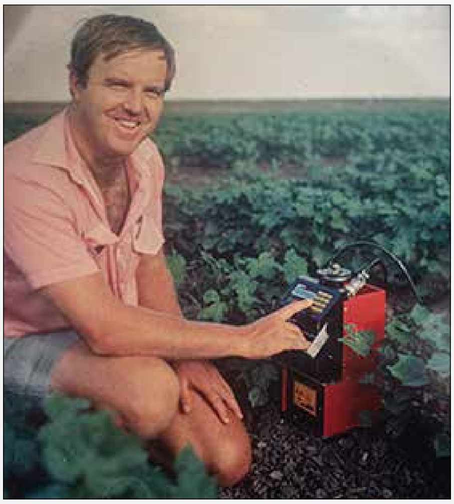
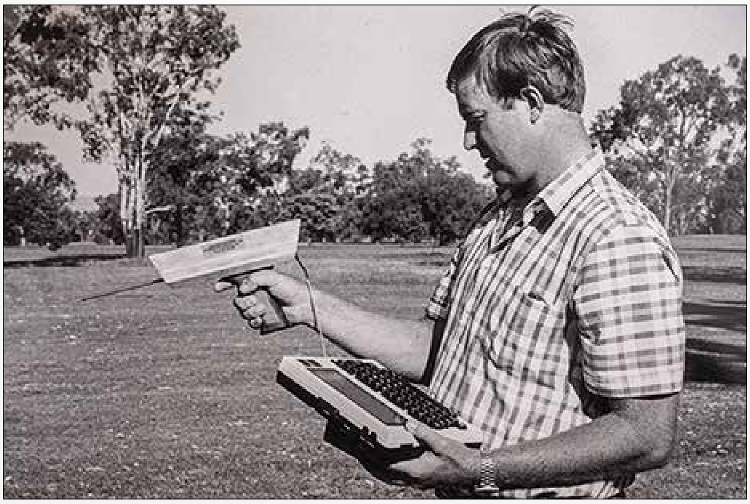
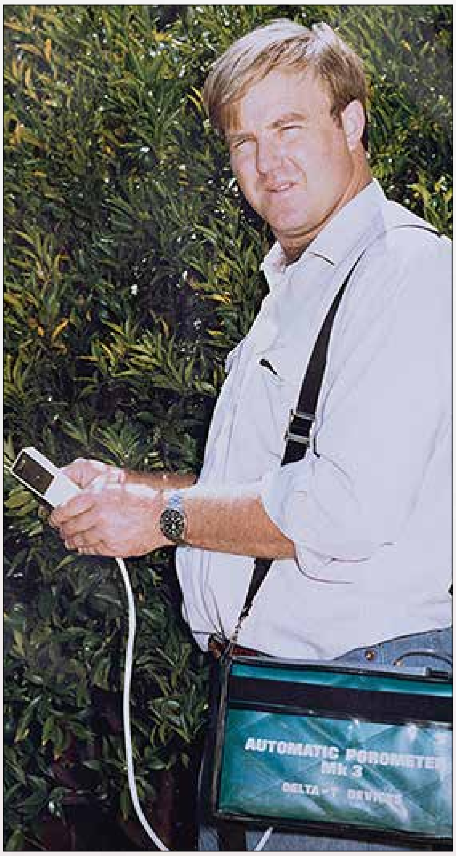
IoT Catalogue 2019-2020

For Real-Time Continuous Monitoring of:
Natural, Built & Agricultural Environments







Innovating & Disrupting Since 1979

Our Capability Statement

ICT International has specialised in plant, soil and environmental monitoring instrumentation since 1979. ICT International is a strongly scientific and applications focused company; constantly developing and evolving monitoring, management and research solutions for environmental, agricultural (cropping, horticultural and plantation), forestry, mining and industrial applications.

ICT International began with a focus on Australian agricultural systems, where low and highly variable rainfall requires the measurement of soil moisture, soil physical properties, plant water use and plant water stress, and the weather, to ensure efficient water use and maximum crop yields.

Australia is a big country geographically but a small country in population. The applications demanded by Australian customers are as diverse and demanding as they would be for a much larger population such as Europe or USA. This has challenged ICT International to develop a detailed knowledge of plant and soil science, the technologies used to collect plant and soil data, sensor behaviour and limitations, and how to use and interpret collected data.

In 2006 ICT International launched a RDI (Research, Development and Innovation) program to address technological limitations in the measurement of key plant and soil parameters. The signature products developed as part of this program were the Sap Flow Meter SFM1 and the Psychrometer PSY1, for continuous monitoring of plant water use and plant water potential; now exported to over 50 countries annually from ICT International's manufacturing facility in Armidale, NSW, Australia.

Over 40 years ICT International has developed strong, long term relationships with leading instrumentation companies from around the world. Working in partnership with these companies, ICT International ensures customers have access to a comprehensive suite of sensors, data loggers and IoT Nodes, as well as the knowledge and know-how necessary to provide comprehensive monitoring solutions.

Today, ICT International's RDI program continues with a focus on enabling the IoT connectivity of sensors for the supply of real time data in the natural and built environment.

The method of data transmission and the manner in which it is presented is determined by the application and chosen by the customer. ICT International has no preference for data transmission. LoRa, LoRaWAN, or Cat-M1/IOT-NB are often the best solution, but not always. Every customer wants the data stored and displayed differently and ICT International will deliver to that request. Scientists will prioritise data security and redundancy ahead of data transmission and presentation, whereas crop management will prioritise timely data transmission and presentation.

IoT monitoring systems offer new opportunities for management in many applications. ICT International IoT monitoring systems are modular and can be easily changed or further expanded, as needed.

This catalogue represents the products and skills necessary to develop IoT monitoring solutions, as demanded by customers globally.

ICT International pursues market opportunities around the world and is always open to new partnerships with individuals and companies involved in every part of our supply chain, from farm gate to sensors and satellites.

ICT INTERNATIONAL

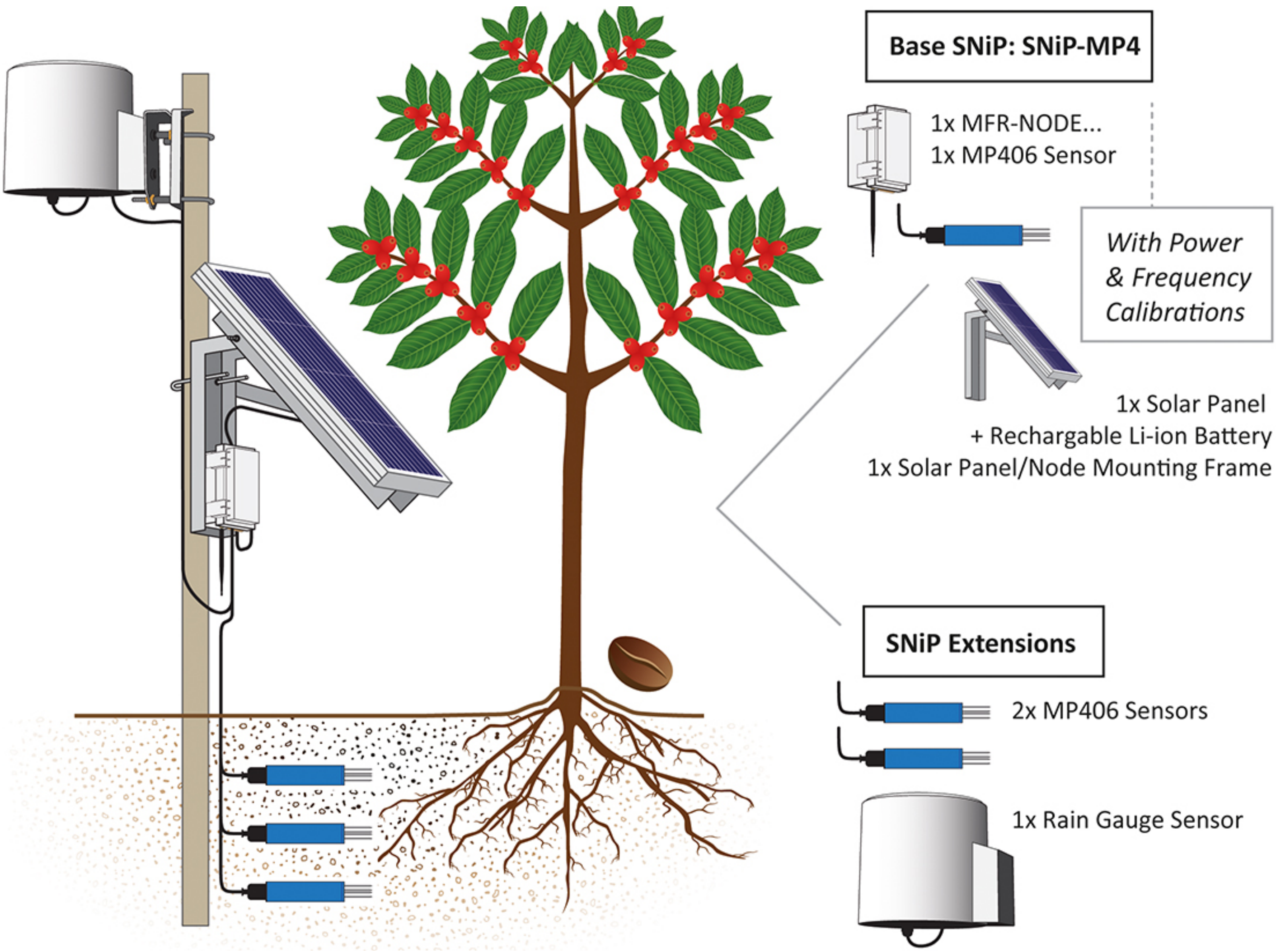
Integrated Sensor Node IoT Packages (SNiPs)

ICT International's integrated Sensor Node IoT Packages (SNiP) provide off-the-shelf pre-configured monitoring solutions.

The range of Base SNiPs provided within this catalogue includes sensor(s), node, power and mounting accessories.

The SNiP can be expanded to incorporate multiples of the base sensor or customised to include other compatible sensors and accessories.

Contact ICT International to discuss the best SNiP and IoT system for your application.



Notes

Contents



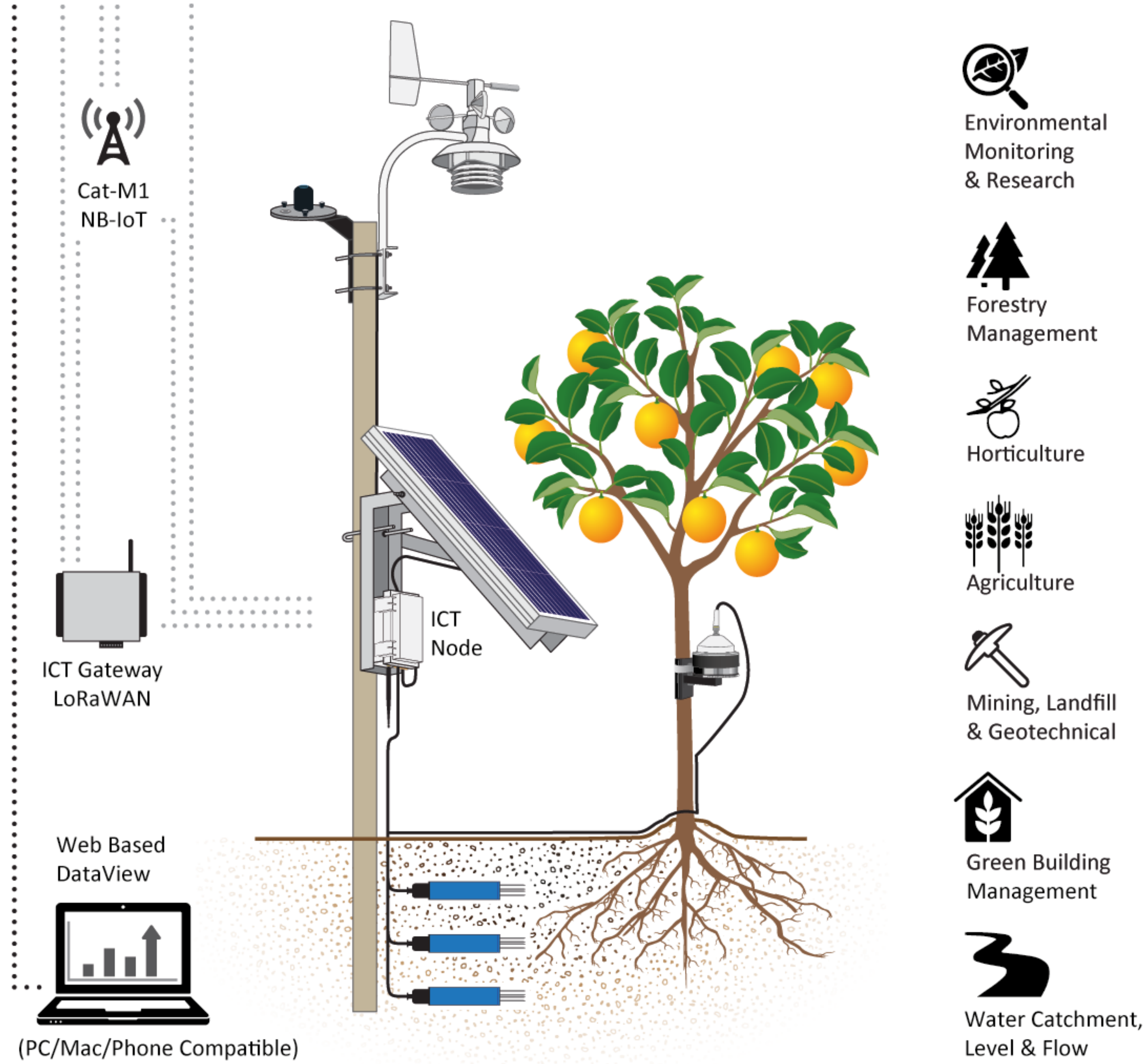

Understanding IoT Networks

For environmental monitoring, in the natural and built environments, IoT provides near real-time data from sensors deployed to monitor the physical environment. Sensing requirements and the applications are broad. Examples can range from a geotechnical engineer monitoring soil drainage on a landfill site to a forester looking at rates of carbon sequestration in a native plantation.

Real time data collection provides information for real time asset management, offsets labour-intensive data collection, and provides surety of data collection for research applications.

The IoT technology used for data delivery will vary between site and sensing requirements; there is no one technology which will best suit every application.

Because ICT International's focus is always on the sensing, our approach to IoT is agnostic; providing a suite of IoT Nodes which will support the most appropriate sensors for the application while also providing the best form of connectivity for the installation site and monitoring network.



Planning Node Locations For A LoRaWAN Network

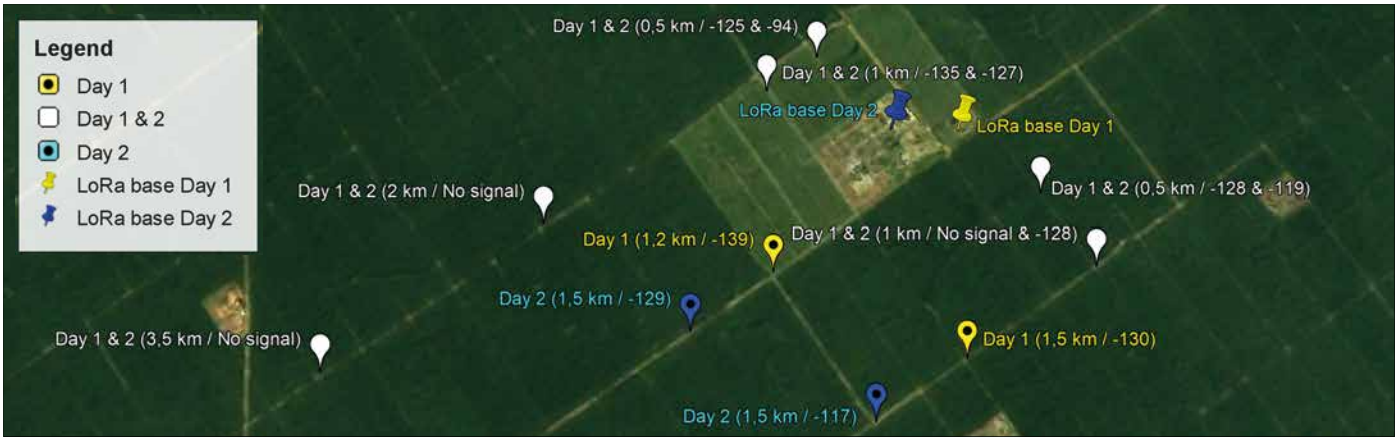
LoRaWan Test Kit - USB Radio with LoRa® P2P

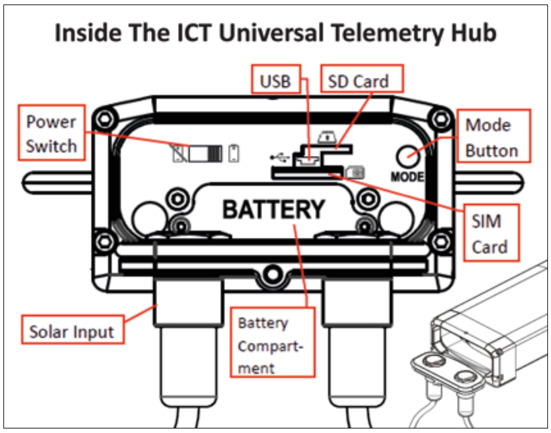
ICT International's LoRa Survey Kit is the ideal tool for determining LoRaWAN network range, infrastructure requirements and identifying site constraints, prior to gateway installation.

The LoRa Survey Test Kit contains paired LoRa transceiver and receiver USB dongles, antennas and a power bank; it works out-of-the-box for Windows 10, Linux, and MacOS (with drivers available for Windows 7 and 8). The built-in AT command allows the user to configure the radios.

Key Features:

- LoRaWAN™ low-power long-range client
- LoRa® Peer-to-Peer (P2P) connectivity
- AT command set
- The built-in AT command allows to user to configure the radios.





The ICT Universal Telemetry Hub (C-NODE)

The ICT International Universal Telemetry Hub (C-NODE) is a modular communications platform designed specifically for remote data collection, forming the foundation for specialised scientific and industrial monitoring networks.

The C-NODE collects and locally stores data from ICT International data loggers and LoRa Nodes, and backhauls to the cloud via Satellite (using the Iridium Short Burst Data service), Penta-band GSM, Cat-M1 or Ethernet. Powered by a replaceable, solar charged, internal Lithium Ion battery, it is supplied with a 20W solar panel, anodised aluminium mounting frame and 3.8m guyed aluminium mast.

Systems & Security

- ARM Cortex M3 processor
- Nested vectored interrupt controller
- DMA controller
- 16 GB MicroSD storage
- RF communications – end to end packet encryption
- GSM - optional SSL connection to cloud

Environmental Data & Reliability

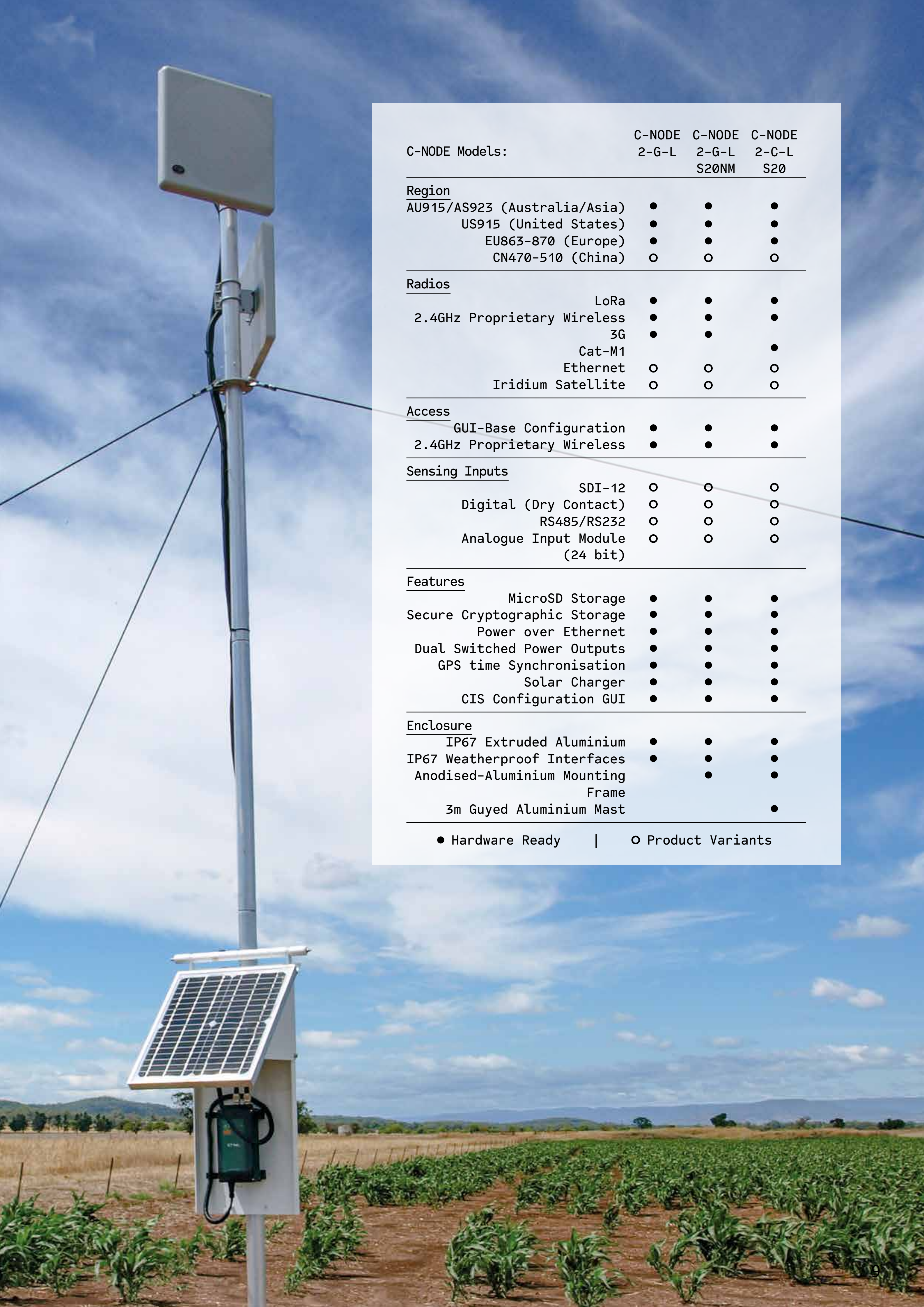
- Operating range –20°C to 60°C
- RoHS compliant (lead-free)
- IP67 rated, extruded aluminium – hard anodised body
- All fasteners 316 stainless steel.
- 5 x IP67 weatherproof interfaces

Features

- LoRa ultra-long range spread spectrum radio; LoRa RF sensitivity -148dBm and max TX power of 20dBm
- Supports CN470-510, EU863-870, AS923, AU915, US915 Frequency Bands
- Proprietary 2.4GHz wireless for ICT International range of data loggers
- Ethernet/3G/Cat-M1/Iridium/Data Backhaul
- Configuration GUI - Combined Instrument Software (CIS)
- Optional SDI-12 logger
- Dual switched power outputs of 4.2V/4A OR up to 15V/1A
- Power management to external sensors
- Auto battery charge rate adjustment based on available sunlight
- User customisable schedules - data collection and cloud upload
- Local CSV file storage on 16GB SD card

Electrical Data

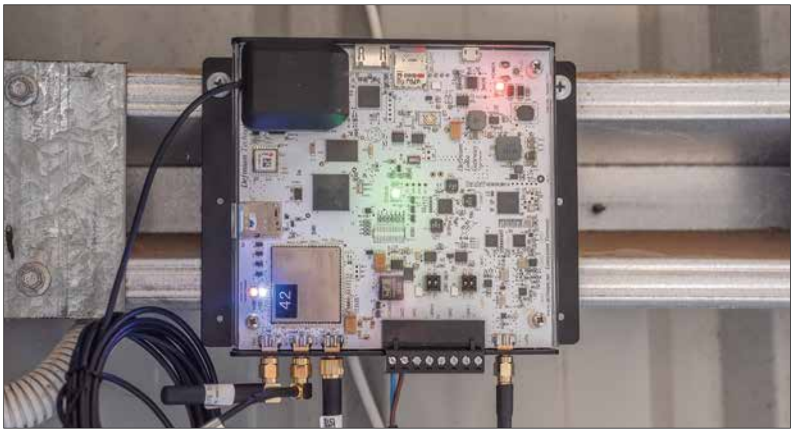
- 4.8Ah wide temperature range, lithium-ion
- Self-managed; solar powered

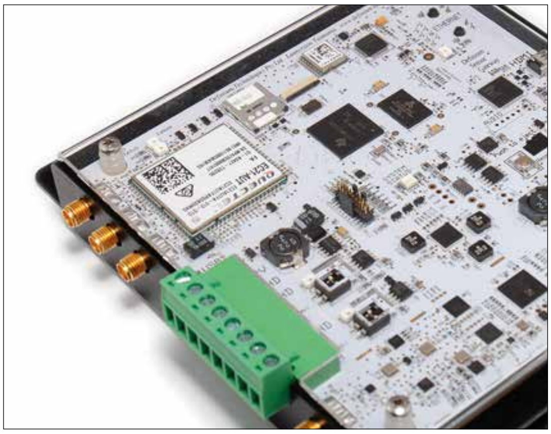


C-NODE Models:	C-NODE 2-G-L	C-NODE 2-G-L S20NM	C-NODE 2-C-L S20
Region			
AU915/AS923 (Australia/Asia)	●	●	●
US915 (United States)	●	●	●
EU863-870 (Europe)	●	●	●
CN470-510 (China)	o	o	o
Radios			
LoRa	●	●	●
2.4GHz Proprietary Wireless	●	●	●
3G	●	●	
Cat-M1			●
Ethernet	o	o	o
Iridium Satellite	o	o	o
Access			
GUI-Base Configuration	●	●	●
2.4GHz Proprietary Wireless	●	●	●
Sensing Inputs			
SDI-12	o	o	o
Digital (Dry Contact)	o	o	o
RS485/RS232	o	o	o
Analogue Input Module (24 bit)	o	o	o
Features			
MicroSD Storage	●	●	●
Secure Cryptographic Storage	●	●	●
Power over Ethernet	●	●	●
Dual Switched Power Outputs	●	●	●
GPS time Synchronisation	●	●	●
Solar Charger	●	●	●
CIS Configuration GUI	●	●	●
Enclosure			
IP67 Extruded Aluminium	●	●	●
IP67 Weatherproof Interfaces	●	●	●
Anodised-Aluminium Mounting Frame		●	●
3m Guyed Aluminium Mast			●

● Hardware Ready | o Product Variants

LoRaWAN Gateways: The Nexus 8





An 8-channel LoRaWAN™ IoT Edge Gateway

The NEXUS 8 range of LoRaWAN™ gateways combine a high-performance LoRaWAN™ radio with multiple back-haul technologies, simplifying the deployment of IoT networks in urban and rural areas. The 8-channel low-power long-range LoRa® ISM-band radio is suitable for coordinating thousands of IoT devices within a radius of up to 25 km.

