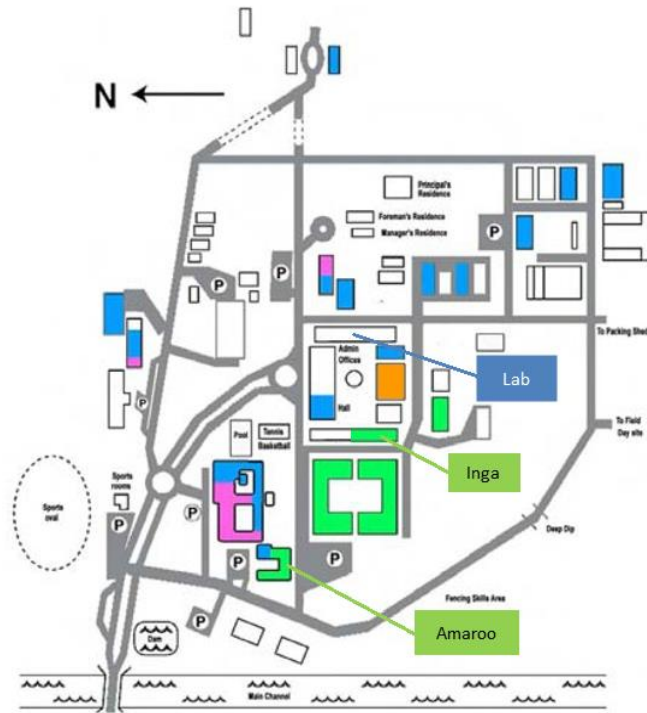
Figure 7-2. Map of the Yanco Agricultural Institute.

Figure 7-1. Location of the YAI at Yanco.

'Amaroo' motel-style accommodation

Amaroo, meaning 'a quiet place', features 15 bed and breakfast (continental) motel-style rooms (see location in Figure 7-2). Each room has a queen bed and a single bed, ensuite, TV, toaster, tea and coffee making facilities, bar fridge, and heating and cooling and wi-fi internet access, and are fully serviced except on weekends. The motel rooms are organised around a central courtyard with barbecue facilities. Price is $110/night/room for double room (incl. breakfast).

'Inga' bunk house accommodation

Inga has 14 rooms (see location in Figure 7-2). 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 $50/night/person. Accommodation arrangements for all participants are listed in Table 7-2.

7.4 Meals

Meal costs will be covered by Monash University or the individual's institutions according to agreed arrangements (ie. participants fully funded by the APPLEx 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 APPLE funded participants (please advise Xiaoling Wu of any particular dietary requirements upon arrival). 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

Table 7-2. Accommodation logistics for APPLEx participants (TBC)

Name of participant	Accommodation type	Check in	Check out
Luisa Murillo	Inga room 4	26-Jan	26-Feb
Louise Drury	Inga room 1	29-Jan	26-Feb
Tatyana Porczak	Inga room 2	29-Jan	26-Feb
Anna Kollmann	Inga room 3	29-Jan	26-Feb
Alexandra Edwards	Inga room 6	29-Jan	26-Feb
Xiaoji Shen	Inga room 5	29-Jan	26-Feb
Ziwei Xiong	Inga room 7	29-Jan	26-Feb
Javier Caceres	Inga room 8	29-Jan	12-Feb
Abby Randall	Inga room 8	12-Feb	26-Feb
Rebecca Wei	Inga room 9	29-Jan	26-Feb
Lixiaozhou Zhou	Inga room 10	26-Jan	26-Feb
Atharva Deshpande	Inga room 11	29-Jan	26-Feb
Zesheng Han	Inga room 12	29-Jan	26-Feb
Daniel Ji Hon Ling	Inga room 13	29-Jan	26-Feb
Siyuan Tian	Inga room 14	29-Jan	26-Feb
Brian Ng	Amaroo 1	29-Jan	12-Feb
James Hills	Amaroo 1	12-Feb	26-Feb
Jeff Walker	Amaroo 2	29-Jan	26-Feb
Jon Johanson	Amaroo 3	29-Jan	26-Feb
Foad Brakhasi	Amaroo 4	29-Jan	26-Feb
Xiaoling Wu	Amaroo 5	29-Jan	26-Feb

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must be pre-packed for carrying with you into the field; remember to also pack a water bottle. Similar to breakfast arrangements described above, guests staying at Inga and funded by the APPLEx project will be provided with a selection of fillings for making sandwiches in the Inga kitchen (please advise Xiaoling Wu of any particular dietary requirements upon arrival). 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 (2 km), Leeton (5 km) or Narrandera (20 km). Typically meals are purchased from the Leeton Soldiers Club or Leeton Hotel; other venues have long wait times and do not allow split bills. Meal purchases should be limited to $30.

7.5 Internet

There will be WiFi access during the stay, individuals can use the shared WiFi or use their own phone for internet access which however has poor service in the accommodation block.

7.6 Daily activities

Field work during APPLEx-1 will consist of collecting data in the Yanco Region and archiving the information collected during the sampling days. Team leaders will in turn report to Xiaoling Wu for technical/equipment repairs. 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 7-33. At the end of the day, each team member will need to coordinate with their team leader (as relevant).

Table 7-3. APPLEx 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 (sunrise)	Teams departure for the sampling location
6:30~7:30	Travel to the focus areas
7:30~16:00	Sampling operations
16:00~17:00	Travel to the YAI
17:00~18:00	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
18:00	Depart for dinner is at 18:00 sharp from Inga
18:00-onward	Dinner
	Refuel vehicles
	Visit supermarket

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> ## 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; samples must be weighed, details entered on the hardcopy pro-forma (see Appendix F) 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 Xiaoling Wu (please, do not wait until the next sampling day!!); and

- Ensure all electronic devices are put to recharge (GETAC, HDAS batteries, UHF radios).

> ## On vegetation and roughness sampling 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.

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

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

7.7   Training sessions

Two training sessions (online and onsite) are scheduled to ensure all APPLEx participants are familiar with the project objectives, the sampling strategy and the use of all the instruments involved in the sampling. The theoretical training session is scheduled to be online and completed prior to arrival, while the practical training session and visit to the sampling areas is scheduled for 30 January 2022 with training to be conducted on the focus farms; the detailed schedule and activities is indicated in Table 7-5.

Theoretical 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;

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- Use of the Hydraprobe Data Acquisition System (HDAS);

- Vegetation height estimation;

- Vegetation type recognition;

- Dew amount recognition; and

- Vegetation sampling procedures.

7.8   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 even death, and therefore requires extreme attention and care and should only be undertaken after appropriate training. Driving through cultivated areas and grasslands should be avoided at all times, due to the serious damage the transit could cause to crops or to the vehicle. 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 (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.

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 3km × 3km 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, or worse, being entirely missed.

- 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

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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 YAI to ensure that NO points have been missed.**

7.9 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 APPLEx participants is listed in Chapter 8.

7.10 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:

Table 7-3. APPLEx-1 transportation and training schedule. (Video preparation and quiz).

Date	Time	Location	Activity	Coordinator
Prior to arrival		Online	Presentation: APPLEx Introduction	J. Walker
			Presentation: Logistics and safety	X. Wu
			Presentation: HDAS sampling and data archiving	R. Raj
			Presentation: Scout sampling and data archiving	F. Brakhasi
			Presentation: Roughness sampling and data archiving	N. Boopathi
			Presentation: Cropscan/LAI/Destructive veg sampling and data archiving	L. Murillo
			Presentation: Intensive vegetation sampling and data archiving	X. Shen
			Presentation: Flight plan	N. Ye
29/01/22	7:30-15:00	Melbourne to Yanco	Travel and check-in at YAI	F. Brakhasi, X. Shen, L. Murillo, Z. Xiong
29/01/22	15:00-16:00	YAI	Complete forms and do Quiz	L. Zhou
30/01/22	8:00-9:00	YAI	Lab/storage tour, HDAS training	X. Shen, L. Murillo, F. Brakhasi
	9:00-13:00	Focus Farms	Survey/familiarisation of focus areas	X. Shen, L. Murillo, F. Brakhasi

- Always work in teams of two.

- Carry a phone and/or UHF radio.

- Please keep unnecessary UHF communication (jokes, chit-chat, etc.) to a minimum; your team mate might be trying to communicate if he/she is in trouble.

- Know where you are. Keep track of your position on the provided farm map.

- Do not approach, touch or eat any unidentified objects in the field.

- Dress correctly; long pants, long sleeves, hiking boots, hat, etc.

- Use sunscreen.

- Carry plenty of water with you in a backpack for hydration.

- Notify your Team mate and Team leader of any pre-existing conditions or allergies before going into the field.

- Beware of harvesting machinery and crop dusters. 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 J.

- 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.

7.11 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 Dr Xiaoling Wu 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 Dr Xiaoling Wu if that is the case) or

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- 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 and drive from there.

- If you are planning to take public transportation, you may take the train from Melbourne Southern Cross train station to Wagga Wagga station (4hrs40min), and then take the bus from Wagga Wagga bus stop to Yanco bus stop at Main Ave (1hr50in). We will have someone picking you up at the Yanco bus stop if we are given the arrival date/time before hand.

NOTE: All ground crew are expected to undertake the online training and attend the onsite training. 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 <u>short</u> 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 interested participants from Melbourne to Yanco on Sat, 29 January (**Meeting point: 17 Alliance Lane, Monash Clayton Campus at 7:30am**) and return to Melbourne on Sat, 26 February (arrival sometime in the afternoon/evening). The "Melbourne shuttle" will consist of 4 vehicles (Monash 4WD #1, Monash 4WD #2, Monash 4WD #3 and one compact car, see Table 7-4). Details on seat allocations are to be advised upon arrival. Dr Xiaoling Wu will coordinate the shuttle from Melbourne to Yanco, and from Yanco back to Melbourne.

Getting to the farms

Each ground sampling team will use their vehicle to drive to the focus areas in the morning and return to the YAI at the end of the sampling. The team leaders will have knowledge of the routes to/from the focus areas to the YAI. However, driving directions from the YAI to the focus areas are provided in Appendix G.

Vehicles

Table 7-4 provides information on pick-up and drop-off dates, and responsible person for Team A, B, C and D vehicles during APPLEx-1.

Table 7-4. Pick-up and drop-off dates and responsible person for rented vehicles and truck during APPLEx-1.

Name	Dates	Rental company	Responsible person
Monash Rental 4WD #1	Pick-up 25/01	Off Road Rentals	Luisa
	Drop-off 26/02		Luisa
Monash Rental 4WD #2	Pick-up 28/01	Off Road Rentals	Foad
	Drop-off 26/02		Foad
Monash Rental 4WD #3	Pick-up 28/01	Off Road Rentals	Xiaoji
	Drop-off 26/02		Xiaoji
Truck (6.4M van)	1st Pick-up 04/01	Budget Truck Rental Clayton	Sarvan
	1st Drop-off 07/01		Sarvan
	2nd Pick-up 23/02	Budget Truck Rental Clayton	Sarvan
	2nd Drop-off 26/02		Sarvan
Monash Rental compact car	Pick-up 28/01	Avis Clayton	Ziwei
	Drop-off 26/02		Ziwei

8. CONTACTS

8.1 Primary contacts for APPLE

The primary contacts for this experiment are:

Prof. Jeffrey Walker	Dr Xiaoling Wu	Foad Brakhasi	Xiaoji Shen	Luisa Murillo
Phone: 03 990 59681	Phone: 03 990 53685	Phone: 03 990 53685	Phone: 03 990 53685	Phone: 03 990 53685
Mobile: 0413 023 915	Mobile: 0425 118 055	Mobile: 0481 205 646	Mobile: xxxxxxxxxxx	Mobile: 0452 355 346
Email: jeff.walker@monash.edu	Email: xiaoling.wu@monash.edu	Email: foad.brakhasi@monash.edu	Email: xiaoji.shen@monash.edu	Email: luisa.whitemurillo@monash.edu

For any other call, please contact the participants via the accommodation in the evening.