Off-the-grid rural or difficult urban deployment is straight-forward using the Nexus8 Field Station, supplied with an IP67-rated enclosure and solar power system. The built-in multi-constellation GNSS can accurately locate the gateway and assists with gateway time synchronisation and radio transmit frequency calibration. The Embedded Linux operating system which powers the gateway is fully open to the user, enabling custom configuration and application installation.

System

- OS Definium Linux 4.x Kernel (Arch Linux derivative)
- Software pre-installed for managing all features
- Hardware 1 GHz ARM A8 with 512 MB RAM
- 16 GB MicroSD storage (OS installed on card)
- LTE/3G Up to 10 Mbps down / 5 Mbps up
- FDD LTE Bands: 1, 3, 5, 7, 28

Certifications and Security

- AS/NZS 60950.1:2011, AS/NZS 4268:2012,
- Secure cryptographic storage of keys and certificates
- Hardware random number generator

Features

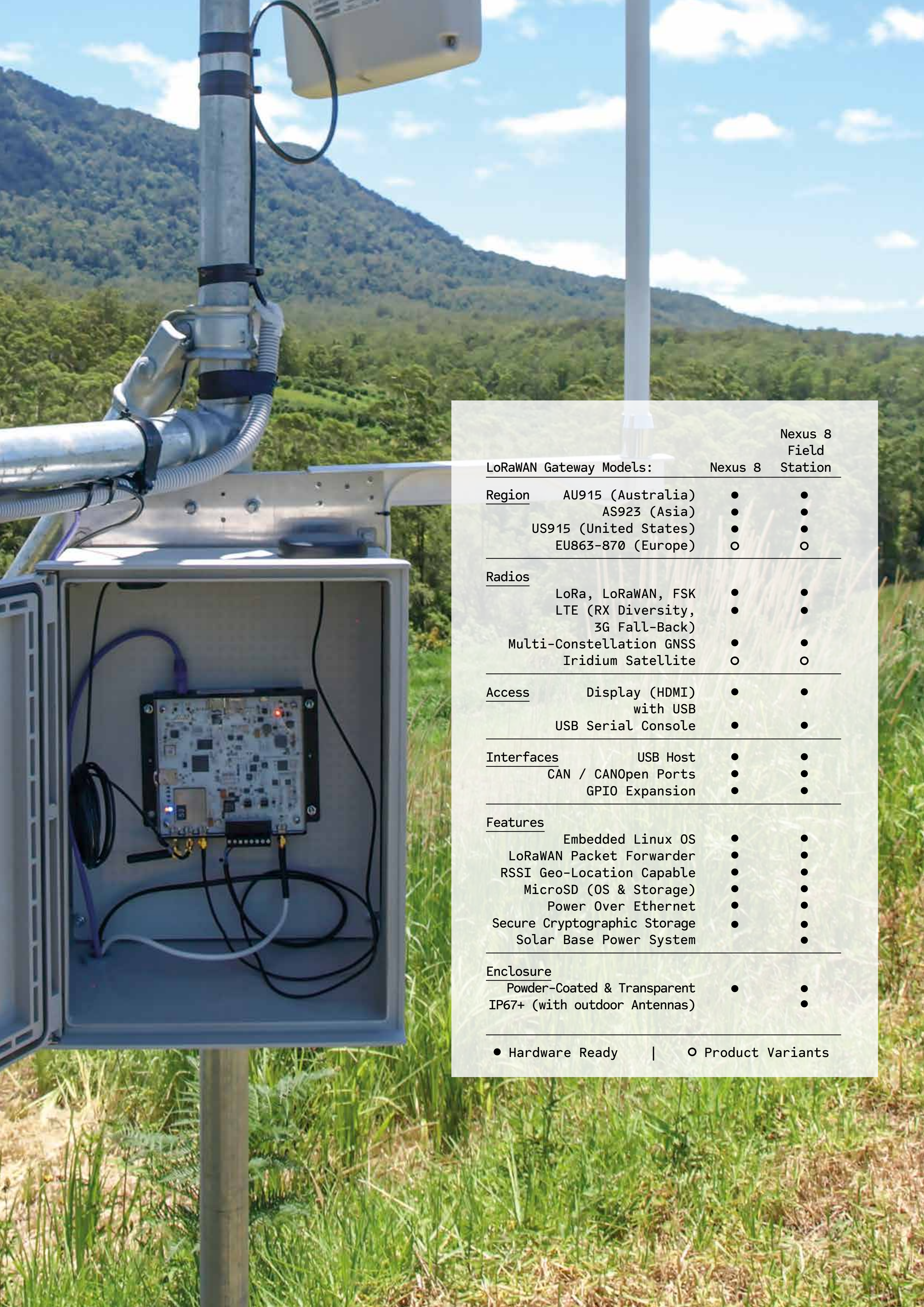
- 8-channel LoRaWAN™ Gateway
- RSSI geo-location capable
- Packet forwarders for major networks
- LoRa®/FSK ISM band low-power long-range radio
- RX: 8_125kHz LoRa®, 1_500kHz LoRa®, 1_FSK
- TX: 1_LoRa®/FSK (half-duplex)
- RX Sensitivity –137 dBm
- Maximum TX power 20 dBm EIRP
- Concurrent multi-constellation GNSS (3)
- GPS, Galileo, GLONASS, BeiDou support
- GPS time synchronisation

Electrical Data

- Power supply 12 V nominal, range 10 V to 24 V DC
- Power-over-ethernet, 44 V to 57 V
- Consumption 5 W average, 7 W peak

Environmental Data & Reliability

- Operating range –20°C to 60°C
- RoHS compliant (lead-free)



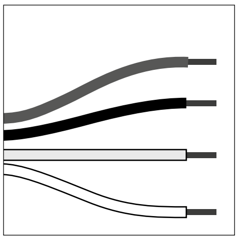
LoRaWAN Gateway Models:		Nexus 8	Nexus 8 Field Station
Region	AU915 (Australia)	●	●
	AS923 (Asia)	●	●
	US915 (United States)	●	●
	EU863-870 (Europe)	○	○
Radios	LoRa, LoRaWAN, FSK	●	●
	LTE (RX Diversity, 3G Fall-Back)	●	●
	Multi-Constellation GNSS	●	●
	Iridium Satellite	○	○
Access	Display (HDMI) with USB	●	●
	USB Serial Console	●	●
Interfaces	USB Host	●	●
	CAN / CANOpen Ports	●	●
	GPIO Expansion	●	●
Features	Embedded Linux OS	●	●
	LoRaWAN Packet Forwarder	●	●
	RSSI Geo-Location Capable	●	●
	MicroSD (OS & Storage)	●	●
	Power Over Ethernet	●	●
	Secure Cryptographic Storage	●	●
	Solar Base Power System		●
Enclosure	Powder-Coated & Transparent	●	●
	IP67+ (with outdoor Antennas)		●

● Hardware Ready | ○ Product Variants

Understanding IoT Nodes

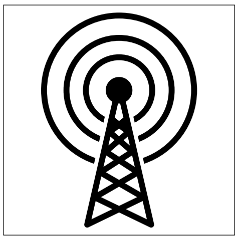
IoT Nodes for researchers, agriculturalists, horticulturalists, foresters, geotechnical engineers, miners, utilities and asset managers.

ICT International's implementation of IoT is guided by over 30 years' experience in environmental sensing. ICT International IoT Nodes are designed specifically to measure key soil, plant and environmental parameters, and encapsulate all the important features in a sensing communication:



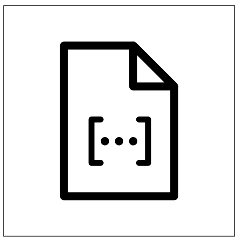
Specific Sensor Inputs

ICT International IoT Nodes support the output signals used in environmental sensing: SDI-12 and high-resolution analogue and digital. For highly specialised monitoring, such as Sap Flow, we engineer custom built and scientifically validated stand-alone products.



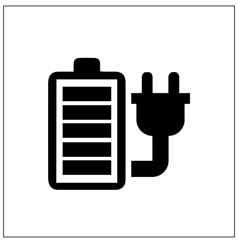
Flexible Connectivity

ICT International's push towards an agnostic connectivity platform is a recognition that the most appropriate from of connectivity will vary between monitoring sites and networks. The IoT platform provides exchangeable LPWAN solutions with options for Low Earth Orbit Satellite (LEO) coming soon.



Open Format Data

ICT LoRaWAN and Cat-M1 Nodes provide data which is open-format and free from proprietary formatting or decoding. This provides full control of data from the point of sensing and allows the end user full flexibility in how they collect, store and view data.

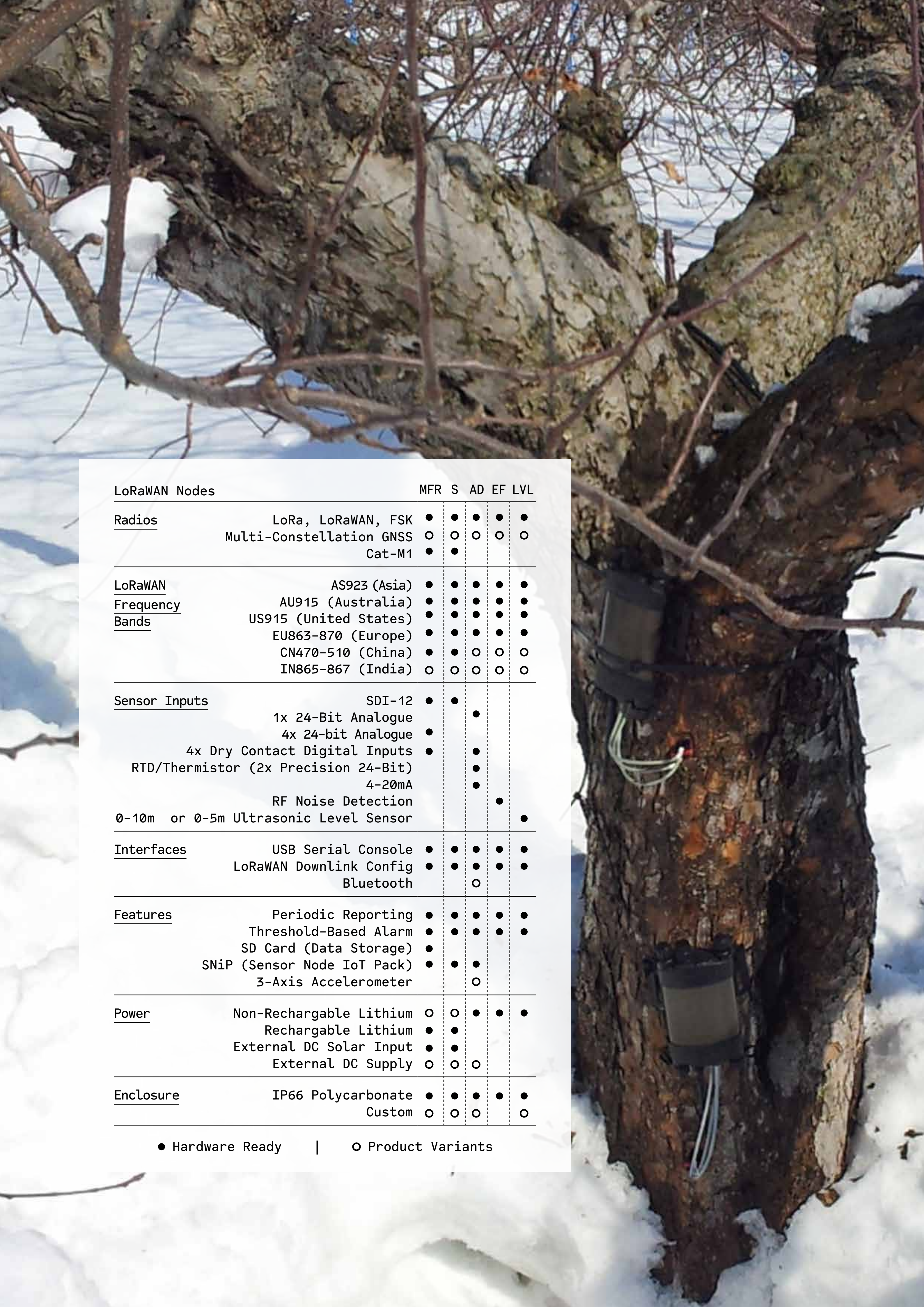


Adaptable Power System

Not all environmental sensors are designed for low power IoT applications. ICT International's IoT Nodes provide flexible power options, including options for external 12 - 24VDC supply, rechargable 6.5Ah or 13Ah Lithium-Ion batteries or a non-rechargable Lithium battery pack.

Environmentally Sealed

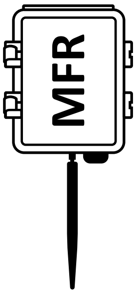
ICT International's IoT Nodes are IP66 rated and have been demonstrated to operate in extreme environmental conditions, from hot Australian deserts to tropical Indonesian rainforests to the Arctic Tundra.



LoRaWAN Nodes		MFR	S	AD	EF	LVL
Radios	LoRa, LoRaWAN, FSK	●	●	●	●	●
	Multi-Constellation GNSS	○	○	○	○	○
	Cat-M1	●	●			
LoRaWAN Frequency Bands	AS923 (Asia)	●	●	●	●	●
	AU915 (Australia)	●	●	●	●	●
	US915 (United States)	●	●	●	●	●
	EU863-870 (Europe)	●	●	●	●	●
	CN470-510 (China)	●	●	○	○	○
	IN865-867 (India)	○	○	○	○	○
Sensor Inputs	SDI-12	●	●			
	1x 24-Bit Analogue			●		
	4x 24-bit Analogue	●				
	4x Dry Contact Digital Inputs	●		●		
	RTD/Thermistor (2x Precision 24-Bit)			●		
	4-20mA			●		
	RF Noise Detection				●	
	0-10m or 0-5m Ultrasonic Level Sensor					●
Interfaces	USB Serial Console	●	●	●	●	●
	LoRaWAN Downlink Config	●	●	●	●	●
	Bluetooth			○		
Features	Periodic Reporting	●	●	●	●	●
	Threshold-Based Alarm	●	●	●	●	●
	SD Card (Data Storage)	●				
	SNiP (Sensor Node IoT Pack)	●	●	●		
	3-Axis Accelerometer			○		
Power	Non-Rechargable Lithium	○	○	●	●	●
	Rechargable Lithium	●	●			
	External DC Solar Input	●	●			
	External DC Supply	○	○	○		
Enclosure	IP66 Polycarbonate	●	●	●	●	●
	Custom	○	○	○		○

● Hardware Ready | ○ Product Variants

MFR-NODE: Multifunction Research Node



The MFR-NODE has been designed to provide flexible communication, sensor and power options. The MFR-NODE supports SDI-12 and up to four 32-bit dry-contact counting digital inputs and two differential / four single-ended analogue inputs, with selectable 12V, 5V or 3.3V excitation. The MFR-NODE supports sensors with higher power requirements; a solar panel can charge either the internal lithium-ion battery or both the node and sensor can be powered by an external DC power system (e.g. battery or mains source).

Cat-M1 provides the option for remote installation and for areas outside the range of existing LoRaWAN networks.

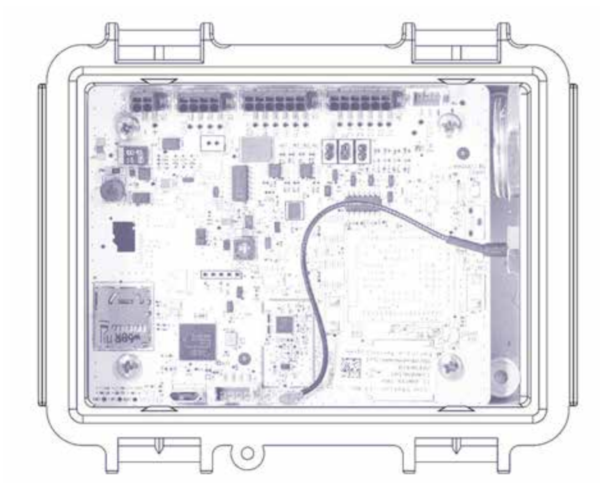
The MFR-NODE has an onboard SD-Card to provide data logging capabilities and full data redundancy in the event of temporary loss of communications or dropped packets – ideal for research applications.

Data is stored in CSV format for ease of use.

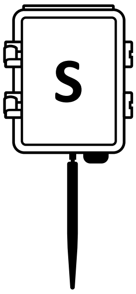
LoRaWAN provides capability for full remote configuration through downlinks, including enabling/disabling confirmed messaging and changing the report interval.

Key Features:

- □ LoRaWAN™ low-power long-range connectivity;
- □ Cat-M1;
- □ SD Card for data storage;
- □ SDI-12;
- □ 4 x 32-bit dry-contact counting digital inputs;
- □ 24-bit ADC for 2x differential / 4x single ended sensor, selectable 3.3V, 5V or 12V excitation;
- □ Solar rechargable 6.5Ah or 13Ah Lithium-ion or external DC power options;
- □ Optional Multi-Constellation GNSS.



S-NODE: For Environmental Monitoring (SDI-12)

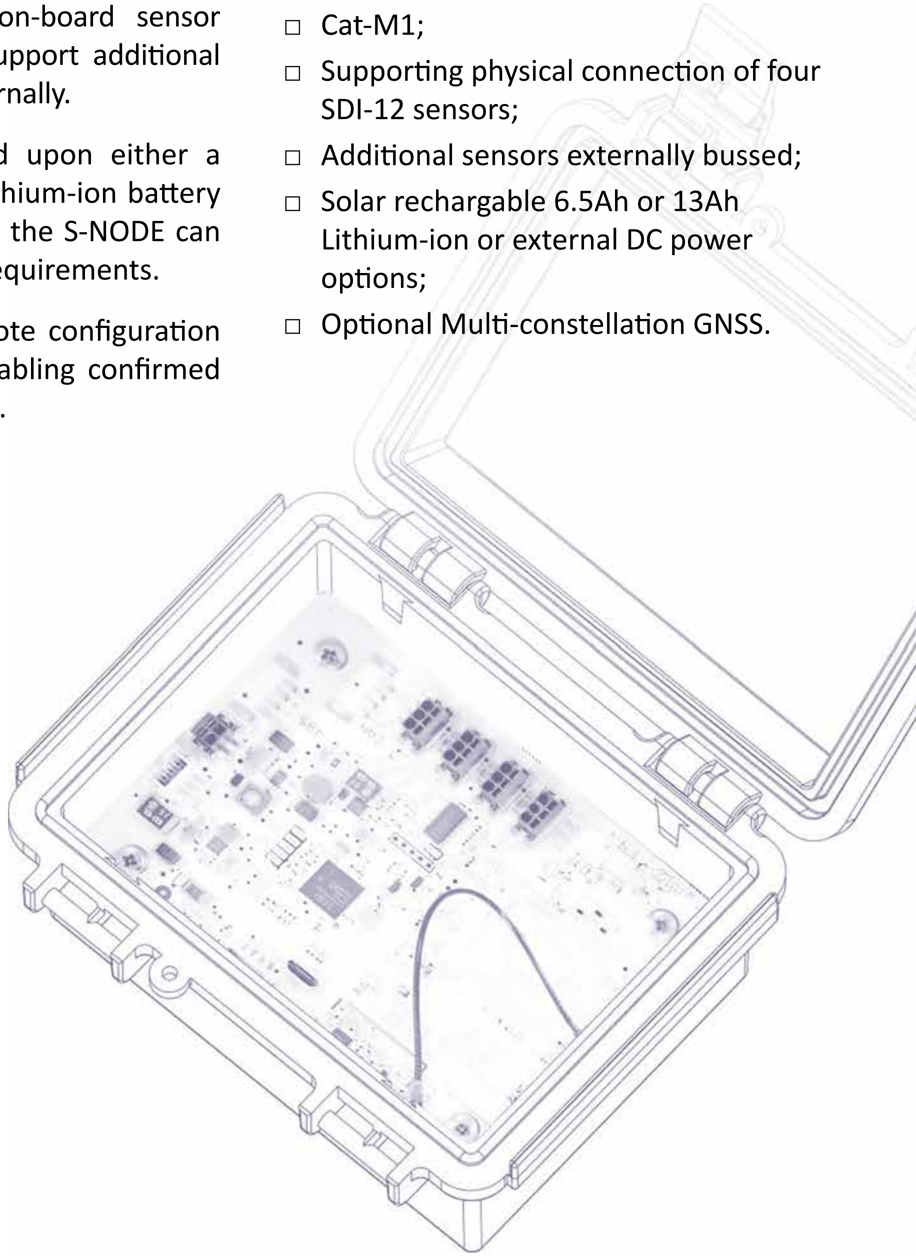


The S-NODE has been designed to support the broad suite of SDI-12 based environmental sensors and includes four on-board sensor inputs and the capacity to support additional sensors which are bussed externally.

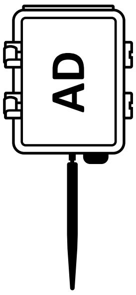
With a power system based upon either a 6.5Ah or 13Ah rechargable lithium-ion battery or external DC power source, the S-NODE can support those sensors with higher power requirements.

LoRaWAN provides capability for full remote configuration through downlinks, including enabling/disabling confirmed messaging and changing the report interval.

- □ LoRaWAN™ low-power long-range connectivity;
- □ Cat-M1;
- □ Supporting physical connection of four SDI-12 sensors;
- □ Additional sensors externally bussed;
- □ Solar rechargable 6.5Ah or 13Ah Lithium-ion or external DC power options;
- □ Optional Multi-constellation GNSS.



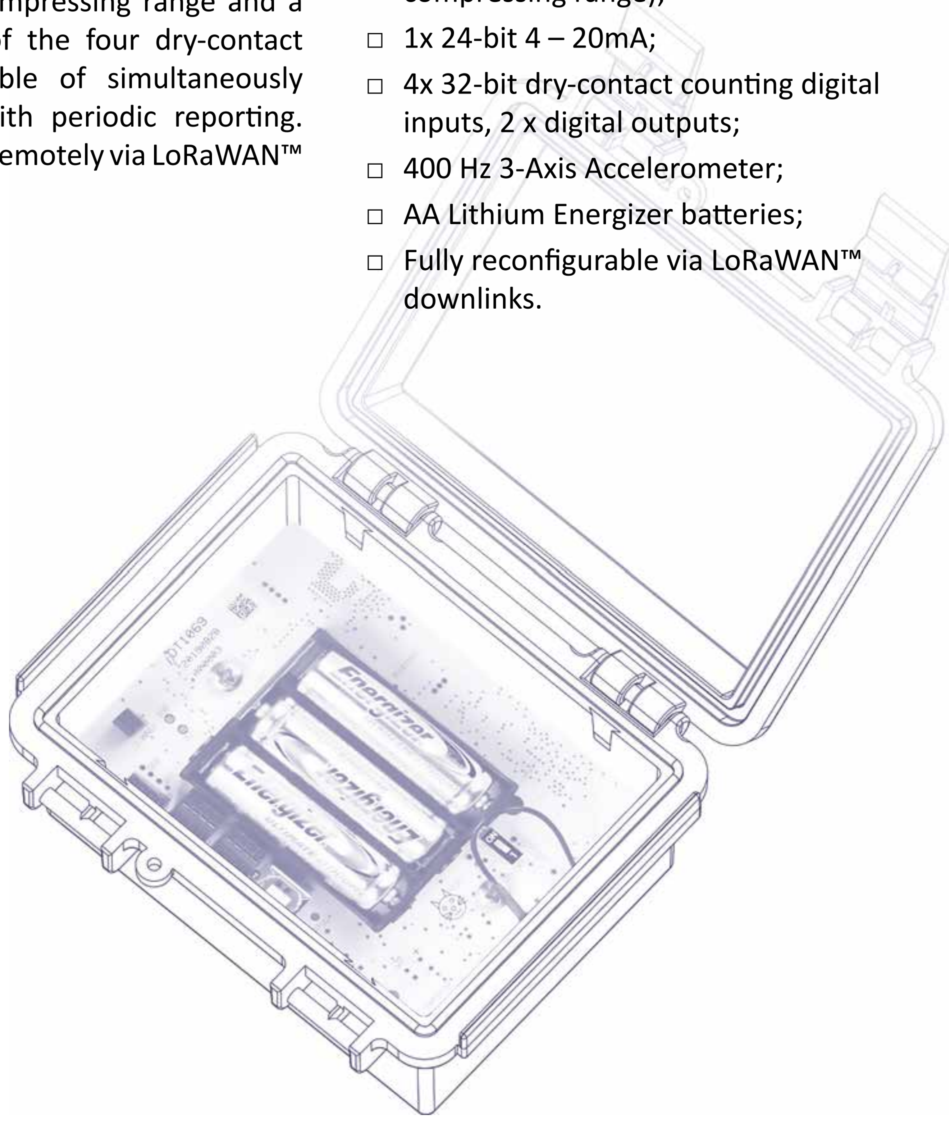
AD-NODE: For High Resolution Analogue & Digital Sensors

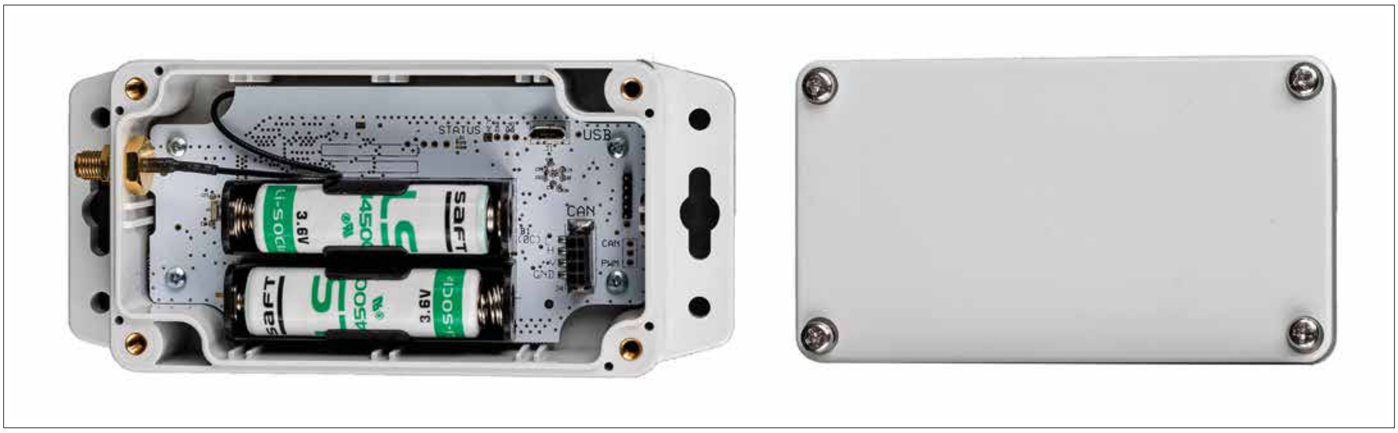


The AD-NODE is designed for those requiring precision in their analogue and digital measurements.

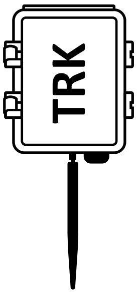
With a 24-bit ADC, the AD-NODE supports two RTDs, a 0–10V with compressing range and a 4–20mA input. Each of the four dry-contact digital inputs is capable of simultaneously sampling at 1 kHz, with periodic reporting. Settings on the device can be altered remotely via LoRaWAN™ or locally via USB.

- LoRaWAN™ low-power long-range connectivity;
- 2x 24-bit RTD;
- 1x 24-bit Voltage input (0–10 V with compressing range);
- 1x 24-bit 4 – 20mA;
- 4x 32-bit dry-contact counting digital inputs, 2 x digital outputs;
- 400 Hz 3-Axis Accelerometer;
- AA Lithium Energizer batteries;
- Fully reconfigurable via LoRaWAN™ downlinks.





EF-NODE: Electric Fence Node



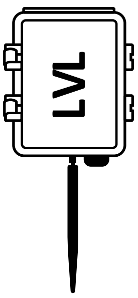
The EF-NODE is a non-contact LoRaWAN™ electric fence fault detection sensor. The EF-NODE awakens at defined intervals and listens for the presence of radio-frequency interference, if it cannot detect a fence or it determines the fence strength is weak it will transmit a LoRaWAN alarm.

The unit will also periodically transmit the minimum, maximum and average strength of RF interference produced by the fence.

Key Features:

- LoRaWAN™ low-power, long-range connectivity;
- Fully reconfigurable via USB or LoRaWAN downlink;
- In-built RF Interference detection;
- Ultra-low-power operational modes that allow advanced power saving and smart sleep-to-wakeup functions.

LVL-NODE: Ultrasonic Water Level Monitoring



A low-maintenance ultrasonic level sensor with LoRaWAN is a drop-in solution for monitoring all types of fluid levels.

Automatic threshold-based alarms for low or high-level conditions are reported in seconds, reducing response time. Backed by long-range low-power LoRa radio, each sensor has a designed battery life of up to 15 years with daily reporting. The ultrasonic sensor is designed to be mounted above the target fluid to be monitored and automatically filters out echoes from minor obstructions (different filtering available on request).

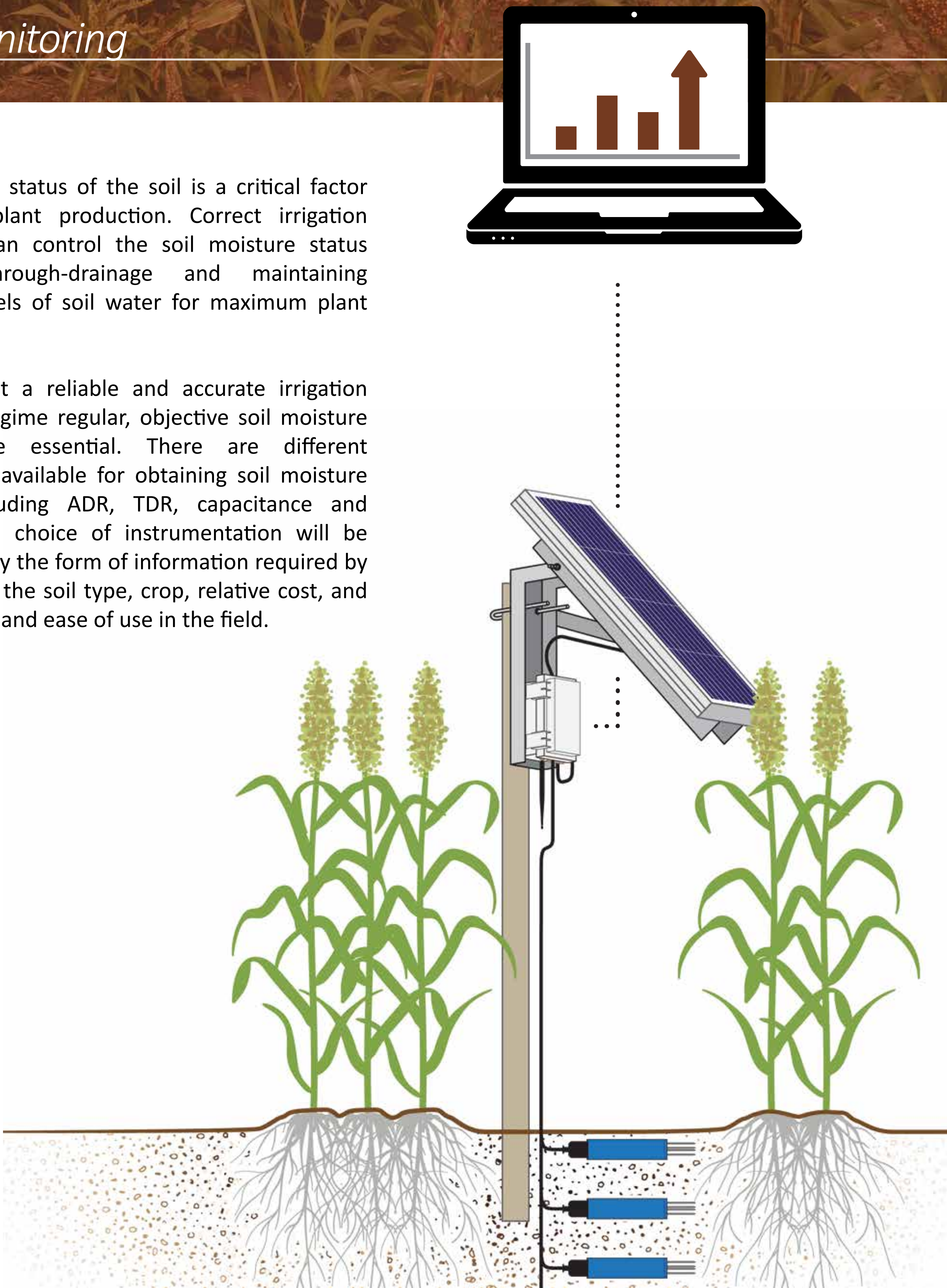
A ruggedised version with IP66-rated connectors and corrosion-resistant sensors is available. Integrating incoming data into existing systems is as easy as connecting to a LoRaWAN server and receiving data within seconds of it being sent.

- LoRaWAN low-power long-range connectivity, & Multi-Constellation GNSS;
- Up to 10 metres ±1 cm precision, 5 metres with ±1mm precision;
- Up to 15 years battery life with multiple reports per day;
- Fully reconfigurable via USB or LoRaWAN downlink;
- Level alarm mode with periodic sampling.

Soil Monitoring

The moisture status of the soil is a critical factor influencing plant production. Correct irrigation scheduling can control the soil moisture status reducing through-drainage and maintaining optimum levels of soil water for maximum plant growth.

To implement a reliable and accurate irrigation scheduling regime regular, objective soil moisture readings are essential. There are different technologies available for obtaining soil moisture content including ADR, TDR, capacitance and neutron. The choice of instrumentation will be determined by the form of information required by the operator, the soil type, crop, relative cost, and the reliability and ease of use in the field.



Soil Moisture & Water Use of Coffee in Vietnam

Project background

In the highlands of Central Vietnam, vast areas of planted coffee rely heavily on seasonal rainfall. With changing climate, rainfall becomes more unpredictable, and necessitates the investment in optimum irrigation. In cooperation with the Western Highlands Agriculture and Forestry Science Institute (WASI) the soil moisture condition in 4 year-old Robusta Coffee crop was monitored.

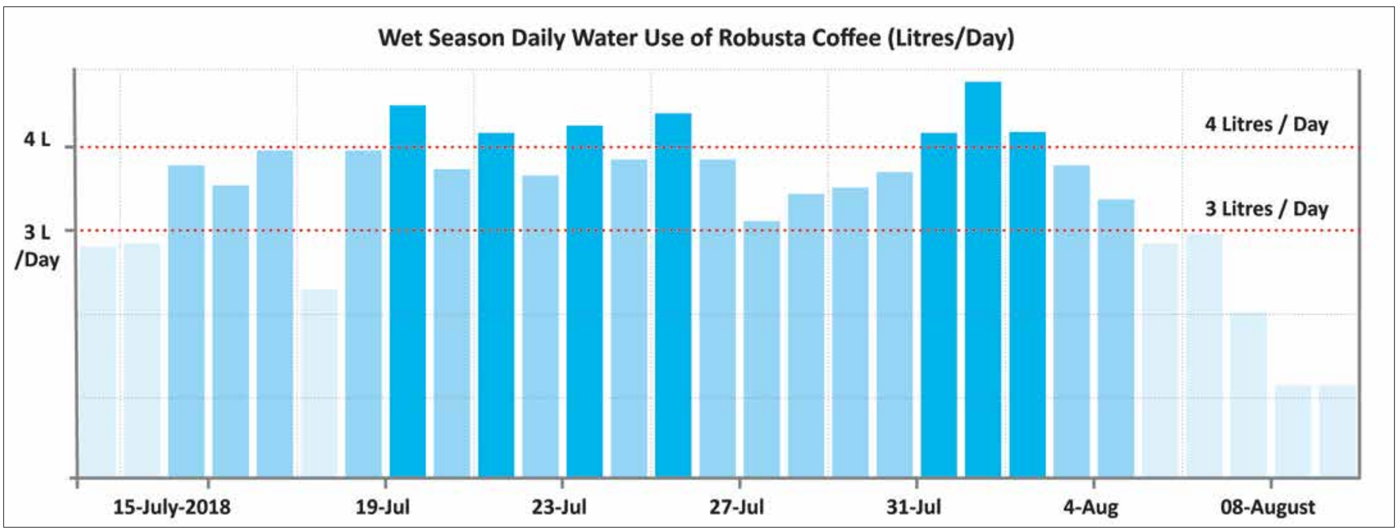
Monitoring and network solution

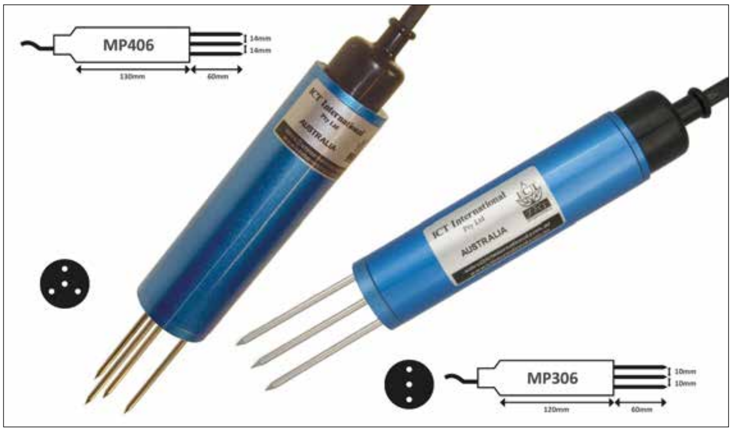
- Soil moisture probes in the surface and at 3 depths – 15, 30 and 45 cm
- Sap flow meter on 4 year old trees
- 4G Telemetry system
- ICT Dataview

Outcomes

The ICT International Moisture Probe (MP406) – designed for permanent installation/burying, connected to ICT Soil Moisture Meter (SMM1), was used to monitor the soil moisture regime from the surface to a 45cm profile depth. This allowed for the calculation of infiltration rates.

The investigation also monitored seasonal variability of tree water use which was found to be reliant not only on soil moisture availability but also on seasonal sunshine duration. Rainy seasons (between May and December) that bring more cloudy days resulted in a lower water usage of the trees. Wet season water use was 3-4 Litres per tree per day and in the Dry season it was 5-6 Litres per tree per day.





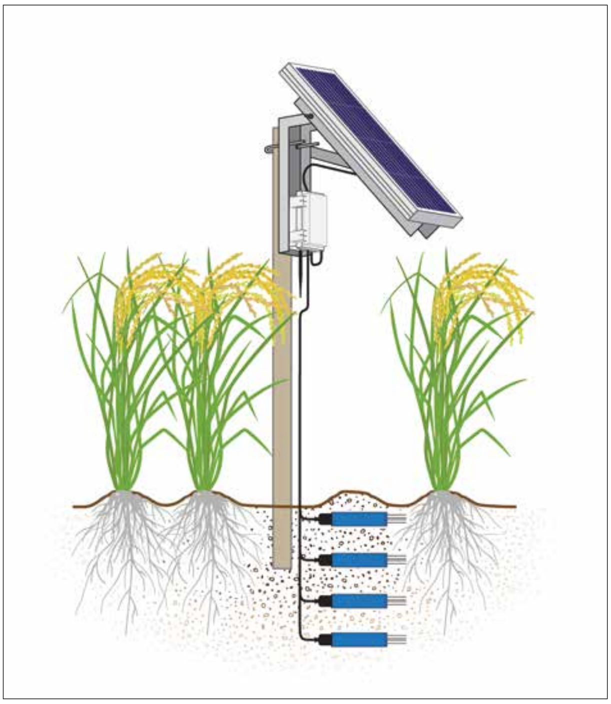
The Standing Wave (ADR) Measurement Principle

Standing Wave, or Amplitude Domain Reflectometry (ADR), uses an oscillator to generate an electromagnetic wave at a consistent frequency, which is transmitted through a central signal rod, using outer rods as an electrical shield. The electromagnetic wave is partially reflected by areas of the medium with different dielectric constants (water content), producing a measurable voltage standing wave. **ADR measures volumetric soil water (VSW%) independently of all other soil variables, including density, texture, temperature and electrical conductivity. ADR does not require in-situ calibration to accurately measure Volumetric Soil Water (VSW%).**

Environmental, agriculture & engineering applications requiring assessment of the changes of soil moisture **in absolute mm and the exact volumetric soil moisture use ADR or TDR technologies**. ADR sensors that have been buried permanently in landfills are still functioning after 15+ years.

The Time Domain Reflectometry (TDR) Measurement Principle

Measures the time taken (in nanoseconds) for an electromagnetic pulse to propagate along a waveguide surrounded by soil. Time of travel, or velocity, of this pulse is effected by the dielectric constant (Ka) of the soil. Wetter soil with a higher dielectric constant, produces a slower velocity pulse. **TDR measures volumetric soil water (VSW%) independently of all other soil variables, including density, texture, temperature and electrical conductivity. TDR does not require in-situ calibration to accurately measure VSW%.**



SNiP NAME:	SNiP-MP4	SNiP-MP3	SNiP-TDR
SNiP Measures	VWC %	VWC %	VWC % / Permittivity / BulkEC / Temperature / Pore Water EC
Core Sensor/Device (Measurement Principle)	MP406 (ADR)	MP306 (ADR)	TDR-315L (TDR)
Calibration	Mineral & Organic Soils		Mineral Soils
UOM	VWC %	VWC %	VWC % / µS / cm (bulk) °C / µS /cm (Pore Water)
SNiP Node	MFR-NODE	MFR-NODE	S-NODE
Total Sensors SNiP Can Support	Up to 4	Up to 4	Up to 4
Mounting / Power	SPLM7 / 10W Solar Panel (SP10)		
Optional SNiP Extensions of Parameters:	Tipping Bucket Rain Gauge	Tipping Bucket Rain Gauge	Micro-Climate

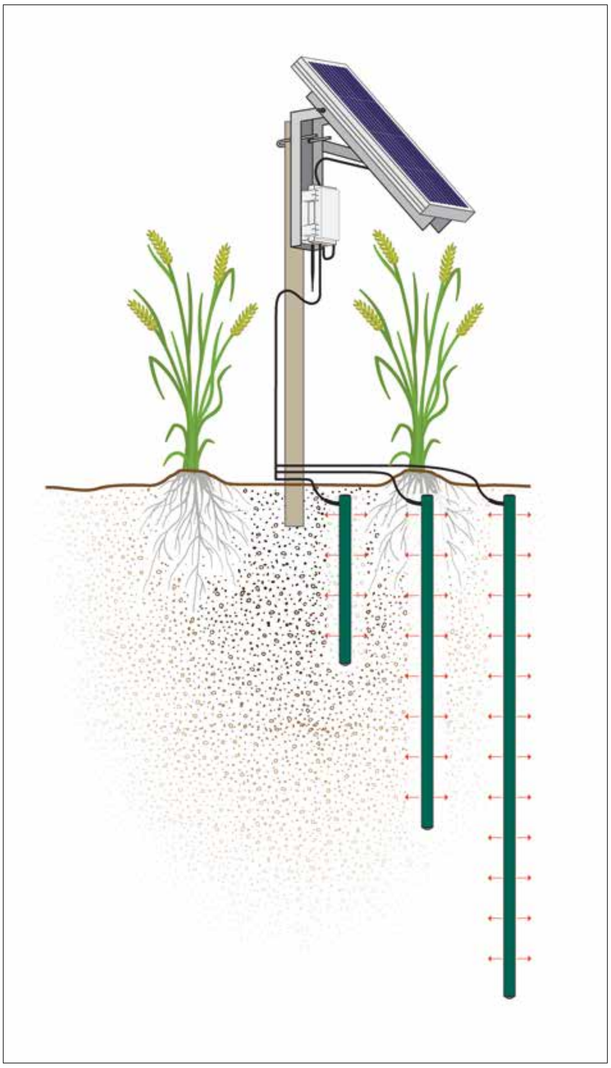


Figure (above) shows down hole capacitance sensors varying in length and sensor spacing.