8.2 Participants

Contact details for all participants are listed below:

Person	Organization	Phone number	E-mail
Jeff Walker	Monash	0413023915	Jeff.walker@monash.edu
Foad Brakhasi	Monash	0481205646	foad.brakhasi@monash.edu
Xiaoji Shen	Monash		xiaoji.shen@monash.edu
Xiaoling Wu	Monash	0425118055	xiaoling.wu@monash.edu
Jon Johanson		0419554656	jonj@flymore.com.au
Kiri Mason	Monash	0421994190	Kiri.Mason@monash.edu
Saravanan Mani	Monash	0421928809	Saravanan.Mani@monash.edu
James Hill	Uni of Tasmania	0409227874	james.hills@utas.edu.au
Brian Ng	Uni of Adelaide	0409426640	brian.ng@adelaide.edu.au
Luisa Murillo	Monash	0452355346	Luisa.WhiteMurillo@monash.edu
Ziwei Xiong	Monash	0423728345	ziwei.xiong@monash.edu
Lixiaozhou Zhou	Monash	0451951830	lixiaozhou.zhou@monash.edu
Javier Caceres		0449925247	caceresjd1010@gmail.com
Abby Randall	Monash	0497324966	aran0030@student.monash.edu
Rebecca Wei	Monash	0449736788	rwei0016@student.monash.edu
Alexandra Edwards	Monash	0422605334	aedw0011@student.monash.edu
Anna Kollmann	Monash	0431566695	annasentchen@gmail.com
Louise Drury	Monash	0402902076	dru0001@student.monash.edu
Tatyana Porczak	Monash	0424000329	tpor0002@student.monash.edu
Atharva Deshpande	Monash	+919527294372	ades0019@student.monash.edu
Zesheng Han	Monash	0451053382	hanzesh258@gmail.com
Daniel Ji Hon Ling	Monash	0403287789	dlin0010@student.monash.edu
Siyuan Tian	ANU	0405550528	siyuan.tian@anu.edu.au

8.3 Emergency

Emergency number in Australia 000 or 112 on a mobile phone

NSW poisons information centre 131 126

Leeton district hospital

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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

8.4   Farmers

Focus Area	Farmer Name (Farm Nr.)	Home Phone	Mobile Phone
YA7	**Greg Kelly (6, 7,13,15,16,25)**	N/A	0427 412 217
	Lance Harland (17)	02 6954 1261	0427 541 262
	Tom Rawson (14)	02 6954 1229	N/A
	Graeme Rawson (24)	N/A	0427 541277
	John Wallace (26)	02 6954 1220	0428 696 330
Almond paddock	Brett Muller		0438 359 067
YA8 & YA9	Paul Flewitt (Tubbo farms)		0428 954 493
YB	Wayne		0407 275 534

8.5   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

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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: Leonie Napier

Phone: (02) 6951 2611

Fax: (02) 6951 2620

Email: leonie.napier@dpi.nsw.gov.au

Budget truck rentals

Contact person: Lisa Bickerdike

Address: 1938 Princes Hwy Clayton VIC 3168

Phone: (03) 9253 1533

Email: clayton@budgetau.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

Walker, J. P., Olivier, M. and Panciera, R., 2006. National Airborne Field Experiment 2006: Experiment Plan. Department of Civil and Environmental Engineering, The University of Melbourne。

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APPENDIX A.   EQUIPMENT LIST

General (2x)	
	per team
Glove pair	1
25 litres water Jerry can	1
Sunscreen Bottle	1
First aid kit	1
First aid book	1
Field book	1
APPLE workplan	1
Pens	2
Hardcopy whole area map	1
Radios	6
Satellite phone	1

HDAS (16x)	
GETAC	16
Poles with probe	20
Batteries	16
Gel cell battery charger	16
GETAC power cable	16
GETAC download cable	16

Gravimetric sampling kits (2x)	
	per kit
Soil sampling ring (5 cm)	5
Crate medium size	1
Garden trowel	1
Blade	1
Spatula	1
Hammer	1
Metal base for hammering rings	1
Plastic bags	100
Rubber bands	200
Print out of soil recording form	5
Pens	2
Markers	1

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Vegetation sampling kit (1x)	
	per kit
Crate in medium size	**1**
Getac	1
Large vegetation clipper	2
Small vegetation clipper	2
Scissors	1
Quadrant	1
Serrated Knife	1
Plastic bags	200
Large trash bags	20
1xmetered sticks	1
CROPSCAN+pole	1
LAI2200	2
Angle meter	1
Digital caliper	1
Compass	1
Print-out of vegetation recording form	5
Paper bags with flat bottoms	30
Pencils	2
Permanent markers	1

Surface Roughness Sampling (1x)	
Getac	1
Roughness profiler (pin, laser, and laser-pin)	3
Level built in	2
Field book	1
Roughness sampling recording form	80
Digital camera	2
Wooden blocks	4
Markers	1
Toughbook	1

Others	
Lake station (UNIDATA salinity and temperature sensor, gel cell battery, floating station, field book, GPS unit, handheld salinity and temperature sensor, boat and oars, laptop, and life jacket)	1

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APPENDIX B.   OPERATING THE HDAS

HDAS Quick Instruction!

1. HDAS set up

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

2. Hydra Probe

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

3. ArcPad

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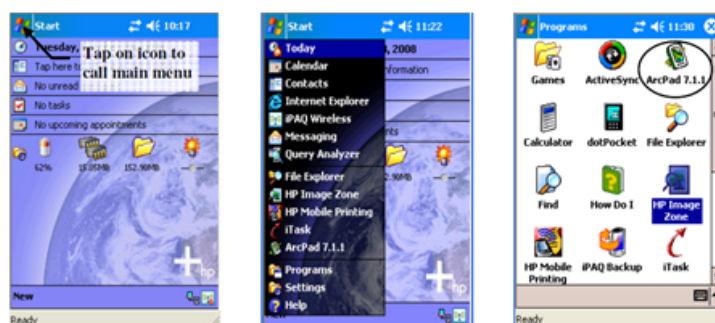
Figure 1. Starting ArcPad software

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

Figure 3. Customised toolbars for HDAS in ArcPad

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

- The ⊘ Symbol indicates your GPS position is lost or is not accurate. **You need to wait until you have a fixed position (symbol ⊕) before sampling.**

- If you don't have a fixed position symbol, check that the GPS is activated by pressing the GPS icon 🛰. If the GPS icon 🛰 is active but you still have the symbol ⊘, you will have to wait until the GPS established a fixed position ⊕.

- Before taking a reading tap on the hydraprobe icon ⬆ to prepare the HydraProbe for reading (unless the hydraprobe icon ⬆ is already active).

- Put the Hydra Probe into the ground at the sampling point, tap wherever within the map area of the screen (**don't tap on the toolbars**) and wait for a few seconds (**NOTE: the exact point on the map area where you tap does not matter, since the coordinates will be taken from the GPS**).

- Tapping on touch screen will start a few seconds event procedure that will communicate with the Hydra Probe and GPS to gather both position and soil moisture related data.

- After a few seconds, a form with collected data will appear in the screen.

- Fill out each of the pages in the form as described in figure 4.
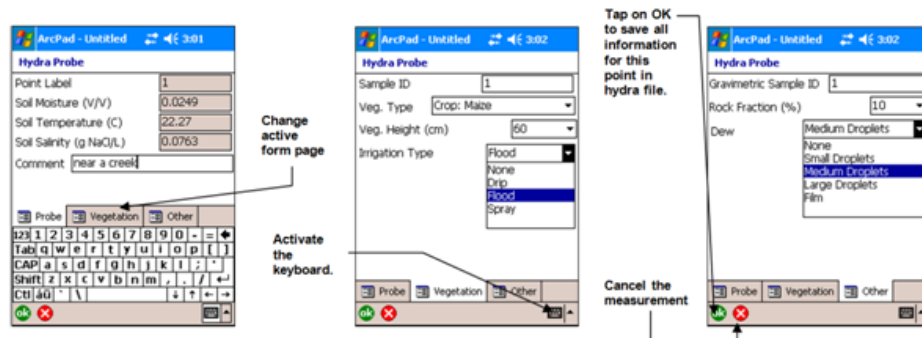
Figure 4. HDAS data entry pages with instructions

- press the ok icon ☑ to save the point or press the red cross icon ✖ to delete the point

- to check the data you have saved at a particular point, activate the information icon ℹ and tap on the desired point

4. Troubleshooting

- "Error 55: Your connection to GPS has not been established". This means that the wrong communication port is set for the GPS. To correct problem, from the desktop "Start" (see Figure 1) → "Settings" → "System" → "GPS" → set GPS program port to COM8. Then go back to ArcPad.

- "Hydra Probe Reading Error: Check connection cable between GETAC and Hydra Probe.". Make sure that the connection cable (gray socket) is connected and screwed to the bottom port of the GETAC

- In case the GETAC freezes for a long time, reboot the GETAC by pressing and holding the power button (bottom right button in the GETAC keypad).

5. Data downloading

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

- Connect the GETAC unit to the field laptop using the GETAC USB cable

- The GETAC unit will be added as a new drive in the "My Computer" (same as for a normal USB pen)

- Click on the drive icon in the windows explorer

- Navigate in the GETAC file system to the folder names "SD Card" in the root directory

- Copy and paste all the files with root name "hydra" or "hydraGRID" (extensions .dbf, .shb, .shx, .prj and .apl)

- Past the files into the desired folder on the field laptop

- empty the folder of the "SD Card" folder by deleting all "hydra" and hydraGRID" shapefiles.

6. Checking out

- Disconnect the GETAC from the laptop

- Put the GETAC to recharge overnight using the GETAC power cable

- Turn off the GETAC by pressing and holding the power button (bottom right button in the GETAC keypad).

- Return all GETAC components (GETA unit, power cable, USB cable, pencil) to the boxes with the same label.

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APPENDIX C.   OPERATING THE SCOUT

METER OPERATION

ON

The ON switch turns the meter on and off. When the meter is turned on, it will display the battery status for 3 seconds. The screen will then display the most recently used MODE screen (Volumetric or Relative water content or measurement period). The data screens for the Water Content Modes are explained on pages 8 and 10. The Period mode is used for doing soil-specific calibrations and is explained on page 14.

```
T100 v7.2 s01234
Battery at 90%
```

```
Stndrd VWC%=27.1
PL=M N008 A=26.5
```

Sample meter power-up and data screens

```
Period = 0950 uS
N015
```

READ

Press the READ button to read the probe and update the screen values. The data point can be cleared from memory with the DELETE/CLR AVG button (below).

Delete Clr Avg

When the DELETE/CLR AVG button is pressed and immediately released, the last data point will be removed from the running average. Pressing and holding this button will reset the running average.

MODE

Pressing the MODE button allows the user to determine the type of measurement that will be taken or select the length of rods connected to the probe.

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Data Measurement Modes
Available measurement options are volumetric water content (VWC) using the standard or high clay mode (see p. 8), up to two relative water content modes (see p. 10), or measurement period (in microseconds). Relative water content options will only appear if they are configured in the software (see Meter Settings, p. 12). The period measurement is available for users interested in performing soil-specific calibrations (see Appendix 1).

Changing Rod Length

```
ROD=MED    (4.7in)
HIT DEL To Chnge
```

Rod Length Options Screen

In order to get accurate volumetric or relative water content (VWC or RWC) readings, the rod length setting must be correct. In the VWC modes, the currently selected rod length appears in the lower left corner of the LCD screen. The options are Long (7.9"), Medium (4.7"), Short (3.0"), Turf (1.5"), T-BLK(1.0"), and T-BLK(0.5") rods. The final two options are only available for customers that have purchased the TDR Turf Rod Spacer (item 6435SP). See p. 13 for further information. Press the MODE button until the LCD displays the rod length options screen. Pressing the DELETE/CLR AVG button will allow you to toggle between the five choices.

Meter Calibration Mode
This mode allows you to calibrate the meter. The calibration procedure is performed in air and distilled water (see Meter Calibration, p. 6). Requires firmware v. 6.5 or greater.

```
CALIBRATION MODE
HIT READ To Cal
```

Meter Calibration Screen

METER CALIBRATION

The meter has internal calibrations for standard and high-clay soil types. These calibrations will work for a large number of soils. However, each meter will have a small difference in how it responds to identical soil conditions. This is due to sensor drift or variability in the electronic components used during manufacturing. Meters with *firmware v. 6.5 or greater* allow for adjustments to the meter calibration to account for these differences. Therefore, if two meters are giving slightly different readings in the same soil, the output of the meters can be standardized such that the meters can be used interchangeably. Because the meter output is partially governed by rod length, the calibration should not be done with rods that are significantly reduces in size because of wear. The calibration procedure is as follows:

1. Use the MODE button to put meter in Calibration mode (see p. 5). Hit the READ button
2. Hold the meter so the rods are in the air. Press the READ button and wait until the meter indicates it is ready.
3. Immerse the rods completely in <u>distilled</u> or <u>deionized</u> water. The container should have a minimum diameter of 3 inches. Press the READ button and wait until the meter indicates it is ready.