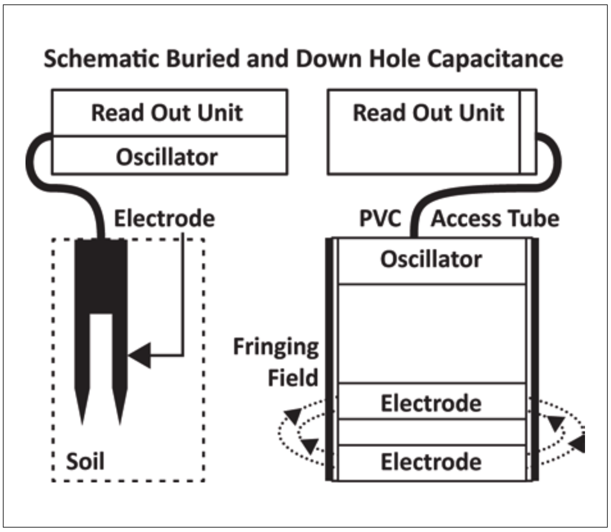
The Capacitance Measurement Principle

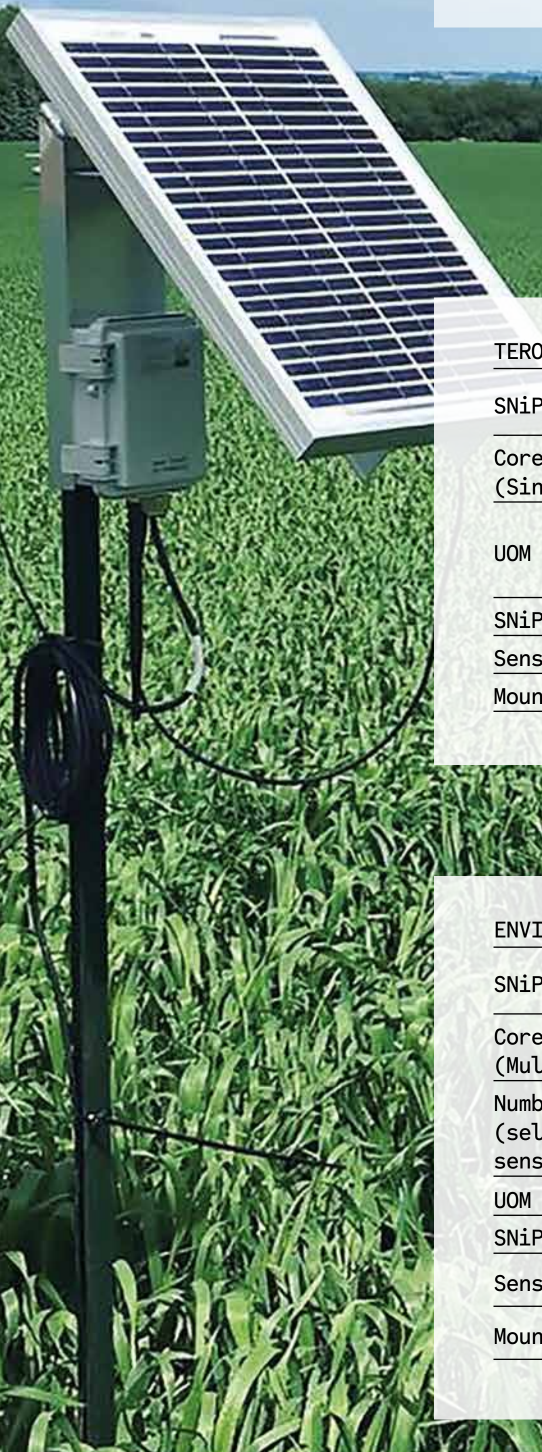
Capacitance sensors measure the dielectric permittivity of a surrounding medium.

The configuration is either like the neutron probe where an access tube, made of PVC, is installed in the soil or buried probes connected to a data logger. In either down hole or buried configuration, a pair of electrodes form the plates of the capacitor with the soil in between these plates, acting as the dielectric. The oscillating electrical field is generated between the two plates and extends into the soil medium either through the wall of the PVC access tube or conformal coating of the buried probe. Changes in dielectric constant of the surrounding media are detected by changes in the operating frequency. The output of the sensor is the frequency response of the soil's capacitance due to its soil moisture level.

Capacitance sensors come in many configurations and have many shapes. Due to the low cost and low power consumption capacitance sensors are common. The impact of temperature and conductivity on the measurement of volumetric soil moisture means they are suited to monitor relative changes of soil water content and require in-situ calibration for accurate measurement of volumetric soil water content (VSW%).

Capacitance sensors have a small volume of measurement and usually a limited life of several years in situ. Capacitance sensors are widely used for irrigation scheduling.

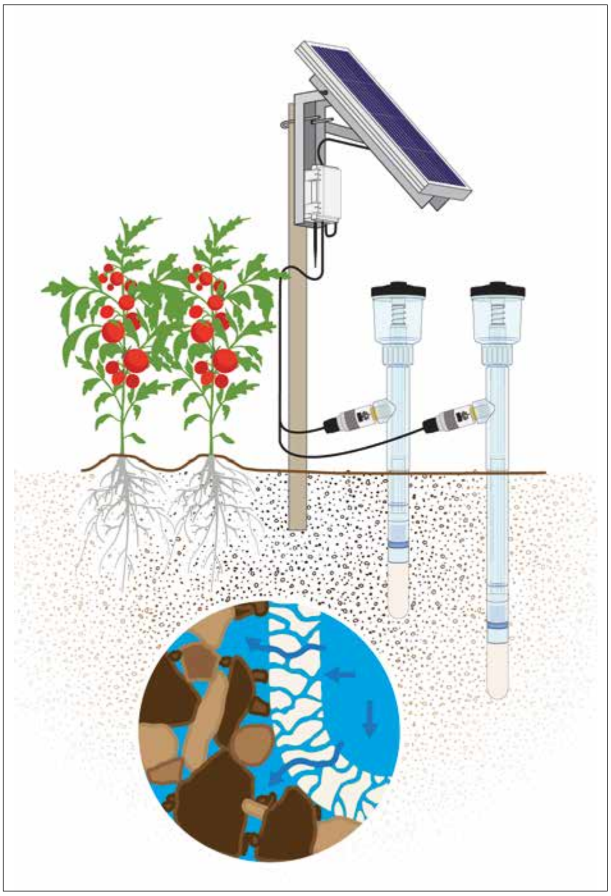




Single-Point FDR SNiPs	SNiP-10HS	SNiP-EC5	SNiP-SMT
SNiP Measures	VWC %	VWC %	VWC % / EC Temperature
Core Sensor/Device (Single-Point)	10HS	EC5	SMT-100
UOM	VWC %	VWC %	VWC % / °C / dS/m (bulk)
SNiP Node	AD-NODE		S-NODE
Sensors SNiP Supports	1		Up to 4
Mounting / Power	LM1		SPLM7 / SP10

TEROS SNiPs	SNiP-TER0	SNiP-TER1	SNiP-TER2
SNiP Measures	VWC %	VWC % / Temperature	VWC % / EC Temperature
Core Sensor/Device (Single-Point)	TEROS-10	TEROS-11	TEROS-12
UOM	VWC %	VWC % / °C	VWC % / °C / dS/m (bulk)
SNiP Node	AD-NODE	S-NODE	S-NODE
Sensors SNiP Supports	1	Up to 4	Up to 4
Mounting / Power	LM1	SPLM7 / SP10	

ENVIROPRO SNiPs	SNiP-EP4	SNiP-EP8	SNiP-EP12
SNiP Measures	VWC % / Temperature	VWC % / Temperature	VWC % / Temperature
Core Sensor/Device (Multi-Point)	EP100GL-04	EP100GL-80	EP100GL-120
Number of Multi-Points (self-contained sensors per Device):	4 sensors (0-0.4m)	8 sensors (0-0.8m)	12 sensors (0-1.2m)
UOM	VWC % / °C	VWC % / °C	VWC % / °C
SNiP Node	S-NODE	S-NODE	S-NODE
Sensors SNiP Supports	Up to 4	Up to 4	Up to 4
Mounting / Power	SPLM7 / SP10		



Jetfill Tensiometers

The force with which water is held in the soil by the soil particles, is referred to as soil suction, soil tension, or soil water potential. It indicates how tightly the water is bound in the soil, and how much energy must be exerted by plant roots to remove and use the water.

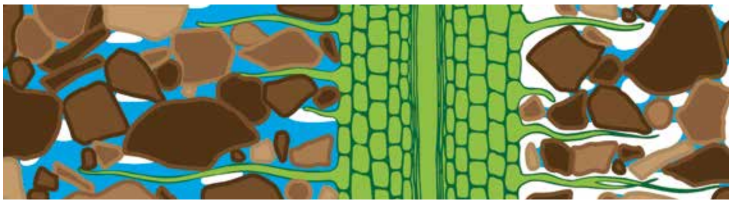


Figure (above): Left of plant root shows water-saturated soil; right of plant root shows dry soil with water particles sticking to soil particles.

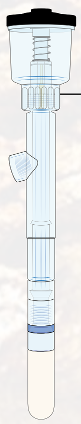
Jetfill tensiometers measure in the range 0-70 kPa. The tensiometer can measure very accurately small changes in soil water potential and because of the fast response these are immediate. The vacuum inside the tensiometer is measured by a vacuum transducer (ICTGT3-15), which gives a continuous analogue output signal. A resolution of 0.1 kPa is attained for this tensiometer transducer. Turf and vegetable crops are typically irrigated at 30kPa and cereal crops closer to 50 kPa.

The basic components of a tensiometer include a porous ceramic cup, a plastic body tube, water reservoir, and a vacuum transducer. The ceramic cup is placed in good hydraulic contact with the soil and allows transfer of water into and out of the tensiometer body according to the tension in the soil. The vacuum inside the tensiometer body equilibrates with the soil water tension, and there is direct response with a vacuum transducer.

Full Range Tensiometers

UGT's Full Range Tensiometers are a recent innovative development and measure over the complete range of soil water tension relevant for plants, that can reach up to 1500 kPa (pF 4.2). Unlike other systems used for this measuring range, the Fullrange Tensiometer measures the soil water potential directly. Even after drying out beyond the limits of the measuring range, the measurement is continued independently as soon as the moisture increases again. Refilling is not necessary.

Soil Water Potential SNiPs	SNiP-GT3	SNiP-FRT
SNiP Measures	Soil Water Potential	Soil Water Potential
Core Sensor/Device	GT3-15	FRT
UOM	kPa	kPa
kPa Range	-100 to +100	-100 to +1500 kPa
kPa Accuracy	±2kPa (1% full range)	1%
SNiP Node	MFR-NODE	MFR-NODE
Sensors SNiP Supports	Up to 2	Up to 2
Mounting / Power	SPLM7 / SP10	
System Extension	Soil Moisture, Precipitation	Soil Moisture



Core Sensor/Device GT3-15 couples with preferred Jet-Filled Tensiometer (length/s):	
ICT2725L06NG *	(15cm depth into soil)
ICT2725L12NG *	(30cm depth into soil)
ICT2725L18NG *	(45cm depth into soil)
ICT2725L24NG *	(60cm depth into soil)
ICT2725L36NG *	(90cm depth into soil)
ICT2725L48NG *	(120cm depth into soil)
ICT2725L60NG *	(150cm depth into soil)

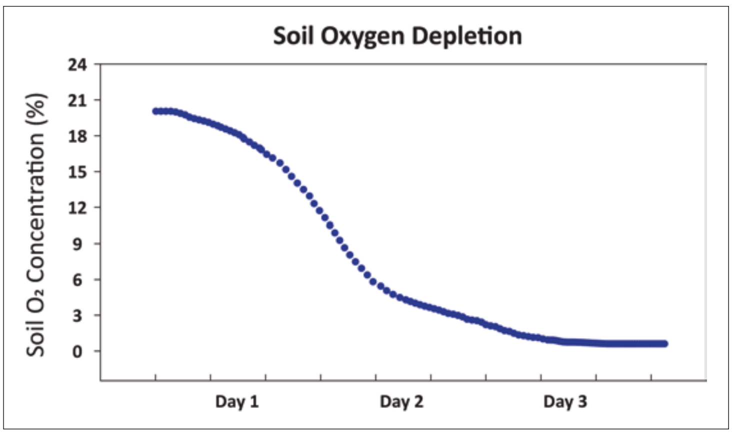
* Jet Filled Tensiometer, Reservoir, Body & Cup

Apogee Soil Oxygen Sensor

The Apogee soil oxygen sensor (SO-411 shown above with AO-001 Diffusion Head) is used to continuously monitor soil oxygen concentration; which is crucial to the productivity of economic crops such as avocado, cotton, tomato and tobacco. Anaerobic soil conditions prevent uptake of water as the roots cannot respire due to excess water in the soil profile and daily water use rapidly declines with resultant significant crop yield loss.

There are two types of O_2 in soil – soil pore O_2 and dissolved O_2 in soil solution. Soil pore O_2 directly impacts upon plant health, and dissolved O_2 upon soil microbial health. A great equilibrium exists between these two 'zones' hence simply measuring the bulk soil O_2 is enough.

The SO-411 comes with a thermistor temperature sensor to correct for temperature changes and a restive heater to raise the temperature of the membrane approximately two degrees above ambient temperature to keep condensation from occurring on the Teflon membrane and blocking the diffusion path of the sensor.



Soil Temperature

The THERM-SS (shown above, right) is a high-quality thermistor embedded in a protective stainless-steel body which can be used in a wide range of applications, from soil monitoring in agriculture to industrial landfill, or mine tailing and concrete monitoring.

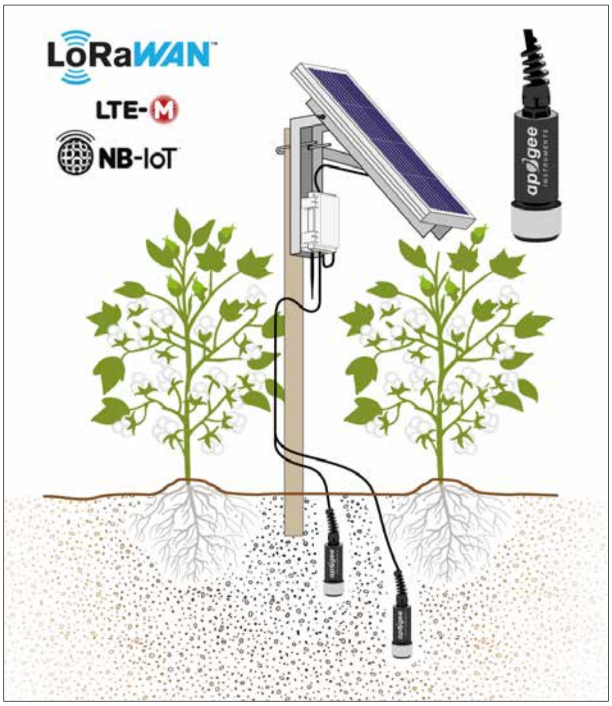
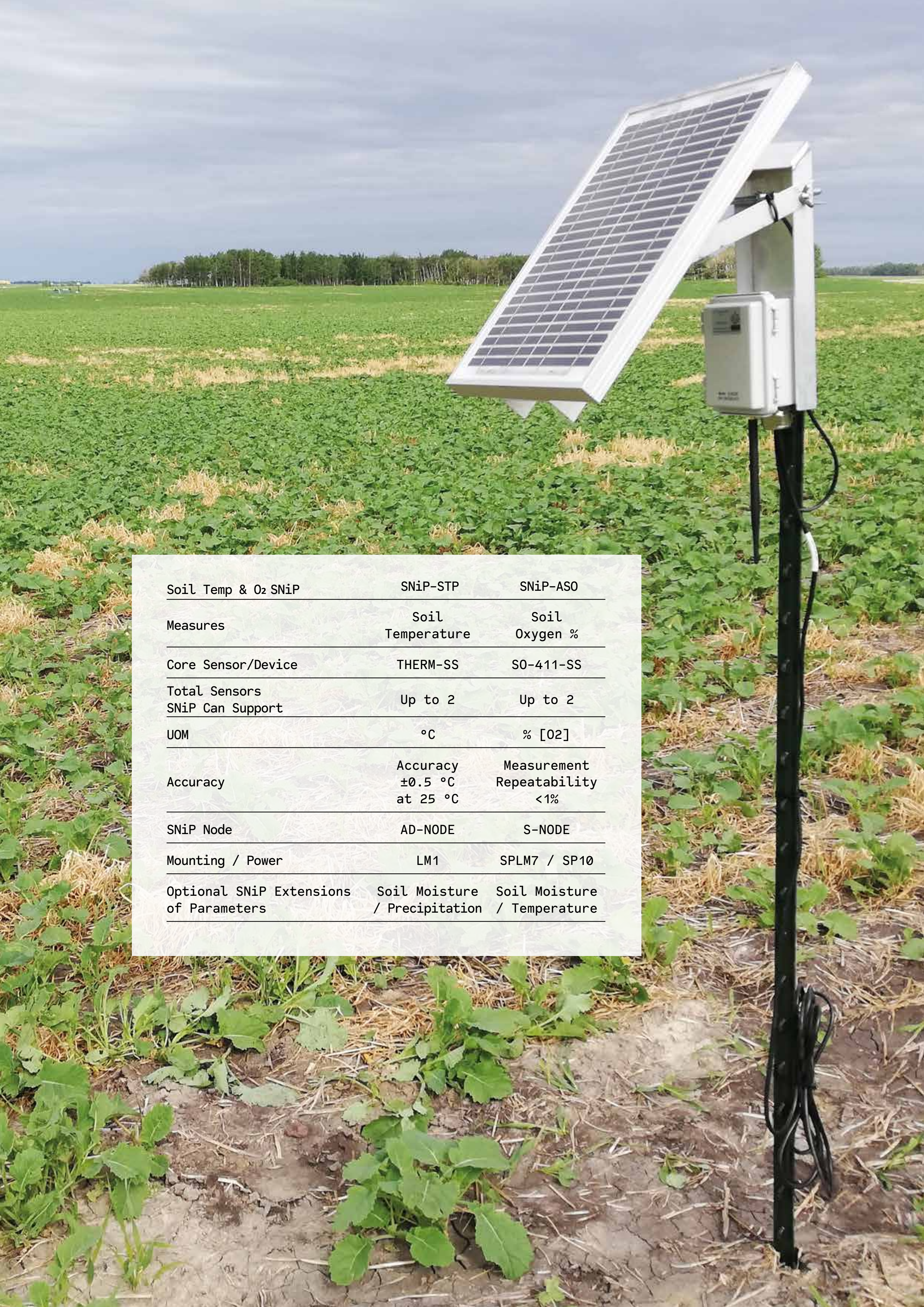


Figure (bottom, left) of Oxygen concentration over 3 days. The oxygen level in the soil started at 20.9%. Immersing the plants completely in water resulted in the plant roots and soil microbes quickly exhausting the soil oxygen supply leaving the soil anaerobic.



Soil Temp & O_2 SNiP	SNiP-STP	SNiP-ASO
Measures	Soil Temperature	Soil Oxygen %
Core Sensor/Device	THERM-SS	SO-411-SS
Total Sensors SNiP Can Support	Up to 2	Up to 2
UOM	°C	% [O2]
Accuracy	Accuracy ±0.5 °C at 25 °C	Measurement Repeatability <1%
SNiP Node	AD-NODE	S-NODE
Mounting / Power	LM1	SPLM7 / SP10
Optional SNiP Extensions of Parameters	Soil Moisture / Precipitation	Soil Moisture / Temperature

Soil Nutrient Drainage Monitoring

Measuring Nutrient Drainage

Drainage volume, and the nutrient loss, are important measurements for determining fertiliser and water use efficiency and for measuring environmental performance. Drainage is often measured in field laboratory settings using column lysimeters, or experimentally in the field using soil solution samplers (suction cups) or miniature lysimeters / drainage gauges. However, due to field variability such measurements require a large number of devices to be installed to obtain accurate field averages which are usually labour-intensive and do not usually allow real-time monitoring.

The GTLA GroundTruth Lysimeter System

The GroundTruth Lysimeter System combines a very large repacked strip lysimeter with automated, real-time drainage measurement and water sampling. This allows accurate measurement of nutrient losses in the field, viewable in real-time. Each strip lysimeter is a transect, usually 10m long. The actual dimensions can be larger and are tailored to the site.

One 10m long, 4m² lysimeter has an equivalent capture area to twenty 50cm diameter column lysimeters, eighty 25cm diameter miniature lysimeters, or approximately 500 suction cups. One lysimeter can monitor average losses from a field site, providing real-time feedback on the effect of management on nutrient loss, to a level of accuracy that would require a large number of smaller sampling devices. 3-5 lysimeters can measure loss to a very high degree of accuracy while providing replication for statistical analysis, replacing an intensive research-grade suction cup array.

The GroundTruth lysimeter can be installed across crop rows or plots, to integrate variation in the field. Once installed, the lysimeter is completely below-ground, unaffected by farm operations, and undamaged by cultivation.

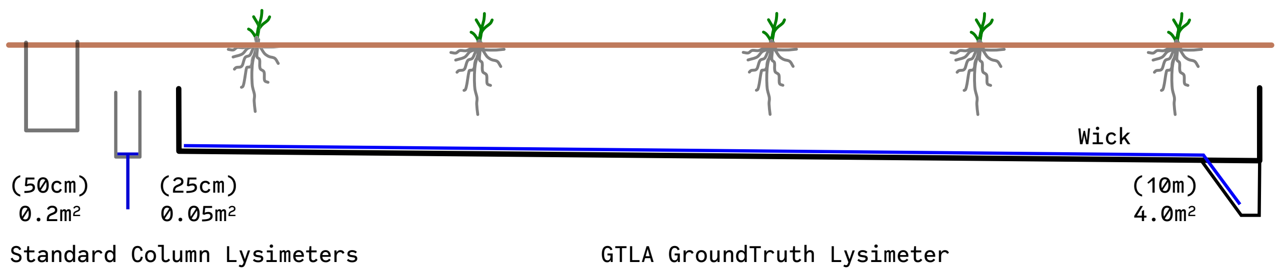
How It Works

All water that drains through this lysimeter is pumped to a LoRaWAN-connected autosampler, located up to 100m away. This allows the lysimeter to be placed in a representative area of a field, while the only above-ground device is at the fenceline. All research and maintenance can occur without entering the field, and without disturbing the crop. The autosampler measures real-time drainage volume and electrical conductivity, and collects a 1% flow-proportional subsample of all drainage for later laboratory analysis, e.g. nutrients, microbiology, pesticide residues. The volume of the sample collected is available online and via email alerts, so the site only needs to be visited when an actual sample requires collection. The system has been designed for remote deployment and easy sample collection by unskilled field staff.

GTLA Lysimeter	
Surface Area	Standard 0.4 x 10 m, 4m² (customisable)
Depth	Standard 1 m (customisable)
Lower Boundary	Wick or free drainage
Side Walls	30cm - 1m
Positioning	Up to 100m from autosample

GTLA Autosampler	Measurement Principles:
Drainage Volume	Pump & Physically Measure
Nutrient Loss (Primary Measurement): (Real-time Estimate):	 1% flow-proportional sample for lab analysis Electrical Conductivity
Data (Real-time): (After Chemical Analysis):	Drainage Volume, EC, Sample awaiting collection Nutrient Loss
Power Supply	Solar 12V
Communications	LoRaWAN (contact us for other options)
Accessories	Rain Gauge. Up to 8 TEROS-12 soil moisture / temperature / EC sensors

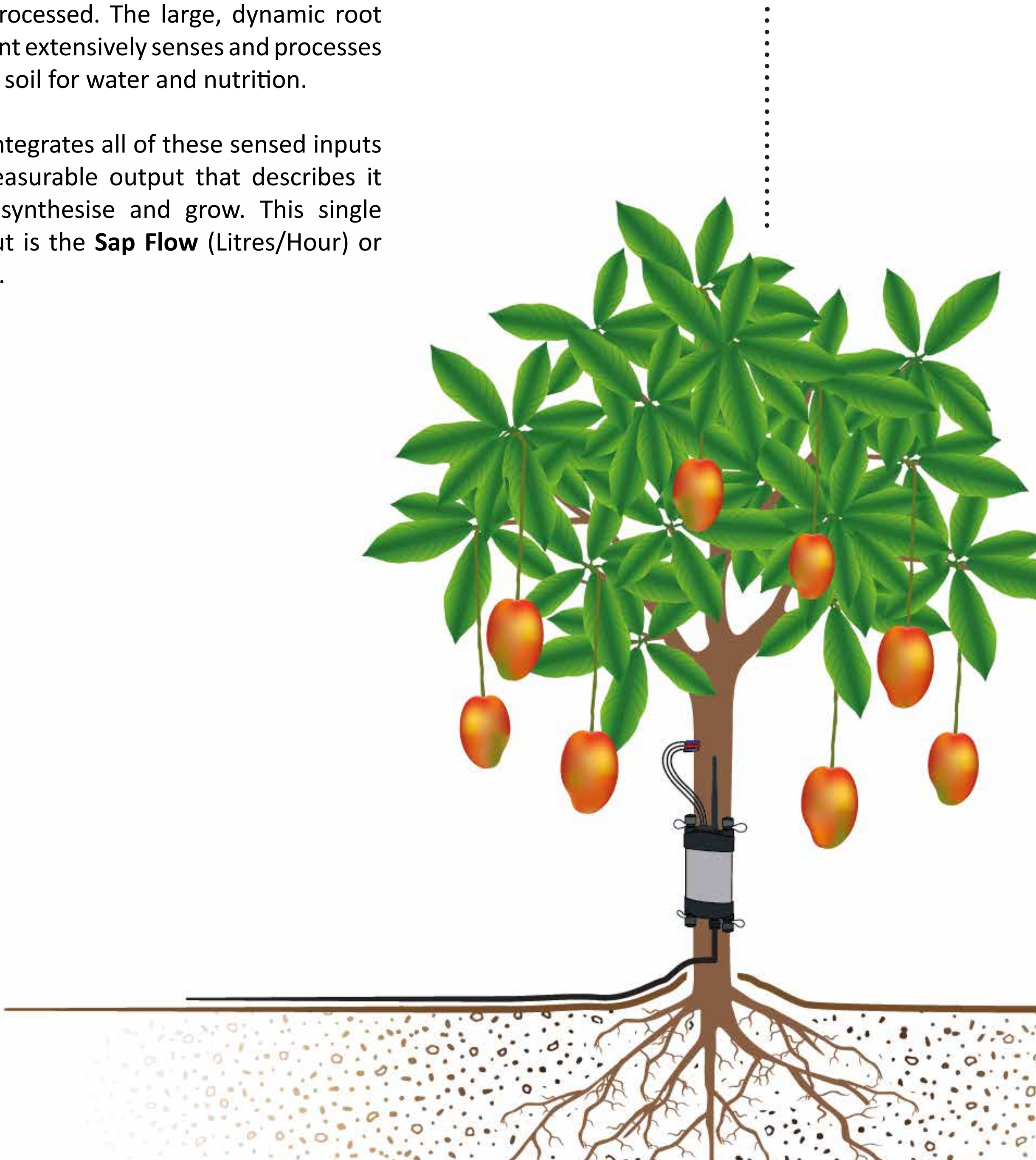
Comparing Lysimeter Size & Area



Plant Monitoring

The plant itself is a very sophisticated transducer or “sensor.” Using every leaf in the plants canopy, radiation, temperature, humidity and wind speed are measured and processed. The large, dynamic root system of the plant extensively senses and processes large volumes of soil for water and nutrition.