The meter will then show that the calibration is complete for that specific rod length. If more than one rod size is being used, a calibration operation must be done for each one.

Note: This procedure is different than a soil-specific calibration (Appendix 1, p. 16) where a unique calibration curve is generated.

CONNECTING TO A PC/ CHANGING BATTERIES

The serial port is accessed by removing the face plate of the digital display. It is through this port that the meter is connected to a PC.

Connecting to a PC

The TDR meter software comes with a black PC interface cable. This cable connects to the 9-pin serial port of your computer and to the meter's serial port. The meter's configuration can be modified by clicking on the **Meter Settings** button (see Meter Settings, p. 12). The **Com Port, Meter Type,** and **Clear Meter Settings** buttons are explained in the Main Toolbar section (p. 11).

Changing the batteries
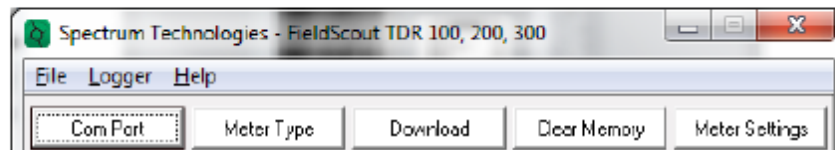
The battery compartment is accessed by removing the meter's face plate. The meter runs on 4 AAA batteries. **When installing new batteries, note whether the batteries immediately feel hot to the touch. The battery has been short-circuited and should be replaced.**

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MAIN TOOLBAR

Com Port

The black software cable connects the meter to the computer data port. Select the Com Port that is assigned to the computer data port. See Identifying the Correct Com Port (p. 14) for instructions on how to determine which port to select.

Meter Type

Select the TDR option from the list of available Field Scout meters.

Meter Settings

Click this button to configure the meter. Refer to "Meter Settings" (p. 12) for more details.

Download and Clear Memory

These functions are not active with the TDR 100.

METER SETTINGS

With TDR model 100, the Meter Settings screen in the Field Scout software is mainly used to enter the set points for the Relative Water Content mode and enable the half-and one-inch probe length options. The meter name and measurement units are also entered here. The fields are described below.

Meter Name: The name given the meter will be the title on the first line of the downloaded text file.

Units: When operating the meter in Relative Water Content mode, the LCD can display the rod length options in English or metric units. The meter will calculate and display the water deficit (see Relative Water Content p. 10) in the same unit system.

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Relative Water Content Set Points: Up to 2 Relative Water Content (see p. 10) modes can be programmed into the meter by entering the wet and dry set points into the appropriate boxes. From the dropdown menus near the bottom of the screen, select which VWC calibration (Standard or High Clay) should be used for each RWC mode. Each of these modes can be given a descriptive name of 5 characters. These names can be used to identify a certain field or soil type.

Finally, for an RWC mode to be available, it must be enabled by checking the Enable Display box. If this box is not checked, that RWC mode will not appear on the LCD during meter operation.

Enable Spacers: If you have purchased the TDR Turf Rod Spacer (item 6435 SP), the **Enable Spacers** button is how the additional rod length options are added to the meter. Instructions for activating this feature are included with the Spacer.

APPENDIX D.   OPERATING THE CROPSCAN MSR16R

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

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

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

Three methods of calibration are supported for the MSR16R systems.

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

Advantages:

- Quick and easy.

- Less equipment required.

- Radiometer may then be used in cloudy or less than ideal sunlight conditions.

- Recalibration required only a couple times per season.

- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

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

Advantages:

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- Provides a more lambertian reflective surface for calibrating the longer wavelength (above about 1200 nm) down sensors than does the opal glass diffuser of the 2-point method.

- Radiometer may then be used in cloudy or less than ideal sunlight conditions.

- Recalibration required only a couple times per season.

- Assumed radiometer is to be used where radiance flux density is the same between that striking the top surface of the radiometer and that striking the target area, as outside in direct sunlight.

Figure D-1. CT100 hand terminal.

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

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

Advantages:

- Only down sensors required, saving cost of purchasing up sensors.

- Best method for radiometer use in greenhouse, under forest canopy or whenever irradiance flux density is different between that striking the top of the radiometer and that striking the target area.

Disadvantages:

- White card must be carried in field and recalibration readings must be taken periodically to compensate for sun angle changes.

- Less convenient and takes time away from field readings.

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

There are six major items you need in the field -

1. MSR16 (radiometer itself)

2. Data Logger Controller & Cable Adapter Box (carried in the shoulder pack, earphones are to hear beeps)

3. CT100 (hand terminal, connected to the DLC with a serial cable)

4. Calibration stand and opal glass plate

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5.   Memory cards

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

Set up

1.   Mount the radiometer pole bracket on the pole and attach the radiometer.

2.   Mount the spirit level attachment to the pole at a convenient viewing position.

3.   Lean the pole against a support and adjust the radiometer so that the top surface of it is level

4.   Adjust the spirit level to center the bubble (this will insure that the top surface of the radiometer and the spirit level are par level)

5.   Attach the 9ft cable MSR87C-9 to the radiometer and to the rear of the MSR Cable Adapter Box (CAB)

6.   Connect ribbon cables IOARC-6 and IODRC-6 from the front of the CAB to the front of the Data Logger Controller (DLC)

7.   Plug the cable CT9M9M-5 into the RS232 connectors of the CT100 and the DLC (the DLC and CAB may now be placed in the shoulder pack for easy carrying)

8.   Mount the CT100 on the pole at a convenient position

9.   Adjust the radiometer to a suitable height over the target (the diameter of the field of view is one half the height of the radiometer over the target)

Configure MSR

1.   Perform once at the beginning of the experiment, or if the system completely loses power

2.   Switch the CT100 power to on

3.   Press ENTER 3 times to get into main menu

4.   At Command * Press 2 then ENTER to get to the ReconFig. MSR menu

5.   At Command * Press 1 then ENTER, input the correct date, Press ENTER

6.   At Command * Press 2 then ENTER, input the correct time, Press ENTER

7.   At Command * Press 3 then ENTER, input the number of sub samples/plot (5), Press ENTER

8.   At Command * Press 6 then ENTER, input a 2 or 3 character name for your sampling location (ex OS for Oklahoma South), Press ENTER; input the latitude for your location, Press ENTER; input the longitude for your location, Press ENTER

9.   At Command * Press 9 then ENTER, input the GMT difference, Press ENTER

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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)

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    d.   Save program/configuration to card (use to save after calibrating)

    e.   Load program/configuration from card (use when DLC loses power)

    f.   Battery check

    g.   M. Main menu

5. There are 2 memory cards, 64K for storing the program/configuration and 256 for storing data in the field

Taking readings in the field

- Switch the CT100 power to on

- Press ENTER 3 times to get into main menu

- At Command * Press 2 then ENTER to get to the ReconFig. MSR menu

- At Command * Press 5 then ENTER, input your plot ID (numbers 1-999 only), Press ENTER

- Press M to return to the MSR main menu

- At Command * Press 8 then ENTER to get to the MSR program

- Press ENTER to continue or M to return to the MSR main menu

- Enter beginning plot number, ENTER

- Enter the ending plot number, ENTER, record plot numbers and field ID in field

- notebook

- Adjust the radiometer to a suitable height (about 2 meters) over the target, point the radiometer towards the sun, center the bubble in the center of the spirit level and make sure that there are no shadows in the sampling area

- Do not take measurements if IRR < 300

- Initiate a scan by pushing SPACE, the message 'scanning' will appear on the screen and a beep will be heard

- When the scan is complete (about 2 seconds) '**' will be displayed and 2 beeps will be heard

- Now, you can move to the next area

- 3 Beeps will be heard when the data has been stored

- Press SPACE to start next scan, R to repeat scan, P to repeat plot, S to suspend/sleep, M to return to the MSR main menu, W to scan white standard, and D to scan Dark reading

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- When you are done scanning at that field location, press M to return to the MSR main menu, then press 10 to put the DLC.

APPENDIX E.   OPERATING THE LAI-2000

Plug the sensor cord into the port labelled "X" and tighten the two screws.

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

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

Clear the memory of the logger

- Press "FILE"

- Use "↑" to place "Clear Ram" on the top line of display

- Press "ENTER"

- Press "↑" to change "NO" to "YES"

- Press "ENTER"

General items

When changing something on the display, get desired menu item on the top line of display and then it can be edited.

Use the "↑" and "↓" to move items through the menu and the "ENTER" key usually causes the item to be entered into the logger.

When entering letters, look for the desired letter on the keys and if they are on the lower part of the key just press the key for the letter; if the desired letter is on the upper part of the key then press the "↑" and then the key to get that letter.

Press "BREAK" anytime to return to the monitor display that contains time, file number or sensor readings on one of the five rings that are sensed by the LAI-2000.

Do not take data with the LAI-2000 if the sensor outputs are less than 1.0 for readings above the canopy.

To begin

- Press "SETUP"

- Use "↑" to get "XCAL" on the top line of the display and press "ENTER"

- Following XS/N is the serial number of the sensor unit, enter appropriate number

- Check or put appropriate cal numbers from LICOR cal sheet into the 5 entries.

- Final press of "ENTER" returns you to "XCAL"

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- Use "↑" to get to "RESOLUTION"

- Set it to "HIGH"

- Use "↑" to get to "CLOCK"

- Update the clock (set to local time using 24 hr format)

- Press "OPER"

- Use "↑" to get "SET OP MODE" on top line of display

- Choose "MODE=1 SENSOR X"

- Enter "↑", "↓", "↓", "↓", "↓" in "SEQ"

- Enter "1" in "REPS"

- Use "↑" to get to "SET PROMPTS"

- Put "SITE" in first prompt

- Put "LOC" in second prompt 144

- Use "↑" to get to "BAD READING"

- Choose "A/B=1"

- Press "BREAK"

- Display will contain the two monitor lines

Use "↑" and "↓" to control what is displayed on the top line in the monitor mode, time, file number or sensor ring output 1 through 5 for the ✕ sensor. (If FI is selected, then the file number is displayed)

Use the "→" and "←" to control what is displayed on the bottom line of the monitor mode, time, file number or sensor ring output 1 through 5 for the ✕ sensor. (If X2 is selected, then ring #2 output is displayed)

Press "LOG" to begin collecting data

Type in the response to the first prompt (if "ENTER" is pressed the same entry is kept in response to the prompt).

Type in the response to the second prompt (if "ENTER" is pressed the same entry is kept in response to the prompt).

Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

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For grasslands:

1.   Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

2.   Place the sensor below the plant canopy in one corner of your sampling area level the sensor and press the black log button on the sensor handle and keep level until the second beep.

3.   Repeat for the other 3 corners

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

For row crops:

1.   Place the sensor head in the appropriate position above the canopy, level the sensor and press the black log button on the handle of the sensor (a beep will be heard when the black button is pushed). Hold the sensor level until the second beep is heard.

2.   Place the sensor below the canopy in the row of plants, level the sensor and press the black log button on the sensor handle and keep level until the second beep.

3.   Place the sensor one-quarter (1/4) of the way across the row and record data again.

4.   Place the sensor one-half (1/2) of the way across the row and record data again.

5.   Place the sensor three-quarters (3/4) of the way across the row and record data again.

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

The logger will compute LAI and other values automatically. Using the " ↑ " you can view the value of the LAI.

NOTE: You will record the "SITE" and "LOC" along with the LAI value on a data sheet.

The LAI-2000 is now ready for measuring the LAI at another location. Begin by pressing "LOG" twice. The file number will automatically increment. When data collection is complete, turn off the logger by pressing "FCT", "0", "9". The data will be dumped onto a laptop back at the Field Headquarters.

Downloading LAI-2000 files to a PC using hyperterminal

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

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

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

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

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

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

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

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

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

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

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

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

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

13.   Using a text editor (like notepad) on the PC, open and check that all the LAI data has been stored in the text file specified in step 3. Make a back-up of this file according to the archiving instructions later in this chapter.

14.   Once you are sure the LAI values look reasonable and are stored in a text file on the PC, use function 22 on the LAI-2000 to delete files on the LAI-2000 and free up its storage space.

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

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

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

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

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

APPENDIX F.   TEAM TASKS SHEET

Table F-3. Soil moisture sampling task sheet (Team A and B).

Measurement	Extent	Point Spacing	Nr. of Samples	Person Responsible
HDAS	3 km × 3 km	50 m or 250 m	3 per point	All team members
Land Use	3 km × 3 km	50 m	3 per point	All team members
Vegetation Type	3 km × 3 km	50 m	3 per point	All team members
Vegetation Height	3 km × 3 km	50 m	3 per point	All team members
Presence of Dew	3 km × 3 km	50 m	3 per point	All team members
Scouts	3 km × 3 km	50 m	3 per point/per pin length	Selected team members
Gravimetric Soil Samples	3 km × 3 km	variable	Min. 3 per focus area	Team leader

Table F-1. Vegetation sampling task sheet (Team C).

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

Table F-3. Intensive vegetation sampling task sheet (Team C).

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

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

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

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/m²)
	Local Date:	**Focus Area:**							**Team:**				
		Lat.	Long.										
	:												
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Express in degrees from magnetic North

Comments: Label bag as Area_ID/DD MM YY/Sample_ID and time

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Intensive vegetation sampling form

Date		Paddock ID		Crop type	

ApproxTime	1x1m Area ID	¹row orientation(deg) ²row spacing(cm) ³nr.plants/m²	Species ID	comment	Species% cover	Plant Photo ID	Plant height (cm)	Stalk length (cm)	Stalk angle (deg from vert.)	Stalk Ø (mm) ¹bot ²mid ³top	Leaf size (mm). Bottom//middle/top leaf			Leaf angle (deg from vert)			Mv	Nr. Leaf
											width	length	thickness	bole	mid	tip		

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Vegetation sample drying form

	Local Date:									
	Person making entry:									

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

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Gravimetric soil moisture sample drying form

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

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

Comments:

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Surface roughness sampling form

Sample ID	Local Time	Lat.	Long.	Land Cover	Veg. Type*	Row Direction**	File or Photo ID					
Local Date			**Focus Area ID**		**Name of Person**		**Team ID**					
DD/MM/YY												
							N-S-1	N-S-2	N-S-3	E-W-1	E-W-2	E-W-3
	:											
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Comments: * Select from the Getac list
**   ** express in degree from magnetic North clockwise**

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APPENDIX H.   SAMPLING AREAS MAPS AND DIRECTIONS

Directions to get from the Yanco Agricultural Institute to the two focus areas:

Focus area YA4 – approx. driving time (30min)

1.   From the YAI, turn right on irrigation way and immediately left on Euroley Rd.

2.   After approx. 8 km turn right left into Euroley Rd

3.   After approx. 5 km turn right into Sturt Hwy (20)

4.   Continue on Sturt Hwy for approx. 20 km

5.   After having crossed the Coleambally Main Canal, turn left into Main Canal Rd

6.   After approx. 7 km turn left into Wallace Rd

7.   YA4 is west of Main Canal Rd. Wallace Rd crosses YA4 at middle latitude

Focus area YA7 – approx. driving time (30min)

1.   As per YA4 (point 1-5)

2.   YA7 is west of Main Canal Rd., 1.5 km south of Wallace Rd until Eulo Rd.

Focus area YA8 & YA9 – approx. driving time (35min)

1.   As per YA7

2.   YA8 and YA9 are east of Main Canal Rd., cross the main canal, drive along the Old Morundah Rd.

Focus area YB – approx. driving time (45min)

1.   As per YA7

2.   Keep driving on the Main Canal road for around 10 km, and then left to the Yamma Rd until the township of Morundah.

3.   Turn right to Newell Hwy and drive for ~4 km to arrive the entrance of YB area

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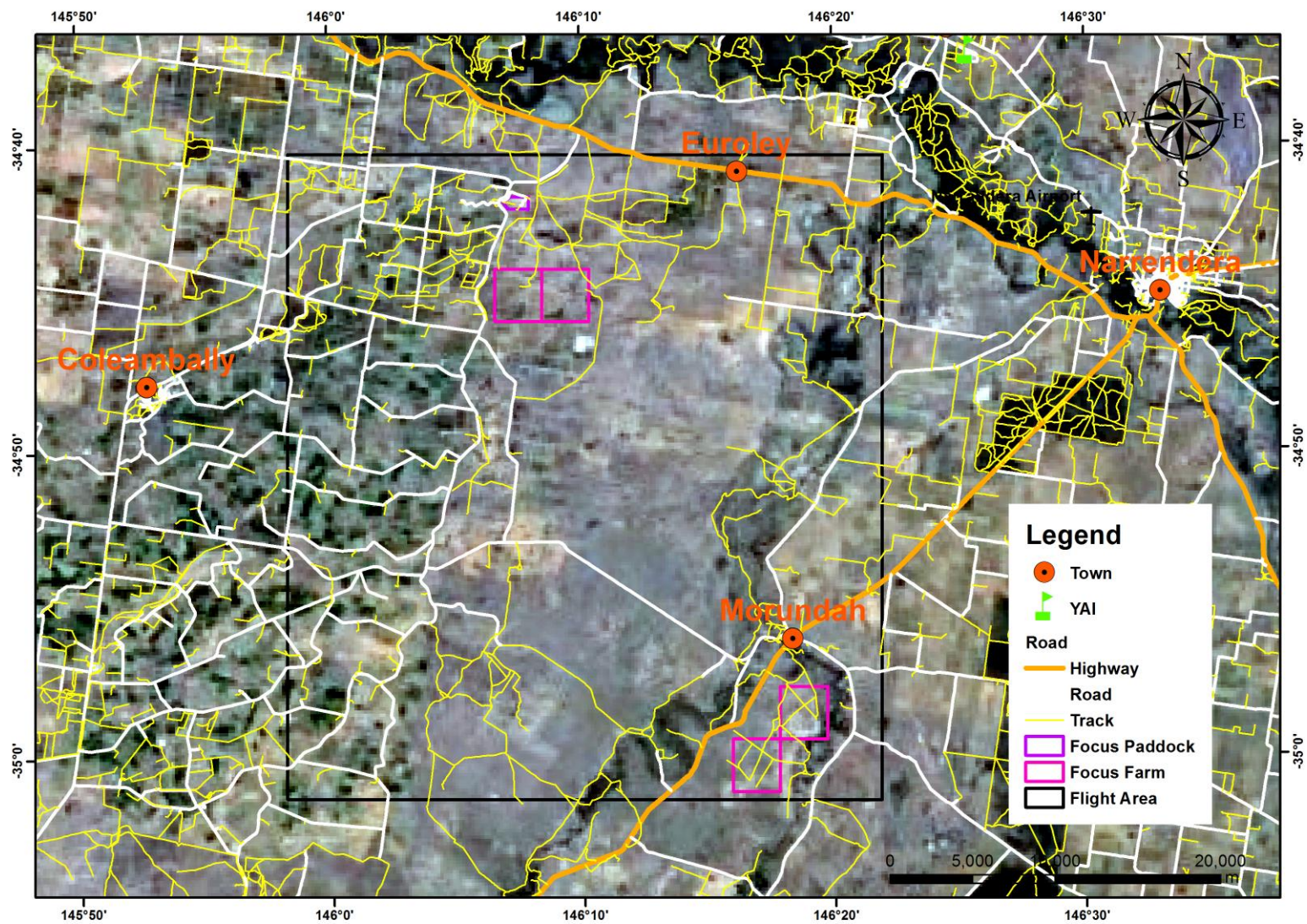
H-1. Road map over the ground sampling area.
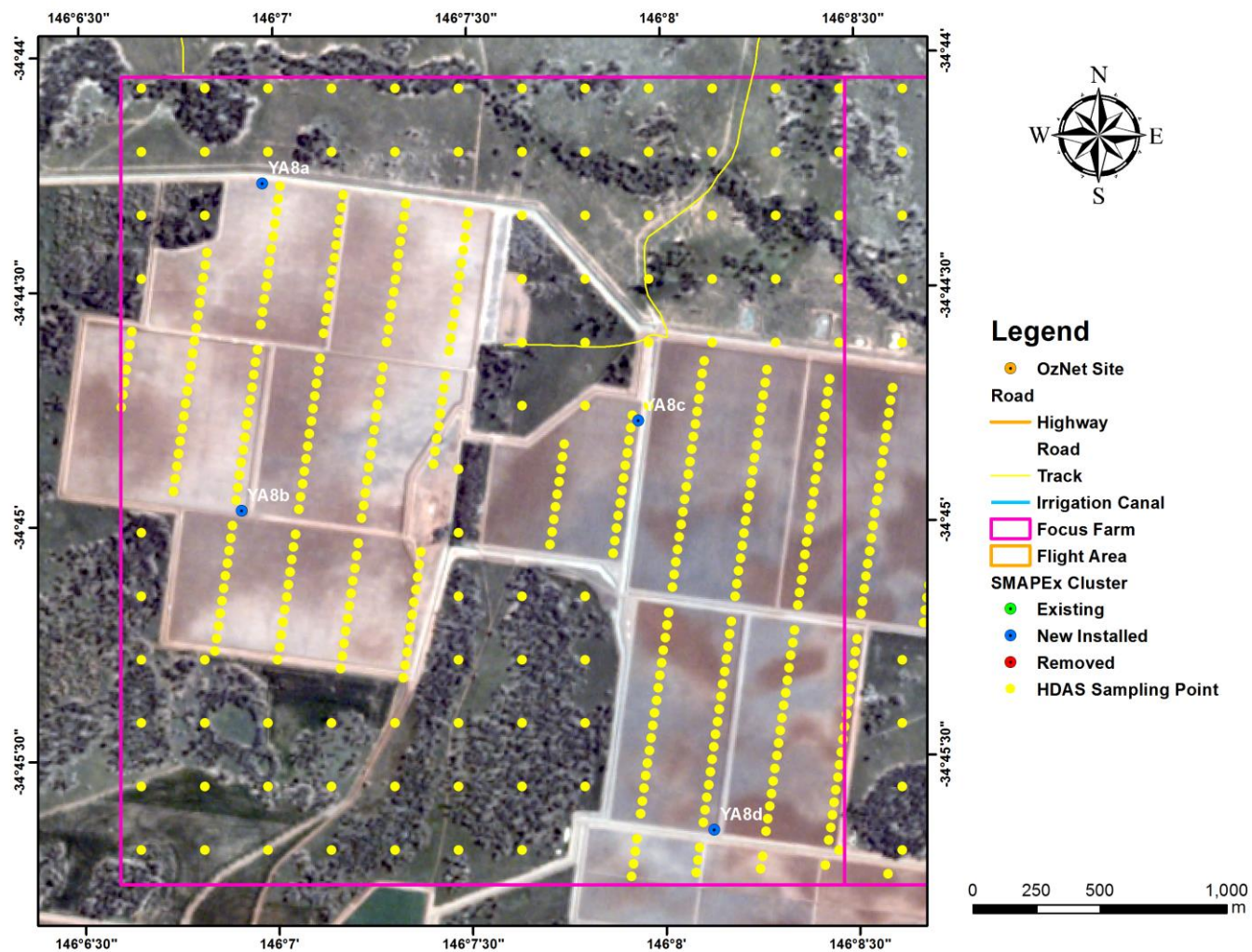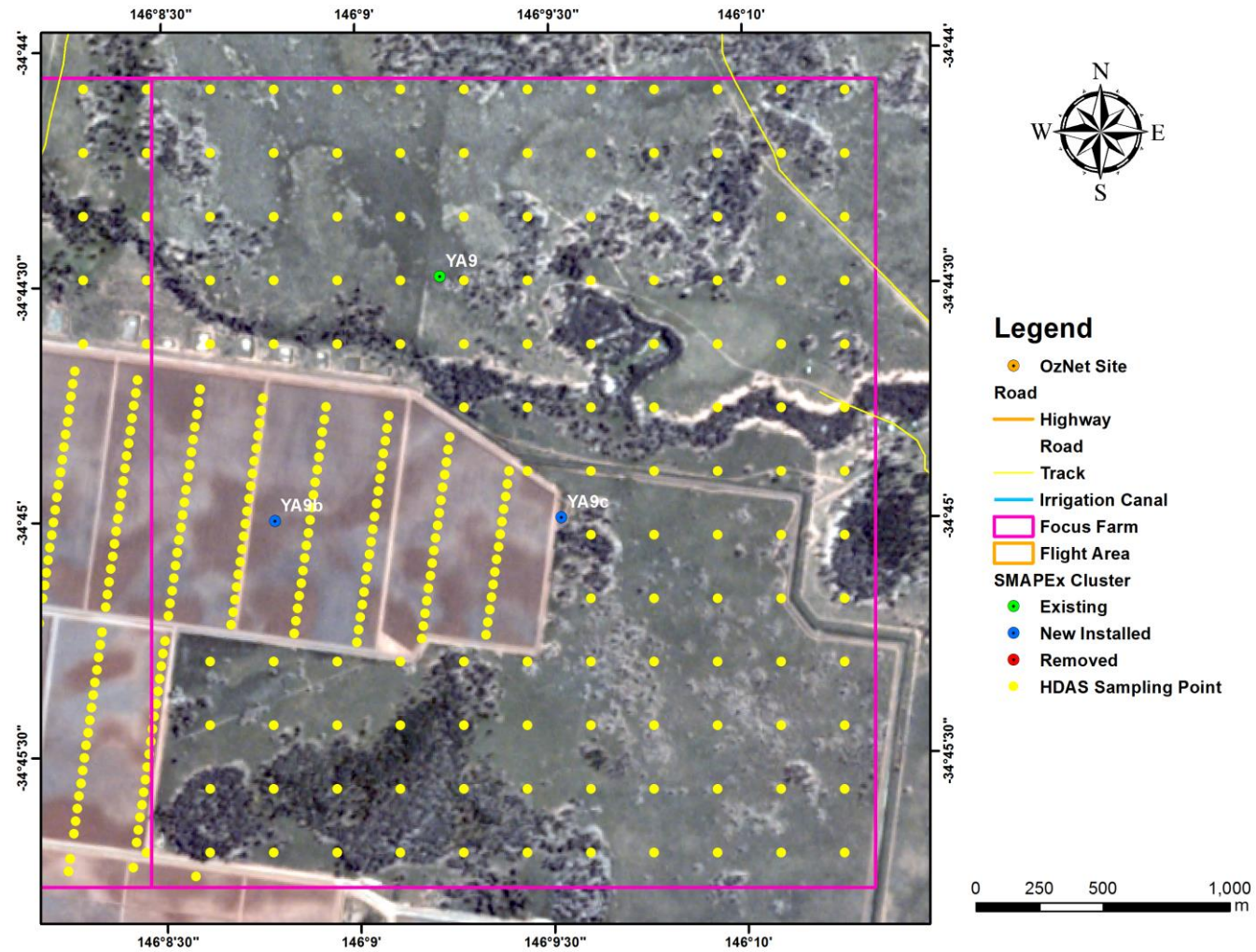
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Figure H-2. Road map over the YA8.