The plant then integrates all of these sensed inputs into a single measurable output that describes it ability to photosynthesise and grow. This single integrated output is the **Sap Flow** (Litres/Hour) or **Plant Water Use**.

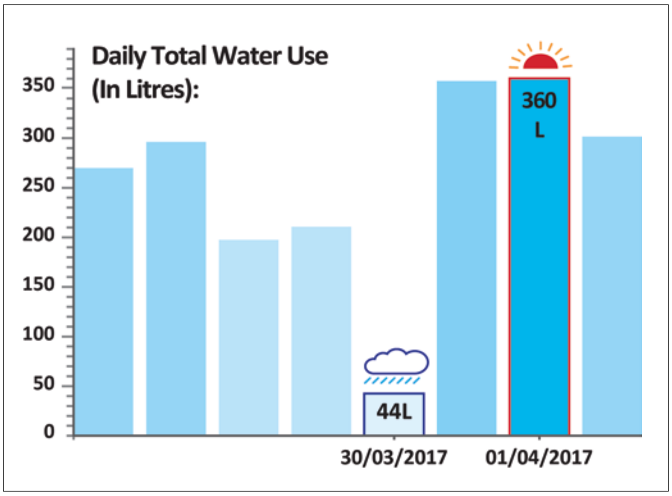


Green Asset Management in Urban Environment

Thresholds to Measure Urban Tree Health

Monitoring urban tree water-use enables the establishment of an upper and lower threshold for optimum water use and tree health, enabling arborists to measure tree health and make confident decisions in the irrigation management of any Urban Forest.

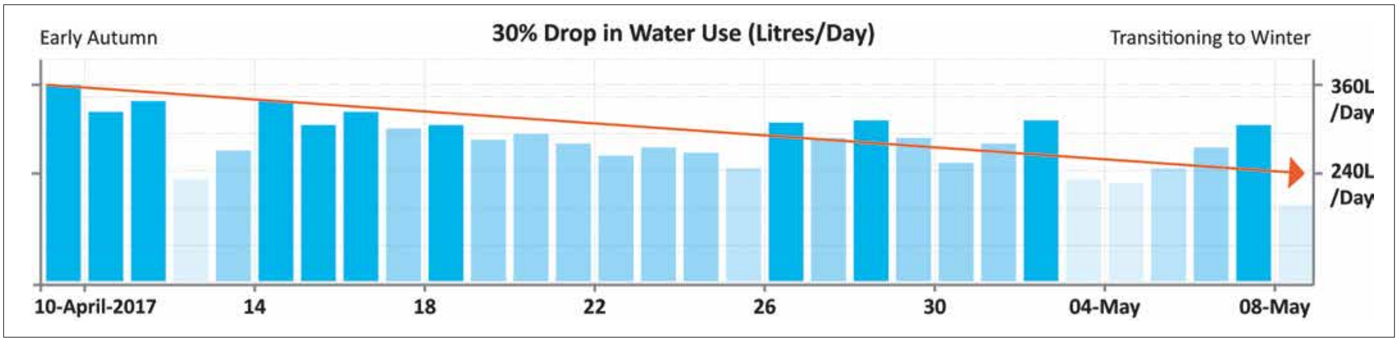
Tree water use is highly variable from day to day, and seasonally. If a tree begins to experience water stress it becomes more susceptible to attack from pests and disease, creating a higher risk of limbfall and insurance payout.



SFM1 Continuously Monitored The Water Use of Heritage Trees in Sydney, Australia

Near the Sydney Opera House, Australia, a Moreton Bay Fig was installed with SFM1 Sap Flow Meters. The graph above (and right) focuses on 7 days of this tree's water use. From hot days in April the tree water use was as much as 360 L/day and on rainy days it was as little as 44 L/day.

Over 30 days, from April 9th to May 8th the water use progressively declined by 30%. This reduction was due to reduced solar radiation and ambient temperature as early autumn transitions towards winter. The graph below demonstrates how peak water use is declining from 360 L/hr to 240 L/hr.



The SFM1 Sap Flow Meter

The SFM1 Sap Flow Meter is a discrete standalone instrument based upon the Heat Ratio Method. This measurement principle has proven to be a robust and flexible technique to measure plant water use; being able to measure high, low, zero and reverse flows in a large range of plant anatomies & species from herbaceous to woody, and stem sizes > 10 mm in diameter.

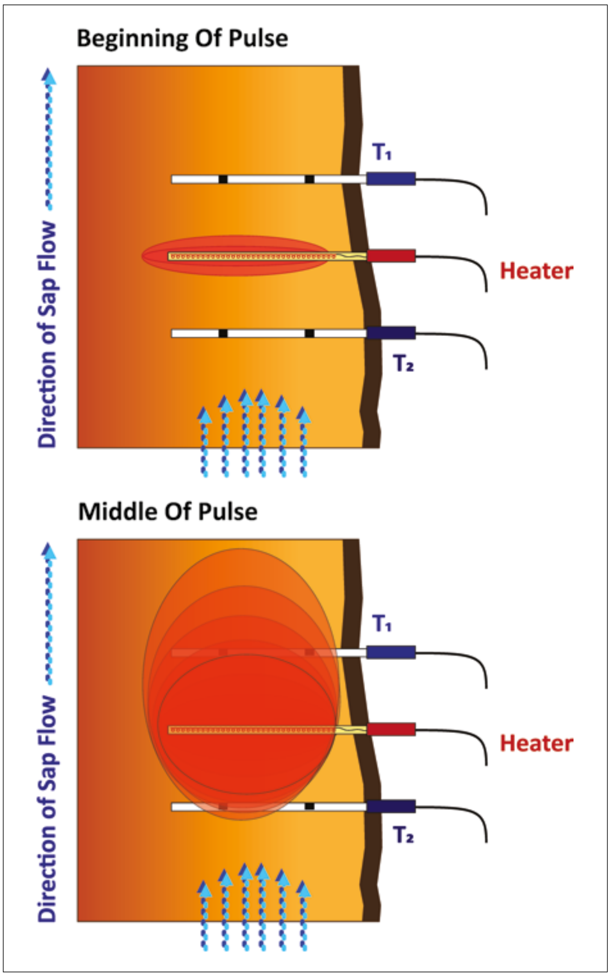
The theoretical basis and ratiometric design of the Heat Ratio Method makes possible the measurement of **high, low, zero and reverse flows**.

The SFM1 Sap Flow Meter consists of two temperature sensing needles arranged equidistance above and below a central heater. These needles are inserted into the water conducting tissue of the plant by drilling 3 small parallel holes. Heat is then pulsed every 10 minutes into the water conducting tissue of the plant. The heat is used as a tracer to directly measure the velocity of water movement in the plant stem. The Heat Ratio Method does not require insulation.

The SFM1 Sap Flow Meter is a dedicated self-contained data logger, with a heater and two temperature sensing needles, that provides power to the heater and logs sap flow in litres per hour of water used by the plant. This is the water actually used by the plant in litres, completely independent of any water that may have been lost to evaporation from bare soil, run off or through drainage.

The Heat Ratio Method

The Heat Ratio Method is represented in the diagrams below:



SFM1 Sap Flow Meter

Measurement Principle	Heat Ratio Method
Needle Diameter	1.3 mm
Needle Length	35 mm
Measurement Position	2 per measurement needle
Measurement Spacings:	7.5 mm and 22.5 mm from the needle tip
Output Options	Raw Temperatures: °C Heat Pulse Velocity: cm hr^{-1} Sap Velocity: cm hr^{-1} Sap Flow: cm^3 hr^{-1} (Litres hr^{-1})
Range	-100 to +100 cm hr^{-1}
Resolution	0.01 cm hr^{-1}
Accuracy	0.5 cm hr^{-1}
Measurement Duration	120 seconds
Heat Pulse	User Adjustable: 20 Joules (default) approx. Equivalent to a 2.5 second heat pulse duration, auto scaling
Logging/Upload Interval	User Adjustable: Minimum interval: 5 minutes Recommended minimum: 10 mins

Connecting a Melbourne Community To Urban Trees

Project Background

Managing urban trees poses many challenges. The use of digital platforms to inform managers and the general public on real-time water use and overall condition of trees is being tested in the first smart urban forest management system.

In collaboration with Swinburne University, Royal Melbourne Institute of Technology (RMIT) and a local community park in Melbourne, ICT International deployed sap flow meters (SFM1), to measure real-time water use of 9 trees at the CERES Community Environment Park. The goals are multifaceted:

1. Monitor water use and water stress of trees in an urban forest using digital platforms accessible by park managers and city residents;
2. Better understand water demands of key endemic trees in an urban setting under current and future climate conditions;
3. Develop a mobile app that will allow trees to “talk back” and engage citizens in urban tree management.

Monitoring and Network Solution

- SFM1 Sap flow meters on 9 trees at the CERES Community Environment Park, Melbourne;
- Weather station;
- 4G Telemetry system;
- ICT Dataview.

Outcomes

Continuous sap flow data shows clearly:

- Impacts of heat wave conditions,
- Seasonal-differences in tree water use,
- Species-differences in tree water use.

"Talk Back" app for citizen engagement is currently under development.

Figure of SFM1 Sap Flow Meter, Solar Panel & Antenna at CERES.

Scientific Paper: New Zealand Forestry Kauri Trees Sharing Water

How does a tree without green foliage keep itself alive?

Dr Martin Bader and Assoc. Prof. Sebastian Leuzinger from Auckland University of Technology have found that when two trees of the same species are close to one another, they are able to undertake Hydraulic Coupling – that is share water, carbon, minerals and microorganisms.

To prove this, they attached ICT International SFM1 Sap Flow Meters and PSY1 Stem Psychrometers to a Kauri Tree and an adjacent stump with no leaves (figure right).

From the data that these instruments captured, Bader and Leuzinger were able to observe the movement of the sap between the stump and the tree.

The SFM1 Sap Flow Meter can measure **very low sap flow** and **reverse sap flow**. This enabled measurement of sap flow toward the tree in day time and reversal of flow toward the stump at night. The hydraulic gradient as measured by the PSY1 Stem Psychrometer reversed from day to night and hence the direction of flow reversed from day to night in relationship to this measured hydraulic gradient.

Figure (above, right) shows SFM1 Sap Flow Meters monitoring sap flow through the stump at different times of day. (Supplied by Assoc. Prof. Sebastian Leuzinger)

Figure (top) is a combined diagram of Daytime & Nightime Shared Sap Flow, Based on the Scientific Paper's Diagrams (Original Photo Supplied: Assoc. Prof. Sebastian Leuzinger).

Full Reference:

Bader, M. K.-F., & Leuzinger, S. (2019). Hydraulic Coupling of a Leafless Kauri Tree Remnant to Conspecific Hosts. IScience. https://doi.org/10.1016/j.isci.2019.05.009

ICT INTERNATIONAL

Realtime Dendrometry Data

Stem diameter is one of the most commonly measured attributes of trees. Dendrometers are used to measure the diameter of fruits, plants and trees. High resolution dendrometers are used to monitor the diurnal swelling and shrinkage of stems. During the day stems "shrink" as stomata open and the tree transpires. At night the stem "swells" due to cessation of transpiration and trunk refilling of moisture.

Maximum Daily trunk Shrinkage (MDS), the calculated difference in daily minimum and maximum stem diameter, is a commonly used parameter in irrigation scheduling. Significant crop research has been undertaken in this field to explore the correlation of MDS to physiological and abiotic parameters including soil moisture and water potential, vapor pressure deficit (VPD) and stem water potential.

Seasonal datasets can be used to compare fertilisation treatments, pruning, thinning or drought treatments. In forestry dendrometers are used for long term data collection in the study of growth dynamics, biomass allocation and carbon uptake. In horticulture Dendrometers are used to monitor MDS for irrigation management.

Band Dendrometer

Dendrometer bands are a long accepted and widely used method of measuring tree circumference and can provide changes in tree diameter at breast height (DBH), basal area, and basal area increment. The DBS60 Band Dendrometer is a high resolution (1µm [0.001mm]), non-invasive sensor capable of measuring a wide range of diameters (50mm>). The stainless-steel band has a very low linear thermal co-efficient. Thermal variations caused by daily or seasonal changes in temperature have no measurable impact on the measurement accuracy. The DBS60 is IP66 rated and is designed to be installed in the harshest field conditions for years at a time.

Pivot Dendrometer

Pivot dendrometers are designed for simple, error free installation, being fastened on the stem by a spring-based lever clamp. Adherence pressure is set as a compromise between the influence on plant tissues and installation stability. The DPS40 Pivot Stem Dendrometer is a high-resolution pivot-based sensor for measurement of small stems, from 5mm to 40mm, the bearing of the position sensor is carefully shaped for minimal effect of temperature and axial forces.

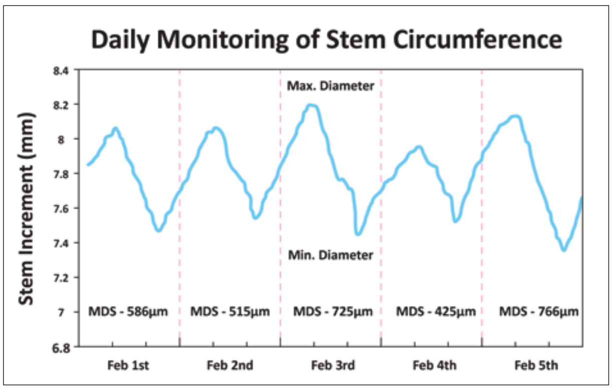


Figure (above) shows Maximum Daily Shrinkage i.e. The maximum daily stem diameter minus the minimum daily stem diameter.

Dendrometry SNiPs	SNiP-DPS	SNiP-DBS4	SNiP-DBS6
SNiP Measures	Tree/Stem Circ. (mm) / Temperature	Tree/Stem Circ. (mm) / Temperature	Tree/Stem Circ. (mm) / Temperature
Core Sensor/Device	DPS40	DBS60 with modified fixing plate	DBS60
UOM	mm / °C	mm / °C	mm / °C
Increment Range	35mm of circ.	60 mm of circ.	60 mm of circ.
Minimum Trunk Diameter	5mm	40mm	60mm
Maximum Trunk Diameter	40mm	80mm	No maximum
Resolution	0.001 mm	0.001 mm	0.001 mm
SNiP Node		S-NODE	
Sensors SNiP Supports		Up to 4	
Mounting / Power	SPLM7 / SP10	SPLM7, DBTAPE / SP10	

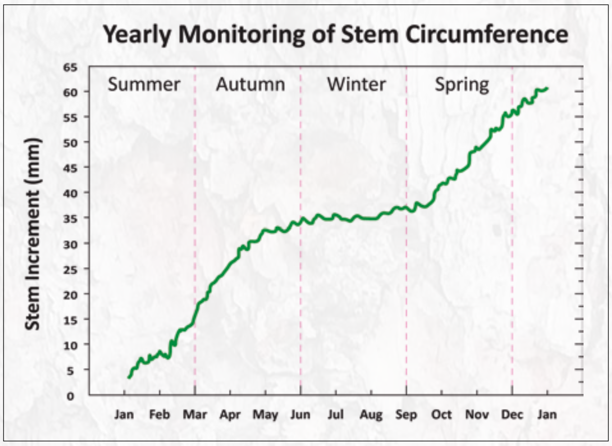


Figure (above) is an example of 12 months of a data set from an Acacia implexa growing near Armidale, NSW, Australia. The DBL60 is manufactured from UV Resistant plastic for many years of data collection.

LoRaWAN Avocado Crop Monitoring

In late 2018, ICT International installed a monitoring program in an avocado orchard with the specific objective to reduce rates of fruit drop (abscission), hence yield loss, by improved irrigation scheduling.

The Site

The farm, located on the Mid-North Coast of NSW Australia, had previously suffered crop losses caused by water stress during flowering and fruit set. Seeking a solution to better detect this risk required real time monitoring to enable pro-active management of irrigation and canopy humidity.

Dendrometer

Calculated VPD & Soil Moisture

Project Background

Avocado trees are particularly sensitive to heat (and thus water stress) at the time of flowering and fruit set. Water stress can result in flower and fruit drop, thereby reducing yield. By forecasting the risk factors which contribute to plant water stress, notably low soil moisture and high Vapour Pressure Deficit (VPD), management decisions can be implemented to minimise the risk of fruit drop.

The Solution: Crop Monitoring Sensors

- Weather station
- Soil Moisture Sensors
- Temperature Sensors
- High Resolution Dendrometers measuring avocado tree trunk diameter
- Micro-climate sensors outside and within the canopy measuring temperature, relative humidity and calculated VPD.

Integrated Into a LoRaWAN Network

Data from the sensors is transmitted over a private LoRaWAN network to a Gateway utilising a fixed-point network connection. Eagle.io is used for data storage / visualisation and alarming of soil moisture, VPD and Maximum Daily trunk Contraction (MDC).

The system notifies operators (via SMS and email) when irrigation is necessary to avoid plant water stress and potential fruit drop, hence crop loss.

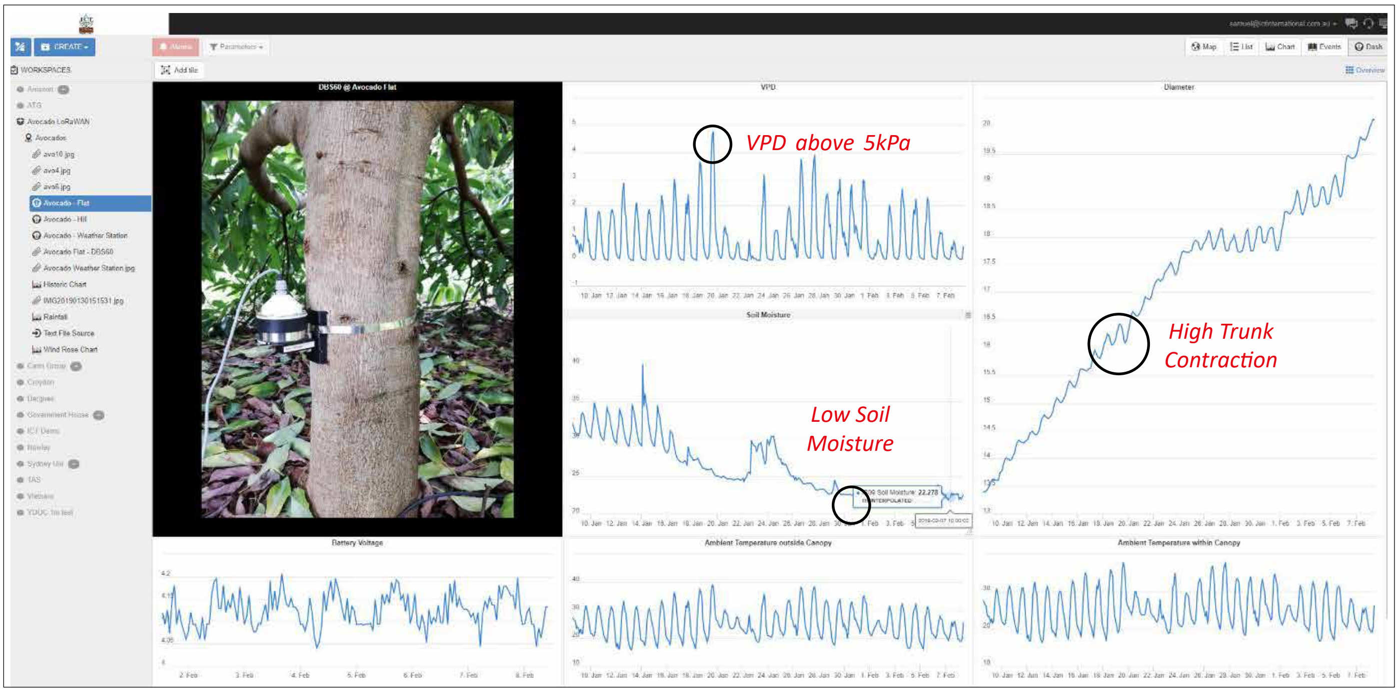
	SNiP-SPW1	SNiP-SPW2	SNiP-SPW3
SNiP Measures	Soil Moisture, Temperature and EC / Tree Circ. / VPD *	Multi-Point Soil Moisture & Temperature / Tree Circ. / VPD *	Soil Moisture / Tree Circumference / VPD *
Core Sensor/Device	SMT-100 / DBS60 / ATH-S2	EP100GL-04 / DBS60 / ATH-S2	MP406 / DBS60 / ATH-S2
SNiP Node	S-NODE	S-NODE	MFR-NODE
Mounting / Power	SPLM7, DBTAPE / SP10		
Optional Extensions:	Solar Radiation		

*VPD is derived from measure of ambient temperature and relative humidity

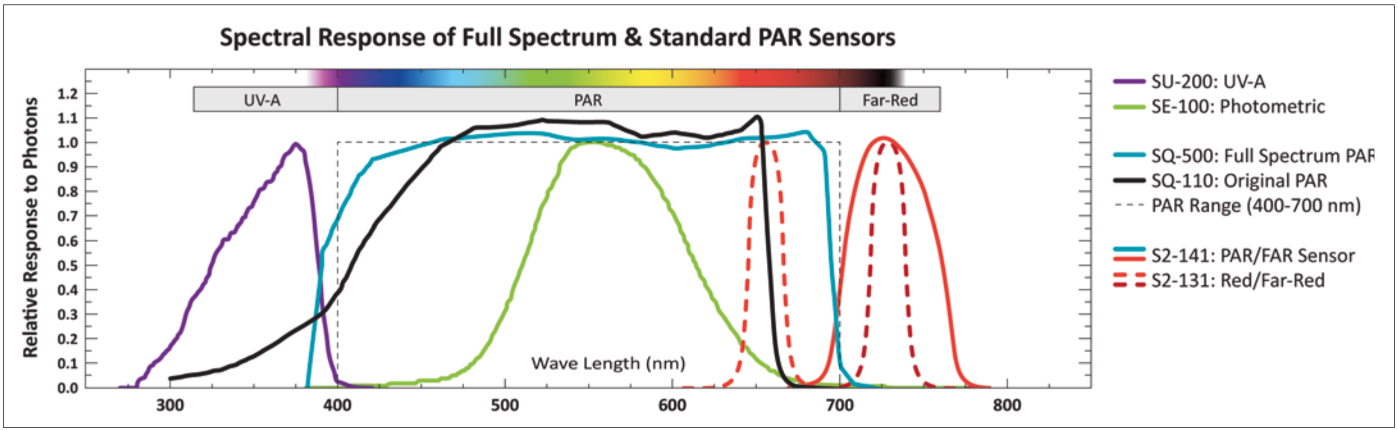
The Outcome

The sensor network was installed in December 2018, prior to a month of extreme heat which occurred during flowering and fruit set. Over January, during fruit set, the sensor network detected two significant plant water stress events, with local VPD levels rising above 5kPa. Low soil moisture during the second event resulted in severe plant water stress, reflected by higher levels of MDC of the trunk. Managers observed high numbers of fruit drop coinciding with the second event.