Figure H-3. Road map over the YA9.
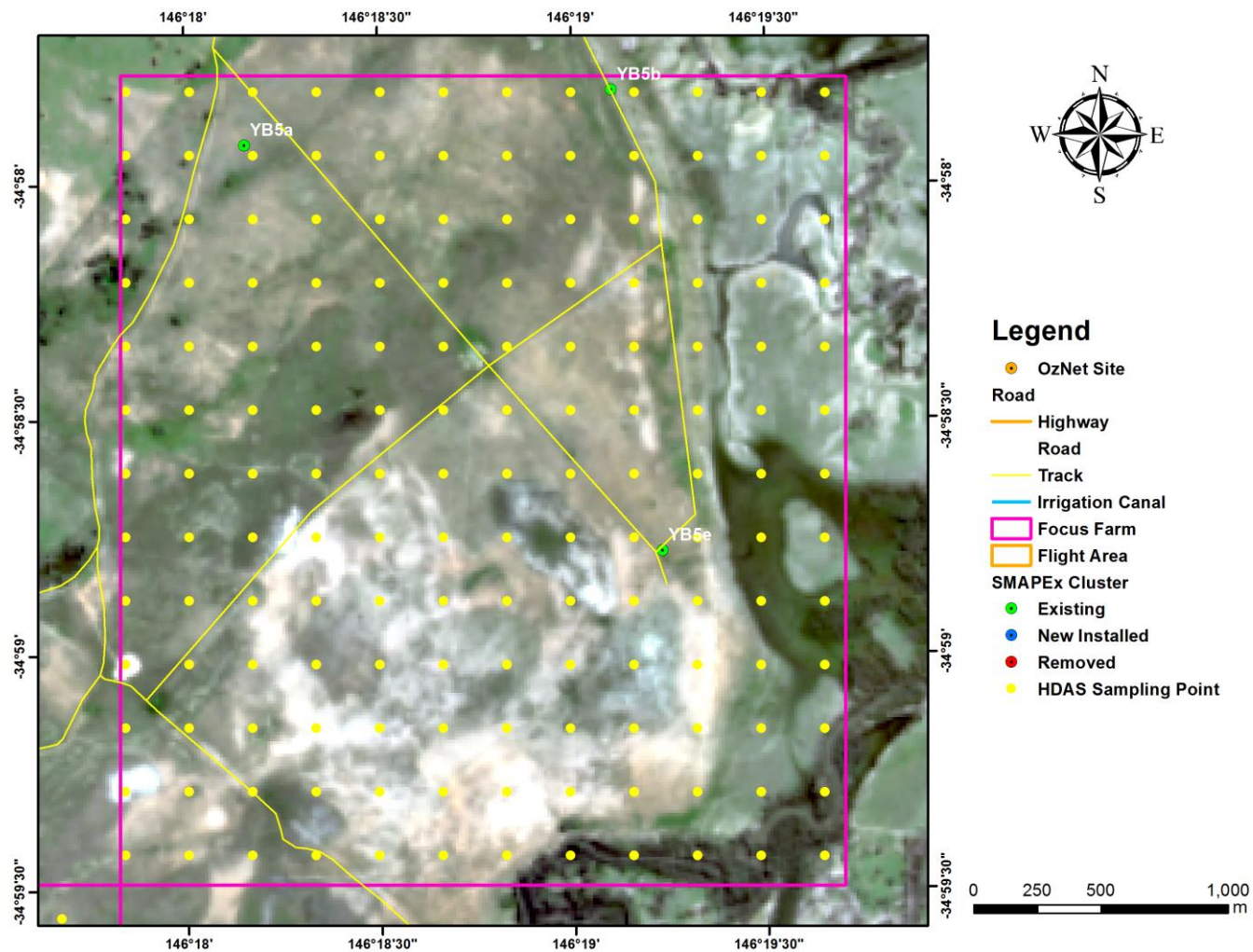
Figure H-4. Road map over the YB5.

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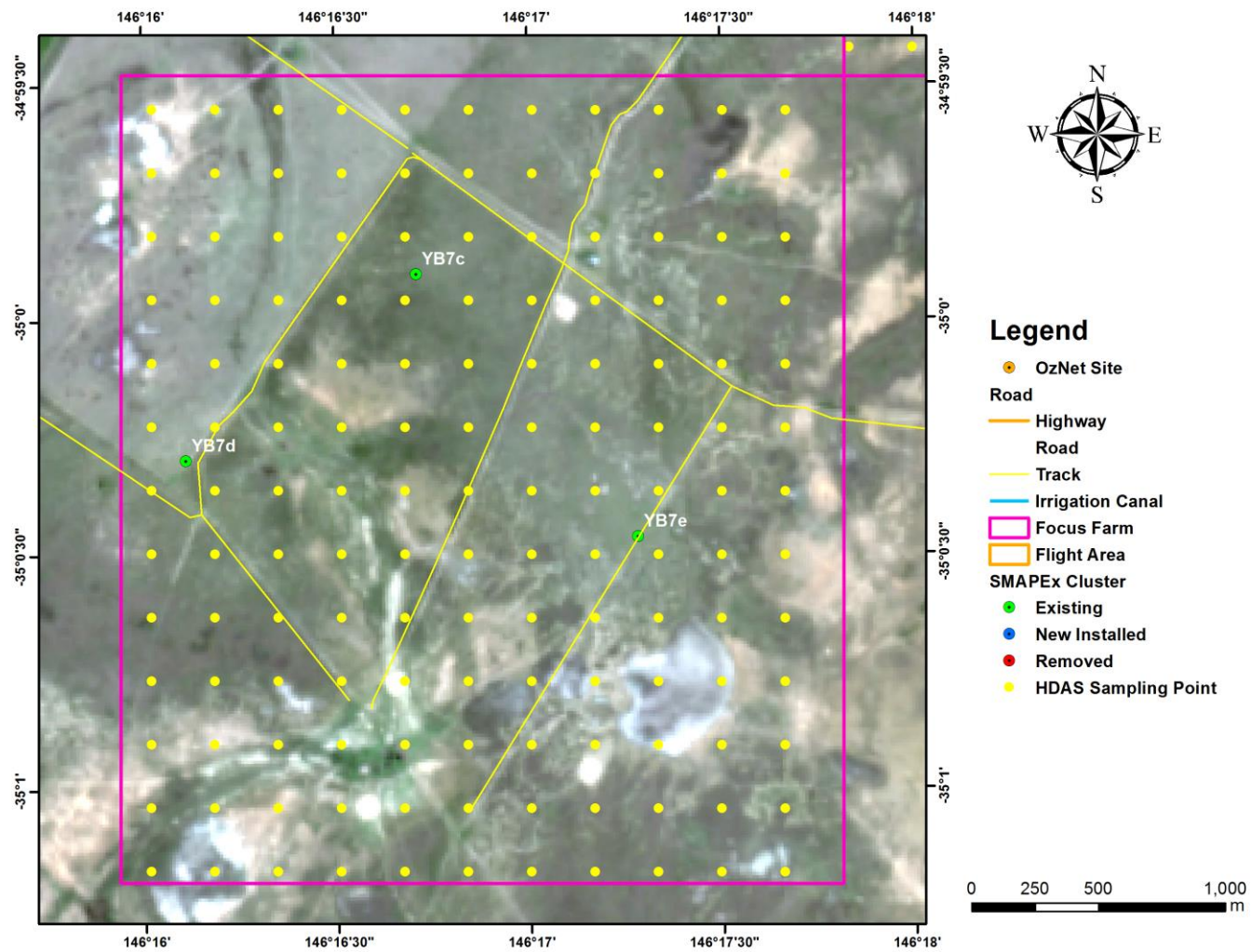
Figure H-5. Road map over the YB7.
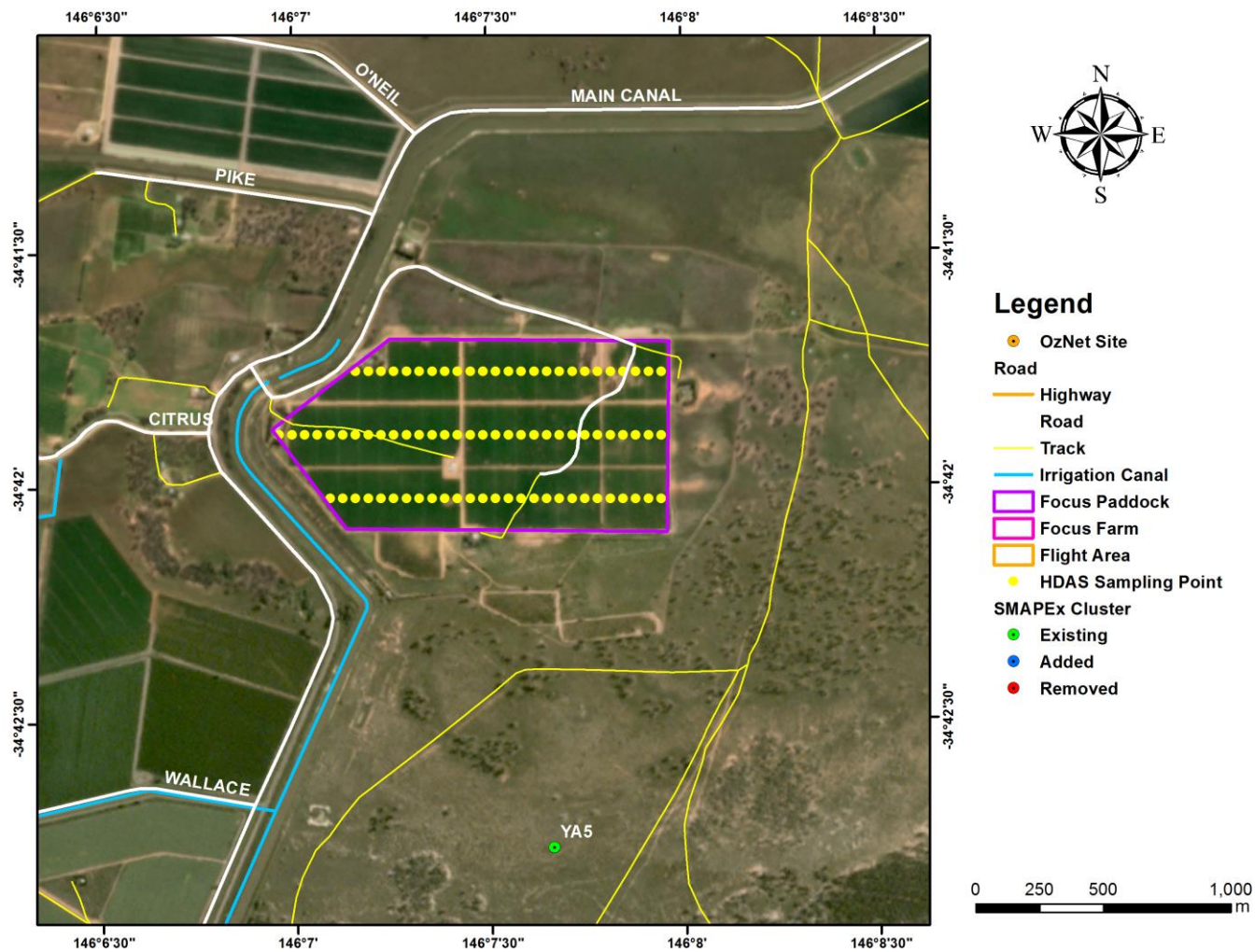
Figure H-6. Road map over the focus paddock.

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APPENDIX I.   APPLEX FLYER

High-resolution Measurement of Soil Moisture and Vegetation

Ground sampling activities for the Active Passive P- and L-band Experiment (APPLEx)

Background

Timely soil moisture status and forecasts are critical for (i) grain growers to make informed decisions on what and when to plant based on likely germination rates and crop yield, (ii) graziers to be proactive in their management of stocking rates based on likely pasture growth, and (iii) high water use agriculture to undertake more efficient irrigation scheduling practices. Remote sensing technology has been used to monitor the soil moisture conditions for Australia but is currently limited in terms of sensing depth and spatial resolution. Consequently, researchers at Monash University are planning to undertake two experiments in the Yanco/Coleambally area to develop new technologies for mapping the soil moisture content over a deeper depth and at higher spatial resolution, and your farm has been selected as a ground validation site of interest. The availability of soil moisture information at high resolution will have important implications in water resources management, including better knowledge of the soil moisture distribution across farms.
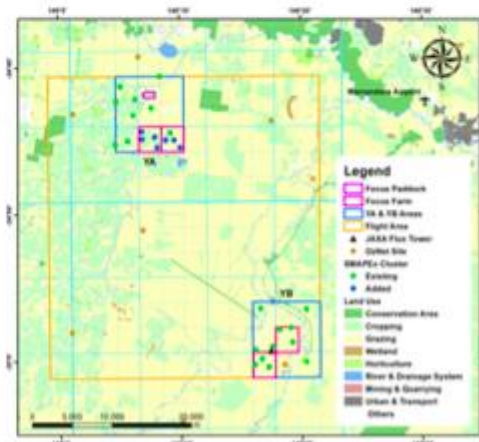

Fig. 1: Location of the study area (orange) and ground sampling areas (purple) and stations (circles) in the Coleambally district.

In order to make sure that the soil moisture information provided by remote platforms is accurate over Australia, researchers at Monash University are planning to make aircraft measurement of soil moisture in the Yanco area, supported by ground measurements of the surface moisture content in carefully selected areas, together with a small number of physical soil and vegetation samples.

Two four-week long aircraft campaigns are envisaged, Jan/Feb 2022 and Oct/Nov 2022, covering a range of soil moisture and vegetation conditions during different seasons in the Yanco/Coleambally area. Airborne measurements 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 four 3km × 3km and one 1km x 1km sampling areas (Fig. 1). In return for granting us access to your farm, you will have access to all the data collected in the campaigns. 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 schematic of a possible sampling points distribution across a farm.

Ground Measurement of Soil Moisture

The ground measurements undertaken on your farm will be conducted by a small team of researchers carrying non-destructive soil moisture probes. Using an integrated GPS, the field technicians will navigate to predefined sampling points at 50m and/or 250m spacing across representative paddocks within each focus area as indicated in Fig. 2.

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Vegetation Sampling

Vegetation sampling is required to determine the vegetation water content of the plants in order to estimate soil moisture from the aircraft and drone. Assuming that vegetation conditions are relatively uniform across the sampling area, only five sampling locations will be required for each paddock. Both non-destructive spectral measurements and complete removal of vegetation to ground level from within a 50cm × 50cm area (see Fig. 3) twice each week will be required at each location. This will allow calibration of the spectral data for estimating the vegetation water content at other locations.

Surface Roughness Sampling

Surface roughness affects the airborne observations by effectively increasing the surface area of electromagnetic wave emission. Its effect on observations is difficult to quantify, and is therefore a critical parameter to be spatially characterised across the different land cover types. During the field experiment surface roughness will be characterized at five locations within each major land cover type and roughness condition in the 3km x 3km focus areas. At each of the locations, two 3m-long surface profiles will be recorded.

General Note on Property Access

Permission to access your property for these campaigns will be treated with the utmost respect, minimising any impact on the soil and vegetation. You may recall that our team has undertaken similar ground monitoring campaigns in your or your neighbours' farms as recently as March 2021, and we hope to continue our good working relationship into the future. Moreover, all participants are aware of the requirements for a good collaboration with local property owners and will be trained and closely supervised during the planned campaign activities.

Fig. 3: Typical vegetation sampling within a 50cm × 50cm area and example of non-destructive spectral measurements.

Fig. 4: Surface roughness sampling using a laser-pin board profiler.

Contact Details

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

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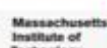Mobile: 0410 168 213
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APPENDIX J.   SAFETY

Field Work Safety Form

Safety Briefing – Surveying Fieldwork

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

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

1. All Fieldwork participants should ensure an 'In case of Emergency' (ICE) number is stored in their mobile phone. (Name: ICE, Number: (Area Code) (Phone Number)
2. All participants should have access to a mobile phone. If a member of the group does not have a mobile phone then a 'buddy system' should be established.
3. Any participant who requires medication as declared on their Off Campus Medical Questionnaire, must ensure that they have sufficient amounts for the duration of the trip.
4. All Fieldwork participants must ensure that they have appropriate Personal Protective Equipment (as identified on the Risk Assessment)
5. All Participants should make themselves aware of the exact location (Street name, nearest cross-road, suburb etc) at which they are working each day. You will need this information if you have the need to contact any of the Emergency Services.
6. A First Aid procedure should be in place. If a First Aid Officer is unavailable to attend the trip then alternative arrangements such as, familiarizing yourself with the local medical facilities, is vital.
7. Continuous communication shall be established at all times of the Fieldwork. This can be verbal/visual – staying within sight and hearing distance of the group or via communication devices – mobile phones, 2-way radios etc. Alternative arrangements can be set up if appropriate.

8. If an incident occurs, all participants must take the following action:
   a. Assess the medical requirements
   b. If serious, call the emergency services (000 or 112 from mobile phones) for assistance
   c. Notify the individual's contact person (their ICE contact)
   d. Complete an S3 Incident report as soon as possible
   e. Notify the Supervisor of the Incident as soon as possible
10. If a dangerous situation (natural disaster, personal threat, animal presence) occurs and you believe you need to evacuate the area, take the following action:
    a. Remove any persons from immediate danger
    b. Notify all members of the group for the need to leave the area
    c. Contain or eliminate the problem, if possible
    d. Evacuate yourself and others if you cannot contain the problem
11. Remember to adopt safe work practices and look out for each other
12. All participants are responsible for their own health and safety and that of others who may be affected by their conduct, including members of the public.
13. If there is something you are not sure of, seek clarification from your Supervisor before commencing the task
14. Do not operate/use equipment that you are not familiar with
15. Ensure appropriate clothing is worn AT ALL TIMES when required, this includes, enclosed footwear, High-visibility vests, sunscreen, hats, long sleeved, long legged clothing etc.
16. Ensure water and snacks are available at all times
17. Conduct regular rest breaks
18. Report any unsafe conditions or hazards to your Fieldwork Supervisor
19. Treat all other members of Fieldwork with respect and courtesy
20. Clean up after yourselves – leave the Fieldwork environment in the same (or better) condition than when you arrived.
21. Notify all members of any planned rest breaks or lunch breaks and where your meeting spot is, i.e. the car, the café etc
22. Work hard and have fun!

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APPENDIX K.   HOW TO PREVENT SNAKE BITE GUIDELINES

Step 1

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

Step 2

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

Step 3

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

Step 4

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

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

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

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

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Snake Bites First Aid Instructions

First in First Aid

SNAKE BITES

MANAGING A SNAKE BITE

1) Check for signs of life:
   • if casualty is unconscious, follow DRABCD (Danger, Response, Airway, Breathing, CPR, Defibrillation).

2) Calm casualty.

3) Apply pressure immobilisation bandage:
   • apply a firm roller bandage starting just above the fingers or toes and moving up the limb as far as can be reached
   • the bandage needs to be very firm.

4) Immobilise casualty:
   • apply a splint to immobilise the bitten limb
   • check circulation in fingers or toes
   • ensure casualty doesn't move.

5) Call 000 for an ambulance.

SIGNS & SYMPTOMS

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

WARNING

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

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

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

Do not try and catch the snake.

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

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APPENDIX L.   OFF-CAMPUS ACTIVITIES INFORMATION AND CONSENT FORM

MONASH University

Off-campus activities Information and consent form

The purpose of this form is to have your (or if under 18 years old, your parents/guardians) authorisation to attend the off-campus activity. The information will be used to indicate to the person in charge of the activity of any medical condition/s which may be aggravated by the activity, affect your ability to participate in the activity and inform them of any special needs so that measures can be taken to facilitate safe participation.

Should you wish not to utilise the form below, you can speak directly with the activity organiser, the university's Disability Liaison Unit (DLU) or Occupational Physician who will work with the university to accommodate your needs.

SCHOOL/DEPARTMENT: _____

OFF CAMPUS ACTIVITY: _____

DESTINATION: _____ DATE(S): _____

Student details	
Name:	Address
Student Number:	Phone number:
Name and relationship of emergency contact:	Phone number:

Relevant Medical Information
Please list any pre-existing medical conditions or allergies that might impact on your ability to undertake the off-campus activity. Eg. Hernia, back pain, recent injury, heart condition, asthma, diabetes, epilepsy, food allergies, pollen sensitivity etc.
Please list any medication that might impair your ability to undertake duties whilst engaged in the activity. Eg. Medication which causes drowsiness and may impact in ability to operate machinery or vehicles?

Special Request
Are there any special needs or requests, including dietary requirements applicable to your participation in this activity?

Authorisation
I have read the information provided for this activity and agree to abide by the guidelines and procedures and the directions provided by supervisors during the activity.
I acknowledge that acceptable standards of behaviour will be expected during this activity. I understand that, in the event of serious misbehaviour during the activity, I will be informed and that I may be sent home and that any costs associated with this return will be my responsibility.
Signature: _____   Date: _____

The information on this form is collected for the primary purpose of enabling you to undertake the off-campus activity. Your personal information may be disclosed to a third party involved in the activity and in the event of an emergency. You have a right to access personal information that Monash holds about you, subject to any exceptions in relevant legislation. If you wish to seek access to your personal information or inquire about the handling of your personal information, please contact the Monash University Privacy Officer on 9902 9589.