Dashboard View of Past & Realtime Data



Remotely controllable irrigation systems are currently being installed. The monitoring system will provide property owners the information required to remotely control irrigation to reduce plant water stress events.



Photosynthetically Active Radiation (PAR)

Light intercepted by a leaf may be absorbed, reflected, or transmitted; the fraction absorbed depends on the spectral content of the radiation and the absorption spectrum of the leaf.

Photosynthetically active radiation (PAR) is light of wavelengths 400-700 nm and is the portion of the light spectrum utilised by plants for photosynthesis. Photosynthetic photon flux density (PPFD) is defined as the photon flux density or PAR. If PAR is low for a given species of plant, growth and carbon assimilation is limited, while too much PAR may damage the photosynthetic apparatus.

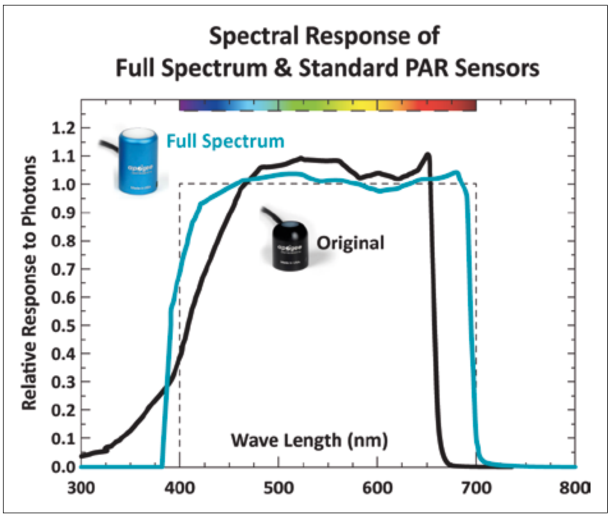
The spectral responses of all quantum sensors deviate from the ideal response to some degree. Spectral error occurs when measuring a light source that has a different spectral output than the light used to calibrate the sensor. This error occurs because no quantum sensor can perfectly match the ideal quantum response, which is defined as an equal response to all wavelengths of light between 400 and 700 nm.

The Apogee SQ-500 Full Spectrum Quantum Sensor has a response closer to that of an ideal quantum sensor than the SQ-110.

Plants sense light using photoreceptors, such as phytochrome, and use wavelengths outside of the PAR range – mainly within the UV and far-red light spectrums to sense and respond to their environment.

The plant canopy selectively absorbs red wavelengths (approximately 660 nm) more than far-red wavelengths (approximately 730 nm) resulting is a decrease in the red: far-red ratio of light toward the base of the canopy, such changes in light quality result in photomorphogenic changes in plant growth.

In agricultural production systems an understanding of these responses is central to optimising planting density and canopy management.



Plant Light SNiPs	SNiP-SQS	SNiP-SQE	SNiP-SQF	SNiP-PFR	SNiP-RFR
SNiP Measures	PAR^	PAR^	PAR^	PAR^ -FAR Red	Red-FAR Red
Core Sensor/Device	SQ-110	SQ-120	SQ-521	S2-441	S2-431
Measurement Range	0 to 4000 µmol m^{-2} s^{-1}		0 to 4000 µmol m^{-2} s^{-1}	0 to 4000 µmol m^{-2} s^{-1} (PAR) 0 to 1000 µmol m^{-2} s^{-1} (Far Red)	0 to 400 µmol m^{-2} s^{-1}
Wavelength Ranges	410 nm to 655 nm		389 to 692 nm ±5 nm	389 to 692 nm ±5nm (PAR) 700 to 760 nm ±5nm (Far Red)	645 to 665 nm ±5nm (Red) 720 to 740 nm ±5nm (Far Red)
Sensor IP Rating	IP68 - Sensor can be submerged in water to 1m depth				
SNiP Node	AD-NODE		S-NODE	S-NODE	S-NODE
Mounting / Power	LM1, AL-120		SPLM7, AL-120 / SP10		
Optional SNiP Extensions of Parameters:	Precipitation, Soil Moisture		Soil Moisture, Microclimate		

^Photosynthetically Active Radiation

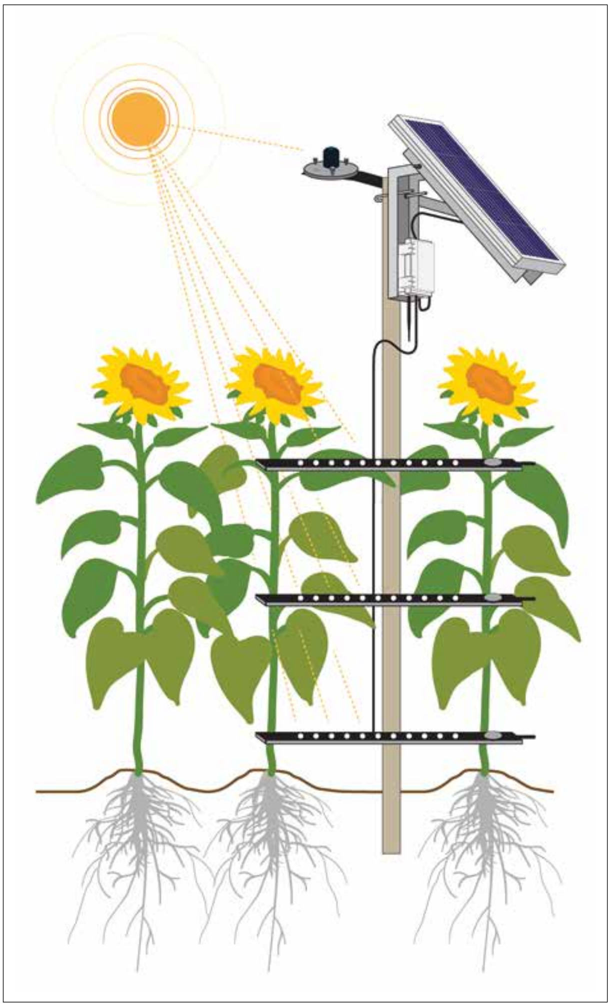
Canopy Light Inception

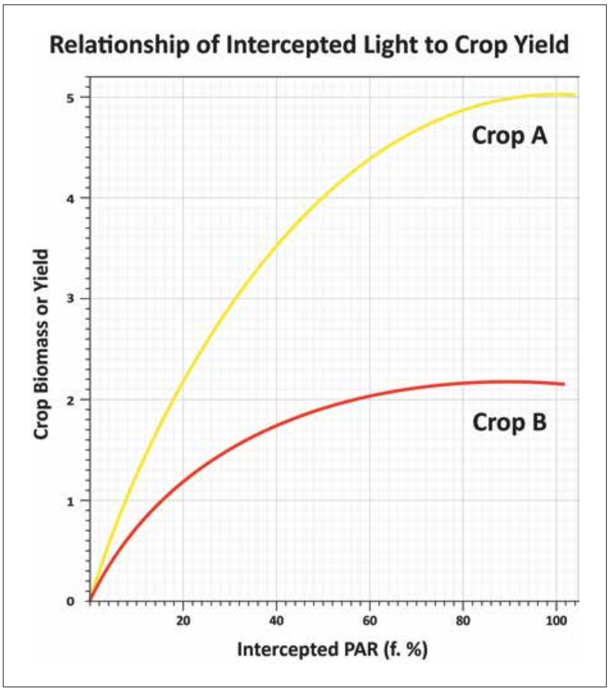
Plant light interception efficiency is a key determinant of carbon uptake by plants; plant productivity over seasonal time-scales is approximately proportional to intercepted light. Canopy architecture, leaf area, leaf angle distribution, and leaf dispersion are determinants in the light distribution and interception within the canopy. In horticultural crops pruning strategies can optimise tree structure and drive higher productivity and increase plant health and longevity.

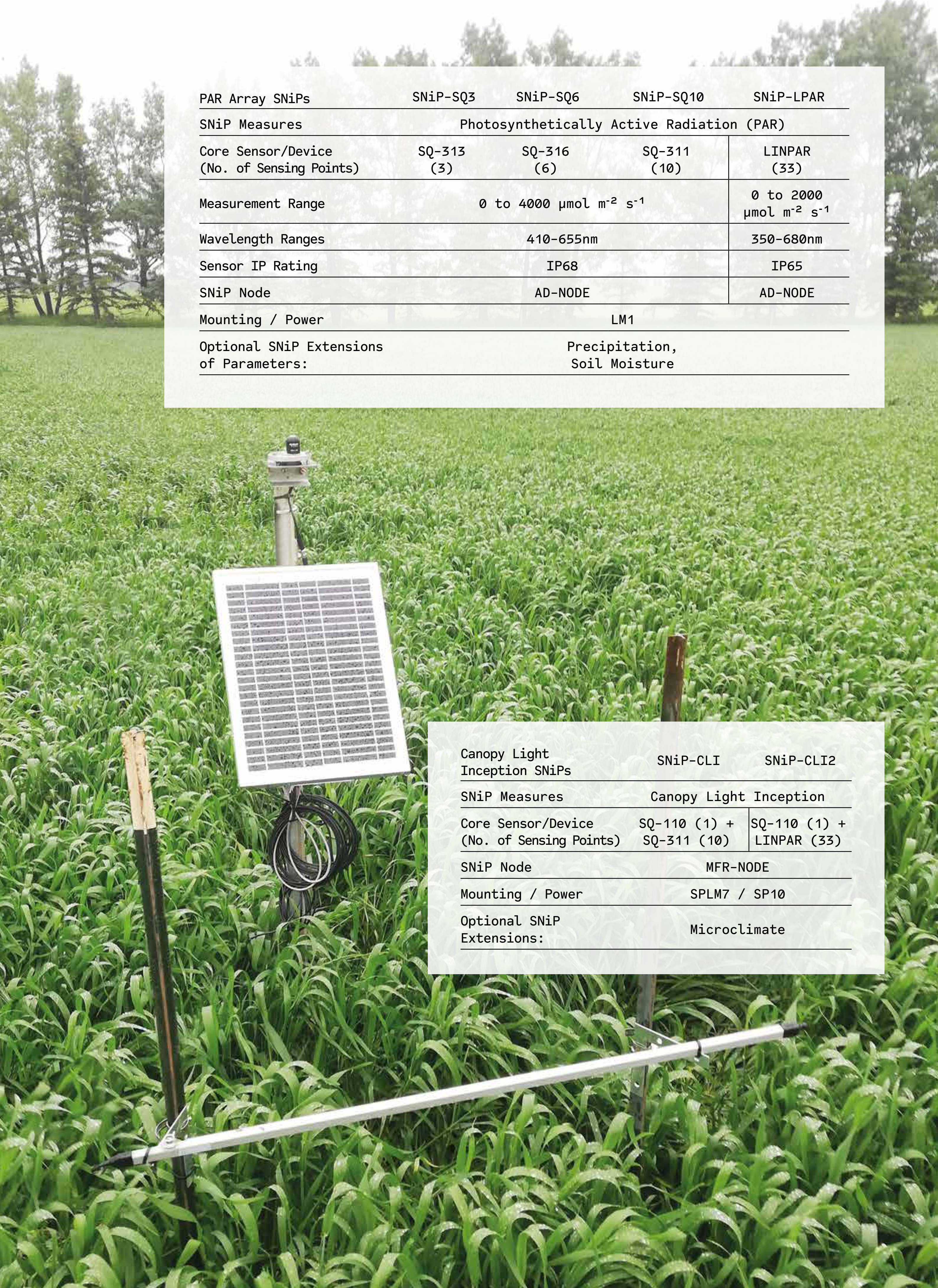
The measurement of fraction of intercepted PAR (f) is an indicator of a plant's light use efficiency or its ability to convert sunlight into biomass. The simple method requires at least one PAR sensor above the canopy to measure direct beam and one or more PAR arrays beneath the canopy.

A PAR array is necessary beneath or within a canopy because it samples a larger area and considers sunlight variability caused by the canopy. Plotting f over a growing season against some measure of yield or biomass indicates the light use efficiency of crops.

The MFR-NODE and AD-NODE can be configured with LINPAR and PAR sensors to measure, monitor and calculate intercepted PAR (f), and hence biomass and yield.

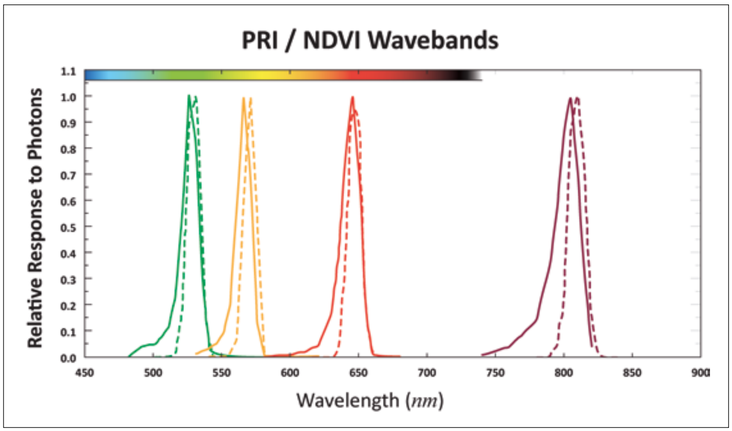






PAR Array SNiPs	SNiP-SQ3	SNiP-SQ6	SNiP-SQ10	SNiP-LPAR
SNiP Measures	Photosynthetically Active Radiation (PAR)			
Core Sensor/Device (No. of Sensing Points)	SQ-313 (3)	SQ-316 (6)	SQ-311 (10)	LINPAR (33)
Measurement Range	0 to 4000 µmol m^{-2} s^{-1}			0 to 2000 µmol m^{-2} s^{-1}
Wavelength Ranges	410-655nm			350-680nm
Sensor IP Rating	IP68			IP65
SNiP Node	AD-NODE			AD-NODE
Mounting / Power	LM1			
Optional SNiP Extensions of Parameters:	Precipitation, Soil Moisture			

Canopy Light Inception SNiPs	SNiP-CLI	SNiP-CLI2
SNiP Measures	Canopy Light Inception	
Core Sensor/Device (No. of Sensing Points)	SQ-110 (1) + SQ-311 (10)	SQ-110 (1) + LINPAR (33)
SNiP Node	MFR-NODE	
Mounting / Power	SPLM7 / SP10	
Optional SNiP Extensions:	Microclimate	



Plant Reflection of Light

NDVI and PRI are calculated from measurements of electromagnetic radiation reflected from plant canopy surfaces.

NDVI (Normalized Difference Vegetation Index) is a standardized index use to measure the state of plant health. Leaf chlorophyll absorbs red light (approximately 680mm), and the cellular structure of the leaves strongly reflect near-infrared light, approximately 730mm. When the plant is water stressed or diseased the spongy layer deteriorates and the plant absorbs more of the near-infrared light, rather than reflecting it.

By observing how NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health.

PRI (Photochemical Reflectance Index) originally defined as an index of the diurnal xanthophyll cycle activity, provides a measure of photosynthetic light-use efficiency (LUE) which can be used as an indicator of stress. PRI bands are centred at 532nm and 570nm.

Leaf Wetness

Leaf wetness refers to the presence of free water on the canopy, and is caused by intercepted rainfall, dew, or guttation. The duration of the time period during which the leaves are wet is generally referred to as leaf wetness duration (LWD).

Leaf wetness is a concern for the development of disease and the dispersal of pathogens; LWD is an important input (along with temperature) in many crop disease models which are used for determining the appropriate time for the use of preventative measures, such as fungicide application.

Leaf Wetness SNiP	SNiP-LWS
Core Sensor/Device	ICT-LWS
Wetness Range	0-100%
Temperature Range	-40 to 80°C
UOM	mA
Measurement Range	4 to 20 mA
SNiP Node	AD-NODE
SNiP Sensor Extensions	Tipping Bucket Rain Gauge

Vegetation Indices SNiPs	SNiP-NDVI	SNiP-PRI
SNiP Measures	NDVI Index	PRI-Index
Core Sensors/ Devices	S2-411-SS (Looks Upward) S2-412-SS (Looks Downward)	S2-421-SS (Looks Upward) S2-422-SS (Looks Downward)
Wavelength Ranges	Red detector = 650 nm with 10 nm FWHM* NIR detector = 810 nm with 10 nm FWHM*	Green detector = 532 nm with 10 nm FWHM* Yellow detector = 570 nm with 10 nm FWHM*
Field of View	180° (Upward-Looking Device) 40° (Downward-Looking Device)	
Measurement Range	2x full sunlight	
Calibration Uncertainty	±5 %	
Sensor IP Rating	IP68	
SNiP Node	S-NODE	
Mounting / Power	SPLM7, AM-400, AL-120 / SP10	
Optional SNiP Extensions of Parameters:	Capacity for an additional two S2-412-SS	Capacity for an additional two S2-422-SS

*FWHM = full-width half-maximum

Leaf, Bud & Canopy Temperature

Infrared Radiometry - Canopy Temperature

An infrared thermometer measures radiant energy. This radiation is simply "light" that is slightly outside the human eye's sensitive range. All objects radiate infrared energy. The intensity of infrared radiation is proportional to the temperature of the object.

Infrared thermometers produce no "intrusion error." A hot object "target" is radiating its infrared radiation in all directions. The object's radiation characteristics, and hence its temperature, are not disturbed by the presence of the infrared thermometer.

The infrared thermometer optics collect a sample of infrared radiation from the hot object (soil & plant) being measured and focus it on the tiny infrared detector. The detector, in turn, converts it to a proportional electrical signal, which is the exact electrical analog of the incoming infrared radiation, and hence the hot object's temperature. This minute electrical signal is then amplified, converted to a digital signal, and digitally linearized and the resultant temperature either displayed or data logged.

Low temperature infrared thermometry (IRT) is technically quite difficult especially when measuring temperatures of crop canopies which have a very weak infrared signal and temperatures are needed to be resolved to 0.1 Deg C to make meaningful irrigation and management decisions. Continuous measurement of the transducer temperature and sky reflectance of infrared light must be undertaken.

Accurate measurements of plant canopy temperature, which, along with other environmental variables, allows estimation of canopy transpiration and crop stress using a calculation such as Crop Water Stress Index (CWSI).

Leaf Temperature

The THERM-MICRO Leaf Temperature Sensor is a very small thermistor that can be adhered to a leaf surface for the measurement of absolute temperature of the leaf at the surface. The THERM-MICRO's small size means that it has almost no thermal mass, resulting in minimal boundary layer influence and measurements which are highly responsive to changes in leaf temperature.

Frost (Leaf & Bud Temperature)

Frost damage to plants can have large impacts on crop yield and quality. The SF-421-SS is a combination of two temperature sensors (precision thermistors) designed to mimic a plant leaf and the other a flower bud. Protection of crops during frost events is dependent on the accuracy of plant temperature predictions.

Quite often, air temperature is not a reliable predictor of timing, duration and severity of frost events because plant canopy temperatures can be significantly different than air temperature under certain environmental conditions. On clear, calm nights, plant leaf and flower bud temperatures can drop below freezing even if air temperature remains above 0°C. This is called a radiation frost and is due to the lack of air mixing (wind) near the surface, and a negative net longwave radiation balance at the surface.

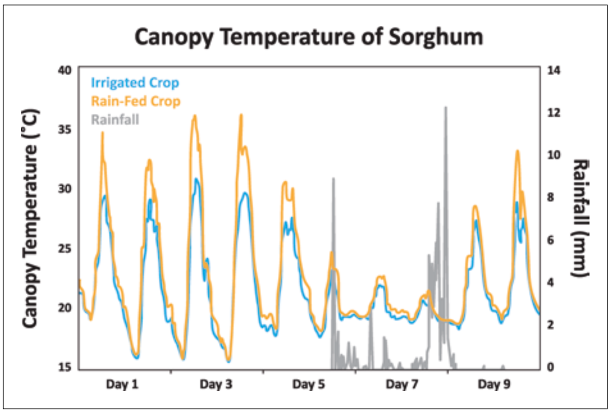
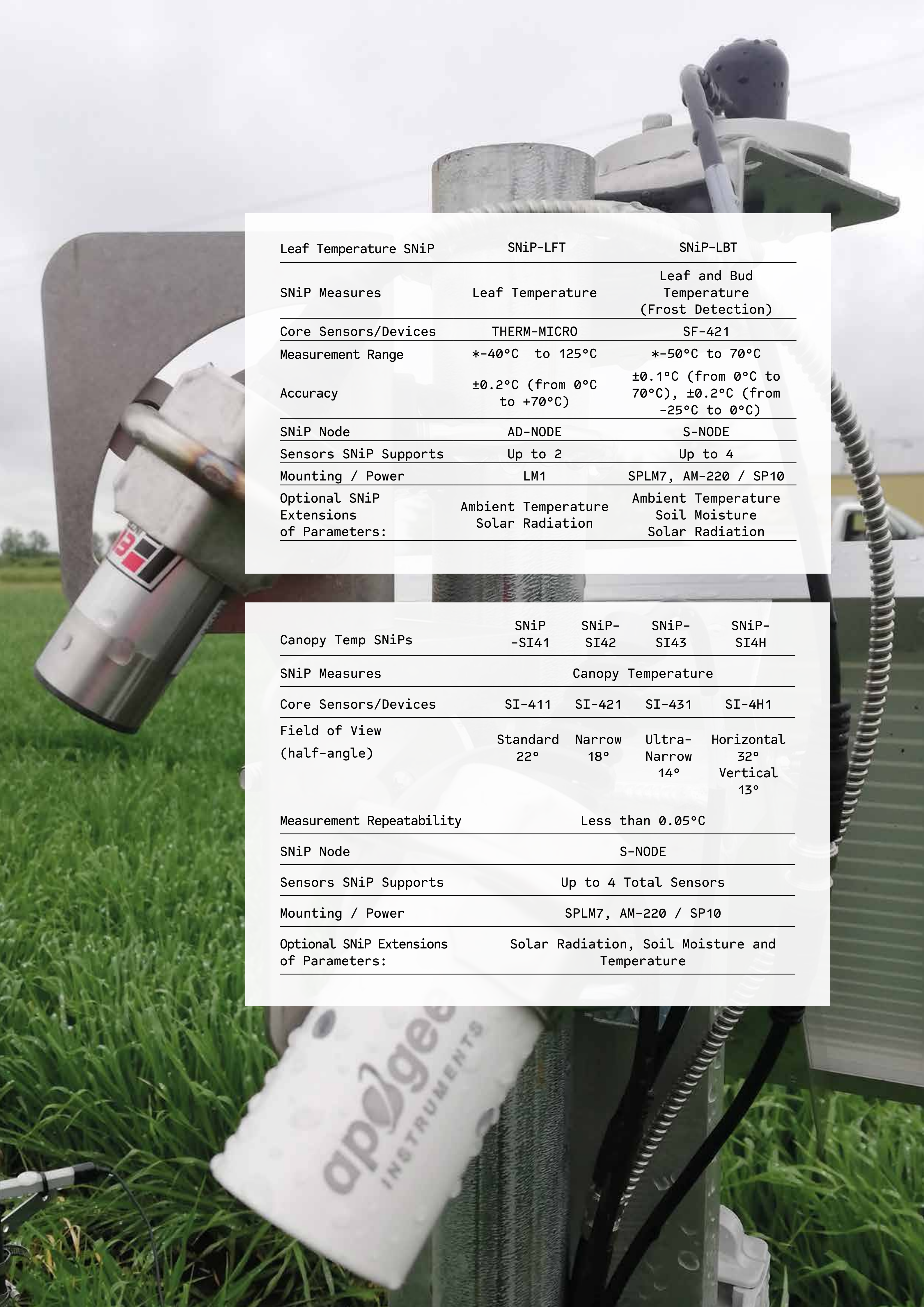


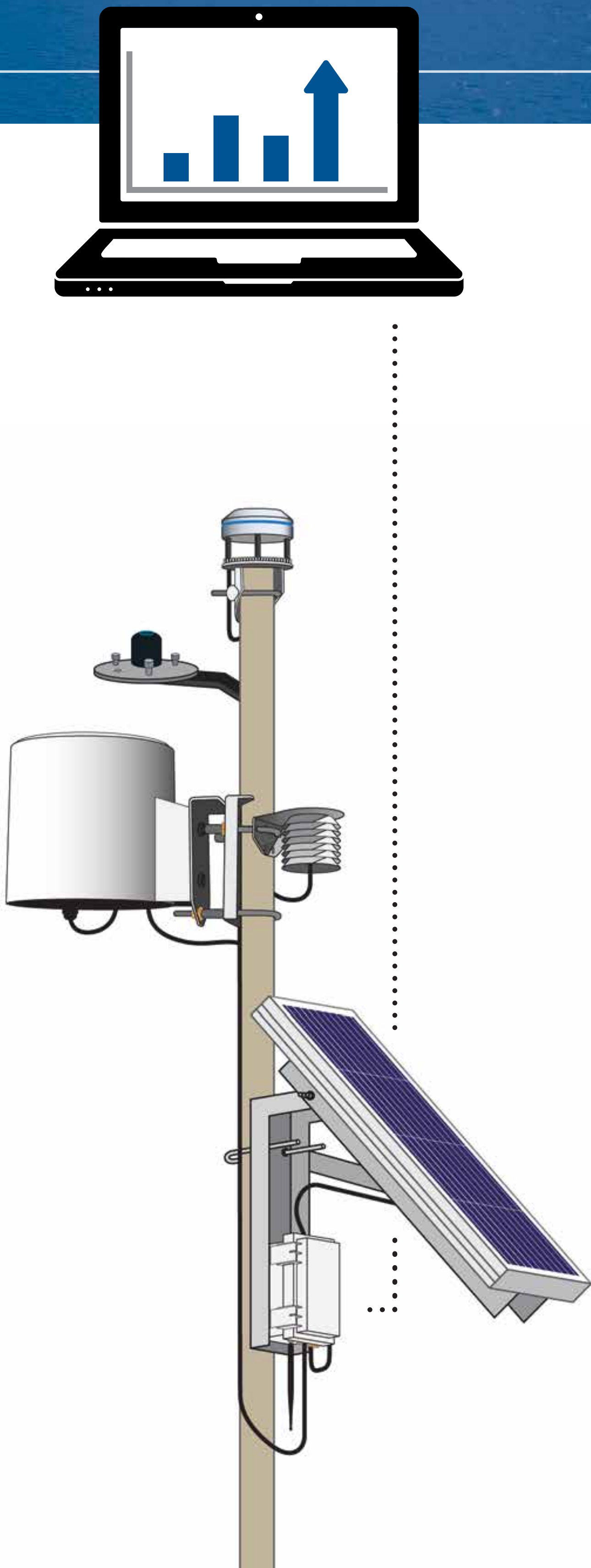
Figure (above) shows irrigated sorghum has a lower canopy temperature than rain-fed sorghum.



Leaf Temperature SNiP	SNiP-LFT	SNiP-LBT
SNiP Measures	Leaf Temperature	Leaf and Bud Temperature (Frost Detection)
Core Sensors/Devices	THERM-MICRO	SF-421
Measurement Range	*-40°C to 125°C	*-50°C to 70°C
Accuracy	±0.2°C (from 0°C to +70°C)	±0.1°C (from 0°C to 70°C), ±0.2°C (from -25°C to 0°C)
SNiP Node	AD-NODE	S-NODE
Sensors SNiP Supports	Up to 2	Up to 4
Mounting / Power	LM1	SPLM7, AM-220 / SP10
Optional SNiP Extensions of Parameters:	Ambient Temperature Solar Radiation	Ambient Temperature Soil Moisture Solar Radiation

Canopy Temp SNiPs	SNiP -SI41	SNiP-SI42	SNiP-SI43	SNiP-SI4H
SNiP Measures	Canopy Temperature			
Core Sensors/Devices	SI-411	SI-421	SI-431	SI-4H1
Field of View (half-angle)	Standard 22°	Narrow 18°	Ultra-Narrow 14°	Horizontal 32° Vertical 13°
Measurement Repeatability	Less than 0.05°C			
SNiP Node	S-NODE			
Sensors SNiP Supports	Up to 4 Total Sensors			
Mounting / Power	SPLM7, AM-220 / SP10			
Optional SNiP Extensions of Parameters:	Solar Radiation, Soil Moisture and Temperature			

Environmental Monitoring



All environmental monitoring programmes should identify the research or management objectives as a base for sensing requirements.

The spatial variability should also be considered in any environmental monitoring program. This affects numbers and locations of sensors in regard the need for representative data.

Key to measuring any physical parameter within the environment is an understanding of the variables affecting both the parameter being measured and the sensor deployed in its measurement. Errors in the measurement are the sum of inherent sensor error and installation error. For example, errors in the measurement of ambient temperature are commonly introduced through the installing of a sensor to close to a source of thermal radiation, such as a paved surface or building. Also errors in soil moisture measurement from airgaps around the sensor and incorrect installation.

The accuracy of long-term data collection is influenced by both the sensing technology used and the diligence in maintenance provided it. Few sensors are set and forget, in marine environments biofouling can occur within weeks of installation.

ICT International is a technical resource on best practice for design, installation and maintenance of environmental sensing systems.

Monitoring Water Use in Urban Ornamental Nursery

Project background

Water is among the three biggest operating costs of commercial ornamental nurseries in urban settings. Furthermore, Australian nursery operators are often restricted with strict water access regulations. Nevertheless, nursery managers must ensure that potted ornamental plants are grown to optimum marketable value. By carefully measuring plant-water relations combined with on-site weather conditions, ornamental nursery managers can manage water use whilst ensuring the supply of quality planting materials.

The key parameters a nursery manager periodically checks typically through manual inspection are:

- Pot soil moisture;
- VPD (vapour pressure deficit calculated from temperature & humidity);
- And leaf temperature (to avoid frost during winter and sun burn during summer).

Monitoring and Network solution

In the Urban Ornamental Nursery, the following sensors and instruments were installed:

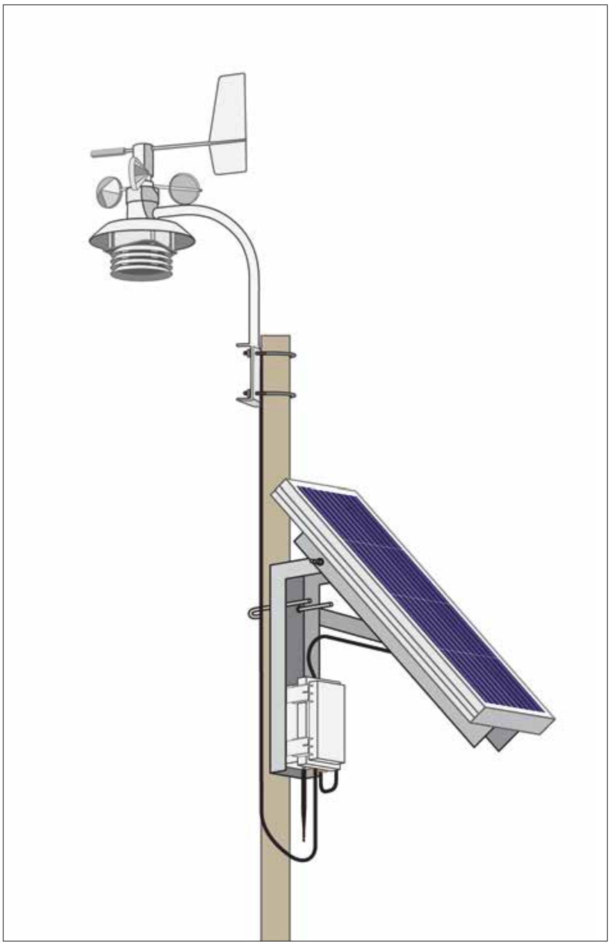
- Soil moisture probes in pots – allowing the monitoring of pot soil moisture;
- Weather station – monitoring of temperature, humidity & VPD extremes, as well as everyday weather events;
- SFM1 Sap flow meter on key potted plants.

With a network solution the nursery manager was enabled to monitor the water use of the plants and the extremes of weather that influence the plant, as this was connected to the internet. There was:

- A 4G Telemetry system – communicating the sensor data to the cloud;
- ICT Dataview - the data storage/visualisation platform;
- Data redundancy for soil moisture, vapour pressure deficit, weather parameters, and sap flow for future analysis.

Outcomes

- Informed decisions on timing and lengths of overhead/drip irrigation;
- Water usage quantification of potted plants;
- Seasonal and Daily variation - quantification;
- Ability to provide exact data for regulatory water audits.



IoT Automatic Weather Station: SNiP-AWS

Built upon the MetOne MSO integrated 5-parameter sensor, the SNiP-AWS is an easily deployed, high accuracy system designed for industry-grade applications.

Wind Speed and Wind Direction are measured using conventional cup and vane techniques. All other measurements are housed in a multi-plate naturally aspirated radiation shield to reduce solar radiation heating errors.

The temperature sensor is a platinum RTD. Relative humidity is a based on an accurate solid-state sensor designed for continuous exposure to adverse climates. The barometric pressure sensor is a robust piezo-resistive device featuring high accuracy and long-term stability. An external stainless steel 0.2mm/0.25mm precision tipping bucket rain gauge connects simply and allows for correct installation and siting per industry guidelines.

The system is powered by an 13Ah Li-Ion battery and 10 – 20W solar panel, scaled to suit the region of installation.

The SNiP-AWS is supplied with all support and power and monitoring hardware making it a drop-in solution for any IoT Network.

Optional SNiP Accessories include:

- MetOne 905 Tripod
- MetOne 191 Cross Arm

This Station Measures

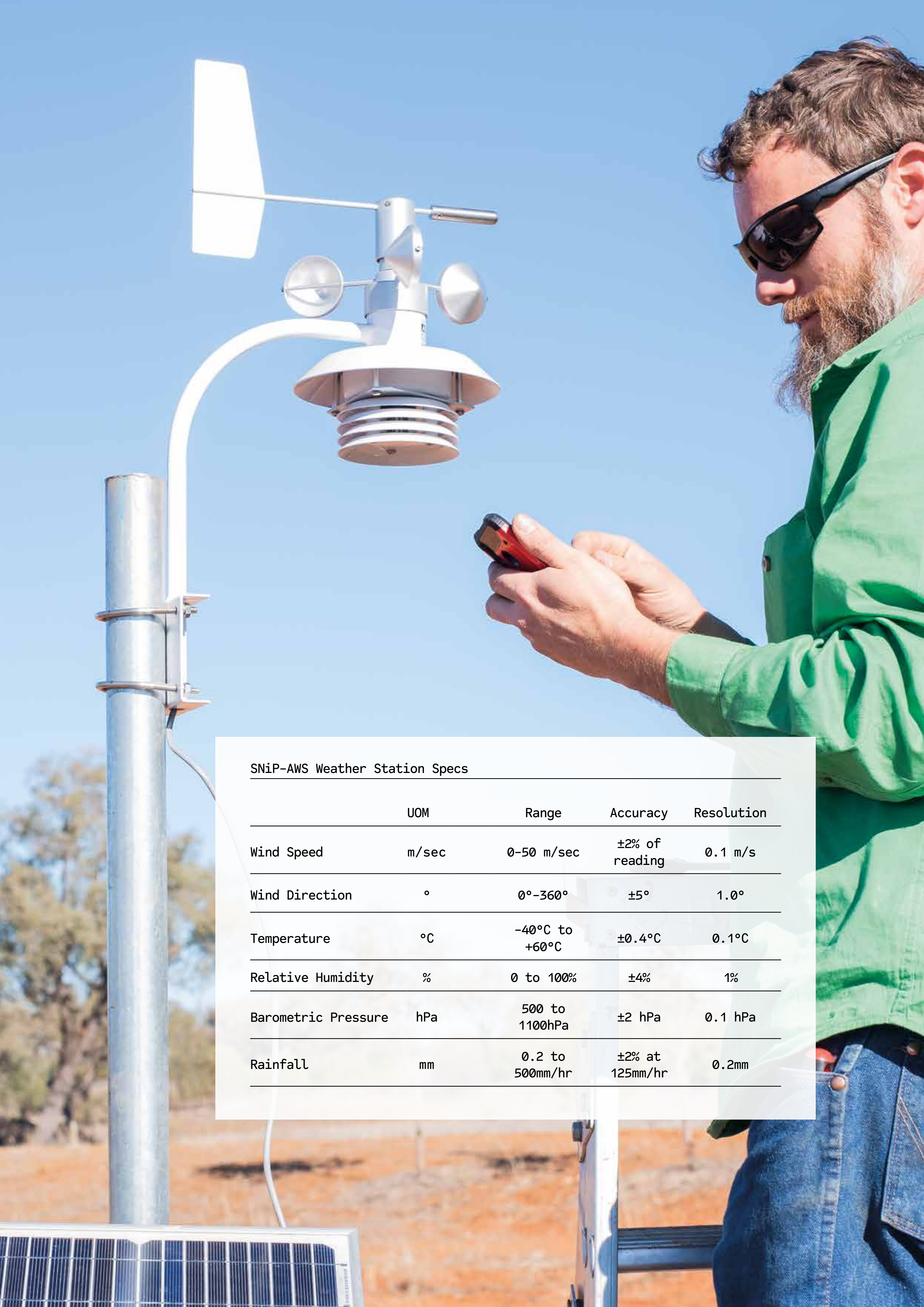
- Wind Speed (m/sec)
- Wind Direction (°)
- Temperature (°C)
- Relative Humidity (RH %)
- Barometric Pressure (kPa)
- Rainfall (mm)

Compatible Nodes:

- S-NODE (Base Node)
- MFR-NODE

Additional SNiP Extension:

- Solar Radiation
- Soil Moisture / Soil Temperature



SNiP-AWS Weather Station Specs

	UOM	Range	Accuracy	Resolution
Wind Speed	m/sec	0-50 m/sec	±2% of reading	0.1 m/s
Wind Direction	°	0°-360°	±5°	1.0°
Temperature	°C	-40°C to +60°C	±0.4°C	0.1°C
Relative Humidity	%	0 to 100%	±4%	1%
Barometric Pressure	hPa	500 to 1100hPa	±2 hPa	0.1 hPa
Rainfall	mm	0.2 to 500mm/hr	±2% at 125mm/hr	0.2mm

Weather Stations & Microclimates

SNiP-A41 Weather Station

The SNiP-A41 an all in one agricultural / research grade micro-environment weather station. Housed in a slim, tubular form factor, the SNiP-A41 has no moving parts, which minimises supporting infrastructure requirements, and makes installation and maintenance easy. The SNiP-A41 is supplied with all support power and mounting hardware making it a drop-in solution for any IoT network.

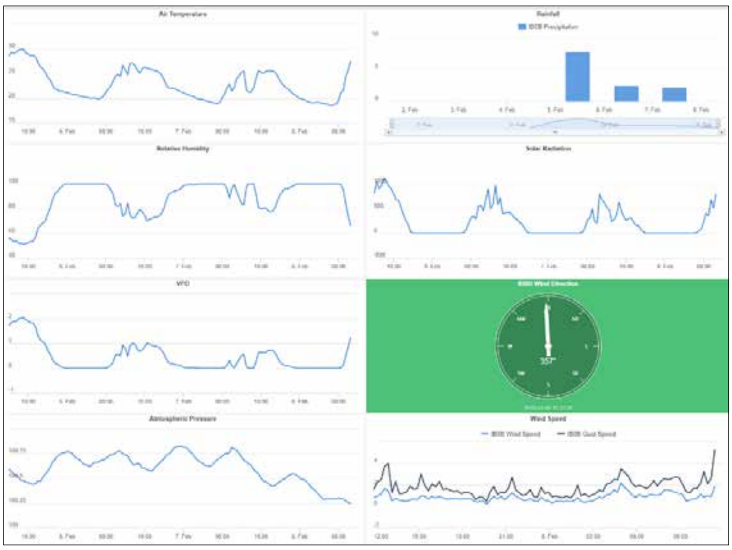
Compatible Nodes:

- ☐ S-NODE (Base Node)
- ☐ MFR-NODE

Optional SNiP Accessories include:

- ☐ MetOne 905 Tripod

Displaying Weather Data



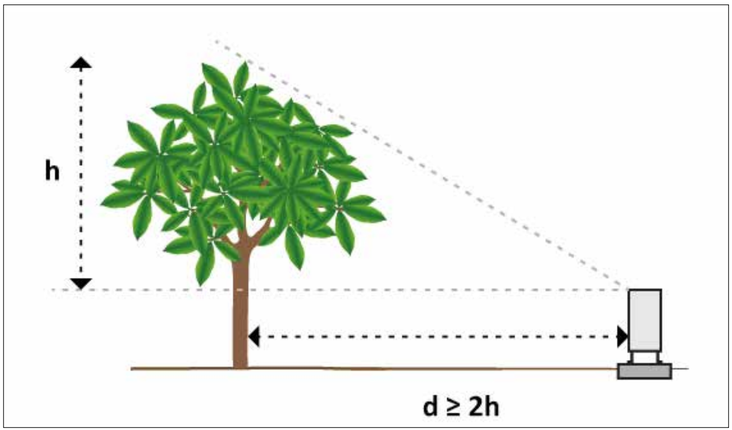
Dataview Web

ICT International offers a web-based data visualisation service, compatible with all ICT Loggers, Nodes and Telemetry Systems.

Featuring customised dashboards; real time data processing and filtering; communications and parameter state alarms; group-based and administrator level security; and metadata filing.

Figure (left) shows realtime weather data streamed from device and displayed in DataView.

A41-SNiP	Measurement Range	Resolution
Wind Speed	0 to 40 m/s	0.01 m/s
Wind Direction	0 to 359°	1.0°
Wind Gust Speed	0 to 40 m/s	0.01 m/s
Temperature Range	-40 to +50°C	0.1°C
Relative Humidity	0 to 100%	0.1%
Barometric Pressure	50 to 110 kPa	0.1%
Vapour Pressure	0 to 47 kPa	0.01 kPa
Rainfall	0 to 400 mm/hr	0.017 mm
Solar Radiation	0 to 1750 W/m²	1 W/m2



Microclimate Monitoring

A Microclimate is a local atmospheric zone where the climate differs from the surrounding areas. The microclimate within a vegetative canopy is characterized by a reduction in temperature extremes and air speed and diffuse solar radiation, and typically higher humidity. Conversely, the microclimate within a urban area is characterized by increases in temperature (commonly refer to as the urban heat island), wind tunnelling, and a reduction in relative humidity.

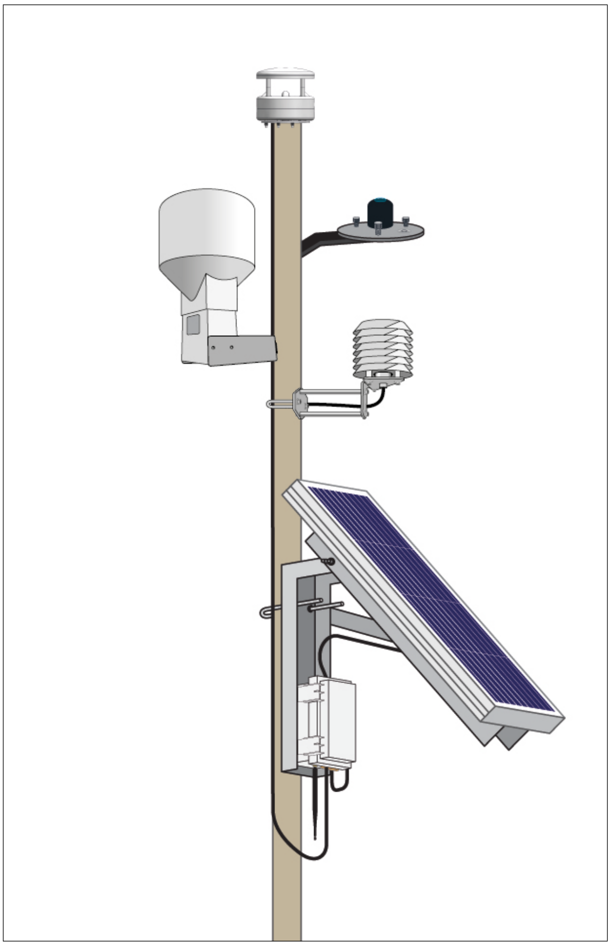
Customised Weather Stations

ICT International provides a diverse range of IoT based solutions for the measurement of rainfall, from low cost systems for catchment wide observations to high resolution industry standard rain-gauges for precision meteorological studies.

Weather Station Siting and Exposure

Selecting the right site for a weather station is central to the collection of accurate and meaningful meteorological data. The site should represent the area of interest and be away from obstructions (such as buildings and vegetation), artificial heat sources, temporary standing water, reflective surfaces and shadowing, and sources of artificial radiation.

Figure (above, left) shows the ratio of WMO's recommended rain gauge siting in relation to surrounding obstacles.



Parameters Available to Station

- ☐ Temperature (air, water, soil)
- ☐ Solar radiation
- ☐ UV, PAR, Net Radiation
- ☐ Relative humidity
- ☐ Barometric pressure
- ☐ Precipitation
- ☐ Wind speed and direction
- ☐ Barometric pressure
- ☐ Soil moisture
- ☐ Soil heat flux
- ☐ VPD
- ☐ Evaporation

Further Reading on the Station Siting and Exposure:

WMO (1983). Guide to Meteorological Instruments and Methods of Observation. World Meteorological Organization No. 8, 5th edition, Geneva Switzerland.

WSD-20	Measurement Range	Resolution
Wind Speed	0 to 60 m/s	0.1 m/s
Wind Direction	0 to 360°	1.0°

ATH-2S	Measurement Range	Resolution
Temperature Range	-40 to +60°C	0.1°C
Relative Humidity	0 to 100%	0.1%

Microclimate SNiPs	SNiP-ATH2	SNiP-WSD	SNiP-MC2	SNiP-WS2
Core Sensors/ Devices	ATH-2S	WSD-20	ATH-2S WSD-20	ATH-2S, WSD-20 PRP-02
SNiP Node	S-NODE	S-NODE	S-NODE	MFR-NODE
Mounting / Power	SPLM7 / SP10			
Optional SNiP Extensions of Parameters	PAR, UV, Solar Radiation, Soil Moisture			

Tipping Bucket Rain Gauge

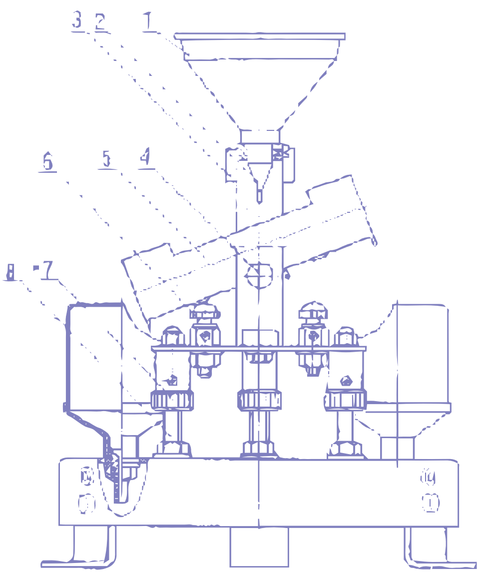
A Tipping Bucket Rain Gauge (TBRG) consists of a collector shaped like a funnel, two ‘buckets’ (0.2mm, 0.25mm, 0.5mm or 1.0mm resolution) mounted on an axle, and an electronic reed switch. Intercepted rainfall and is funnelled into one of two small buckets, which when full, tips and causes a magnet to contact the electronic reed and generate a digital pulse which is recorded by a connected data logger or node.

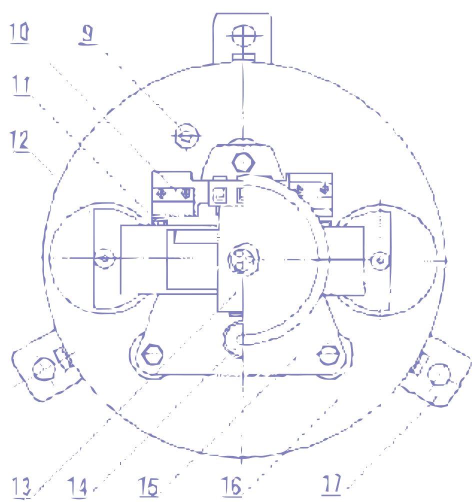
The rainfall intensity of a tipping-bucket gauge is calculated based on the number of tips in a periodic sampling rate and averaged over a chosen time interval.