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APPENDIX M.   OFF-CAMPUS ACTIVITIES VOLUNTEERS INFORMATION SHEET

MONASH University

Off campus activities
Volunteer information sheet

SCHOOL/DEPARTMENT OF _____

Details of Volunteer

Name: _____

Address: _____

_____

Phone: _____

Emergency Contact

Name: _____

Relationship: _____   Phone: _____

Address: _____

_____

Details of activity

Date(s): _____

Location(s): _____

Monash student/staff member present (name): _____

Declaration: I have volunteered to accompany the Monash University student/staff member named above on the activity as specified. I have been informed of the risks involved in doing this work and have read the risk assessment. I have been informed of the risk controls that have been implemented and I agree that I will comply with the risk control measures to the best of my ability.I have read and will comply with the following university policies, procedures & guidelines:

Conduct and Compliance policies:

- Unacceptable behaviour in the workplace
- Staff/student relationships

OHS procedures & guidelines:

- Off-campus activities procedure
- Guidelines for management of alcohol and other drug issues amongst staff and students

Monash University student charter

Monash University discrimination and harassment grievance procedures

Signature: _____   Date: _____

Off-campus activities emergency contacts proforma, v .2	Responsible Officer: Manager, OHS	Page 1 of 1
Date of first issue: November 2013	Date of last review: February 2015	Date of next review: 2018

For the latest version of this document please go to: http://www.monash.edu.au/ohs

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APPENDIX N.   FLIGHT LINES COORDINATES AND SENSOR CONFIGURATION

PLMR flight with PLMR, PLIS, and PPIS (860 MHz)
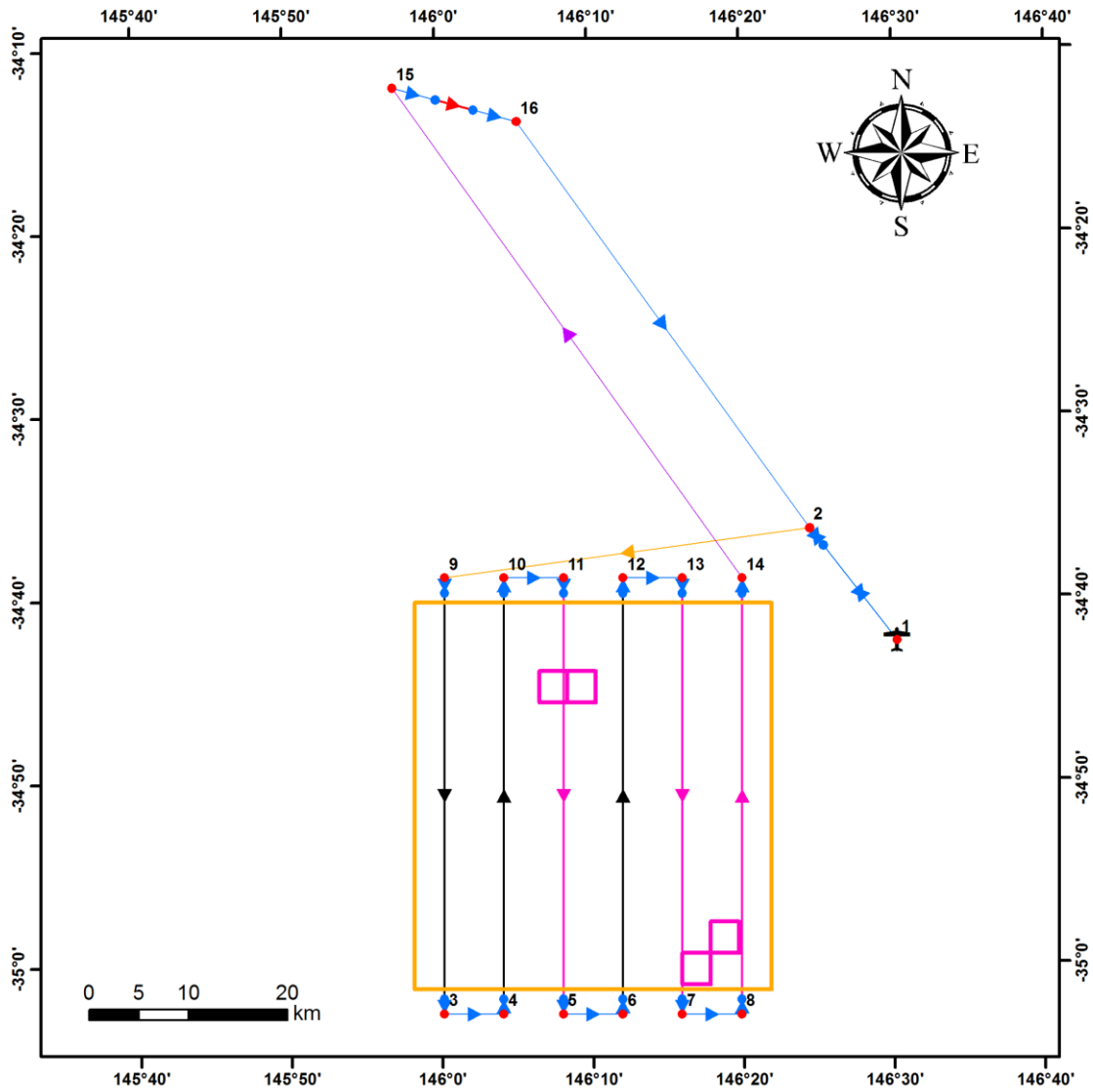
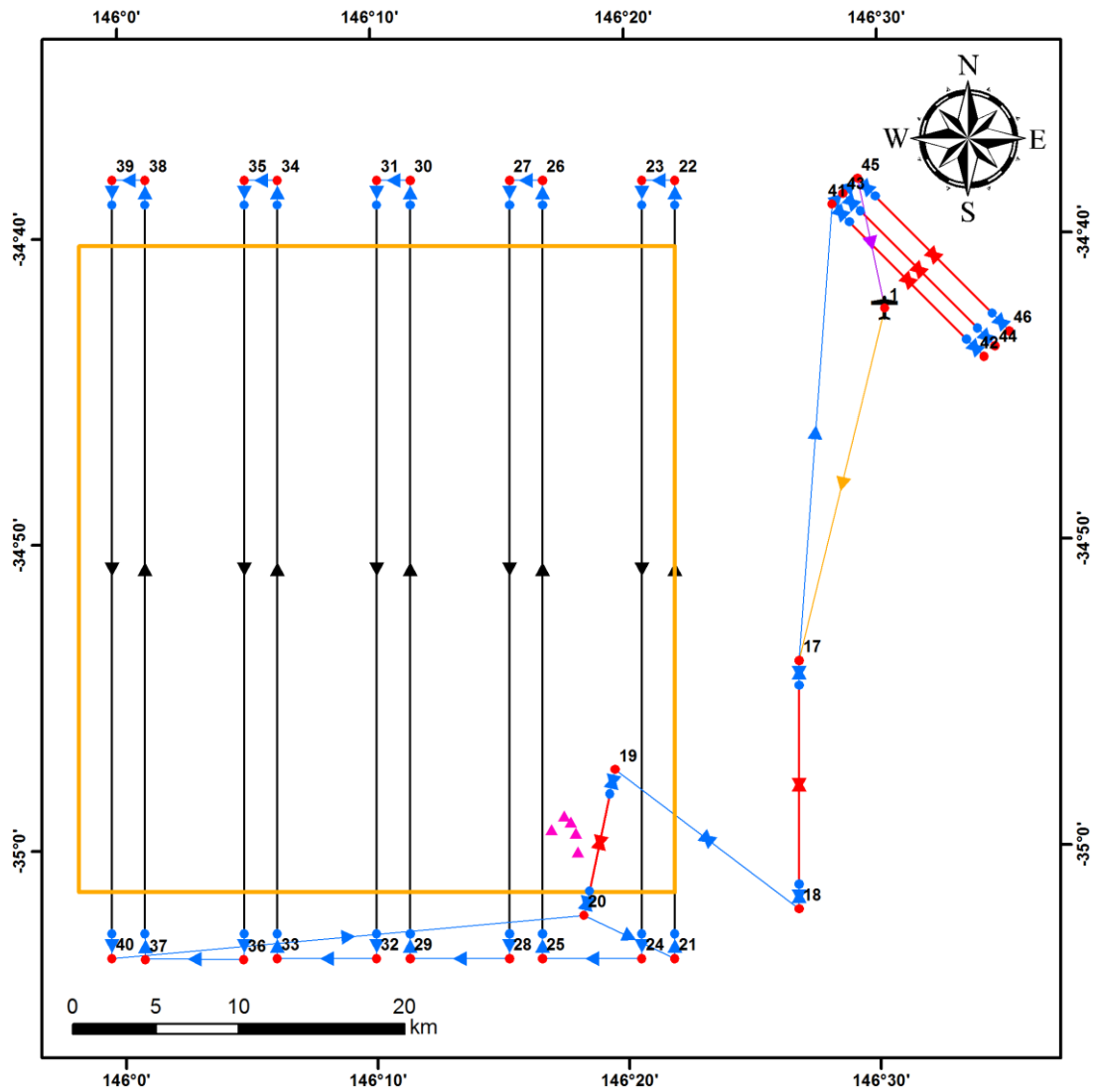**PLMR flight with PLMR, PLIS, and PPIS (860 MHz)**

Altitude 10,400ft (ASL) and duration 2.5 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146˚30.293'E	34˚42.454'S	9	146˚.42'E	34˚38.903'S
2	146˚24.532'E	34˚36.3'S	10	146˚4.348'E	34˚38.934'S
3	146˚.134'E	35˚2.706'S	11	146˚8.276'E	34˚38.963'S
4	146˚4.08'E	35˚2.738'S	12	146˚12.204'E	34˚38.99'S
5	146˚8.027'E	35˚2.767'S	13	146˚16.132'E	34˚39.014'S
6	146˚11.974'E	35˚2.794'S	14	146˚20.06'E	34˚39.037'S
7	146˚15.921'E	35˚2.819'S	15	145˚57.257'E	34˚12.143'S
8	146˚19.868'E	35˚2.842'S	16	146˚5.414'E	34˚14.029'S

Route: 1, 2, **(alt↑ 10,400ft),** 9, 3, 4, 10, 11, **(switch on radar)**, 5, **(switch off radar)**, 6, 12, 13, **(switch on radar)**, 7, 8, 14, **(switch off radar)**, **(10,400ft↓917ft)**, 15, **(Lake Calibration),** 16, 2, 1

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Radar flight with PLIS and PPIS (860 and 440 MHz)

Radar flight with PLIS and PPIS (860 and 440 MHz)

Altitude 10,400ft (ASL) and duration 3.9 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146˚30.293'E	34˚42.454'S	32	146˚9.992'E	35˚3.592'S
17	146˚26.836'E	34˚53.95'S	33	146˚6.045'E	35˚3.564'S
18	146˚26.781'E	35˚2.065'S	34	146˚6.321'E	34˚38.137'S
19	146˚19.51'E	34˚57.479'S	35	146˚5.012'E	34˚38.128'S
20	146˚18.24'E	35˚2.235'S	36	146˚4.711'E	35˚3.596'S
21	146˚21.836'E	35˚3.664'S	37	146˚.795'E	35˚3.565'S
22	146˚22.031'E	34˚38.236'S	38	146˚1.084'E	34˚38.097'S
23	146˚20.722'E	34˚38.229'S	39	145˚59.775'E	34˚38.086'S
24	146˚20.52'E	35˚3.657'S	40	145˚59.466'E	35˚3.512'S
25	146˚16.572'E	35˚3.634'S	41	146˚28.221'E	34˚39.055'S
26	146˚16.794'E	34˚38.207'S	42	146˚34.214'E	34˚44.052'S
27	146˚15.485'E	34˚38.199'S	43	146˚28.653'E	34˚38.701'S
28	146˚15.256'E	35˚3.626'S	44	146˚34.646'E	34˚43.698'S
29	146˚11.308'E	35˚3.601'S	45	146˚29.243'E	34˚38.219'S
30	146˚11.557'E	34˚38.174'S	46	146˚35.236'E	34˚43.215'S
31	146˚10.248'E	34˚38.165'S			