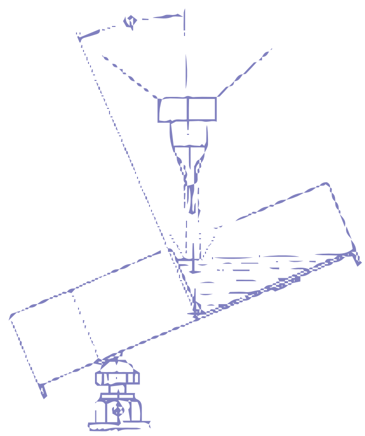
Figure of Tipping Bucket Rain Gauge Calibration Field Kit In Use on a ICT International SRG0

TBRG Calibration

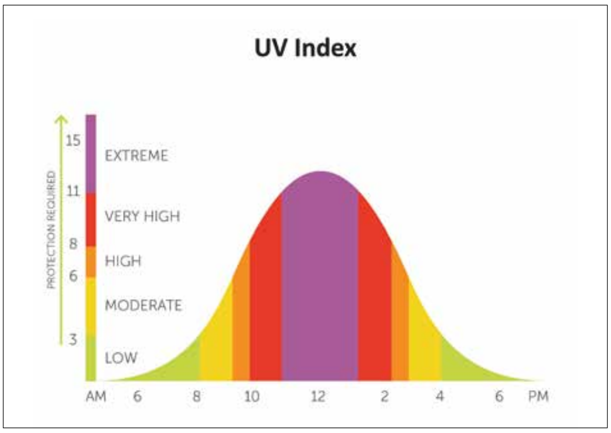
Calibration of the tipping bucket is accomplished by passing a known amount of water through the tipping mechanism at various rates and by adjusting the bucket height to the known volume.







Rainfall Gauge SNiP:		SRG-SNiP	PRP-SNiP	PRS-SNiP
Core Sensor/Device		SRG0	PRP-02	PRS-1
Orifice Size	50cm²			●
	200cm²		●	
	324cm²	●		
Measurement Principle	Tipping POM Spoon		●	●
	Tipping Bucket	●		
Resolution	1mm			●
	0.2mm	●	●	
Accuracy @ 100mm/hr	+5%			●
	+2%	●	●	
Material	Styrosun Thermoplastic		●	●
	Stainless Steel	●		
Mounting Accessory	Pole		●	●
SNiP Node			AD-NODE	



Solar Radiation

Total solar radiation, direct beam and diffuse, incident on a horizontal surface is defined as global shortwave radiation, or shortwave irradiance, and is expressed in Watts per square meter. Typical applications of pyranometers include incoming shortwave radiation measurement in agricultural, ecological, and hydrological weather networks and solar panel arrays. Solar radiation is often used in evapotranspiration models.

Net Radiation

Net radiation is the balance between incoming and outgoing shortwave and longwave radiation and is spatially and temporally variable due to changes in position of the sun with respect to Earth's surface, changes in atmospheric conditions, and differences in land surface conditions. Net radiation is the main source of energy for the physical and chemical processes that occur in the surface-atmosphere interface, including photosynthesis and evapotranspiration. The Apogee SN-500 net radiometer is a four-component instrument, with individual upward- and downward-looking pyranometers and pyrgeometers and on-board calculation of net shortwave, longwave and total net radiation. Typical applications of net radiometers include measurement of net radiation on surface flux towers and weather stations.

UV Monitoring

Ultraviolet (UV) radiation constitutes a portion of the electromagnetic spectrum from 100 to 400 nm, and classified by wavelength into three regions : UV-A (315 to 400 nm), UV-B (280 to 315 nm) and UV-C (100 to 280 nm). The erythema action spectrum provides an internationally accepted representation of the erythema-inducing effectiveness of wavelengths in the UV part of the spectrum, forming the basis of the UV index used for public health information. Typical applications of UV sensors include the providing of real time public health information, total UV radiation measurement in outdoor environments or in laboratory use with artificial light sources (e.g., germicidal lamps).

Illuminance

Illuminance is a measurement of radiant energy on a surface, weighted by the human eye response, which is sensitive to radiation from about 380 to 780 nm but is most sensitive in the middle of this range near 555 nm. Sensors that measure illuminance are referred to by many names, including light sensors, photometric radiometers, photopic sensors, and lux sensors. Illuminance is quantified in units of lux or footcandles. Typical applications of illuminance sensors include determination of optimum light levels in indoor environments, public areas and sporting facilities.

Radiation SNiPs	SNiP-NRA	SNiP-SRAD	SNiP-LUX	SNiP-UV	SNiP-UVI
SNiP Measures	Net Radiation	Solar Radiation	Illuminance	UVA and UVB	UV Index
Core Sensor/Device	SN-500	SP-212	SE-202	SU-200	SKU-440
UOM	$W\ m^{-2}$	$W\ m^{-2}$	Lux	$W\ m^{-2}$ or umol $m^{-2}\ s^{-1}$	UV Index
Measurement Range	-200 to +200 $W\ m^{-2}$* 0 to +2000 $W\ m^{-2}$^	360 to 1120nm	0 to 200klux	250 to 400nm	0 to 20UVI
SNiP Node	S-NODE	AD-NODE	AD-NODE	AD-NODE	MFR-NODE
Mounting / Power	SPLM7, AM-500 / SP10	LM1, AL-120			SPLM7, AL-120 / SP10

* Net Longwave Irradiance ^ Net Shortwave Irradiance

Dissolved Oxygen

Dissolved oxygen (DO) refers to the level of free, non-compound oxygen present in water, and is a critical factor in the capacity of an aquatic ecosystem to support living organisms. Two methods are used for the in-situ measurement of DO in surface waters: Winkler titration, membrane-covered electrochemical sensors (polarographic or galvanic cell), and luminescent-based optical sensors. Optical technology has quickly become a preferred method for measurement of DO, due to accuracy advantages over electrochemical sensors when it comes to fouling and long-term drift.

pH and Redox Potential

The pH value describes the activity of hydrogen ions in aqueous solutions typically on a scale of 0 to 14, from which liquids are characterized as being acidic, alkaline or neutral. In environmental sampling and monitoring, high or low pH values can be indicative of pollution. Oxidation-reduction potential (ORP) measures the ability of an aquatic environment to break down waste products, such as contaminants and dead plants and animals. The potentiometric method for measuring pH is used by most major sensors manufacturers.

Conductivity (Salinity)

Electrical conductivity can be used to determine concentration of solutions, detect contaminants and determine the purity of water. There are two types of conductivity measurement: contacting and inductive. The choice of which to use depends on the amount of conductivity, the corrosiveness of the liquid, and the quantity of suspended solids. The inductive method is generally better when the conductivity is high, the liquid is corrosive, or suspended solids are present. Conductivity, along with temperature, also allow for salinity values to be calculated through algorithms.

Turbidity

Turbidity is the measurement of water clarity. Suspended sediments, such as particles silt, clay and sand frequently enter the water from disturbed soils and can contain pollutants such as phosphorus, pesticides, or heavy metals which adversely affect the aquatic ecosystem. Turbidity sensors measure in either Nephelometric Turbidity Units (NTU) or Formazin Nephelometric Units (FNU). Due to the different light sources used in each of these measurements results are not directly comparable.

Water Quality SNiPs	SNiP-DOT	SNiP-pHR	SNiP-NTU
SNiP Measures	Dissolved O2 / Temperature	pH / Redox / Temperature	Turbidity / Temperature
Core Sensor/ Device	OPTOD	pHEHT	Digisens NTU
UOM	mg/L or ppm or %, °C	pH, mV, °C	NTU, °C
Range	0-20mg/L, or ppm, or 0-200% / 0°C to 50°C	0 – 14pH, -1000 to +1000mV, 0°C to 50°C	0 to 4000 NTU in 5 ranges, 0°C to 50°C
SNiP Node	S-NODE	S-NODE	S-NODE
SNiP Supports	Up to 3 Water Quality Sensors		
Mounting / Power	SPLM7 / SP10		

Buoy Mounting Available

Water Quality SNiPs	SNiP-SAL	SNiP-SAL2
SNiP Measures	Salinity / TDS Conductivity / Temperature	Salinity / Conductivity / Temperature
Core Sensor/ Device	C4E	CTZN
UOM	g/kg, ppm, mS/cm, °C	g/kg, mS/cm, °C
Range	5 to 60 g/kg 0 to 133,000 ppm 0 to 200mS/cm^ 0 to 50 °C	5 to 60 g/kg 0 to 100mS/cm 0 to 40 °C
SNiP Node	S-NODE	S-NODE
SNiP Supports	Up to 3 Water Quality Sensors	
Mounting / Power	SPLM7 / SP10	

Buoy Mounting Available
^Selectable Ranges

Submersible Pressure Transducers

Submersible pressure transducers (SPT) are submerged at a fixed depth below the water surface and measure equivalent hydrostatic pressure of the water head above the sensor diaphragm for the calculation of the total liquid depth. Vented pressure sensors, which use a vented cable to connect the base of the pressure transducer to atmospheric pressure, compensate for barometric pressure changes at the surface.

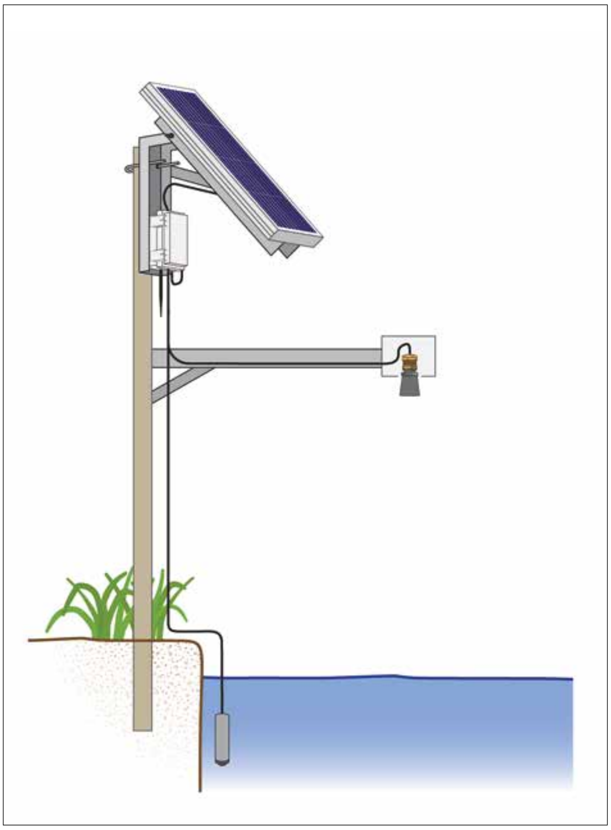
Variances in accuracy of measurement depend on the model of pressure sensor used, the accuracy of some sensors is reduced by temperature variation, non-linearity and hysteresis, as well as long-term drift. The potential for sensor fouling should be a consideration before installation of SPT.

SPTs can be used in a wide range of applications, including for both surface and groundwater as well as tanks.

Shaft Encoder

A shaft encoder is an electro-mechanical device which converts the position of a shaft to an electrical signal. The rotational shaft utilizes a float and counter-weight attached to a line or tape placed around a pulley, as the water level changes, the float moves up and down and rotates the shaft, which records a change in water level.

Shaft encoders can be use in some surface water applications and for pan evaporation monitoring.

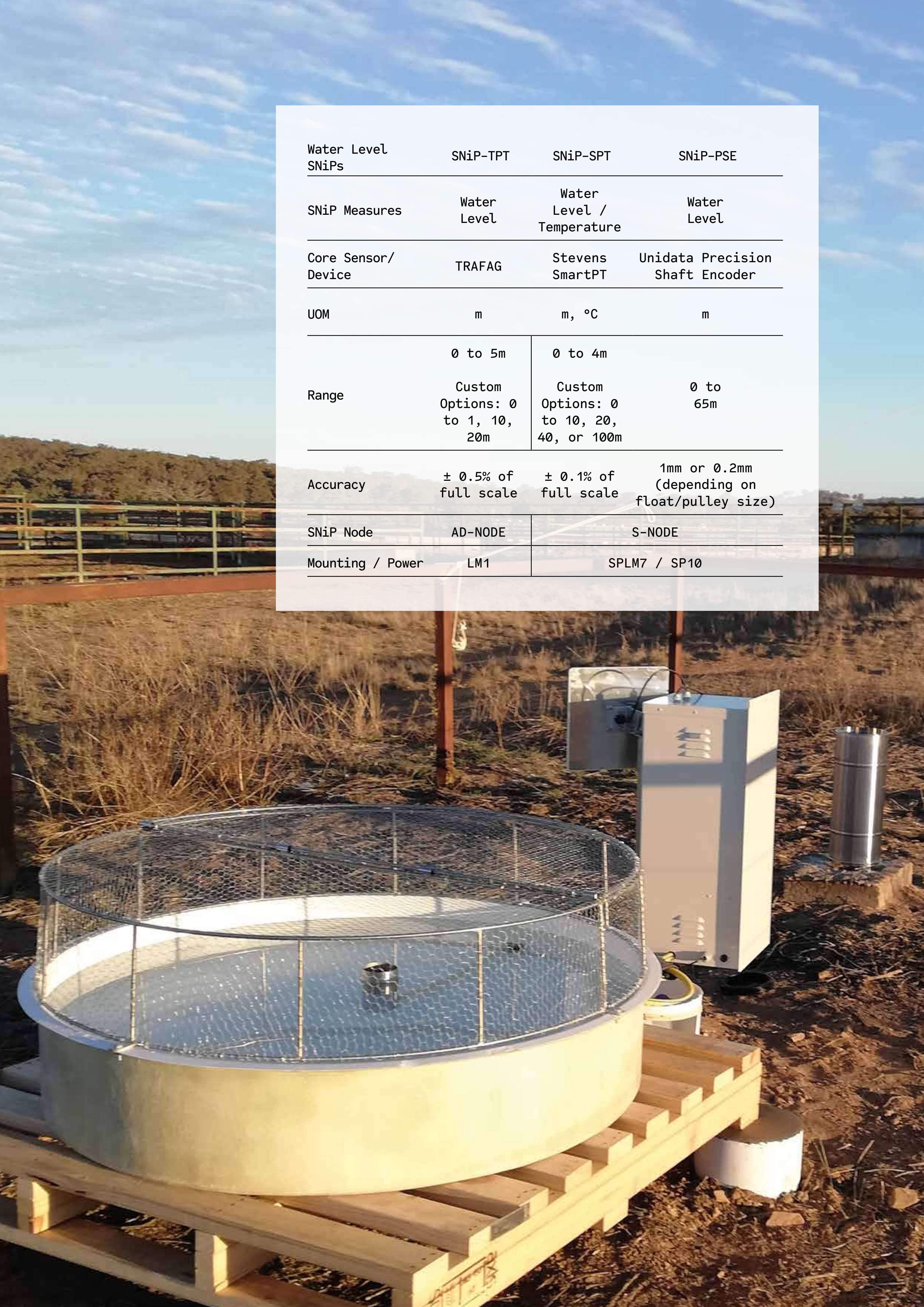


Ultra-Sonic Sensors

Ultrasonic water level instruments use sound waves in frequency range ~20-200 kHz to determine fluid level. A transducer directs bursts sound waves down onto the surface of the water which then reflects an echo of these waves back to the transducer. The transducer performs calculations to convert the distance of wave travel into a measure of height, and therefore distance to water surface.

The accuracy of Ultrasonic sensors can be affected by condensation on the transducer and very high concentrations of fine sediment in suspension, which can scatter and absorb the sonic pulse.

Ultrasonic sensors can be use in some surface water applications and for tank monitoring.



Water Level SNiPs	SNiP-TPT	SNiP-SPT	SNiP-PSE
SNiP Measures	Water Level	Water Level / Temperature	Water Level
Core Sensor/ Device	TRAFAG	Stevens SmartPT	Unidata Precision Shaft Encoder
UOM	m	m, °C	m
Range	0 to 5m Custom Options: 0 to 1, 10, 20m	0 to 4m Custom Options: 0 to 10, 20, 40, or 100m	0 to 65m
Accuracy	± 0.5% of full scale	± 0.1% of full scale	1mm or 0.2mm (depending on float/pulley size)
SNiP Node	AD-NODE	S-NODE	
Mounting / Power	LM1	SPLM7 / SP10	

Heat Flux

Heat transfer is driven by temperature differences, with heat flowing from a source to a sink, from a hot to a cold environment. Heat flux sensors measure heat transfer, the energy flux onto or through a surface (W/m^2) which results from convection, radiation or conduction sources of heat.

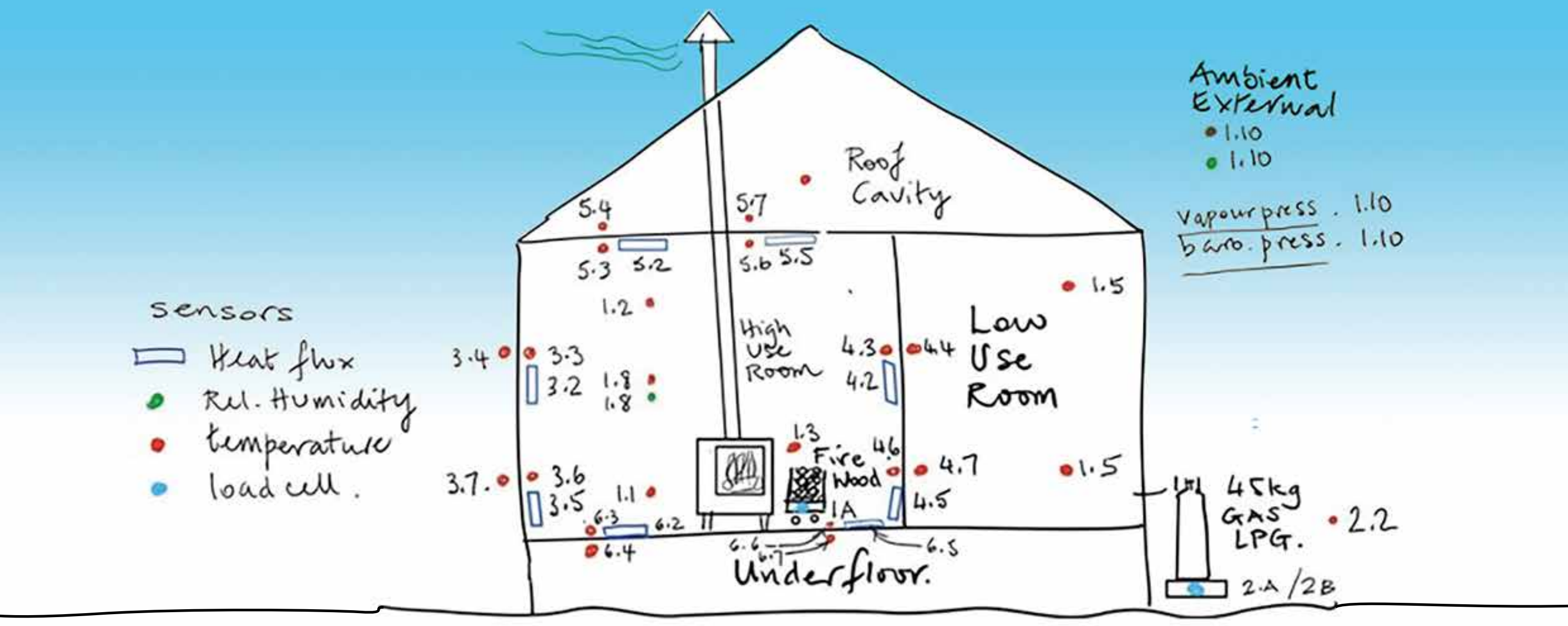
Convective and conductive heat fluxes are measured by letting this heat flow through a heat flux sensor. Heat flux sensors provide an in-situ measurement of material thermal resistance, commonly referred to as R-Value, and are therefore an important tool in the study of building thermal dynamics.

Surface Temperature Measurement

ICT International offers both contact and non-contact (infrared temperature) surface temperature sensors.

Surface contact sensors measure the temperature via physical contact Infrared (IR) thermometers, measure surface temperature from a distance by measuring the amplitude of IR energy being radiated from the surface.

Temperature SNiPs	SNiP-HFP	SNiP-AT	SNiP-EMD
SNiP Measures	Heat Flux	Ambient Temperatures	Surface Temperature
Core Sensor/Device	HFP01	THERM-EP	EVEREST 3000MD
UOM	W/m2	°C	°C
Measurement Range	-2000 to +2000 W/m^2	-40°C to +80°C	-70°C to +400°C
Accuracy	± 3 %	±0.5°C at 25°C	±0.5°C (0°C TO 50°C)
SNiP Node	MFR-NODE	AD-NODE	MFR-NODE
SNiP Sensor Extensions	Surface Temperature		Ambient Temperature
Mounting / Power	LM1 / CH24	Passive Radiation Shield, LM1	SPLM7 / SP10



Examining Thermal Efficiency in Housing

Carbon Neutral Living in Existing Buildings

In collaboration with Z-NET Uralla, ICT International has been working to examine the efficiency by which houses of varying design eras utilise energy inputs to achieve and maintain thermal comfort, compared to those that are thermally improved.

Monitoring and Network solution

The study houses were equipped with sensors to measure energy use (gas, wood, electricity) and to monitor internal temperature gradients and thermal comfort of living areas, and heat loss through structural elements within high-use living areas. This data was collected via a series of loggers and IoT Nodes for transmission to the cloud.

Outcomes

Preliminary results show how effectively energy inputs are being used by the house to maintain heat within the thermal comfort zone. In a thermally unimproved 1915 Federation style weatherboard clad dwelling, energy inputs are rapidly dispersed through external walls and ceilings; temperature gradients of above 20°C were observed between floor and ceiling zones. With further monitoring it is hoped that the best insulation strategies can be identified; thus enhancing measures employed to enhance the efficiency of energy inputs.

Sensors used included: HFP01 for Heat Flux Plates; thermistors; load cells for firewood / gas cylinders; VP3 for internal temperature and relative humidity; VP4 for external temperature and humidity.

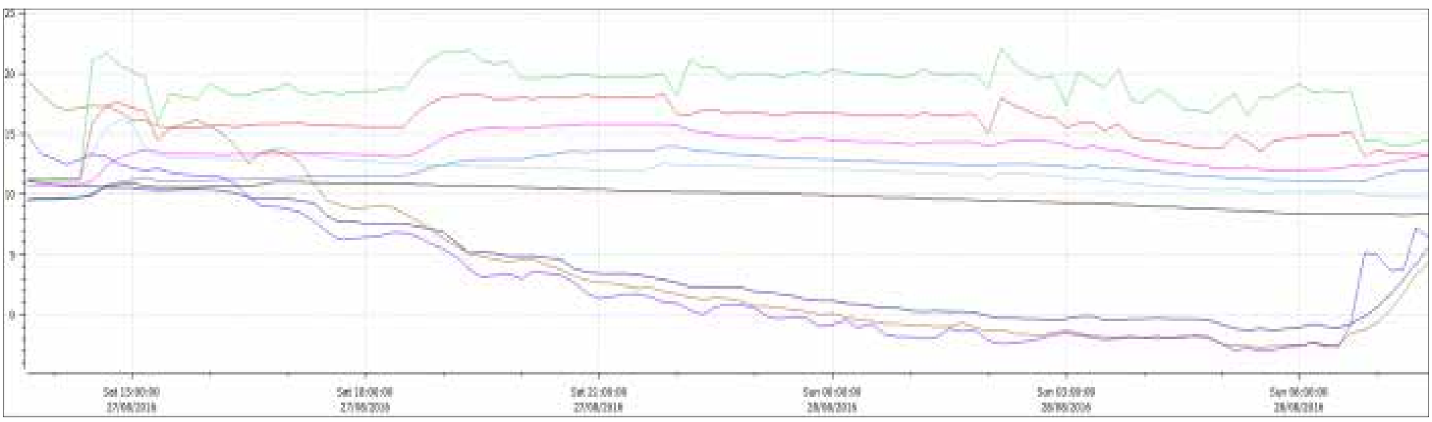


Figure above shows the internal temperature changes against gas usage as the residents have been coming and going through the day; as can be seen there are a number of spikes in temperature change, and an associated change in the amount of gas in the cylinder (measured by the load cell under the cylinder).

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