Route: 1, **(alt↑10,400ft)**, 17, **(Forest Calibration)**, 18, 19, **(PRC Calibration)**, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 20, **(PRC Calibration)**, 19, 18, **(Forest Calibration)**, 17, 41, **(PARC 1 Right)**, 42, **(PARC 1 Left)**, 41, 43, **(PARC 2 Right)**, 44, **(PARC 2 Left)**, 43, 45, **(PARC 3 Right)**, 46, **(PARC 3 Left)**, 45, **(10,400ft↓)**, 1

**Operational limitation: no more than 175Kts GROUND speed**

PPMR flight with PPMR
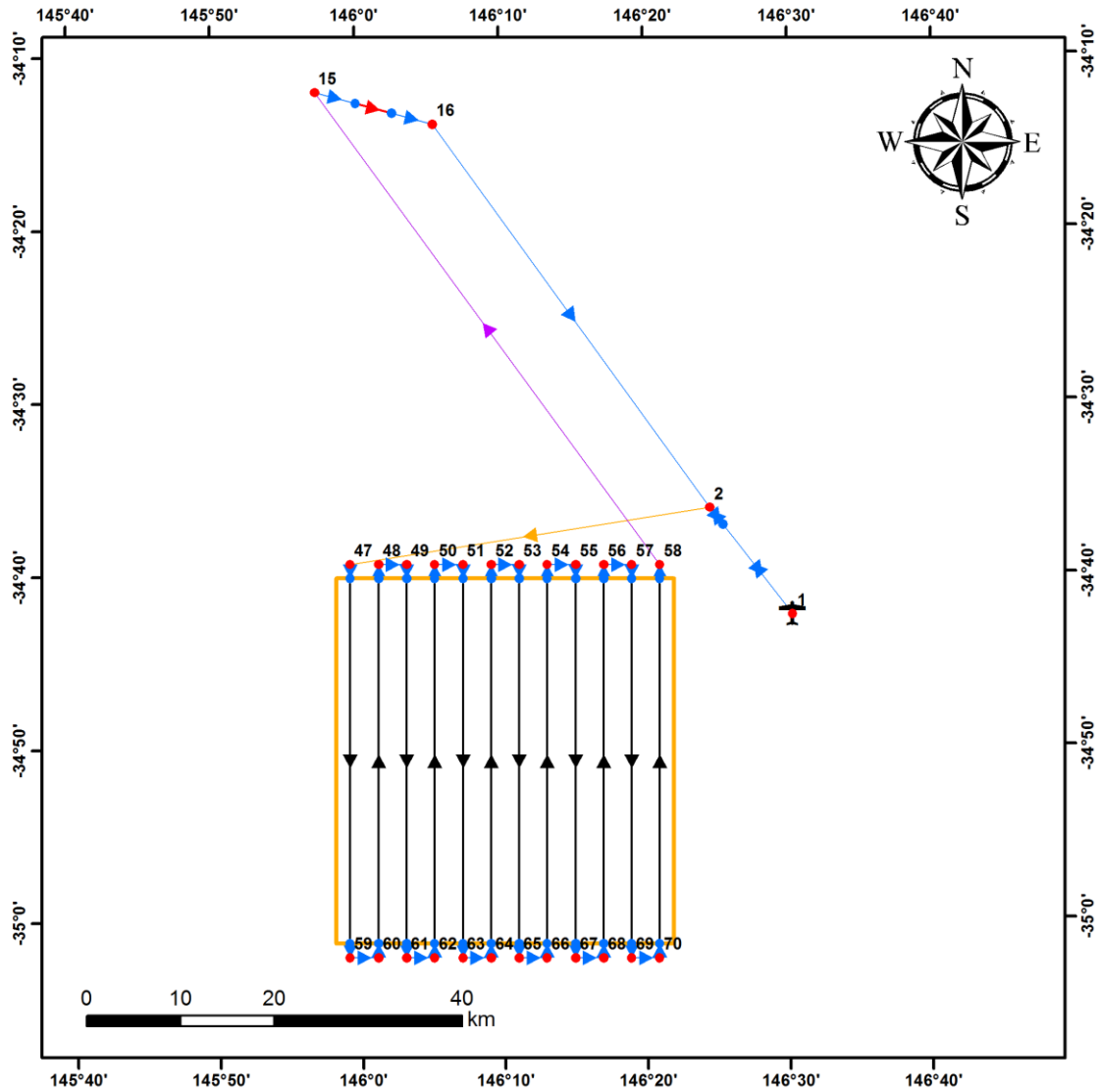
PPMR flight with PPMR
Altitude 3,400 ft (ASL) and duration 3.6 hours

Point ID	Longitude	Latitude	Point ID	Longitude	Latitude
1	146˚30.293'E	34˚42.454'S	59	145˚59.154'E	35˚2.157'S
2	146˚24.532'E	34˚36.3'S	60	146˚1.127'E	35˚2.173'S
47	145˚59.432'E	34˚39.436'S	61	146˚3.1'E	35˚2.189'S
48	146˚1.396'E	34˚39.452'S	62	146˚5.073'E	35˚2.204'S
49	146˚3.36'E	34˚39.468'S	63	146˚7.046'E	35˚2.219'S
50	146˚5.324'E	34˚39.483'S	64	146˚9.02'E	35˚2.233'S
51	146˚7.288'E	34˚39.497'S	65	146˚10.993'E	35˚2.246'S
52	146˚9.253'E	34˚39.511'S	66	146˚12.966'E	35˚2.259'S
53	146˚11.217'E	34˚39.524'S	67	146˚14.939'E	35˚2.272'S
54	146˚13.181'E	34˚39.537'S	68	146˚16.913'E	35˚2.284'S
55	146˚15.145'E	34˚39.549'S	69	146˚18.886'E	35˚2.295'S
56	146˚17.11'E	34˚39.561'S	70	146˚20.859'E	35˚2.306'S
57	146˚19.074'E	34˚39.572'S	15	145˚57.257'E	34˚12.143'S
58	146˚21.038'E	34˚39.583'S	16	146˚5.414'E	34˚14.029'S

Route: 1, 2, **(alt↑3,400ft),** 47, 59, 60, 48, 49, 61, 62, 50, 51, 63, 64, 52, 53, 65, 66, 54, 55, 67, 68, 56, 57, 69, 70, 58, **(3,400ft↓),** 15, **(Lake calibration),** 16, 2, 1

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Specifications of the PARC

	PARC#1	PARC#2	PARC#3
Latitude	34˚41.863'S	34˚41.857'S	34˚41.86'S
Longitude	146˚30.907'E	146˚30.777'E	146˚30.842'E
Azimuth	12° from True East to South	12° from True East to South	12° from True East to South
Incidence angle for P1	15° from nadir	15° from nadir	15° from nadir
Incidence angle for P2	30° from nadir	30° from nadir	30° from nadir
Incidence angle for P3	45° from nadir	45° from nadir	45° from nadir

Radar calibrations targets PRC
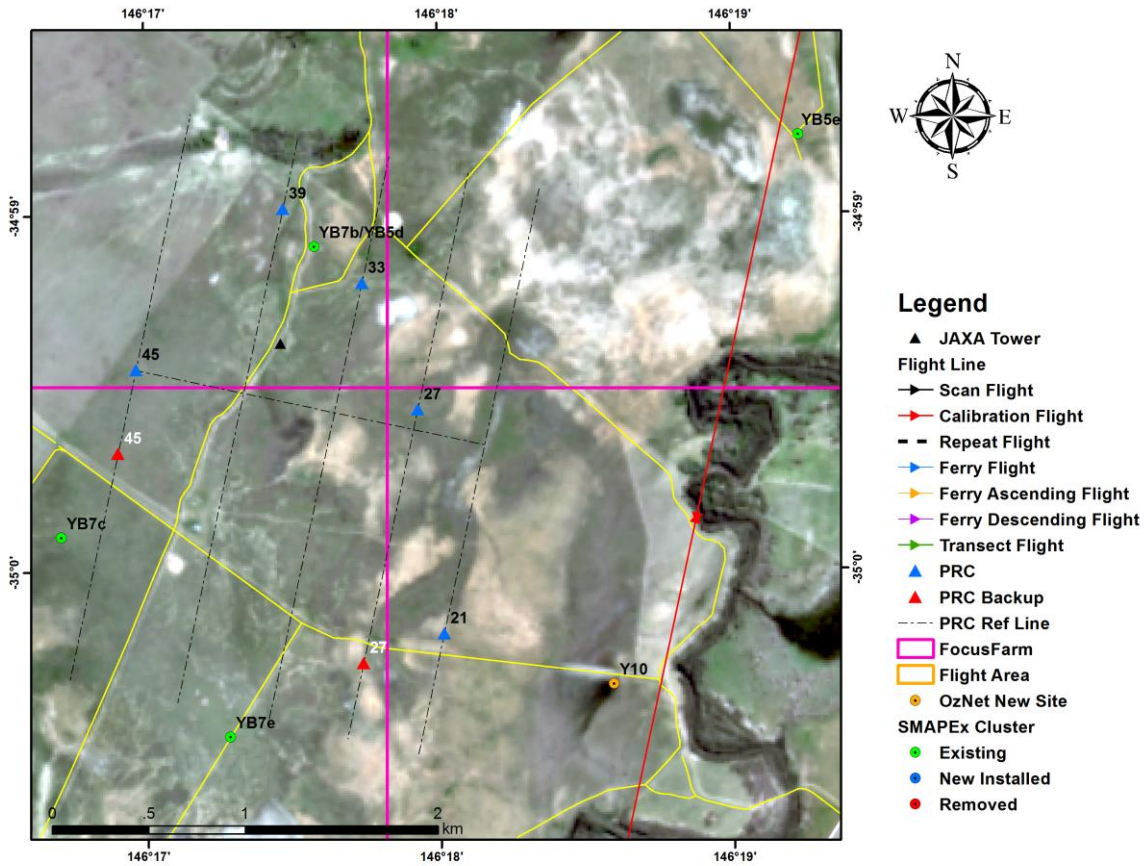
Specifications of PRC

All PRC face to the 102° from True North to East

Incidence angle	Size	Latitude [°]	Longitude [°]	Northing [m]	Easting [m]	Bottom face angle from the horizon [°]
21	3.31m	-35.0030	146.3002	6126404.44	436147.97	33.74
27	1.65m	-34.9925	146.2988	6127565.94	436009.67	27.74
33	3.31m	-34.9866	146.2957	6128221.42	435719.75	21.74
39	1.65m	-34.9831	146.2912	6128605.74	435309.56	15.74
45	3.31m	-34.9906	146.2828	6127768.94	434548.30	9.74
27 Backup	1.65m	-35.0043	146.2957	6126250.36	435729.81	27.74
45 Backup	3.31m	-34.9945	146.2818	6127335.82	434456.24	9.74

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PLIS Setting Parameters

Altitude	PRP	# range gates	Data trigger delay	Chirp length/BW	Attenuation	Decimation	filter
10000ft	330 μs	832	20,000 ns	10 μs / 30 MHz	0	3	none

PPIS Setting Parameters

Altitude	Altitude Padding	PRP	Frequency	Chirp length/BW	Attenuation	Decimation	filter	Append calibration loop
10000ft / 3050m	200 m	120	Dual 860 MHz 440 MHz	10 μs / 20 MHz 10 μs / 20 MHz	0 0	4 4	Matched	Yes
10000ft / 3050m	200 m	100	Dual 860 MHz 440 MHz	3 μs / 20 MHz	0	4	Matched	Yes

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APPENDIX O.   MONASH COVID SAFE PLAN

Come to field trip well
Check symptom
Assessment on sickness

Physical distancing
1.5m, activity density quotients
Timetable/Scheduling control

Face coverings
Mask to be carried all the time
Masks to be worn when in the same vehicle
Masks to be worn when 1.5m distancing can't be achieved

Personal Hygiene
Hand sanitizer
Cough etiquette
Soap and water

Well ventilated space
Max fresh air intake
Max air changes
Outdoor spaces
Rolling down the car windows at regular intervals

Increased cleaning
High contact surfaces
Accessible cleaning products

Positive case management
Tracing and tracking
Communications

Sharing facilities
Maximum occupancy
Clean after use

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APPENDIX P.   RISK ASSESSMENT

Note: Risk assessment can be found from separate document